

23rd INTERNATIONAL MULTIDISCIPLINARY SCIENTIFIC GEOCONFERENCE - SGEM 2023

28 – 30 November 2023 - Vienna, Austria

CONFERENCE PROCEEDINGS OF SELECTED PAPERS in ENERGY AND CLEAN TECHNOLOGIES ISSUE 4.2

Editors-in-Chief:

- **Prof. DSc. Oleksandr Trofymchuk, National Academy of Sciences of Ukraine, UKRAINE**
- **Prof. Dr. hab. oec. Baiba Rivza, Latvian Academy of Sciences, LATVIA**

DISCLAIMER

The International Multidisciplinary Scientific GeoConference SGEM (Survey, Geology, Ecology and Management) are focused on GLOBAL WARMING, CLIMATE CHANGE, CO_2 REDUCTION, BIODIVERSITY, AND GREEN TECHNOLOGIES FOR A SUSTAINABLE FUTURE.

Authors are responsible for the content and accuracy of the written papers. Opinions expressed are not meant to represent or reflect the position of the SGEM International Scientific Committee members.

No part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical, for any purpose, without the express written permission of the SGEM International Scientific Committee on Earth and Planetary Sciences.

Copyright © SGEM WORLD SCIENCE (SWS) Scholarly Society 2023
10/11 Gerlgasse, Vienna 1030, Austria
Published by STEF92 Technology
Total print: 5000

E-mail: **science@sgemviennagreen.org** | URL: **www.sgemviennagreen.org**

ISBN 978-619-7603-65-1
ISSN 1314-2704
DOI: 10.5593/sgem2023v/4.2

FOREWORD

The International Multidisciplinary Scientific GeoConference SGEM is focused on AGENDA 2030 Goals - GLOBAL WARMING, CLIMATE CHANGE, CO_2 REDUCTION, BIODIVERSITY, AND GREEN TECHNOLOGIES FOR A SUSTAINABLE FUTURE.

In an ever-evolving world, amidst the vast expanse of the universe, Earth remains our singular home — a beacon of life, mystery, and endless curiosity. It is with immense pride and anticipation that we present the **2023 Conference Proceedings in Earth and Planetary Science, a collective endeavor of minds passionate about our world and the celestial wonders beyond.**

The beauty of science, particularly in the realm of geosciences, lies in its ability to unite us. It transcends borders, politics, and cultural divides, binding us together in pursuit of knowledge, understanding, and enlightenment. This year, our focus aligns with the noble aspirations of Agenda 2030, reminding us that our planet's health and sustainability are integral to our shared future. Every paper within these pages stands as a testament to our collective commitment to that goal.

Moreover, this conference encapsulates the harmonious dance between the Earth as a place we live in and to care for, and the Planet, with its place in the Universe - different but intertwined, sharing the primary goal of interpreting, understanding and celebrating the Universe and our place in it. Like an artist who captures the majesty of a mountain range or the vastness of space, our researchers, too, paint with data, hypotheses, and discoveries, sketching a future where knowledge drives progress.

In a world where discord often grabs headlines, this gathering underscores that there exist realms untouched by strife, where camaraderie and cooperation reign supreme. This is the world of geosciences: a haven for curious minds, a frontier for explorers, a canvas for dreamers.

As you delve into these meticulously peer-reviewed articles, let them not only inform you but inspire you. Let them remind you of the magic that happens when diverse minds converge for a singular purpose. **And let them serve as a beacon of hope, signaling a future where science, with its inherent artistry, continues to light our way.**

In anticipation of the better future and optimism,
Sincerely yours,

Prof. DSc. Oleksandr Trofymchuk
Editor-in-Chief of XXIII SGEM GeoConference Proceedings
National Academy of Sciences of Ukraine, UKRAINE

Prof. Dr. hab. oec. Baiba Rivza
Editor-in-Chief of XXIII SGEM GeoConference Proceedings
Member of the Presidium of the Latvian Academy of Sciences, LATVIA
President of the Latvian Academy of Agricultural and Forestry Sciences
Vice-chair of the Latvian Council of Higher education
President of Latvian universities professors' association
Expert from the European Academy of Sciences Academic Advisory Board (EASAC)

CONFERENCE PROCEEDINGS CONTENTS

SECTION RECYCLING

1. CHARACTERIZING THE MEMBRANE CONCENTRATE FROM LEACHATE TREATMENT: HAZARDOUSNESS EVALUATION AND ITS POTENTIAL TO LANDFILL RECIRCULATION, PhD Lidia Kim, Razvan Laurentiu Dinu, PhD Adriana Cuciureanu, Georgiana Cernica, PhD Valeriu Badescu 3

2. CHALLENGES TO THE FOOD WASTE RECYCLING SYSTEM IN LATVIA, Prof. Dr. Aija Eglite, Dr. Dace Kaufmane 13

3. COMPOSTING OF BIODEGRADABLE PLASTIC WASTE - CHANGES IN THE MICROBIAL COMMUNITY, Assoc. Prof. Dr. Bilyana Grigorova-Pesheva, Assoc. Prof. Dr. Boyka Malcheva 21

4. ENHANCING SOIL QUALITY AND NUTRIENT AVAILABILITY WITH ZEOLITES AND DIATOMACEOUS EARTH, Dr. Ana Katsarova 29

5. MUNICIPAL ORGANIC WASTE COMPOSTING IN ROMANIA - RESOURCES AVAILABILITY AND RECENT ADVANCES, PhD Elena Manea, PhD Costel Bumbac, Laurentiu Dinu, PhD Valeriu Badescu, PhD Ioana Ionescu 37

6. RECYCLING IN CONSTRUCTION MATERIALS - ANALYSIS OF THE USE OF AMORPHOUS MATERIALS POLY(ACRYLONITRILE-CO-BUTADIENE-CO-STYRENE) (ABS) IN STRUCTURAL CONCRETE., Assoc. Prof. Dr. Anna Stepien, Prof. Ryszard Dachowski, Assoc. Prof. Dr Agnieszka Molendowska.....45

7. OPTIMIZATION MEASURES FOR IMPROVING THE RATIONAL USE OF THE SURFACE LAYER OF ANTHROPOGENIC LANDSCAPES IN THE KRYVYI RIH LANDSCAPE-TECHNICAL SYSTEM., PhD Tetiana Koptieva, Pavlo Lotsman 53

8. RECYCLING IN CONSTRUCTION - CHARACTERISTICS OF COMPOSITE AND RECYCLED MATERIALS USED IN STRUCTURAL ELEMENTS OF BUILDINGS, Assoc. Prof. Dr. Anna Stepien, MSc. Patrycja Wojarska-Gniady.....61

9. RESEARCH REGARDING THE USE OF EGGSHELLS POWDER FOR SOILS REHABILITATION CONTAMINATED WITH CD AND PB, PhD Antoanela Cozma, PhD Maria Rada, Assoc. Prof. Ariana Velciov, PhD Casiana Mihut, PhD Anisoara Duma Copcea 71

10. STRATEGIES FOR MINIMIZING PAPER USAGE IN LATVIA MUNICIPALITIES, PhD Lilita Abele, Prof. Dr. Peteris Rivza, Prof. Dr. Baiba Rivza, Prof. Dr. Elita Jermolajeva 79

11. STUDIES ON THE INFLUENCE OF ANIMAL WASTE ON SOIL FERTILITY. CASE STUDY - PIG SLURRY, PhD Liliana Brei, Dr. Adina Berbecea, PhD Doris Floares, PhD Nicoleta Vicar, Prof. Dr. Isidora Radulov 87

12. THE COSTS AND RATE OF RETURN CALCULATION OF THE NEW ESTABLISHED PIG AND POULTRY MANURE FERMENTATION PLANT, Dr. Anita Csiba, Dr. Arpad Ferencz 95

13**. THE ROLE OF INVESTMENT AND INNOVATION POLICY IN THE FORMATION OF A CIRCULAR ECONOMY,** Dr. oec. Arturas Simanavicius, PhD Lilita Abele, Dr.oec. Borys Samorodov 105

14. VALORIZATION OF COMMON BEAN (PHASEOLUS VULGARIS L.) BY-PRODUCTS TO OBTAIN NEW BAKERY PRODUCTS, Dr. Alina Maier, Assoc. Prof. Dr. Cristina Maria Canja, Assoc. Prof. Dr. Mirabela Ioana Lupu, Vet. Geronimo Raducu Branescu, Prof. Dr. Vasile Padureanu 113

SECTION AIR POLLUTION AND CLIMATE CHANGE

15. ADAPTATION TO CLIMATE CHANGE AND THE INTERPLAY BETWEEN ENERGY EFFICIENCY AND SOBRIETY: LESSONS LEARNED FROM THE ITALIAN EXPERIENCES OF L' AQUILA RUGBY ASSOCIATION AND COMMUNITY COOPERATIVE MELPIGNANO, PhD Gianna Giardini 123

16. ANALYSIS OF METEOROLOGICAL PARAMETERS AND CLIMATE VARIABILITY IN THE WESTERN PART OF ROMANIA IN THE PERIOD 2010-2020, Assoc. Prof. Dr. Ana-Codruta Chis, PhD Vlad Marazan, Assoc. Prof. Dr. Antoanela Cozma, Assoc. Prof. Dr. Vlad Dragoslav Mircov, Assoc. Prof. Dr. Carmen Claudia Durau 135

17. CLIMATE CHANGE MITIGATION APP FOR SUSTAINABLE CITIES USING URBAN GREEN DATA FOR CO_2 ABSORPTION, Dimitra Papagiannopoulou, Thekla Tsitsoni, Zacharoula Andreopoulou, Vasiliki Xathopoulou-Tsitsoni, Nikolaos Morfopoulos 143

18. CLIMATE CHANGE VULNERABILITY, MITIGATION, AND ADAPTATION FOR A LARGE INFRASTRUCTURE PROJECT IN ROMANIA, PhD Raluca Nicolae, Drd. Petru Nicolae 151

19. CLUB CONVERGENCE IN ENERGY TRANSITION OF EU MEMBER STATES, Prof. PhD Claudia Popescu, Assistant. Prof. PhD Mihaela Covrig 159

20. CONSUMER INTENTION TO BUY ELECTRIC CARS: EXPLORING THE INFLUENCE OF FUTURE UNCERTAINTY DUE TO THE WAR IN UKRAINE IN THE FRAMEWORK OF THEORY OF PLANNED BEHAVIOR, PhD Roberta Riverso, Assoc. Prof. Francesco La Barbera, Carmela Altamura 167

21. DATA SET ANALYSIS OF THE COMPOSITE MATERIALS WITH THIN PROFILE USING DESCRIPTIVE STATISTICS, PhD Carmen Mihai, PhD Student Alina - Florentina Vladu, PhD Alexandra Gabriela Ene, PhD Student Laurentiu Dinca.....175

22. DROSOPHILA MELANOGASTER AS A TEST-SYSTEM FOR ASSESSMENT OF THE AIR POLLUTION BY USING THE CITY OF KAZAN AS AN EXAMPLE, Rustam Sokolov, PhD Viktoria Kostenko, Tansu Gazieva, Prof. DSc. Natalya Stepanova 183

23. EFFECT OF MOISTURE AND ORGANIC MATTER CONTENT ON N2O EMISSIONS, Mg.sc.ing. Sindija Liepa, Mg.sc.ing. Luize Lepiksone, Mg.sc.ing. Dace Butenaite, Mg.sc.ing. Jovita Pilecka-Ulcugaceva, Assist.prof. Inga Grinfelde.....191

24. EFFECT OF SOIL GRANULOMETRIC COMPOSITION AND MOISTURE ON THE FORMATION OF N2O ISOTOPES, Mg.sc.ing. Sindija Liepa, Mg.sc.ing. Dace Butenaite, Mg.sc.ing. Jovita Pilecka-Ulcugaceva, Bc.sc.ing. Kristaps Siltumens, Assist.prof. Inga Grinfelde 199

25. EFFECTIVENESS OF SIMPLE ELECTRIC FANS IN REDUCING THE NUMBER OF HOURS WITH HEAT STRAIN INSIDE BUILDINGS, Atlas Ramezani, Marco Manzan.....207

26. ENVIRONMENTAL PROBLEMS SOLVING AS A FACTOR IN THE FORMATION OF A SUSTAINABLE AND BALANCED DEVELOPMENT PARADIGM, Professor Valentyna Voronkova, Professor Roman Oleksenko, Professor Vitalina Nikitenko 215

27. EXTERNAL COSTS OF ROAD TRANSPORT IN FRAMES OF THE TRANSITION TO A LOW-CARBON ECONOMY, Prof. Dr. Olga Kudryavtseva, Dr. Anastasiia Baraboshkina 227

28. GHG EMISSION VARIABILITY FROM SOIL IN CONVENTIONAL FARMING SYSTEM, PhD Kristine Valujeva, Mg.sc.env Inga Grinfelde, PhD Candidate Jovita Pilecka-Ulcugaceva 235

29. HOW SUSTAINABLE AND GREEN IS TODAY'S MODERN PRINTING INDUSTRY? MYTHS AND FACTS, Prof. Dr. Csaba Horvath, Prof. Dr. Cem Aydemir, Prof. Dr. Semiha Yenidogan 243

30. HYBRID ENERGY SYSTEM FOR FISHING VESSELS CONSIDERING FUTURE ENVIRONMENTAL REGULATIONS: AN APPLICATION „HENSUS“ FOR FAST PRELIMINARY POWER SYSTEM CONFIGURING, PhD Marija Korican, Assoc. Prof. Dr. Nikola Vladimir, Prof. Dr. Kresimir Vuckovic, Prof. Dr. Tatjana Haramina, Assoc. Prof. Dr. Neven Alujevic 251

31. INFLUENCE OF COATED UREA APPLICATION ON SOIL ORGANIC CARBON SEQUESTRATION, PhD Nicoleta Vicar, Assoc. Prof. Dr. Adina Berbecea, Assoc. Prof. Dr. Alina Lato, PhD Liliana Brei, Prof. Dr. Isidora Radulov 259

32. INTERACTION BETWEEN METHANE AND CARBON DIOXIDE EMISSIONS USING METHANE-REDUCING BIOCOVER, Bc.sc.ing Kristaps Siltumens, Assoc. Prof. Inga Grinfelde, Dr. Juris Burlakovs, Mg.sc.ing. Sindija Liepa, Mg.sc.ing. Jovita Pilecka-Ulcugacev 267

33. INTERACTION BETWEEN METHANE AND NITROUS OXIDE EMISSIONS USING METHANE-REDUCING BIOCOVER, Bc.sc.ing Kristaps Siltumens, Assoc. Prof. Inga Grinfelde, Dr. Juris Burlakovs, Mg.sc.ing. Sindija Liepa, Mg.sc.ing. Jovita Pilecka-Ulcugaceva.....275

34. INVESTIGATING THE IMPACT OF CLIMATE CHANGE IN MEDITERRANEAN SEMI-ARID REGIONS, PhD Georgios Xekalakis, Assoc. Prof. Christos Anastasiou, Evi Kazamia, Prof. Yannis Tsompanakis, Assoc. Prof. Dr. Petros Christou 283

35. INVESTIGATIONS OF POTENTIALLY HARMFUL LIMONENE PHOTOOXIDATION PRODUCTS UNDER NOX AND NOX-FREE ATMOSPHERIC SIMULATED CONDITIONS, Dr. Alina-Giorgiana Negru, Dr. Claudiu Roman, PhD Student Cornelia Amarandei, Prof. Dr. Cecilia Arsene, Prof. Dr. Romeo Iulian Olariu 291

36. LEVERAGING MODERN LANGUAGES AND TRANSLATIONS FOR SUSTAINABLE ENVIRONMENTAL PRACTICES, Dr. Raul Pascalau , Assoc. Prof. Dr. Laura Smuleac, Prof. Sorin Stanciu, Prof. Dr. Florin Imbrea, Assoc. Prof. Dr. Adrian Smuleac 299

37. MANAGEMENT AND ASSESSMENT OF URBAN GREEN: A DIGITAL DATABASE APPLICATION, Valia Xanthopoulou-Tsitsoni, Zacharoula Andreopoulou, Dimitra Papagiannopoulou, Nikolaos Morfopoulos.....307

38. PRECIPITATION AND TEMPERATURE CHANGES IN SLOVAKIA DURING THE GROWING SEASON IN 1961-2020, Ing. Martin Minarik, Assoc. Prof. Jan Cimo, Dr. Vladimir Kiss 315

39. THE DISTRIBUTION OF TUNGSTEN IN JELGAVA CITY AT 2022 AND 2023, PhD Candidate Jovita Pilecka-Ulcugaceva, PhD Candidate Anda Bakute, PhD Candidate Maris Bertins, Bc. sc. ing Kristaps Siltumens, Assoc. Prof. Inga Grinfelde 323

40. THE GOOD, THE BAD AND THE EFFECTIVE? TRENDS IN SUSTAINABILITY REPORTING IN NEW ZEALAND-LISTED COMPANIES, Assoc. Prof. Dr. Michaela Balzarova, Kathryn Bell 329

41. THE IMPACT OF CLIMATE CHANGE ON TEMPERATURES AND PRECIPITATION IN THE REGIONS OF SLOVAKIA IN 1961-2020, Dr. Vladimir Kiss, Ing. Martin Minarik, Dr. Jakub Pagac, Dr. Andrej Tarnik, Assoc. Prof. Dr. Martin Prcik.....337

42. THE POTENTIAL ROLE OF MODERN TECHNOLOGY IN PROMOTING NATURE-BASED SOLUTIONS ADDRESSING GLOBAL CLIMATE CHANGE, Denis Vasiliev, Lennart Bornmalm, Rodney Stevens, Richard Hazlett 345

43. THE RIGHTS OF FUTURE GENERATIONS IN ITALIAN-EUROPEAN ENVIRONMENTAL LAW, PhD Giovanna Di Benedetto 353

44. THE USE OF WEB MAPS IN MANAGING CRISES CAUSED BY CLIMATE CHANGE, Assoc. Prof. Anna Bluszcz, Assoc. Prof. K. Tobór-Osadnik, Assoc. Prof. A. Manowska, Ing. A. Kelíšek, PhD 359

45. TRANSITION TO SUSTAINABLE ECONOMY - REVIEW OF POLICY CHOICES SUGGESTED BY INTERNATIONAL AGENCIES, Livia Bizikova 371

46. UHI ANALYZES FOR AREAS SUSCEPTIBLE TO LANDSLIDES IN THE CITY OF IASI, PhD Paul Gherasim, Professor Dr. Dima Mihai, PhD Pascariu Alexandru Ion, PhD Popa Andreea Silvia 381

47. URTICA DOICA PLANTS: A POSSIBILITY TO EVALUATE CLIMATE CHANGE, PhD Patricia Cristina Tarkanyi, PhD Georgeta Sofia Popescu, PhD Laura Radulescu, Assoc. Prof. Dr. Monica Cristina Dragomirescu, Assoc. Prof. Dr. Despina-Maria Bordean 389

48. WATER CONFLICTS LINKED TO CLIMATE CHANGE AND POPULATION EXPLOSION, Assoc. Prof. Dr. Georgi Bardarov 397

SECTION MODERN ENERGY AND POWER SOURCES

49. A PROPOSAL OF MARINE SHORT RANGE TRANSPORTATION, IN MEDITERRANEAN SCENARIO, TO REDUCE CO_2 EMISSIONS AND IMPACT OF ENVIRONMENT., Prof. Valerio Ruggiero.....407

50. AN ANALYSIS OF AN INNOVATIVE, ENERGETICALLY INDEPENDENT SALES SYSTEM (VENDING MACHINE) FOR COLD AND HOT PRODUCTS Ioan Mihail Savaniu ,Oana Tonciu, Ancuta Neagu, Magdalena Culcea.....415

51. BIOMASS UTILIZATION AS SUSTAINABLE ENERGETIC ROOT, Dr. Simona Gavrilas, Assoc. Prof. Dr. Eugenia Tigan, Assoc. Prof. Dr. Oana Brinzan, Dr. Radu-Lucian Blaga.....423

52. ENERGY SECURITY OPPORTUNITIES ARISING FROM SDGS AND THE RECOVERY AND RESILIENCE PLAN, Ing. Lenka Kazimirova, Assoc. Prof. Dr. Denisa Ciderova, Ing. Simona Sakacova, Ing. Jozef Cernak.....431

53. GREEN BONDS AS A LONG-TERM SOURCE OF FINANCE FOR RENEWABLE ENERGY INVESTMENTS, Assoc. Prof. Dr. Meltem Gurunlu 447

54. INVESTIGATION OF ORGANIC WASTES CONVERSION INTO USEFUL ENERGY RESOURCES USING PYROLYSIS PROCESS, Assoc. Prof. DSc. Elena David, Prof. Janez Kopac, Dr. Roxana-Maria Marinescu, Drd. Adrian Armeanu.....455

55. NEW ASPECTS OF EXPLOSIVE CHARACTERISTICS OF HYBRID MIXTURES OF DUST/GAS DISPERSIONS, Ing. Matous Helegda, Ing. Iris Helegda, PhD Ing. Jan Skrinsky, Ing. Katerina Kubricka, PhD Jiri Pokorny.....463

56. SOLAR TRACKER SYSTEM FOR MONITORING THE MAXIMUM SUN POTENTIAL THAT CAN BE PRODUCED IN A SPECIFIC PLACE, Prof. Dr. Razvan Bogdan Itu, Prof. Dr. Alexandra Soica, Prof. Dr. Lorand BOGDANFFY.....471

57. THE CARBON BORDER ADJUSTMENT MECHANISM (CBAM): A QUALITATIVE LEAP IN ENVIRONMENTAL TAXATION FOR A WORLD IN ECOLOGICAL TRANSITION., PhD Elisabetta Ceroni.....479

58. THE ENERGY TRANSITION PATHWAY FOR ALASKA, Assoc. Prof. Arthur Nash.....487

59. THE HYDROGEN CONCENTRATION ON NETWORKS FOR GAS SUPPLY, Assoc. Prof. Dr. Martin Boyadjiev.....495

SECTION RECYCLING

CHARACTERIZING THE MEMBRANE CONCENTRATE FROM LEACHATE TREATMENT: HAZARDOUSNESS EVALUATION AND ITS POTENTIAL TO LANDFILL RECIRCULATION

Lidia Kim*
Razvan Laurentiu Dinu
Adriana Cuciureanu
Georgiana Cernica
Valeriu Badescu
National Research and Development Institute for Industrial Ecology – ECOIND, Bucharest, **Romania**

ABSTRACT

One of the main challenges in treating landfill leachate through membranes is managing the resulting concentrate. Depending on the membrane installation's performance and the stored waste's characteristics, significant quantities of concentrate may remain after leachate treatment. Therefore, it is necessary to identify an optimal disposal or treatment method for it. In the European Union List of Waste, the membrane concentrates are associated with leachates and are classified as either hazardous or non-hazardous waste and assigns them "mirror entries" codes: 19 07 02* or 19 07 03. Consequently, it is crucial to evaluate their hazardousness for proper management. If the concentrate is non-hazardous, it can be recirculated to the waste deposit under certain conditions. However, legislation only permits the storage of solid waste or sludge from the treatment plant with humidity < 60%. The paper refers to the characterization and evaluation of the hazardous properties of three liquid wastes, known as membrane concentrates, from treating municipal waste deposits leachates by reverse osmosis. In this study, the concentrations obtained for the main indicators in the three concentrates were found to be within the following ranges: ammonium (620 - 1120 mg/L); chlorides (12114 - 21349 mg/L); dissolved organic carbon (4270 - 10450 mg/L); total dissolved solids (60840 - 81000 mg/L). Reporting these concentrations to the limits imposed on the hazardous properties HP1-HP15, the wastes fall under code 19 07 03, related to non-hazardous waste. Even if the treatment facility would handle the treatment of a more polluted leachate resulting as concentrate is recirculated to the landfill, according to the legislation, due to the high concentrations of dissolved organic carbon, the three wastes cannot be eliminated on the waste deposits.

Keywords: membrane concentrates, hazardousness evaluation, municipal waste landfill, recirculation, reverse osmosis

* Corresponding author: lidia.kim@incdecoind.ro

INTRODUCTION

The membrane concentrates (MCs) results from treating leachate from municipal waste deposits through membrane filtration processes. The leachate is formed from the humidity of waste, the degradation of organic residues, and the percolation of rainwater in the covering layers of the landfill cells [1]. The leachate and the MC are liquid wastes assimilated to highly contaminated liquid effluents with dark colors and a pestilential smell. The leachate contains a high load of organic matter, nutrients, and inorganic compounds and low concentrations of emerging contaminants such as pharmaceutical compounds and persistent organic pollutants [1, 2]. The characteristics and composition of the leachate vary in time and space and are influenced by factors such as the age of the waste landfill, environmental conditions, the deposit's mode of operation, the decomposition process of organic matter, precipitation, and the degree of compaction of the landfill cells. These factors also influence the amount of leachate generated from the landfill [1, 3]. Reverse osmosis (RO) is used in wastewater treatment to remove low molecular weight compounds and dissolved substances such as salts and heavy metals. In the last two decades, due to the high efficiency of removing contaminants, RO has been used on a large scale for treating leachates [3-5]. The disadvantages of using the RO process are the membranes' loading, which leads to decreased permeate flow, and the management of the resulting MC [5]. Compared to raw leachate, in addition to a higher content of contaminants, the MC also mainly contains non-biodegradable inert substances [4]. To treat the MC, conventional treatment technologies such as evaporation, adsorption, distillation, electrodialysis, coagulation, and advanced oxidation processes are widely used [5-7]. The recirculation of the MC on the landfill remains a conventional approach to adjust the humidity and facilitate the degradation of organic matter. However, this method has some negative aspects, such as the accumulation of pollutants in the leachate and the destabilization of the landfill [7, 8]. Some studies have shown that the recirculation of the MC can be beneficial for producing methane from the degradation of waste under anaerobic conditions [9]. However, by recirculating the MC, the concentration of pollutants in the leachate increased, especially the content of inorganic salts, affecting the efficiency of the RO system [10]. An essential aspect of MC management is its classification in the European Union List of Waste (LoW) [11]. The MC does not have a specific code in the list, but it can be assimilated to the leachate, classified in chapter 19, subchapter 19 07, codes 19 07 02 or 19 07 03. The two codes refer to "mirror entries" waste (waste that can be under certain conditions, either hazardous waste (MH) or non-hazardous waste (MNH), depending on their composition and specificity). Since the MC falls under the incidence of waste according to Directive 2008/98/EC, for proper management, it is necessary to it classification by assigning one of the two codes [12].

In this work, three MCs generated from the treatment of leachates through the RO process were characterized and analyzed to evaluate their hazardousness and classify them according to the specific waste legislation. Also, their recirculation potential in the landfill was evaluated according to current practices and current legislation [13].

MATERIALS AND METHODS

For the study, three liquid MCs (coded W1, W2, and W3) were chosen. These MCs were generated from leachates treated through RO from three municipal waste landfills.

To evaluate the hazardousness of the wastes, a methodology was used that we developed in a previous study for assessing the hazardousness of "mirror entries" wastes [14]. The data regarding the source of the waste, the technological process of generation, and the substances/materials used in the process were provided by the waste operators. Potentially hazardous compounds were identified based on the safety data sheets of the substances used in the technological process and based on the physical-chemical analyses. The concentrations were reported to the limits imposed in the Annex to Regulation 2014/1357/EU for the hazardous properties [15].

In order to evaluate the potential of waste recirculation in the landfill, the specific physical-chemical indicators for the acceptance of solid waste for storage were analyzed. This approach was chosen to determine whether the MC waste could be assimilated with other solid waste from a storage point of view. The results were reported to the limits imposed by the MMGA Order 2005/95, transposed into the Romanian legislation from Decision 2003/22/EC. The MMGA Order establishes the maximum admissible values (MAV) and the criteria for accepting waste at storage in inert, non-hazardous, and hazardous waste landfills [16, 17]. All physical-chemical indicators were determined according to standardized methods. The reagents used in the analyses were of analytical purity grade. For the heavy metals content, the samples were mineralized by microwave digestion and analyzed by the ICP-MS technique.

Figure 1, schematically shows the steps for assessing the hazardousness of wastes.

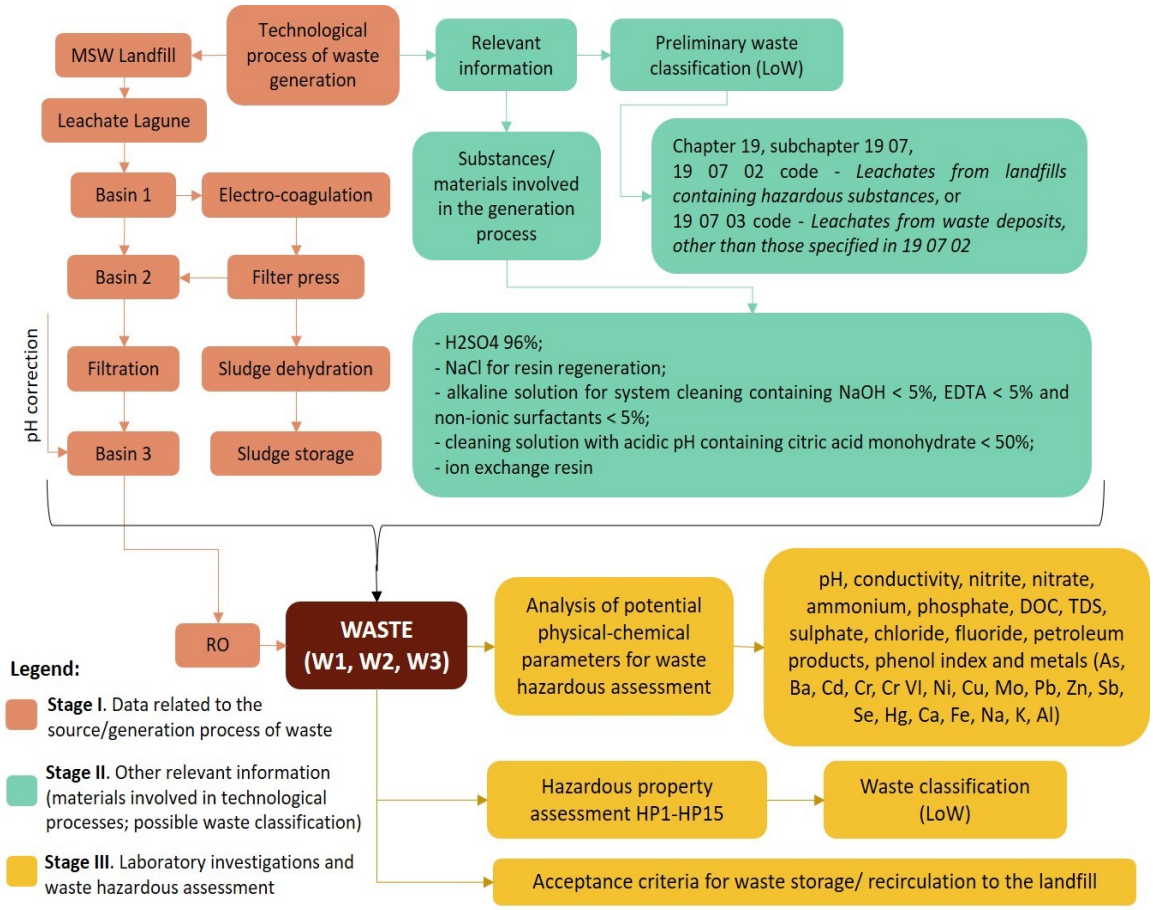


Figure 1. The presentation of the stages for waste hazardousness assessment [5, 14]

RESULTS

Table 1, shows the results of the physical-chemical analyses for W1, W2, and W3.

Table 1. The concentrations of the physical-chemical indicators

Physical-chemical indicators	**W1**		**W2**		**W3**	
pH *(pH unit)*	7.81		7.26		7.63	
Conductivity *(mS/cm)*	45.2		38.6		34.1	
Units	*mg/Kg*	*%*	*mg/Kg*	*%*	*mg/Kg*	*%*
Phosphate	157	0.016	80.9	8.09×10^{-3}	43.1	4.31×10^{-3}
Ammonium	620	0.062	1120	0.112	957	0.096
Nitrate	131	0.013	388	0.039	474	0.047
Nitrite	1.33	1.33×10^{-4}	< 0.05	-	< 0.05	-
Petroleum products	< 25	-	< 25	-	< 25	-
Ca	199	0.020	1346	0.135	95.9	9.59×10^{-3}
Total Fe	12.7	1.27×10^{-3}	49.1	4.91×10^{-3}	10.8	1.08×10^{-3}
Na	8466	0.847	9564	0.956	5498	0.535
K	8952	0.895	6464	0.646	5352	0.498
Al	209	0.021	20	0.002	3.98	3.98×10^{-4}
Cr VI	< 0.05	-	< 0.05	-	<0.05	-
As	-*	1.07×10^{-4}	-*	4.93×10^{-5}	-*	8.41×10^{-5}
Ba	-*	1.31×10^{-4}	-*	2.15×10^{-4}	-*	4.18×10^{-4}
Cd	-*	-	-*	2.8×10^{-6}	-*	1.33×10^{-5}
Total Cr	-*	7.87×10^{-4}	-*	9.25×10^{-4}	-*	7.56×10^{-4}
Cu	-*	3.11×10^{-5}	-*	1.85×10^{-4}	-*	3.93×10^{-5}
Hg	-*	-	-*	-	-*	-
Mo	-*	9.60×10^{-6}	-*	2.89×10^{-5}	-*	4.21×10^{-5}
Ni	-*	1.55×10^{-4}	-*	2.65×10^{-4}	-*	1.18×10^{-4}
Pb	-*	9.90×10^{-6}	-*	2.39×10^{-5}	-*	7.24×10^{-5}
Sb	-*	4.99×10^{-5}	-*	3.31×10^{-5}	-*	5.52×10^{-5}
Se	-*	2.60×10^{-6}	-*	-	-*	-
Zn	-*	1.09×10^{-3}	-*	6.43×10^{-4}	-*	2.66×10^{-4}
Chloride	-*	2.135	-*	1.757	-*	1.211
Fluoride	-*	3.21×10^{-4}	-*	8.04×10^{-4}	-*	3.71×10^{-4}
Sulphate	-*	2.276	-*	1.784	-*	0.604
Phenol index	-*	2.43×10^{-3}	-*	2.01×10^{-3}	-*	1.02×10^{-4}
DOC	-*	1.045	-*	0.427	-*	0.874
TDS	-*	8.10	-*	6.47	-*	6.084

DOC - Dissolved Organic Carbon; TDS - Total Dissolved Solids; <, under the methods determination limit; *, the results are presented in Table 2; Since the maximum allowed limits are expressed in percentages (Annex to Reg. 1357/2014), the results in Table 1 are expressed both as mg/kg and %.

The results regarding the concentrations of the physical-chemical indicators in the wastes compared to the maximum admissible values according to MMGA Order 2005/95 are presented in Table 2.

Table 2. The physical-chemical indicators analyzed for the evaluation of the recirculation potential

Physical-chemical indicators	W1 *(mg/Kg)*	W2 *(mg/Kg)*	W3 *(mg/Kg)*	MMGA Order 2005/95 (MAV)		
				Inert	Non-hazardous	Hazardous
As	1.07	0.493	0.841	0.5	2	25
Ba	1.31	2.15	4.18	20	100	300
Cd	<0.002	0.028	0.133	0.04	1	5
Total Cr	7.87	9.25	7.56	0.5	10	70
Cu	0.311	1.85	0.393	2	50	100
Hg	< 0.005	<0.005	<0.005	0.01	0.2	2
Mo	0.096	0.289	0.421	0.5	10	30
Ni	1.55	2.65	1.18	0.4	10	40
Pb	0.099	0.239	0.724	0.5	10	50
Sb	0.499	0.331	0.552	0.06	0.7	5
Se	<0.12	<0.12	<0.12	0.1	0.5	7
Zn	10.9	6.43	2.66	4	50	200
Chloride	21349	17572	12114	800	15000	25000
Fluoride	3	8.04	3.71	10	150	500
Sulphate	22759	17840	6042	1000	20000	50000
Phenol index	24.3	20.1	1.02	1	-*	-*
DOC	10450	4270	8742	500	800	1000
TDS	81000	64700	60840	4000	60000	100000

<, under the methods determination limit; MAV, maxim admissible values; *, there are no imposed limits;

The values correspond to inert waste deposits
The values exceed the MAV for inert waste deposits
The values exceed the MAV for non-hazardous waste deposits
The values exceed the MAV for hazardous waste deposits

The results regarding the hazardous properties of the compounds present in the wastes and the associated hazard phrases are presented in Table 3.

Table 3. Assessment of hazardous properties for W1, W2 and W3

Hazardous Property	Hazard Phrase	Analyzed indicator/ Possible Hazardous Compounds (PHCs)	Concentrations of PHCs (%)			Concentration limit (%) Regulation 2014/1357/EU
			W1	W2	W3	
HP4 *Irritant - skin irritation and eye damage*	H314	$Fe/FeCl_3$ x $6H_2O$	0.006	0.024	0.005	1
	H318	$Fe/FeCl_3$ x $6H_2O$	0.006	0.024	0.005	
		$Al/Al_2(SO4)_3x18H_2O$	0.258	0.025	0.005	
		Total	*0.265*	*0.048*	*0.010*	*10*
	H315 H319	$Nitrate/NaNO_3$	0.018	0.053	0.065	
		Na/Na_2SO_4 x $10H_2O$	2.840	3.208	1.844	
		$Al/Al_2(SO4)_3x18H_2O$	0.258	0.025	0.005	
		$Ca/CaCl_2$ x $4H_2O$	0.091	0.616	0.044	
		$Chloride/NH_4Cl$	3.217	2.648	1.825	
		$Fe/FeSO_4$ x $7H_2O$	0.006	0.024	0.005	

		Total	*6.430*	*6.574*	*3.789*	*20*
HP5 *Aspiration Toxicity*	H335	$Al/Al_2(SO4)_3x18H_2O$	0.258	0.025	0.005	20
HP 6 *Acute Toxicity*	H302	$Nitrate/NaNO_3$	0.018	0.053	0.065	25
	H332	$Fe/FeCl_3$ x $6H_2O$	0.006	0.024	0.005	
		$K/KClO_4$	3.180	2.296	1.901	
		Total	*3.204*	*2.373*	*1.972*	*22.5*
HP 8 *Corrosive*	H314	$Nitrate/NaNO_3$	0.018	0.053	0.065	
		$Ca/Ca\ (OH)_2$	0.020	0.249	0.018	
		Total	*0.038*	*0.302*	*0.083*	*5*
HP 14 *Ecotoxic*	H410	$Al/Al_2(SO4)_3x18H_2O$	0.258	0.025	0.005	
	H411	Na/Na_2SO_4 x $10H_2O$	2.840	3.208	1.844	
	H411	$Chloride/NH_4Cl$	3.217	2.648	1.825	
		Total	*6.314*	*5.880*	*3.674*	*25*

DISCUSSION

Analyzing the results from Table 1, it can be seen that the highest concentrations were obtained for the following indicators: Chlorides in the range of 1.211 - 2.135%; Sulphates in the range of 0.604 - 2.276%; Sodium in the range of 0.535 - 0.956%, Potassium in the range 0.498 - 0.895%, Ammonium in the range 0.062 – 0.112%, DOC in the range 0.427 – 1.045% and TDS in the range 6.084 – 8.10%. Similar results have been reported in the literature [6]. Among the most common possible hazardous compounds that can form in the case of these indicators are Ammonium Chloride (NH_4Cl), Ferric Chloride ($FeCl_3$), Sodium Sulphate (Na_2SO_4), Aluminum Sulphate ($Al_2(SO4)_3$), Sodium Nitrate ($NaNO_3$), Potassium Perchlorate ($KClO_4$) and Calcium Hydroxide ($Ca(OH)_2$). Since the concentrations of the other metals are small (concentration range 10^{-3} – 10^{-6}), any compound associated with these metals will have a concentration lower than the most restrictive limit of 0.1% imposed in the legislation [15]. Considering the visual appearance of the wastes and the manner of their generation, these are not hazardous by HP1 (explosive), HP2 (oxidizing), HP3 (inflammable), HP12 (sensitive) and HP15 (waste capable of exhibiting a hazardous property listed in HP1–HP14 not directly displayed by the original waste) properties. The property HP9 (infectious) has no limit values imposed by the legislation. The evaluation of the hazardous properties HP4-HP8, HP10, HP11, and HP14 is presented in Table 3. The potentially hazardous compounds identified did not have hazard phrases associated with the hazardous properties HP10 and HP11. All the concentrations of possible hazardous compounds were lower than the imposed limit values. About the Persistent Organic Pollutants in the literature, studies have identified the presence of Polyfluoroalkyl Compounds (PFCs) in leachate, the concentrations of individual compounds being in the concentration range of 4-3000 ng/L [18]. Therefore, their percentage concentrations are very low compared to the limits imposed by Regulation 2014/1357/EU.

Considering the aspects mentioned above and the definition of hazardous waste given by Directive 2008/98/EC ("any waste that presents one or more of the hazardous properties"), the analyzed wastes are non-hazardous.

From the point of view of the recirculation of the MC on landfill, it is found that the concentration of DOC indicator exceeds the MAV limit set by MMGA Order 2005/95 for waste acceptance to storage in all three types of waste (Table 2). Moreover, it is required by law that waste should be subjected to a leaching test for storage that is not applied to liquid wastes. These findings are particularly relevant when considering the recirculation of the MC on landfill. The literature studies present the advantages and disadvantages of recirculating the concentrate on the landfill [7, 9, 10].

CONCLUSION

The assessment of the hazardousness of the wastes W1, W2, and W3 according to the legislation on the waste regime led to the conclusion that they are non-hazardous. These can be classified in the EU LoW at Chapter 19 - *Waste from waste management facilities, off-site wastewater treatment plants and the preparation of water intended for human consumption and water for industrial use*, Subchapter 19 07 - *Landfill leachate*, Code 19 07 03 – *Landfill leachate other than those mention in 19 07 02* (code 19 07 02 refers to landfill leachate, which contains hazardous substances). Even if the studied wastes are non-hazardous, they are associated with highly contaminated effluents. Therefore, the wastes cannot be discharged into natural receptors or on the soil and require an appropriate treatment to eliminate/reduce the existing contaminants. Even if the concentrate recirculation remains an option due to some advantages of methane production, the recirculation method cannot be applied in all conditions. The disadvantages are given by the legislative restrictions and by overloading the landfill with salts, metals, and DOC. The overloaded leachate presents the risk of disrupting the performance of the RO system and the membrane overload, which can cause higher energy consumption and high maintenance costs. However, the recirculation of the concentrate on the deposit remains one of the most preferred methods due to its simplicity and profitability.

ACKNOWLEDGEMENTS

This work was carried out through the Core Program within the National Research Development and Innovation Plan 2022-2027, with the support of the Ministry of Research, Innovation and Digitization, the projects PN 23 22 03 01 and PN 23 22 03 02.

REFERENCES

[1] Luo, H., Zeng, Y., Cheng, Y., He, D.Pan, X., Recent advances in municipal landfill leachate: A review focusing on its characteristics, treatment, and toxicity assessment. Science of The Total Environment, vol. 703, pp 135468, 2020. DOI: https://doi.org/10.1016/j.scitotenv.2019.135468.

[2] Moravia, W.G., Amaral, M.C.Lange, L.C., Evaluation of landfill leachate treatment by advanced oxidative process by Fenton's reagent combined with membrane

separation system. Waste Management, vol. 33/issue 1, pp 89-101, 2013. DOI: http://dx.doi.org/10.1016/j.wasman.2012.08.009.

[3] Miao, L., Yang, G., Tao, T.Peng, Y., Recent advances in nitrogen removal from landfill leachate using biological treatments–A review. Journal of environmental management, vol. 235, pp 178-185, 2019. DOI: https://doi.org/10.1016/j.jenvman.2019.01.057.

[4] Talalaj, I.A., Removal of nitrogen compounds from landfill leachate using reverse osmosis with leachate stabilization in a buffer tank. Environmental technology, vol. 36/issue 9, pp 1091-1097, 2015. DOI: https://doi.org/10.1080/09593330.2014.982207.

[5] Topal, A.D.Atasoy, A.D., Reverse osmosis treatment system for landfill leachate: Operation conditions, advantages and challenges. Environmental Research and Technology, vol. 5/issue 2, pp 119-127, 2022. DOI: https://doi.org/10.35208/ert.1027553.

[6] Keyikoglu, R., Karatas, O., Rezania, H., Kobya, M., Vatanpour, V.Khataee, A., A review on treatment of membrane concentrates generated from landfill leachate treatment processes. Separation and purification technology, vol. 259, pp 118182, 2021. DOI: https://doi.org/10.1016/j.seppur.2020.118182.

[7] De Almeida, R., Porto, R.F., Quintaes, B.R., Bila, D.M., Lavagnolo, M.C.Campos, J.C., A review on membrane concentrate management from landfill leachate treatment plants: The relevance of resource recovery to close the leachate treatment loop. Waste Management & Research, vol. 41/issue 2, pp 264-284, 2023. DOI: https://doi.org/10.1177/0734242X221116212.

[8] Lebron, Y.A.R., Moreira, V.R., Brasil, Y.L., Silva, A.F.R., de Souza Santos, L.V., Lange, L.C.Amaral, M.C.S., A survey on experiences in leachate treatment: Common practices, differences worldwide and future perspectives. Journal of environmental management, vol. 288, pp 112475, 2021. DOI: https://doi.org/10.1016/j.jenvman.2021.112475.

[9] Morello, L., Cossu, R., Raga, R., Pivato, A.Lavagnolo, M.C., Recirculation of reverse osmosis concentrate in lab-scale anaerobic and aerobic landfill simulation reactors. Waste Management, vol. 56, pp 262-270, 2016. DOI: https://doi.org/10.1016/j.wasman.2016.07.030.

[10] Talalaj, I.A., Mineral and organic compounds in leachate from landfill with concentrate recirculation. Environmental Science and Pollution Research, vol. 22, pp 2622-2633, 2015. DOI: https://link.springer.com/article/10.1007/s11356-014-3533-0.

[11] Commision Decision 2000/532/EC replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishing a list of hazardous waste. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32000D0532 (accessed on 14 November 2023).

[12] Directive 2008/98/EC on Waste and repealing certain Directives. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098 (accessed on 14 November 2023).

[13] Council Directive 1999/31/EC on the landfill of waste. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999L0031 (accessed on 14 November 2023).

[14] Kim, L., Cuciureanu, A., Pascu, L.F., Tache, O.C.Catrina, G.A., A Comprehensive Methodology for Assessing the Hazardousness of Waste Categorized in the European Union Legislation as "Mirror Entries"-Case Studies. Environments, vol. 10/issue 10, pp 183, 2023. DOI: https://doi.org/10.3390/environments10100183.

[15] Commission Regulation 2014/1357/EU replacing Annex III to Directive 2008/98/EC on waste and repealing certain Directives. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R1357 (accessed on 14 November 2023).

[16] Council Decision 2003/33/EC establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32003D0033 (accessed on 14 November 2023).

[17] MMGA Order 2005/95 - The Criteria for the Acceptance and Preliminary Acceptance Procedures for Waste at Storage and National List of Waste Accepted in Each Class of Waste Landfill. Available online: https://www.ecotic.ro/wp-content/uploads/2015/07/1e62400fcaa487767564187df6343e669b6f36ad.pdf (accessed on 14 November 2023).

[18] Busch, J., Ahrens, L., Sturm, R.Ebinghaus, R., Polyfluoroalkyl compounds in landfill leachates. Environmental pollution, vol. 158/issue 5, pp 1467-1471, 2010. DOI: https://doi.org/10.1016/j.envpol.2009.12.031.

CHALLENGES TO THE FOOD WASTE RECYCLING SYSTEM IN LATVIA

Prof. Dr. Aija Eglīte[1]

Dr. Dace Kaufmane[2]

[1, 2]Latvia University of Life Sciences and Technologies, **Latvia**

ABSTRACT

Prevention and reduction of food waste production, food waste conversion into energy and products as well as the proper disposal are sequential processes in the food system. Technological standards and a legal framework for food waste recycling, as well as amendments to the relevant legal acts – both national- and municipal-level ones – have been made in Latvia. In addition, the compliance with the European Waste Classification for Statistics have been verified and the participation of non-governmental organizations have been promoted. Consumer education, financial stimuli, technical support, public awareness and tracking and reporting strategies are applied in Latvia. The present research aims to briefly review the objectives achieved and the respective future plans in order to reduce food waste and increase the proportion of recycled food waste in Latvia. The research is based on a content analysis and expert interviews.

The largest challenge to waste sorting is to ensure that the quality of the waste sorted allows the food waste collected to be recycled. In 95% cases, the biological waste sorted is of poor quality and cannot be used for high-quality compost.

Food waste is managed differently across municipalities. By motivating and stimulating households, the number of those sorting biological waste could increase, driven by both environmental conviction and economic rationalism. Overall in Latvia, the food waste management system is strictly regulated for companies, yet it is not profitable enough for households to prepare compostable material from food waste.

Keywords: food waste, recycling, system

INTRODUCTION

Preventing food waste, reducing food waste production, converting the waste into energy and products, as well as the proper disposal are sequential procedures in the food supply chain system. For many years, researchers and non-governmental organizations have emphasized that in the European Union (EU), serious efforts in the fight against food waste are not made and are not considered a serious environmental problem. Unfortunately, it is not possible to reduce the money spent on food purchased, which is consequently wasted, or reduce the cost of recycling food waste if the consumers do not change their eating habits and pay attention to the impacts of food waste [1]. Agricultural economics focuses on every stage in the entire food supply chain – not only the supply of food to the population but also food waste sorting and recycling. These

problems have been researched during a long period. As food availability and access improved in the 21st century, the problem of food wastage added to food security problems, thereby requiring researching the motivating factors in food wastage as well as how reducing the potential amount of food wasted affects access to the food in a particular region. This requires starting researching food consumption habits and the food disposal, which also affect access to the food (the practice of food donation), as well as food recycling practices to come up with a vision for better food waste recycling [2] The food industry is one of the industries that requires the most resources, yet it is the food waste that makes up 40% of the total waste [3]. It is a huge resource for biogas production, compost for crop production as well as feed. Industrialized countries apply various approaches and techniques to achieve the goals set. However, the interests of the stakeholders involved are also important, which could be met in various ways. By not tackling the problem of food waste in a timely manner, the average percentage of food waste in the EU, which was approximately 22-25%, could not be reached in Latvia.

The research aims to briefly review the measures taken to reduce food waste and increase the proportion of food waste recycled.

The following specific research tasks were set:

1. To give a theoretical insight into food waste production and the need for recycling the waste in the context of economics and the related sciences.
2. To analyse the problem of food waste in industrialized countries with regard to the relevant legal framework and institutions.
3. To identify challenges for food waste recycling in Latvia.

MATERIALS AND METHODS

The research is based on a content analysis and expert interviews.

RESULTS

In research studies, the amounts of food waste identified applying various approaches vary, yet there is a correlation: the higher the average income in a country, the more food is wasted. Income is positively related to the amount of food sold, but not to the amount of food consumed. If nothing is done about this problem, the amount of food waste could certainly increase in the future [1].

Some research studies conducted in Latvia in 2016 have established [4] that people in cities waste food the most. Households with only adults waste food the least. Single-person households produce the largest amount of food wasted. Households earning the highest incomes waste more food.

Food waste belongs to the category of biological waste, which is recycled in three ways: mechanically and biologically, composted or used for biogas production. Catering waste represents leftover food, including used cooking oil, from restaurants, catering enterprises and kitchens, including centralized and household kitchens. Food waste is recycled in two ways: separately collected food waste is composted or recycled by biogas plants, with quality requirements being set for compost and fermentation residues.

In Latvia, research on biogas production was conducted already during the Soviet period. The research was done by laboratories, as well as semi-industrial and industrial models were created. At the beginning of the 1980s in Latvia, a biogas plant was built near a collective farm with 3000 pigs, where extensive applied research was conducted. Intensive work was also done on various experimental equipment that recycled food industry wastewater and residual products from dairies, juice and beverage facilities, the Jelgava sugar factory, a starch production facility located in Aloja village etc. The purpose of the facilities was not biogas production but the purification of heavily polluted wastewater, i.e. the first stage of the applied wastewater technology was anaerobic or methane fermentation. [5]

In the mid-1980s in Latvia, an experimental facility was built, and in 1985, for the first time in the Soviet Union, electric energy was generated from biogas. Based on the technologies developed by Latvian scientists, such facilities were also built in the then Soviet Union: in Leningrad and Vladimir, as well as in Novosibirsk and Abakan regions, as well as in Georgia.

At the beginning of the 1990s, wastewater treatment facilities were built in the city of Riga, where one of the technological facilities was a biogas facility (3 fermenters, each having a volume of 4000 m^3, which gave an opportunity to recycle 700-800 tons of sludge and liquid food waste per day and generate almost 2 MW of electricity per hour). From 1991 to about 2006, there was a decline in biogas production. For the idea of biogas production not to disappear from the Latvian lexicon and somehow preserve the previous experience, the Latvian Biogas Association was founded in 1994.

At present, we have entered a new stage of development, as even universities are announcing intellectual property auctions for biogas production technologies, e.g. Riga Technical University (RTU) holds an auction in December 2023 for environmentally friendly zero-residue technology for the production of liquid biofuel and biogas from biomass [6].

Legal and institutional frameworks

Countries around the world have various approaches to and experience in collecting and recycling food waste.

Japan has adopted the Food Recycling Law governing the recycling loop, which requires entities engaged in the food supply chain to buy raw materials/commodities from producers who use food waste as compost for crop production and feed for livestock production. Food waste is sorted by households in Japan. Special bags for food waste are taken out from homes and collected by waste management companies on certain days. On other days, they are kept at homes. Food waste stored in non-specialized bags, taken out from homes on other days or stored not in the municipality is fined up to 10 million Japanese yen (approximately EUR 70 thou.) [7].

The US state of Massachusetts has completely banned commercial food waste. Hotels, grocery stores, universities, sport and entertainment venues that produce more than one ton of food waste per week have the choice of either donating the food that is not used or sending the spoiled food to special composting sites where it processed into either biogas or used as feed. Supermarket managers have found that such a requirement has made it possible to save even from USD 1 to 2 million per year. Similar regulations

have been adopted in cities such as Vermont, Connecticut, New York and San Francisco [7].

The relevant EU directives focus on reducing the environmental impact of food waste. The Waste Framework Directive requires that all food waste be collected, transported and stored. The EU Waste Framework Directive sets a target for the reduction of biodegradable waste moved to landfills, considering the 1995 biodegradable waste level in each Member State as a reference level. The EU adopted the Waste Framework Directive as late as 2018, which is being revised in 2022-2023. Citizens were also involved in this process, and 800 EU citizens from all 27 EU Member States participated in panel discussions [8]. The purpose of the panel discussions was to encourage citizen creativity in order to generate new ideas and come up with specific recommendations for the European Commission. The result was a list of recommendations that was submitted to the European Commission in 2023. The panel discussions on food waste were held by the European Commission (Directorate-General for Communication in cooperation with the Directorate-General for Health and Food Safety). The discussions have resulted in a legislative proposal submitted in 2023 to revise the EU Waste Framework Directive adopted in 2018. It will then be discussed with the European Parliament and the Council of the European Union, which represents the governments of all Member States, until a consensus is reached. At the end of this broad process, new legal acts are going to be adopted (possibly in 2025, depending on the progress of political negotiations). Each EU Member State will then have to incorporate the new legal provisions into their own legislation.

Section 1 of the Waste Management Law (2010) adopted in Latvia [9] defines food waste in accordance with Regulation (EC) No. 178/2002 of the European Parliament and of the Council of 28 January 2002). Section 11 of the law defines waste production and states that the Cabinet is responsible for a food waste prevention programme and the monitoring thereof. According to Section 20 of the law, the Cabinet prescribes the procedure whereby the Ministry of Environmental Protection and Regional Development (MoEPRD) shall ensure the determination of the quantity of composted biological waste, waste intended for re-use, and food waste in particular weight and the frequency of determination. The MoEPRD is responsible for food waste management. However, non-governmental organizations (NGOs), municipalities and companies, including catering enterprises and farms, are involved institutionally. Compared with other Baltic States, the separate waste collection system was introduced in Latvia relatively late.

The Latvian Association of Waste Management Companies is a public organization founded in 1996 and operates according to its Statute [10]. It represents professional companies engaged in waste management: collection, storage, recycling, transport, recycling and disposal. The association actively participates in the development of national laws and regulations, submitting proposals to the competent national institutions for solving waste management problems. The members of the association cooperate to jointly procure waste management equipment, develop a unified household waste management tariff system etc. The association has more than 50 members having a market share of almost 90%. The association has stated that its field of activity is waste collection, sorting, storage, processing, transport and disposal, as well as public education.

According to data from the Central Kurzeme Waste Management Organization, the cost of sorted biowaste collection is 30% lower than that for unsorted waste. The biological (bio) waste collection service available to legal entities was supplied within a pilot project implemented from 7 October 2022 to 31 December 2023. Heat-treated and raw dairy products, meat, fish and other foods of animal origin (including bones, shells), flour products, fruits, vegetables and other perishable waste are accepted from legal entities as biological waste. As of 1 January 2024, the separate waste collection system for biowaste is mandatory and provided throughout Latvia.

DISCUSSION

Food waste problems viewed from the perspectives of food availability, access, consumption and recycling are associated with the legal framework for food and labelling, food consumption habits and food waste recycling.

A group of European citizens recommend governments to use bans, incentives and tax relief, retailers to donate, manufacturers to change labels, catering providers to reduce portion sizes, NGOs to hold campaigns to change public opinion. However, an unanswered question regarding the civic initiatives is who will pay for it and how much. What will be the input-output ratio, who will calculate it and who will be interested in it? Households have their own financial interest and can relatively early have the financial benefit and economic effect, as well as the invaluable experience, yet who and how will calculate the effectiveness and sustainability of the campaign? Nevertheless, no matter how effective the involvement of civil society is, there is no need to reinvent the wheel. It would be worth using the experience of the USA and Japan, which is indicated by some specific financial indicators and economic effects that have and can be calculated by any household, food producer or retailer that can express the benefits in numbers.

Eight hundred EU citizens from all 27 EU Member States participated in panel discussions [8]. The purpose of the panel discussions was to encourage citizen creativity in order to generate new ideas and come up with specific recommendations for the European Commission. However, the main objective of the European Economic and Social Committee is to hold a unique forum intended for civil society groups to discuss and achieve specific goals in the public interest. [11]. The committee mainly intends to advise the European Commission. Consequently, there has been a duplication of functions between the EU institutions in this regard.

In the EU, decisions on food waste recycling are made slowly, involving not only experts but also the public from all EU Member States, with the aim of amending the relatively recently adopted legal act. The European Commission will amend the legal act by 2025, and the new legal provisions then must be incorporated by each Member State in their national laws and regulations.

One can be glad and feel satisfied that in 2023, the Michelin Guide noticed and rated restaurants in Latvia, awarding a Michelin Green Star to a restaurant in Ligatne village for the complete or 100% efficient use of food waste. The high rating of such restaurant work and awarding a globally recognized and recognized distinction will also have a lasting economic effect. This could allow Latvia to attract gastronomic and ecological tourists and green lifestyle practitioners, while Latvian businesses have more

opportunities to popularize the Latvian way of life. It can contribute to GDP growth not only in Latvia but also in the entire Baltic region.

CONCLUSION

1. In Japan and the USA, their anti-food waste legal frameworks focus on banning commercial food waste, introducing recycling loops, changing food consumption habits regarding food waste sorting, as well as food donation policies. In the EU and the Member States, the legal frameworks focus on preventing food waste from ending up in landfills.
2. In Latvia, T. Tokareva produced a doctoral thesis, the findings of which can be recommended for the development of legal frameworks governing food waste management.
3. In the USA and Japan, collecting and recycling food waste is based on economic mechanisms, more precisely on the concept of economic rationalism or the interest of the stakeholders involved as well as economic profitability. In the EU, food waste collection and recycling is actually based on the idea of maintaining environmental sustainability and convincing residents to save food in order to reduce the environment impact with voluntary, reasonable and socially responsible involvement of the residents.
4. In Latvia, scientific research into food waste recycling has been conducted since the second half of the 20th century. The first biogas facilities were built near large agricultural and food processing facilities with the aim of purifying industrial wastewater, yet their operation and development potential were stopped by the overall privatization that was carried out in the 1990s. Nevertheless, the scientific research is gradually being renewed in the 21st century by means of EU funding, which culminates in the auction of patents.
5. In Latvia, the traditions of maintaining the circular economy have not been lost even during the period of the linear economy. Public catering enterprises also continue to cooperate with local farms on the voluntary use of food waste.

REFERENCES

[1] Tokareva T., Eglīte A., Kaufmane D. Sustainable Production and Use of Resources versus Food Wasting, *Economy & Business: Journal of International Scientific Publications*. Volume 11, 2017, pp. 458-465, 2017.

[2] Tielens J., Candel J.Reducing food wastage, improwing food security? The Netherlands. Food& Busines Knowledge Platform. P. 37, 2014.

[3] Mata-Alvazer, J., Mace S., Llabres P. Anaerobic digestion of organic solid wastes. An overview of research achievements and perspectives. In: Bioresource Technology Issue 74, pp. 3-16, 2000.

[4] Tokareva T., Eglīte A., Food Waste in Latvian Households: Amounts, Economic Aspects *Economics Science for Rural Development:* Proceedings of the International Scientific Conference, Nr. 46. Jelgava, pp. 213-219, Latvia, 2017.

[5] Biogāzes attīstības Latvijā. http://www.latvijasbiogaze.lv/pakalpojumi/

[6] Riga Technical University announces an intellectual property auction on biogas production technologies (in Latvian) https://business.gov.lv/sadarbibas-piedavajums/rigas-tehniska-universitate-izsludina-rakstisku-intelektuala-ipasuma-1#msdynttrid=1lFP1AUT1RqWOoA1v1u5p0YYRIHgcY10quN0EXHMql0

[7] Tokareva T. Latvian Households' Food Wasting in the Context of Eating Habits. Summary of the doctoral dissertation for the scientific degree of Dr. oec., Latvia, 2017, p.14, 24

[8] European Commission, Eiropas pilsoņu grupa. Pārtikas atkritumi. 2021, 18 p.

[9] Atkritumu apsaimniekošanas likums. 2010, https://likumi.lv/ta/id/221378-atkritumu-apsaimniekosanas-likums

[10] Latvijas Atkritumu saimniecības uzņēmumu asociācija. https://www.lasua.lv/

[11] Uzziniet, ko EESK var darīt jūsu labā. www.eesc.europa.eu

COMPOSTING OF BIODEGRADABLE PLASTIC WASTE - CHANGES IN THE MICROBIAL COMMUNITY

Assist. Prof. Dr. Bilyana Grigorova-Pesheva

Assoc. Prof. Dr. Boyka Malcheva

University of Forestry, Faculty of Forestry, Department of Silviculture, **Bulgaria**

ABSTRACT

The present study aimed to track the changes in microbial communities during home composting of biodegradable plastic products (PLA). 6 waste mixtures and controls were prepared, with C:N about 30, placed in containers. The amount of PLA compared to the compostable mixture is 1%. Different depositing methods were used - active composting and placing part of the material in biodegradable bags. Temperature, humidity, pH, C:N ratio were measured. The amounts of bacteria, actinomycetes, micromycetes were recorded during the individual phases of composting, including the initial mixing of the materials. The microbiological analyzes were performed using the counting plate method. The reading is done in colony forming units. Total microbial number (TMN) was calculated. The ratio of the microbial populations in the studied samples with PLA was compared with the dynamics of development of the microbial populations in the control samples. Samples with added PLA have a higher TMN. For samples placed in a biodegradable bag, the thermophilic phase occurs faster and the amounts of microorganisms are higher. In all tested variants, the controls gave lower values of TMN. Some of the biodegradable materials (cutlery) are still discernible at the end stage of the composting process. Standard dynamics were observed in changing the percentage participation of individual microbial groups during the different phases of composting, regardless of added PLA. PLAs stimulate the composting process.

Keywords: biodegradable plastic, PLA, microorganisms, composting, home compost

INTRODUCTION

Sustainable management of the ever-growing amount of plastic waste is one of the most serious challenges of the modern world [1]. Biodegradable plastics as a product and composting as a possible method for their treatment represent a solution to one of the main problems in today's society - the amount of plastic waste generated. Bioplastics are a separate family of materials with specific characteristics. The International Association for Standardization ASTM has developed evaluation standards that classify specific plastic products as biodegradable and compostable based on their organic basis and environmental performance [2],[3]. For a given plastic to be classified as biodegradable and compostable, it must convert 90% of its carbon content to carbon dioxide in accordance with ASTM International (D5338) like PLA. When compostable plastic breaks down, no toxic residues are left and the characteristics of standard compost are not changed. In the process of composting, microorganisms break down

organic matter releasing carbon dioxide, water and heat, transforming the organic mass into a stable end product with high qualities - humus. The optimal course of the process depends on the input materials, the C/N ratio, the temperature, the humidity and the acidity of the compostable mass. [4], [5].

The main aim of the present study is to track the potential changes occurring in the microbial communities during home composting of a mixture of organic waste and bioplastic PLA waste.

MATERIALS AND METHODS

For the purposes of the present study, six mixtures were prepared to monitor the changes in the microbial community during the home composting process. The compostable mixtures are placed in 40 liters containers equipped with air holes. An active composting process is used. The following starting mixtures were prepared. Compost series 1: potatoes + coffee grounds + fruit peels + soil in a ratio (1:1:4:0.5). C/N ratio=30:1. Composting mixture (CM) 1.1 with added biodegradable plastic waste (BPW) of PLA. CM 1.2 with added biodegradable plastic waste of PLA that is placed in a biodegradable plastic bag. CM 1.3 – control. Compost series 2: sprouted potatoes + wood chips + lettuce + soil (2:0.25:1:0.75). C/N ratio=31:1. CM 2.1 with added biodegradable plastic waste of PLA. CM 2.2 with added biodegradable plastic waste of PLA that is placed in a biodegradable plastic bag. CM 2.3 – control. Compost series 3: sprouted potatoes + tomatoes + cucumbers + lemons + wheat + soil (5:0.3:1:4:4:2:1.5). C/N ratio=31:1. CM 3.1 with added biodegradable plastic waste of PLA. CM 3.2 with added biodegradable plastic waste of PLA that is placed in a biodegradable plastic bag. CM 3.3 – control. The C/N ratio at the end of the composting process, in the finished product, was reported. Carbon was measured using the modified Turin method, and nitrogen was measured using the Kjeldahl digestion method (ISO 11261). The temperature, humidity and pH are measured daily during the composting process, using specialized electrical equipment. Microbiological analyzes were carried out to count the individual microbiological groups and determine the total microbial number during the three main stages of composting – mesophilic phase, thermophilic phase, phase of cooling and maturation, as well as during the initial mixing of the material. The microbiological studies were carried out on the basis of successive dilutions of the studied material using the KOH method and subsequent inoculation of suitable solid nutrient media. To count the number of bacteria, Nutrient agar was used and inoculation for 48 hours at 24°C. Actinomycetes were isolated on specific isolation medium for actinomycetes for 7 days at 35°C. Chapek Dox Agar was used to isolate the micromycetes at 30°C for 7 days. The count was made as colony forming units per gram dry soil (CFU/g dry soil). Data were statistically processed using the StatSoft Statistica 12, at significance thresholds of 95%.

RESULTS

The results of the microbiological analyzes are presented in Table 1.

Table 1. Analyzed microbiological indicators during the individual phases of the composting process

	Initial mixing of the materials					**Mesophilic phase**			
	TMN	Bacteria	Actinomycetes	Micromycetes		TMN	Bacteria	Actinomycetes	Micromycetes
CM 1.1	2.03 ± 0.47	0.93 ± 0.17	0.67 ± 0.16	0.43 ± 0.15	CM 1.1	2.86 ± 0.68	1.64 ± 0.33	0.24 ± 0.09	0.99 ± 0.27
CM 1.2	2.02 ± 0.47	0.95 ± 0.17	0.60 ± 0.16	0.47 ± 0.15	CM 1.2	3.34 ± 0.68	1.94 ± 0.33	0.30 ± 0.09	1.10 ± 0.27
CM 1.3	2.03 ± 0.47	0.97 ± 0.17	0.62 ± 0.16	0.44 ± 0.15	CM 1.3	2.18 ± 0.68	1.43 ± 0.33	0.10 ± 0.09	0.65 ± 0.27
CM 2.1	1.26 ± 0.47	0.61 ± 0.17	0.40 ± 0.16	0.25 ± 0.15	CM 2.1	1.70 ± 0.68	1.19 ± 0.33	0.05 ± 0.09	0.46 ± 0.27
CM 2.2	1.25 ± 0.47	0.63 ± 0.17	0.36 ± 0.16	0.27 ± 0.15	CM 2.2	1.89 ± 0.68	1.35 ± 0.33	0.07 ± 0.09	0.47 ± 0.27
CM 2.3	1.25 ± 0.47	0.65 ± 0.17	0.30 ± 0.16	0.30 ± 0.15	CM 2.3	1.59 ± 0.68	0.99 ± 0.33	0.09 ± 0.09	0.51 ± 0.27
CM 3.1	0.97 ± 0.47	0.58 ± 0.17	0.26 ± 0.16	0.14 ± 0.15	CM 3.1	1.50 ± 0.68	1.03 ± 0.33	0.05 ± 0.09	0.42 ± 0.27
CM 3.2	0.95 ± 0.47	0.55 ± 0.17	0.30 ± 0.16	0.11 ± 0.15	CM 3.2	1.81 ± 0.68	1.24 ± 0.33	0.09 ± 0.09	0.48 ± 0.27
CM 3.3	0.97 ± 0.47	0.60 ± 0.17	0.28 ± 0.16	0.10 ± 0.15	CM 3.3	1.28 ± 0.68	0.91 ± 0.33	0.05 ± 0.09	0.33 ± 0.27
	Thermophilic phase					**Cooling and maturation phase**			
	TMN	Bacteria	Actinomycetes	Micromycetes		TMN	Bacteria	Actinomycetes	Micromycetes
CM 1.1	31.79 ± 9.79	25.35 ± 8.69	5.89 ± 1.53	0.55 ± 0.25	CM 1.1	37.37 ± 10.77	18.97 ± 6.09	9.86 ± 3.99	8.55 ± 2.41
CM 1.2	35.30 ± 9.79	27.96 ± 8.69	6.55 ± 1.53	0.79 ± 0.25	CM 1.2	40.74 ± 10.77	23.74 ± 6.09	11.20 ± 3.99	5.80 ± 2.41
CM 1.3	30.77 ± 9.79	24.80 ± 8.69	5.55 ± 1.53	0.42 ± 0.25	CM 1.3	35.62 ± 10.77	19.50 ± 6.09	10.86 ± 3.99	5.26 ± 2.41
CM 2.1	10.07 ± 9.79	6.55 ± 8.69	2.78 ± 1.53	0.75 ± 0.25	CM 2.1	13.43 ± 10.77	9.86 ± 6.09	1.28 ± 3.99	2.29 ± 2.41
CM 2.2	12.74 ± 9.79	7.49 ± 8.69	4.30 ± 1.53	0.95 ± 0.25	CM 2.2	16.89 ± 10.77	11.50 ± 6.09	1.60 ± 3.99	3.79 ± 2.41
CM 2.3	8.90 ± 9.79	5.24 ± 8.69	3.17 ± 1.53	0.50 ± 0.25	CM 2.3	11.27 ± 10.77	7.26 ± 6.09	2.26 ± 3.99	1.76 ± 2.41
CM 3.1	20.59 ± 9.79	12.71 ± 8.69	6.99 ± 1.53	0.90 ± 0.25	CM 3.1	26.44 ± 10.77	20.26 ± 6.09	4.95 ± 3.99	1.24 ± 2.41
CM 3.2	25.66 ± 9.79	18.90 ± 8.69	6.31 ± 1.53	0.45 ± 0.25	CM 3.2	31.25 ± 10.77	24.30 ± 6.09	4.15 ± 3.99	2.80 ± 2.41
CM 3.3	20.05 ± 9.79	15.75 ± 8.69	4.11 ± 1.53	0.20 ± 0.25	CM 3.3	24.01 ± 10.77	17.92 ± 6.09	4.30 ± 3.99	1.79 ± 2.41

https://doi.org/10.5593/sgem2023V/4.2/s18.03

The amounts of the main microbiological groups (bacteria, micromycetes and actinomycetes) were monitored during the individual phases of composting. The obtained results show constantly increasing amounts of microorganisms in all compost variants as the composting process progresses. In all investigated compost variants, regardless of their composition, no atypical distribution of microbial groups was found for the composting process.

The main parameters relevant during the composting process were measured: temperature, pH, humidity.

Figure 1 presents the data for the reported temperature values.

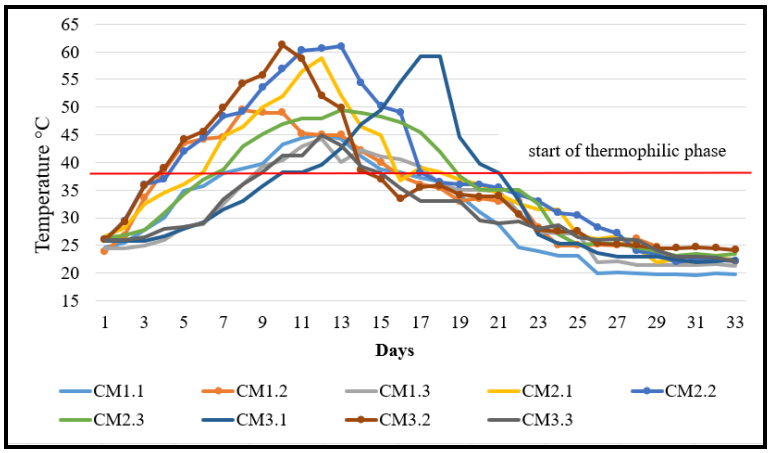


Figure 1. Recorded temperature during the composting process

Figure 1 shows the difference in the onset of the initial stage of the thermophilic phase for the different compost mixes and the different methods of application. All mixes placed in biodegradable plastic bag rise faster in temperature and the thermophilic phase lasts for a longer time.

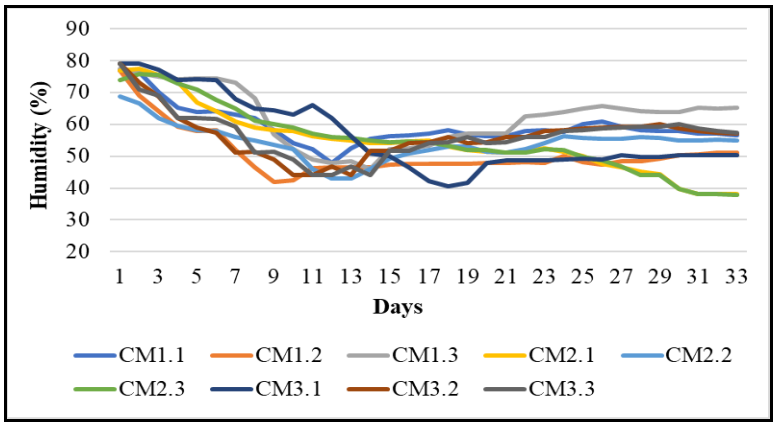


Figure 2. Recorded humidity (%) during the composting process

For the purpose of the present study, the percentage humidity of all compost variants was also recorded (Figure 2). When depositing waste, its humidity is high, ranging from 68.9% to 78.2%. This is a typical moisture content for fresh plant waste. After starting the composting process, the humidity begins to gradually decrease, as a result of the active microbiological activity and the rise in temperature in the

composters. The most drastic decrease in humidity is observed during the thermophilic phase. During the cooling and ripening phase, humidity is a relatively constant quantity that is strongly influenced by ambient temperature.

Figure 3 presents the data from the measured acidity values in the studied compost variants.

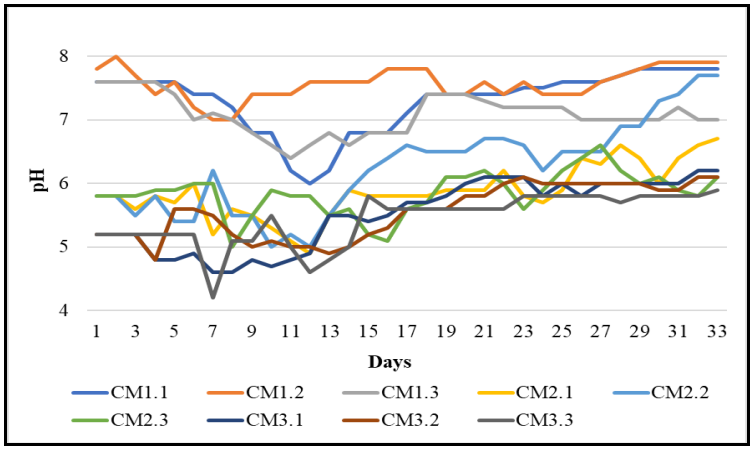


Figure 3. Dynamics of pH during the composting process

As can be seen from the graph, the acidity strongly depends on the input material of the compost pile. Series 3 variants have a significantly lower initial pH compared to the rest of the compost mixes. Series 1 compost mixes have neutral to alkaline acidity. In the composting process, pH is a dynamic indicator that reflects the transition between individual compost phases.

During the statistical analysis of the data, a high correlation was found between the pH of the compostable mass and the reported number of microorganisms regardless of the composting phase (primary mix r=0.99; mesophilic phase r=0.91, thermophilic phase r=0.91, ripening and cooling phase r =0.72)

DISCUSSION

One of the main tasks of the present study was to analyze the microbial community changes during the composting process of biodegradable plastic waste. Similar to other authors [6], our results indicate that with increasing composting time, the number of microorganisms in compost mixtures increases. In contrast to these data, there are reported results for a decrease in the number of microorganisms during the thermophilic phase and declined further in the cooling phase [7]. Such data necessitate comparison and analysis of microorganisms in similar and specific starting mixes and in specific volume. As a result of the conducted study, we found that the addition of compostable plastic waste to the compost mixes did not affect the standard distribution of microorganisms during the different phases of composting. Temperature dynamics during the composting cycle is a determining factor for the metabolic activity of microorganisms [8]. In the initial stage of composting through the mesophilic phase, mesophilic bacteria and fungi dominate. They quickly digest soluble sugars. The temperature in the compost rises and mesophilic bacteria are displaced by thermophilic species. During the thermophilic phase, a decrease in the amount of micromycetes and

an increase in the role of actinomycetes in the decomposition of organic matter was observed in all investigated compost mixtures. Only the most heat-tolerant micromycetes are in the thermophilic phase. As the process progresses and the temperature drops, the group of bacteria again dominates. As a result of a decrease in temperature, micromycetes from cooler zones again cover the entire volume and, together with actinomycetes, digest polysaccharides, hemicellulose and cellulose, breaking them down to monosaccharides, which are used by a wide range of microorganisms. The rate of heat release becomes very low and the temperature drops to that of the surroundings. Of all the investigated compost mixtures, only Variant 2.2 and Varinat 3.2 reach a temperature above 60°C, which guarantees the destruction of pathogens [9]. Bacteria make up the most numerous group of microorganisms during the all stage of composting process. This is due to their specificity of metabolism and their high adaptability to changes in environmental conditions [10]. A number of authors have established their ability to actively participate in decomposing and mineralizing of organic matter in a wide temperature range [11], [12]. The results of our study show that added bioplastic waste affects the number of microorganisms. In all CMs in which PLA is added, the microbial microflora is stimulated and its number is increased. Of interest are the results obtained when placing the waste in a biodegradable bag. In these variants (1.2; 2.2 and 3.2) an earlier onset of the thermophilic phase was observed, including its longer duration. These data indicate a potential opportunity to collect household waste together with biodegradable waste and compost it together with the biodegradable bag in which it is collected. The analyzed CM 3 of the compost mixes showed a slower increase in temperature compared to the other options considered. Inhibition of thermophiles at low pH is an important key needed to understand the common delay in the transition stage between the mesophilic and thermophilic phases [13]. This delay is due to the low pH values at the beginning of the composting process, which lead to suppression of microbial activity and a delay in temperature rise. The reported high correlation dependence between the pH of the compost mixes and the abundance of microorganisms determines the acidity of the substrate as one of the main factors influencing the composting process. According to our data the higher microbiological activity of the variants placed in a biodegradable bag is due to the better moisture regime. In these samples, even during the thermophilic phase, optimal humidity levels were observed until the moment of rupture of the biodegradable plastic bag. The conducted research shows that home composting of biodegradable plastic waste is possible without requiring additional treatment. These wastes stimulate the composting process to such an extent that when they are added, an increase in the total amount of microorganisms is observed. We believe that the composting process would be affected in terms of duration by changing the amount of plastic biodegradable waste as a percentage of the total compostable mass. As a result of the research conducted, it was found that for a period of 33 days, an optimal composting process takes place, but the ripening phase of the compost continues. In the cooling phase, visible parts of some of the biodegradable plastic products were still visible. This leads us to conclude that the addition of biodegradable plastic products can slow down the composting process, as it ends when all the starting materials become indistinguishable in the compost. It is necessary not to exceed the amount of added biodegradable plastic products to the compostable mixture, because this can lead to a delay in the composting process [14]. After the 45th day, there were no clearly distinguishable parts of the added biodegradable plastic waste.

CONCLUSION

The main objective of the present study was related to the assessment of the changes occurring in the microbial community during composting of biodegradable plastic waste. This paper analyzed the microbiological characteristics of different compost mixtures in which biodegradable plastic waste was added, constituting 1% of the compostable mass. A control was also prepared for each compost mixture. The present study found that there was no change in the standard distribution of microbial groups across the individual composting phases for all compost mixes examined. However, added PLA have an impact on the number of microorganisms. All varieties with added biodegradable plastic waste have higher values compared to the controls. When placing part of the compostable material in a biodegradable bag, the thermophilic phase occurs faster and is longer. All variants placed in a biodegradable bag have an increased microflora, as a result of improved conditions of humidity and temperature. Statistical processing of the data found a high correlation between the acidity of the medium and the number of microorganisms. In all the variants where the pH is acidic, the microflora has lower values compared to the variants with slightly acidic to neutral pH. According to the data from the conducted research, biodegradable plastic products are completely suitable for composting at home and do not have a negative impact on the final product. We consider placing them in a biodegradable bag with a mixture of waste and covering it with residual organic waste as the most successful method for their composting. The results of the present study can serve as a basis for more in-depth future studies. The present data can be used to compare the degradation behavior of biodegradable plastic products in unregulated release into the environment versus their composting.

ACKNOWLEDGEMENTS

The current study was performed in the framework of 'Investigating interrelationships in different variations of organic waste composting, by creating dynamic compost mixtures with the addition of ameliorants and tracking microbiological and enzyme activity - variants for applying a quality organic-mineral compost-based improver in agricultural practice.' – КП-Н-66/10" funded by Research Fund of Ministry of Education and Science in Bulgaria.

REFERENCES

[1] Polman, E.M., Gruter, G.-J.M., Parsons, J.R., Tietema, A. Comparison of the aerobic biodegradation of biopolymers and the corresponding bioplastics: A review. Sci. Total Environ. 2021, 753, 141953, https://doi.org/10.1016/j.scitotenv.2020.141953

[2] Bishop, G., Styles, D., Lens, P.N., Environmental performance comparison of bioplastics and petrochemical plastics: A review of life cycle assessment (LCA) methodological decisions, Resour. Conserv. Recycl. 2021, 168, 105451. https://doi.org/10.1016/j.resconrec.2021.105451

[3] Emadian, S.M.; Onay, T.T.; Demirel, B., Biodegradation of bioplastics in natural environments. Waste Manag. 2017, 59, 526–536. https://doi.org/10.1016/j.wasman.2016.10.006

[4] Partanen, P., Hultman, J., Paulin, L., Auvinen, P., Romantschuk, M. Bacterial diversity at different stages of the composting process. BMC Microbiology, 2010, 10:94;

[5] Franke-Whittle, I., Confalonieri, A., Insam, H., Schlegelmilch, M., Körner, I., Changes in the microbial communities during co-composting of digestates, Waste management 34, 632-641, 2014, DOI: 10.1016/j.wasman.2013.12.009.

[6] Mironov, V., Vanteeva, A., Merkel, A., Microbiological Activity during Co-Composting of Food and Agricultural Waste for Soil Amendment, Agronomy, 11(5), 928, 2021, https://doi.org/10.3390/agronomy11050928

[7] Chandna P., Nain, L., Singh, S., Kuhad, R., Assessment of bacterial diversity during composting of agricultural byproducts, BMC Microbiology, 13, 99, 2013 https://doi.org/10.1186/1471-2180-13-99.

[8] Lin, Y., Simulation modeling and process control of composting systems under complexity and uncertainty, University of Regina, 2006, 14-23.

[9] Roman, P., Martinez, M., Pantoja, A, Farmers's compost handbook. Experiances in Latin America. Santiago:Fao, 2015.

[10] Zhao, X., Li, J., Che, Z., Xue, L., Succession of the Bacterial Communities and Functional Characteristics in Sheep Manure Composting, Biology, 11(8), 1181, 2022, doi: 10.3390/biology11081181.

[11] Wang, J., Liu, Z., Xia, J., Chen, Y., Effect of microbial inoculation on physicochemical properties and bacterial community structure of citrus peel composting. Bioresour. Technol. 2019, 291, 121843, 2019, https://doi.org/10.1016/j.biortech.2019.121843

[12] Qiao, C., Ryan Penton, C., Liu, C., Shen, Z., Ou, Y., Liu, Z., Xu, X., Li, R., Shen, Q., Key extracellular enzymes triggered high-efficiency composting associated with bacterial community succession, Bioresour. Technol. 2019, 288, 121576, https://doi.org/10.1016/j.biortech.2019.121576

[13] Sundberg, C., Smars, S., Jonsson, H., Low pH as an inhibiting factor in the transition from mesophilic to thermophilic phase in composting, Bioresource Technology, 95 (2), 145- 150, 2004, https://doi.org/10.1016/j.biortech.2004.01.016.

[14] Hottle, T., Aguero, M., Bilec, M., Landis, A., Alkaline Amendment for the Enhancement of Compost Degradation for Polylactic Acid Biopolymer Products, ompost Science & Utilization 24(3):159-173, 2016, DOI: 10.1080/1065657X.2015.1102664

ENHANCING SOIL QUALITY AND NUTRIENT AVAILABILITY WITH ZEOLITES AND DIATOMACEOUS EARTH

Dr. Ana Katsarova[1]

[1] Institute of Soil Science Agrotechnologies and Plant Protection N. Poushkarov, Agricultural Academy, **Bulgaria**

ABSTRACT

Organic farming has a future, but a significant obstacle to its application is the need for more organic fertilisers and the imbalance of macronutrients - nitrogen, phosphorus and potassium. We set the following working hypothesis: whether the simultaneous application of natural zeolites and diatomaceous earth, in combination with a compost mixture, optimises the nutrient elements in two types of soils, taking into account their agrochemical and physicochemical parameters. The research includes experiments with Vertisols and Chernozems. Five different variants were tested with two replicates. After the investigation, the obtained data on the content of N, P, K, and Si in the soil showed a significant effect of the combined application of zeolite and diatomaceous earth combined with the compost mixture. The values of plant-available phosphorus in these variations are twice as high as in the control variations. In the containers with added zeolite, the amount of plant-available potassium significantly increased to 223.9 mg.100g-1 in the combined soil-zeolite-compost mixture variation. The data on the silicon content in the Chernozems in variant soil-diatomaceous earth, where the content was recorded to be half as much as in the control variation, was intriguing. No change in soil pH was observed for the entire experiment period.

Keywords: soil quality, nutrition, composts, zeolite, diatomaceous earth

INTRODUCTION

In the cultivated areas in Bulgaria, a double decrease in the content of organic matter, deficiency of macro and micronutrients, and processes of mild acidification are observed, especially with the imposition of monoculture farming over the last 25 years. Despite the mentioned facts, the lands continue to be assessed to have high fertility and soil productivity [10].

Organic farming has a future in our country. Still, a significant obstacle to its implementation is the lack of a sufficient quantity of organic fertilisers and the imbalance of macro-elements – nitrogen, phosphorus, and potassium in them. This gives rise to the working hypothesis that the simultaneous incorporation of compost mixture and products such as natural zeolites and diatomite (used in brewing production) into the soil will lead to a more balanced model of soil fertilisation. This aims to introduce regenerative practices in agriculture and reduce mineral fertilisers. In an incubation experiment by Filcheva & Tsadilas [6], it was noted that adding zeolite to two soils with low humus content increased soil pH. It is suggested that excess ammonium ions bind with zeolite in the soil and gradually release into the soil solution, helping the nitrogen mechanisms to nourish plants. Diatomaceous earth enhances the soil's water retention coefficient and permeability [4]. Aksakal et al. [1] applied diatomaceous earth to sandy

clay soil, noting a 30% increase in field capacity. According to the results of other studies, diatomite and zeolite can be used to improve the physical properties of the soil primarily [2]. Research has revealed that the development of multicomponent organic fertilisers based on nano-structural diatomite and products of organic waste and raw materials processing is a compelling direction for the development and dissemination of organic farming technologies, especially in conditions of increasing aridity of the growing season (reduction of precipitation with an increase in the average daily air temperature) [13].

This study focused on two types of heavy soils widely spread in Bulgaria – Chernozems and Vertisols. The soil structure has a significant impact on productivity, affecting water retention capacity, cation exchange capacity (CEC), drainage, the depth of the topsoil layer, and the efficiency of nitrogen utilization.

The Chernozems soils are considered the wealth of our country, covering approximately 23 million hectares, with 85% being cultivable. They are primarily located in northern Bulgaria. These soils boast a substantial, dark humus layer that extends up to 150 cm and features a commendable 3-4% humus content. With a neutral acidity, they exhibit moderate richness in phosphorus and nitrogen while being notably abundant in potassium. Their mechanical composition leans towards the heavier side, showcasing a well-structured granular texture and an impressive ability to retain water [11].

The Vertisols cover a total area of approximately 700,000 ha and are widespread in the plains and basin fields of Southern Bulgaria. The humus content in the upper layer ranges from 3% to 4%, gradually decreasing with the depth of the soil profile. The soil reaction varies from neutral to slightly acidic in the non-carbonate layers and slightly alkaline in the carbonate layers. These soils are somewhat deficient in nitrogen and phosphorus but exhibit a favourable potassium regime.

The Vertisols represent the heaviest soils in Bulgaria and display unfavourable hydro-physical properties: they expand significantly when moistened and contract and crack when drying. Despite their heavy mechanical composition, Vertisols have high natural fertility, which should be preserved by improving their physical properties through organic fertilisation [5].

The study is focused on optimising the nutrient regime of two types of soils, which is important in achieving sustainable agriculture. The basis for achieving this effect will involve comparing natural zeolites and diatomaceous earth (used in brewing) with a compost mixture. It is expected that these amendments will have a positive impact on the physicochemical and agrochemical parameters of soil quality.

MATERIALS AND METHODS

To achieve the main goal, a model experiment was conducted in the greenhouse of the Institute of Plant Genetic Resources "Nikola Poushkarov" on two soil types: Vertisols (VR) and Chernozems (CH) by World References Base [12].

The primary approach of the study involved a model experiment with 1 kg pots to test the following schemes:

Vertisols (VR)	Chernozems (CH)
(untreated) pure soil (PS)	(untreated) pure soil (PS)

soil – compost (SC)	soil – compost (SC)
soil – zeolite (SZ)	soil – zeolite (SZ)
soil – compost – zeolite (SCZ)	soil – compost – zeolite (SCZ)
soil – diatomite (SD)	soil – diatomite (SD)
soil–compost – diatomite (SCD)	soil–compost– diatomite (SCD)

A fraction (0 – 0.8 mm) of natural zeolites and diatomite was used for better interaction with the soil. The materials were applied at a concentration of 10% relative to the weight of the soil in the pots. The experiment was set up in three replicates for each variant. The experiment was 60 days, during which optimal moisture (75% field water capacity) was maintained in the pots.

The following methods were used for analysis: determination of soil reaction [8], sorption capacity, and degree of saturation with bases, as well as basic cations [7]. The soil's basic nutrient elements were analysed before setting up the experimental pots and after the experiment concluded. The soil's ability to provide the necessary nutrient elements was assessed using the following standard methods: mineral nitrogen - extraction with 1M KCl (1:10) and distillation [3], and available P and K - extraction with ammonium acetate and calcium lactate at pH 4.2 [9].

RESULTS

The output for physicochemical characteristics of materials (soils and composts) before the experiment is given in Table 1.

Table 1. Physicochemical characteristics of start material and soils before composting

Description	pH $_{H2O}$	$T_{8.2}$	$H_{8.2}$	Ca^{2+}	V, %
		cmol (+).kg^{-1}			
compost	6.40	31.20	4.20	22.00	86.54
VS	6.20	54.00	2.80	46.00	94.81
CH	6.30	28.60	2.00	22.00	93.00

The agrochemical parameters of the initial soils in Table 2 indicate that Vertisols have unsatisfactory levels of mineral nitrogen but good to very good reserves of phosphorus and potassium. Chernozems show lower levels of resources for the main macro-nutrients.

Table 2. Content of agrochemical parameters of soils before and after composting

	Vertisols				Chernozems			
	$NH^{4+}+NO_3^-$ mg .kg^{-1}	P_2O_5	K_2O	Humus %	$NH^{4+}+NO_3^-$ mg .kg^{-1}	P_2O_5	K_2O	Humus %
		mg .100g^{-1}				mg .100g^{-1}		
PS	17.84	27.8	44.6	3.20	10.95	11.9	20.4	3.10
SC	16.7	50.51	88.5	3.71	13.25	28.74	52.8	3.45
SZ	10.94	40.56	216.5	2.94	11.52	27.9	242	3.11
SCZ	12.67	78.5	223.9	3.74	12.67	73.86	235	3.77

SD	9.22	44.58	76.67	2.32	10.94	28.79	46.75	2.22
SCD	13.82	82.82	90.13	2.57	9.79	63.04	59.01	2.66
min	9.22	27.80	44.60	2.32	9.79	11.90	20.40	2.22
max	17.84	82.82	223.90	3.74	13.25	73.86	242.00	3.77
mean	13.53	54.13	123.38	3.08	11.52	39.04	109.33	3.05

From the physicochemical characteristics presented in Table 3, it can be observed that there is an increase in cation exchange capacity in all variants, even in Vertisols.

Table 3. Physicochemical characteristics after composting

	Vertisols				Chernozems			
	pH $_{H2O}$	$T_{8.2}$	$H_{8.2}$	Ca^{+2}	pH $_{H2O}$	$T_{8.2}$	$H_{8.2}$	Ca^{+2}
		cmol (+).kg^{-1}				cmol (+).kg^{-1}		
PS	6.20	54.00	2.80	22.00	6.30	28.60	2.00	22.00
SC	6.50	52.10	2.80	46.00	6.70	27.30	1.60	21.20
SZ	6.50	52.20	2.90	44.20	6.70	27.30	1.60	21.20
SCZ	6.25	52.00	3.00	44.20	6.60	27.30	1.70	21.00
SD	6.50	52.20	2.60	43.80	6.80	27.20	1.20	21.40
SCD	6.35	52.20	3.00	44.40	6.50	25.90	1.80	19.80

Figure 1 shows data on the silicon content of the two soils of interest. Zeolites contain 70.65% SiO_2, diatomaceous earth is almost pure amorphous silicon dioxide.

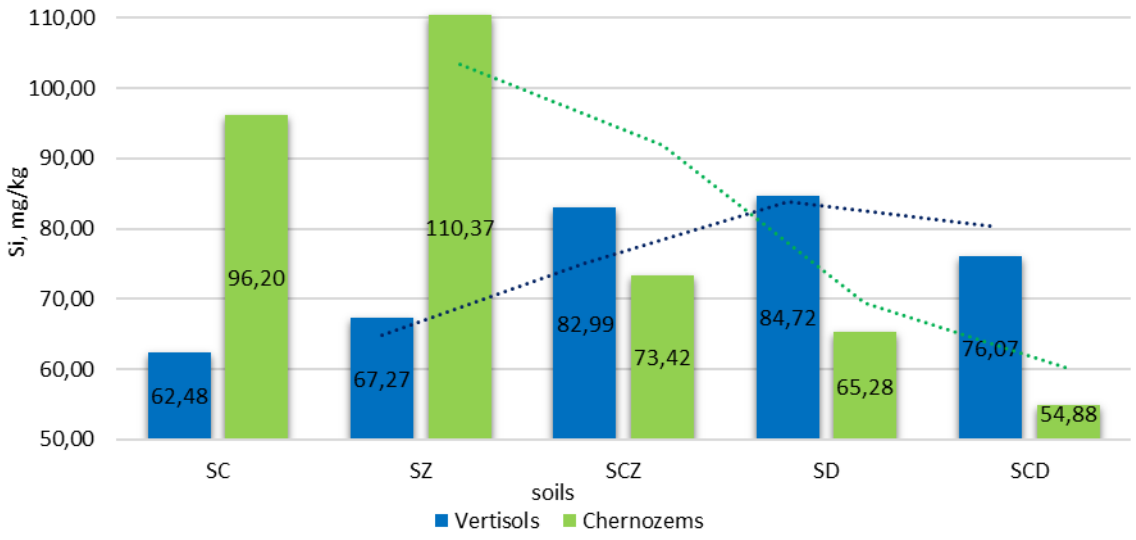


Fig. 1. Content of Si in mg.kg^{-1} in soils after composting

DISCUSSION

Physicochemical processes can be most accurately identified through ion-exchange adsorption characteristics, as they express the reactive state of the adsorptive structures

in the soil. For the present study, the distribution of soil characteristics was analysed – cation exchange capacity ($T_{8.2}$), total acidity ($H_{8.2}$), exchange acidity (Al) and composition of the more important exchange adsorbed cations of the soils.

The studied Vertisols and Chernozems have a CEC of 54.00 and 28.60 cmol. kg-1, which is estimated to have a very high sorption capacity. This corresponds well to the definition of soils based on their mechanical composition. The starting soils have a slightly acidic soil reaction in water (Table 1). They are moderately rich in humus but have low mineral nitrogen levels (Table 2). Typical for Chernozems, mineral nitrogen content and available phosphorus could be better. Whereas with Vertisols, phosphorus levels are good. Both soils have a high content of available potassium.

The agrochemical analysis of the soils after the trial ended showed that the mineral nitrogen content of both soils remained unsatisfactory despite the applied compost. Regarding the presence of phosphorus in the soil, the values rise to 78.50 (SCZ) and 82.82 mg .100g^{-1} (SCD) for Vertisols and from 63.04 (SCD) to 73.86 mg .100g^{-1} (SCZ) for Chernozems.

Zeolites show affinity for most cations, especially ammonium and potassium. The levels of exchangeable potassium in the soils in the variants with the presence of zeolite were significantly above the optimal content, varying from 4.8 (VS) to 4.5 (CH) times compared to the control variant.

From the data presented in Table 3, it can be seen that after the experiment's end, the soil reaction changes to neutral. The effect of improvers on pH is good. CEC is strongly influenced by soil structure. The ability of the soil to attract nutrients and water and then give them to the plants depends on the cation exchange capacity. The introduction of zeolite and diatomite, alone and in combination in compost, does not affect the cation exchange capacity of soils. Although, in some studies, it increases due to the addition of zeolite. The results for exchange adsorbed cations are interesting. Vertisols show that Ca^{2+} increases 2 times in all tested variants.

Primary sources of silicon in the soil include silicate minerals, plagioclase, orthoclase, feldspars, plant residues, rice husks, bagasse from sugarcane, calcium silicate slag, magnesium silicate, silicon acid, and Si nanoparticles. The zeolite rocks used in this study primarily comprise clinoptilolite, containing crystal clasts, lithoclasts, and altered pumice fragments. Crystal clasts consist of plagioclase, potassium feldspar, amphibole, muscovite, pyroxene, quartz, biotite, etc., while lithoclasts are volcanic rocks. The high value for the Si content in Vertisols (Fig. 1.), the SZ variant, shows better indicators for improving the soil with Si considering the properties of zeolite and its mineral composition compared to the SC variant. The results for SD and SCD variants are lower due to the mineral composition of the diatomaceous earth. The characteristic of diatomaceous rocks is that they are formed by biogenic or autogenic sedimentation and contain over 50% SiO_2. SiO_2 is present in quartz, chalcedony, and opal in these rocks, implying a more challenging release of Si compared to crystal clasts such as plagioclase and potassium feldspar found in zeolite rocks.

CONCLUSION

Zeolite and diatomite are minerals which possess a wide range of valuable properties. Their characteristic features are the presence of amorphous active silicon dioxide on the

one hand and a fine-porous structure. These properties make these materials chemically highly active and make it possible to use them as sorbents, filtering and heat-insulating materials.

The use of zeolites can reduce the need for potassium fertilizers, as zeolites themselves serve as carriers of potassium. The controlled release properties of zeolites enable the gradual introduction of necessary nutrients, such as potassium, ammonium, or phosphates, from the soil to the plant.

The combined introduction of diatomite, zeolite and compost into the soil leads to an increase in the soil reaction. Mobile nutrients such as nitrogen (N) leach through light soil and are lost through denitrification in heavy soil. Our study showed that improvers and compost conserved mineral nitrogen content. Add compost with a higher nitrogen content is necessary to reach optimum values for growing plants.

ACKNOWLEDGEMENTS

This scientific research is with the financial support of the Ministry of Education and Science through the National Program "Young Researchers and Postdoctoral - 2", the Agricultural Academy is a beneficiary under the program.

REFERENCES

[1] Aksakal, E.L., I. Angin and T. Oztas. (2011). Effects of diatomite on soil physical properties. Catena 88:1–5.

[2] Boyraz, D., & Nalbant, H. (2015). Comparison of zeolite (clinoptilolite) with diatomite and pumice as soil conditioners in agricultural soils. Pak. J. Agric. Sci, 52(4), 923-929.

[3] Bremner, J. M., and Dennis R. Keeney. Steam distillation methods for determination of ammonium, nitrate and nitrite. Analytica chimica acta, 32, 1965, pp 485-495;

[4] Deying, L., K.J. Young, N.E. Christians and D.D. Minner. (1999). Inorganic soil amendment effects on sand-based sport turf media. Crop Sci. 40: 1121-1125.

[5] Encyclopedia "Bulgaria", vol. 7, page 446, BAS Publishing House, Sofia, 1997

[6] Filcheva, E. G., & Tsadilas, C. D. (2002). Influence of clinoptilolite and compost on soil properties. Communications in soil science and plant analysis, 33(3-4), 595-607.

[7] Ganev S., Arsova A. Methods for determining the strongly acidic and lightly acidic cation exchange in soil. Soil Science and Agrochemistry, 15, 1980, pp 19-33;

[8] ISO 10390:2011. Soil Quality. Determination of pH

[9] Ivanov, P. (1984). A new acetate-lactate method for the determination of plant available phosphorus and potassium in soil. Soil Science and Agrochemistry, 6, 3-7.

[10] Nikova I, Dinev N, Hristov B, Hristova M. Study of basic physico-chemical parameters of soil fertility. Soil science agrochemistry and ecology. 2018;51(3-4):29-35.

[11] Teoharov, M., Shishkov, T., Hristov, B., Filcheva, E., Ilieva, R., Lubenova, I., Kirilov, I., Dimitrov, G., Krasteva, V., Georgiev, B., Banov, M., Ivanov P., Hristova M., Mitreva Z. Chernozems in Bulgaria–Systematic, Specific Features and Problems. Soil science agrochemistry and ecology. 2014; XLVIII (3-4):4-9.

[12] USS Working Group WRB. World Reference Base for Soil Resources 2014, update 2015. International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome. 2015;

[13] Zudilin S, Olenin O, Vasilisko A. The use of biotechnology for the production of organic fertilizers based on diatomite for crop production. International Multidisciplinary Scientific GeoConference: SGEM. 2020;20(6.2):169-76.

MUNICIPAL ORGANIC WASTE COMPOSTING IN ROMANIA – RESOURCES AVAILABILITY AND RECENT ADVANCES

PhD. Elena Elisabeta Manea
PhD. Costel Bumbac
Laurentiu Dinu
PhD. Valeriu Badescu
PhD. Ionescu Ioana
National Research and Development Institute for Industrial Ecology - NRDI ECOIND, **Romania**

ABSTRACT

Composting municipal organic waste is important for several reasons, including greenhouse gas emissions reduction, soil health improvement, nutrients recycle, waste reduction, costs reduction (by reducing the waste volumes, the handling costs are decreased). Information on the practices of municipal organic waste composting in Romania is limited, thus a comprehensive evaluation of the limiting factors and current solution was carried out. According to the European Environment Agency, Romania has made progress in organic recycling, including composting, as part of its municipal waste management. The evolution of municipal solid waste (MSW) recycling in Romania was limited to 7% in 2010. Afterwards, Romania has made progress in organic recycling, including composting, as part of its municipal waste management. The amounts composted and digested include output from treatment of mixed municipal waste in mechanical-biological treatment plants. Home composting could be a solution to reduce biowaste losses in rural areas. Municipal selective collection of organic waste is an effective way to increase the percentage of organics composting and improve the quality of organic waste. By collecting organic waste separately, it can be processed more efficiently and effectively, leading to higher quality compost. This can also help reduce greenhouse gas emissions and improve air and water quality. Composting organic waste creates a product that can be used to improve soil health, grow crops, and reduce the need for chemical fertilizers.

Keywords: organic waste, composting, recycling

INTRODUCTION

In recent decades, a global surge in solid waste generation has occurred, primarily attributed to population growth, changing lifestyles, and modern standards resulting from economic development and urbanization [1]. The world produced an estimated 2 billion tons of solid waste by 2016 [2]. This increase in waste has raised environmental concerns, prompting the need for effective solid waste management integrated into circular economy programs. Recognizing the importance of environmentally sound practices, recycling, and reuse, the European Parliament introduced a package of measures titled "closing the loop" to promote circular business models. This proposal focuses on fostering the production and sale of fertilizers, including organic materials

like composts derived from organic wastes, aiming to positively impact society and the environment. Specifically, it encourages the reuse of organic waste as healthy nutrients for farming purposes, particularly the organic fraction mainly composed of household waste [3,4].

In Romania, waste management has undergone significant transformations, driven by the country's integration into the European Union, which accelerated efforts to adopt sustainable waste treatment practices. Financial support from the European Union facilitated the development of waste management infrastructure, ranging from source-separated collection to regulated disposal. However, challenges such as limited awareness of legislation among local authorities and a low absorption rate of European funds have contributed to shortcomings in waste management [5].

According to the national waste management plan for 1995–2000, the average index of municipal waste generation was 293 kg/person * year, or 0.8 kg/person * day, based on a population of 21 million inhabitants in 2002, with a subsequent decrease of 0.25% per year until 2007 and 0.20% per year until 2013. Notably, there is a significant difference in waste generation between urban and rural areas, with rural areas producing approximately 256 kg/person * year of municipal waste, representing just over half of the amounts generated in densely populated urban areas (approximately 488 kg/person * year of municipal waste, including 290 kg/person * year of household waste) [6].

Proper management of municipal organic waste is essential to reduce environmental impact and utilize available resources. An effective option is composting, which involves transforming organic waste into compost, a natural fertilizer rich in nutrients for the soil. Promoting awareness and practices to reduce food waste can contribute to minimizing waste generation.

It is crucial to recycle and manage these organic waste sources through composting, selective collection, or other treatment methods to avoid negative environmental impact and to leverage these materials as valuable resources. Adequate management of organic waste is essential for several reasons. Firstly, these wastes can release harmful gases, such as methane, when decomposing in landfills, contributing to the greenhouse effect and climate change. By composting these wastes in a controlled process, such as home or community composting, the emission of these gases into the atmosphere can be avoided.

The study aimes at evaluating the organic matter availability for intensive composting in Romania, the main data sources for waste quantities and compositions being the national waste management plan and the regional waste management plans, as well as the current stage of composting systems implementation and scale at a national level.

RESOURCES AVAILABILITY

Organic waste refers to biodegradable residues originating from plant or animal materials. This primarily includes food waste, such as fruit and vegetable peels, leftovers, fallen leaves, grass clippings, sawdust, undecomposed paper, cardboard, and other similar organic materials. There are several sources of organic waste, including food waste, garden waste, kitchen scraps, sawdust and straw, paper and cardboard and animal-origin waste. Food waste constitutes a significant portion of organic waste, including leftover food and other food products that are not consumed or have become spoiled. Examples of food waste include leftover food, vegetable and fruit peels,

expired food products, cooking byproducts (such as such as vegetable peels, seeds, or eggshells may be generated, contributing to food waste), and spoiled and damaged food. To efficiently manage organic waste, it is important to collect it separately from other types of waste and treat it appropriately. This may include composting at an individual or collective level, participating in selective collection programs, or utilizing anaerobic digestion systems to produce biogas and energy. Many communities and cities have implemented such systems to reduce the amount of organic waste sent to landfills. By reducing the quantity of organic waste sent to landfills and transforming it into valuable resources, we can contribute to conserving natural resources and reducing our impact on the environment.

Even before joining the European Union, Romania began transposing European directives into its waste management legislation. One of the European requirements is the development of strategic documents for waste management planning. Among these are two fundamental instruments designed to ensure the implementation of European policies in Romania: the national strategy and the national waste management plan. The national strategy outlines Romania's waste management objectives, while the national plan ensures the strategy's implementation, providing information on measures necessary to achieve the objectives defined by the strategy. Both documents were published by the Ministry of Environment in 2004, developed for the period 2003-2013, and are periodically revised.

In the years leading up to and following Romania's EU accession, waste management in the country experienced significant evolution. Integration into the European Union accelerated efforts to adopt measures for sustainable development through ecologically sound waste treatment and disposal. The EU provided financial support for establishing adequate waste management infrastructure, ranging from source-separated collection to treatment and regulated disposal. However, lack of awareness of legislation by local authorities and low absorption of European funds are among the primary reasons for inadequate waste management [5].

According to the national waste management plan for 1995–2000, the average municipal waste generation index was 293 kg/person * year, or 0.8 kg/person * day. The population reported for this calculation was 21 million inhabitants for the year 2002, with a decrease of 0.25%/year until 2007 and 0.20%/year until 2013.

Significantly different waste generation rates are noteworthy between urban and rural areas. Municipal waste quantities in rural areas are approximately 256 kg/person *year (including 150 kg/person* year of household waste), slightly over half the quantities generated in densely populated urban areas (approximately 488 kg/person *year of municipal waste, including 290 kg/person* year of household waste). The waste composition in the early 2000s, highlights that the organic fraction has the highest share, representing over half of Romania's waste [6].

Through the projects related to integrated waste management systems that are either implemented or in the process of implementation, significant capacities for the treatment of municipal biodegradable waste are made available, both through composting (approximately 200,000 tons/year) and through mechanical-biological treatment (total capacities of around 1.4 million tons/year).

In 2007, the National Waste Management Plan 2015-2025 was published [7], followed by County Waste Management Plans. According to the data from the National Waste Management Plan 2017, waste production in the period 2010-2025 shows a decreasing trend, with an anticipated reduction of approximately 31%. The content of

biodegradable materials in waste is also expected to have a descending trend, reaching up to approximately 28% (Fig1).

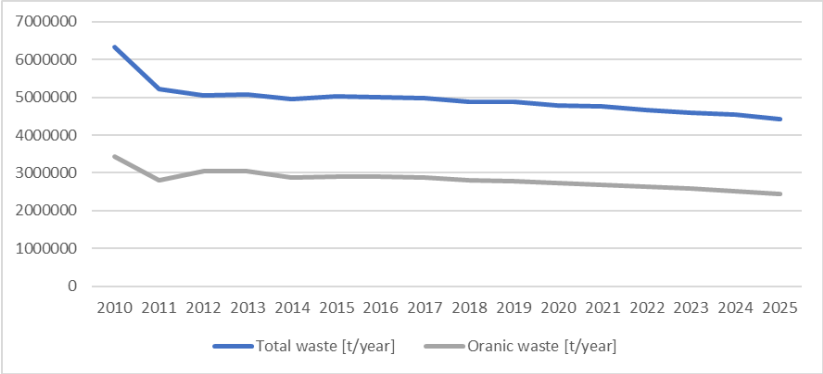


Fig. 1. The variation in quantities of generated waste according to the National Waste Management Plan (PNGD) 2017.

Maintaining the focus on the biodegradable component of waste as a source of materials for the composting process, the quantities generated at the level of each county were evaluated for the years 2014-2019 [8], along with statistical estimates for the upcoming period (2019-2025) (Fig2).

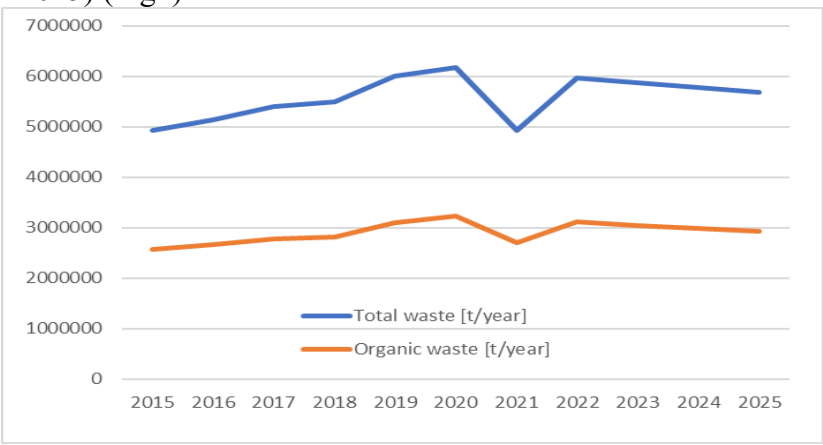


Fig.2. The variation in quantities of generated waste according to the Regional Waste Management Plans (PNGD) 2017.

From the comparison of figures 1 and 2, the evident difference in estimating waste quantities between the National Plan and the sum of the values identified in the 42 county plans is obvious. Thus, while according to the data provided in the National Waste Management Plan, the trend of generated waste quantities (both total and biowaste) is decreasing, the cumulated data from the county plans indicate an upward trend and an increase in the proportion of the biodegradable fraction of waste over time.
An assessment of the data identified in the county waste management plans for the period 2015-2025 resulted in a content of biodegradable compounds in waste ranging from 25.8% to 82%, with an average of 55%. The highest estimated quantity of biodegradable waste is 407,750 tons/year, for the city of Bucharest, which also corresponds to the highest value of the quantity of waste generated, at 1,064,621 tons/year.
According to statistical data provided by the National Institute of Statistics (INS), the quantity of waste generated by households varied between 6,503,356 and 4,256,889 tons/year during the period 2008-2020. The data are in good correlation with the values

identified in the PNGD/county waste management plans. The limiting component at present is the selective collection of biodegradable organic waste, which is carried out on a very small scale nationally.
The data shows a wide range of resources available for composting applications both at small and large scale. The main limiting factor is the mixt waste collection, composting becomes more challenging when waste isn't collected separately because mixed waste streams may contain contaminants, making it harder to maintain the ideal conditions for effective and high-quality composting.

CURRENT STATE OF COMPOSTING ORGANIC MUNICIPAL SOLID WASTE IN ROMANIA

Composting in Romania has gained increasing importance in recent years, becoming a widespread practice in organic waste management. Many waste management operators in Romania have introduced systems for the selective collection of organic waste in various localities. This allows citizens to separate food waste and other organic materials from the rest of the waste, facilitating the composting process.
In Romania, the selective collection of organic waste has become increasingly common, with efforts to implement it in various localities. The national legislation and European directives on waste management regulate the selective collection of waste, including organic waste. Law no. 211/2011 on waste management establishes objectives and general requirements for waste management, including the separate collection of organic waste. Many localities in Romania have implemented systems for the selective collection of organic waste, either through special containers or the use of biodegradable bags. These are often collected separately from other waste and directed to composting facilities.
In recent years, the quantity of selectively collected organic waste in Romania has significantly increased as more cities and communities have implemented separate collection systems. This is due to the efforts of local authorities and increased awareness and participation of citizens. For example, some areas collect organic waste in special containers or biodegradable bags, directing them to composting facilities or organic waste processing centers. In other cases, home or community composting may be promoted, where citizens compost organic waste in their own gardens or composting spaces. It's important to note that the quantities of selectively collected organic waste can vary depending on population density, the level of involvement of local authorities, and the awareness and participation of citizens. Additionally, infrastructure and organic waste processing capacities can influence the quantities collected.
In Romania, there are both industrial and community composting facilities. These facilities process collected organic waste and produce high-quality compost used in agriculture, gardening, or landscaping. Several examples of composting facilities in Romania include the Integrated Waste Management Center in Brașov, Compo Eco Park in Sibiu, and Compozit SRL in Bucharest. Community composting facilities are also used in various localities to process locally generated organic waste and produce compost for local use.
More Romanians are practicing home or community composting, encouraged to compost food waste and garden residues to produce quality compost for their gardens or plants. Home composting in Romania is becoming increasingly popular, with citizens utilizing composters of various sizes and types, such as wooden, plastic, or metal composters, tailored to individual needs and available space.

In various regions of Romania, there are local projects and initiatives promoting composting and educating communities about its benefits. These include training programs, distribution of home composters, and organizing composting-related events. The compost produced through composting is used in Romania for various agricultural, horticultural, and landscaping applications, enhancing soil fertility and supporting the growth of healthy plants.

Despite the progress made, there is still room for the development and improvement of composting practices in Romania. It is crucial for local authorities, institutions, and citizens to continue promoting and supporting this sustainable practice to reduce the amount of organic waste sent to landfills and utilize these resources in a useful and environmentally beneficial way. In this regard, significant steps have been taken in recent years regarding the necessary legislative framework to accelerate the implementation of existing solutions in composting.

Introduced in 2020, the Compost Law [9], which mandates the separate collection of biodegradable waste, came into effect in February 2021, and currently, the regulatory norms to make it operational are being developed. Law no. 181/2020 on the management of non-hazardous compostable waste transposes a European directive into Romanian legislation, imposing the obligation for both individuals and legal entities to separately collect biodegradable waste. This includes waste from gardens and parks, food waste from private households, offices, canteens, restaurants, wholesale trade, catering companies, and retail stores, as well as similar waste from food processing units. At the time of the law's adoption in Romania, less than 15% of municipal waste was recycled, in the form of paper, plastic, metal, and glass, and by 2025, European norms require us to reach 55%. The legislative act is currently being supplemented by methodological norms being developed by both the Ministry of Environment and the Ministry of Agriculture. These institutions are responsible for elaborating and issuing a joint order with the Technical Norms regarding composting and anaerobic digestion.

There are several studies available for composting organic waste in Romania. One study used a closed composting system with sludge from a wastewater treatment plant, market waste, and wood chips as input materials, and found that the resulting compost met the regulatory standards for heavy metal concentrations and could be used in agriculture [10]. Another paper highlighted the importance of separating organic waste at the source to enable safe composting, with private companies encouraged to undertake composting through public-private partnerships [11]. The improper management of municipal waste in Romania has led to a low percentage of waste being composted, with the majority being landfilled [12]. However, there are efforts to improve waste management practices, including the use of compost as a fertilizer in the agricultural sector [13]. Local and regional authorities play a significant role in waste management, developing and implementing municipal waste management plans [14].

CONCLUSION

In light of the increasing global solid waste challenge and the environmental imperatives associated with effective waste management, this study sought to comprehensively evaluate the status of municipal organic waste composting in Romania. The significance of this evaluation lies in its potential to address critical aspects such as reducing greenhouse gas emissions, improving soil health, recycling nutrients, minimizing waste, and cutting costs associated with waste handling.

Romania, as a member of the European Union, has made commendable progress in organic recycling, particularly in the realm of composting, in alignment with municipal waste management goals. Although the initial municipal solid waste (MSW) recycling rate stood at a modest 7% in 2010, subsequent years witnessed notable advancements. The integration of selective collection systems, coupled with increased citizen awareness and participation, has contributed to a positive shift. Selective collection of organic waste emerges as a pivotal strategy, enabling the efficient processing of organic materials and yielding high-quality compost.

The findings highlight that, even before Romania's EU accession, strategic waste management initiatives were underway, driven by the transposition of European directives into national legislation. However, challenges persist. Disparities between national waste generation estimates and those from regional plans suggest a need for harmonized data and streamlined waste management strategies. The biodegradable component, a vital resource for composting, varies widely across regions, indicating the need for targeted interventions.

While Romania has witnessed a surge in both industrial and community composting facilities, the study reveals a critical limiting factor: mixed waste collection. Composting efficacy hinges on separate waste streams, and failure to collect organic waste separately poses challenges. The upcoming implementation of the Compost Law, mandated in 2020, is poised to address this gap by compelling the separate collection of biodegradable waste.

Home and community composting initiatives have gained traction, signifying a shift toward decentralized waste management. Local projects and educational initiatives have played a crucial role in fostering awareness and encouraging composting practices. The study acknowledges the recent legislative strides, particularly the Compost Law, as a pivotal step towards achieving the EU-mandated recycling targets by 2025.

In conclusion, Romania stands at a crucial juncture in its waste management journey, with composting emerging as a key solution. To unlock the full potential of composting municipal organic waste, concerted efforts are required. These include continued public awareness campaigns, streamlined legislative implementation, and fostering collaborations between local authorities, communities, and private entities. By capitalizing on the available resources, addressing regional variations, and aligning with EU directives, Romania can position itself as a trailblazer in sustainable municipal waste management, setting a precedent for circular economy practices across the European Union.

ACKNOWLEDGEMENTS

This work was carried out through the Nucleu Program within the National Research Development and Innovation Plan 2022-2026 with the support of Romanian Ministry of Research, Innovation and Digitalization, contract no. 3N/2022, Project code PN 23 22 03 02

REFERENCES

[1] Chen, P.; Xie, Q.; Addy, M.; Zhou, W.; Liu, Y.; Wang, Y.; Cheng, Y.; Yanling, C.; Ruan, R. Utilization of municipal solid and liquid wastes for bioenergy and bioproducts production. Bioresour. Technol. 2016, 215, 163–172.

[2] The World Bank. Solid Waste Management. 2019. Available online: https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management (accessed on 1 March 2020)

[3] Ghosh, P.K.; Ramesh, P.; Bandyopadhyay, K.K.; Tripathi, A.K.; Hati, K.M.; Mishra, A.K.; Acharya, C.L. Comparative effectiveness of cattle manure, poultry manure, phospho-compost and fertilizer-NPK on the cropping systems in vertisols of semi-arid tropics; crop yield and system performance. Bioresour. Technol. 2004, 95, 77–83.

[4] Meng, L.; Li, W.; Zhang, S.; Wu, C.; Lv, L. Feasibility of co-composting of sewage sludge, spent mushroom substrate and wheat straw. Bioresour. Technol. 2017, 226, 39–45.

[5] Berechet M., Ecological Assessment of Household Waste Management Systems in Some European Union Countries , PhD Thesis, Timisoara 2018

[6] Ministery of Environment and Forests, National Waste Management Plan, 2004, available online at: http://www.mmediu.ro/protectia_mediului/strategii_planuri.htm

[7] Ministery of Environment, National Waste Management Plan, 2017

[8] Regional Waste management plans, available online at: online https://ecoteca.ro/pjgd

[9] Compost Law 181/2020 , available online at: https://www.cdep.ro/pls/proiecte/docs

/2020/pr041_20.pdf

[10] Cocarta D., M., Feodorov C., Pasvantu I, Gogoncea A. C., Composting of biosolids in romania - a case study. Proceedings of 22nd International Multidisciplinary Scientific GeoConference SGEM 2022, doi: 10.5593/sgem2022/5.1/s20.015, 2022

[11] Ungureanu G., Ignat G., Leonte E., Costuleanu C., L., Jitareanu S., Donosa. D., Soare E., T., Sandu I G., (2018). Management of Urban Organic Solid Waste Applied in Romanian Metropolitan City. Revista De Chimie, doi: 10.37358/RC.18.6.6375

[12] Iacoboaea C., Luca O., Petrescu F., An analysis of romania's municipal waste within the european context. Theoretical and Empirical Researches in Urban Management, Research Centre in Public Administration and Public Services, Bucharest, Romania, vol. 8(4), pages 73-84, November

[13] Capatina C., Simonescu C., M., Management of waste in rural areas of gorj county, romania. Environmental Engineering and Management Journal, doi: 10.30638/EEMJ.2008.096, 2008.

[14] Schiopu. A.-M., Apostol I., Hodoreanu M., Gavrilescu M., Solid waste in romania: management, treatment and pollution prevention practices. Environmental Engineering and Management Journal, Vol.6, No.5, 451-465 doi: 10.30638/EEMJ.2007.055, 2007

RECYCLING IN CONSTRUCTION MATERIALS - ANALYSIS OF THE USE OF AMORPHOUS MATERIALS POLY(ACRYLONITRILE-CO-BUTADIENE-CO-STYRENE) (ABS) IN STRUCTURAL CONCRETE.

Assoc. Prof. Dr. Anna Stepien[1]

Prof. Ryszard Dachowski[1]

Assoc. Prof. Dr Agnieszka Molendowska[1]

[1] Kielce University of Technology, Kielce, **Poland**

ABSTRACT

Activities related to industrial aspects in the 21st century focus on, among others, low-emission economy, sustainable construction, recycling of processed materials, possibilities of recovery of building materials after the decision to demolish and ecology. The most popular building material is currently concrete used to make monolithic structures and prefabricated elements. There are many modifications to concrete, and the topic of recycling in building materials has become a priority. One of the materials is ABS, i.e. poly(acrylonitrile-co-butadiene-co-styrene). ABS is an amorphous, metastable material characterized by high resistance, impact strength, hardness and scratch resistance. It is also resistant to light and UV radiation and has favorable insulating properties. The only drawback is the lack of resistance to acids, esters and ketones. In order to determine the impact of ABS modification on the properties of the concrete mix, the following tests were performed: compressive strength, density and microscopic tests.

Keywords: concrete, ABS, polyacrylonitrile, recycling, sustainable.

INTRODUCTION

The article concerns the characteristics of screeds and the reduction of the use of quartz sand by using recycled material and an addition in the form of basalt powder with cryptocrystalline properties. The basic purpose of using a screed is to level the subfloor for the floor or the ceiling for the finishing material, which allows the top layer of the floor to bear loads freely. The screed can be used both in new buildings (residential buildings, service buildings, production halls) as well as during the renovation of an existing building. There are two types of screeds: liquid screed and dry screed [1].
Two types of modifiers were used for modification: basalt flour and ABS. Basalt powder is most often fine-grained mineral waste generated in the production of dust removal from crushed aggregate. It can also be obtained as waste from mechanical processing of aggregate during the production of, for example, mineral-asphalt masses (MMA). In both cases, it is not reused, so a common problem is its further disposal and storage, e.g. by the factories of the above-mentioned mineral and asphalt masses. It is a component of a very fine fraction, often similar to the dust fraction. Currently, solutions are being sought for the disposal of industrial waste, and similar solutions are being sought for basalt powder. Due to its fine fraction, it is used as a partial replacement for sand [2]. Due to the appropriate chemical and mineral composition of all types of dust, it was used in the production of cement mortars and concretes, and also as a partial

replacement for sand or even cement. Thanks to its natural properties, it has a positive effect on the produced mortar or concrete through the "filler effect", which consists in tightening the structure of the cement matrix, and thus improving the mechanical parameters of the produced materials. The disadvantage of using the additive, flour and rock dust as a substitute for fine aggregate is the larger specific surface than sand, which results in increased water demand and deteriorated workability. To neutralize this effect, add more water and flour or dust, which may result in increased shrinkage.

Due to the increasing production, various proposals are being made for further exploitation of leftover material. An example is the research work of P. Kostrzewa-Demczuk and all [3], who used samples with an additive content of 10%, 20% and 30% in the production of autoclaved brick with the addition of basalt dust. They showed that the best parameters have bricks with 10% basalt powder content, creating a cheaper brick with better mechanical parameters compared to the standard composition. The disadvantage of this solution is the need to add more water due to the high content of small grains in the basalt powder, which in too large amounts (according to researchers, above 15%) is problematic when forming a brick.

M. Dobiszewska in her work: "The use of rock dust as a cement replacement in cement composites: an alternative approach to the sustainable production of mortars and concrete" [4] collected numerous articles proposing innovative ways to reuse basalt flour. In addition to stating that the influence of rock dust is related to the "filler effect", it indicates that the main factors prevailing in shaping the properties of concrete materials are the modification of the particle size distribution of hydrate precipitation (primarily C-H and C-S-H) on the rock powder particles and cement dilution. As a substitute for cement, it can have a positive effect on hydration in the early stage of maturation, but unfortunately, due to the possibility of diluting the cement, this effect should be mitigated by using a greater fineness of the additive. In the work "Mechanical properties and microstructure of the interfacial transition zone of concrete with the addition of waste basalt powder" [5], the impact of replacing part of the sand with basalt flour was described. For this purpose, samples were made with the following parameters: percentage of replacement of sand with basalt flour: 0%, 5%, 10%, 20% and 30%. The analysis showed that as the maturation period increases, i.e. 7, 14, 28 and 90 days, the compressive strength increases along with the increase in the amount of basalt powder. Another group used to modify the mixture and created as waste from industrial production are plastics, which also pose an increasingly serious disposal problem [6]. ABS, i.e. acrylonitrile-butadiene-styrene copolymer, is a material commonly used in the production of dashboards in cars, in the production of toys, and housings of household appliances. As a separate material, it is characterized by very good impact resistance, scratch resistance and aging resistance. Additionally, it has high stiffness and resistance to stress corrosion cracking. Due to the constantly increasing use of plastic, there is a problem of increasing production and post-exploitation waste.

A. Palos and his team developed a method of using powdered ABS waste in mortars [7]. The tests conducted showed that mortar with a 3:1 ratio of sand to cement and the addition of ABS plastic in the amount of 8, 15 and 25% increases the compressive strength. However, the addition of maleic anhydride (to ABS waste) resulted in an increase in adhesion to reinforcing steel, which is particularly important in structural elements. In their research, the authors also noticed a reduction in pores in samples with 15% ABS added. A different perspective is presented by the study carried out by the team of Gurbir Kaur and Sara Pavia [8], whose aim was to investigate the impact of

partial replacement of sand in the cement mortar by adding ABS plastic aggregates with a volume of 10%, 15% and 30%. They showed in their work that replacing sand in the cement mortar reduces the compressive strength by 14.4% - for 10% of the volume, 22.8% - for 15% of the volume and 23.6% for 30% of the volume. In the case of bending strength, the results were as follows, i.e. a reduction in strength of 8.8% - for 10% of the volume, 13.7% - for 15% of the volume and 14.5% for 30% of the volume. It was found that replacing part of the sand with plastic had a smaller impact on flexural strength compared to compressive strength. This is due to the increase in porosity that was created by the quality of the contact between the sand and the matrix. Additionally, the bulk density was reduced and it was noticed that cement mortars with the addition of plastic cracked in a way typical of increased plasticity. Despite the described defects, it was found that from a practical point of view the samples do not show any major losses.

MATERIALS AND METHODS

The research part of the article includes tests on standard mortars in which the content of quartz sand was reduced with a modifier in the form of ABS plastic (poly(acrylonitrile-co-butadiene-co-styrene)) and basalt flour was used. The tests were performed according to the following standards: PN-EN 196 – 1, mortar density (PN-EN 1015-6), consistency test (PN-EN 1015-3), strength tests [Fig.1] such as compression and bending (PN-EN 196-1:2006). CEM II/C-M (V-LL) 32.5 R multi-component Portland cement with a density of 3.0 g/cm^3 was used for the tested sample. The composition of cement production complies with the PN-EN 197-5:2021-07 standard. It is a material from the ECOPlanet green cement series, the use of which allows for the reduction of the emission of constructed structures. The tested sample used sand with a density of 2.65 g/cm^3 with a fraction of 0-2 [mm], from H+H Silikaty Sp. z o. o. Company in Ludynia (Poland)- the plant extracts sand locally. Basalt flour with a density of 3.0 g/cm^3, fraction 0-2 [mm] was used as a mineral additive. As a second addition, ABS plastic was added, i.e. acrylonitrile-butadiene-styrene copolymer, with a density of 1.05 g/cm^3.

The analyzes were performed based on the Statistica program and an experimental plan created according to the procedure of mathematical experiment planning was used (Table 1). A full fractional plan 3**(2-0) was used, with the number of input quantities (independent variables - 2, number of systems (measurements) -9, number of blocks –1.

Table 1. Experiment planning matrix with a description of the levels of independent factors

Nº Sapmles	Independent factors			
	Conventional scale		Natural scale	
	X1	X2	X1 (MB)	X2 (ABS)
1	-1	-1	10	5
2	0	-1	20	5
3	1	-1	30	5
4	-1	0	10	10
5	0	0	20	10
6	1	0	30	10
7	-1	1	10	15
8	0	1	20	15
9	1	1	30	15
ZN	-	-	-	-

The photos Fig. 2 show fractures of materials resulting from modifications and after strength tests.



Fig. 1. Strength test



Fig. 2. Samples of cement mortar elements modified with ABS.

RESULTS

The research showed that the density of the mortar (Fig.3) decreases due to the increased amount of ABS added, which has a low bulk density compared to other materials, i.e. 1.05 [g/cm^3], an attempt to increase the density value by adding a larger amount of basalt powder is visible. The value close to the standard mortar is only the content of 5% (ABS) and 30% (Basalt Powder), the difference between them is 1.1%. This is probably due to the higher content of basalt powder than ABS plastic. In other cases, it has a decreasing tendency. At the lowest point, the difference between the densities of the standard and modified mortar is 13.6%.

Table 2. Average results of compressive and bending strength tests Bending strength Compressive strength.

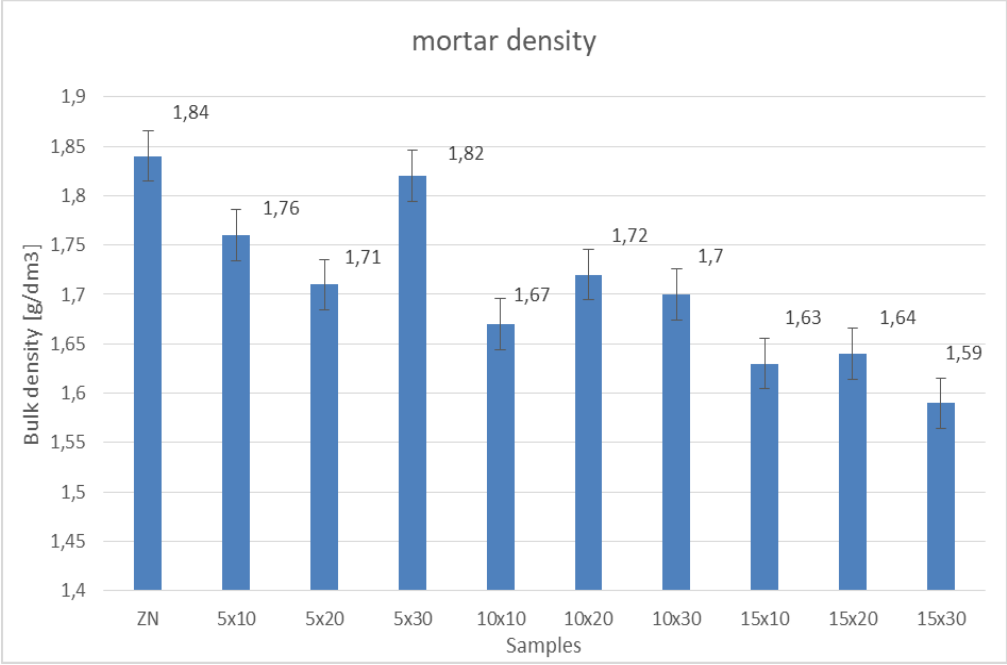


Fig. 3. Graph showing the density of fresh mortar.

Table 2 and drawings Fig. 4, Fig. 5 and Fig. 6 show the results of mortar modification with modifiers in the form of ABS and basalt flour.

Table.2. Bending and compressive strength of standard mortar and mortar modified with ABS and basalt powder.

Sample		Flexural strength [MPa]	Compressive strength [MPa]
Standard mortar		5,00	34,91
5	10	4,53	31,45
5	20	4,80	33,97
5	30	5,36	36,09
10	10	4,86	28,16
10	20	4,50	28,73
10	30	3,90	25,04
15	10	4,84	30,67
15	20	4,24	26,74
15	30	4,49	27,48

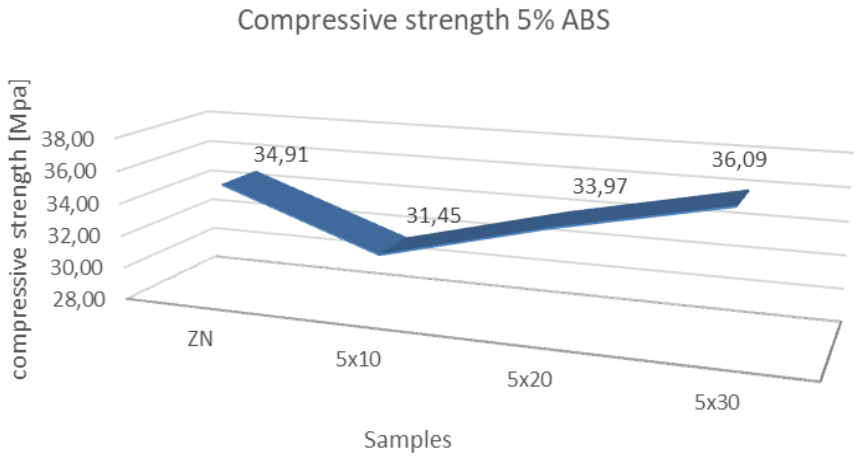


Fig. 4. Mortar modified with basalt powder and 5% ABS.

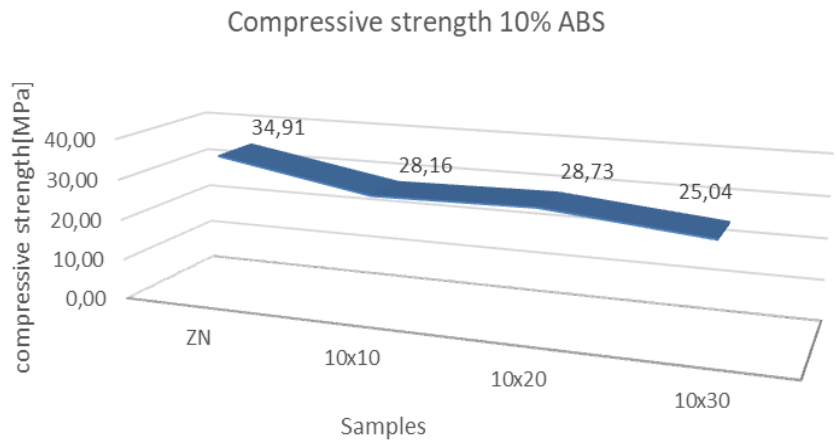


Fig. 5. Mortar modified with basalt powder and 10% ABS.

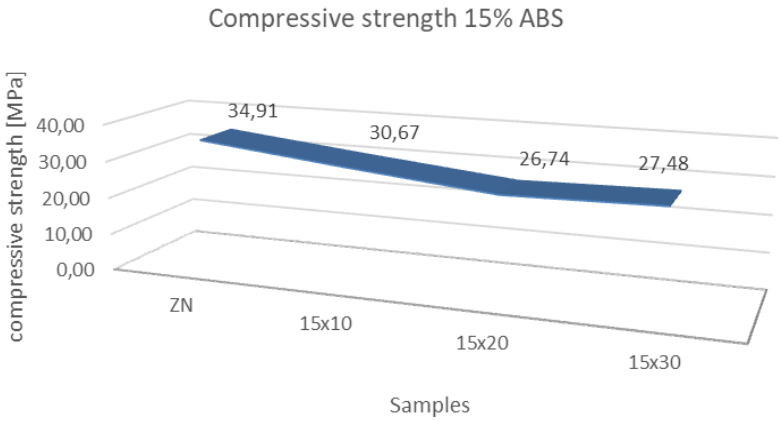


Fig. 6. Mortar modified with basalt powder and 15% ABS.

It is concluded that the best sample in terms of parameters is the one containing 5% ABS plastic and 30% Basalt powder, which is characterized by increased compressive strength - 3.4% with the highest share, i.e. recycling of waste material consumption, which will be basalt powder. Samples 5x10 and 5x20, despite a slight decrease compared to the standard mortar, will also be a good replacement.

CONCLUSION & DISCUSSION

The developed results have abbreviations that mean: ZN - Standard Mortar, MB - Basalt powder, while the numbers next to the values indicate the content of individual ingredients in the compared samples, i.e. 5x10 - 5% ABS, 10% Basalt powder, 15x10 - 15% ABS and 10 % Basalt powder. It is known that 60-70% of concrete is the amorphous CSH phase and it is thermodynamically stable up to a temperature of 25-30^{o}C, then it crystallizes (and here depending on the amount of silicon binder, the amount of water, temperature, other chemical admixtures) crystallization runs in different directions. Thanks to its structure, the CSH phase can absorb harmful substances from the environment depending on their concentration and prior design. The most important information at this stage is the analysis of the amount and confirmation of the presence of the CSH phase in the designed concrete mix (but it is there, as indicated by the production temperature and a number of literature tests). Use appropriate methods of showing data. Don't try to manipulate the data to make it look like you did more than you actually did.

REFERENCES

[1] Hajduk P. Industrial Flooring Design, EAN: 9788301198381, PWN 2013.

[2] Rashad A. Cementitious materials and agricultural wastes as natural fine aggregate replacement in conventional mortar and concrete. Journal of Building Engineering 5, 2016.

[3] Kostrzewa-Demczuk P., Stępień A., Dachowski R., Krugiełka A. The use of basalt flour in autoclaved bricks as a method of managing production waste. JOURNAL OF CLEANER PRODUCTION, 2021.

[4] Dobiszewska M.. Bagcal O., Beycioğlu A., Goulias D., Köksal F., Płomiński B., Ürünveren H. Utilization of rock dust as cement replacement in cement composites: An

alternative approach to sustainable mortar and concrete productions" Jurnal of Building Engineering 69, 2023.

[5] Dobiszewska M., Schindler A.K., Pichór W. Mechanical properties and microstructure of the interfacial transition zone of concrete with the addition of waste basalt powder. BUDOWNICTWO I MATERIAŁY BUDOWLANE, 2018.

[6] M. Dobiszewska The use of basalt dust as a substitute for sand in mortar and cement concrete. BUDOWNICTWO I ARCHITEKTURA 15(4), 2016

[7] Palos A., Souza N.A.D., Snively C.T., Reidy R.F. Modification of cement mortar with recycled ABS. CEMENT AND CONCRETE RESEARCH nr 31/2001.

[8] Kaur G., Pavia S. Physical properties and microstructure of plastic aggregate mortars made with acrylonitrile-butadiene-styrene (ABS), polycarbonate (PC), polyoxymethylene (POM) and ABS/PC blend waste. JOURNAL OF STRUCTURAL ENGINEERING, Elsevier, 2020.

OPTIMIZATION MEASURES TO IMPROVE THE RATIONAL USE OF THE SURFACE LAYER OF ANTHROPOGENIC LANDSCAPES IN THE KRYVYI RIH LANDSCAPE- TECHNICAL SYSTEM

Tetiana Koptieva, PhD in the field of study 10 Natural sciences, specialty 103 Earth sciences
Lotsman Pavlo, Candidate of Geographical Sciences
H.S. Skovoroda Kharkiv National Pedagogical University, Kharkiv, **Ukraine**

ABSTRACT

The article is devoted to the study of optimization measures to improve the rational use of the surface tier of anthropogenic landscapes in the Kryvyi Rih landscape and technical system. The surface tier of anthropogenic landscapes is analyzed and defined on the example of mining and settlement landscapes. The problems associated with the active development of the mining industry and the causing such factors as poor soil quality, derivative processes and phenomena, pollution and uncontrolled use of resources are identified. The article describes various optimization measures, such as reclamation, revitalization, cultivation, landscape monitoring, conservation, green spaces, landscape design, etc. The importance of cooperation between the public, authorities and research institutions to achieve a more sustainable use of anthropogenic landscapes is also considered. The results of the study show that optimization measures can contribute to the improvement of the ecological state and ensure the sustainable development of anthropogenic landscapes in the Kryvyi Rih landscape and technical system.

Keywords: Kryvyi Rih landscape-technical system, surface layer, mining landscape, settlement landscape, optimization measures

INTRODUCTION

The Kryvyi Rih landscape-technical system, operating in Ukraine on the territory of Kryvyi Rih, Dnipropetrovsk region, was formed over almost 150 years thanks to the active mining industry. The Kryvyi Rih iron ore basin, which has significant reserves of iron ore - more than 18 billion tons, is the basis of the KLTS [6]. This system is a complex object that includes a variety of natural and mainly anthropogenic landscapes, as well as infrastructure and technical facilities located on the territory of Kryvorizkyi district.

The Kryvyi Rih landscape-technical system is a complex of unique natural and technogenic elements, which are characterized by a special landscape and technical structure in the area of the city of Kryvyi Rih in Ukraine. This system includes the following components:

1. Nature elements: Kryvyi Rih hills, which are significant uplands with a characteristic relief and rich flora and fauna. Here you can find such types of landscapes as steppe, forest-steppe and forests.

2. Technogenic elements: Kryvyi Rih iron ore basin, which is one of the largest in the world. This basin has significant industrial potential and includes quarries, mines, iron ore plants and other industrial facilities.

3. Infrastructure: Kryvyi Rih landscape-technical system includes also a road, railway, building and communication system that provides the development and functioning of this territory. This system is of great importance both economically and ecologically. It provides mining and processing of iron ore, which is favorable for the development of industry in the region. At the same time, it requires the rational use of disturbed lands as a result of the mining industry in the territory of the Kryvyi Rih landscape-technical system. On the territory of the Kryvyi Rih landscape and technical system a two-tiered anthropogenic landscape was formed as a result of the active mining activity, namely on the mining and residential landscapes.

MATERIALS AND METHODS

The main scientific results of the work were obtained by using a complex of general scientific and special research methods, namely: methods of analysis, synthesis, generalization, historical, statistical and comparative methods and anthropogenic landscape forecasting.

RESULTS

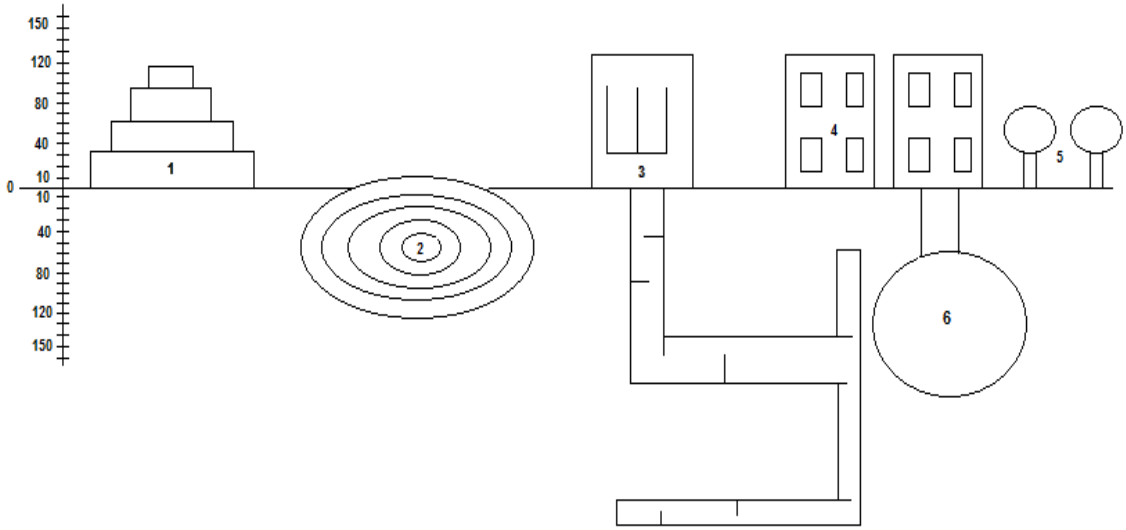
The mining industry is a key factor leading to the complete transformation from natural landscapes into anthropogenic conditions in the KLTS.

The area of anthropogenic landscapes in the KLTS is constantly increasing. According to the percentage ratio, agricultural landscapes occupy the largest area (61.2% of the region), followed by residential (13.1%), industrial (11.5%), water management (8.1%), forestry (3.5%) , transport (2%) and others (0.6%) [1]. However, residential and mining landscapes are of particular importance among the anthropogenic landscapes of the KLTS. Mining landscapes are formed through the mining and mining technology. They significantly change all components of the natural environment and affect the composition, development and structure of natural and anthropogenic landscapes [5]. Settlement landscapes, according to the classification of V. L. Kazakov , are divided into non-residential (cemetery) and residential. Service landscapes include domestic, administrative, research and trade subtypes [3].

The correlation of two-tieredness with altitudinal differentiation still does not have deep enough analysis, but this phenomenon is observed in cases of anthropogenic landscapes. Although there may be common elements between these concepts, they are distinct from each other. Altitudinal differentiation is due to the variety of climatic conditions at different altitudes and their influence on vegetation. Two-tieredness occurs as a result of the influence of all factors of the landscape formation, such as geological (geological structure, relief), climatic, hydrological (action of surface water), hydrogeological (underground water), soil and vegetation. The two-tiered structure is divided into surface and underground tiers. For example, in mining landscapes, the surface layer is formed due to quarries, dumps, sludge storages. The largest quarries, such as the SMPP quarry (over 400 m), one of the largest reclaimed dumps – Burshchitskyi (110 m), as well as flooded reclaimed quarries, such as Zhovtnevyi (110 m) and Karachunivskyi, are operating on the territory of the KLTS (250 m).

The underground layer of mining landscapes is divided into shafts (separate shafts, cross-cuts, strike-entries, blind shafts), driftways and sinkholes. The deepest mines: Hvardiiska mine (1190 m), Kryvorizka mine (1580 m).

The settlement landscape of the KLTS includes both surface and underground layers. The surface layer includes buildings such as high-rise residential buildings, industrial complexes, various shopping centers, as well as buildings for cultural and artistic needs. The underground layer of the residential landscape includes a high-speed tram, which moves both above-ground and underground routes, which is characteristic of the territory of KLTS (Fig. 1)



Legend:

1. Dumps (mining landscape, surface layer); 2. Quarries (mining landscape, surface layer); 3. Mine (mining landscape, underground layer); 4. Residential area (residential landscape, surface layer); 5. Garden and park zone (residential landscape, surface tier); 6. High-speed tram (residential landscape, pedestrian tier).

Fig. 1. Two-tiered anthropogenic landscapes of the Kryvyi Rih landscape-technical system

The main components for the optimization of the surface layer of mining landscapes are their reclamation and revitalization.

Reclamation of mining landscapes is a complex process that includes a wide range of engineering, mining, reclamative, environmental, sanitary and hygienic measures. These measures are aimed at rehabilitating areas that have been damaged by industrial activities, with the aim of using them for various natural purposes, such as agriculture, forestry or recreational purposes.

Before mining begins, each mining enterprise usually develops a reclamation project to restore damaged mining and industrial landscapes.

Reclamation is necessary for all mining complexes where the thickness of deposits, topography, soil cover and vegetation change. As a rule, reclamative measures are carried out when mining enterprises and permanent (decommissioned) systems that remain from the previous activity of the enterprise are closed.

The reclamation takes place in two stages in Kryvorizhzhia: mining and biotic. The mining technical stage includes the preparation of land plots, relief modeling, application of nutrient soils on the area of the mining facility, reclamation works and other measures [8]. For example, the filling of pit No. 2 of the Central Mining and Processing Plant (CMPP) (Fig. 2).

The biotic stage of reclamation includes a set of agricultural engineering and phytomelioration measures aimed at restoring the natural environment for living organisms and increasing the economic productivity of land (Fig. 3).



Fig. 2. Mining technical stage of reclamation of the surface layer of mining landscapes of the KLTS.



Fig. 3. The biotic stage of reclamation of the surface layer of mining landscapes of the KLTS.

Reclamation includes phytomelioration, which is a set of effective measures aimed at improving the fertility of reclaimed lands by growing grassy, shrubby, and tree plants of reclamation crops [8]. Phytomelioration differs from biological reclamation

because it can use the natural potential for self-regeneration of vegetation to optimize mining landscapes and can be applied without prior mining reclamation.

Phytoreclamation on quarry and dump complexes was carried out by various methods - from manual planting of seeds and seedlings to sowing with the help of helicopters.

To date, the six most common areas of reclamation of the mining landscapes of Kryvorizhzhia are known: agricultural (creation and development of agrocenoses), forestry (creation of forest plantations), water management (use of quarry and technogenic excavations under reservoirs), recreational (we have proposed a project of recreational reclamation of the Karachunivskyi quarry-dump complex, sanitary and hygienic (suspension of the negative impact of disturbed lands on the environment) and construction (development of construction).

Revitalization, which comes from the Latin words " re " meaning reverse or repeated action and " vita " meaning life, represents a new approach in restoring disturbed mining landscapes. For the last years scientists focus more and more on this sphere. Revitalization is used for improvement restoration strategies for damaged mining landscapes [7]. The main revitalization goals (Fig. 4) are space socialization, development of social infrastructure for regulation of recreation and tourism, development of production and improvement of ecological state of mining landscapes [4].

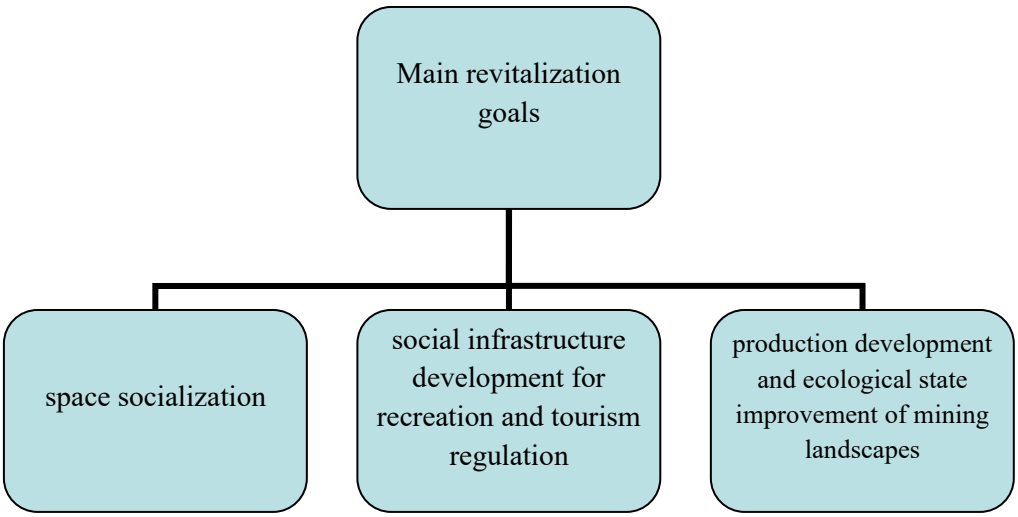


Fig. 4. The main goals of revitalization

According to E. A. Ivanov research [2], the choice of methods for optimizing mining landscapes depends on the complexity of their structure, the intensity of the destruction processes, and the financing of the project. A significant part of the territory of Kryvorizhzhia is occupied by mining landscapes, therefore, revitalization requires large expenditures of money and time. Unfortunately, revitalization is implemented in a rather limited way in Ukraine.

In Poland, in the commune In Hrybów , at the site of underground sulfur mining, the " Jeziorko " recreation area was created with the funds of the National Fund for Nature Protection and Water Management of the Republic of Poland. More than 50% of mining enterprises in the European Union have ceased operations and have been preserved, and a significant part of them is used for the disposal of industrial and household waste [7, p. 187].

To improve the disturbed lands of the surface layer of residential landscape it is used landscape monitoring, cultivation and preservation.

Landscape monitoring is a system of observation and control of the state of mining landscapes and their structural elements both during their exploitation and in the post-exploitation period. Its purpose is to assess, forecast and scientifically justify the optimal use of these territories [4, p.137].

When studying the optimization measures of the residential landscape of the Kryvyi Rih landscape and technical system, you should pay attention directly to:

1. Green spaces: Increasing the number of green spaces in city can improve air quality, provide shade, reduce noise and improve aesthetics. The creation of parks , squares , gardens and planting of new trees and bushes (garden and park landscape) is of primary significance.

2. Development of more bicycle lanes: The creation of bicycle lanes and infrastructure for cyclists can help to reduce traffic jams, improve the health of residents and reduce air pollution, since the KLTS has quite high air pollution indicators due to the active action of industry.

3. Active involvement of pedestrian zones: The creation of pedestrian zones and walking platforms can promote an active lifestyle, promote social interaction and increase the attractiveness of the residential area landscape.

4. Using walls for vertical gardening: Installing vertical gardens on the walls of buildings can help to green urban spaces, provide additional oxygen and reduce temperatures in the summer (landscape).

5. Reconstruction of industrial areas: The transformation of outdated industrial areas into green zones or parks can improve the quality of life of residents and make the city more attractive for tourists (using the revitalization method of conversion post-mining landscapes, recreational and tourist facilities .)

7. Designing green buildings: Supporting the construction of energy-efficient and sustainable architecture can reduce energy consumption and impact on the environment.

8. Increasing the number of public spaces: Creating more public spaces and places for recreation can improve the life quality of residents and promote social interaction.

In this way, these measures can contribute to improve the residential landscape, to do city more ecologically stable and attractive for life.

DISCUSSION

In Ukraine, the complex problems of reclamation of mining territories and objects formed as a result of extensive development of industrial sectors and resource-intensive technologies are gradually being solved. There is experience of successful land reclamation within Donbas and Lviv region - Volyn coal basin, Dnipro lignite basin (Ivanov, Bilaniuk, 2017). Among the iron ore enterprises, the Komysh-Burun metallurgical plant has the most experience , on the territory of which more than 4,300 hectares of agricultural land have been disturbed. However, the rates of land reclamation in some regions of Ukraine for various reasons remain insufficient for reproduction (Sorokina, 2004).

CONCLUSION

The Kryvyi Rih landscape-technical system is a complex system that requires the acceleration of optimization measures at the surface and underground layers of mining and residential landscapes. The mining industry is a key factor on which the transformation of natural landscapes into anthropogenic conditions depends. Mining landscapes are of particular importance, as they significantly modify natural environments and affect their structure. Observations show that two-tieredness is a characteristic feature of these landscapes and depends on a variety of factors. This relationship is observed both in mining and residential landscapes, which are represented by various elements at the surface and underground levels.

The mentioned work on mining and settlement landscapes of the Kryvyi Rih landscape-technical system revealed important aspects of their structure and impact on natural environments. The identification of two-tiered structures, the formation of surface and underground layers, the identification of various methods of reclamation and revitalization strengthen the awareness of the need to intensify optimization measures. Recommendations for the use of landscape monitoring, the increase of green spaces and the creation of ecological infrastructure reveal the way for improving the quality of life of residents and creating attractive conditions for tourists. However, it is important to consider the complexity of implementation and the financial costs of revitalization measures, especially in comparison with other countries. For example, Poland has already implemented a successful project to create recreational zones at raw material extraction sites, which is a potential model for Ukraine. This approach can contribute to improving optimization strategies and ensuring sustainable development in the Kryvyi Rih landscape and technical system.

ACKNOWLEDGMENTS

On the occasion of the 74th anniversary of the birth, I am very grateful to the Doctor of Geographical Sciences, professor, professor of the Geography Department of Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University, Honored Figure of Science and Technology of Ukraine - Denysyk Hryhorii Ivanovych for his help in the research, I am also grateful to my parents and my family.

REFERENCES

[1] Denysyk G. I., Zadorozhnia H. M. Derivatives processes and phenomena in the landscapes of technogenesis zones : monograph . Vinnytsia : Vinnytsia regional publishing house , 2013. 220 p.

[2] Ivanov E. A. Ecological and landscape basis of reclamation of mining areas. Problems of landscape diversity of Ukraine. 2000. P. 221–225.

[3] Kazakov V. L. Anthropogenic landscapes of Kryvorizhzhia : history of development, structure. Geographical studies of Kryvbas: Mater. the cathedral scientific research . topics 2007. Issue _ 2. P. 27–35.

[4]. Koptieva T.S. Altitudinal differentiation and diversity of mining landscapes of Kryvorizhzhia: monograph. Vinnytsia: TVORY, 2023.138p.:ill- (“Modern Nature and Landscapes of Ukraine”) ISBN 978-617-552-486-2.

[5] Koptieva T.S. Mining landscapes of Kryvyi Rih landscape technical system / T.S. Koptieva // Human and the environment Problems neoecology. – 2021. – Issue 35. - P. 18 -26. DOI: https://doi.org/10.26565/1992-4224-2021-35-02

[6] Koptieva T.S. Kryvyi Rih landscape technical system: development, current state and ways of optimization / T.S. Koptieva , HI Denysyk // Physical geography and geomorphology . – 2021. – Issue 1–3 (105–107). - WITH . 25-29 .DOI: https://doi.org/10.17721/phgg.2021.1-3.03

[7] Rudko G. I., Ivanov E. A., Palamarchuk I. P. Mining geosystems of the Western region of Ukraine : monograph. Kyiv - Chernivtsi : Bukrek , 2019. Vol. 1. 464 p. ISBN 978-617-7663-42-2

[8] M. Syvyi. Mineral resources of Podillia: structural and geographical analysis and synthesis: monograph. Ternopil: Textbooks and manuals, 2004. 656 p.

RECYCLING IN CONSTRUCTION - CHARACTERISTICS OF COMPOSITE AND RECYCLED MATERIALS USED IN STRUCTURAL ELEMENTS OF BUILDINGS

Assoc. Prof. Dr. Anna Stepien[1]

MSc. Patrycja Wojarska-Gniady[2]

[1] Kielce University of Technology, **Poland**
[2] Kielce University of Technology & Prefamax, **Poland**

ABSTRACT

The article discusses the issue of recycling and the use of recycled substrates in building materials and parts of building structures. Recycling is one of the elements compatible with the current functioning of society and which has its significant place in a sustainable economy and construction. There are currently many modifications of construction materials such as concrete or bricks. The concrete mass or base from which modified bricks are made include: recycled glass components (powder and glass sand), HIPS, ABS, geopolymers, etc. Currently, vinyl sheet pile walls are being created as elements that constitute an alternative to walls. tight steel. Another example of the use of composite materials in building materials and structures is the use of composite bars as replacement reinforcement for steel when constructing monolithic ceilings. The use of composite bars as reinforcing bars can now be found in every field of construction. Elements that can be made from reinforcing bar include: foundations, walls, ring beams, ceilings, floors or as repair elements for reinforced concrete structures. Composite rods fit perfectly into the canons currently perceived by modern society, achieving features for the sustainable development of construction. These rods can have a positive impact on the construction market, not only due to the environment in which they can be located, but also by extending their service life and reducing operating costs. At the same time, it meets the features of a sustainable building, which are: a healthy and comfortable environment for users, savings, use of resources, avoidance of toxic emissions, reduction of the amount of waste produced, and the use of environmentally friendly materials. The amount of construction waste increases with the development of construction. Various recycling methods allow for the management and reuse of waste that is generated, which helps protect the environment. A way to use the waste generated is the "downcycling" method, where a larger amount of waste can be directed as a raw material for reuse with reduced values, which does not mean worse. One of such materials is concrete, which has a positive impact on the ecological and economic aspects of the current environment. Unlike the previous method, the "upcycling" method aims to increase the value of the processed raw material, such materials may be re-melted steel or plastics.

Keywords: sand, construction, recycling, sustainable, steel, geopolymers.

INTRODUCTION

The construction industry includes the construction of buildings and structures, as well as the transport and production of building materials. Each building, regardless of its purpose, construction technology, shape or size, creates one inseparable block. The implementation of construction projects is a series of activities aimed at achieving a specific goal, i.e. a building, and the implementation of the constructed buildings is regulated by the expectations of investors, the principles of construction art, construction law and applicable standards [1-8]. An important stage in the construction of buildings is the selection of materials or the possibility of finding alternative material

solutions, the so-called replacements corresponding to the originals. The materials from which buildings are constructed affect energy efficiency and the life of the building. In Poland, the traditional and most common method of single-family construction is brick technology. Every building, regardless of its purpose, including a single-family building (Fig. 1,2) consists of structural elements such as:

- foundations,
- foundation walls,
-load-bearing walls and partitions,
- ceilings,
-roof [1].





Fig.1. Concreting the ceiling [37].
Fig.2. Single-family building under construction [37].

However, recent years have shown, how progressive development and the desire to improve living comfort (Fig.3) have influenced the environment and disturbed the possibility of natural renewal of minerals used in construction, e.g. sand and natural aggregates (Fig. 4,5) [9]. The current trend is sustainable development and sustainable management of both natural and recycled resources. The Technical Terms WT2021 standards [2] allowed the construction industry to be directed towards energy-efficient buildings, and subsequent restrictions require the disposal of waste materials also in the construction industry [10].

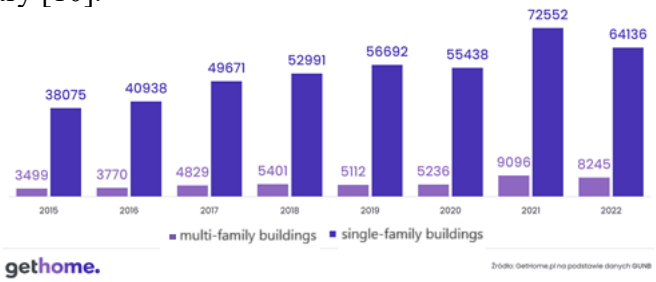


Fig.3. Residential buildings with building permits and notifications in the first half of the year (PL) [11].

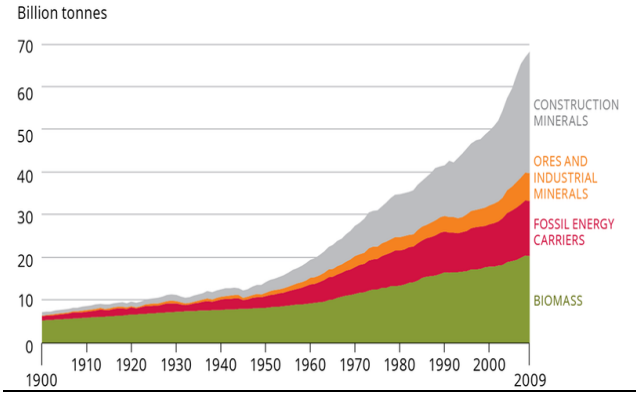


Fig. 4. Mineral consumption in the years 1910-2009 [12]

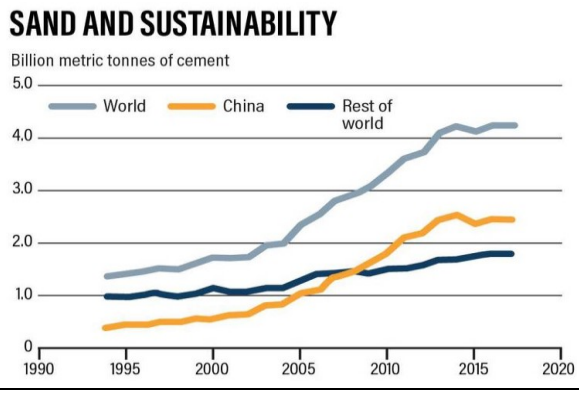


Fig. 5. The amount of minerals used in construction in particular parts/countries of the World [13].

Moreover, the pandemic Covid that began in 2020 also led to rapid changes in the construction industry by disrupting the production of materials, supplies and the possibility of implementing construction facilities (due to the isolation of employees and companies). The above factors led to difficulties in obtaining materials and resulted in shortages on the market followed by a sharp increase in prices and demand. The

drawings (Fig. 6,7) show the number of construction applications for single-family buildings in Poland (growth trend) and the percentage share of building materials used to construct buildings on the Polish construction market [13, 14].

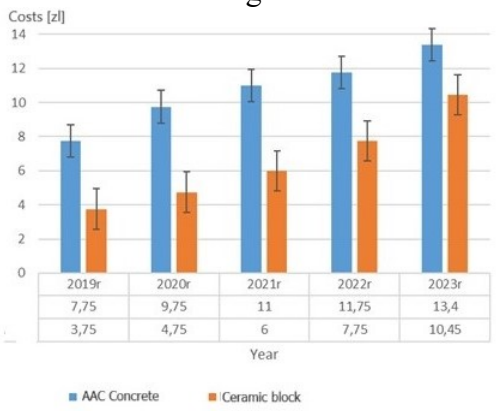


Fig. 6. Chart of average material prices in the years 2019-2023.

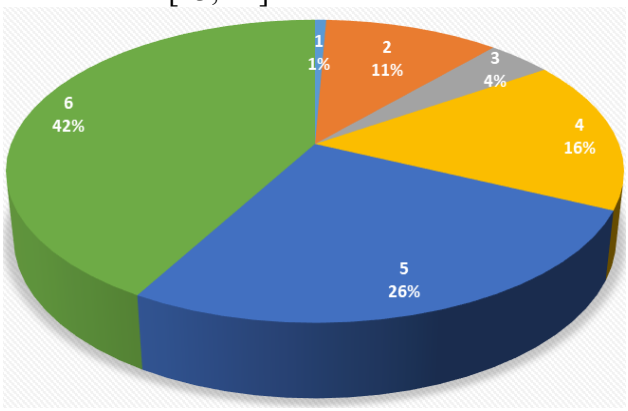


Fig.7. Percentage share in the market of materials for building walls; aerated concrete, 5-ceramics, 4-silicates, 3-normal and light concrete blocks, 2-monolithic, 1-other[14]

The article presents an analysis of the possibility of using two alternative materials that can replace traditional solutions used in construction:
- production of silicate brick based on glass sand or partial replacement of quartz sand with glass sand (recycling of bottle glass);
- possibility of using composite rods as an alternative to steel rods necessary for use in the construction of monolithic ceilings (Fig.10).

Masonry technology - traditional, considered the most popular technology for constructing buildings, followed by monoliths and frame construction, which involves constructing walls using blocks, hollow bricks or bricks, joined using appropriate ordinary mortars or mortars for thin joints. Walls built using this technology perform both structural and insulating functions (Fig. 8-10). However, in order to meet today's requirements due to heat losses, such walls are supplemented with additional thermal insulation[15,16,17,18].

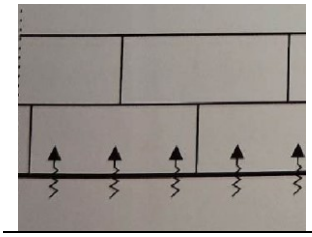


Fig. 8. Horizontal waterproofing [20]

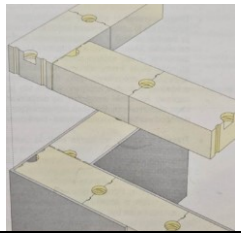


Fig. 9. Wall in single-layer brick technology, YTONG SYSTEM [15]

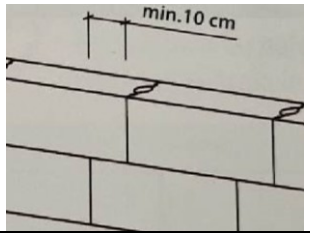




Fig.10. Silicate bricks with 50% GS&50% QS

The drawings show the arrangement of structural walls in single-family housing using monolithic technology in terms of wall design.

Due to the above aspects, the use of composite rods in construction, as well as the partial or complete replacement of quartz sand with recycled glass sand during brick production, seems to be beneficial, especially since great emphasis is currently placed on the so-called economy *"closed circuit"*. In 2010, O-I conducted a life cycle assessment (LCA) of glass, tracing the full life cycle of the packaging, i.e. from the extraction of raw materials to the reuse or recycling of the glass container [19]. Using

publicly available data on aluminum and PET plastic production, glass has been shown to have the most favorable carbon footprint. It should be added that 1 ton of glass cullet replaces 1.2 tons of non-renewable natural raw materials (extraction and transport). An increase in the share of cullet by 1% in glass production results in energy savings of approximately 0.25%, and also saves water needed for production and reduces the emission of harmful oxides into the atmosphere [20,21].

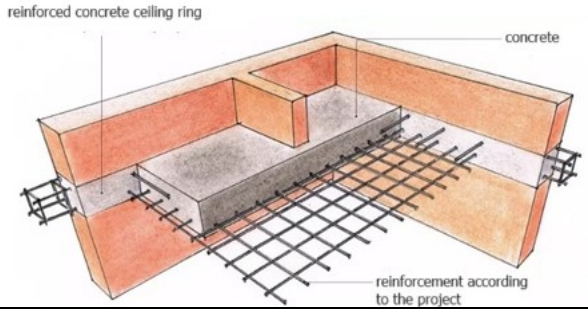


Fig. 11. Monolithic ceiling [23]



Fig. 12. Monolithic ceiling with roof truss.

The durability of the structure (Fig. 11,12) is ensured by the appropriate selection of reinforcement and the appropriate class of steel (Fig.13) and concrete, selected in accordance with generally applicable standards, as well as the correctness of execution using appropriate technology in accordance with the art of construction and generally applicable rules of construction work [24, 25, 26, 27].

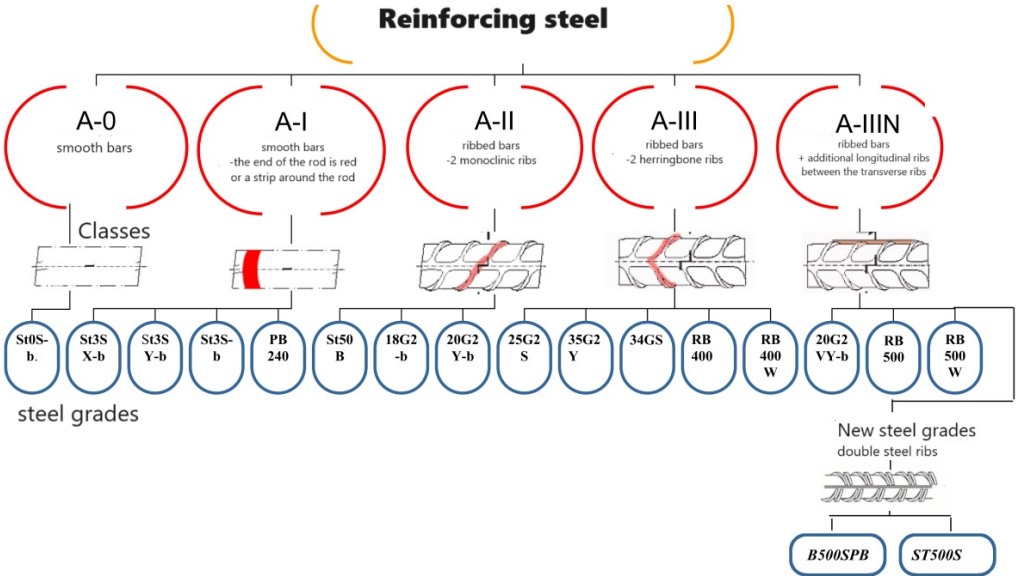


Fig. 13. Reinforcing steel grades [23].

MATERIALS AND METHODS

The analyzes and possibilities of taking into account alternative materials were based on the following legal acts and industry standards: Administrative law, with particular emphasis on the Act of July 7, 1994. as Construction Law (consolidated text: Journal of Laws of 2021, item 2351, of 2022, items 88, 1557, 1768, 1783, 1846, 2206, 2687) regulating technical conditions. Civil Code - Act of April 23, 1964 (consolidated text: Journal of Laws of 2022, items 1360, 2337, 2339, of 2023, item 326), Construction Law, regulating the changes taking place with current regulations[1-4, 28]. The research

and the presented tests were performed based on the CEN standards: PN-EN 772-13: 2001, CEN. PN-EN 1996-2, CEN. PN-EN 771-2, PN-EN 1936:2010 [5-8].
The analysis included the characteristics of a monolithic ceiling using steel rods and alternative composite rods, while the tests included the strength characteristics and structure of silicate bricks modified with recycled glass sand.

RESULTS

The above solutions seem to have beneficial aspects, first of all, due to the possibility of relieving the natural aggregates and the use of recycled aggregate in the form of autoclaved bricks made by partial or complete reduction of the share of quartz sand in the silicate mass in favor of glass sand (Fig.14,15) and the use of composite rods (Fig.17) instead of steel rods (Fig.16) due to to the high price of steel, the possibility of corrosion and market shortages that could be seen even in 2022.



Fig. 14. Traditional sand-lime bricks (QS)

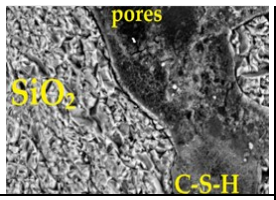


Fig. 15. SEM photo of sand-lime brick.



Fig. 16. Inter-story ceiling.



Fig. 17. Composite rod [29]

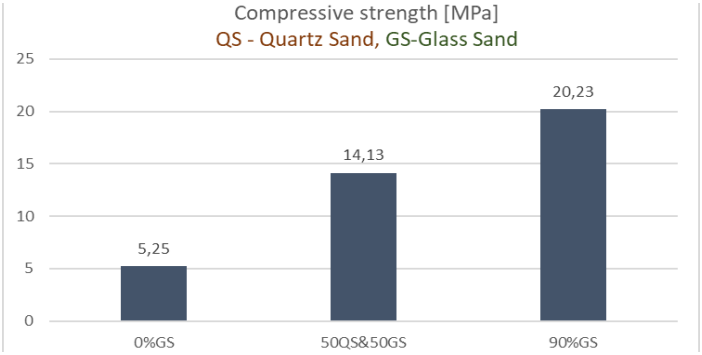


Fig. 18. Compressive strength chart of silicate bricks with 50% glass sand and 50% quartz sand (90% sand + 7% CaO + 3%H_2O).

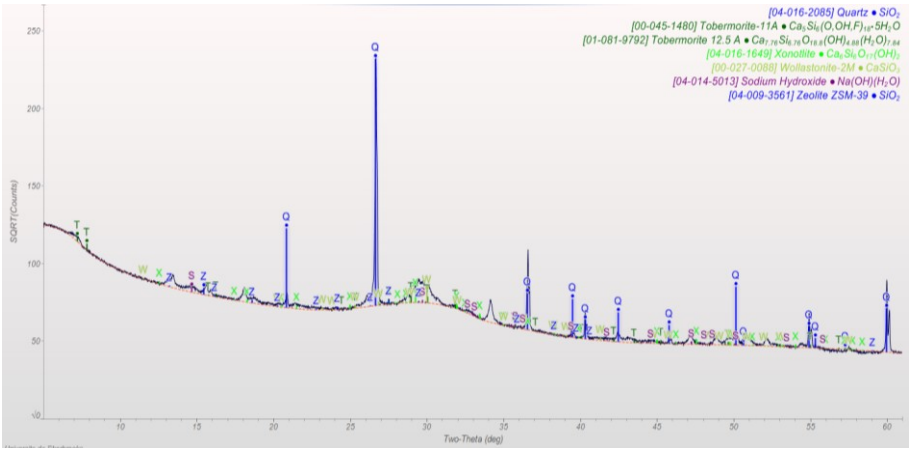


Fig. 19 a) XRD analysis of silicate brick modified by 50% Glass Sand (GS) and 50% Quartz Sand (QS).

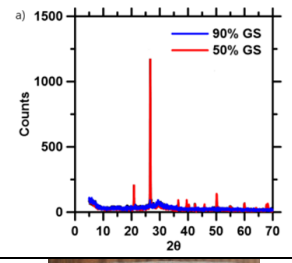




Fig. 19 b) XRD silicate bricks with GS after 24 months [34].
Fig. 19c) Brick wiht GS.

The graph Fig. 18 and 19c show the compressive strength of silicate bricks made in laboratory conditions. The strength of silicate bricks increased four times when using only glass sand compared to bricks made of quartz sand. The phase structure of a silicate brick created as a result of modifying a lime-sand mass with GS glass sand is significantly similar to the structure of a traditional brick. Sand peaks are visible in the figure - especially quartz, the tobermorite phase and a visible elevation of the background of amorphous phases (Fig. 19a,b).

The durability of reinforced concrete and monolithic structures is influenced by the negative effects of external environmental conditions, and in Polish conditions the structures are exposed to high and low temperatures (+30 to -15ºC). The result of weather anomalies is, for example, corrosion. Instead of standardly preventing undesirable effects, composite materials can be used as an alternative solution. Composite rods are increasingly used in construction. The composite rod consists of fibers (glass, carbon, basalt, aramid) and resin-based polymers. The properties of reinforcing bars are obtained thanks to the very good quality of composite materials and the production technology. They are characterized by: High corrosion resistance, resistance to chemical effects, no electrical conductivity, low thermal conductivity, long service life, weight [29-31]. Nowadays, the use of composite bars as reinforcing bars can be found in every field of construction, and in housing construction as substitute reinforcement. Elements that can be made of reinforcing bar are: foundations, walls, ring beams, ceilings, floors or as repair elements of reinforced concrete structures[32,36].

Table. 1. Selection of reinforcement - steel bar - composite bar [32]

REINFORCEMENT SELECTION TABLE BASED ON DIAMETER					
REINFORCEMENT STEEL BARS			COMPOSITE REINFORCEMENT BARS		
Diameter [mm]	Mass [kg/mb]	Length W 1T (mb)	Diameter [mm]	Mass [kg/mb]	Length W 1T (mb)
6	0.22	4545	4	0.02	50000
8	0.40	2530	6	0.06	16667
10	0.62	1613	7	0.08	12500
12	0.89	1126	8	0.10	10000
14	1.21	826	10	0.16	6250
16	1.58	633	12	0.22	4545
18	2.00	500	14	0.31	3225
20	2.47	405	16	0.40	2500

Based on the table Tab.1 of the appropriate selection of composite bars corresponding to steel bars and the prices of materials for the first quarter of 2023, using a price comparator [33], the average price of each material was estimated, and the results of the analysis were presented in the form of a radar chart in Fig.19.

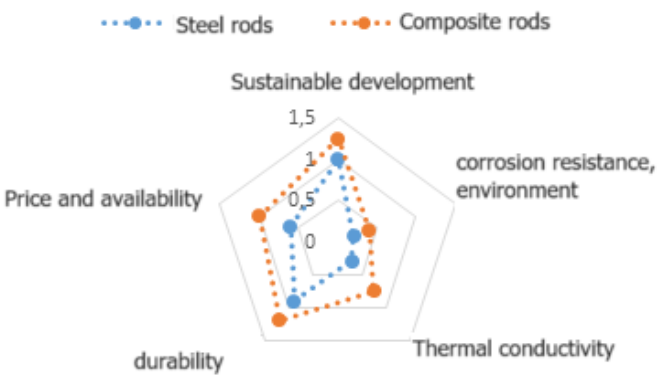


Fig. 19. Comparative analysis of the use of steel bars and composite bars [37].

The drawings Fig. 19 clearly show that the composite rod, both as a material and its solution, has higher properties than a steel rod. Both the steel and the composite bar are influenced by input factors such as quality, steel class, and properties of the given solutions.

CONCLUSION & DISCUSSION

The analysis of the share of glass components in the form of recycled glass sand on the process of binder hydration, autoclaving and crystallization of amorphous phases in silicate bricks modified with recycled glass sand showed:

- Improvement of functional properties (compressive strength more than 15MPa-standard silicate bricks have a strength of 15MPa and this class of bricks is aimed at during modifications).

The technical and economic analysis performed for steel and composite bars showed that composite bars can be used in the construction of ceilings, having slightly lower structural strength, extending the life of the ceiling due to the lack of corrosion, and reducing operating costs and limiting the use of natural resources.

Moreover, the analysis performed for monolithic ceilings indicated a positive solution for modern ceilings using composite bars as a replacement for the traditional monolithic ceiling with steel reinforcement. Each solution was subjected to the same evaluation criteria, which are important for the operation of ceilings. The technology of making traditional ceilings using steel rods is currently a common solution in single-family construction. However, due to constant changes in the economy around the world and the lack of availability of the raw material steel, a composite bar is the best solution as reinforcement. At the same time, composite bars fit into the criteria of sustainable construction. Composite elements or in the form of composite reinforcement are also used in other technologies, such as a vinyl sheet pile wall, which fits in with sustainable construction and in situations where it is not possible to use a traditional steel sheet pile wall, composite elements/vinyl profiles are used. Sheet piles are used in: retaining structures, where the wall holds the topsoil, damming structures, where the sheet pile wall is a diaphragm preventing water penetration, urban buildings, where the sheet pile wall is an important retaining element preventing soil from being washed out from under the foundation, structures fulfilling protective functions, e.g. breakwaters, bridge abutment structures, temporary structures used as elements of other work technologies, e.g. tunnel drilling[1, 35, 37].

REFERENCES

[1] W.Żenczykowski Budownictwo ogólne, Arkady 1981.

[2] Prawo budowlane. Warunki techniczne i inne akty prawne. Przepsiy. Wolters Kluwer 2023r.

[3] E.Szymański Materiałoznawstwo budowlane, Warszawa 1997.

[4] *https://izosystems.pl/content/18-warunki-techniczne-WT-2021-dla-przegrod-budowlanych*

[5] CEN. PN-EN 772-13: 2001

[6] CEN. PN-EN 1996-2

[7] CEN. PN-EN 771-2

[8] CEN. PN-EN 1936: 2010

[9] A.Stepien Recycling in Building Materials: Analysis of the Possibilities and Results of Using Recycled Glass Sand in Autoclaved Materials. ENERGIES 2023, 16(8), 3529, pp. 1-29.

[10] *https://www.domywstylu.pl/blog/2014/01/31/nowe-warunki-techniczne/*

[11] *https://ceo.com.pl/20-mniej-pozwolen-na-budowe-w-i-polroczu-2022-r-34213.*

[12] *https://www.eea.europa.eu/data-and-maps/figures/global-total-material-use-by*

[13]*https://www.thenationalnews.com/uae/environment/global-sand-demand-unprecedented-extraction-rates-could-lead-to-shortage-1.867437*

[14] L.Misiewicz Rynek materiałów budowlanych do wznoszenia ścian w Polce w 2021roku, Materiały Budowlane 4/2022.

[15] P.Markiewicz Vademecum projektanta prezentacja nowoczesnych technologii budowlanych, Kraków 2004.

[16] Ewa Osiecka Materiały budowlane, Warszawa 2010.

[17] M.Kowalik Nowoczesne technologie robót budowlanych w budownictwie jednorodzinnym, Tarnów 2008.

[18]T.Rybarczyk, J.Chojnowski, R.Janik, Ł.Sęk, P.Wójtowicz Zeszyt techniczny SPB, SBN 978-83-946388-1-8.

[19] http://www.recykling.pl/recykling/index.php/technologia/27

[20] A.Kuśnierz Recykling szkła,
www_bg_utp_edu_plartpicimb20nr2062010picimb6kusnierz22.pdf

[21] https://www.swiat-szkla.pl/kontakt/948-technologiczne-aspekty-produkcji-szkla.html

[22]*https://budujemydom.pl/stan-surowy/sciany-i-stropy/a/2054-rodzaje-stropow-wady-i-zalety-oraz-koszty-wykonania*

[23] Stal zbrojeniowa, *budujdom.pl, http://www.ogrzejdom.home.pl/stal.pdf*

[24]K. Pawłowski, „Projektowanie przegród poziomych w budownictwie energooszczędnym. Obliczenia cieplno¬ wilgotnościowe przegród stykających się z gruntem, stropów oraz dachów i stropodachów w świetle obowiązujących przepisów prawnych”, Grupa Medium, Warszawa 2018

[25] Zhang S, Zhang H, Liu H, et al. Resonance enhanced magnetoelastic method with high sensitivity for steel stress measurement[J]. 584 Measurement. 2021, 186: 110139.

[26]Abdel-Jaber H, Glisic B. Monitoring of prestressing forces in prestressed concrete structures—An overview[J]. Structural Control 535 and Health Monitoring. 2019, 26(8): e2374. /10.1002/stc.2374

[27] Cappello C, Zonta D, Laasri H A, et al. Calibration of Elasto-Magnetic Sensors on In-Service Cable-Stayed Bridges for Stress 565 Monitoring[J]. SENSORS. 2018, 18(2): 466.

[28] Kodeks cywilny - Ustawa z dnia 23 kwietnia 1964r. (t.j. Dz. U. z 2022 r. poz. 1360, 2337, 2339, z 2023 r. poz. 326.

[29]M. Szumigała, D. Pawłowski Zastosowanie kompozytowych prętów zbrojeniowych w konstrukcjach budowlanych. Przegląd budowlany 3/2014 s. 47-50.

[30] *https://plgbc.org.pl/zrownowazone-budownictwo/definicja/*

[31] Zhong X G, Zhang T Y, Zhao C, et al. New non-destructive dynamic tensile testing of prestressing fine-rolled screw-threaded 550 steel bars[J]. ENGINEERING STRUCTURES. 2019, 182: 153-163.

[32] *https://kompozytowe.pl/prety-kompozytowe/*

[33] *www.pretyzkompozytow.pl/porownywarka-cen.html*

[34] Anna Stepien (autor korespondencyjny) , Jerzy Z. Piotrowski Thermal insulation of autoclaved materials JOURNAL OF PHYSICS: CONFERENCE SERIES (OPIScience) J. Phys.: Conf. Ser. 2069 012037, Vol. 2069, 2021.

[35] *https://www.jsjlcmetal.com/products/sheet_pile/steel_sheet_pile.html?gclid=Cj0KCQiA4NWrBhD-ARIsAFCKwWtwDyjKfAGui1b_S5vyCs9gj7wXBAtG2U6wJazUko87Mo0omNPQXV4aAjN3EALw_wcB*

[36] Use of FRP Composites in Civil Engineering, Wydział Inżynierii Lądowej, Politechnika Warszawska.

[37] P.Wojarska Project of a single-family house, MSc Thesis, Kielce University of Technology 2023.

RESEARCH REGARDING THE USE OF EGGSHELLS POWDER FOR SOILS REHABILITATION CONTAMINATED WITH Cd AND Pb

Lecturer PhD Antoanela Cozma[1*]
Lecturer PhD Maria Rada[2]
Assoc. Prof. Dr. Ariana Velciov[1]
Lecturer PhD Casiana Mihut[1]
Lecturer PhD Anisoara Duma Copcea[1]

[1] University of Life Sciences "King Michael I" from Timisoara, **Romania**
[2] University of Medicine and Pharmacy "Victor Babes " from Timisoara, **Romania**

ABSTRACT

Eggshells are one of the widely used by-products in the food processing and manufacturing industries. Due to the increased content of minerals, especially calcium and magnesium and less trace elements (iron, zinc, manganese, copper), chicken eggshell waste can be used in many agricultural activities as a mineral fertilizer, as an additive for improving the physical parameters of the soil, or reducing the accessibility of lead and cadmium from soils polluted with heavy metals, as a substitute for natural calcium carbonate or as a nutritional improver in animal feed. The purpose of this paper was to characterize the eggshell waste resulting from household activities of food preparation and their use for the regeneration of the acid soils contaminated with heavy metals. The objectives of this study was to evaluate the effectiveness of eggshells as a material for blocking lead and cadmium in acidic soils contaminated with heavy metals. The use of eggshells in agricultural soil rehabilitation activities contributes both to increasing soil fertility and can also be an effective way of neutralize eggshell waste from agro-industrial activities. It can be also said that chicken eggshell powder can be recommended both as an organic fertilizer, which increases the mineral intake of plants, and as a soil stabilizer, improving plant health.

Keywords: eggshell powder, microelement, agricultural fertilizer, eggshell waste

INTRODUCTION

Soil contamination with heavy metals has become an extensive problem both for human health and for the environmental pollution. Due to the potential major risk, contamination of the agricultural soil is worldwide, one of the significant environmental pollution issues [1,3]. The presence of heavy metals in soil is a result of two processes: the genetic inheritance from the parental rocks and materials on which the soils formed and evolved (geogenic origin) and the anthropogenic impact caused by agricultural and industrial technologies (anthropogenic origin).

* Corresponding author: antoanelacozma@yahoo.com , cozma@usvt.ro

The anthropogenic impact on the soil produced by mineral fertilizers, pesticides, amendments, zoo-technical residues, sludge and waste water, traffic, garbage incineration brings significant amounts of heavy metals into the soil [5,9]. In the terrestrial food chain, plants take up the most important amount of heavy metals, including Pb and Cd, directly from the soil or indirectly, from other technological activities. Once reaches in the soil, lead and cadmium can be a source of groundwater contamination being accumulated by absorption in plant tissues, directly affecting human health. The potential toxicity of heavy metals in soil depending on their mobility and also their bioavailability [1,3,5].

To avoid the risk of exposure to Pb and Cd, several remediation techniques were used, including soil washing, stabilization/solidification, electrokinetic bioremediation. Reducing heavy metals mobility and bioavailability in soil through the addition of exogenous materials represents one of the technologies for the remediation of contaminated soils. Use of these techniques for the agricultural soils requires consideration not only of reducing the mobility of heavy metals, but also avoiding unfavorable effects on soil fertility and plant growth. Nowadays, the use of agricultural residues is a priority for the development of sustainable agriculture. The use of eggshells in agricultural soil rehabilitation activities contributes both to the increasing soil fertility and can also be an effective way of neutralize eggshell waste from agro-industrial activities [2,5,7]. Eggshells resulting as waste from agro-industrial activities still contain significant amounts of valuable compounds that can be used in agricultural activities such as: natural fertilizer or soil amendment, as a supplement in animal feed, as well as for the rehabilitation of soils contaminated with heavy metals. In recent years, great efforts have been made to transform eggshell waste into a valuable product. Eggshells are one of the widely used by-products in the food processing industry. Most eggshell waste is currently accumulated on site without any pre-treatment [16].

To minimize environmental problems, eggshell waste residues must be efficiently managed through recycling and reuse, turning them into a valuable product. Eggshells are waste materials produced in huge amount by poultry industry houses, restaurants and the domestic activities of food preparation [5, 6]. Especially, the increased content of calcium and the alkaline pH of eggshells recommend the use of this undervalued waste for the immobilization of some heavy metals in the soils polluted with such metals with toxic properties and/or the reduction of the acid reaction of these soils. The major components of the eggshell are calcium carbonate (98.2%), magnesium (0.9%) and phosphorus (0.9%), while the major components of the eggshell membrane are proteins (69.2%), fats (2.7%), moisture (1.5%). %) and ash (27.2%) with collagen as the main protein. Chemically, chicken eggshell is composed of water (2%), solid material (98%), protein (5%) and ash (93%) [10].

Eggshell powder is a highly concentrated source of minerals, containing over 94% ash content. In addition to calcium, eggshell powder also contains important amounts of magnesium and smaller but appreciable amounts of other mineral elements, including iron, zinc, copper, manganese, sulfur, silicon [4, 5]. Eggshell waste can be processed into more useful products, such as: natural fertilizers and amendments in agriculture and animal feed, mineral additives in the food industry, medicines as calcium supplements, and composite or construction materials etc. [5, 11, 14, 15].

The aim of this study is to characterize the eggshell powder obtained from eggshells of free laying hens, resulting from domestic food preparation activities, and its use for the regeneration of acidic soils contaminated with heavy metals. The results show that the eggshell powder experimentally obtained has a high content of minerals (95.12% ash), especially calcium (36.99% Ca, respectively 92.47% CaCO3), extremely low amounts of Pb and Cd (<0.05 ppm) and a pH value equal to 8.45. These values recommend the use of eggshell powder for blocking Pb and Cd in soils contaminated with such heavy metals. Under the present conditions, the treatment of soil contaminated with Pb and Cd, with eggshell powder, in proportions of 100:1, respectively 100:5 (mass ratio soil: eggshell) produces the fixation of significant amounts of heavy metals in soil: 2.3 - 7.4 mg Pb, respectively 0.43 - 0.84 mg Cd. In addition, the use of eggshell powder has the effect of increasing the soils pH with an acidic reaction, unsuitable for crops.

MATERIALS AND METHODS

Preparation of the soil sample artificially contaminated with lead and cadmium

To evaluate the immobilization degree of lead and cadmium, in soils contaminated with heavy metals it was proceeded to the artificial contamination of a soil with a moderately acid reaction (pH=5.55) and low contents of lead and cadmium (28.7 ppm Pb, 2.57 ppm Cd – total forms, respectively 12.36 ppm Pb and 0.64 ppm Cd- mobile forms) collected from Banat (Romania). This soil, previously dried and ground, was enriched with Pb and Cd, by mixing it with an aqueous solution with a content of 150 mg Pb2+ and 10.0 mg Cd2+, according to Ashrafi and colaborators [3]. Because the toxicity of Pb and Cd is conditioned not only by their total concentrations, but also by their mobility, the extraction of Cd and Pb from the contaminated soil was carried out in the solution of EDTA 0.01 M - ammonium acetate 1N (pH = 7).

Eggshell powder preparation

The dried eggshell powder (ESP) required to immobilize lead and cadmium in contaminated soil was obtained from eggshell attained from free backyard laying hens. Obtaining of the eggshell powder was carried out in the discipline's laboratory following a protocol recommended by Platon and colaborators [13].

Determination of pH

The soil pH was determined in accordance with the SR ISO 10390:1999 standard. The reaction of the soil was determined by measuring the pH of the aqueous soil suspension in a mass ratio, soil: water 1:2.5 using Mettler Toledo type pH meter equipped with combined electrode. To calibrate the device, buffer solutions with pH between 4 and 9 were used. The pH of the eggshell powder was carried out under the same conditions as for the soil samples.

Determination of total concentrations of Pb and Cd

Total concentrations of Pb and Cd were determined by the extraction method in royal water according to ISO 11466/1999 using the Varian 280 FS Atomic Absorption Spectrophotometer [18].

Determination of the mobile forms of lead and cadmium

The concentration of the mobile forms of Pb and Cd were determined using as an extractant the EDTA-ammonium acetate solution with a pH = 7.0 according to the

method recommended by Lăcătusu et al, adapted to the specific working conditions also used by Gogoașa [9,12].

Determination of the eggshells powder mineral concentration

The determination of the mineral concentration of the eggshells powder was made by atomic absorption spectrometry, after the calcination method, at 550 °C, followed by ash solubilization in 0.5 N nitric acid and measuring the elements absorbance in the solution using the Varian 280 FS Spectrometer [7].

Reagents and Apparatus

-Merck nitric acid, 65% (ρ = 1.39 g/cm3) essential to prepare the 0.5 N HNO_3
-Multi-element standard solution (1g/L) Merck - Germany, used to prepare working standards for Ca, Mg, Fe. Mn, Zn and Cu; distilled water.
-Nabertherm, thermo-adjustable calcination furnace type 6/11
-Atomic absorption spectrophotometer in air-acetylene flame, Varian 280 FS
- pH-meter type – Mettler Toledo

RESULTS AND DISCUSSION

The pH values of the contaminated soil and the eggshells powder prepared under the experimental conditions (8.50, respectively 8.45) shows that the contaminated soil has a moderately acidic reaction, and the eggshell powder has an alkaline reaction.

Total concentrations of Pb and Cd in artificially contaminated soil

The total concentrations of lead and cadmium determined in the artificially contaminated soil are shown in Table 1.

Table 1. The concentration of Pb and Cd in dried contaminated soil

Specification	Concentration, ppm	
	Pb	Cd
Total forms, in royal water	164	12.6
Mobile forms, in EDTA - ammonium acetate	32.1	2.85

As can be seen from table 1, the artificially contaminated soil sample contains amounts of Pb and Cd (164 ppm Pb, respectively 12.6 ppm Cd) which are above the intervention level provided by the legislation: 100 ppm Pb, respectiv 5 ppm Cd [19]. Therefore, from the point of view of the content of Pb and Cd, this soil does not belong to the category of soils intended for plant cultivation.
The results obtained by determining the accessible concentrations of Pb and Cd, extracted in EDTA - ammonium acetate (table 1) shows that the concentrations of the mobile forms of Pb and Cd (32.1 ppm Pb and 2.85 ppm Cd) are above the accepted toxicity limits: 18 ppm Pb, respectively 1.0 ppm Cd [12].

Mineral characterization of eggshell powder

The mineral concentration of the chicken eggshell powder experimentally obtained are presented in table 2.

Table 2. Mineral concentration of the eggshell powder

Specification	Values	Specification	Values
Ash,%	95.12	Mn, mg/kg	8.14
Na, mg/kg	438	Zn, mg/kg	5.87
K, mg/kg	462	Cu, mg/kg	3.11
Ca, mg/kg	369.870	Pb, mg/kg	<0, 05
$CaCO_3$, %	92.47	Cd, mg/kg	<0, 05
Mg, mg/kg	83.2		
Fe,mg/kg	87.6	-	-

As can be seen from Table 2, the chicken eggshell powder (ESP) prepared under the conditions of this experiment has an alkaline pH (pH=8.45) and an increased mineral content (95.12% ash). Among the analyzed mineral elements, calcium predominates, which was determined in a concentration of 369,870 mg/kg (36.90%). Given the fact that in the eggshell, calcium is found in the form of carbonate it can be affirmed that the eggshell powder analyzed has a content of 92.47% CaCO3. Calcium carbonate has a porous structure which makes the eggshells semi-permeable to air and moisture. In addition, significant amounts of essential mineral bio-elements have been also identified in the eggshell, essential for the growth and development of crop plants.

The concentration of the mobile forms of Pb and Cd in the soils treated with eggshell powder

Evaluation of lead and cadmium fixation capacity from the contaminated soil was made for soils with 1%, respectively 5% eggshell powder. Choosing the percentage levels of eggshell powder added to the contaminated soil was done taking into account the recommendations of Yong Sik Ok and collaborators [17]. The total content of Pb and Cd cannot provide enough information about their different forms, mobility, bioavailability or potential risks regarding their translocation in plants [1]. The mobility and bioavailability of accessible trace metals depend on their specific chemical forms or of the binding behavior to each soil phase. The results obtained for the determination of Pb and Cd concentrations, in EDTA extract - ammonium acetate, from the soil contaminated with the addition of eggshell powder are presented in table 3.

Table 3. Concentrations of Pb and Cd mobile forms in soils treated with 1 and 5% ESP

Specification	Concentration	
	Pb	Cd
Untreated soil (control)	32.1	2.85
Soil with 1% eggshell	29.8	2.42
Soil with 5% eggshell	24.7	2.01

As can be seen from table 3, the mobile concentrations of Pb and Cd determined from the soil with the addition of ESP show lower values compared to the untreated soil (control) which differ according to the amount of eggshell powder applied and the

nature of the heavy metal. So, it can be noted that the eggshell powder led to the blocking in the soil of significant amounts of Pb and Cd.
The highest amounts of Pb and Cd fixed in the contaminated soil are recorded in case of using a percentage of 5% eggshell (7.4 mg Pb, respectively 0.84 mg Cd). Lower amounts of Pb and Cd were fixed in case of using a percentage of 1% eggshell (2.3 mg Pb and 0.43 mg Cd, respectively). Comparing the amounts of Pb and Cd extracted from the soil with those blocked in the contaminated soil, for the same percentage of ESP, it can be seen that the lowest values are recorded in the case of Pb. Therefore, the method used is more efficient for the immobilization of cadmium. The results obtained under the conditions of the present experiment shows that eggshell waste can be used as an alternative to CaCO3 use for immobilization of heavy metals in soil. According to a study made by Yong Sik Ok the extractability of metals from soil always decreased in response to CaCO3 and eggshell treatments, regardless of extractant [17].
Under these conditions, it will grow the amount of heavy metals locked in the contaminated soil. Remediation of acid soils contaminated with lead and cadmium with ESP obtained from household waste or activities of the agro-food industry contribute to the efficient solution of environmental problems related to waste management.
In addition, the use of eggshells can replace a good part of the amount of lime used for soil rehabilitation, industrially obtained product with high energy costs and the release of high amounts of carbon dioxide into the atmosphere. By using eggshell powder as a fertilizer or for the rehabilitation of polluted soils (correction of the soil reaction, fixation of heavy metals in the soil, etc.) additional analyzes are necessary. In order to calculate the amount of eggshell powder required to rehabilitate a certain area of contaminated soil, other physico-chemical characteristics of the soil must be determined: electrical conductivity, cation exchange capacity, organic matter content, etc., as well as physico-chemical parameters of eggshell powder obtained from eggshell waste.

CONCLUSION

The eggshell powder prepared in the conditions of this experiment has an alkaline reaction, (pH=8.45) and a high content of mineral substances (95.12% ash). Among the analyzed mineral elements, calcium predominates, determined in concentration of 36.90% Ca respectively 92.47% CaCO3. These values recommend the use of eggshell powder for blocking Pb and Cd in acid soils contaminated with such heavy metals.

Under the present conditions, the treatment of soil contaminated with Pb and Cd, with eggshell powder, in proportions of 100:1, respectively 100:5 (mass ratio soil: eggshell) produces the fixation of significant amounts of heavy metals in soil: 2.3 - 7.4 mg Pb, respectively 0.43 - 0.84 mg Cd. In addition, the use of eggshell powder has the effect of increasing the soils pH with an acidic reaction, unsuitable for crops.

The obtained results recommend the use of eggshell powder for the fixation of Pb and Cd in acid soils contaminated with heavy metals. In addition, the superior valorization of eggshell waste for the purpose of agricultural soil rehabilitation, contributes both to increasing the soil fertility and to reducing the consumption of calcium carbonate (used as an amendment) and it can also be an efficient way of liquidating eggshell waste from agro-industrial activities.

ACKNOWLEDGEMENTS

This research paper is supported by the project Institutional Development Fund (FDI), domain 6, by National Council for the Financing of Higher Education (CNFIS), CNFIS-FDI-2023-F-0307

REFERENCES

[1] Ahmed S. A. Asmoay, Salman A. Salman, Amr M. El-Gohary and Hassan S. Sabet, Evaluation of heavy metal mobility in contaminated soils between Abu Qurqas and Dyer Mawas Area, El Minya Governorate, Upper Egypt, Bulletin of the National Research Centre 43:88 https://doi.org/10.1186/s42269-019-0133-7 , 2019

[2] Al Seadi T., Holm-Nielsen J.B.: III. 2 Agricultural wastes. Waste Management Series, 4: 207–215, 2004

[3] Ashrafi, M., Sharifah, M., Ismail, Y., Fauziah, S.H., Immobilization of Pb, Cd, and Zn in a contaminated soil using eggshell and banana stem amendments: metal leachability and a sequential extraction study. Environ. Sci. Pollut. Res. 22, 223–230. https://doi. org/10.1007/s11356-014-3299-4, 2015

[4] Arif S., I. Pasha, H. Iftikhar, F. Mehak, Sultana R., Effects of eggshell powder supplementation on nutritional and sensory attributes of biscuits, Czech Journal of Food Sciences, Vol.40, (1): 26–32, 2022

[5] Burezq H. A, Utilization of Eggshell as Valuable Products for Sustainable Ecosystem and Agriculture (Review), Poultry Science Journal 9(2): 147-165, 2021

[6] Chakraborty S., Santa Datta (De), Eggshell: An alternative, cheap, bioavailable source of calcium in human diet, RRJoDST (2019) 25-33 © STM Journals, 2019

[7] Cozma Antoanela, Velciov Ariana, Iasmina Anghel, Bogdan Cozma, Vlad Marazan, 2023, Development of chicken eggshells powder as agricultural fertilizer and soil conditioner, Actual tasks on Agricultural Engineering, ATAE Croatia, Expert Paper- in press, 2023

[8] Gogoasa I., 2005, Research on the pollution (contamination) with heavy metals of some vegetables and fruits from the western area of Romania, PhD thesis, University of Agricultural Sciences and Veterinary Medicine of Banat, Timișoara

[9] Gogoasa, I., Oprea, G., Gergen, I., Alexa, E., Cozma, A., Bordean, D., Moigrădean, D., Alda L., Researches regarding the soil contamination with heavy metals in the Banat mountains, Journal of Agroalimentary Processes and Technologies, 15(1), 172-176, 2009

[10] Khan F.A, Ameer K., Qaiser M.A., Pasha I., Mahmood Q., ANJUM F.M., Riaz A., Amir R M., Development and analysis of bread fortified with calcium extracted from chicken eggshells of Pakistani market, Food Science and Technology, Campinas, 41(Suppl. 1): 14-20, 2021.

[11] Laohavisuti N., Boonchom B., Wimonmat B., Kittichai Chaiseeda K. & Seesanong S., Simple recycling of biowaste eggshells to various calcium phosphates for specific industries, Sci Rep 11, 15143, 2021

[12] Lăcătuşu R., Răuţă C., Dumitru M., Avram N., Medrea N., Cârstea S., Kovacsovics B., Lungu M., Serdaru M., 1996, Pb flow in soil-water-animal system within the Baia Mare polluted area, In: Proceedings of the 7th International Trace Element Symposium, Budapest, 11-20

[13] Platon Nicoleta, Vasilica-Alisa Arus, Ana-Maria Georgescu, Ileana Denisa Nistor, Narcis Barsan, White bread fortified with calcium from eggshell powder, Rev. Chim., 71(7): 299-306 Revista de Chimie, https://doi.org/10.37358/Rev. Chim.1949 , 2020

[14] Radhika Y, Sriram M & Aarti T. (2020). Egg shell powder as an unusual food ingredient for calcium fortification, Food and Agriculture Spectrum Journal. 1: 3.

[15] Schaafsma A., Pakan I., Hofstede G.J.H., Muskiet F.A.J., Van Der Veer E., De Vries P.J.F., Mineral, Amino Acid, and Hormonal Composition of Chicken Eggshell Powder and the Evaluation of Its Use in Human Nutrition. Poult. Sci., 79, 1833–1838, 2000

[16] Tsai W.T., Hsien K.J., Hsu H.C., Lin C.M., Lin K.Y., Chiu C.H. (2008a): Utilization of ground eggshell waste as an adsorbent for the removal of dyes from aqueous solution. Bioresource Technology, 99: 1623–1629

[17] Yong Sik Ok, Sang Soo Lee, Weon-Tai Jeon, Sang-Eun Oh, Adel R.A. Usman, Deok Hyun Moon, Application of eggshell waste for the immobilization, of cadmium and lead in a contaminated soil, Environ Geochem Health 33:31–39. DOI 10.1007/s10653-010-9362-2; 2011

[18] ***Calitatea solului. Extracţia microelementelor solubile în apă regală. SR ISO 11466:1999

[19] *** Valori de referinţă pentru urme de elemente chimice în sol. Ordin al MAPPM nr. 756, 1997

STRATEGIES FOR MINIMIZING PAPER USAGE IN LATVIA MUNICIPALITIES

PhD Lilita Ābele[1,2]

Prof. Dr. Baiba Rivza[2]

Dr. habil. sc. ing. Peteris Rivza[2]

Dr. oec., Elita Jermolajeva[2]

[1] Liepaja University, Circular Economy Center, **Latvia**
[2] Latvia University of Life Sciences and Technologies, **Latvia**

ABSTRACT

Statistical data, as well as public reports and comments from industry experts, show that the transition of local governments to the digitisation of internal processes has several challenges, mainly related to ensuring sustainability, reducing the impact on the environment, data security, and technical maintenance [2,3]. Therefore, it is essential to assess the situation in local governments and choose the most appropriate support system for Latvia's situation, which would not only be financial support. In public and expert discussions, different visions of the necessary support tools and benefits from the transition of local governments to the digitalisation of internal processes appear. One of the main benefits is reducing paper, which diminishes recycling and resource consumption [5, 6, 11]. The readiness of local government employees for the transition to digitalisation of internal processes has already been written about in previous studies. This study developed four possible scenarios for supporting municipalities in the transition process, and a group of seven experts was selected for their evaluation. The expert survey was conducted in June and July 2023. Five factors influencing the transition were offered for expert evaluation: Technical infrastructure, social-psychological aspects, legal, security and data protection elements, financial resources, sustainability, and environmental factors. For each group of factors, three factors were suggested to be ranked in order of importance. Then, using the four previously developed support scenarios, the most suitable one was searched using the multi-criteria decision-making method, the Analytic Hierarchy Process (AHP).

The research uses expert surveys, analytical hierarchy process analysis, and statistical data processing methods. As a result of the study, the most suitable support scenario for Latvian municipalities was determined, moving to the digitisation of internal management processes and reducing paper consumption.

Keywords: paper reduction, digitisation, support scenarios

INTRODUCTION

Paper constitutes a significant part of solid household waste. The paradigm shift towards resource conservation and environmental sustainability emphasises reducing paper consumption [1, 10] This study examines strategies for reducing paper use in

Latvian municipalities. The study comprehensively evaluates practical approaches to reducing paper, considering the technological, socio-psychological, legal, financial and environmental dimensions. This research paper contributes to the broader discussion on sustainable resource management by emphasising the importance of reducing paper consumption in line with today's environmental demands.

MATERIALS AND METHODS

An interconnected composition is created at four levels to analyse hierarchies. At the first level, the main goal "Transition of local governments to electronic management in internal management processes" was defined. At the second level, groups of evaluation criteria are put forward - "Technical infrastructure", "Social psychological aspects", "Legal, security and data protection aspects", "Financial resources", and "Sustainability and environmental aspects". At the third level, three evaluation criteria were determined in each criteria group, totalling 15 criteria.

Technical infrastructure	Social psychological aspects	Legal, security and data protection aspects	Financial resources	Sustainability and environmental aspects
State of computers and servers, infrastructure performance	ICT skills of employees	Compliance with legislation	Technology acquisition and software update costs	Reducing the amount of paper, waste and emissions
Software and application base, sufficiency	Employee well-being and ability to adopt the latest technologies and innovations	Legal force of digital documents and signatures	Purchase of paper and toners and cost of electricity	Reduction in document processing time and transfer speed
Ability to provide data exchange and integration with other national or regional systems and platforms	Remote work options	Ensuring the confidentiality of documents and protection of personal data	Costs of organizing training	Improving data management and decision-making

Figure1 Five criteria groups and criteria

At the fourth level, four alternative or development scenarios are offered (Figure 2).

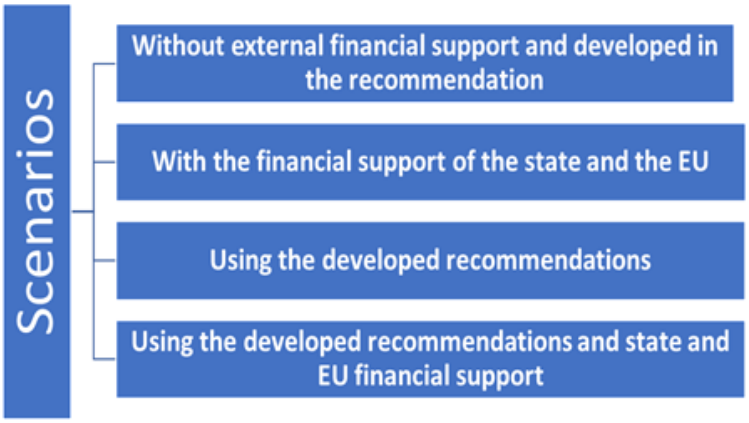


Figure 2 Municipalities are moving to paperless internal management process scenarios

A scenario dynamic matrix based on two assumptions was used to create the scenarios [12]. Inertia scenario (Scen.1), without additional funding or recommendations, and development scenarios (Scen. 2,3,4) using additional funding or/and developed recommendations.

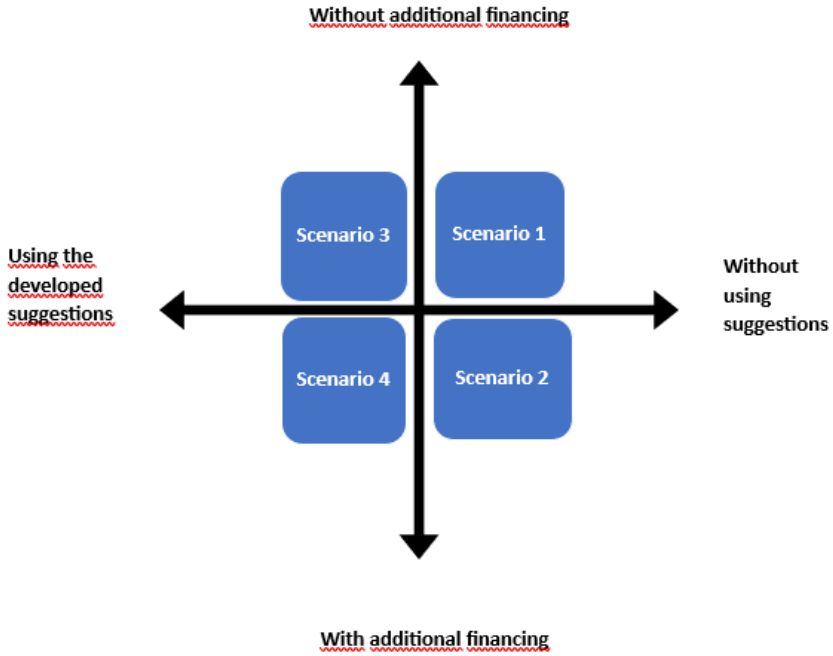


Figure 3 Development scenario modelling plane

Scenario 1 Municipalities move to paperless internal management processes without external financial support and developed in the recommendation.

Characteristics: Municipalities develop and implement electronic document management systems that help centralise and digitise the flow of documents and enable the preparation, processing, storage, and distribution of documents online, thus reducing paper use. It is encouraged and supported by the municipality's management without being influenced by external factors. The scenario describes the current situation and aims to digitise document management and promote the efficiency of internal communication.

Scenario 2 Municipalities move to paperless internal management processes with state and EU financial support.

Characteristics: Municipalities can use state and EU funds to modernise and develop IT infrastructure, which would be more challenging to implement without financial support. Financial support for less developed municipalities provides an opportunity to innovate and create new digital solutions. It helps to improve management efficiency and appeal to citizens. Financial support for the transition to paperless governance in less developed municipalities can help reduce the digital divide. There is a risk of choosing the most inappropriate financial instruments and not achieving the desired result.

Scenario 3 Municipalities move to paperless internal management processes using the developed recommendations.

Characteristics: Municipalities, before transitioning to the digitisation of internal management processes, use the best examples of municipalities included in the recommendations, reducing possible risks. The developed recommendations include sequential steps, samples of employee survey questionnaires, and calculations of potential financial benefits and risk mitigation options. The recommendations consider employees' psycho-emotional needs, such as opportunities for employees to expand their knowledge and skills by offering training and development programs. Municipalities may not need additional funding for the transition to complete digitisation of internal management processes.

Scenario 4 Local governments move to paperless internal management processes using the developed recommendations and state and EU financial support.

Characteristics: Municipalities use the developed recommendations before transitioning to complete digitisation of internal management processes. The recommendations allow one to choose the most suitable financial support instrument and its amount based on the process inventory and the employee survey results. It is possible that most of the funding should be directed towards improving employees' digital skills in a specific area. The areas are determined according to the description of the work to be performed and based on the existing knowledge and skills of the employees, which were clarified as a result of the survey.

RESULTS AND DISCUSSION

Seven experts with sufficient knowledge in municipal work, ICT, project management, environmental problem solving and legal issues were selected for HAP.
Five groups of criteria, fifteen criteria and four scenarios were offered for evaluation by seven experts. After filling the hierarchy matrices, a priority vector is calculated for each hierarchy element, indicating their importance to each higher level's criteria. Finally, all criteria subordinate to one goal must be compared. This is achieved by using a particular scale of relative importance, which allows you to convert verbal information into numbers (Table 1).

Table 1

Relative importance scale

Intensity of relative importance	Definition
1	Equal importance
3	Moderate superiority of one over the other
5	Substantial or strong superiority
7	Significant superiority
9	Extreme superiority
2,4,6,8	Intermediate values

The priority vector is obtained by computing a set of eigenvectors for each pairwise rating matrix and then normalising the result by 1. Computing the eigenvectors is relatively easy but labour-intensive.

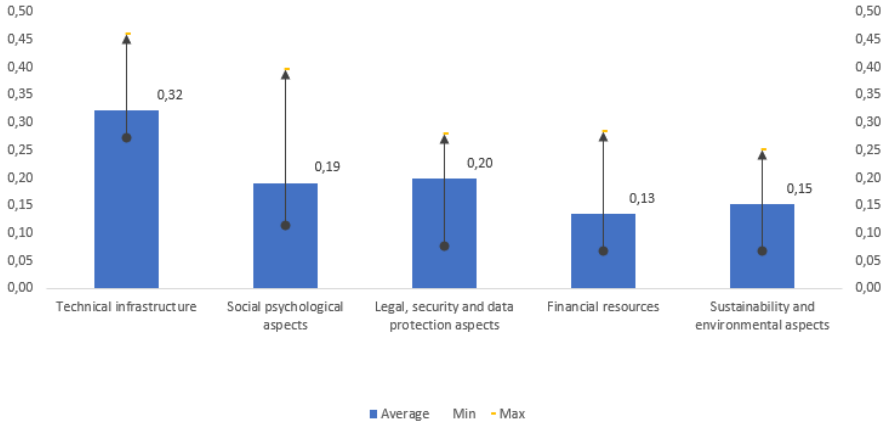


Figure 4 Comparing and evaluating groups of criteria against a main objective

Comparing the evaluation of criteria groups, it can be concluded that the highest evaluation is for Technical infrastructure (0.32), and the following assessment is Legal, security and data protection aspects (0.20) (see Fig. 4). Rating entertainment is the most significant for the Social Psychological aspect.

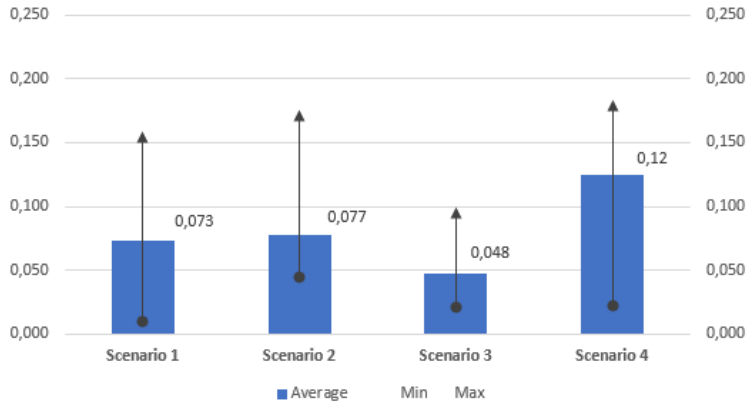
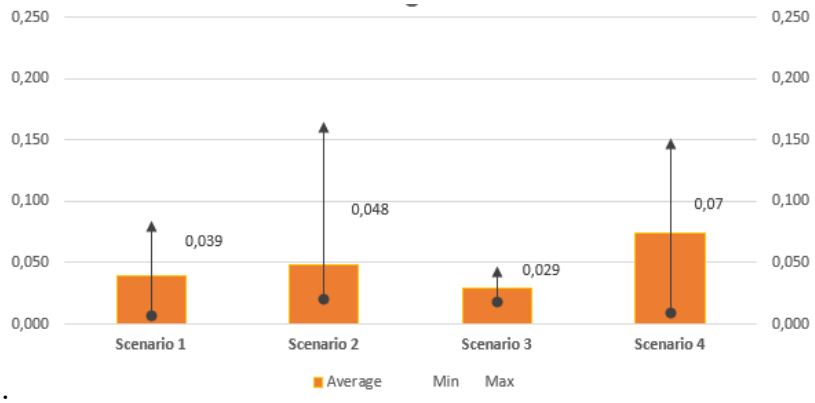


Figure 5 Comparison of technical infrastructure and scenarios

According to the evaluation of the criteria of the Technical Infrastructure Group, scenario 4 got the highest score (0.12), followed by scenarios 2 and 1 (see Fig. 5). The biggest dispersion in experts' assessments is also about the 4th scenario.



.

Figure 6 Comparison of social - psychological aspects and scenarios

According to the evaluation of Social-psychological aspects criteria, scenario 4 got the highest rating (0.07), followed by scenarios 2 and 1 (see Fig. 6). The biggest dispersion in experts' assessments is also about the 4th scenario and the 2nd scenario.

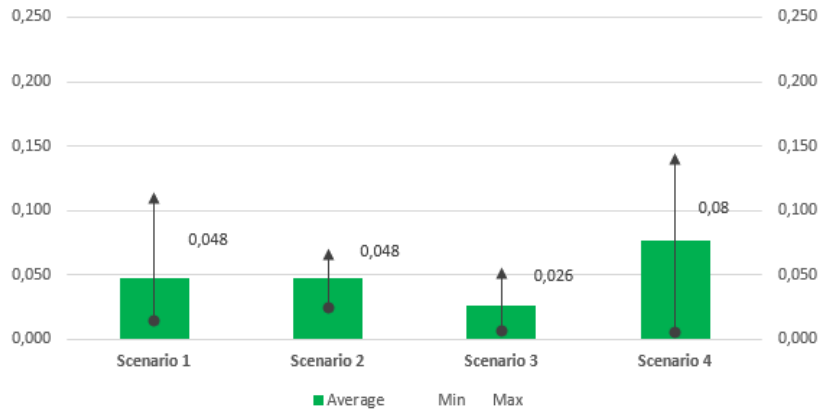


Figure 7 Comparison of legal, security and data protection aspects and scenarios

According to the evaluation of the Legal, security and data protection aspects criteria, scenario 4 (0.08) also got the highest rating, followed by scenarios 2 and 1 (see Fig. 7). The biggest dispersion in experts' assessments is also about the 4th scenario.

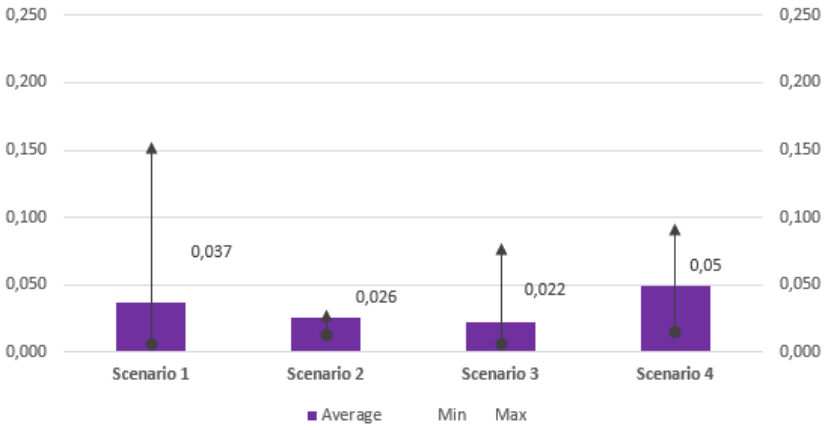


Figure 8 Comparison of financial resources and scenarios

Pēc financial resources kritēriju vērtējuma visaugstāko vērtējumu ieguva arī 4.scenārijs (0.05) tam seko 1. scenārijis (sk.8.att.). Lielākā izkliede ekspertu vērtējumos ari ir par 1.scenāriju.

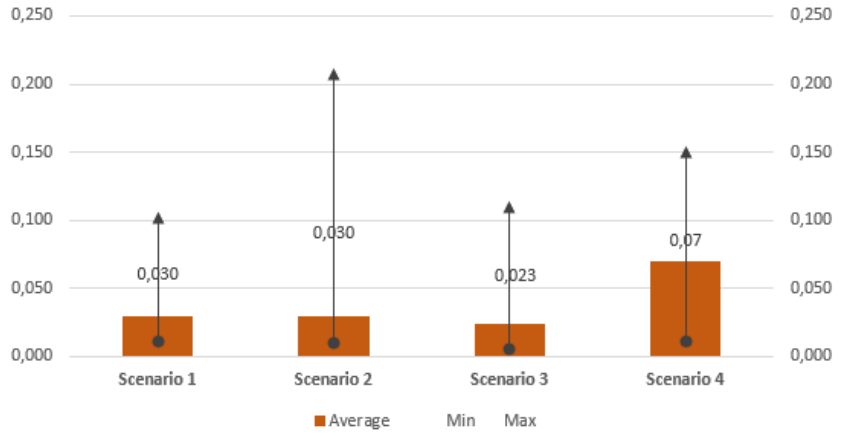


Figure 9 Comparison of sustainability, environmental aspects and scenarios

Regarding sustainability and environmental aspects, scenario 4 got the highest rating (0.07), followed by scenarios 1 and 2 (see Fig. 9). The biggest dispersion in experts' assessments is also about scenarios 2 and 4.

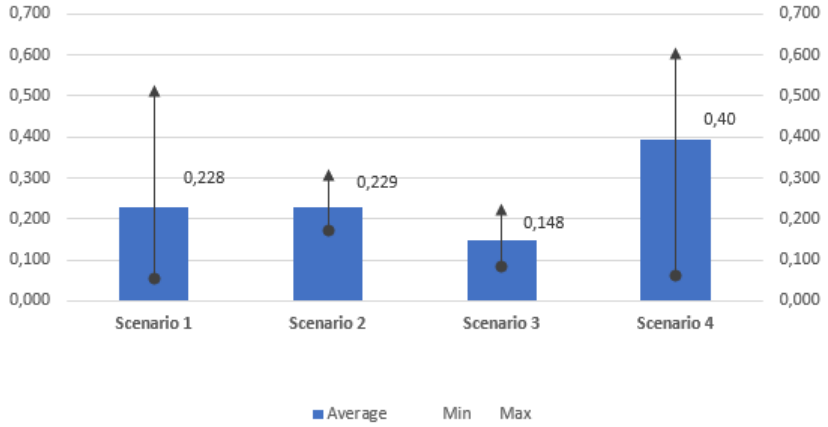


Figure 10 Comparison of criteria summary with scenarios

Finally, according to all criteria, scenario 4 got the highest rating (0.04), followed by scenarios 2 and 1 (see Fig. 10). The biggest dispersion in experts' assessments is for scenarios 2 and 4. Thus, the 4th scenario, according to the evaluation of the criteria of individual groups and, in general, according to all the criteria, has obtained the highest evaluation.

CONCLUSION

The study results show that reducing paper use is essential in municipalities and the country. A multi-criteria decision-making method is useful to search for the most suitable scenario, using the scenario dynamic matrix and the analytical hierarchy process (AHP). According to the compilation of the opinions of seven experts, the criteria of the Technical Infrastructure group have the highest weight among the five criteria groups. According to the assessment of individual groups of criteria and the assessment of all criteria, scenario 4 got the highest rating, namely - Local governments move to paperless internal management processes using the developed recommendations and state and EU financial support.

ACKNOWLEDGEMENTS

The article was written with the financial support of the Latvia University of Life Sciences and Technologies within the programme "Strengthening of Scientific Capacity" by the project Z58 «Opportunities for circular economy in Latvian municipal enterprises».

REFERENCES

[1] Abele, L., Jermolajeva, E., & Alksne, L. (2023). Assessment of knowledge and habits for planning dematerialization of municipalities. International Multidisciplinary Scientific GeoConference: SGEM, 23(5.1), 337-344.

[2] Digitālā Latvija - ārkārtējās situācijas laika izaicinājumi un iespējas, Latvijas Formula 2050, *https://www.pkc.gov.lv/lv/aktualit%C4%81tes/digitala-latvija-arkartejas-situacijas-laika-izaicinajumi-un-iespejas*.

[3] European Commisison, The European Green Deal Investment Plan and Just Transition Mechanism explained, COM(2020), https://ecommercedb.com/insights/european-ecommerce-market-worth-us-1-1-trillion-by-2026/3982

[4] Lafioune, N., Desmarest, A., Poirier, É. A., & St-Jacques, M. (2023). Digital transformation in municipalities for the planning, delivery, use and management of infrastructure assets: Strategic and organizational framework. Sustainable Futures, 6, 100119.

[5] Nesse, P. J., & Erdal, O. B. (2022, July). Smart Digitalization in Nordic Cities and Municipalities Through Internet of Things. In Economics and Finance Readings: Selected Papers from Asia-Pacific Conference on Economics & Finance, 2021 (pp. 33-55). Singapore: Springer Nature Singapore.

[6] Ringenson, T., Höjer, M., Kramers, A., & Viggedal, A. (2018). Digitalization and environmental aims in municipalities. Sustainability, 10(4), 1278.

[7] Saaty, T. L. (1977). A scaling method for priorities in hierarchical structures. Journal of mathematical psychology, 15(3), 234-281.

[8] Saaty, T. L. (2004). Decision making—the analytic hierarchy and network processes (AHP/ANP). Journal of systems science and systems engineering, 13, 1-35.

[9] Saaty, T. L., Vargas, L. G., Saaty, T. L., & Vargas, L. G. (2001). How to make a decision. Models, methods, concepts & applications of the analytic hierarchy process, 1-25.

[10] Šneiderienė, A., Viederytė, R., & Abele, L. (2020). Green growth assessment discourse on evaluation indices in the European Union. Entrepreneurship and sustainability issues, 8(2), 360-369.

[11] Župerkienė, E., Paulikas, J., & Abele, L. (2019, September). Employee behavioural patterns in resisting the implementation of organisational innovation. In Forum Scientiae Oeconomia (Vol. 7, No. 3, pp. 89-100).

[12] Van Vuuren, D. P., Kriegler, E., O'Neill, B. C., Ebi, K. L., Riahi, K., Carter, T. R., Winkler, H. (2014). A new scenario framework for climate change research: scenario matrix architecture. Climatic change, 122, 373-386.

STUDIES ON THE INFLUENCE OF ANIMAL WASTE ON SOIL FERTILITY. CASE STUDY - PIG SLURRY

PhD. Liliana Brei[1]
Dr. Adina Berbecea[1]
PhD. Doris Floares[1]
PhD. Nicoleta Vicar[1]
Prof. Dr. Isidora Radulov[1]
[1] University of Life Sciences "King Mihai I" from Timisoara, **Romania**

ABSTRACT

The use of pig slurry as fertilizer has a clear impact on farm-level energy input requirements, being a correct and natural way of its decomposition and also contributing to the reducing of the amount of chemical fertilizers used, which, in addition to the high cost, may leads to the pollution of the areas where they are applied. Swine sludge could provide between 38 and 61% of the nitrogen, phosphorus and potassium in chemical fertilizer. The purpose of the work is to determine the changes that the application of pig sludge, as a fertilizing resource, has on some soil fertility indicators, such as: pH, organic carbon content, C/N ratio and the content of nitrate and ammonium ions. The experiments in the field were carried out on a soil with low fertility, in the pedoclimatic conditions of the western part of Romania. The sludge was applied in doses between 80 and 95 mc/ha, for 4 consecutive years, resulting in acidification of the soil, an increase in the organic carbon content, but also in the content of nitrate ions in the soil. Considering both its fertilizer value and the increasing cost of chemical fertilizers, the economic value of slurry is beyond doubt.

Keywords: pig slurry, soil, nitrogen, phosphorus, potassium

INTRODUCTION

The dramatic change in global population in recent centuries, from 1 billion people in 1800 to 8 billion today, has attracted the development of large animal husbandry complexes in order to ensure food and food security. These resulted in increased manure and waste water content that stress the environment [1,2]. In the context of the circular economy and the crisis of raw materials for obtaining chemical fertilizers, the use of animal droppings as an organic fertilizing resource is encouraged [3]. Animal manure, although it has a lower content of nutrients compared to chemical fertilizers and must be applied in a higher dose, has beneficial effects on the soil through the gradual release of nutrients and the increase of the C/N ratio [4]. It must be specified, however, that the application of these wastes must be done in compliance with the legislation, in the sense that this practice does not represent a threat to the environment and human health, both in the short term and in the long term [5].

Application of pig slurry to field crops is considered an appropriate agricultural practice for maintaining and improving soil fertility status [6]. Although pig slurry is a

source of greenhouse gases and NH_3 in the atmosphere, applying the right technologies and complying with the maximum dose allowed at European level of 170 kg N·ha-1·year-1 and weather recommendations, the environmental impact is reduced [3.7]. The use of pig slurry can increase environmental pollution by releasing NH_3, N_2O and NO into the atmosphere and by leaching NO_3^-, NO_2^-, NH_4^+ into ground water and surface water [8]. If the fertilization is conducted according to the nitrogen requirement of the crops, an oversupply of P is generally produced due to the low N:P ratio, thus causing P leaching and eutrophication of waters [9]. Acidification of pig slurry represents a variant of reducing CH_4 and NH_3 emissions, because at increased pH values, the NH_4^+/NH_3 chemical balance is shifted towards the formation of NH_3, prone to volatilization [10]. Pig slurry is an important source of macronutrients (N, P, K, Ca, Mg) and micronutrients (Mn, B, Fe, Ni) and especially Cu and Zn [3].

Through their characteristics, pig slurry can improve soil properties and reduce pollution, a fact of great significance for sustainable agriculture. The effects of using these fertilizing resources consist in: increasing the level of the harvest, the content of organic matter and decreasing the acidity of the soil [11].

MATERIAL AND METHOD

The experiment was carried out over a period of 4 years (2018, 2019, 2020, 2022), in the Western area of Romania, which belongs to the Great Tisa Plain, on an entic, distric and vertic gleic alluvium, with the following characteristics for depth 0 – 20 cm.

Table 1

Characteristics of alluvial soil [12]

Parameter	Interval	Interpretation
pH	4.79 – 5.20	Weak to moderate acid
IN (nitrogen index)	0.81 – 1.13	Very poor to good supply
H(%)	1.98 – 2.84	Poor to good humus content
P mobile	10.8 – 23.6	Low to medium supply
K mobile	42 – 104	Very poor to poor supply

Pig slurry is a mixture of urine, faeces, food waste and water, with a variable chemical composition, which depends on the age of the animals, the maintenance and feeding system, the quality of the feed, the conditions and the duration of storage [9].

The physico-chemical characteristics of the pig slurry applied during the 4 years of experience are shown in table 2.

Table 2

The main chemical characteristics of pig slurry

Parameter	2018	2019	2020	2022
pH	7.53	6.87	7.39	7.66
OM (%DM)	53.70	66.14	58.23	55.65
Humidity (%)	99.44	98.76	99.29	99.44

N_{total})(%)	0.12	0.10	0.14	0.11
Mobile P_2O_5 (%)	0.08	0.069	0.0143	0.021
Mobile K_2O (%)	0.17	0.10	0.300	0.16

OM – organic matter; DM – dry matter

Pig slurry was applied in a single dose, in autumn, in the doses mentioned in table 3, on 2 experimental fields. In all 4 years, wheat was cultivated on the 2 surfaces.

Table 3

Dose of pig slurry (t/ha) applied on the 2 experimental fields and the established culture

Year	Experimental field A	Date of fertilization	Experimental field B	Date of fertilization
2018	80	October	70	October
2019	90	October	100	October
2020	85	October	100	October
2022	95	October	95	October

The amount of nutrients introduced through the doses of pig slurry applied during the 4 years of experience, at the doses mentioned above, is shown in table 4.

Table 4

The amount of nutrients contained in the doses of pig slurry applied

Year		2018	2019	2020	2022
N_{total} (kg/ha)	A	96	90	119	104.5
	B	84	100	140	104.5
Mobile P_2O_5	A	64	62.10	12.15	19.95
(kg/ha)	B	56	69	14.30	19.95
K_2O mobile	A	136	90	255	152
(kg/ha)	B	119	100	300	152
OM	A	230	730	340	290
(kg/ha)	B	200	820	410	290

In order to determine the effect on which pig slurry had on the fertility indices of the soil, in the months of November - December, soil samples were collected, according to the regulations in force. The following quality indicators were determined: pH, Ntot (%), Organic carbon, mobile P, mobile K, NO_3^-, NH_4^+.

- pH was determined by the conductometric method, using a Mettler Toledo Delta pH-meter, in aqueous extract.
- mobile phosphorus (P ppm) in ammonium lactate acetate, according to the Egner – Riehm – Domingo method and colorimetric dosage, at the wavelength λ = 715 nm, using a Cintra UV-VIS spectrophotometer;
- mobile potassium (K ppm) in ammonium lactate acetate according to the Egner – Riehm – Domingo method and dosage by atomic absorption spectrometry, at the wavelength λ = 710 nm;
- organic carbon by the Walkley Black oxidimetric method modified Gogoașa;
- total nitrogen content by the Kjeldahl method;
- nitric and ammoniacal nitrogen by the colorimetric method, at λ = 430 nm, using a Cintra spectrophotometer;
- humidity was determined by the gravimetric method.

Results and discussion:

The experimental results obtained after determining the main quality indicators of the soil, on whatthe 2 experimental fields, in the 4 years, are presented in tables 5 and 6.

Table 5

The values of soil fertility indicators on the experimental field A, determined in the 4 years of experiences

Year	Dose (t/ha)	pH	Nt (%)	OC (%)	NO_3^- (ppm)	NH_4^+ (ppm)	K_{AL} (ppm)	P_{AL} (ppm)	U (%)
2018	80	4.98	0.11	0.4	5.81	5.59	122	16.84	13.7
2019	90	5.26	0.11	0.68	47.66	22.89	255	14.26	2.85
2020	85	5.49	0.15	0.51	23.06	2.14	294	33.6	7.94
2022	95	5.45	0.15	0.84	3.77	9.03	254	9.52	12.55

Table 6

The values of soil fertility indicators on experimental field B, determined in the 4 years of experiences

Year	Dose (t/ha)	pH	Nt (%)	OC(%)	NO_3^- (ppm)	NH_4^+ (ppm)	K_{AL} (ppm)	P_{AL} (ppm)	U (%)
2018	70	5.18	0.14	0.69	9.88	3.82	113	21.8	15.59
2019	100	5.41	0.13	0.79	41.03	12.91	326	32.22	7.48
2020	100	5.66	0.18	1.62	14.15	10.64	322	41.72	8.17
2022	95	6.33	0.18	1.38	1.26	1.21	161	10.04	15

RESULTS AND DISSCUSSIONS

pH

One of the most important soil properties is pH. This is considered to be the dominant factor that directly influences other properties, such as nutrient availability and abundance [13]. All macronutrients are best available in neutral or slightly alkaline soils. The values determined for pH are in the range 4.98 ÷ 6.33. The lowest value was determined in 2018, 2 months after the application of the first dose of pig slurry, and the highest, in 2022, at the end of the experience. A slight increase in pH values is observed.

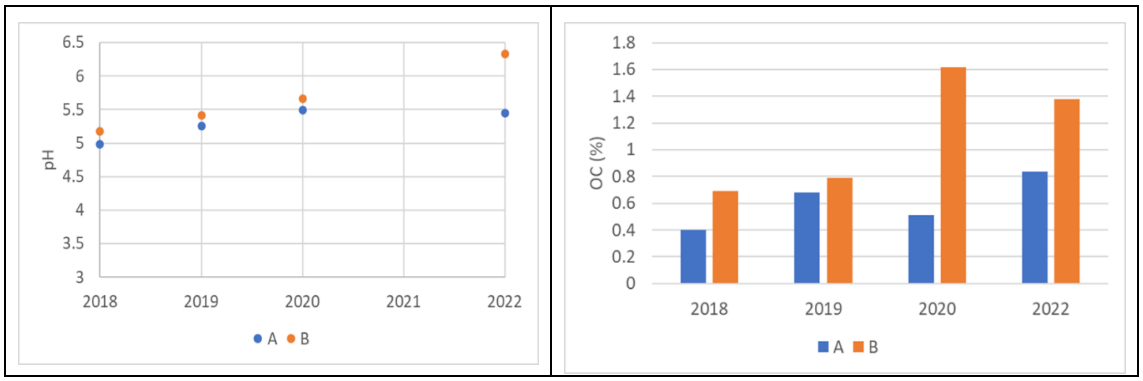


Fig.1 pH and Organic Carbon variation under the effect of pig slurry application

Organic carbon OC(%)

The determined organic carbon content is in the range 0.4 ÷ 1.62. There is an increase in the OC content in the soil, with the increase in the dose of pig slurry applied. The increase in OC content at the highest dose of manure applied is 42% higher than that determined after the application of the first dose of pig slurry.

Total nitrogen Nt(%)

A significant amount of the organic nitrogen retained in the soil after the application of pig slurry derives from the immobilization of N-NH_4^+, but already a few months after the application the immobilized nitrogen is stabilized and released slowly. It is expected that on the soil on which pig slurry was regularly applied, there would be an increase in the N content [14].

The values of the total nitrogen content determined from the soil samples collected at the end of autumn, the beginning of winter, after the application of pig slurry, are in the range of 0.1 ÷ 0.18%, indicating a low to normal supply. The total nitrogen content increases with the increase in the dose of pig slurry applied as well as with the increase in the application period.

Ammonium (NH_4^+)(ppm) and Nitrate content (NO_3^-) (ppm)

In a warm aerated soil N-NH_4^+ is rapidly nitrified, and losses as N_2O have been attributed to denitrification. In humid and cold conditions, small accumulations of N-NO_3^- were found. [8]

Shortly after pig slurry application, N is found in the form of NH_4^+, organic N and clay-fixed N. The decrease in soil NH_4^+ content reflects its dynamics from pig slurry [15]. On the other hand, the use of manure with a high dry matter content during rainy periods causes a greater loss of N through surface washing [14].

The ammonium content determined in the soil samples varies within very wide limits, being in the range of 1.21 ÷ 22.89 ppm. Low values of the ammonium content were also determined in years when high doses of manure were applied, and implicitly a large amount of total nitrogen was determined, due to the fact that N-NH_4^+ was immobilized.

The content of (NO_3^-) (ppm) determined is located in the range of 1.26 ÷ 47.66 ppm. A significant increase in the N-NO_3^- content is observed after the second year of manure application, followed by a considerable decrease in the third and fourth year of experience. The decrease in NO_3^- content can be attributed both to the denitrification process (which takes place under anaerobic conditions) and to leaching, due to climatic conditions.

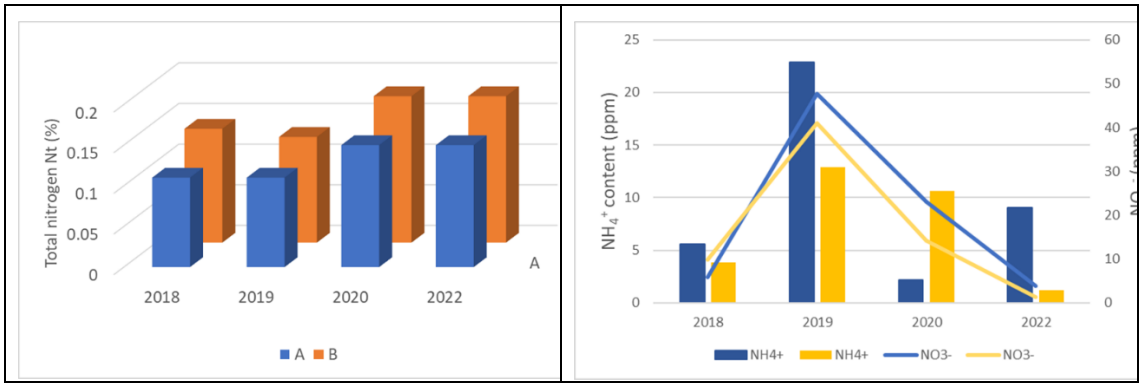


Fig.2 Total nitrogen, ammonia and nitrate content variation under the effect of pig slurry application

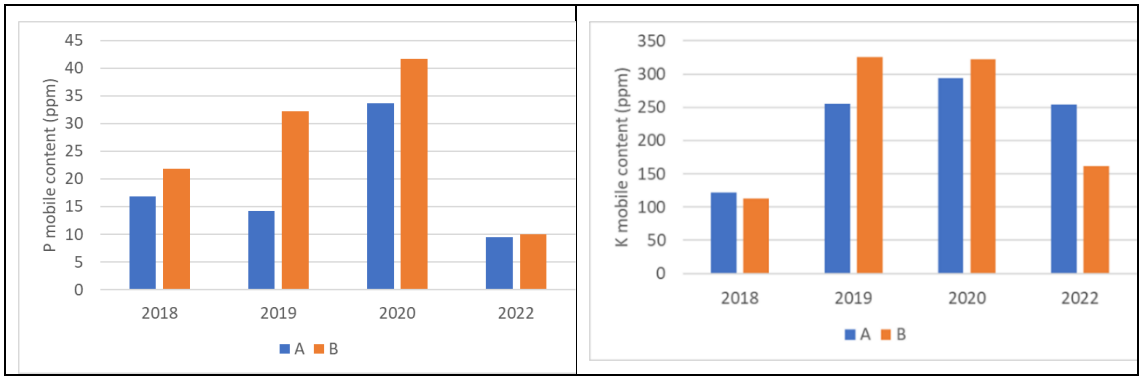


Fig.3 P mobile and K mobile content variation under the effect of pig slurry application

Repeated application of pig slurry can lead to significant accumulations of P in the soil, most of which is in the form of weakly bonded P in the topsoil. This fact increases the potential for P leaching, resulting in the contamination of aquatic systems. Most of the P contained in pig slurry is found in inorganic form [15].

The determined mobile P content is located in the range of 9.52 ÷ 41.72 ppm P, values that characterize the state of soil supply as very low to medium. The lowest values were determined in November 2022. The increasing values of the mobile P content in the years 2019, 2020 are due to the high P inputs through manures. The decrease in mobile P

content in 2022 was due to the reduced input in the last 2 years, as well as its consumption by cultivated plants as well as leaching due to precipitation.

The determined mobile K content is located in the range 113 ÷ 326 ppm., indicating a medium to very high supply. The increase in mobile K content in the first 3 years of experience is due to the application of increasing doses of K together with pig slurry. In 2022, the content of mobile K decreased, due to the decrease in the dose of K applied in the years 2020, 2022 and their consumption by plants.

CONCLUSIONS

In the context of the rapid development of the pig farming industry and the introduction of the circular economy concept, pig slurry is considered an indisputably useful fertilizer resource, due to the content of nutrients necessary for crops and organic substances with an important role in maintaining soil fertility.

Its positive or negative effect on the maintenance and improvement of soil fertility depends on the physico-chemical characteristics of the soil, the applied dose and the environmental conditions during and after application. It is difficult to estimate how much nutrients will be used by the plants and how much will pollute the environment in the form of emissions after manure application.

It's crucial for farmers to follow best management practices and guidelines to maximize the benefits of pig slurry while minimizing environmental impacts. Sustainable and responsible use of pig slurry can contribute to improved soil fertility and crop productivity.

AKNOWLEDGEMENT

This research paper is supported by the project: Consolidation of the research-innovation ecosystem within USVT code CNFIS-FDI-_2023-F-0343.

REFERENCES

[1.] Roser M. and Ritchie H. - "How has world population growth changed over time?" Published online at OurWorldInData.org. (2023) Retrieved from: 'https://ourworldindata.org/population-growth-over-time' [Online Resource]

[2.] Wancen L., Dingge C., Yongfang W., Zhicheng X., Guoxue L., Long D. Nghiem, Wenhai L., Occurrence and transformation of heavy metals during swine waste treatment: A full scale study, Science of The Total Environment, Volume 895, 2023, 164947, mISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2023.164947.

[3.] Jiménez-de-Santiago D.E., Yagüe M.R, Bosch-Serra À D., Soil water repellency after slurry fertilization in a dryland agricultural system, CATENA, Volume 174, 2019, Pages 536-545, ISSN 0341-8162, https://doi.org/10.1016/j.catena.2018.11.040.

[4.] Hlisnikovský L., Menšík L., Čermák P., Křížová K., and Kunzová E.. "Long-Term Effect of Pig Slurry and Mineral Fertilizer Additions on Soil Nutrient Content, Field Pea Grain and Straw Yield under Winter Wheat–Spring Barley–Field Pea Crop Rotation on Cambisol and Luvisol" Land 11, no. 2: 187. 2022 https://doi.org/10.3390/land11020187.

[5.] Sonne Ch., Sik Ok Y., Dietz R., KO Alstrup A., Pig slurry needs modifications to be a sustainable fertilizer in crop production, Environmental Research, Volume 178, 2019, 108718, ISSN 0013-9351, https://doi.org/ 10.1016/j.envres.2019.108718.
[6.] Shakoor, A., Bosch-Serra, À.D., Alberdi, JRO et al. Seven years of pig slurry fertilization: impacts on soil chemical properties and the element content of winter barley plants. Environ Sci Pollut Res 29, 74655–74668 (2022). https://doi.org/10.1007/s11356-022-21030-2
[7.] Hlisnikovský L., Menšík L., Čermák P, Křížová K, Kunzová E. Long-Term Effect of Pig Slurry and Mineral Fertilizer Additions on Soil Nutrient Content, Field Pea Grain and Straw Yield under Winter Wheat–Spring Barley–Field Pea Crop Rotation on Cambisol and Luvisol. Land. 2022; 11(2):187. https://doi.org/10.3390/land11020187
[8.] Rochette, P., Angers, DA, Chantigny, MH, Bertrand, N. and Côté, D. (2004), Carbon Dioxide and Nitrous Oxide Emissions following Fall and Spring Applications of Pig Slurry to an Agricultural Soil. Soil Sci. Shock. I have. J., 68: 1410-1420. https://doi.org/10.2136/sssaj2004.1410
[9.] Herrera A., D'Imporzano G., Clagnan E., Pigoli A., Bonadei E. Meers E., and Adani F., Pig Slurry Management Producing N Mineral Concentrates: A Full-Scale Case Study, ACS Sustainable Chemistry & Engineering 2023 11 (19), 7309-7322, DOI: 10.1021/acssuschemeng.2c07016.
[10.] Beyers M., Duan Y-F., Stoumann Jensen L., Bruun S., Effect of natural and regulatory conditions on the environmental impacts of pig slurry acidification across different regions in Europe: A life cycle assessment, Journal of Cleaner Production, Volume 368, 2022, 133072, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2022.133072.
[11.] Hanxi W., Xu J., Liu X., Zhang D. Li L., Li W., Sheng L., Effects of long-term application of organic fertilizer on improving organic matter content and retarding acidity in red soil from China, Soil and Tillage Research, Volume 195, 2019, 104382, ISSN 0167-1987, https://doi.org/10.1016/j.still.2019.104382.
[12.] Țărău D., Rogobete Gh., Dicu D.D., Soils from Western Romania, characterization, evaluation, improvement, Eurobit Publishing House, Timișoara, 2016, ISBN 978-373-132-312-1.
[13.] Ceretta C. A., Girotto E., Rogério Lourenzi C., Trentin G., Renan Costa Beber Vieira, Gustavo Brunetto, Nutrient transfer by runoff under no tillage in a soil treated with successive applications of pig slurry, Agriculture, Ecosystems & Environment, Volume 139, Issue 4, 2010, Pages 689-699, ISSN 0167-8809,https://doi.org/10.1016/j.agee.2010.10.016
[14.] Sørensen P., Amato M., Remineralisation and residual effects of N after application of pig slurry to soil, European Journal of Agronomy, Volume 16, Issue 2, 2002, Pages 81-95, ISSN 1161-0301, https://doi.org /10.1016/S1161-0301(01)00119-8.
[15.] Antezana-Julian, WO.; Blas, CD.; García-Rebollar, P.; Rodríguez, C.; Beccaccia, A.; Ferrer Riera, P.; Cerisuelo, A... (2016). Composition, potential emissions and agricultural value of pig slurry from Spanish commercial farms. Nutrient Cycling in Agroecosystems. 104(2):159- 173. doi:10.1007/s10705-016-9764-3

THE COSTS AND RATE OF RETURN CALCULATION OF THE NEW ESTABLISHED PIG AND POULTRY MANURE FERMENTATION PLANT

Dr. Anita Csiba[1]

Dr. Arpad Ferencz[1]

[1] University of Szeged Faculty of Agriculture, **Hungary**

ABSTRACT

Nowadays the manure management is a very actually topic. There is an important part of it the manure processing technology. However, we need for it a manure fermentation plant with an adequate capacity and there is important, the processing plant must be near for the pig and poultry farm to process the manure as soon as possible to reduce the harmful emission and bind the valuable nutrients in the fermented manure. The new established processing plant added advantages, that their produces excellent qualities and huge quantities fermented pig a poultry manure as a final products, which can be sold for good price, thus increasing the company's profit. There is all allows for the fastest return on the investment. In our study we calculated the investment costs of the pig and poultry manure fermentation plant and the return based on the estimated expected revenues from the sales of manufactured final products. However, it is important not only in terms of additional income and return, but also in terms of reducing harmful emissions required by the stricter directives and regulations of the European Union, in order, that the companies able to comply with the increasingly strict of the European Union's regulations and thus to be able to access resources in the future.

Keywords: cost of the new manure fermentation plan, pig and poultry manure management

INTRODUCTION

Climate change and environmental degradation are an existential threat to Europe and the world. To overcome these challenges, the European Green Deal will transform the EU into a modern, resource-efficient and competitive economy, ensuring no net emissions of greenhouse gases by 2050 economic growth decoupled from resource use no person and no place left behind. The European Commission has adopted a set of proposals to make the EU's climate, energy, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels. [1]

On top of all that the 2016/2284 numbered directive of the European Union about the reduction of emissions of certain atmospheric pollutants (NEC) requires to the

governments of the member states to reduce by 32% the level of atmospheric ammonia emissions compared to the 2005 level to 2030. [5]

The Farm to Fork Strategy is at the heart of the European Green Deal aiming to make food system fair, healthy and environmentally-friendly. Putting our food systems on a sustainable path also brings new opportunities for operators in the food value chain. New technologies and scientific discoveries, combined with increasing public awareness and demand for sustainable food, will benefit all stakeholders. The Farm to Fork Strategy's one of its main objective to accelerate our transition to a sustainable food system that should have a neutral or positive environmental impact help to mitigate climate change and adopt to its impacts. To enable and accelerate the transition to a fair, healthy and environmentally-friendly food system, advisory services, financial instruments, but also research and innovation are instumental as they can help resolve tensions, develop and test solutions, overcome barriers and uncover new market opportunities. [2]

According The European Food Safety Strategy and Healthcare Strategy's European Green Deal titled first general objective the DG SANTE's work on safe and sustainable food will play an important role in the European Green Deal, helping to make Europe the first climate-neutral continent by 2050, supporting sustainable and inclusive growth that leaves no one behind, boosting the economy, improving people's health and life quality, and caring for nature. Safe food is essential for public health and food security and a crucial part of the EU's action on food sustainability. [3]

The common agricultural policy is key to securing the future of agriculture and forestry, as well as achieving the objectives of the European Green Deal. On 2 December, 2021, the agreement on reform of the common agricultural policy (CAP) was formally adopted. The new legislation, which entered into force on 1 January 2023, paves the way for a fairer, greener and more performance-based CAP. It seeks to ensure a sustainable future for European farmers. Agriculture and rural areas are central to the European Green Deal, and the CAP 2023-27 will be a key tool in reaching the ambitions of the Farm to Fork and biodiversity strategies. [4]

In this research project I search for the appropriate solutions for these problems and already I have found some possible effective solutions for example the practical using of modern precision and digitalization technologies and the using of the circular farming in the agricultural sector, especially in poultry manure and pig slurry processing.

MATERIALS AND METHODS

Investment of the new established manure treatment and fermentation for pig slurry and poultry manure

Pig slurry treatment

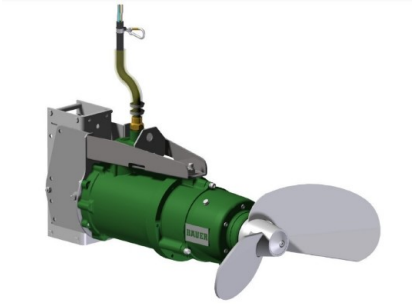
Liquid manure as valuable fertilizer

Since the establishment of agriculture, people have understood the importance of biological forms of fertilizer. Liquid manure has always been among the most valuable of natural fertilizers. Rudolf Bauer made efficient wide-area fertilization possible with

construction of the first high-pressure manure pump in 1930. This was followed by over 80 years of experience in liquid manure management. Correct handling, preparation and distribution of liquid manure became a core competence of Bauer. This yielded a developmental edge that Bauer still maintains today, making it a specialist in liquid manure management and a leading problem-solver for cattle, hog and chicken manure and other agricultural wastewater. [6]

Slurry stirring (Agitation technology)

Properly stirred slurry guarantees uniform distribution of nutrients, that is to say optimum growth and increased yields. [7]



Picture 1: Submersible Motor Mixer MSXH [10]

Pumping technology

An essential factor in order for the complete system to function is the transportation of fluid mediums on agricultural farms, but also in the industrial field. The gear and pedestal pumps with special and powerful cutting units are also suitable for conveying slurry or fluids with long fibres and a solids content up to 12%. [8]

Submersible pump

The pump is suitable in combination with separator systems is the most efficient in the pig slurry treatment. [9]

The application of the submersible pump can be feeding of the separator.



Picture 2: Submersible motor pump [9]

Separator

Separation stands at the forefront of liquid manure management. It is the starting point of subsequent meaningful liquid manure preparation. After separating into solid and

liquid media, many useful opportunities for further processing exist. For instance, the separated solid portion is used today to produce valuable bedding material or compost. The liquid manure in turn ensures reliable growth in the fields during every growing season. It replaces chemical fertilizer to save money, lowers environmental impact and promotes animal health. [11]



Picture 3: Standard Extent of Supply S 855 GB type Bauer separator [12]

Pig slurry and poultry manure fermentation treatment

Manure fermentation in practice with Hosoya manure fermentation system

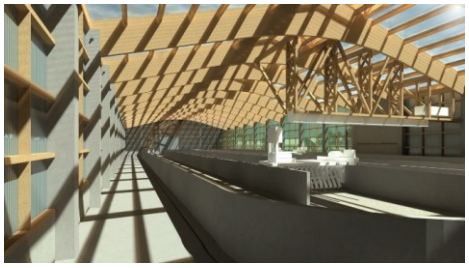
The plans of the new established building of the manure fermentation system are showed below pictures.

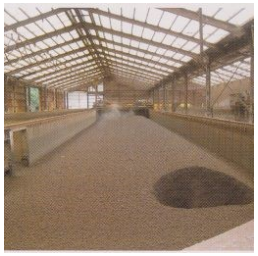


Picture 4: The building of the manure fermentation plant

Manure fermentation in Hosoya manure fermentation system

In the Hosoya fermentation system's F1 (Phase-1 system) tanks the fresh separated pig- and poultry manure is mixed with return fermented manure of about 35% moisture, the moisture content reaches about 60%, and a large amount of actinomycete acts immediately to cause hard fermentation and its temperature becomes about 70 ° C. This severe high-temperature fermentation finishes only on the right side (A side) and after shifting to the left side (B side), the poultry manure is gently fermented and aged (point C), pulled out, the first fermentation process is over and the second fermentation It is transferred to the tank. The stirrer is agitated very gently by a pair of special rotary blades. [13]

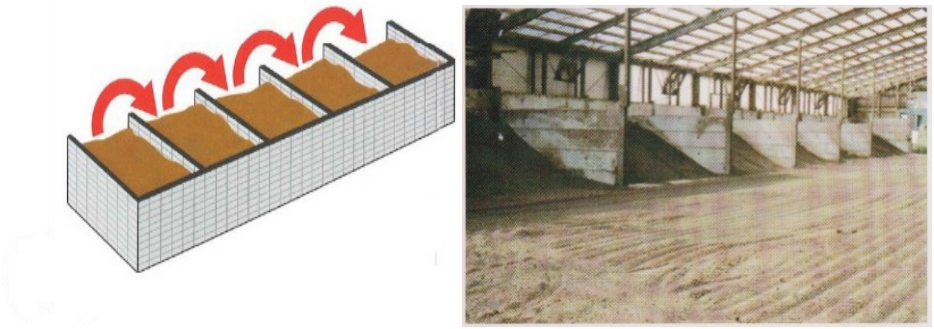




Picture 5: Hosoya fermentation tank [14]

Secondary fermentation box

From the phase-1 system tank the manure is forwarded to the next part of the fermentation system, the secondary phahse-2 fermentation system part, that content 5 to 6 fermentation boxes. The manure is sequentially transferred to the next fermentation box every 3 days, and the turnover is done at this time. Thus, in four compartments 3 days X 5 cells = 15 days, that is, about 15 days, it becomes fermented poultry manure with a moisture amount of about 20%. [13]



Picture 6: Secondary fermentation and drying [13] [15]

Organic fertilizer (Poultry and pig manure fermented fertilizer)

Organic fertilizer made by poultry and pig manure fermentation/drying system of Hosoya is an excellent organic fertilizer containing many effective chemical ingredients suitable for growing plants. It can be classified into several kinds according to the size of the grain, and it can be used according to each purpose such as vegetables, fruit trees etc. In addition, Hosoya's organic fertilizer is a fertilizer that is easy to handle without odor of the product owing to the agglomeration phenomenon of actinomycetes, the product is granular and easy to spread fertilizer, and it is manufactured by the process of high temperature fermentation. [13]

RESULTS AND DISCUSSION

The costs of new established pig and poultry manure processing technology

In the below tables (Table 1- Table 4) we can show you the cost of the investments of the new established pig slurry and poultry manure technologies and we made calculations for their capacity and the return of these investments. We can show it for the capacity calculation in the Table 2 and Table 4, and the return of the investments in the Conclusion chapter in the Table 5 and Table 6.

Table 1: Costs of pig slurry processing technology

Costs of pig slurry processing technology	
Costs of pig slurry treatment and separation technology	
Submersible motor pump	34.261 €
Submersible Motor Mixer MSXH	25.586 €
Standard Extent of Supply S 855 GB type Bauer separator	77.487 €
Σ	137.334 €
Costs of pig manure fermentation treatment	
Hosoya fermentation tank	524.712 €
Stirrer applicator	12.755 €
Building of the manure fermentation plant	1.082.039 €
Field area of fermentation manure plant	26.317 €
Hosoya fementation system	1.645.823 €
Σ	1.723.310 €
Operational costs of pig slurry treatment, separation and fermentation	
Annual labor cost	48.980 €
Transportation cost	255.102 €
Energy cost	156.888 €
Annual maintenence cost of Manitu	40.816 €
Change of stirrer applicator costs	12.775 €
Cost of big bag packaging	31.122 €
Cost of packaging machine	103.571 €
Σ	649.354 €
Total cost of the investment	**2.509.998 €**

Table 2: The planned annual income of fermented pig manure product

The planned annual income of fermented pig manure product	
Amount of annual sold fermented pig manure (with 17-18 % moisture content)	3222,22 t
Price per ton of fermented pig manure	114,8 + VAT €/t
Annual planned income from the fermented pig manure	369.898 + VAT €

Table 3: The planned annual income of fermented poultry manure product

The planned annual income of fermented poultry manure product	
Amount of annual sold fermented poultry manure (with 17-18 % moisture content)	8.536,59 t
Price per ton of fermented poultry manure	114,8 + VAT €/t
Annual planned income from the fermented poultry manure	980.000 + VAT €

Table 4: The costs of poultry manure fermentation system

Costs of poultry manure fermentation treatment	
The investment cost of Hosoya fermentation technology for poultry manure	1.017.249€
The investment cost of building of the manure fermentation plant	2.097.728 €
Field area of fermentation manure plant	25.510 €
Solar panel (100kWh)	71.429 €
Packaging machine	102.041 €
Σ	3.313.957 €
Operational costs of poultry manuretreatment, separation and fermentation	
Annual labor cost	97.960 €
Transportation cost	255.102 €
Annual diesel cost of Manitu	30.000 €
Annual maintenence cost of Manitu	10.000 €
Change of stirrer applicator costs	12.775 €
Cost of packaging for 1 year	71.204 €
Cost of packaging machine	103.571 €
Σ	580.612 €
Total cost of the investment	**3.894.569 €**

CONCLUSION

The subject of the development, that described in our study fits the aim of the Green Deal, the Farm to Fork Strategy a The European Food Safety and Healthcare Strategy, 2016/2284 numbered directive of the European Union about the reduction of emissions of certain atmospheric pollutants (NEC), and the Common Agricultural Policy (CAP), because the objective of the development projects are the by-products, that produced from animal husbandry, processing with environmental technology. The new established investment realizes the processing of second category by-product, like pig slurry and poultry manure, in additional we can reduce the amount of harmful pollution material, that cause the soil and soil water pollution, the greenhouse gasses emission and it can be realized the circular economy, the soil structure will be better and the water and nutrient management of the soil will be also improved. The processing of the above mentioned by-products we can produce valuable main product, thereby the profit of the company can be increasing.

Table 5: Costs and return of the new established investment of pig slurry processing teshnology

Costs and return of the new established investment of pig slurry processing technology	
Total cost of the new established pig slurry processing technology	2.509.998 €
Support intensity	25-80 %
Non-refundable grant	629.499,5 € - 2.007.998,4 €
Annual income from the sold fermented manure	369.898 €
Own financed costs of investment	1.880.548,5 € - 501.999,6 €
The return of investment	5,08 years - 1,36 years

Table 6: Costs and return of the new established investment of poultry manure processing technology

Costs and return of the new established investment of poultry manure processing technology	
Total cost of the new established poultry manure processing technology	3.894.569 €
Support intensity	25-80 %
Non-refundable grant	973.642,25 € - 3.115.655,2 €
Annual income from the sold fermented manure	980.000 €
Own financed costs of investment	2.920.926,75 € - 778.913,8 €
The return of investment	2,98 years - 0,79 years

The new established investment for technological development, that installed will be suitable for processing poultry manure and pig slurry. As a result of these projects will be possible to reduce the ammonia- and greenhouse gasses emission with the using of the new processing technology, different additional nutrients and substances, that improve the soil structure, while the valuable nutrient content of the manure is preserved. The result of using the new technology the fermented manure using is rich in nutrients, supplemented with natural minerals, and it is excellent for supplying plants with their nutrients. It helps to increase the yield of the mineral and microelement content of the plants and what's more, the plants use these nutrients more efficiently. Fermented organic manure produced as a prototype product also opens up further product development opportunities, as it can be sold in small packages at a higher price than in bulk or big bag packages.

REFERENCES

[1] EU Directorate-General for Communication, Recommendation for 2040 target to reach climate neutrality by 2050, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[2] EU Directorate-General for Communication, European Green Deal, Food Safety https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en

[3] Strategic Plan 2020-2024, DG Health and Food Safety (SANTE), Ref. Ares (2020)4618565 – 04/09/2020, https://commission.europa.eu/system/files/2020-10/sante_sp_2020_2024_en.pdf

[4] https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cap-2023-27_en

[5]2016/2284 numbered directive of the European Union about the reduction of emissions of certain atmospheric pollutants (NEC)

[6] https://portal.bauer-at.com/en/products/slurry-technology

[7] BAUER GmbH, Roehren- und Pumpenwerk, Agitation technology https://portal.bauer-at.com/en/products/slurry-technology/agitation-technology

[8] BAUER GmbH, Roehren- und Pumpenwerk, Pumping technology https://portal.bauer-at.com/en/products/slurry-technology/pumping-technology

[9] BAUER GmbH, Roehren- und Pumpenwerk, Pumping technology/ motor pump https://portal.bauer-at.com/en/products/slurry-technology/pumping technology/submersible-motor-pump

[10] BAUER GmbH, Roehren- und Pumpenwerk, Agitation technology /Motor mixer, https://portal.bauer-at.com/en/products/slurry-technology/agitation-technology/submersible-motor-mixer-msxh

[11] BAUER GmbH, Roehren- und Pumpenwerk, Separation technology, https://portal.bauer-at.com/en/products/slurry-technology/separation-technology#

[12] BAUER GmbH, Roehren- und Pumpenwerk, Separation technology / s885 https://portal.bauer-at.com/en/products/slurry-technology/separation-technology/separator-s855-gb

[13]http://khosoya.co.jp/en/file/pdf/Hosoy%20Poultry%20Manure%20Fermentation%20System%20ver200602.pdf

[14] hosoya – fertilizer machine, https://hevesgep.hu/en/termek/hosoya-fertilizer-machine/#gallery-4

[15] hosoya – fertilizer machine, https://hevesgep.hu/en/termek/hosoya-fertilizer-machine/#gallery-8

THE ROLE OF INVESTMENT AND INNOVATION POLICY IN THE FORMATION OF A CIRCULAR ECONOMY

Dr.oec., Arturas Simanavicius[1]

PhD Lilita Abele[2]

Dr. oec., Borys Smorodov[3]

[1] Lithuanian Sports University, **Lithuania**
[2] Liepaja University, Circular Economy Center, **Latvia**
[3] V.N.Karazin Kharkiv National University, **Ukraine**

ABSTRACT

Pursuing sustainability in a rapidly changing global landscape has necessitated a paradigm shift in economic models. At the forefront of this transformation is the Circular Economy, characterized by the continuous reuse, recycling, and remanufacturing of products and materials, which has gained prominence as a means to address pressing environmental challenges while fostering economic growth.

This research explores the interplay between the circular economy, innovation, investment, and social responsibility. These four pillars are essential components of a unified approach to achieving a circular economy through a project management approach. The impact is determined using a survey of ten experts from different sectors of Ukraine, who were surveyed electronically in 2023 from May to August. The Kendell correlation method assessed the extent of expert consensus to present survey results. As a result of the research, an algorithm for implementing the circular economy is proposed innovatively, ensuring companies implement material recycling and create industrial symbioses more successfully. This study aims to guide companies and interested parties in bringing the circular economy to life by ensuring material recycling from light industrial plants.

Keywords: circular economy, recycling, project management, security, investment and innovation policy.

INTRODUCTION

Creating a circular economy focused on saving resources and recycling is relevant under limited resources and unlimited human needs. Developing effective investment and innovation policies that support and encourage sustainable economic practices are crucial to implement a circular economy. These policies may include incentives for material reuse, support for research and development of environmentally friendly technologies, and funding for sustainable projects.

Investments in the circular economy can have a positive economic impact. For example, the development of new sustainable technologies and innovative project management can create new job opportunities, increase economic activity, reduce waste and reduce production costs, which can increase the profitability of companies in the long run.

At the national and international level, governments and organizations have recognised the importance of investment and innovation policies in promoting the circular

economy. For example, the European Union has created a Circular Economy Action Plan, which includes various policy measures to promote sustainable economic practices across the EU.

LITERATURE REVIEW

As a theoretical and methodological basis for the study of information as an economic factor of development were the works of scientists on the theory of socio-economic aspects of production [9,10,11,12]. The essence and mechanism of enterprise economic security are investigated [1,3]. Economists have studied the problem of ecological and financial security in scientific developments [4]. Environmental economics studies are included in economists' papers [2,5]. The concept of the circular economy has gained momentum among scientists and practitioners. Authors analyse the current understanding of the circular economy concept, often depicted as a combination of activities focused on reduction, reuse, and recycling [7]. Theoretical and methodological foundations of environmental security, development of new and adaptation of existing mechanisms and environmental and economic tools, and a wide range of current ecological security issues at all system levels (state - region - business - person) are considered in the papers [6].

The authors justify the conceptual principles of state regulation for developing the circular economy in Ukraine. They provide an overview of the indices used to assess the level of development of the circular economy. The article discusses the challenges and critical aspects of circular economy implementation in different countries. The circular economy and the benefits of implementing this concept in Ukraine have been studied based on the experience of the European Union. The recommendations provided by the Ellen MacArthur Foundation and the European Commission, which governments should consider, are also presented, considering the critical environmental situation worldwide. The possibilities of forming and developing circular business models in Ukraine are justified, using the best European practices.

MATERIALS AND METHODS

Investment and innovation policy's role in forming a circular economy is crucial by providing incentives and financial support. Investment policies can encourage businesses to adopt circular practices, such as eco-design, recycling, and resource efficiency.

On the other hand, innovation policies foster the development and diffusion of innovative technologies, business models, and processes that enable the transition to a circular economy. These policies can include research and development funding, intellectual property rights protection, and collaboration between academia, industry, and government. Investment in circular initiatives drives innovation, while innovation enhances the feasibility and effectiveness of circular practices, making them more attractive to investors. Furthermore, these policies can help create an enabling environment for the circular economy by addressing barriers and challenges. Evaluating and understanding the innovative potential of the enterprise is essential to identify the most suitable and effective strategies for innovation. The innovative potential of an enterprise in a circular economy can be assessed in more detail and fundamentally, taking into account the key characteristics and multipliers of various factors, such as

resources and capabilities, research and development, intellectual property (IP) assets, market knowledge and customer insights, collaboration and networking (Fig. 1).

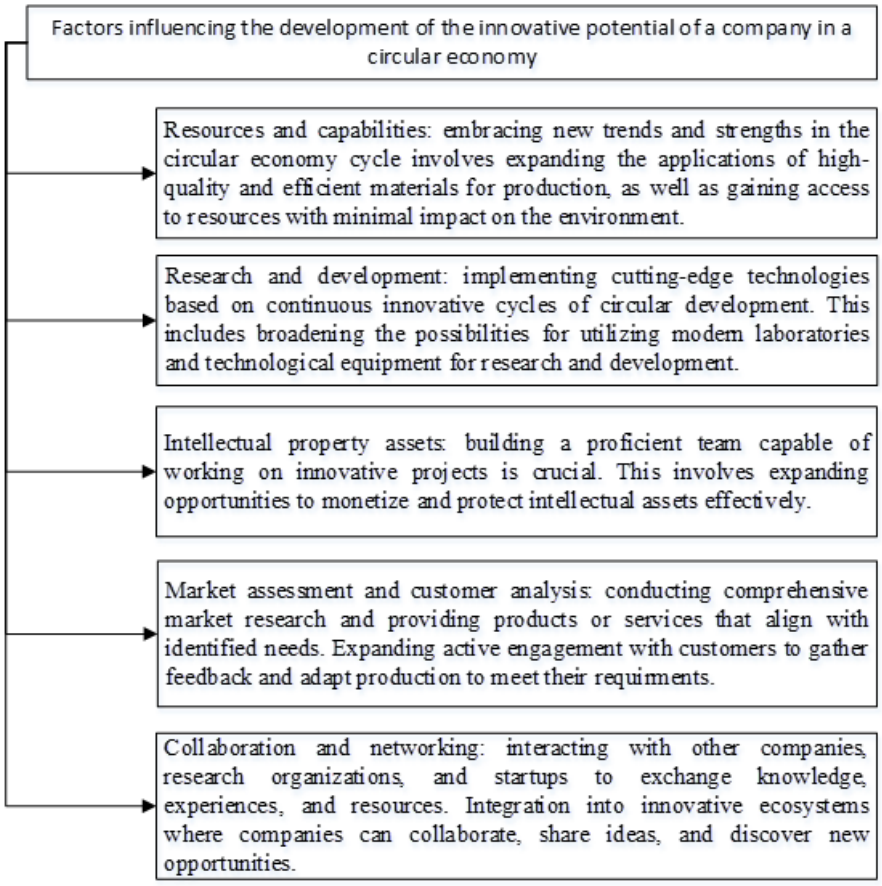


Figure 1. Factors influencing the development of the innovative potential of a company in a circular economy (formulated by the authors)

The circular economy also emphasises the need for more efficient resource management, a transition to sustainable technologies and products, and implementing principles of material recycling and reuse. All the factors mentioned above should aim to create a sustainable, innovative business model that considers the principles of the circular economy.

It is necessary to analyse the conditions and factors of the external environment to determine the innovation strategy. The external environment includes various factors and influences impacting an organization's innovation efforts. By understanding these factors, an organization can better identify opportunities and challenges and develop a strategy that aligns with the external environment. Elements of an innovation strategy for determining the impact of investment and innovation policy on the formation of a circular economy (Fig. 2):

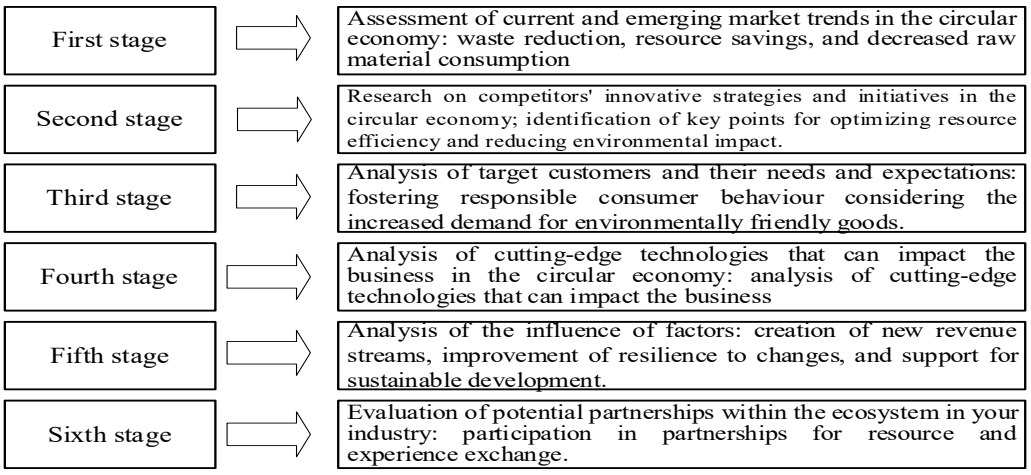


Figure 2. Elements of an innovation strategy for determining the impact of investment and innovation policy on the formation of a circular economy (formulated by the authors)

The critical significance consists of creating incentives for innovation, developing new technologies and production methods, and supporting companies striving for a circular economy. Elements of an innovation strategy for determining the impact of investment and innovation policy focused on sustainability can contribute to forming more efficient and responsible approaches to resource utilisation and producing goods and services.

Organisations can make informed decisions about their innovation strategy by thoroughly analysing the external environment.

The authors used the expert evaluation method to determine the impact of investment and innovation policies on creating a circular economy. Individual and collective expert ratings were distinguished, and collective expert ratings are considered more reliable. Evaluation methods of expert cooperation include determining the degree of specialist agreement formulated by individual experts on the prospective development directions of the forecasting object. A group of ten Ukrainian experts from various sectors was selected for the analysis and involved in the process. The survey was conducted in 2023 from May to August. The group of experts was formed from specialists of various specialised institutions of the Kharkiv region, namely: Kharkiv Regional Administration - economic department (1 expert); Social Policy Department (1 expert), National Natural Park "Dvurechanskyi" (2 experts); Karazin Kharkiv National University - biology faculty (1 expert), geological and geographical faculty (2 experts), ecological faculty (2 experts); Kharkiv City State Environmental Inspection (1 expert).

RESULT

Using an electronic survey questionnaire, ten experts were asked to determine the degree of influence of each factor. The expert survey results on the factors' degree of power are reflected in Table 1. When ranking the objects, the experts considered that 1 represents the most influential group of factors, and 8 is the least significant group of elements.

Table 1

Ranking Matrix of the Degree of Influence of Groups of Factors in Investment and Innovation Policy on the Formation of a Circular Economy

Nr.	Factor Groups	Experts									
		1	2	3	4	5	6	7	8	9	10
1	Market Factors	1	2	1	1	1	1	1	1	1	1
2	Resource Factors	2	1	2	2	2	3	2	3	2	3
3	Stakeholder Contacts	3	3	3	3	3	2	3	2	3	2
4	Economic Factors	4	4	4	4	4	4	4	5	4	4
5	Scientific-Technological Factors	6	7	5	5	6	6	5	6	6	7
6	Social Factors	5	5	7	6	5	5	6	4	5	5
7	Political-Legal Factors	7	6	6	7	7	7	7	7	7	6
8	Environmental Factors	8	8	8	8	8	8	8	8	8	8

This study uses mathematical and statistical methods to process the results of the surveys to create a consolidated assessment of the panel of experts. The evaluation results are shown in Table 2.

Table 2

The assessment results

Nr.	Factor Groups	Sum of Ranks	Deviation from the Mean Value	Square Deviation
1	Market Factors	11,00	-34,00	1156,00
2	Resource Factors	22,00	-23,00	529,00
3	Stakeholder Contacts	27,00	-18,00	324,00
4	Economic Factors	41,00	-4,00	16,00
5	Scientific-Technological Factors	59,00	14,00	196,00
6	Social Factors	53,00	8,00	64,00
7	Political-Legal Factors	67,00	22,00	484,00
8	Environmental Factors	80,00	35,00	1225,00
Total			360.00	-
Mean Value of the Sum of Ranks		45.00	-	-

To confirm the results, the level of concordance between experts' opinions was evaluated using Kendall's correlation coefficient. Calculations were made using formulas:

$$W = \frac{12S}{n^2(m^3 - m)}, \quad (1)$$

S - the sum of squares of deviations of all rank assessments for each object of evaluation from the mean value,
n - number of experts,
m - number of evaluation objects.

The coefficient of Kendall's concordance ranges from 0 to 1, where 0 indicates complete disagreement and 1 indicates entire agreement.

A Kendall's concordance coefficient value of 0.95 indicates a high degree of agreement among the experts regarding assessing the influence level of each factor group on the formation of the circular economy.
Based on the obtained sum of ranks, the authors calculated the weight indicators for each factor group. To do this, transform the matrix of ranks of external environmental factor groups (Table 2) into a matrix of transformed ranks (Table 3).
To transform the ranks used the formula:

$$N_{ij} = x_{\max} - x_{ij} \quad (2)$$

Nij - the value of the transformed rank for the i-th expert of the j-th group,
X_{max} - the maximum rank value (X_{max} = 8),
X_{ij} - the assigned rank value by the i-th expert of the j-th group.

Table 3

Matrix of transformed ranks

Nr.	Factor Groups	Experts										Sum	Validity
		1	2	3	4	5	6	7	8	9	10		
1	Market Factors	7	6	7	7	7	7	7	7	7	7	69	0,2464
2	Resource Factors	6	7	6	6	6	5	6	5	6	5	58	0,2071
3	Stakeholder Contacts	5	5	5	5	5	6	5	6	5	6	53	0,1893
4	Economic Factors	4	4	4	4	4	4	4	3	4	4	39	0,1393
5	Scientific-Technological Factors	2	1	3	3	2	2	3	2	2	1	21	0,075
6	Social Factors	3	3	1	2	3	3	2	4	3	3	27	0,0964
7	Political-Legal Factors	1	2	2	1	1	1	1	1	1	2	13	0,0464
8	Environmental Factors	0	0	0	0	0	0	0	0	0	0	0	0
Total												280	1

The table calculates the sum of transformed ranks and their respective weights. The weight represents the importance or significance of each factor group in the evaluation process.

DISCUSSION

According to experts, market-oriented and natural resource factors are the factors that most influence the creation of a circular economy. These factors are crucial in promoting circular practices and sustainable resource use. Market-oriented factors include consumer demand and market incentives. Natural resource factors include resource availability and recycling capabilities.

Investors and supply chain partners have moderate influence, but their involvement and support can contribute to the successful implementation of circularity initiatives.

Economic factors, such as the profitability of circular practices, also play an essential role in influencing companies' decisions to adopt circular strategies. If circular methods are economically viable, companies are more likely to adopt them.

On the other hand, social, political, legal, and environmental factors have relatively less influence on the transition to a circular economy. However, they should not be overlooked, as social acceptance, supportive policies and regulations, and environmental considerations remain important drivers to create an enabling environment for circular practices.

According to experts, understanding factors oriented towards the market and natural resources is crucial to successfully building a circular economy. However, it is also essential to be aware of the interaction of other factors and to consider a holistic approach that includes social, political, legal and environmental aspects to realise the potential of the circular economy fully.

Based on the results of calculations, their assessment and analysis regarding the role of innovation and investment policy factors, and their significance and influence, the authors developed an adaptive algorithm for introducing a circular economy in Ukraine (Figure 3.).

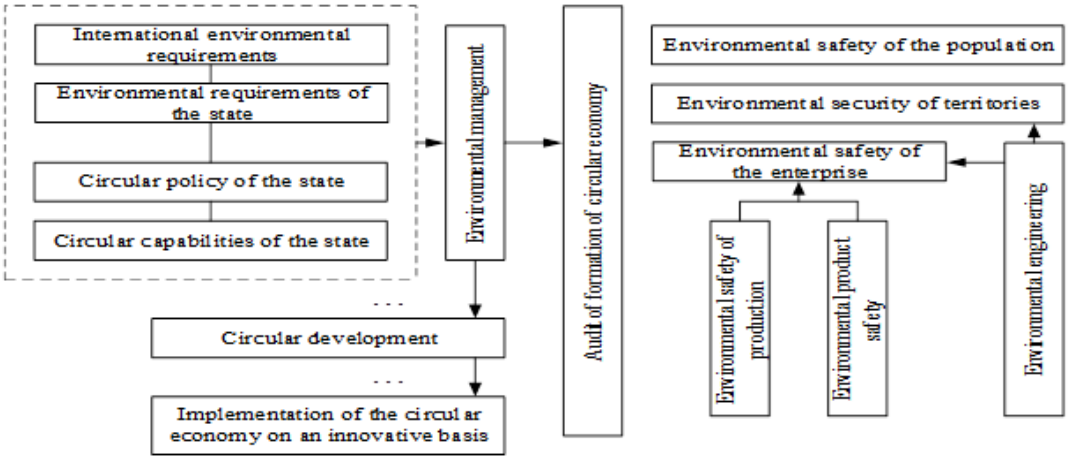


Figure 3. Algorithm for implementing circular economy on an innovative basis (constructed based on [8])

CONCLUSION

Considering the investment and innovation policy, the developed circular economy implementation algorithm for material recycling will improve the quality of company management decisions.

Investment and innovation policy levers play a crucial role in implementing the circular economy and material recycling, promoting the transition to sustainable and efficient use of resources and reducing the negative impact on the environment.

The circular economy implementation algorithm is offered innovatively, providing companies with a more successful implementation of material recycling and the creation of industrial symbiosis. During this research, cloud-based testing was conducted on industrial enterprises in Kharkiv that had relocated to the Poltava region due to military aggression. These enterprises produce natural fabrics, and their waste is directed to

construction companies as raw materials for insulation manufacturing. In subsequent studies, calculating the socio-economic efficiency of implementing a circular economy on an innovative basis is planned. However, we can already note the positive effects of introducing a circular economy, namely:

- Resource savings: reduced consumption of raw materials and energy, leading to resource savings.
- Waste reduction: decreased volume of waste and pollution of the environment.
- Economic efficiency: creating new revenue sources through material recovery and developing sustainable products.
- Job creation: potential emergence of new jobs in recycling and processing.
- Enhanced competitiveness: improved company reputation, attracting new customers and investors due to a responsible business approach.
- Support for sustainable development: contribution to social responsibility and support for the sustainable development of society.

Implementing a circular economy not only contributes to the efficient use of resources but also has the potential to create more sustainable and innovative business models that foster both environmental and economic sustainability.

REFERENCES

[1] Andriichuk, V. H. (2013). Ekonomichna bezpeka Ukrainy: stan, kryterii vymiru ta preventyvni zakhody yii zmitsnennia [Economic security of Ukraine: state, measurement criteria and preventive measures to strengthen it]. Ekonomika, finansy, pravo. s period-Economics, finance, law, 6, 12-17.

[2] Barkemeyer, R., Figge, F., Hoepner, A., Holt, D., Kraak, J. M., & Yu, P. S. (2017). Media coverage of climate change: An international comparison. Environment and Planning C: Politics and Space, 35(6), 1029-1054.

[3] Batini, N. (2019). Reaping what we sow. Finance & Development, 56(4), 31-33.

[4] Gryshchenko, V., & Petrushenko, M. (2020). Main stages of economic security management in the conditions of innovative and inclusive entrepreneurship development. InterConf.

[5] Hofmann, K. (1998). Environmental Economics (From Scientific Heritage). Moscow: Editorial URSSS.

[6] Khlobystov, Y. V., Anderson, V. M., Andrieieva, N. M., & Alymov, O. M. (2011). Stalyi rozvytok ta ekolohichna bezpeka suspilstva: teoriia, metodolohiia, praktyka [Sustainable development and ecological safety of society: theory, methodology, practice]. Simferopol: IT «ARIAL»[in Ukrainian].

[7] Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. Resources, conservation and recycling, 127, 221-232.

[8] Mashchenko, M. (2018). Process of management of environmental security of the enterprise. Development, 4(3).

[9] Mill, J. S. (2007). Principles of Political Economy with some of their applications to social philosophy, trans. from Engl. Moscow: Eksmo (In Russian).

[10] Ricardo, D. (1821). On the principles of political economy. London: J. Murray.

[11] Schumpeter, J. A. (1934). The Theory of Economic Development; Harvard Economic Studies 46, no. 1600, 0404; Redvers, O., Translator.

[12] Smith, A. (1937). The wealth of nations [1776] (Vol. 11937). na.

VALORIZATION OF COMMON BEAN (*PHASEOLUS VULGARIS* L.) BY-PRODUCTS TO OBTAIN NEW BAKERY PRODUCTS

Lecturer Dr. Alina Maier[1]
Assoc. Prof. Dr. Cristina Maria Canja[1]
Assoc. Prof. Dr. Mirabela Ioana Lupu[1]
Vet. Geronimo Răducu Brănescu[1]
Prof. Dr. Vasile Pădureanu[1]
[1] Transilvania University of Brașov, Faculty of Food and Tourism, **Romania**

ABSTRACT

Disposal of by-products from the processing of plant foods is a major industry concern, but these by-products are also promising sources of compounds with technological or nutritional properties and are now being considered as a possible source of functional compounds. The common bean (*Phaseolus vulgaris* L.), which contains a high protein content, fiber, and other critical minerals for humans, is one of the most significant pulses in the world. The objective of this work is to exploit the properties of common bean (*Phaseolus vulgaris* L.) by-products by including them in powder form in new bread products, in order to improve their properties. Empty common bean (*Phaseolus vulgaris* L.) pods were dried, mild and incorporated with different levels (5%, 10% and 15%) into dough and breads made from wheat white flour. The moisture content decreased in proportion to the amount of wheat flour substituted. Analysis of the bread showed that the addition of empty bean pod powder did not significantly improve the textural profile of the bread. In fact, there was an increase in hardness (1011.26 N/mm^2 for the control and 1027.38 N/mm^2 for the breads enriched with 15% powder, respectively). The pH and porosity also increased in proportion to the amount of wheat flour substituted. Regarding the sensory analysis, the breads obtained with different proportions of vegetable waste powder additions were liked by several categories of people and were noted with high scores. To conclude, the powders obtained from vegetable by-products can be used as functional compounds and can partially replace the wheat flour added to make bread.

Keywords: by-products, empty common bean (*Phaseolus vulgaris* L.) pods, bakery products

INTRODUCTION

One of the key strategies for reducing food waste is to recover and convert it for human use. The disposal of by-products from the processing of plant foods can be managed in several eco-friendly ways such as: composting (this process can convert organic waste into nutrient-rich fertilizer; it reduces waste volume, kills pathogens, decreases weed germination in agricultural fields, and destroys malodorous compounds) [1], anaerobic digestion (organic matter such as food or plant waste is broken down by micro-organisms in the absence of oxygen; this process creates biogas, which can be used as a source of energy, and a bio-fertilizer by-product) [2], recycling/reusing (waste can be recycled or reused for utilization by other industries; for example, food waste created during the

production process can be turned into animal feed) [1], [3], or feeding surplus food to needy people (surplus food can be donated to those in need) [4]. These methods not only help in managing waste but also contribute to environmental sustainability. They can be applied to various types of plant food processing by-products such as pomace from fruit and vegetable processing, hull/bran from grain milling, meal/cake from oil extraction, bagasse from sugar processing, and brewer's spent grain from brewing.

Common bean (Phaseolus vulgaris L.) is a nutritious legume that contains proteins, carbohydrates, dietary fibre, minerals, antioxidants, and bioactive compounds [5]–[7]. Common bean by-products, such as hulls, pods, and seeds, are usually discarded or used as animal feed, but they can also be a source of functional compounds, such as phenolic acids, flavonoids, anthocyanins, and phytosterols [8]. Functional compounds are substances that have beneficial effects on human health beyond basic nutrition, such as reducing the risk of chronic diseases, modulating physiological functions, and enhancing well-being [5]. Common bean by-products can be processed into various forms, such as flours, extracts, concentrates, and isolates, and incorporated into food products for sportspeople, such as bars, drinks, and supplements, to enhance their nutritional and functional properties [7].

Bread enriched with by-products from the food industry is often referred to as "functional bread". The incorporation of these by-products can enhance the nutritional value of the bread and reduce food waste [9], [10]. For instance, a study investigated the combined effect of carob pod flour, sugar beet fibers, and molasses on dough rheology and bread quality. The presence of high share of dietary fibers increased dough resistance to extension and reduced dough extensibility. The addition of molasses had a positive effect on bread quality. Moreover, carob flour increased the content of polyphenols and antioxidant capacity [11].

The objective of this work is to exploit the properties of common bean (*Phaseolus vulgaris* L.) by-products by including them in powder form in new bread products, in order to improve their properties.

MATERIALS AND METHODS

The commercial wheat white flour type 650 (fat: 1.8%; carbohydrates: 68.2%; protein: 11.1%; dietary fiber: 4.5%) was provided by a local supplier. Type 650 flour is the least refined, so it retains most of its nutritional properties. In addition, this type of flour has a greater amount of protein, which is necessary for the development of gluten, so it also has a higher gluten content, which is ideal for elastic doughs. The ingredients for the bread - iodized salt, dry yeast - were purchased at a nearby market. The national water distribution system provided the tap water used.

After being dehydrated for 12 hours at 40 degrees Celsius in the multitray dryer Klarstein, the empty common bean (Phaseolus vulgaris L.) pods (BP) were shred using the Thermomix TM5 food processor and then divided into size classes using the Analysett 3 Spartan sieves. To create the mixtures, the percentage with particles smaller than 20 nm was employed.

The breads were made by varying the amount of empty bean (Phaseolus vulgaris L.) pods powder (BPP) added to wheat flour in proportions of 5%, 10% and 15% (w/w). A control sample (CB) was also prepared without the addition of BPP. Thus, four loaves of bread

formulations were prepared. The recipe of the control sample consists of 500 g of wheat flour, 12.5 g of salt, 15 g of compressed yeast and the amount of water needed to form a dough with optimal characteristics. In bread recipes with added BPP, the wheat flour was replaced by a mixture of wheat flour and 25 g of empty bean pods powder, 50 g and 75 g, respectively. The coding of the bread samples is shown in Table 1.

Table 1 Sample coding

Type	Coding	Wheat flour (g)	BPP (g)
Control sample	CB	500	-
Sample with 5% BPP	BBPP5	475	25
Sample with 10% BPP	BBPP10	450	50
Sample with 15% BPP	BBPP15	425	75

*Empty bean (Phaseolus vulgaris L.) pods powder (BPP)

The dough was made with a KitchenAid Artisan 5KSM7580XEER laboratory mixer. To construct and thoroughly develop the gluten network, all constituents were dosed correctly and mixed for 10 min minutes at 200 RPM. After that, the dough was allowed to ferment for sixty minutes. Following a sixty-minute period, the dough was lightly mixed for thirty seconds before being hand divided into pieces weighing 250g±5g.

The samples were formed, placed into 600 cm^3 rectangular baking molds, and allowed to finish leavening for 30 minutes at 37 degrees Celsius. The Wirlpool 6 scence convection oven was used for baking, and the loaves of bread were baked for 30 minutes at 220 ºC. The breads were weighed and cooled to room temperature before before measuring all parameters. After cooling, the loaves were placed in special bread packaging and stored at 20ºC prior to testing.

The gravimetric method described in ISO 712:2009 [12] was used to determine the moisture content of bread samples. The samples were dried in a drying oven at 130 °C until a constant weight was reached. Samples were weighed in 5 g using an analytical balance into a weighing vial. The weight percentage (%) was used to report the results.

Texture parameters: the mechanical properties of bread were subjected to a double compression cycle using Zwick-Roell Z005 (Zwick, Ulm-Einsingen, Germany). The crumb cubes were subjected to a maximum load of 500 N, 50% penetration depth using a 40 mm diameter probe, and a 20 s interval between cycles. Firmness, or the maximum degree of force during the first compression (N/mm^2), and the deformation (mm) were the parameters analyzed. Measurements were taken 24 hours after baking [13].

pH of the samples was measured using a HALO2 (Hanna Instruments, Inc.) pH-meter. Samples of length, width, and height measuring 1.5 x 1.5 x 1.5 cm from the geometric center of the crumb were obtained for each type of bread in order to determine the porosity [13]. Helium was used as the displacement fluid for the gas pycnometer (Stereopycnometer SPY-3, Quantachrome, Syosset, N.Y., USA) in order to estimate the volume of solids (V_S, m^3). The formula for expressing the solid density (kg/m^3), which is the ratio of dry solids' mass to volume, is as follows: $\rho_s = m_s/V_s$. The following formula was used to estimate the bulk density from the measurement of the real geometrical properties of the bead sample: $\rho_b = m_s/V_b$. The porosity was calculated from the following equation: $P\ (\%) = 1 - \rho_s/\rho_b$.

40 panelists aged 18-60 assessed the organoleptic properties of breads by rating each item on a ten-point hedonic scale for crust color, crumb color, elasticity, porosity, flavor, taste, aftertaste, attractiveness, general acceptability.

Each bread sample was tested in triplicate, and the results were gathered from three separate tests. All data are shown as three-replicate averages, followed by the standard deviation (SD). The significance of mean differences was assessed using one-way ANOVA [14]. Tukey's test (p 0.05) was used to compare mean differences.

RESULTS AND DISCUSSION

The determinations carried out on all the samples of bread gave a series of results which are summarized in Table 2.

Table 2

Sample	Moisture content [%]	Firmness [N/mm^2]	Deformation [mm]	pH	Porosity [%]
CB	38.7±0.9	1011.26±2.07	9.25±0.08	5.55±0.09	73.1±0.02
BBPP5	37.9±0.82	1022.64±1.99	10.27±0.24	5.61±0.11	75.0±0.09
BBPP10	37.6±0.65	1025.43±1.54	10.76±0.31	5.87±0.05	76.3±0.09
BBPP15	37.1±0.32	1027.38±1.23	11.02±0.28	6.02±0.03	77.4±0.08

***** Control sample (CB); Bread with 5% empty bean pods powder (BBPP5); Bread with 10% empty bean pods powder (BBPP10); Bread with 15% empty bean pods powder (BBPP15).

From the analysis of the data in the table above, it can be seen that the moisture content of the samples obtained with different percentages of empty bean pod powder additions was significantly lower compared to the control sample. Thus, the lowest value of moisture content, 4.13% lower than the control sample, was obtained for the sample with 75 g of empty bean pod powder added. The following samples were 2.84% (50 g sample) and 2.07% (25 g sample) less than the control sample. All the percentages of the additions used influenced the moisture retention capacity of the samples obtained, their character being reflected in the results obtained.

The textural features of the loaves of bread are critical for achieving consumer approval. During mastication, the brain assesses the physical characteristics of the food and evaluates its texture. Food texture has a significant impact on consumer like and preference for a food product [15]. Analyzing the figures from the graph in Figure 1, it is clear that the values required to achieve maximum force during initial compression (measured in N/mm2) follow a fairly comparable pattern.

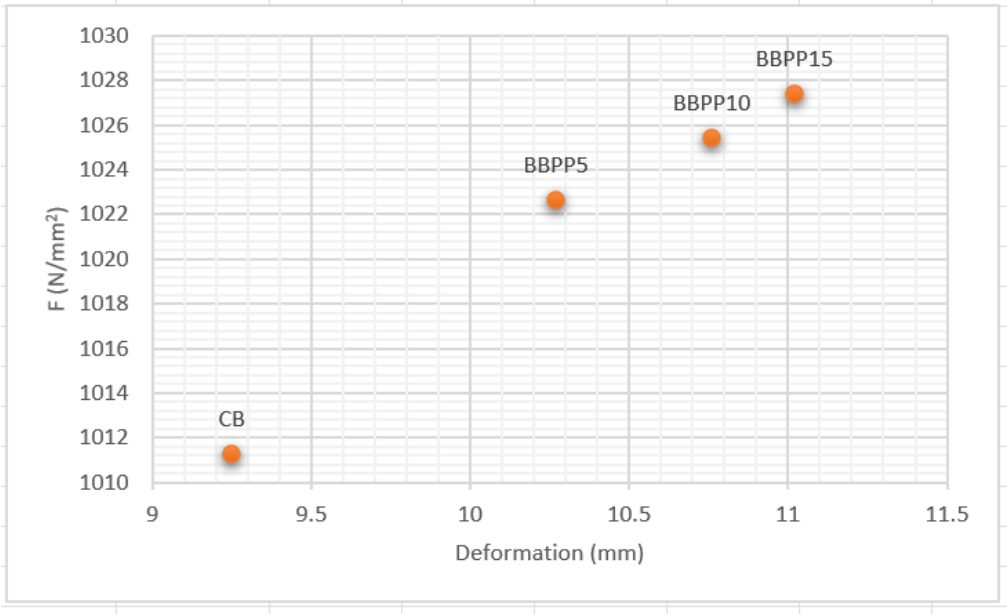


Figure 1 Firmness of the bread samples. Control sample (CB); Bread with 5% empty bean pods powder (BBPP5); Bread with 10% empty bean pods powder (BBPP10); Bread with 15% empty bean pods powder (BBPP15).

The differences were observed for maximum degree of force during the first compression (N/mm^2), the highest value being recorded for sample with the higher amount of empty bean pods powder added – BBPP15 with 15% of empty bean pods powder. The lowest value of the maximum degree of force was recorded for sample containing 5% empty bean pods powder – BBPP15, comparing to the control sample, where the maximum degree of force was lower. The maximum degree of force during the first compression of bread samples with empty bean pod powder added increased by 1.13%, 1.40% and 1.59%, respectively, compared to the control sample. Thus, the results showed that the addition of empty bean pod powder at different proportions of 5 - 15% did not significantly affect the textural profile of the bread.

From the analysis of the data obtained after determining the pH of the samples, it can be seen that the sample with the highest pH was sample BBPP15, with the highest amount of empty bean pod powder - 15%. Moreover, the addition of the three powder components led to high pH values, the bioactive compounds contained in them influencing the values obtained. Compared to the control sample, which has a pH of 5.55, the value obtained in the samples with the addition of 5% of powder from empty bean pods was not significantly different, but the other samples prepared with the addition of 10% and 15%, respectively, were significantly different, which supports the conclusion that the addition of powder from empty bean pods has a definitive effect on the pH of the samples.

After analyzing the data, we saw that the porosity changed according to the amount of BPP added. The higher the dosage of BPP, the more the volume of the bread developed, the larger the pores, and the less the elasticity in the center. Compared to the control sample with a porosity of 73.1%, the samples containing empty bean pod powder exhibited significant variations in porosity. The porosity values were higher by 2.6%, 4.38%, and 5.88%, depending on the amount of powder added. We appreciate that

incorporating powders sourced from vegetable waste yielded a positive impact on the results obtained through the porosity's physico-chemical analysis.

Figure 2 shows the sensory attributes of bread samples with varying percentages of empty bean pod powder, including crust color, crumb color, elasticity, porosity, flavor, taste, aftertaste, attractiveness, general acceptability.



Figure 2 Sensory analysis of the bread samples. Control sample (CB); Bread with 5% empty bean pods powder (BBPP5); Bread with 10% empty bean pods powder (BBPP10); Bread with 15% empty bean pods powder (BBPP15).

The bread with medium BBPP5 empty bean pods powder, to which 5% powder was added, received the highest mean score of 10.00 out of 10, indicating its preference among customers due to its distinctive characteristics. This finding implies that consumers prefer a lower amount of empty bean pods powder in their bread. On the other hand, samples with 15% powder additions were given a lower score of 8.56 points and rejected. The sample BBPP10, which had 10% empty bean pods powder added, received a rating of 9.22 points, slightly lower than the control sample which received 9.89 points.

CONCLUSION

When compared to the control sample, the samples that had varying amounts of empty bean pod powder added to them had substantially less moisture content. The moisture retention capacity of the samples was affected by all of the addition percentages utilized, and the character of the samples was represented in the outcomes. Our results revealed the texture profile of the bread was not considerably altered by the addition of empty bean pod powder in various amounts between 5 and 15%. Moreover, the addition of powder from empty bean pods has a definitive effect on the pH of the samples. In the same time, the porosity changed according to the amount of BPP added. The higher the dosage of BPP, the more the volume of the bread developed, the larger the pores, and the less the elasticity in the center. Sensory analysis shows that consumers might prefer a lower amount of empty bean pods powder in their bread. To conclude, the powders obtained

from vegetable by-products can be used as functional compounds and can partially replace the wheat flour added to make bread.

REFERENCES

[1] A. Tiwari and R. Khawas. Food Waste and Agro By-Products: A Step towards Food Sustainability, Innovation in the Food Sector Through the Valorization of Food and Agro-Food By-Products, IntechOpen, 2021. doi: 10.5772/intechopen.96177.

[2] D. Dey, J. K. Richter, P. Ek, B.-J. Gu, and G. M. Ganjyal. Utilization of Food Processing By-products in Extrusion Processing: A Review, Front Sustain Food Syst, vol. 4, Jan. 2021, doi: 10.3389/fsufs.2020.603751.

[3] Waste Management in the Food Processing Industry. Accessed: Sep. 12, 2023. [Online]. Available: https://www.bioenergyconsult.com/waste-management-in-food-processing-industry/

[4] C. Torres-León et al. Food Waste and Byproducts: An Opportunity to Minimize Malnutrition and Hunger in Developing Countries, Front Sustain Food Syst, vol. 2, Sep. 2018, doi: 10.3389/fsufs.2018.00052.

[5] C. Câmara, C. Urrea, and V. Schlegel. Pinto Beans (Phaseolus vulgaris L.) as a Functional Food: Implications on Human Health, Agriculture, vol. 3, no. 1, pp. 90–111, Feb. 2013, doi: 10.3390/agriculture3010090.

[6] I. Karavidas et al. Agronomic Practices to Increase the Yield and Quality of Common Bean (Phaseolus vulgaris L.): A Systematic Review, Agronomy, vol. 12, no. 2, p. 271, Jan. 2022, doi: 10.3390/agronomy12020271.

[7] K. Kostrakiewicz-Gierałt. Products for Sportspeople Containing Constituents Derived from the Common Bean Phaseolus vulgaris L. (Fabaceae)—A Narrative Literature Review, Sports, vol. 11, no. 11, p. 211, Oct. 2023, doi: 10.3390/sports11110211.

[8] A. H. Nassar, K. A. El-Tarabily, and K. Sivasithamparam. Growth promotion of bean (Phaseolus vulgaris L.) by a polyamine-producing isolate of Streptomyces griseoluteus, Plant Growth Regul, vol. 40, no. 2, pp. 97–106, 2003, doi: 10.1023/A:1024233303526.

[9] I. Amoah, N. Taarji, P.-N. T. Johnson, J. Barrett, C. Cairncross, and E. Rush. Plant-Based Food By-Products: Prospects for Valorisation in Functional Bread Development, Sustainability, vol. 12, no. 18, p. 7785, Sep. 2020, doi: 10.3390/su12187785.

[10] D. Šoronja-Simović, J. Zahorec, Z. Šereš, A. Griz, M. Sterniša, and S. Smole Možina. The food industry by-products in bread making: single and combined effect of carob pod flour, sugar beet fibers and molasses on dough rheology, quality and food safety, J Food Sci Technol, vol. 59, no. 4, pp. 1429–1439, Apr. 2022, doi: 10.1007/s13197-021-05152-y.

[11] R. Miolla, G. Ottomano Palmisano, R. Roma, F. Caponio, G. Difonzo, and A. De Boni. Functional Foods Acceptability: A Consumers' Survey on Bread Enriched

with Oenological By-Products, Foods, vol. 12, no. 10, p. 2014, May 2023, doi: 10.3390/foods12102014.

[12] "ISO 712:2009 Cereals and cereal products – Determination of moisture content – Reference method." Accessed: Sep. 11, 2023. [Online]. Available: https://www.sis.se/api/document/preview/911751/

[13] K. Tsatsaragkou, S. Yiannopoulos, A. Kontogiorgi, E. Poulli, M. Krokida, and I. Mandala. Mathematical approach of structural and textural properties of gluten free bread enriched with carob flour, J Cereal Sci, vol. 56, no. 3, pp. 603–609, Nov. 2012, doi: 10.1016/j.jcs.2012.07.007.

[14] JASP Team, "JASP." 2022. [Online]. Available: https://jasp-stats.org

[15] P. Rayas-Duarte, C. M. Mock, and L. D. Satterlee. Quality of spaghetti containing buckwheat, amaranth, and lupin flours, Cereal Chem. , vol. 73, no. 3, pp. 381–387, 1996.

SECTION

AIR POLLUTION AND CLIMATE CHANGE

ADAPTATION TO CLIMATE CHANGE AND THE INTERPLAY BETWEEN ENERGY EFFICIENCY AND SOBRIETY: LESSONS LEARNED FROM THE ITALIAN EXPERIENCES OF THE L'AQUILA RUGBY ASSOCIATION AND THE COMMUNITY COOPERATIVE OF MELPIGNANO

PhD Gianna Giardini
School of Advanced Studies IUSS PAVIA, **Italy**
University of Camerino, **Italy**

ABSTRACT
In the EU's perspective, energy efficiency is one of the most effective ways to reduce energy consumption and contribute to the fight against climate change. Recent studies have shown that energy efficiency alone is not sufficient to achieve sustainable development goals. The real challenge is to combine energy efficiency with energy sobriety. This work aims at raising a debate about the relationship between energy efficiency and energy sobriety and at studying how the principle of sobriety works. In particular, the objective of this paper is to investigate how the principle of sobriety is expressed in the acts of private autonomy and to show how civil law relationships, inspired by the principle of energy sobriety and thus subject to a positive "control of merit", can contribute to a bottom-up, just and inclusive energy transition and to adaptation to climate change, in accordance with the objectives of the European Green Deal, the EU Adaptation Strategy and, more generally, the UN 2030 Agenda (Goals 7, 11, 13). This paper uses legal institutes and arguments of "civil law and constitutional legality" applied to energy and links them to real-life experiences with a normative approach. The work also has to be considered as the outcome of an empirical analysis of two case studies: L'Aquila Rugby Association, Centre Italy; Cooperativa di Comunità in Melpignano, Southern Italy.

Keywords: energy efficiency - energy sobriety - adaptation to climate change - private autonomy - control of merit - active citizenship

1. INTRODUCTION

1.1. The interest in adaptation and the function of the principle of sobriety in its implementation.

Adaptation is one of the two main strategies identified by the *Intergovernmental Panel on Climate Change* (IPCC) to cope with climate change [1]. This strategy stems from the consideration that the climate system has irrevocably changed and it is necessary to "react" to climate stimuli through a new regulation of ecological, social and economic systems, developing "positive actions", of adaptive nature, to protect the right of people and society to sustainable development [2].

From the legal standpoint, it has been observed that adaptation pertains to the legal sphere of interest [3]. Trying to articulate its content, adaptation is the public and private, collective and individual interest keeping the capacity to satisfy one's needs unchanged. When needs change, as a result of contingent external circumstances, which cannot be controlled and with which people must deal with, the interest in adaptation is expressed through all those manifestations of the will aimed at conforming social reality to the new climatic scenarios [4]. Adaptation to climate change is currently considered a priority on

the political agenda of the European Union, which, consequently, has outlined a precise strategy to forge a climate-resilient Europe through several investments of "systemic nature" which covers the energy sector, agribusiness, land use and the protection of biodiversity, the action plans for the circular economy and zero pollution, the strategy for sustainable and intelligent mobility, and the renewed strategy for sustainable finance [5].
In its regulatory afflatus, the European Union pays particular attention to the energy sector, due to the impact of energy on the climate system. Among the different regulatory actions in the field of energy, with which the European Union plans to "adapt" the electricity market in the new climatic and geo-political scenarios, the proposal for the reform of the electricity market, presented on 14 March 2023 by the European Commission to the European Parliament and the Council and currently being negotiated, is of particular interest[6]. Through this reform, the European Commission, on the one hand, aims to support structural energy efficiency measures with investments in renewable energy sources. Indeed, green energy is perceived as a growth sector that can create jobs, improve the economy, as well as increase the resilience of the electricity system and reduce energy dependency on Third Countries. On the other hand, it plans to empower households and companies, to which it assigns an active role in the electricity market, encouraging the adoption of energy production and exchange models, through peer-to-peer contracts under private law. In the new EU vision, the demand side is reactive to system conditions, using and storing energy when it is abundant, and reducing demand when it is scarce. A major role is given to digital transformation, and in particular to new technologies such as smart meters, which everyone will have to place, to monitor their consumption and direct their actions.
In light of this private empowerment, there is an urgent need to develop behaviour inspired by energy sobriety. Energy sobriety emphasises voluntary actions and aims to develop environmentally friendly behaviour by individuals, companies, public administrations, and associations, useful for minimising the impact of energy use [7].
The IPCC does not define energy sobriety, but gives a definition of sufficiency from which to draw. According to the IPCC sufficiency is "a set of everyday measures and practices that avoid the demand for energy, materials, land and water while ensuring human well-being for all within the planet's boundaries"[8]. In the political arena, indeed, the only example of energy sobriety is the French experience of the Energy Sobriety Plan [9].
From a legal perspective, the principle of sobriety transpires in Article 194 (1) (c) TFEU, according to which the Union's energy policy is intended to promote "energy savings" as an expression of "solidarity" between Member States. Indeed, looking into the Electricity Market Reform Proposal, the principle of energy sobriety is revealed in the new Article 15a, to be inserted in Directive (EU) 2019/944, which introduces "the right to energy sharing". Sharing will lead to new legal relationships in which the parties will be called upon to act moderately (i.e. "soberly") in the execution of the contracts, in order to protect each other's interests in a context of limited energy resources.
Energy sobriety seems to permeate the reforming soul of the European Union. Nevertheless, the concrete applications of the principle of energy sobriety are still little studied from a legal point of view. Therefore, the objective of this paper is to investigate how the principle of sobriety is expressed in the acts of private autonomy and to show how civil law relationships, inspired by the principle of energy sobriety, can contribute to adaptation to climate change.

1.2. Method and theory.

This paper introduces a debate on the legal models with which the principle of energy sobriety is put in place. Moreover, through the analysis of two case studies, it attempts to give its own key to interpretation of the legal phenomenon, finding in the "control of merit" the means by which to assess the sobriety of actions [10]. The work uses legal institutes and arguments of "civil law and constitutional legality"applied to energy and links them to real-life experiences with a normative approach. The work is the result of a collaboration with the Ensiel Consortium - Consorzio interuniversitario per energia e sistemi elettrici and the transdisciplinary research (law and electrical engineering) carried out during the training experience.

1.3. Findings and results.

The work suggests the following theory:
(i) The local level is the basis for adaptation;
(ii) at the local level, private autonomy plays a decisive role in leading society towards adaptation strategies. In the renewed value framework brought about by climate change, adaptation constitutes a specific individual and general interest. In this context, energy sobriety is a principle that characterises the will of acts of private autonomy. A will that leads to the "functionalisation" of the contents of private autonomy acts, also of associations and companies, to purposes of general interest determined by the current needs, characterised by the ongoing climate crisis;
(iii) Sports associations and new forms of mutual enterprises, such as community cooperatives, are suitable legal models for developing forms of local adaptation; on the one hand, by adopting energy-efficient measures; on the other hand, by conforming their acts of will to the principle of sobriety.

2. Energy and Climate Change: the role of private autonomy.

The energy sector remains the main contributor to climate change, producing more than two thirds of greenhouse gas emissions. Consequently, it must innovate to clean and affordable energy production (Goal 7 UN Agenda 2030). Energy affects every aspect of real life, therefore, its renewal can have a transformative function for modern society, socially, economically and environmentally [11].
Alongside the regulatory interventions of the European legislator, private autonomy can play a decisive role in this transformation, on the one hand, by practically implementing energy efficiency measures; on the other hand, by critically conforming its own acts of will to the principle of sobriety.
Energy efficiency is undoubtedly a priority for European policy (*Energy Efficiency First Principle)*, which has been well mapped out through the adoption of a series of regulatory and financial measures, significantly affecting buildings and energy-related products, with the aim of achieving climate neutrality by 2050 [12].
However, political objectives are affected by the interest and will of private autonomy.
In order to achieve them, it is necessary for individuals, companies or associations, to adopt acts and behaviours inspired by energy sobriety, in order to minimise energy use and reduce waste,
Current definitions of sobriety come mainly from sociology, behavioural economics and political experience. The content of energy sobriety remains poorly investigated from a legal perspective and, in particular, through the lens of private law.

Therefore, the question addressed in this paper is: from a private law perspective, how is the principle of energy sobriety implemented and how can it contribute to climate change adaptation?

2.1. Sport as a legal driver of energy sobriety principle in the adaptation era: L'Aquila Rugby Experience.

The result of the research stems from the empirical observation (visits and interviews), with a normative approach, of two Italian experiences which present themselves as private law models inspired by energy sobriety.

The first case concerns the history of L'Aquila Rugby, a sports association, settled in a small province in Central Italy. The association manages a municipally owned sports facility and, during the year 2022, it started a rigorous process of energy efficiency in the facility, thanks to which it drastically reduced its energy consumption, creating new value to reinvest in favour of young members in disadvantaged economic conditions. The association received non-repayable European funding with which it completely renovated the building that houses the stands, changing rooms, storerooms, infirmary and administrative offices. The work, carried out in just 120 days, also involved the roofing of the pitch and the lighting system. A photovoltaic system was installed and, as a result, a new electrical system was built. The association chose to use materials of the highest quality and, above all, suitable to make the building, almost in its entirety, "energy self-sufficient". The pre-eminent value of the new system, however, is invisible: high technology for first-class plant engineering and remote control of both the water and the electrical system.

As a result of the energy efficiency process, energy savings of 60-70 % were estimated. Energy and gas consumption was reduced from around € 60,000 per year to € 15,000 per year. In addition, the beauty and tangible sustainability of the work resulted in an increase of user members by 40 per cent. Moreover, after the renovation, the sports association joined a collaboration with the Faculty of Electrical Engineering of the University of L'Aquila and the EnSiEL Consortium - Consorzio interuniversitario per energia e sistemi elettrici- for monitoring, through remote control systems, the energy consumption of all the facility components. The purpose is to control and measure the consumption of all energy-consuming elements and thus plan their conscious use in the long term (e.g. alternating the switching on of light towers), and also remotely.

The savings and new revenues were allocated to new services. In addition, the financial savings due to lower energy consumption made it possible to help athletes from poor families. The aim of the association is to educate new generations in the concept of care and multidisciplinarity and to make sport accessible to all.

The L'Aquila Rugby experience is the result of an innovative combination of sport and energy. A successful experience whereby sport becomes a vector for the values of energy, ecological and digital transition. Indeed, sport has the innate potential to act as a driver for the dissemination of values, especially among future generations. A union, the one between energy and sport, which also becomes an instrument of inclusion and involvement of the less affluent. It is no coincidence, therefore, that the Italian legislator has recently approved Constitutional Law no. 1 of 26 September 2023, with which, in addition to Article 33 of the Constitution, has recognised "the educational, social and promotion of psychophysical wellbeing value of sporting activity in all its forms"[13]. Sport also receives consideration at European level. For example, the Treaty on the Functioning of the European Union grants the Union a so-called supporting competence

in the field of sport (Art. 6(1)(e)). Furthermore, Article 165(1)(2) TFEU expressly provides that “The European Union shall contribute to the promotion of European sporting issues, while taking account of its specific nature, its structures based on voluntary activity and its social and educational function”. The “considerable social function” of sporting activity has also been recognised by the European Court of Justice (see Bosman judgment, para. 106, Malaja judgment, para. 32). The fundamental right to sport, moreover, finds explicit acknowledgment at international level. Indeed, Article 12 of the UN Covenant on Economic and Social Rights guarantees the right of every individual to enjoy the best conditions of physical and mental health. Similarly, UNESCO has been the promoter of an International Charter on Physical Education and Sport in which, after affirming that “the practice of physical education, physical activity and sport is a fundamental right for all” (Art. 1), it calls on all stakeholders, competent to make choices for sport, to a ‘"strategic vision” (Art. 3) in which "the general principle of economic, social, environmental or sporting sustainability” (Art. 5) is duly taken into account.

In the current climate scenario, as emerges from the experience of the L'Aquila Rugby association, sport fulfills its social function as it communicates the urgency of an energy and ecological transformation and becomes the tool for spreading a culture and education on climate change among future generations. Moreover, it raises awareness on mitigation and adaptation issues, through the care of the places where it is practised. For this reason, the experience of the sports association is undoubtedly a positive example of adaptation to climate change in a transgenerational perspective.

In a broader view, the experience of the L'Aquila Rugby association, in addition to its educational importance for the new generations, reflects the values of “subsidiarity” and “solidarity". On the one hand, it is an experience in which the private sector shares services with the public [14]. On the other hand, it is a manifest expression of solidarity, as it cares for the other and his/her fundamental rights, resulting from the planning and rapid realisation of what is necessary for fostering social welfare [15].

In such a scenario, energy sobriety is shown in the members will to adopt balanced and innovative organisational rules, for the planning of common action, in which the optimal management of energy and the attention to the savings deriving from it, guide the association decisions and create added value not only within the organisation but also towards the society in which it operates [16].

A willingness that, in the current climate scenario, should gradually give way to duty[17]. The climate crisis, in fact, calls for a review of behavioural networks and, more generally, of economic systems and the search for new organisational statutes under private law (associative or entrepreneurial), which are not directed by the mere logic of profit (objective or subjective) but pursue the protection of the environment and people.

The current historical contingencies and the urgency that characterises them impose, in fact, that respect for the principle of sobriety is used, for the future, as a parameter to evaluate the “merit” of associative action. Acts of private autonomy become in essence the subject of a value judgement, which is implemented through a balance between contractual freedom and social welfare. In such a scenario, sobriety, together with the criteria of reasonableness and proportionality, delimits the real meaning of the merit of civil law’s acts, working as a judgement of value that ensures the best realisation of patrimonial rights and, at the same time, other rights such as the full development of the human person, the quality of life and education, health and the healthiness of the environment.

Therefore, sobriety is, on the one hand, an expression of the principle of sustainability, meant as a trade-off between the rational management of natural resources (Art. 191 (1)TFEU) and the balance between the interests of the individual and the present and future interests of the community; on the other hand, it is the implementation of the principle of solidarity, stated by Art. 194 (1) (c) TFEU and by the Italian Constitution in Art. 2, and aimed at the protection of the person [18]. Principle of solidarity, which requires that expressions of private will take into account purposes of general interest. Principally in the current historical context in which issues involving the climate, the environment and energy call for law to sketch a new normative reality, which cannot ignore the irreversible transformations of natural reality and, consequently, the needs of the complex social reality. Sobriety permeates the content of the contract and generates new responsibilities [19].

2.2. Community cooperative as a suitable legal model to support the adaptation to climate change : lesson learned from Melpignano, Apulia Region, Italy.

The second case study concerns the story of the Cooperativa di Comunità of Melpignano, in the South of Italy, Apulia Region.

The cooperation model started from a project called "Photovoltaic on roofs" of the Municipality of Melpignano: an initiative for the realisation of a diffuse system on the roofs of houses in the territory of Melpignano. The Municipality of Melpignano proposed to its citizens to create a Cooperative Community, the first in Italy, composed of citizens - users. The social objective of the cooperative is the construction and management of plants for the production of energy from renewable or alternative sources, their proper use and maintenance, with the attention to environmental compatibility and the natural balance of the territory. This activity has been accompanied by initiatives to publicise, raise awareness and disseminate the use of renewable or alternative energy sources across the society , as well as coordinating, advising and assisting members in finding, purchasing, installing and using plants for the production of energy from renewable sources at the best economic, technical and environmental conditions.

By taking out a loan, the Community Cooperative of Melpignano financed the construction of 28 renewable energy plants on the roofs of 28 user-members. Once the systems were installed, the user-members could benefit from self-consumption. The credits, present and future, deriving from the payment of the support schemes recognised by the Gestore dei Servizi Elettrici to the owner of the plant, were granted to the Cooperative Community as payment for services rendered for the construction and maintenance of the photovoltaic plant. These revenues, in turn, are used by the cooperative to render services to the community. According to the Statute, the ordinary assembly approves the final balance sheet and "allocates the profits". This means that all decisions are taken by the members, who are given the opportunity to manage the services of their community, thus contributing to its growth.

The community cooperative is an atypical legal form of enterprise, not regulated by national law, but exclusively by regional laws, constituting a legal example of regional private law [20].

The community cooperative of Melpignano was established pursuant to Article 2 of Apulia Regional Law No. 23 of 20 May 2014. Its members are committed to invest their energies and skills in activities aimed at pursuing the general interests of the community of reference.

In Italy, community cooperatives are all regulated by regional laws (currently 13 regions have enacted specific regulations on the matter).
By comparing Italian regional laws, it is possible to identify the characteristics of the community cooperative [21]. The purpose of the community cooperative is mainly to meet the needs of the local community, improving its social and economic quality of life through the provision of public services, including local ones, and public utilities, or the recovery of environmental and monumental assets, or the creation of job offers. The community cooperative aims to enhance the skills of the resident population, territorial vocations, and cultural traditions. Therefore, the participation of citizens in the management of common goods is essential. Community cooperatives aim to contribute to sustainable development through the exercise of eco-sustainable economic activities, and, also pursue objectives of social cohesion and solidarity of local communities, especially those characterised by socio-economic hardship and demographic depletion, with particular reference to those located in marginal territories, those located in mountain and inland areas, and also urban areas with social and demographic impoverishment. They tend to respond to unsatisfied community needs, boost the production of goods and services in small local areas and encourage the creation of new employment.
This is undoubtedly a legal business model that guarantees the full enjoyment of citizenship rights and the on-site generation of social capital. Drawing on the words of the Italian Constitutional Court (ruling no. 131 of 20 May 2020), as well as those of the Court of Justice (C-50/14 Casta et al. and C-113/13 Asl no. 5 Spezzino), it is an organisational model inspired not by the "principle of competition" but by the "principle of solidarity".
The regulatory contents of the community cooperative, deduced from a comparison of Italian regional laws, trace the image of the Italian territory. In Italy, according to the 2020 report on the territory, as the most recent survey available, municipalities in inland areas account for 51.4% of the total, and collectively represent 21.9% of the population and about 60% of the national surface area, suffering high levels of depopulation and demographic fragility [22]. They represent the essence of Italian identity, made up of small towns, guardians of an extraordinary heritage of cultural and environmental assets, traditions and manufacturing skills, knowledge and cultures, flavours and quality of agricultural production. Unfortunately, a great part of Italy lives in a condition of strong settlement discomfort, due to the reduction of territorial services - schools, health centres, post offices, commercial activities, school transport, assistance to the elderly.
In this context, the community cooperative constitutes an innovative model of local development that grasps, and tends to mitigate, the needs dictated by the current climatic contingencies. In Italy, it finds its legal basis in Articles 45, paragraph one, 117 and 118, paragraph four of the Italian Constitution. Art. 45 of the Italian Constitution explicitly recognises the "social function" of cooperation with a mutuality character and without private speculation purposes and promotes its development. The social function, in particular, represents the core of the constitutional definition of the cooperative phenomenon and assumes a causal relevance in the cooperative contract, which must act towards a socially useful interest and therefore worthy of protection [23]. Moreover, it is an expression of the principle of horizontal subsidiarity under article 118 of the Constitution because it provides the active participation of individuals in analysing needs and offering services to the community of reference, while pursuing objectives of social and urban regeneration. The community cooperative also reflects the spirit of the new art. 9 of the Italian Constitution, which introduced the environment among the fundamental

values of the Republic, in its transgenerational dimension: in fact, there are immanent values of the past (artistic and historical heritage), of the present (landscape, environment, biodiversity and ecosystem) and of the future (culture, scientific and technical research, future generations).
The picture of Italy as regards inland areas and small municipalities does not differ, however, from the overall picture of the European Union. The Opinion of the European Committee of the Regions - EU strategy for revitalising rural communities (2021/C 37/03) reveals that in the European Union rural and intermediate areas make up 88 % of the territory, and 55 % of the population live in them, 43 % of gross value added is produced and 56 % of jobs are located there. It also shows that rural areas are not homogeneous, but that some of them face major demographic challenges (depopulation, problems of an ageing population, etc.) that hinder their economic and social development. As a result, the Committee proposes an agenda for rural renaissance that must include: the promotion of sustainable and dynamic rural communities, business support, education, training, employment and job creation, urban development that takes into account local demographic realities, improving digital connectivity, public services (health, education, justice, etc.) and infrastructure, maximising the potential of rural tourism in a healthy and diverse natural and agricultural landscape, and harnessing the creativity and cultural potential of rural areas [24].
In this context, community cooperatives, and their purpose, are a model of development that can be replicated across Europe. At European level, community cooperatives currently find their French twin in the *Société coopérative d'intérêt collectif (Société coopérative d'intérêt collectif*) introduced into the French legal system by Law no. 2001-624 of 17.6.2001 and governed by Art. 19 *quinquies* et seq. of Law no. 47/1175 i.e. *Portant Statut de la Coopération,* whose purpose is the production or supply, also to non-members, of goods and services of collective interest, having a social utility function. In the UK, on the other hand, there are *Communities Interest Companies* defined by the UK government as companies that "work for the good of the community'" and provide services by and for communities. To be registered as a CCI, a company must declare how it will benefit society by providing information on the nature of the community interest it intends to pursue [25]. These legal models share with the Italian model of community cooperatives not only the interest underlying the establishment of the company, but also the voting mechanism, whereby each member has one vote, and the prohibition of redistribution of profits, hence the mutualistic character.
Besides being a development model, community cooperatives are also distinguished as an adaptation tool because they grasp community needs from below, also determined by climate change and its effects (e.g. rising energy prices, water shortages, etc.) and are endowed with an entrepreneurial statute that aims to a rational organisation of available resources.
Community cooperatives are also a suitable legal model for the implementation of energy-related projects, especially in light of the new energy market design outlined by the European Union, which seems oriented on making energy a commodity available to the private sector. It is no coincidence that some of the regional laws in Italy (Campania and Piemonte Regions, known for having developed virtuous models of energy communities) have stated the establishment of energy communities precisely in the legislative framework of community cooperatives. In such a scenario, as in the case of associations, sobriety is a principle that must conform to the will of the autonomy acts of the company. Also in this case, sobriety is an indicator of the "merit" of entrepreneurial

action, which is no longer aimed at pursuing purely economic-patrimonial interests of the enterprise but also general ones. Sobriety becomes a parameter of the control of merit of acts and negotiation relationships; a control that implies a value judgement on private activity which, to be considered worthy, must implement a fair balance between the freedom of enterprise and the fundamental rights and interests, both individual and general. Including, on the one hand, the interest in adaptation and a reasonable use of energy resources; on the other, the right to sustainable development, the right to health, the right to a healthy environment, the right of each individual to have access to clean energy.

Therefore, the climate crisis and its consequences call for a market approach that takes social issues into account [26]. This approach finds its foundation in a renewed reading of the duties of social solidarity, which considers worthy all those organisational models that are useful in creating shared value through strategic choices and operational practices aimed at improving competitiveness and at the same time promoting environmental, social and economic conditions in the community in which it operates. The creation of shared value aims at reinforcing the connections between “positive economic results” and “social welfare" and requires the care of a relationship between business actions and the environmental and social context of reference [27].

The legal model, to be transformative, must be based on the principle of solidarity, inclusiveness and well-being, in harmony with nature [28]. In this context, community cooperatives could be a valuable contractual tool with which to implement a transformative energy transition in the European Union, through the revitalisation of local communities, the basis for adaptation.

3. CONCLUSION

The purpose of this paper was to promote a debate on the role and the impact of the principle of energy sobriety in acts of private autonomy. It has been described as a principle conforming to the will to adopt an innovative governance model in which decision-making processes are driven by the optimal planning and management of energy resources giving attention to the savings resulting from it. It enables to get benefits not only within the social structure but also towards the society in which the private entity operates. In a broader view, sobriety is a means through which the principle of sustainability is implemented. In fact, it implies the development of a conscious capability to satisfy one's own needs without compromising the possibility for the present and future community to satisfy its needs.

Basically, through the principle of sobriety there is a functionalisation of private legal relations to the interests of sociality. Private legal relationships become worthy of protection if they are capable of realising the interests of the entire community. Through the principle of sobriety, acts of private autonomy are “conformed" to the interests of society.

To this end, the principle of solidarity, expressed in Article 194(1)(c) TFEU and, in the Italian legal system, in Article 2 of the Constitution, and its dutifulness, becomes a substantial component of decision-making processes. It is a constitutive element of new organisational models of private law, which, due to the serious prejudices suffered by contemporary society, “must contribute jointly to the collective welfare, to the safeguarding of common goods and to the promotion of the general interest (in a word, to a duty of active citizenship)”[29]. The experiences narrated, in fact, show how an active and aware citizenship at the local level, which manages energy in an optimal way,

resorting to particular forms of association or cooperatives, can not only produce environmental, economic and social benefits in the field in which it operates, affirming the role of subsidiarity and solidarity as principles of social justice, but in addition, it is useful to develop new local forms of adaptation to climate change and it is fundamental to achieving an inclusive and just energy transition, in accordance with the objectives of the European Green Deal, the EU Adaptation Strategy and the UN 2030 Agenda.

REFERENCES

[1] IPCC, 2021: *Summary for Policymakers.* In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3-32, doi:10.1017/9781009157896.001.

[2] P. Perlingieri, *I diritti umani come base dello sviluppo sostenibile. Aspetti giuridici e sociologici,* in Id., *La persona e i suoi diritti. Problemi del diritto civile*, Naples, 2005, p. 71 ff.; A. Buonfrate, A. Uricchio, *Trattato breve di diritto allo sviluppo sostenibile*, Cedam, 2023.

[3]Smit, B., Pilifosova, O., Burton, I., Challenger, B., Huq, S., Klein, R., Yohe, G., Adger, WN., Downing, T., & Harvey, E., *Adaptation to climate change in the context of sustainable development and equity* in JJ. McCarthy, O. Canziani, NA. Leary, DJ. Dokken, & KS. White (Eds.), *Climate Change 2001: Impacts, Adaptation and Vulnerability,* Cambridge University Press, 2001, pp. 877-912; Rossi, J., Ruhl, J. B., *Adapting Private Law for Climate Change Adaptation* in Vanderbilt Law Review, 74, 2003, pp. 827-898.

[4] E. Betti*, Interesse (Teoria generale),* in Nuovissimo Digesto Italiano, VIII, Turin, 1962, p. 839; P. Femia, *Interessi e conflitti culturali nell'autonomia privata e nella responsabilità civile*, Naples, Edizioni Scientifiche Italiane, 1996.

[5] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions *The European Green Deal* Com/2019/640 Final.

[6] Proposal for a Regulation of the European Parliament and of the Council amending Regulations (EU) 2019/943 and (EU) 2019/942 as well as Directives (EU) 2018/2001 and (EU) 2019/944 to improve the Union's electricity market design COM/2023/148 final; G. Zachmann et al., *The design of the European Union Electricity Market*, September 2023, available at http://www.europarl.europa.eu/supporting-analyses.

[7] Darby, Sarah & Fawcett, Tina. (2018). *Energy sufficiency - an introduction: A concept paper* for ECEEE. 10.13140/RG.2.2.31198.08006. ascha Samadi, Marie-Christine Gröne, Uwe Schneidewind, Hans-Jochen Luhmann, Johannes Venjakob, Benjamin Best, *Sufficiency in energy scenario studies: Taking the potential benefits of lifestyle changes into account, Technological Forecasting and Social Change,* Volume 124, 2017, Pages 126-134, ISSN 0040-1625, https://doi.org/10.1016/j.techfore.2016.09.013.

[8] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change , above.

[9] https://www.ecologie.gouv.fr/sites/default/files/dp-plan-sobriete.pdf. Gaspard, A., Chateau, L., Laruelle, C., Lafitte, B., Léonardon, P., Minier, Q., Motamedi, K., Ougier, L., Pineau, A., Thiriot, S. *Introducing sufficiency in the building sector in net-zero scenarios for France*, in Energy and Buildings, 2023, p. 278.

[10] P. Perlingieri, *L'incidenza dell'interesse pubblico sulla negoziazione privata,* in *Il diritto dei contratti tra persona e mercato* - Problemi del diritto civile, Naples, Edizioni Scientifiche Italiane, 2003, p. 55 - 69; H.W. Micklitz, *Constitutionalization, Regulation and Private Law in S. Grundmann, H.W.. Micklitz, M. Renner, New Private Law Theory. A Pluralist Approach*, Cambridge University Press, 2023.

[11] Raphael J Heffron & Louis De Fontenelle (2023) *Implementing energy justice through a new social contract*, in *Journal of Energy & Natural Resources Law*, 41:2, 141-155; Van Loon H. (ed), *The Private Side of Transforming our World - UN Sustainable Development Goals 2030 and the Role of Private International Law*, Cambridge-Antwerp-Chicago, 2021.

[12] Directive (EU) 2023/1791

[13] https://www.senato.it/leg/18/BGT/Schede/Ddliter/55068.htm

[14] B. Di Mauro, *Il diritto dei borghi nel PNRR: verso una (stagione di) rigenerazione urbanisticamente orientata alla conservazione e lo sviluppo dei valori locali*, in *Urbanistica e appalti*, 4, 2022, p. 458.

[15] P. Perlingieri, *Il diritto civile nella legalità costituzionale nel sistema italo-europeo delle fonti*, II, 4th ed. Napoli, ESI, 2020.

[16] Arnout Geeraert and Frank van Eekeren (eds.), *Good Governance in Sport*, Routledge, 2022.

[17] E. Caterini, *Sostenibilità e ordinamento civile*, Naples, Edizioni Scientifiche Italiane, 2018.

[18]S. Rodotà, *Il principio di correttezza e la vigenza dell'art. 1175 cod civ*. in BBTC, 1965, I, 149 ff.

[19]M. Pennasilico, *Sviluppo sostenibile e "contratto ecologico": un altro modo di soddisfare i bisogni* in *Rassegna di diritto civil*e, no. 4/2016.

[20] S. Giova, *Ordinamento civile e diritto privato regionale*, Naples, Edizioni Scientifiche Italiane, 2008.

[21] V. Della Croce, *Cooperative di comunità: la legislazione regionale vigente e la prospettiva di una normativa generale*, in *Osservatorio Costituzionale*, 4, 2021, pp. 98-128; F. Bandini, R. Madei, C. Travaglini, *Territorio e persone come risorse: le cooperative di comunità*, in Impresa Sociale, 5, 2015, pp. 19 - 35; G. Capo, Le cooperative di comunità, in Giurisprudenza Commerciale, 4, 2021, p. 616.

[22] ISTAT, Land Report, 2020.

[23] G. TATARANO, *L'impresa cooperativa*, in Tr. Cicu-Messineo, Milan, 2002, 37 ff.).

[24] Opinion of the European Committee of the Regions - EU strategy for revitalising rural communities

[25] Henry Peter, Carlos Vargas Vasserot, Jaime Alcalde Silva (eds), *The International Handbook of Social Enterprise Law Benefit Corporations and Other Purpose-Driven Companies*, Springer, 2023.

[26] L. Vicente, *The Social Enterprise: A New Form of Enterprise*? in *American Journal of Comparative Law*, 1, 2022, pp. 155 - 184.

[27] M.E. Porter, M.R. Kramer, *Creating Shared Value* in *Harvard Business Review*, 89, 2011, pp. 62-77

[28] United Nation, *Global Sustainable Development Report* (GSRD) 2023, available at https://sdgs.un.org/gsdr

[29] S.A. Cerrato, *Appunti per una via italiana all'ESG. L'impresa costituzionalmente solidale (anche alla luce dei nuovi artt. 9 e 41, comma 3, Cost.)*, in *Analisi Giuridica dell'Economia*, 1, 2022, pp. 63-114.

Disclaimer

This paper and related research have been conducted during and with the support of the Italian national inter-university PhD course in Sustainable Development and Climate change at the University School for Advanced Studies IUSS Pavia and at University of Camerino (link: www.phd-sdc.it) Cycle XXXVIII, with the support of a scholarship financed by the Ministerial Decree no. 351 of 9th April 2022, based on the NRRP - funded by the European Union - NextGenerationEU - Mission 4 "Education and Research", Component 1 "Enhancement of the offer of educational services: from nurseries to universities" - Investment 4.1 "Extension of the number of research doctorates and innovative doctorates for public administration and cultural heritage".

ANALYSIS OF METEOROLOGICAL PARAMETERS AND CLIMATE VARIABILITY IN THE WESTERN PART OF ROMANIA IN THE PERIOD 2010-2020

Assoc. Prof. Dr. Ana-Codruta Chis[1]

PhD. Vlad Marazan[2]

Assoc. Prof. Dr. Antoanela Cozma[1]

Assoc. Prof. Dr. Vlad Dragoslav Mircov[1]

Assoc. Prof. Dr. Carmen Claudia Durau[1]

[1] University of Life Sciences "King Michael I" from Timişoara, **Romania**
[2] Politehnica University of Timişoara, **Romania**

ABSTRACT

Through mathematical modeling at the local or regional level, local or zonal trends for meteorological factors can be determined and the main hazards to which elements of the infrastructure, the economy and the population are exposed.

In the present study, a statistical analysis was aimed at trying to determine the analysis of variability and climate change in the western part of Romania and a statistical correlation between the temperature variation and the amounts of precipitation recorded at the Timisoara weather station.

By interpolating the mathematical methods with the observational methods used in operational meteorology, it was possible to establish some correlations regarding the seasons and climatological periods.

It is noted that there is a tendency to shift the cold season from the months of December - January - February to the spring season. Thus, it can be observed from the statistical processing presented, that the winter months for the western part of Romania extend from the third decade of January to the beginning of April. By using several analysis parameters and by integrating all levels of the troposphere (lower, middle and upper), a clear picture can be drawn on the dynamics of the atmosphere and on the influence that the main semi-permanent pressure centers have on the climate variability in the area of western Romania. The interpolation between the statistical analysis and the meteorological analysis revealed significant features in what means the shift from the winter season to the spring months.

Keywords: climate change, regression model, precipitation, temperature.

INTRODUCTION

Romania benefits from a transitional temperate continental climate, very variable. Located in the contact area between the vast platform of Eastern Europe and the inhomogeneous relief of Central Europe, our country lends characteristics to both regions. Thus, the temperate character is given by the existence of the four seasons and an average

annual temperature in the country of 11°C. The continental character is given by the large thermal amplitude between the two extreme seasons (summer and winter) and by the moderate values of the average amounts of annual precipitation, located between 500 and 600 mm. The variable character is highlighted by the changes that occur in the circulation of air masses. The transitional character is explained by the influences of the Mediterranean climate for the south-western part of the country and the continental Baltic climate for the north of Moldova [4].
The specialized studies carried out by the climatology section of the National Meteorological Administration and the Dynamic Climatology Collective of the Institute of Geography of the Romanian Academy [6] indicates that during the period 1901-2005 a significant warming at the average annual level was evident in most regions. This warming of 0.5° Celsius, with higher values in the northern regions, on the coast and at some stations in western Romania (approximately 0.7° Celsius).
At the level of the transitional seasons and during the winter, although the trend is towards warming throughout the country, with an average of 1.0° Celsius per country, this is significant in the area of the Extracarpathian arc, where the values are between 0.9° and 1.6° Celsius.
For the period 1961-2007, a more intense warming signal is noted, this being significant throughout the country during the summer, the average reaching 1.7° Celsius per country, with high values in the west and southwest of the country. This last aspect is also one of the reasons why the research focuses on the western area of Romania.

MATERIALS AND METHODS

In the case of the present work, data from the meteorological archive of the Timişoara station were used. The location of the Timişoara meteorological station in the north-eastern area of the city, near the Green Forest and in an open space allows the recording of values with a precision in accordance with the requirements of the World Meteorological Organization. The reference period chosen is eleven years, i.e. the period 2010-2020.

The meteorological parameters used in this paper are the basic ones, namely the minimum temperature, the maximum temperature, the average temperature and the amount of precipitation. The data were structured as monthly averages for each of the eleven years, resulting in a stream of 528 data that were subjected to statistical analysis.

Descriptive statistics elements were calculated for the variables considered in the study (mean, minimum value, maximum value and standard deviation). Kruskal Wallis and Mann-Whitney statistical tests were applied to determine significant differences. To determine the links between variables, linear correlation coefficients were determined. The statistical analysis was performed using the statistical software IBM-SPSS 20.

RESULTS AND DISCUSSION

The precipitation recorded during the analyzed period varied between the minimum of 0.11 mm in 2018 and the maximum of 147.34 mm in 2012 in the case of August. It is also observed that there were some other high values, namely 134.38 mm in July 2018, 134.33 mm in 2017, and the minimum of the annual averages was recorded in 2018, which was 33.98 mm, and the maximum of 63.02 mm in year 2012 (Figure 1).

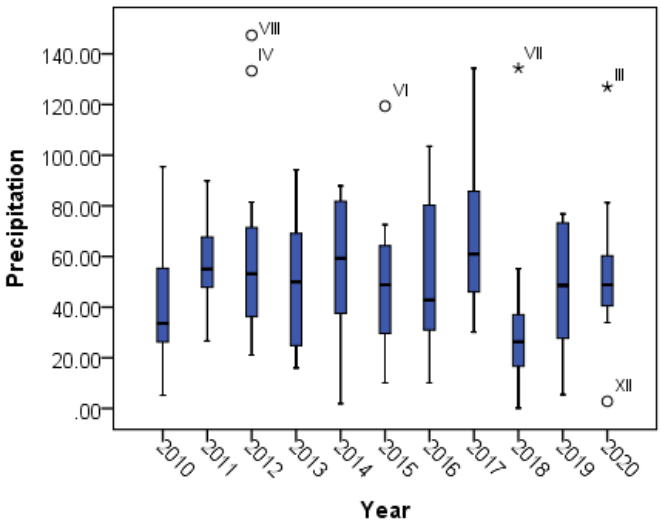


Figure 1. Box-plot diagrams associated with annual precipitation recorded in the period 2010-2020

The maximum monthly precipitation average was recorded in May, with a value of 67.83 mm, and the minimum in January with a value of 40.26 mm, so that the driest month is January and the month in which the most precipitation is the month of June (Figure 2).

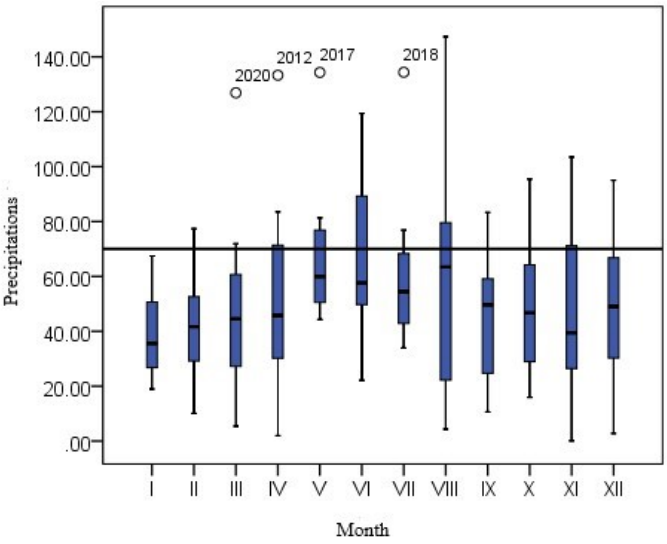


Figure 2. Box-plot diagrams associated with monthly precipitation in the period 2010-2020

The month of January is characterized, in general, from a climatological point of view, as the period when air masses of polar origin enter the territory of Romania and produce temperature drops, and their continental character does not produce moisture transport.
The month of May, on the other hand, is characterized by strong intrusions of maritime air masses, rich in moisture, and atmospheric instability is precisely due to the coupling of air masses specific to continental areas and coastal areas. The formation of convective structures practically reaches a maximum during May in relation to the spring period.
The minimum temperatures recorded during the studied period range from 9.94 °C in 2010 to 17.37 °C in 2019, and the average of the minimum temperatures was 6.04 °C (Figure 3). Applying the Kruskal Wallis test, it is observed that there are significant differences between the minimum monthly temperatures recorded during the studied

period (χ^2= 124.022, p = 0.000 < 0.05). The determination of significant differences between monthly minimum temperatures was done by applying the Mann-Whitney test and insignificant differences were obtained between the months in table 1.

Table 1. The Whitney test applied to monthly minimum temperatures

Luna i vs Luna j	I vs II	III vs XI	IV vs X	V vs IX	VII vs VIII
U	52	36	53	49	44
p	0.577	0.108	0.622	0.45	0.279

The minimum average temperature recorded was -5.95°C in 2019 and the maximum average value was 23.79°C in 2010 (Figure 3). The minimum of maximum temperatures recorded was -1.52°C in 2019 and the maximum was 32.24°C also in 2019 (Figure 3).

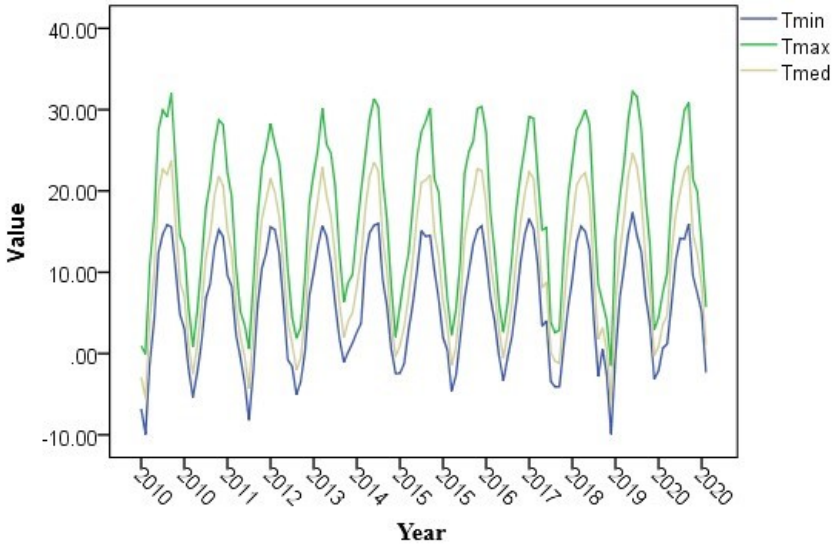


Figure 3. Evolution of temperatures in the period 2010-2020

Applying the Kruskal Wallis test, it is observed that there are significant differences between the maximum monthly temperatures recorded in the studied period (χ^2= 124.318, p = 0.000 < 0.05). The determination of significant differences between monthly maximum temperatures was done by applying the Mann-Whitney test and insignificant differences were obtained between the months in table 2.

Between December and January there is a significant difference in terms of the maximum annual temperatures recorded, the average value of the maximum temperatures in December exceeding the average maximum values of January (U=25, p=0.039<0.05), (Figure 4).

.

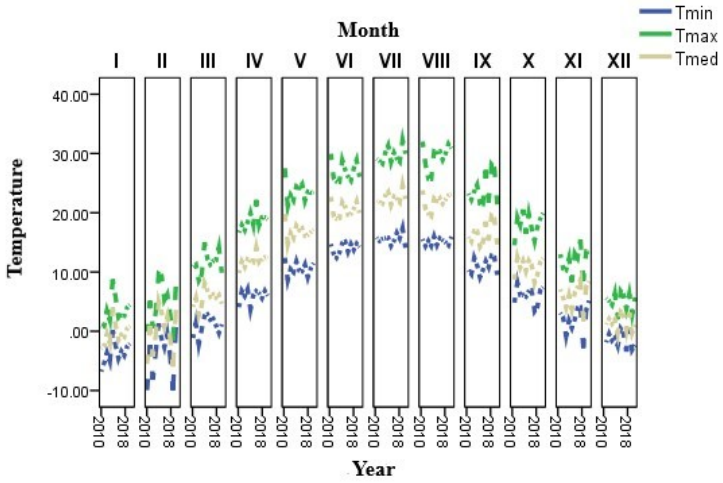


Figure 4. The evolution of temperatures during 2020-2020 depending on the month in which they were recorded

Table 2. The Whitney test applied to maximum monthly temperatures

Luna i vs Luna j	I vs II	III vs XI	IV vs X	V vs IX	VII vs VIII
U	49	49	50	59	54
p	0.478	0.45	0.491	0.992	0.67

The linear correlation coefficient R = 0.982***(p=0.000) between the minimum temperatures and the maximum temperatures shows us that there is a direct, significant connection between these variables (Table 3).

Table 3. Regression coefficients for the regression model between minimum temperatures and maximum temperatures

Model		Unstandardized Coefficients		Standardized Coefficients	t	p-level	Significance
		B	Std. Error	Beta			
1	(Constant)	9.180	0.211		43.487	0.000	***
	Tmin	1.327	0.023	0.982	58.547	0.000	***
a. Dependent Variable: Tmax							

R = 0.982***(p=0.000); Significance for the test t: ns p>0.05; * p≤0.05; ** p≤0.01 ; *** p≤0.001

The statistical analysis shows that there is a weak, statistically significant positive correlation between precipitation and maximum temperatures R = 0.239** (p = 0.006 < 0.01) (Table 4).

Table 4. Regression coefficients for the regression model between precipitation and minimum temperatures.

Model		Unstandardized Coefficients		Standardized Coefficients	t	p-level	Significance
		B	Std. Error	Beta			
2	(Constant)	3.071	1.219		2.519	0.013	*
	Precipitații	0.057	0.020	0.239	2.803	0.006	**
a. Dependent Variable: Tmin							

R = 0.239**(p=0.006<0.01); Significance for the test t: ns p>0.05; * p≤0.05; ** p≤0.01 ; *** p≤0.001

CONCLUSION

From the point of view of the volume of precipitation recorded during the studied period, the minimum of the annual averages was reached in 2018 and the maximum of the annual averages in 2017, with a maximum variability in the year 2012.

The climate change process is a normal one as long as there is a certain period that can compensate for another extreme period. Thus, if in 2010 there were lower amounts of precipitation compared to the climatological norm, in 2017 the amounts were above the climatological norm, and the balance was restored to some extent.

During the warm season, hailstones with a diameter of over 5 cm, gusty wind speeds of over 120 km/h and quantitatively significant precipitation were observed. It should be noted that torrential rainfall does not have a beneficial role in the field of agriculture either.

The minimum annual temperature average was recorded in 2012 and the maximum in 2020.

The statistical analysis showed the variations in temperature and precipitation recorded during the studied period, observing a shift towards the spring months of the cold season from December-January-February. Thus, years were recorded when the periods with low temperatures were those from the third decade of January to the first decade of April.

ACKNOWLEDGEMENTS

This research paper is supported by the project Institutional Development Fund (FDI), domain 6, by National Council for the Financing of Higher Education(CNFIS), CNFIS-FDI-2023-F-0307.

REFERENCES

[1] Bojariu, R., Bîrsan, M. V., Cică, R., Velea, L., Burcea, S., Dumitrescu, A., Dascălu, S. I., Gothard, M., Dobrinescu, A., Cărbunaru, F., Marin, L. 2015. Schimbările climatice – de la bazele fizice la riscuri şi adaptare, Editura Printech, București.

[2] Bojariu, R., Cica, R., Velea, L., Turcus, C. 2013. Heatwave risks in urban area – a case study for Arad municipality in Romania. EGU General Assembly Conference Abstracts.

[3] Bojariu, R., Dinu, M. 2007. Snow variability and change in Romania. Proceedings of the Alpine Snow Workshop, Munich, 5-6.10.2006, 64-68.

[4] Boroneanţ, C., Rîmbu, N. 1992. Some aspects of temperature regime as appearing at some representative stations in Romania. Meteorology and Hydrology, Vol. 22, No. 2, 17-21.

[5] Burada, C. 2013. Variabilitatea climatică în Oltenia în corelație cu tipurile de circulație atmosferică la scară sinoptică, București.

[6] Busuioc, A., Caian, M., Cheval, S. 2010. Variabilitatea şi schimbarea climei în România, Editura ProUniversitaria, București.

[7] Cuculeanu, V. 2003. Impactul potențial al schimbării climei în România, Editura Ars Docendi, București. .

[8] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

[9] Mărăzan, V. 2018. The management of severe meteorological events, Editura Eurostampa, Timişoara.

[10] Staniforth, A. 2022. Global atmospheric and oceanic modelling, Cambridge University Press, Cambridge.

[11] Trenberth, K. 2022. The changing flow of energy through the climate system, Cambridge University Press, Cambridge.

[12] World Meteorological Organization. 2017. World Meteorological Organization Guidelines on the calculation of climate normal, Berna.

CLIMATE CHANGE MITIGATION APP FOR SUSTAINABLE CITIES USING URBAN GREEN DATA FOR CO_2 ABSORPTION

Papagiannopoulou, Dimitra[1]

Prof. Dr. Tsitsoni, Thekla [2]

Prof. Dr. Andreopoulou, Zacharoula[3]

Xanthopoulou, Tsitsoni Vasiliki [4]

MSc. Morfopoulos, Nikolaos[5]

[1 2 3] School of Forestry & Natural Environment, Aristotle University of Thessaloniki, **Greece**

[4] School of Economics, Aristotle University of Thessaloniki, **Greece**

[5] MSc Chemical Engineer, Aristotle University of Thessaloniki, **Greece**

ABSTRACT

Sustainable cities are urban center engineered to improve their environmental impact through proper urban planning and management. The implementation of green infrastructures is one of the most important characteristics in sustainable cities. Urban green areas play a basic role in the socio-economic development and in the sustainability of the cities. Climate change is one of the factors that needs to be into consideration during the design of sustainable cities, as it constitutes a major problem that humanity has to face. Urban green areas could contribute to mitigate the effects of climate change to cities' adaptation to these effects. Information and Communication Technologies (ICTs) have an important role in addressing the major challenges related to climate change and sustainable development. They are tools that can be used for the monitoring of climate change, such as the absorption of CO_2 by urban trees, the mitigation of its effects contributing to the development of the urban green economy. These tools promote new improved relationships between cities and natural environment. Main aim of this paper is to provide the CO_2 absorption by urban green areas taking into account the data that entered in the online application which was constructed in the framework of the European project LIFE CliVut (Climate Value of Urban Trees) LIFE18 GIC/IT/001217.

Keywords: urban green areas, sustainable cities, CO_2 absorption, ICTs

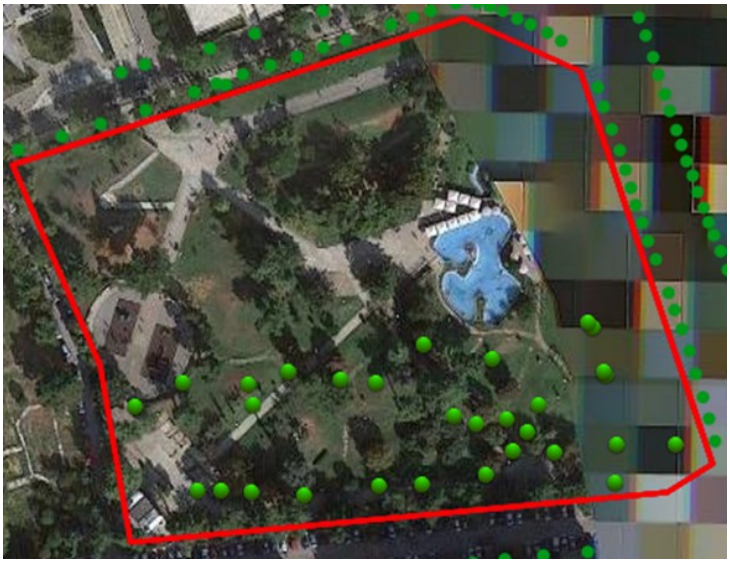
INTRODUCTION

The world is undergoing the largest wave of urban growth in history. Almost above the half of the world population lives in urban regions while by 2030 the urban population is expected to be twice as large as the corresponding rural [1]. Taking into account the urbanization, the design management of cities must change. The cities must be more sustainable than today. So, in proper management of cities urban green spaces need to be

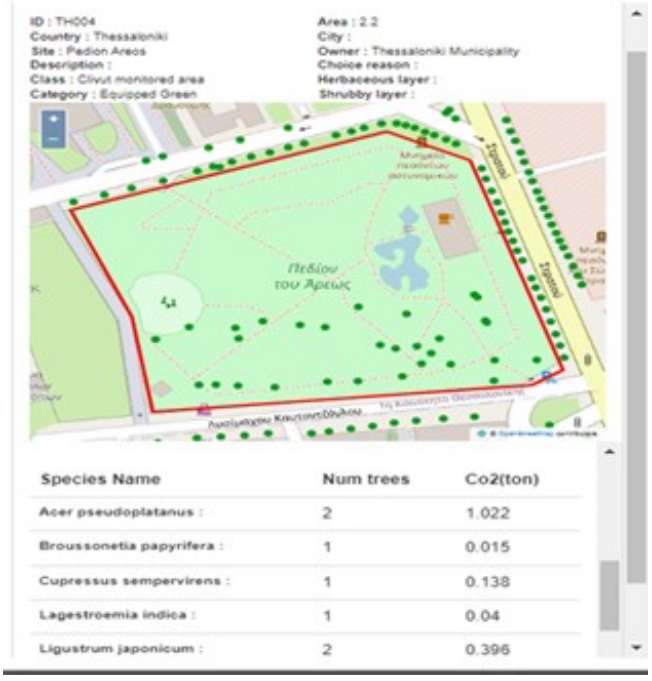
considered green assets [2]. A major problem that globally has to be faced is the climate change and mostly what deals with global warming. Climate change refers to any significant change in the measures of climate lasting for an extended period of time [3]. Urban trees and green spaces can mitigate the impacts of climate change through the absorption of the C that takes part in greenhouse gases through their role as carbon sinks. So, urban trees can decrease CO_2 emissions [4]. Green IT is a part of IT science that is known for its use in the context of the natural environment and natural resources. It takes into consideration sustainability [5]. ICTs in urban planning include methods that help to management and design of urban areas [6]. According to the proposed Sustainable Development Goals (SDGs) by United Nations, countries have long considered the establishment of sound policy to deal with climate change [7]. ICTs are tools for green energy as it is correlated to low carbon emissions as they can mitigate the effects of climate change through environmental monitoring. They are also making decision tools [8]. The traditional planning models did not concern as a basic factor environmental protection [9]. In recent years, new approaches that are based on the ecosystem services have been considered as an alternative planning model [10]. A web database was constructed in the framework of a European project, LIFE CliVut project. The LIFE CliVut project (LIFE18 GIC/IT/001217) is coordinated for Greece by the Department of Forestry and Natural Environment of the Aristotle University of Thessaloniki. One of the objectives of the project is to mitigate the impact of climate change. The project partners are the University of Perugia, the Municipalities of Bologna and Perugia, the Italian Institute CESAR and the Portuguese Institute ISG. In this online database, dendrometric characteristics such as tree height and breast diameter are entered. Then, it extracts results correlated to the absorption of CO_2. This digital application is a modern decision tool that contributes to the creation of sustainable cities.

Material and Method

In the framework of LIFE Clivut project a digital database (a digital inventory) was created for 10 urban green spaces (Census Areas) in Thessaloniki. The tree database includes data related to tree and shrub inventory, dendrometric characteristics such as tree height, breast diameter from 10 urban green areas in Thessaloniki. The 10 urban green areas were selected as they have special importance for the city and its inhabitants. In this paper, the results of two from ten areas are presented. The first Census areas is called Pedion Areos Park is characterized as a neighborhood park approximately 3 ha and is located on the eastern edge of the historic city center (Picture 1 and 2). The second one is called Nea Helvetia Park, and is also characterized as a metropolitan park, is 4 ha and is located in eastern Thessaloniki (Picture 3 and 4). The Census areas are shown in Table 1. This online application extracts results about PM10 absorption, CO_2 absorption. Georeferenced data referring to the urban green asset is also available. In the digital inventory qualitative and quantitative information was included. The dendrometric characteristics that were measured for the trees and shrubs in the census areas are shown in Table 2. The first page of the LIFE Clivut database is shown in Picture 3.



Picture 1. Pedion Areos Park. A Census Area in Municipality of Thessaloniki. Censused urban trees are shown in green.

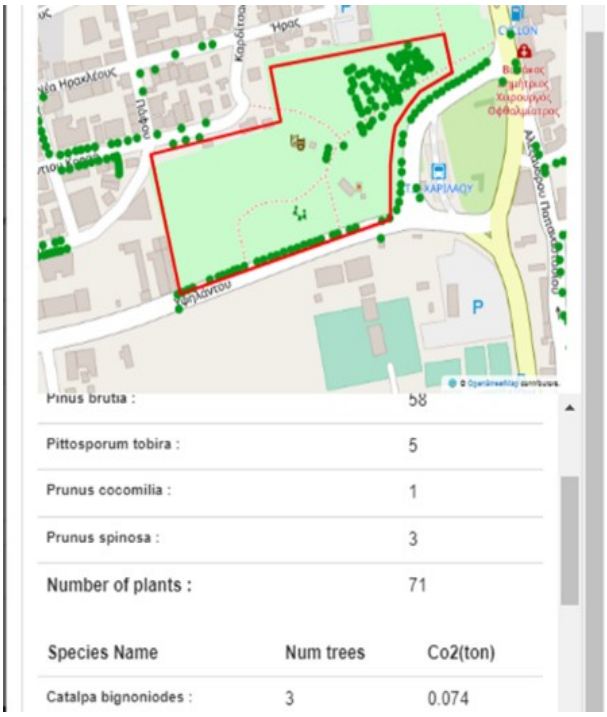


Picture 2. Detail Page in LIFE CLIVUT tree database from Pedion Areos Park. This page shows number of trees in this area, CO_2 absorption by urban trees in tons.

https://doi.org/10.5593/sgem2023V/4.2/s19.17



Picture 3. Nea Helvetia Park. A Census Area in Municipality of Thessaloniki. Censused urban trees are shown in green.



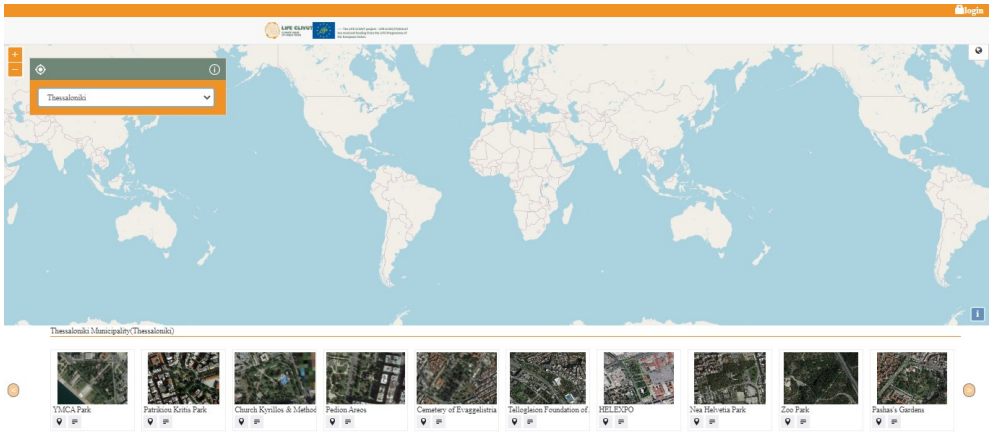
Picture 4. Detail Page in LIFE CLIVUT tree database from Nea Helvetia Park. This page shows number of trees in this area, CO_2 absorption by urban trees in tons.

Table 1. 10 Census Areas in Thessaloniki. The dednrometric characteristics of urban trees were measured in these urban green spaces.

Number	Site Name	Owner	Category (ISI_2001)	Area (ha)
1	**YMCA Park**	Thessaloniki Municipality	Equipped Green, Urban Parks	4.30
2	**Patrikiou Kritis Park**	Thessaloniki Municipality	Equipped Green	0.64
3	**Church of Kyrillos & Methodios**	Thessaloniki Municipality	4. Gardens	0.93
4	**Floral Exhibition Park (Pedion Areos)**	Thessaloniki Municipality	Equipped Green	3
5	**Cemetery of Evaggelistria**	Thessaloniki Municipality	Cemeteries, Historic Green	2.99
6	**Tellogleion Foundation of Art (Gallery)**	Aristotle University	Gardens	3.02
7	**Helexpo**	Helexpo	Gardens	1.91
8	**Nea Helvetia Park**	Thessaloniki Municipality	Equipped Green, Urban Parks	4
9	**Zoo Park**	Forest Service	Zoo	4.78
10	**Pashas's Gardens**	Thessaloniki Municipality	Urban Parks, Historic Green	2.45

Table 2. Dendrometric characteristics are shown in this table and evaluation. In each area, tree species were identified, height, crown height and breast diameter were measured. Tree health data were evaluated for each tree.

Tree Species	Tree Location	Height
Crown height	Breast height diameter	Tree health data



Picture 3. LIFE Clivut tree database-Homepage. Ten Census Areas in Municipality of Thessaloniki.

RESULTS

30 urban trees in Park Pedion Areos absorb 18 tons of CO_2 and 71 urban trees in Nea Helvetia Park absorb 39 tons of CO_2. Urban green spaces are basic components of a city as they provide several ecosystem services. Urban trees play an important role in adoption of cities to climate change via their role as carbon sinks. In total, 101 urban trees absorb 57 tons of CO_2. According to Papagiannopoulou et. al. 2019, 638 urban trees in Thessaloniki absorb 159.5 CO_2. Tsitsoni et. al. [11] found that 38000 street trees absorb 11010 tons of CO_2 (6000 tons of C).

CONCLUSIONS

The conclusions are shown below:

Urban trees in urban green areas can sequestrate larger amounts of CO_2 compared to street trees, because they have more growth space than street trees have and they do not subject to intense interventions [12].

ICTs through their role as making-decision tools help to monitor and analyze short- and long-term climate trends, contribute to the protection of the environment and the reduction of carbon emissions.

Information technology can also be used to increase sustainability, by providing tools and systems for tracking and managing environment. This can reduce the environmental impact of human activities and enhance public health.

REFERENCES

[1] Samara T. and Tsitsoni T. (2010). The effects of vegetation on screening road traffic noise from a city ring road. *Noise Control Engineering Journal*, 59 (1): 68-74.

[2] Höjer, M. and Wangel, J. (2014). Smart Sustainable Cities: Definition and Challenges. In book: *ICT Innovations for Sustainability* Edition-Publisher: Springer.

[3] United States Environmental Protection Agency, (2014). Glossary of Climate Change Terms. http://www.epa.gov/climatechange/glossary.html#Climate_change (Accessed in 25-12-2020).

[4] Shashua-Bar L. Hoffman M.E., 2000. Vegetation as a climatic component in the design of an urban street: an empirical model for predicting the cooling effect of urban green areas with trees. *Energy and Buildings*, 31(3): 221-235.

[5] Andreopoulou, Z., Papagiannopoulou D., Tsitsoni, T. (2023). Online *app for the evaluation of climate change impact in urban green areas.* Proceedings of the 21st International Conference on e-Society 2023, Portugal, 485-488.

[6] Al-Douri, F.A. (2022). How information and communication tools (ICT) affect the processes and decision-making in professional urban design practice?, *URBAN DESIGN International* [Preprint]. Available at: https://doi.org/10.1057/s41289-022-00196-8.

[7] N'dri, L. M., Islam, M., & Kakinaka, M. (2021). ICT and environmental sustainability: any differences in developing countries?. *Journal of Cleaner Production*, 297, 126642.

[8] Andreopoulou, Z., (2016). Green ICTs for Climate Change Mitigation and Energy Sustainability: EU Challenge. Calitatea, 17(S1), p.492.

[9] Ronchi, S., Arcidiacono, A. and Pogliani, L. (2020). Integrating green infrastructure into spatial planning regulations to improve the performance of urban ecosystems. Insights from an Italian case study. *Sustainable Cities and Society*, 53.

[10] Pantaloni, M., Marinelli, G., Santilocchi, R., Minelli, A., Neri, D. (2022). Sustainable Management Practices for Urban Green Spaces to Support Green Infrastructure: An Italian Case Study. *Sustainability*, 14(7): 4243.

[11] Tsitsoni, T., Gounaris, N., Kontogianni, A., Xanthopoulou-Tsitsoni, V. (2015) Criteria and Indices for a holistic evaluation of Urban Greening. Greece 2015.

[12] Papagiannopoulou, D., Tsitsoni, T. and Kontogianni, A. (2019). The Contribution of the Park Trees to the Adaptation of a City to Climate Change. The Case of Thessaloniki. www/sustainablemediterraneanconstruction.eu, No. 10 (Accessed in 01-12-2023).

CLIMATE CHANGE VULNERABILITY, MITIGATION, AND ADAPTATION FOR A LARGE INFRASTRUCTURE PROJECT IN ROMANIA

Dr. Raluca Ioana Nicolae[1]

Drd. Petru Nicolae[1]

[1] GEOSTUD SRL, **Romania**

ABSTRACT

The increasing impacts of climate change have necessitated a comprehensive reassessment of large infrastructure projects, particularly highways, to ensure their resilience and sustainability. The article focuses on the analysis of climate change vulnerability, mitigation measures, and adaptation strategies within the context of a major highway project in Romania.

With climate change accelerating, highways in Romania are becoming increasingly vulnerable to extreme weather events, shifting precipitation patterns, temperature fluctuations, and related environmental changes. The paper highlights key findings from vulnerability assessments, emphasizing the project's exposure to climate-induced risks and its implications for the highway's infrastructure.

Mitigating the impact of climate change is a fundamental objective for this highway project. The article discusses mitigation efforts, which include minimizing greenhouse gas emissions during construction and operation phases, incorporating sustainable construction materials, and adopting energy-efficient technologies and practices. These measures align with Romania's commitment to reducing its carbon footprint. Also, the paper outlines adaptation measures, such as engineering design solutions to withstand extreme weather events, the integration of flexible design elements, and the establishment of climate monitoring and early warning systems to mitigate disruptions.

In conclusion, the article underscores the urgency of integrating climate change vulnerability assessments, mitigation measures, and adaptation strategies into the planning and construction of highways in Romania. By adopting a comprehensive approach that addresses climate-related challenges, this highway project aims to contribute to a sustainable, resilient, and environmentally conscious transportation network for the country.

Keywords: climate change, infrastructure, mitigation, adaptation, vulnerability

INTRODUCTION

By signing the Kyoto Protocol (1997) and the Paris Agreement (2015), the European Union committed to participating in the global effort to reduce greenhouse gas emissions. In line with the obligations undertaken by all signatories, the EU aims to reduce its greenhouse gas emissions by 40% by 2030 and by 80-95% by 2050 [1]. Romania's National Strategy on Climate Change 2013-2020 [2] addresses this issue in two distinct ways: reducing greenhouse gas emissions to meet national targets and

adapting to the effects of climate change in accordance with European Union policies and relevant European-level documents. Resilient transportation to climate change entails sustainable infrastructure, including roads and bridges that can withstand extreme temperatures and flooding, addressing challenges such as infrastructure damage, speed restrictions, and unforeseen maintenance costs caused by the effects of climate change. The current climate-related concerns necessitate a shift in the calculation approach for transport infrastructure design by introducing more cautious correction indices related to bearing capacity of the foundation soil, buoyancy coefficient, materials, and equipment used in transportation infrastructure construction, among others.

The article presents an assessment of vulnerability to climate change as well as a series of measures for mitigating and adapting to its effects for a highway project in Romania. With a length of 93,269 km and a project-defined occupied area of approximately 1932 ha, the Târgu Neamț – Iași – Ungheni highway is part of the Trans-European Transport Network (TEN-T) and is also included in Romania's General Transport Master Plan. The territory of Iași county, where the project is located, falls within the zone of pronounced temperate continental climate, influenced by the Atlantic and Euro-Asian anticyclones. Against the backdrop of the overall temperate continental climate due to the county's location and the distribution of solar radiation globally, dynamic factors, through their actions over time and spatially specific manifestations, contribute to its classification in the climatic sector with aridity influences.

MATERIALS AND METHODS

To conduct a detailed assessment of the project's vulnerability to climate change, existing long-term meteorological data and studies on regional climate models were utilized. Additionally, climate maps for the specific area and future climate projections were employed. Data related to the project's infrastructure, including construction materials and techniques, were also taken into account in the assessment. The vulnerability assessment represents the integrated result of two distinct analyses: the sensitivity of the project's main components to the effects of climate change (sensitivity) and the probability that these effects will impact the project both presently and especially in the future (exposure) [3]. The vulnerability classification matrix, composed of an overlay of sensitivity and exposure elements, is presented in Table 1.

High and extreme vulnerability to climate risks imply a significant impact on the highway's components, while medium vulnerability to climate risks suggests a lower impact that necessitates the implementation of risk mitigation measures. A set of relevant variables has been identified for the project's location, taking into account the specific nature of the planned project (road infrastructure) and the characteristics of the project implementation area. Table 2 presents the current status and trends of the variables considered, with the analysis conducted using territorial maps and existing climate data. An example of such a map is depicted in Figure 1.

Table 1. The vulnerability (V) classification matrix

			Sensitivity (S)				
			without	low	medium	high	extreme
			1	2	3	4	5
Exposure (E)	without	1	1	2	3	4	5
	low	2	2	4	6	8	10
	medium	3	3	6	9	12	15
	high	4	4	8	12	16	20
	extreme	5	5	10	15	20	25

Legend

Vulnerability	without	low	medium	high	extreme
Range	1-3	4-6	7-10	11-16	>17

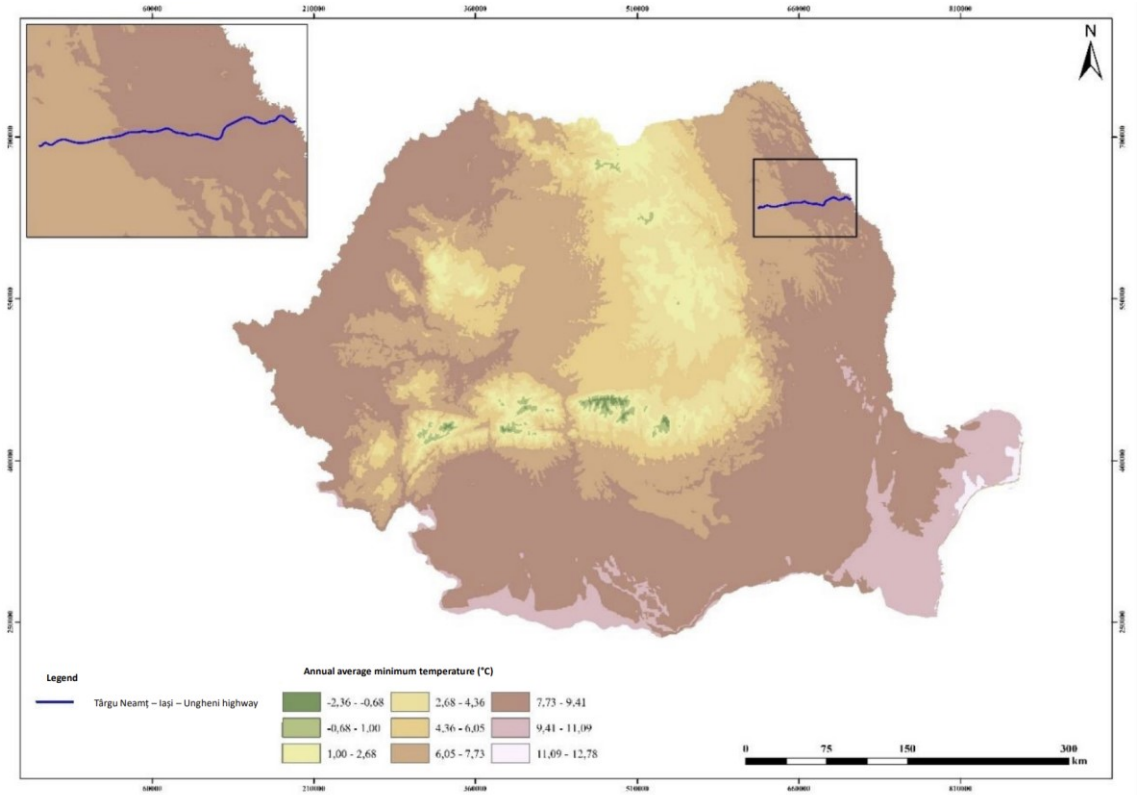


Figure 1. Average minimum temperature values for the year 2050 at national level

Table 2. Summary of the main trends in the project area's key variables

No.	Variable	Present	Trend	
1	Annual average maximum temperature	11,8-13°C	2050: 16,2-20°C	↑
2	Annual average minimum temperature	3,5-9°C	2050: 6-9°C	↑
3	Annual average precipitation	530-630 mm/year	2050: 480 - 580 mm/year	↓
4	Floods	The project intersects 7 zones of 1% floodplain	Constant	→

https://doi.org/10.5593/sgem2023V/4.2/s19.18

		and 7 areas of 1% flood hazard.		
	Fog	The analyzed zone exhibits favorable characteristics for the formation of fog.	The current exposure is considered high, while the future exposure is considered moderate.	↓
5	Soil erosion	Approx. 730-900 mm/year	2050: mainly 730-900 mm/year	→
6	Landslides	Moderate to high risk	2050: Major geotechnical risk in some areas, due to both challenging soils (loess deposits, expansive soils) and steep slopes (sloping terrain with landslide potential).	↑
7	Wind speed	Mainly 0,7 kPa	2071-2100: 0,5 kPa	↓
8	Snow load on the ground	2,5 kN/m^2	2050: It will decrease, correlated with rising temperatures and reduced precipitation.	↓
9	Maximum frost depth	Mean value of 95 cm	Constant	→
10	Vegetation fires	With mainly low risk	Constant	→
11	Earthquakes	Peak ground acceleration values for design ag = 0.25g, for earthquakes with the average recurrence interval ARI = 100 years.	Constant	→

RESULTS

The project's vulnerability to climate change has been analyzed from both current and future perspectives (Table 3). The most unfavorable scenario has been considered to anticipate possible phenomena.

Table 3. Assessment of the project's vulnerability in relation to the analyzed variables, under present (p) and future (f) conditions

No.	Variable		S		E		V (SxE)	
			p	f	p	f	p	f
1	Temperature	Increase in the number of days with extreme high temperatures	2	3	3	4	6	12
		Increase in the number of days with extremely low temperatures	2	2	3	3	6	6
2	Precipitation	Extreme heavy precipitation	3	4	3	4	9	16
		Floods	3	4	3	4	9	16
3	Wind regime		2	2	2	2	4	4
4	Soil erosion and landslides		3	4	3	4	9	16
5	Vegetation fires		1	3	1	2	1	6
6	Freeze-thaw phenomenon		2	3	3	3	6	9
8	Snowfall		2	3	3	3	6	9

DISCUSSION

The matrix in the table above indicates a higher vulnerability of the project under future climatic conditions compared to the vulnerability under current conditions for variables such as temperature, precipitation, floods, soil erosion, and landslides. Part of the assessment of adaptation measures to the effects of climate change for the analyzed project is presented in Table 4.

Table 4. Main effects associated with climate change and adaptation measures

No.	Effect associated with climate change	Possible impact on the project	Proposed adaptation measures
1	Increase in the annual average maximum temperature	Degradation of the asphalt pavement. Affecting the expansion joints of bridges due to thermal expansion.	Compliance with temperature conditions during the manufacturing and pouring of asphalt mixtures; Adoption of technical measures provided by current regulations to prevent and remedy road defects; Arrangement of service areas with vegetation zones for shading and improving thermal comfort.
2	Precipitation	Infiltrations can occur in cracks in the asphalt. Porous surfaces, potholes, or embankment tilts may occur, clogging of planned drainage. Degradation of road signs and horizontal markings. Reduced	Appropriate studies and practices are recommended to determine the drainage slopes and the strategy for directing and evacuating rainwater; Maintenance of horizontal markings. Maintenance of ditches, gutters, or channels to allow water drainage.

		visibility. Risk of aquaplaning.	Displaying warnings about aquaplaning, adapting driving speed, and maintaining safe following distances in traffic.
3	Floods	Flooding of certain road sections.	Designing infrastructure to handle increased precipitation (up to 20% more) by improving rainwater collection. Using permeable materials and vegetation on embankments. In areas where the highway crosses watercourses, arranging the riverbeds for proper drainage. Sizing ditches, gutters, and casings for efficient rainwater collection and drainage. Enhancing the foundation soil with ballast columns to reduce settling.
4	Soil erosion	Degradation of project components. Appearance of dust clouds that can reduce visibility.	Proper drainage of water to prevent soil displacement and clogging. Planting and consolidation works.
5	Landslides	Clogging of drainage systems. Serious road damage that can affect traffic. Movement of engineering works. Relocation of traffic signs.	Implementation of measures and recommendations from specialized geotechnical studies. Ensuring emergency response teams to restore traffic.

Studies related to the impact of implementing a highway on air quality have been conducted for a similar project under construction, namely the Buzău-Focșani highway. It has been demonstrated that greenhouse gas (GHG) emissions from the burning of fossil fuels during the operation of national roads have a rising trend, unlike emissions during the operation of a highway designed to accommodate the corresponding traffic [4]. The graph demonstrating the emissions stabilization trend for the Buzău-Focșani Highway and their increase for the National Road used as an alternative transport artery is presented in Figure 2. It is recommended to conduct a similar study to determine the amount of CO_{2e} that will be reduced through the implementation of the project.

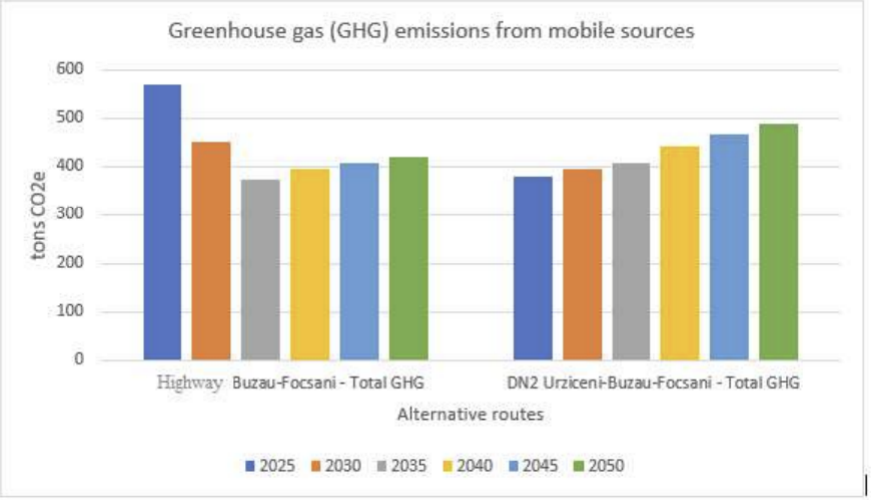


Figure 2. Comparative GHG from mobile sources for the two alternative routes

In addition to the direct reduction of GHG emissions through vehicle traffic on the highway, emissions reductions can also be achieved during the construction period by adopting measures such as:

- sourcing materials and supplies from locations as close as possible to the construction site;
- optimizing routes to provide additional compaction during equipment movement;
- using recycled and excavated materials from other sites whenever possible;
- reusing excavated material during construction when feasible;
- responsible equipment usage to avoid emission increases;
- periodic inspection and maintenance of equipment, especially concerning carbon monoxide levels and exhaust emission concentrations;
- selecting low-emission fuels whenever possible.

In line with European and national strategies, it is essential to implement measures to achieve the established objectives. The highway represents an adaptable platform for technological changes, especially in the context of the increasing number of electric vehicles. Promoting the use of these vehicles can contribute to reducing greenhouse gas emissions and improving air quality in the project-affected area. To support this environmentally friendly option, it is suggested to install electric vehicle charging stations at the highway service areas, with the possibility of powering these stations with solar energy, either through solar panels on the service area roofs or in their immediate vicinity. For even more efficient use of the highway, aiming for green energy generation and emissions reduction, the airflow generated by vehicle movement can be harnessed [5]. In this regard, turbines can be installed in the spaces between the lanes, and the energy generated can power the highway's lighting system.

CONCLUSION

Climate models demonstrate that average annual temperatures in Romania will continue to steadily rise, especially during summer and winter. It is anticipated that precipitation will be higher for shorter periods and over smaller areas, leading to increased frequency of floods and longer drought periods, ultimately resulting in a deficit of water resources,

the risk of forest fires, loss of biodiversity, soil and ecosystem degradation, and desertification. The new highway section will attract vehicles from county and national roads, decongest traffic, and consequently lead to improved air quality. Permitted speeds on the highway and traffic flow contribute to fuel savings and the reduction of greenhouse gas emissions released into the atmosphere.

The consequences of climate change for the studied infrastructure project must be assessed and incorporated into the design parameters to prevent undesirable effects. Considering that roads have a projected operational lifespan that often exceeds 100 years, it is important to establish their safety and reliability against climate change risks. Furthermore, as climate change is expected to increase the frequency and intensity of extreme events (e.g., floods), the importance of constructing resilient infrastructure that can maintain at least a minimum level of functionality during these events is emphasized. Therefore, it is necessary to identify the impact of climate change on natural and anthropogenic systems, their vulnerability, and adaptation to the effects of climate change.

It is essential for infrastructure projects to consider the impact of climate change from the planning phase and to adopt innovative and sustainable solutions to address these challenges. By taking measures at the individual project level, Romania can contribute to global efforts to combat climate change and ensure a more sustainable future for all its citizens.

Furthermore, investments in climate-resilient infrastructure can bring significant benefits in terms of reducing maintenance costs, creating jobs, and promoting technological innovation. Therefore, it is important for governments and local authorities to pay special attention to this aspect in the planning and implementation of future infrastructure projects.

REFERENCES

[1]. European Court of Auditors, Special Report No. 18/2019: Greenhouse Gas Emissions Generated in the EU, 2019;

[2] Ministry of Environment, Waters, and Forests, Romania's National Strategy on Climate Change 2013 – 2020;

[3]. Jaspers, Joint Assistance in Supporting Projects in European Regions, "The Basics of Climate Change Adaptation Vulnerability and Risk Assessment," 2017;

[4]. Nicolae R.I., Nicolae P., Brăileanu A.-M., Reducing greenhouse gas emissions by implementing sustainable infrastructure projects, Geolinks International Conference, Conference Proceedings, Book 1, Volume 3, Extended version, 17-18 May 2021, Online edition, ISBN 978-619-7495-17-1, doi: 10.32008/GEOLINKS2021/B1/V3;

[5]. Kunkel L. C., Hall, D. M., Improving site assessment tools in emerging technologies: The case of highway vertical-axis wind turbines in the United States, Energy Research & Social Science, 64, 101456, 2020.

CLUB CONVERGENCE IN ENERGY TRANSITION OF EU MEMBER STATES

Professor PhD Claudia Popescu[1]

Assistant Professor PhD Mihaela Covrig[2]

[1] Bucharest University of Economic Studies & Institute of Geography Romanian Academy, **Romania**
[2] Bucharest University of Economic Studies, **Romania**

ABSTRACT

The European Union stands apart through its ambitious blueprint to reach carbon neutrality by 2050. Playing a pivotal role within this process, the energy transition in EU is challenged by the trilemma of supply security, competitiveness and sustainability. Historical contingencies and contextual factors trigger different evolutionary trajectories in terms of temporalities and geographies. Testing the club convergence hypothesis, studies addressed the heterogeneity of EU member states either from energy or environmental perspectives. Our study relying on two streams of research on club convergence and core-periphery model is set to provide: (1) an up-to-date assessment of energy transition pathways pursued by EU members; and (2) a comprehensive outlook based on multiple variables to capture the economic, environmental, energy, social and policy dimensions of energy transition. We employ time-series data issued by EUROSTAT at the level of EU-27 national economies from 2015 (Climate Paris Agreement) to 2021 (European Green Deal). The analysis is based on the measurement of absolute, conditional and relative convergence to test the assumption that EU member states are organized into convergence clubs along core-periphery patterns. Absolute and conditional beta convergence, as well as sigma convergence have been confirmed by data, and five convergence clubs have been identified. However, their membership does not confirm the core-periphery theory in its classical tenets; it rather reflects multiple energy transition paths. We intent to contribute to the scholarship on climate and energy aiming to endorse informed policy across EU.

Keywords: energy transition, climate change, club convergence, core-periphery patterns, EU member states

INTRODUCTION

In the aftermath of the Climate Paris Agreement (2015), the European Union launched the Green Deal in 2021 as the roadmap to become climate-neutral by 2050. Energy transition plays a pivotal role within this process encompassing radical transformation of the energy regime, production and consumption patterns, supplier-consumer dependencies, social acceptance, and political commitment to engage with adaptive policies. Although sharing a common policy and targets to reach zero-net emissions, the EU member states pursue various energy transition pathways whereby distinct temporalities and geographies are grounded on structural heterogeneities of the EU energy system. Dealing with the particular context of EU and its ‘one hundred thousand

energy transitions' [1], a growing stream of research aimed to test the club convergence hypothesis in the fields of energy and environmental economics.

Environment-energy nexus has been approached from different angles. Assessing environmental performance is key to provide insights into the efficiency of EU policy to mitigate climate change effects. Studies focused on carbon intensity (per capita CO_2 emissions) to identify club convergence in environmental quality. The findings reject the overall convergence hypothesis of EU-27 sample [2-3]. Conversely, strong empirical evidence point to the dynamics of convergence clubs along time-varying frames of analysis [4] and differentiated sectoral emphasis [5-6]. EU member states group in multiple clusters transitioning from disequilibria to specific steady-state positions in the long run [7]. Particular convergence patterns in CO_2 intensity are identified within the EU-15 and EU-13 (old versus new members) [3] highlighting the relative convergence at EU level [5] and, hence, the need to design tailor-made policies and regulations with a view to reducing heterogeneity among member states [7].

The current energy transition entails the shift from fossil fuels to renewable sources in energy generation within the global context of 'climate emergency'. Tracking the progress toward the common goal of achieving 20% renewable energy in 2020, research examined the convergence of EU-27 in different clusters due to historical contingencies and complex idiosyncratic characteristics rooted in economic, social, cultural and geographic specificities [8]. Applied to EU-15, the convergence of per capita renewable energy consumption, albeit rejecting for full panel data, showed the existence of more clubs with converging trends in the long run [9].

Convergence in energy productivity is partial but stable over time with relatively homogeneous clusters that need policy interventions to ensure further cohesion [10]. As a proxy for energy efficiency, productivity shows convergence trends despite the EU enlargement process and economic crisis [11]. Closely related are the patterns of energy innovation convergence; several clubs are identified with growing disparities among them due to varying environmental R&D expenditure, human resources and environmental policy stringency [12]. Environmental taxes are applied in all EU member states, hence a high level of convergence is detected with positive effects on the implementation of energy and climate policies [13-14]. Likewise, convergence clubs are empirically tested in terms of energy poverty. Structural housing conditions, climate variability and increasing energy costs are major determinants for the creation of convergence clubs across EU-28 [15-16].

Based on energy and environmental variables, research on convergence clubs reveals different trajectories pursued by EU member states, either enhancing the homogeneity of energy transition (environmental taxes, energy efficiency), or deepening the existing heterogeneities (CO2 emissions, renewable energy share), or even delineating sharp geographical divisions (energy poverty). Some studies point to the core-periphery alignment of energy transition [5] and the West-East 'energy divide' embedded in various socioeconomic geographies [17]. Together with few others [8-9], our study aims to focus on convergence in renewable energy consumption, less approached so far, by bringing together in a unified conceptual framework the multiple dimensions of energy transition. To this end, we test the convergence clubs hypothesis spanning the 2015-2021 period to provide a comprehensive outlook on energy paths while searching evidence on whether the core-periphery model of energy transition holds true across EU-27. Understanding the

spatial patterns of energy transition helps policy adjustments to cope with the current energy crisis and attain the decarbonized future through energy and environmental convergence.

MATERIALS AND METHODS

Club convergence hypothesis refers to the tendency of a group of economies to converge to the same steady state when their circumstances and structural features are similar [5]. However, the studies devoted to environment-energy nexus pinpointed inherent complexities and heterogeneities of EU energy transitions. Moreover, attaining a low-carbon economy is challenged by overall economic divergence, varying dependencies on energy imports, particular combinations of physical, social, economic and political factors, and the changing geopolitical context. Starting from this, our approach takes as a proxy of energy transition the share of renewable energy in gross final energy consumption (Renew_share) to test the convergence hypothesis in connection with economic (energy intensity – to measure the energy needs in relation with GDP – NRG_IND_EI), energy (energy imports dependency to reflect the exposure to volatile market prices – ENERG_IMP_DEP), environment (CO_2 emissions per capita as an indicator of policy effectiveness - CO2KGPC), social (population unable to keep home adequately warm by poverty status to express the interrelations of welfare and access to energy – WARM_TOTAL), and policy factors (gross value added in environmental goods and services sector as a proxy of innovation policy and creation of green jobs - GVA; and, share of environmental taxes in total tax revenues to summarize the promotion of renewables – ENV_TAX). The relevance of these variables derives from their inclusion in EU Sustainable Development Goals data set used to monitor progress under the European Green Deal.

The methodological approach applies tests for the existence of beta and sigma convergence, and the method proposed by Phillips and Sul [18] that detects convergence clusters between heterogeneous economies along relative transition paths [13-15]. Employing data from EUROSTAT, we measure the absolute, conditional and sigma convergence to test the assumption that EU member states are organized into convergence clubs along core-periphery patterns. Sigma and beta (absolute and conditional) convergence analysis were performed in R, with the REAT package [19], with the focus on estimating specific regression models. The analysis of the existence of convergence clubs, their identification and their characterization were carried out using functions from the ConvergenceClubs R package [20] including the regression model for Log-t test.

RESULTS

Sigma convergence was analyzed both in the variant for two moments, 2015, as the initial one, and 2021, as the reference one, as well as in the trend variant. The standard deviations of Renew_share for 2015 and 2021 are equal to 0.6197861, and 0.4436449, respectively suggesting a decline in dispersion. The calculated value of the F test statistic for the equality of variances and the reported P-value corresponds to the two tailed test. However, in our case, in order to test the sigma convergence for 2015 and 2021, the alternative hypothesis is a right-tailed test, therefore the corresponding P-value is smaller than 0.05, thus we reject the null hypothesis in favour of the alternative hypothesis of sigma convergence for the two moments of analysis.

Sigma convergence for multiple periods, the sigma trend regression, was evaluated using the regression model $\sigma_t = \alpha_0 + \alpha_1 t + u_t, t = \overline{2015,2021}$. The results show that the regression model is statistically significant and the slope α_1 is negative and statistically significant, as $\hat{\alpha}_1 = -0.03342 < 0$ with Pvalue=0.000581<0.05, therefore the data support the sigma convergence.

Beta convergence was confirmed both in the unconditional (absolute) and in the conditional version. The estimation results for the regression model, where the initial moment is $t_0 = 2015$, and $T = 6$, $t_0 + T = 2021$, shows beta parameter significantly less than 0 (estimated value is -0.0548 with Pvalue less than 0.001), so the data support the hypothesis of unconditional beta convergence, but the convergence process is a very slow one because it is observed that the estimated value of the half-life to reach the steady state is 73.69, i.e. about 74 years.

The conditional beta convergence was evaluated in relation to several variables that can explain the differences between countries at the initial moment $t_0 = 2015$, taking into account specific economic, energy, environmental, social or policy conditions. We estimated three regression models for conditional beta convergence, the distinction between them being the variable showing vulnerability, as a percentage of the population that cannot adequately heat their home during the winter. This is presented in three variants WARM_TOTAL2015, WARM_BELOW2015, WARM_ABOVE2015. All regression models are statistically significant, the beta parameter is negative and statistically significant in each case, so the hypothesis of conditional convergence is valid. Among the introduced condition variables, it is noted that NRG_IND_EI2015 and CO2KGPC2015 are the only ones that do not have a significant influence or contribution on the change or dynamics of Renew share. The introduction of the independent condition variables leads to an improvement in the explanatory power of the regression models compared to that of the absolute beta convergence, as well as to a decrease in the estimated duration by which the equilibrium value is reached (steady state) to around 63 years.

Testing the existence of clubs is carried out by estimating the Log-t regression model proposed by Phillips and Sul (2007), using the panel data 2015-2021 of Renew_share. We obtained the estimated beta of -0.9555<0, with Pvalue<0.01, suggesting the existence of different convergence regimes. Therefore, we further continued to determine the clubs. Applying the algorithm, we detected 5 convergence clubs depicted in Table 1, and two countries, Austria and Sweden, as divergent units. The former stands apart through the slower than average progress of changing the energy regime; the latter through its share of renewable in energy consumption, much higher than the average.

Table 1. Log-t test results for each club

Clubs	Number of countries	Countries	Beta estimate	std.err	tvalue	pvalue
Club 1	3	Finland, Latvia, Estonia	0.0862	1.1624	0.0742	0.5296
Club 2	3	Denmark, Portugal, Croatia	0.8149	0.9847	0.8275	0.796
Club 3	6	Lithuania, Slovenia, Romania, Greece, Cyprus, Slovakia	0.3255	0.0986	3.3	0.9995
Club 4	7	Spain, France, Germany, Italy, Czechia, Bulgaria, Netherlands	0.326	0.4077	0.7998	0.7881
Club 5	6	Poland, Hungary, Belgium, Ireland, Malta, Luxembourg	0.65	0.7462	0.871	0.8081

Further on, we characterized the convergence clubs relating the Renew_share to the other variables included in the conditional beta model. We found that the mean values of

Renew_share are directly associated with the level of innovation and the creation of green jobs, and environmental taxes; while inverse association is found in relation with imports dependency. The social variable, the share of population unable to keep home adequately warm, shows a mixed trend that might be explained by the subjective perception permeating the data collection based on survey, as well as the country-specific level of incomes (Table 2).

Table 2. Mean values of variables

Mean values	Renew share	NRG_IN D_EI	ENERG_ IMP_DE P	CO2KG PC	GVA	ENV_TA X	WARM_ TOTAL	WARM_ BELOW	WARM_ ABOVE
Club 1	37.451	160.043	31.604	7163.814	4.701	8.475	4.3	9.157	3.024
Club 2	31.396	97.22	50.11	6084.897	2.345	7.97	10.086	22.214	7.51
Club 3	19.898	117.99	62.921	5200.278	2.086	8.129	15.436	29.417	12.479
Club 4	16.367	124.234	55.652	5861.530	2.17	6.583	10.118	21.343	7.551
Club 5	10.887	123.737	73.549	6844.847	1.540	6.545	5.312	13.498	3.860

Figure 1 depicts the time evolution of the relative transition paths clearly differentiating each club with respect to the horizontal blue line that represents the panel average (h=1) as well as the ideal convergence pattern. Countries in club 1 and 2 perform in each year above the panel average, quite the opposite trajectory is observed for countries in club 4 and 5, as their relative transition paths are below the panel average, while club 3 displays the closest behavior towards the limit, yet its average is slightly below 1.

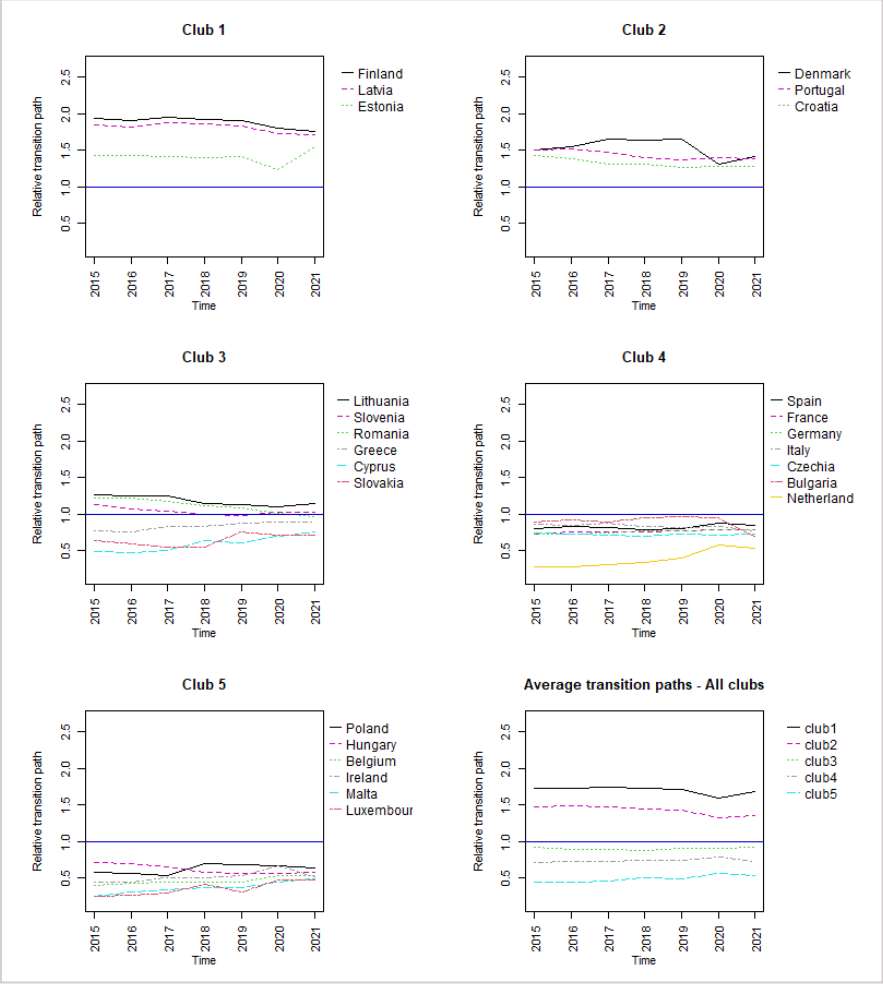


Figure 1. Relative transition paths of clubs, 2015-2021

DISCUSSION

Responding to our main research question concerning club convergence in energy transition, we assessed the transition paths employing a wider range of variables than those commonly addressed by previous studies. Absolute and conditional beta convergence, as well as sigma convergence have been confirmed by the data series, and five convergence clusters have been identified. The findings show convergence of Renew_share as a decline in dispersion, a harmonization tendency across EU member states and a catching up process of countries with lower initial values with those having higher values due to variable growth rates and convergence regimes.

Energy transition is conditioned by the availability of energy sources, i.e. their shares in the energy mix and its contingencies upon national circumstances related to the financial and institutional support, and regulatory policies [8]. The shares of renewables in energy consumption provide insights into the heterogeneous energy paths and the growing macro-regional inequalities that underpin energy transitions despite the overall upward trend of EU-27 [17]. In the same vein, we found a wide variation among clusters, ranging from 37.5% (cluster 1) and 10.9% (cluster 5). The EU average (21.8% in 2021) delineates the groups of countries placed below and above this value pinpointing the heterogeneity of each group where neither the accession time nor the geographical alignments are relevant.

Among the introduced condition variables, we notice that energy imports dependency, gross value added in environmental goods and services sector and the share of environmental taxes in total tax revenues are statistically significant demonstrating the role of energy and policy dimensions to determine the transition paths. Conversely, we identify that energy intensity and CO_2 emissions are variables that do not have a significant influence on the changing share of renewables in consumption. We argue, as others have done previously [8-9], that this is an outcome of the slow progress towards decoupling the economic growth from environmental impact and, hence the shift from fossil fuel energy consumption to green sources. However, unlike [5] we did not find evidence to demonstrate the gaps between the core European countries as the best performing club members and the CEE countries as laggards, albeit pursuing slightly divergent paths.

The relevance of energy poverty is essential when related to sustainable societies, social inclusion and social rights [15]. Additionally, there are empirically evidenced effects of energy poverty on convergence across EU-27 [16] that point to the income disparities and associated access to energy services, current crisis of energy prices, varied energy efficiency and challenges of geopolitical context [15-17]. To gain an in-depth understanding of the social variable, we used three variants (WARM_TOTAL2015, WARM_BELOW2015, WARM_ABOVE2015 according to the risk of poverty threshold of 60% of median equivalized income) and found a negative influence of energy poverty on the dynamics of the Renew_share. However, we did not find evidence to support a 'social energy divide' as hypothesized by [17].

An interesting finding refers to the speed and time to reach the steady state. With the stable speed of absolute beta convergence all along the period and the improvement of harmonization of beta conditional convergence, the Renew_share gap between countries will be reduced by half in a 10-year shorter period of time. This comes in sync with studies

that support the need of convergence in energy transition to reach a shared understanding of global threats and to enhance the efficiency and speed of implementing policies placed at the environment-energy nexus [7-8]. Not least, this is key for EU-27 to reach climate neutrality by 2050.

CONCLUSION

Our study relying on two streams of research on club convergence and core-periphery model was set to provide: (1) an up-to-date assessment of energy transition pathways pursued by EU members; and (2) a comprehensive outlook based on multiple variables to capture the economic, environmental, energy, social and policy dimensions of energy transition. While comprehensive in relating the various dimensions of energy transition, our research provides more nuanced understandings of the challenges faced by EU-27 in their way toward a decarbonized future. The main conclusion is that the convergence of Renew_share is very slow with different convergence regimes during a relatively short period of time (2015-2021). Our analysis points to substantial progress of the common policy in reducing exposure to changing market prices and geopolitical context, promoting innovation and green jobs and imposing environmental taxes on fossil fuel energy. On the contrary, we highlighted that variation in energy intensity and CO_2 emissions prevent the convergence in energy transition. Therefore, an insightful direction of research might concern the need of harmonization to achieve climate, economic and policy goals.

So far, studies identified different divisions among EU-27 member states, either in terms of the scale and speed of energy transition - frontrunners vs laggards [8], accession time to EU – old vs new [5], or geographical location – North-West vs South and Central and Eastern Europe [17]. In one way or another, all suggest a core-periphery pattern across EU. Testing the convergence hypothesis through a multi-dimensional approach, we emphasized the gaps in the pursuit of energy transition among EU-27 member states; however, we did not find evidence to support core-periphery alignments in the classical understanding underpinned by spatial contiguity. The membership of our convergence clubs is geographically diverse suggesting that the macro-scale patterns of energy transition reflect the cross-country development paths. This puzzle-like pattern invites scholars to reassess the core-periphery theory in the light of ongoing energy transition.

REFERENCES

[1] Sarrica M., Brondi S., Cottone P., Mazzara, B. M., One, no one, one hundred thousand energy transitions in Europe: The quest for a cultural approach, Energy Research & Social Science, vol. 13, pp 1-14, 2016.

[2] Kounetas K.E., Energy consumption and CO_2 emissions convergence in European Union member countries. A tonneau des Danaides?, Energy Economics, vol. 69, pp 111-127, 2018 https://doi.org/10.1016/j.eneco.2017.11.015.

[3] Emir F., Balcilar M., Shahbaz M., Inequality in carbon intensity in EU-28: analysis based on club convergence, Environmental Science and Pollution Research, vol. 26, pp 3308-3319, 2019.

[4] Ulucak R., Apergis N., Does convergence really matter for the environment? An application based on club convergence and on the ecological footprint concept for the EU countries, Environmental Science & Policy, vol. 80, pp 21-27, 2018.

[5] Morales-Lage R., Bengochea-Morancho, A., Camarero, M., Martínez-Zarzoso I., Club convergence of sectoral CO2 emissions in the European Union, Energy Policy, vol. 135, 111019, 2019, https://doi.org/10.1016/j.enpol.2019.111019.

[6] Cialani C., Mortazavi R., Sectoral analysis of club convergence in EU countries' CO2 emissions, Energy, vol. 235, 121332, 2021.

[7] Presno M. J., Landajo M., González P. F., GHG emissions in the EU-28. A multilevel club convergence study of the Emission Trading System and Effort Sharing Decision mechanisms, Sustainable Production and Consumption, vol. 27, pp 998-1009, 2021.

[8] Presno M.J., Landajo, M., EU-28's progress toward the 2020 renewable energy share: a club convergence analysis, Environmental Science and Pollution Research, vol. 28, pp 66830–66844, 2021, https://doi.org/10.1007/s11356-021-15084-x.

[9] Kasman A., Kasman S., Convergence of renewable energy consumption in the EU-15: evidence from stochastic and club convergence tests, Environmental Science and Pollution Research, vol. 27, pp 5901–5911, 2020, https://doi.org/10.1007/s11356-019-07378-y

[10] Baležentis T., Butkus M., Štreimikienė D., Energy productivity and GHG emission in the european agriculture: The club convergence approach, Journal of Environmental Management, vol. 342, 118238, 2023.

[11] Menegaki A., Tiwari A. K., Energy Efficiency in Europe: Stochastic-Convergent and Non-Convergent Countries, Energy and Environmental Strategies in the Era of Globalization, pp 305-333, 2019.

[12] Kijek T., Kijek A., Bolibok P., Matras-Bolibok, A., The patterns of energy innovation convergence across European countries, Energies, vol. 14/issue 10, 2755, 2021.

[13] Delgado F. J., Freire-González J., Presno, M. J., Environmental taxation in the European Union: Are there common trends?, Economic Analysis and Policy, vol. 73, pp 670-682, 2022.

[14] Famulska T., Kaczmarzyk J., Grząba-Włoszek M., Environmental Taxes in the Member States of the European Union—Trends in Energy Taxes, Energies, vol. 15/issue 22, 8718; 2022,https://doi.org/10.3390/en15228718.

[15] Anastasiou A., Zaroutieri E., Energy poverty and the convergence hypothesis across EU member states, Energy Efficiency, vol. 16/issue 5, 38, 2023, https://doi.org/10.1007/s12053-023-10113-9.

[16] Huang Z., Ming X., Duan H., Heterogeneous effects of energy poverty convergence in Europe, Energy Strategy Reviews, vol. 41, 100822, 2022, https://doi.org/10.1016/j.esr.2022.100822.

[17] Bouzarovski S., Herrero S. T., Energy poverty in Central and Eastern Europe: Understanding the European Union's core-periphery divide, Post-Socialist Urban Infrastructures (OPEN ACCESS), pp 21-37, 2019.

[18] Phillips P.C.B., Sul D., Transition modeling and econometric convergence tests, Econometrica vol. 75, pp 1771–1855, 2007.

[19] Wieland T., REAT: A Regional Economic Analysis Toolbox for R, REGION, European Regional Science Association, vol. 6, pp 1-57, 2019.

[20] Sichera R., Pizzuto, P., ConvergenceClubs: A Package for Performing the Phillips and Sul's Club Convergence Clustering Procedure, R Journal, 11.2, p. 142, 2019.

CONSUMER INTENTION TO BUY ELECTRIC CARS: EXPLORING THE INFLUENCE OF FUTURE UNCERTAINTY DUE TO THE WAR IN UKRAINE IN THE FRAMEWORK OF THE THEORY OF PLANNED BEHAVIOR

PhD Roberta Riverso

Assoc. Prof. Francesco La Barbera

Carmela Altamura

University of Napoli Federico II, **Italy**

ABSTRACT

The topic of sustainable mobility has been prioritized on the EU's political agenda, with the goal of lowering CO2 emissions and air pollution. This goal entails the introduction of low-polluting cars, such as those driven by an electric battery (BEV), into the EU car market. The current investigation was guided by the theory of planned behavior (TPB): The three main TPB constructs—attitudes, subjective norm, and perceived behavioral control—as well as the intention to purchase a BEV have been measured. In addition, we were interested to explore the influence of individuals' uncertainty due to the Ukrainian war on the intention to buy a BEV. Future uncertainty related to the war in Ukraine might enhance individuals' concern about economy and energy, thus influencing the intention to buy BEVs. An online survey was conducted, with measures of the TPB main constructs and war-related uncertainty. Results show that attitude, subjective norm, and perceived behavioral control significantly predict the intention to buy BEVs. In addition, future uncertainty due to war in Ukraine has a significant positive indirect effect on participants' intention to buy BEVs *via* attitude and subjective norm. Theoretical contributions and practical implications of results are discussed in the paper.

Keywords: Urban Air Pollution, Electric Cars, Sustainable Mobility, Theory of Planned Behavior, War in Ukraine

INTRODUCTION

The first United Nations Framework Convention on Climate Change was drafted at the UN Conference on Environment and Development in Rio de Janeiro in 1992, and the first international agreement on climate change was signed in 1997. Nevertheless, the years from 2015 to now have been the warmest ever recorded, with temperatures rising by 1.2 degrees Celsius over pre-industrial levels. Other phenomena related to global temperature rise include changing precipitation patterns, sea level rise, and changes in jet streams; these phenomena have negative consequences particularly for low-income countries, which have contributed less to greenhouse gas production [1]. To combat these challenges, it is vital to minimize greenhouse gas emissions (carbon dioxide, methane and

nitrous oxide). To that end, the European political agenda has made sustainable mobility a priority, with the goal of lowering carbon dioxide emissions into the atmosphere and air pollution.

Apart from the dynamics of climate change, another factor that has been having a significant global impact since February 2022 is the conflict in Ukraine. Regarding the conflict in Ukraine, citizens of EU member states exhibit a high perceived threat [2]. Researchers have shown its detrimental effects on economic dynamics and energy systems. The Ukrainian crisis also brought attention to the need for a quicker ecological conversion and the preservation of non-renewable energy resources. It has also made concerns about climate change more pressing [3].

The introduction into the European car market of low-polluting cars, such as cars powered by an electric battery (BEV) is viewed as a sustainable alternative to conventional vehicles that address the economic and environmental needs imposed by current global issues. BEVs are particularly helpful in reducing urban air pollution, enhancing the cities' air quality [4]. BEV sales in the EU increased by 29% in 2022 compared to 2021. Nonetheless, there are considerable discrepancies across member countries: Norway experienced the greatest gain (+79.3%), while Italy experienced a contraction of -0.9% despite economic incentives provided by the Italian government. As a result, Italy appears to be an ideal scenario for investigating consumers' persistent uncertainty regarding the purchase of BEVs. [5]

Scholars have been studying the negative attitudes and beliefs that prevent people from purchasing electric vehicles with increasing interest. The theory of planned behavior (TPB) has guided a significant amount of research on this topic. TPB considers intention to be the direct antecedent of behavior. Attitudes (ATT), subjective norm (SN), and perceived behavioral control (PBC), in turn, form individuals' intention [6]. TPB-based research has shown that ATT, SN and PBC are significant predictors of individuals' intentions to buy a BEV [7]. Also in Italy, the validity of a TPB-based model of the intention to buy a BEV has been supported [5].

In addition, future uncertainty related to the war in Ukraine might enhance individuals' concern about economy and energy, thus influencing the intention to buy BEVs. A recent study conducted in Switzerland showed that the war in Ukraine has increased support for policies aiming at the phasing out of fossil fuels and for policies supporting the phasing-in of clean energy alternatives [8]. However, the effect of uncertainty generated by Ukrainian war on beliefs, attitudes, and intention related to BEVs has been little explored. Considering the relevance of environmental issues in the current Russo-Ukrainian conflict, the uncertainty related to the war in Ukraine may improve individuals' attitudes towards BEVs. In a similar fashion, the shift towards greater sensitivity on energy issues may increase the perception by individuals of a positive social pressure as regards BEVs. Hence, the uncertainty related to the war may exert a positive indirect effect on the intention to buy a BEV through attitudes and subjective norm.

The current study aims to assess—into a TPB-based model—the role of the uncertainty deriving from the Russian-Ukrainian conflict. The TPB maintains that three major factors—attitudes, subjective norm, perceived behavioral control—are sufficient to predict behavioral intention; this is known as the sufficiency principle. Additional factors are thus conceptualized as background factors, and they are not thought to exert any direct influence on intention; rather, they are expected to have an indirect effect on intention, mediated by attitudes, subjective norm and perceived behavioral control [9].

Therefore, in line with previous research, we hypothesized a significant effect of the three TPB major constructs—attitude, subjective norm, and perceived behavioral control—on intention to buy a BEV (H1). In addition, based on the theoretical considerations discussed above, we hypothesized that the uncertainty related to the war in Ukraine positively affects the intention to buy a BEV through attitudes (H2) and subjective norm (H3).

MATERIALS AND METHODS

In March 2022, shortly after Russia's invasion, an online survey was administered to a convenience sample of 350 Italian participants. The link to the questionnaire was shared on the major social networks to recruit participants. Because 15 participants did not complete the questionnaire, they were omitted from the analysis. The final sample size was 335 people, with 186 identifying as females, 124 as males, 1 as non-binary gender, and 24 preferring not to communicate their gender. The sample's mean age was 34.52 (SDage = 14.58), with participants ranging in age from 18 to 87. 170 participants have a university degree, and 137 have completed high school; thus, educated people are overrepresented in the sample compared to the Italian overall distribution.

Participants volunteered for the study and were not compensated for their time. They were assured of their anonymity and informed that they could withdraw from the study at any time without penalty. Following their consent, they completed an online TPB questionnaire with an additional uncertainty measure (see below). All items used a 7-point response format, were presented in non-thematic order, and followed the guidelines provided by Fishbein and Ajzen [9]. Appendix 1 contains the complete list of items, along with descriptive statistics.

The five-item scale by Riverso and colleagues [10] was employed to measure future uncertainty due to the Ukrainian conflict. Responses were averaged, with higher values indicating higher uncertainty (Cronbach's $\alpha = .82$). Two items were used to measure the intention to buy BEVs. Responses were averaged, with higher values indicating a stronger intention (Spearman-Brown $\varrho = .82$). Three items were used for measuring attitude towards BEVs. A composite measure was computed by averaging the scores (Cronbach's $\alpha = .93$). Higher values indicate more positive attitudes. Two items were employed to measure subjective norm. The answers were aggregated into a single average score (Spearman-Brown $\varrho = .76$). Higher values indicate subjective norms supportive of buying a BEV. Two items were used to measure perceived behavioral control. The items were averaged to create a single score (Spearman-Brown $\varrho = .91$). Higher values indicate higher perceived behavioral control.

Descriptive statistics and bivariate correlations were obtained by SPSS 27 (SPSS Inc., Chicago, IL, USA). The reliability of the measures was tested by Cronbach's alpha; Spearman-Brown's coefficient was used for two-item scales. The mediation analysis was conducted using the Process procedure for SPSS [11], Model 4, 5,000 bootstrap samples. The accepted level of significance of the null hypothesis test was set at $p < 0.05$.

RESULTS

Means and standard deviations of the study variables are shown in the main diagonal of Table 1. As expected, the bivariate correlations among the TPB variables were significant and of moderate to large magnitude. Future uncertainty was not correlated with intention, instead.

Table 1. Means, standard deviations and correlations among study variables

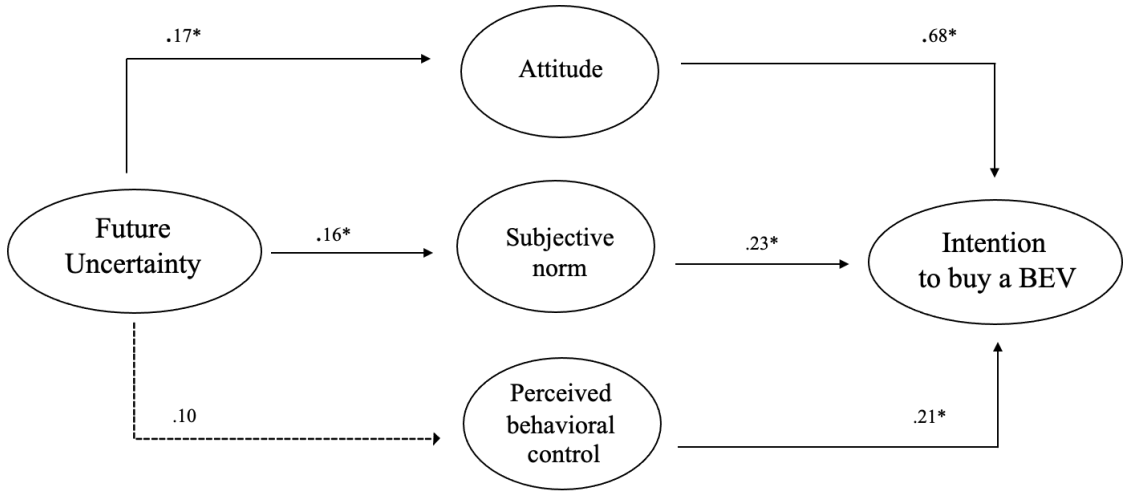
	INT	ATT	SN	PBC	FU
INT	4.08 (1.92)				
ATT	.790***	5.05 (1.59)			
SN	.560***	.569***	4.15 (1.57)		
PBC	.349***	.214***	.284***	3.48 (1.62)	
FU	.094	.125*	.121*	.073	5.30 (1.18)

Note. The table shows Pearson's r correlation coefficients. Diagonal cells show means (SD in parentheses). INT = Intention; ATT = Attitude; SN = Subjective norm; PBC = Perceived behavioral control; FU = Future Uncertainty due to the war in Ukraine.
* $p < .05$; *** $p < .001$
Source: Authors' elaboration.

In order to test the direct effect of ATT, SN and PBC on intention to buy a BEV, as well as the indirect effect of future uncertainty due to Ukrainian war mediated by ATT, SN, and PBC, we used the PROCESS procedure for SPSS developed by Hayes [11], a regression-based tool which provides bootstrap tests of mediation. In this procedure, we used the Model 4, which allows to test indirect effects with multiple (parallel) mediators, testing each mediation path (see Figure 1).

The model explained a substantial proportion of variance on intention to buy BEV, $R^2 = .57$, $F(4, 330) = 107.89$, $p < .001$, and the TPB factors were significantly associated with intention (H1). In line with theoretical expectations (i.e., the *sufficiency principle*), the direct effect of uncertainty due to war on intention was not significant, $\beta = -.02$, $t < 1$. In line with our hypotheses, instead, we found by means of bootstrap mediation tests (5,000 bootstrap samples) a significant and positive indirect effect of uncertainty on intention *via* attitude (H2), $b = .11$, bias corrected bootstrap confidence intervals [.008; .219], and a significant and positive indirect effect of uncertainty on intention *via* subjective norm (H3), $b = .04$, bias corrected bootstrap CI [.007; .090]. The indirect effect of uncertainty on intention *via* perceived behavioral control was not significant (bias corrected bootstrap CI containing zero).

Fig. 1: A TPB-based model of intention to buy a BEV including future uncertainty due to the war in Ukraine



Note. The direct effects of variables are reported on arrows. Statistically not significant paths are represented by dashed lines. All direct effects are significant at $p < .05$.
Source: Authors' elaboration.

DISCUSSION

The main theoretical contribution of the current research regards the role of future uncertainty due to the Ukrainian war in relation to the intention to buy a BEV, which has never been investigated. In line with our hypothesis, results suggest that uncertainty positively influences attitudes and norms, indirectly raising the intention to buy a BEV.
The growing uncertainty, associated with rising gasoline prices and reduced oil imports, may have fostered positive (utilitarian) beliefs about BEVs, thus improving individuals' attitudes towards these cars, considered as a sustainable alternative to traditional ones, and as a tool to cope with energy insecurity. As regards social norm, several calls have been made by politicians, institutions, and mass media in the aftermath of Russia's invasion to consumers and producers, who were invited to curb energy consumption and replace gas and oil with green energy. One of the main sectors to focus on electrification has been the transport sector [12]. Therefore, those who feel more insecure about war may have perceived a positive social pressure towards BEVs, that increased their intention to buy BEVs.
In the best of our knowledge, this is the first study to address the influence of future uncertainty due to the Ukrainian conflict on the intention to buy BEVs in the TPB framework. The influences and psychological mechanisms highlighted by the current study may be similar or different in relation to other targets (buying objects different from BEVs), behaviors (different from purchasing), and contexts (countries different from Italy, uncertainty not related to war, and so forth). As such, the recommendations derived from our results should not be taken for granted in relation to other contexts and targets. Future research on the topic is warranted.
Cross-national comparisons may be particularly interesting given that, as previously noted, the BEV market is increasing in quite diverse ways between EU member states. Therefore, a key study topic from a psychology perspective is what beliefs differentiate those various circumstances. Actually, the majority of research on BEVs within the TPB

framework has focused on direct assessments of the major constructs of TPB, paying little attention to the fundamental beliefs that underpin them or their relative importance [9]. Future study should prioritize extending our understanding of the most important behavioral, normative, and control beliefs and measuring their impact on the intention to purchase BEVs. Moreover, the identification of key beliefs serves as the foundation for developing successful communication plans that attempt to influence people's intentions and actions [13].

Several TPB-guided studies have made a distinction between instrumental attitudes, which are based on beliefs about the benefits or drawbacks of a particular behavior, and experiential attitudes, which are based on people's expectations about their feelings at the time of executing a behavior [9]. The current study, like the majority of TPB research, has only looked at instrumental attitude; nevertheless, expectations regarding the emotions and experiences associated with operating a BEV may have an impact on the decision to purchase one. Thus, this may be an additional subject that merits further research.

There are a number of limitations to the current study that must be noted. A convenience sample of Italian individuals was employed for the study; as previously noted, further research is required before extending our findings to other settings and behavioral patterns. Furthermore, in compliance with TPB, the study's dependent variable was the participants' intention to purchase a BEV; however, a behavioral measure was absent. This is a frequent problem in TPB-based research, however it is partially alleviated by the generally strong correlations found between behaviors and intentions [9]. Future studies using behavioral measurements are advised, nevertheless. Lastly, there are drawbacks to using an online questionnaire. because it might lead to sample biases: younger and more tech-savvy individuals are typically drawn to online surveys [14].

CONCLUSION

The current study adds to our understanding of the psychological factors that impact a person's intention to purchase a BEV in a number of ways. The TPB-based model of intention to purchase a BEV proved significant and highly predictive, supporting our first hypothesis. The TPB components—attitude, subjective norm, and perceived behavioral control—have a strong correlation with intention, and the model explains a meaningful proportion of the variance in intention. Among the three antecedents, attitudes seem to have the most influence—regression coefficient is more than twice as high as for SN and PBC. According to Fishbein and Ajzen [9], attitudes are shaped by beliefs about the advantages and disadvantages of adopting certain behaviors. For this reason, the decision to purchase a BEV appears to be primarily motivated by utilitarian beliefs. This is of special interest because there is a lack of research on the psychological factors which might explain the low intention to buy BEV.

From a practical standpoint, these results suggest that the best way to raise people's intention to purchase BEVs may be to communicate the benefits of BEVs and provide updates on how their main limitations are being overcome. This will help to improve people's attitudes by influencing utilitarian beliefs. In a situation like Italy, where the study was carried out, where the market is still very small, this recommendation may be very helpful.

REFERENCES

[1] Ripple, W. J., Wolf, C., Newsome, T. M., Gregg, J. W., Lenton, T. M., Palomo, I., ... & Rockstrom, J. (2021). World Scientists' Warning of a Climate Emergency 2021. *BioScience*, *71*(9), 894-898.

[2] Moshagen, M., & Hilbig, B. E. (2022). Citizens' Psychological Reactions following the Russian invasion of the Ukraine: A cross-national study. Psyarxiv.com

[3] Zhou, X. Y., Lu, G., Xu, Z., Yan, X., Khu, S. T., Yang, J., & Zhao, J. (2023). Influence of Russia-Ukraine war on the global energy and food security. *Resources, Conservation and Recycling*, *188*, 106657.

[4] Hu, X., Chen, N., Wu, N., & Yin, B. (2021). The potential impacts of electric vehicles on urban air quality in Shanghai City. *Sustainability*, *13*(2), 496.

[5] Riverso, R., Altamura, C., & La Barbera, F. (2023). Consumer Intention to Buy Electric Cars: Integrating Uncertainty in the Theory of Planned Behavior. *Sustainability*, *15*(11), 8548.

[6] Ajzen, I. (1991). The theory of planned behavior. *Organizational behavior and human decision processes*, *50*(2), 179-211.

[7] Moons, I., & De Pelsmacker, P. (2012). Emotions as determinants of electric car usage intention. *Journal of marketing management*, *28*(3-4), 195-237.

[8] Steffen, B., & Patt, A. (2022). A historical turning point? Early evidence on how the Russia-Ukraine war changes public support for clean energy policies. *Energy Research & Social Science*, *91*, 102758.

[9] Fishbein, M., & Ajzen, I. (2010). *Predicting and changing behavior: The reasoned action approach*. Taylor & Francis.

[10] Riverso, R., Amato, M., Verneau, F., & La Barbera, F. (2022). Compliance with rules and future uncertainty related to the Covid19 pandemic: trust in government, trust in science, and perceived threat. *Psychology Hub*, *39*(2), 21-30.

[11] Hayes, A. F. (2012). PROCESS: A versatile computational tool for observed variable mediation, moderation, and conditional process modeling [White paper]. Retrieved from http://www.afhayes.com/ public/process2012.pdf

[12] Nygaard, A. (2023). The geopolitical risk and strategic uncertainty of green growth after the Ukraine invasion: how the circular economy can decrease the market power of and resource dependency on critical minerals. *Circular Economy and Sustainability*, *3*(2), 1099-1126.

[13] Steinmetz, H., Knappstein, M., Ajzen, I., Schmidt, P., & Kabst, R. (2016). How effective are behavior change interventions based on the theory of planned behavior?. *Zeitschrift für Psychologie*.

[14] Zwarun, L., & Hall, A. (2014). What's going on? Age, distraction, and multitasking during online survey taking. *Computers in human behavior*, *41*, 236-244.

Appendix 1

Item	M (SD)
Next time I'll buy a car, I intend to buy a BEV	4.20 (2.10)
I feel ready to buy a BEV	3.96 (2.10)
In my opinion, buying a BEV is (negative/positive)	5.18 (6.61)
In my opinion, buying a BEV is (useless/useful)	5.08 (1.74)
In my opinion, buying a BEV is unfavorable/favorable)	4.92 (1.74)
Most of the people important to me think that I should buy a BEV	4.13 (1.65)
People I care about would buy a BEV	4.18 (1.85)
In my opinion, buying a BEV is (difficult/easy)	3.79 (1.81)
From an economic point of view, I am able to buy a BEV	3.17 (2.08)
I expect the Ukrainian crisis to get worse due to unpredictable events	4.87 (1.53)
The war in Ukraine makes me feel uncertain about my future	4.86 (1.72)
The war in Ukraine is out of control, nobody really knows how it ends	5.17 (1.66)
It is not possible to predict when we will be able to say that the war is over.	5.85 (1.34)
The war in Ukraine makes me feel uncertain about the future of the economy	5.78 (1.41)

DATA SET ANALYSIS OF THE COMPOSITE MATERIALS WITH THIN PROFILE USING DESCRIPTIVE STATISTICS

PhD. Eng. Carmen Mihai[1]

PhD. Student Alina Florentina Vladu[1]

PhD. Eng. Alexandra Gabriela Ene[1]

PhD. Student Laurentiu Dinca[1]

[1] The National Research and Development Institute for Textiles and Leather, Bucharest, **Romania**

ABSTRACT

Composite materials are widely used in high-tech fields of industry, especially in the aeronautical and aerospace industry, land and water transport. Weight reduction, high creep resistance, very good damping deformations compared to traditional materials, represent some of the advantages for these materials' usage. The studies carried out aim to determine the evolution of the physical-mechanical characteristics of a composite material with a thickness of less than 1 mm, using descriptive statistics techniques. In this context, the following four differentiated systems were tested in the accredited laboratories: CM – continuous structure composite material, P1 joined panel (the upper mark on the weft direction and the lower one tilted at 45° - Method 1), P2 joined panel (the upper mark on the warp direction and the lower one tilted at 45° - Method 2), P3 joined panel (both marks on the weft direction). The analysis report drawn up for 13 variables with the help of a specialized software evidenced that the series are very homogeneous, with little variation, the average being representative. Also, 60% of the values of the studied characteristics are placed between the 75th percentile and the maximum value, and the boxplot graphs demonstrated a very low variability of the results. The subsequent experiments will be carried out under real conditions of use, the functional model being placed on an IAR330 or SOCAT helicopter.

Keywords: data management, composite material, textile structure, homogeneity, correlation coefficients.

INTRODUCTION

Composite materials with thin profiles (below 1 mm) based on a matrix of woven structure with breaking strength greater than 1500N, having a high report strength / mass, are used on a large scale in special fields such as: the aeronautical industry and aerospace, transport, including naval, etc. This is due to the fact that, by using these materials, the weight of the entire system is reduced by approx. 25%, the creep resistance is higher, and the damping characteristics are better compared to those of the traditional materials. [1], [2], [3]. Even if there are in-depth studies related to the physico-mechanical and physico-chemical characteristics of a composite materials [4],

[5] represented by a textile matrix (fibers, yarns, woven or knitted structures, non-woven materials), their behavior over time, remains a challenge because, under conditions of variable tension and speed of loading (in real conditions of use, such as, for example, a system, of a certain shape and suspended, by means of straps connecting an aircraft that has a cruise speed of 70 m/s). These materials can yield due to the viscoelastic and viscoplastic deformations that can appear in the structure, and that cannot be controlled [6], [7], [8] Additionally, it must be considered that the properties of the 2 or 3 components (2 polymer matrixes, on the front and back of the fabric constituting the matrix) are complementary, the properties of the assembly being superior to those of the individual components. The paper presents the statistical analysis of the data obtained from the experiments in the laboratories accredited according to SR EN ISO 17025/2018 for 4 types of composite materials, differentiated as follows: CM – continuous structure composite material, P1 joined panel (the upper landmark on the direction of the weft and the lower tilted at 45° - Method 1), P2 joined panel (the upper mark on the warp direction and the lower one tilted at 45° - Method 2), P3 joined panel (both marks on the weft direction). The database was created with the help of a special program and includes 13 variables representing the physical-mechanical characteristics for 4 types of materials. The statistical analysis report was drawn up.

MATERIALS AND METHODS

The 3 panels were differentiated by the used type of joints and by the placement of the landmarks relative to each other, respectively:

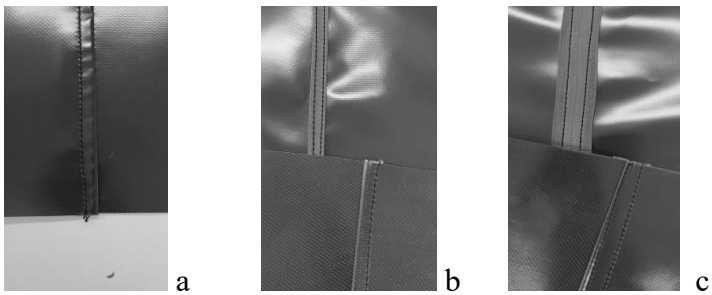


Fig. 1. a. joined panel Method 1 -P1; b. joined panel Method 2-P2; c. joined panel Method 3-P3.

The created database includes 13 variables, and the used codes are presented in table 1. With the help of the specialized program, the correlation coefficients and the significance threshold were calculated. Using descriptive statistics:

i) the parameters that reflect the extent to which the data are homogeneous or not, measuring their dispersion and implicitly the differences that exist within the data series, were determined, respectively: minimum, maximum values, average, median and standard deviation (table 2).

ii) the coefficients of variability which demonstrate to what extent the data groups are homogeneous or heterogeneous were calculated.

iii) the histograms of each variable, highlighting the asymmetry of the distribution, with the predominant frequencies or variables were drawn.

iv) the level (average, median) and dispersion indicators were represented simultaneously - the box-plot graphs (Fig. 2).

v) the correlation graphs that define the interdependence between the studied variables were drawn.

Table 1. Used codes

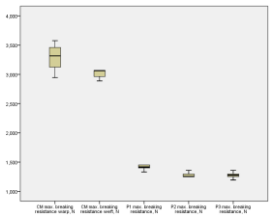
	Composite material CM	Joined panel Method 1 -P1	Joined panel Method 2-P2	Joined panel Method 3-P3
Max. breaking resistance, N	warp x1 weft x2	x5	x8	x11
Tearing force, trouser, N	warp x3 weft x4	x6	x9	x12
Tearing force, wing, N	-	x7	x10	x13

RESULTS

The resulting values are presented in tables 2, 3, 4 and 5 and fig. 2, 3 and 4 only for the variables between which there is a correlation, the rest being excluded from the analysis.

Tabel 2. Case Summaries

xn	Min	Max	Mean	Median	Std. Dev.	Kurtosis	Std. Error of Kurtosis	Skewness	Std. Error of Skewness
1	2944.0	3576.0	3284.0	3316.0	235.3	-1.378	1.12	-0.247	0.58
2	2888.0	3064.0	3008.8	3064.0	74.3	-1.116	1.12	-0.814	0.58
3	230.0	231.0	230.6	231.0	0.5	-2.094	1.12	-0.455	0.58
4	343.0	367.0	355.8	360.0	8.9	-1.402	1.12	-0.300	0.58
5	1331.0	1452.0	1410.2	1416.0	46.1	-0.442	1.12	-0.889	0.58
6	109.5	118.2	113.0	113.4	3.3	-1.052	1.12	0.442	0.58
7	191.3	196.4	193.7	193.4	2.3	-1.967	1.12	0.119	0.58
8	1250.0	1359.0	1282.6	1254.0	43.2	-0.313	1.12	1.124	0.58
9	83.5	84.4	84.0	84.2	0.4	-2.043	1.12	-0.356	0.58
10	2689.8	3829.4	3256.5	3316.0	327.1	-0.586	1.12	-0.187	0.58
11	1194.5	1359.0	1271.9	1276.7	47.1	-0.269	1.12	0.051	0.58
12	83.5	84.7	84.1	84.2	0.4	-0.978	1.12	-0.274	0.58
13	152.9	168.5	161.8	163.6	4.1	0.052	1.12	-0.518	0.58


a

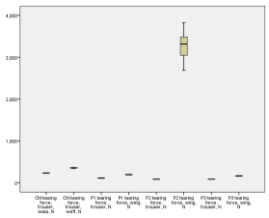
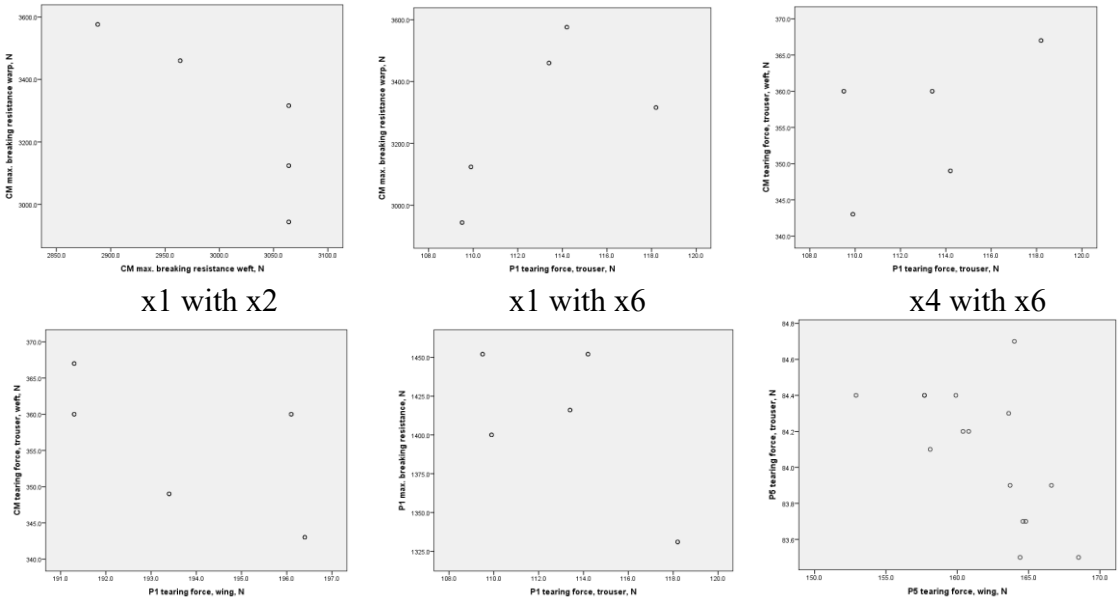

b

Fig. 2. Boxplots

The correlation graphs drawn for the studied characteristics are presented in fig.3.



x1 with x2 x1 with x6 x4 with x6

x4 with x7 x5 with x6 x12 with x13

Fig.3. Correlation graphs

Table 3. The correlation coefficients and the significance threshold for the variables x1 - 7

		x1	x2	x3	x4	x5	x6	x7
1	Pearson Correlation	1	-0.846**	-0.029	-0.027	-0.037	0.629*	0.254
	Sig. (2-tailed)		0.000	0.919	0.923	0.895	0.012	0.360
2	Pearson Correlation	-0.846**	1	-0.059	0.251	-0.497	-0.211	-0.235
	Sig. (2-tailed)	0.000		0.834	0.366	0.059	0.451	0.399
3	Pearson Correlation	-0.029	-0.059	1	0.408	0.040	0.357	-0.938**
	Sig. (2-tailed)	0.919	0.834		0.131	0.886	0.191	0.000
4	Pearson Correlation	-0.027	0.251	0.408	1	-0.439	0.561*	-0.621*
	Sig. (2-tailed)	0.923	0.366	0.131		0.102	0.030	0.013
5	Pearson Correlation	-0.037	-0.497	0.040	-0.439	1	-0.670**	0.129
	Sig. (2-tailed)	0.895	0.059	0.886	0.102		0.006	0.648
6	Pearson Correlation	0.629*	-0.211	0.357	0.561*	-0.670**	1	-0.336
	Sig. (2-tailed)	0.012	0.451	0.191	0.030	0.006		0.221
7	Pearson Correlation	0.254	-0.235	-0.938**	-0.621*	0.129	-0.336	1
	Sig. (2-tailed)	0.360	0.399	0.000	0.013	0.648	0.221	

Table 4. Correlation coefficients and significance threshold for x1-3 and x8-9.

		x1	x2	x3	x8	x9
1	Pearson Correlation	1	-0.846**	-0.029	0.358	-0.826**
	Sig. (2-tailed)		0.000	0.919	0.190	0.000
2	Pearson Correlation	-0.846**	1	-0.059	0.033	0.928**
	Sig. (2-tailed)	0.000		0.834	0.906	0.000
3	Pearson Correlation	-0.029	-0.059	1	0.559*	0.295
	Sig. (2-tailed)	0.919	0.834		0.030	0.285
8	Pearson Correlation	0.358	0.033	0.559*	1	0.224
	Sig. (2-tailed)	0.190	0.906	0.030		0.422
9	Pearson Correlation	-0.826**	0.928**	0.295	0.224	1
	Sig. (2-tailed)	0.000	0.000	0.285	0.422	

Table 5. Correlation coefficients and significance threshold for x1 – 2, x12-13

		x1	x2	x12	x13
1	Pearson Correlation	1	-0.846**	-0.311	0.343
	Sig. (2-tailed)		0.000	0.259	0.210
2	Pearson Correlation	-0.846**	1	0.463	-0.279
	Sig. (2-tailed)	0.000		0.082	0.314
12	Pearson Correlation	-0.311	0.463	1	-0.637*
	Sig. (2-tailed)	0.259	0.082		0.011
13	Pearson Correlation	0.343	-0.279	-0.637*	1
	Sig. (2-tailed)	0.210	0.314	0.011	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION

- For the synthetic indicators of the variant: the values obtained for the coefficient of variability of the 19 variables studied demonstrate that V<=5%, so the series are very homogeneous, with very low variation, the average being very representative.

- The quartiles (which divide the distribution series into four equal parts and presented below in the form of lines resulting from statistical processing) highlight the following:

- For CM the quartile deviation for:

a. the maximum force in weft, highlights that 25% of the determined values for this variable are below 3034 N, 50% between 3316 and 3518 N and 25% above 3518N, the maximum force in warp, 25% of the determined values are below 2926 N and 75% over 3064 N,

b. tearing force on weft-shaped pants type specimens, demonstrates that 25% of the values are below 230 N, 25% between 230 and 231 N, 50% are above 231 N,

c. tearing force on trouser-type specimens in warp, 50% of the values are below 360 N, 50% above 360 N.

- For P1 the quartile deviation for:

a. the maximum force shows that 50% of the values are below 1416 N, 50% above 1416 N

b. tearing force on pants type samples, the 25th percentile highlights that 25% of the values determined for this variable are below 109.7 N, the 50th percentile demonstrates that 50% are between 109.7 and 113.4 N, and the 75th -th percentile shows that 25% of the values are above 116.2 N

c. tearing force on wing-type specimens, highlights that 25% of the values determined for this variable are below 191.3 N, 50% between 191.3 and 193.4 N and 25% above 196.3 N.

Regarding the asymmetry indicators, using the relations $\bar{x} > Me > Mo$ and $\bar{x} < Me < Mo$ and taking into account the Skewness and Kurtosis values, it can be appreciated that for all the variables studied, the series show right or negative asymmetry, with large values predominating. Negative kurtosis curve is leptokurtic, i.e., it shows a weak variation of the variable in parallel with a strong variation of the frequencies.

- The box-plot graphs demonstrate: very low variability of the results for all 19 variables, because the dimensions of the box are small and in the vast majority of cases are median, so the central tendency overlaps its edges.

- Analysing the correlations between the variables, the significance threshold is below 0.05, so there is a relationship between the variables x1 with x2, x3 with x7, x5 with x6, x1 with x9 and x2 with x9. The sign of the correlation evidences the nature of the link between them, directly proportional if the sign is positive and inversely proportional if the sign is negative.

- Regarding the correlation graphs, could be evidence that:

- when the relationship between two considered variables is positive or directly proportional, the cloud of points has an orientation from lower left to upper right. This is the case of variables x1 with x6 (coefficient 0.629), x2 with x9 (coefficient 0.928), x3 with x8 (coefficient 0.559) and x4 with x6 (coefficient 0.561).
- for the inversely proportional relationship, the Pearson coefficient is negative, and the cloud of points is oriented downward (from top left to bottom right), in the case of variables: x1 with x2 (coefficient -0.846), x3 with x7 (coefficient -0.938), x4 with x7 (coefficient -0.621), x5 is with x6 (coefficient -0.670), x1 with x9 (coefficient -0.826), and x12 with x13 (coefficient -0.637).
- the proportion of the variant explained by the relationship found, highlights that, for example, 86.1% of the variation observed in the case of variables x2 and x9 is found in reality, or in other words, the relationship between the two variables is present in this way (directly proportional) at 86.1 % of the population, so an increase in breaking resistance in weft for composite material causes an increase in tearing force, trouser for the panel joined according to method 2, or an increase in tearing force, trouser in warp for composite material causes a decrease in tearing force, wing for the joint panel according to method 1.

Initially, for the modeling of the series, the ARMA (autoregressive moving average) processes are proposed. These processes combine the autoregressive (AR) and moving average (MA) lags, by considering that the thickness of the composite material can be modeled depending on the observations related to the obtained experimental data. The experience led to the conclusion that its usage is indicated for predicting the behavior of the composite material over time (minimum 90 days), depending on the independent variables with stochastic trends, the error term being imposed from the beginning to be stationary. Thus, by using the software package, the type of process for the thickness of the material and the average dissipation of the product will be determined.

CONCLUSION

The information obtained as a result of the data analysis process using descriptive statistics techniques, is the basis for improving the production process of composite materials with textile matrix and for the systematization of the assembly and adjustment parameters of the equipment used in different phases of the technological process.

The absolute sizes of the correlation coefficients indicate that there are strong links between all the variables that entered the study, because their values are greater than 0.05.

The quartiles that divide the distribution series into four equal parts and that are presented below in the form of lines resulting from statistical processing highlight the fact that approx. 60% of the values/characteristic are placed between the 75th percentile and the maximum value.

When the information obtained from the data statistical analysis will be used correctly, the decision-making process regarding the type of composite material to be used for a specific application (especially for the aeronautical and naval fields, such as parachute air mode for extinguishing fires) will be much faster and with greater accuracy compared to the standard method currently used.

ACKNOWLEDGEMENTS

This scientific paper is funded by the Ministry of Research, Innovation, Digitalisation within Program 1 - Development of the national RD system, Subprogram 1.2 - Institutional Performance - RDI excellence funding projects, Contract no. 4PFE/2021.

This work was carried out through the Core Programme within the National Research Development and Innovation Plan 2022-2027, carried out with the support of MCID, project no. 6N/2023, PN 23 26 02 01, project title "Innovative, resilient digital solutions for the recovery and sustainable growth of terrestrial and aquatic natural resources, as well as for the exploitation of non-conventional aerial energy resources (THORR)″.

REFERENCES

[1] Young, J.F., Mindess, S., Gray, J., Bentur, A., The Science and Technology of Civil Engineering Materials, Prentice Hall, Upper Saddle River, SUA, 1998.

[2] Tai-Ran Hsu, The Finite Element Method in Thermomecanics, Ed. Allen&Unwin, Boston, SUA, 1986.

[3] Knight, M., Curliss, D., Composite Materials, Encyclopedia of Physical Science and Technology (Third Edition), 2003.

[4] Suciu, V., Suciu M.V., Studiul materialelor, Ed. Fair Partners, Bucuresti, pp. 203 – 207, 2008.

[5] Dumitrescu C., Saban R., Metalurgie fizica tratamente termice, Ed. Fair Partners, Bucuresti, pp. 157 – 189, 2008.

[6] Zweben, C.H., Encyclopedia of Condensed Matter Physics, Composites: Overview, Elsevier Ltd., pp.178 – 201, 2021.

[7] Pellicer E., Encyclopedia of Materials: Composites, Smart Composite Materials: An Introduction, Elsevier Ltd., Vol 2, pp. 378 – 397, 2021.

[8] Adamovic D., Zivic F., Encyclopedia of Materials: Composites, Static Mechanical Characterization of Ceramic Matrix Composites, Elsevier Ltd.,Vol 2, pp. 158–182, 2021

[9] Millea V., Z., Gestionarea si analiza datelor cu SPSS si PSPP, Introducere in gestionarea datelor statistice cu SPSS si PSPP, Ed. Presa Universitara Clujeana, Partea I, pp. 104 - 174

[10] Tong Y., Tien I., Time-Series Prediction in Nodal Networks Using Recurrent Neural Networks and a Pairwise-Gated Recurrent Unit Approach, ASCE – ASME Journal of Risk and Uncertainty in Engineering Systems Part A, Civil Engineering, Vol. 8 (2), 2022

DROSOPHILA MELANOGASTER AS A TEST-SYSTEM FOR ASSESSMENT OF THE AIR POLLUTION BY USING THE CITY OF KAZAN AS AN EXAMPLE

Rustam Sokolov
PhD Viktoria Kostenko
Tansu Gazieva
Prof.DSc Natalya Stepanova
Kazan Federal University, **Russia**

ABSTRACT

Drosophila as a model for toxicological study is a simple and effective test-system owing to (i) availability of a wide range of accessible methods allowing the integral assessment of the negative effect of the factor under study on the vital characteristics at all levels of the organism vital activity (from molecular to population), (ii) possibility of obtaining results within a relatively short period of time (from 2 days to 2 weeks); (iii) low price of working methods, (iv) absence of specific requirements as to work with an object. The aim of the work was to assess the air quality in the city of Kazan based on the change of the drosophila's vital parameters: the survival rate at the stage of embryogenesis, the fertility (the number of eggs), the locomotion, the degree of the intestines tissue damage and the level of DNA-comets. To analyze the air quality, we selected such city zones as, Privolzhsky (1), Moskovsky (2), Sovetsky (3). It was shown that flies that were in zones 1 and 2, but not in 3, are characterized by a decrease in fertility, an increase in embryonic death of offspring, intestines tissue damage and DNA damage.

Keywords: air pollution, genotoxicity, drosophila, adaptation

INTRODUCTION

Air pollution is one of the major health risk factors associated with the environment. From the environmental standpoint, the most important atmospheric pollutants released by industries and fossil fuel vehicles are polycyclic aromatic hydrocarbons (PAHs), metallic compounds, and particulate matter [1]. According to the WHO data, solids present in the atmospheric air have an adverse effect on the human health, even very small amounts of these pollutants may affect deoxyribonucleic acid (DNA), posing a considerable health hazard [2]. The city of Kazan, which was chosen in this research, was subject to a marked increase in industrial, real estate, and populational growth. According to our previously data, the chemicals coming with the atmospheric air (PM10, CO, NO_2, and SO_2) are effect on cardiovascular and respiratory system on population health in the city of Kazan [3; 12]. For more effective atmospheric quality monitoring need using *in vivo* protocols. The use of simple model organisms in this case will allow us to solve these problems. Nowadays, *Drosophila melanogaster* is used as a test-system to assess toxicity of chemical compounds in foods and drugs; water quality. Determination of the embryonic

death rate and appearance of somatic mutations are applied for this type of research. At present there are no cheap and effective biological test-systems for assessing the air pollution and effects of such pollution on the human body. A search for indicator species as reliable and cost-effective instruments for monitoring the environmental quality is a pressing challenge today. Drosophila as a model for toxicological study is a simple and effective test-system owing to (i) availability of a wide range of accessible methods allowing the integral assessment of the negative effect of the factor under study on the vital characteristics at all levels of the organism vital activity (from molecular to population), (ii) possibility of obtaining results within a relatively short period of time (from 2 days to 2 weeks); (iii) low price of working methods, (iv) absence of specific requirements as to work with an object. The aim of the work was to assess the air quality in the city of Kazan based on the change of the drosophila's vital parameters.

MATERIALS AND METHODS

The fruit flies used in this study were the Canton-S strain *Drosophila melanogaster*. They were cultured and maintained at an optimum temperature of 22-25℃ with access to a standard cornmeal diet composed of corn flour, agar, yeast, propionic acid, and distilled water, as well as a natural light-dark cycle. In the experimental groups the flies at the imago stage (females and males by 50 individuals each) were immersed in containers with a volume of 5 l with standard nutrient and were left for 48h in the city area. To analyse the air quality we selected such city zones as, Privolzhsky (1), Moskovsky (2), and Sovetsky (3) (fig.1). In the control group the flies were in laboratory condition. The flies were tested in the period of June, 2023. The following parameters were assessed as vital characteristics: the survival rate at the stage of embryogenesis, the fertility (the number of eggs), the locomotor activity, the degree of the intestines tissue damage, DNA comets.



Figure 1. City districts of Kazan. 1 – Privolzhsky district, 2 – Moskovsky district, 3 – Sovetsky district.

The frequency of lethal mutations during embryogenesis was used as an indicator of the changes occurring in gametes of experimental imagoes. The frequency of embryo lethality was determined as the fraction of the eggs that stopped their development at a certain stage out of the total number of the eggs laid. To perform the experiment, males

and females from all control and experimental groups were put together for 12 h for mating. Subsequently, inseminated females were placed in Petri dishes (d = 10 cm) with temporary medium (5 individuals per dish) for 12 h to obtain eggs. In the next day, the eggs were counted using a stereoscopic microscope and then placed in a thermostat (t = 24 °C) for 48 h. The sample size was 10 Petri dishes for each experimental group. The embryo lethality level was calculated according to [4]. Using the indicators of preimaginal development (the number of eggs and embryonic death) for each group, the selection index (I_{tot}) was calculated according to the Crow formula [5]. The selection index takes into account the rates of fertility, fertility dispersion and death/survival in the prereproductive period of development:

$I_{tot} = l_m + I_f / p_s$, where lm – differential mortality component, and If – sampling component associated with differential fertility.

To detect locomotor behavior in control and each experimental group we used climbing assay previously described by Chambers et al. [6]. Groups of ten flies were placed in an empty climbing vial and then tapped down to the bottom. They were allowed 20 seconds to climb past a dotted line marked 10 cm from the bottom of the vial. The number of flies above the 10 cm mark at 20 seconds was recorded as a percentage of flies able to climb/vial. A minimum of 3 separate trials were run per experimental group.

Trypan blue staining was performed on third instar larvae by following a reported protocol [7]. Larvae (n = 25 for control, n = 25 – for each experimental groups) were collected and washed with 1xPBS solution thoroughly to remove any food traces prior experiment. Larvae were then transferred to trypan blue stain [8] and kept in shaking condition for 30 min. With the onset of time, the larvae were washed thoroughly with PBS solution again for 15 more minutes to remove any extra dye that may be present on its surface or that might have been ingested. The larvae were then observed under a stereomicroscope and imaged to check cell damage in intestine.

To assess DNA damage in the gut of flies, an alkaline variant of the DNA comet assay was used; this allows for the determination of single-strand DNA breaks in cells [9]. Fluorescence microscopy (Carl Zeiss Axio Imager M2, Oberkochen, Germany) was used to visualize and rank the DNA comets. The DNA damage index was calculated using the formula $(0 \times n0 + 1 \times n1 + 2 \times n2 + 3 \times n3 + 4 \times n4)/\Sigma$, where n0 to n4 are the numbers of DNA comets of each type, and Σ is the sum of the analyzed DNA comets.

Statistical data processing was performed using the software Statistica 12.0 using one-factor analysis of variance (one-way ANOVA) using a Bonferroni post hoc test and GraphPad Prism version 6.0 for Windows (GraphPad Software). Experiments were performed in three repetitions. For each indicator, the arithmetic mean, its error, and standard deviation were calculated.

RESULTS

The obtained results of the atmospheric air effect on the drosophila vital characteristics are given in Figure 2 and Table 2. The analysis of adaptability traits associated with reproductive function resulted in revealing a significant decrease of fertility and increase of the embryonic death (Fig.2B and 2C) in experimental groups. Compared with the control group, the fertility in zone 1 decreased by 34% ($p<0.05$) and in zone 2 – by 42% ($p<0.05$). Compared with the control group, the embryonic death rate in zone 1 increased

by 21% ($p<0.05$) and in zone 2 – by 28% ($p<0.05$). No significant differences were revealed in zone 3 compared with the control group. The results of adaptation components study were used for specifying the selection intensity on exposure to environmental factors. The selection index was calculated for embryonic period of development. The data show that compared with the control group (I_{tot} = 0.16), the total selection index increased in the experimental groups: by 24% ($p<0.05$) in zone 1, by 30% ($p<0.05$) in zone 2 and by 20% ($p>0.05$) in zone 3.

In addition, taking into account the data of de Santana et al. [10], we also evaluated the toxigenicity and genotoxicity of the groups against the intestinal tissue of flies. With this aim, we analyzed the number of enterocytes of flies with DNA damage and the index of DNA comets (IDC). The results of the studies are presented in Fig. 2E. The data analysis revealed that the DNA damage index increased significantly by 35% ($p<0.05$) in zone 1, and by 67% ($p<0.05$) in zone 2 compared with the control group. Analysis of the intestines integrity by means of trypan blue dye showed that the increase of the intestines tissue damage rate by 17% was observed in the flies in zone 2. In the control group, as well as in zones 1 and 3, the rate did not exceed 3-5% (Fig 2D).

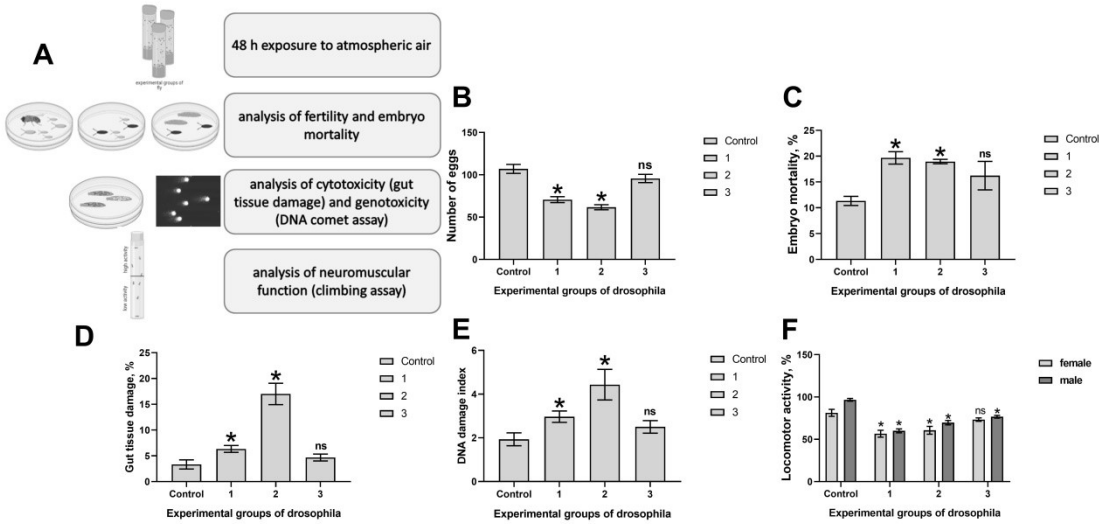


Figure 2. Assessment of vital traits and genetic damage in *D. melanogaster* exposed to environmental stress in an urban area in Kazan. (a) Scheme of an experiment. (b to c) Indicators characterizing the reproductive potential of drosophila. (d and e) Indicators that allow assessment of the environmental stress to the genome integrity of drosophila enterocytes. Data present as mean±SEM. The values were compared with each other using one-factor analysis of variance (one-way ANOVA) using a Bonferroni post hoc test; *, $p < 0.05$ compared to the control group.

Air pollution, especially PM2.5 and nitrogen oxides (NOx), is known to affect the CNS, causing systemic inflammation and neuroinflammation [11]. Therefore we analyzed the locomotor activity of the offsprings produced from the flies exposed to atmospheric air within the limits of the city of Kazan. During a behavioral test of the locomotor index, the imago decreased in the experimental groups compared with the control one (Fig 2F). A significant decrease of the locomotor activity in females was demonstrated in experimental groups 1 (by 41%, $p<0.05$) and 2 (by 25%, $p<0.05$) compared with the control group. By applying ANOVA data it was found that the environmental factor in zones 1 (Privolzhsky district) and 2 (Moskovsky district) had a significant effect on vital

parameters of the flies – adaptability (reproductive traits), and tissue and DNA integrity. The η^2 index varied from 0.63 to 0.97. As for zone 3 (Sovetsky district), a significant effect was revealed only for such indicator as locomotor activity in males – $\eta^2 = 0.94$.

Table 1. ANOVA analysis of assessment of vital traits and genetic damage in Drosophila exposed to environmental stress in an urban area in Kazan

Experimental groups	Parameters	F	p	η^2
Privolzhsky district	**Egg production**	6.86	0.05	0.63
	Embryo lethal	31.25	0.005	0.88
	Locomotor activity (female)	18.31	0.012	0.82
	Locomotor activity (male)	165.7	0.0002	0.97
	Gut tissue damage	7.36	0.05	0.64
	DNA damage index	8.22	0.05	0.67
Moskovsky district	**Egg production**	10.86	0.03	0.73
	Embryo lethal	60.69	0.001	0.93
	Locomotor activity (female)	11.07	0.02	0.73
	Locomotor activity (male)	76.21	0.0009	0.95
	Gut tissue damage	36.54	0.003	0.90
	DNA damage index	10.85	0.03	0.73
Sovetsky district	**Egg production**	1.87	0.24	0.31
	Embryo lethal	3.24	0.15	0.44
	Locomotor activity (female)	3.06	0.15	0.43
	Locomotor activity (male)	72.0	0.001	0.94
	Gut tissue damage	1.45	0.29	0.26
	DNA damage index	1.87	0.24	0.31

F – the F-statistics; p- the p-value; η^2 – the partial eta-squared (expresses the degree of influence or the strength of the effect (factor) on the dependent variable (attribute); the value of η^2 lies in the range from 0 to 1).whether the strength of the effect (factor) on the dependent variable (attribute); the value of η^2 lies in the range from 0 to 1).

DISCUSSION

The data on assessment of the flies' adaptability parameters obtained in our research indicate the air pollution in the selected districts in the city of Kazan. The results of our research showed that the fertility decreased and the embryonic death rate increased in the experimental flies. The selection index, which we calculated in the flies exposed to the environment, depended on the death rate rather than fertility. The decrease of reproductive potential is likely to be associated with the pollution of the air with the derivatives of anti-knock agents in petrol. For instance, in the period of wide use of tetraethyl lead, its mutagenic and teratogenic effect on the early stages of drosophilae development was described in the work of Kennedy et al. [13]. The increase of the DNA damage index in drosophilae enterocytes, which we found, was probably associated with the atmospheric air pollution in urban area. Drosophila is known to be widely used as a model in toxicological studies on the compounds with different nature, since it demonstrates high sensitivity to chemical compounds in high concentrations. It was shown in the works of Alves et al [14] and Billet et al [15] that Fe, Si, Al and Mn accumulated on PM filters, which were used in the city area. These chemicals are connected with road dust and have impact on the air quality and the human health. It was shown in the work of Núñez-Millacura et al. [16], for example, that iron in high concentrations had genotoxic effect and could accumulate in neuronal cells. As of today, molecular mechanisms underlying the nervous function disorders in response to exposure to volatile compounds in the air are not yet identified. The changes in locomotor activity of experimental flies, which we revealed, were in agreement with data given in the work of Eom H.-J. et al [17] about the effect of volatile compounds in the air (toluene and formaldehyde) on the drosophilae behavior.

CONCLUSION

Based on our results (low fertility, increase of embryonic mortality, high DNA damage index) a conclusion can be made that the selected districts of Kazan are characterized by low air quality. The results of this research can give basic understanding of the air pollution concentration in the city of Kazan. One of the tasks of this research was to assess drosophilae as alternative system for biomonitoring. Further investigations in this field with the use of drosophila as a test-system *in vivo* can give valuable information on molecular mechanisms of the stress response of the organism in regard to components contributing to air pollution. Since we have determined that the selection index depend on the death rate at the embryonic stage of the insect development, this research will allow to specify, what kind of anthropogenic load the insects inhabiting the Republic of Tatarstan (RT) experience, because in this territory, there are about 109 types listed in the Red-Book of RT. The obtained results and further use of drosophila as a model for the environmental pollution study can complete the applied monitoring protocols for assessing the risk of the human health exposure to environmental factors.

ACKNOWLEDGEMENTS

The work was performed in frames of the Kazan Federal University Strategic Academic Leadership Program (PRIORITY-2030).

REFERENCES

[1] Lemos A. T., Coronas M. V., Mutagenicity of particulate matter fractions in areas under the impact of urban and industrial activities, Chemosphere, vol. 89, pp 1126–1134, 2012;

[2] Domingues É.P., Silva G. G., Genotoxic effects following exposure to air pollution in street vendors from a high-traffic urban area, Environ Monit Assess, vol. 190, p 215, 2018;

[3] Stepanova N., Valeeva E., The atmospheric air quality analysis and the health risk assessment for the Kazan city population (The Republic of Tatarstan), International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, vol. 22, is. 5.1, pp 457–464, 2022;

[4] Gavrilova E., Kostenko V., Repression of Staphylococcus aureus and Escherichia coli by Lactiplantibacillus plantarum Strain AG10 in Drosophila melanogaster In Vivo Model, Microorganisms, vol. 11, is. 5, p 1297, 2023;

[5] Danilova A. L., Sukhomiasova A. L., Vital statistics and the crow index among the indigenous population of the Republic of Sakha (Yakutia), Ekologiya cheloveka (Human Ecology), vol. 28, N. 6, pp 12-20, 2021;

[6] Chambers, R. P., Call G. B., Nicotine increases lifespan and rescues olfactory and motor deficits in a Drosophila model of Parkinson's disease, Behav. Brain Res. Vol. 253, pp 95–102, 2013;

[7] Sabat D., Patnaik A., Investigation of titania nanoparticles on behaviour and mechanosensory organ of Drosophila melanogaster, Physiol Behav, vol. 167, pp 76–85, 2016;

[8] Siddique, Y. H., Protective role of curcumin against the toxic effects of cyclophosphamide in the third instar larvae of transgenic Drosophila melanogaster (hsp70-lacZ) Bg9, Alternative Medicine Studies, vol. 2, is. 1, p e2-e2, 2012;

[9] Mukhopadhyay I., Chowdhuri D. K., Evaluation of in vivo genotoxicity of cypermethrin in Drosophila melanogaster using the alkaline Comet assay, Mutagenesis vol. 19, pp 85–90, 2004;

[10] de Santana S. L., Verçosa C. J. Drosophila melanogaster as model organism for monitoring and analyzing genotoxicity associated with city air pollution, Environ Sci Pollut Res Int.;vol.25, is. 32, pp 32409-32417, 2018;

[11] Kim H., Kim W.- H., Air Pollution and Central Nervous System Disease: A Review of the Impact of Fine Particulate Matter on Neurological Disorders, Front. Public Health, vol. 8, p 575330, 2020;

[12] Maludze G; Stepanova N., Risk assessment of the incidence of cardiovascular diseases on the basis of evolutionary model, European Journal of Clinical Investigation, vol. 52, R. 20, 2022;

[13] Kennedy G. L., Arnold D., Mutagenic and teratogenic studies with lead acetate and tetraethyl lead, Toxicol Appl Pharmacol, vol. 19, pp 370-375, 1971;

[14] Alves C. A., Evtyugina M., Chemical profiling of PM10 from urban road dust, Sci Total Environ, vol. 634, pp 41–51, 2018;

[15] Billet S., Landkocz Y., Chemical characterization of fine and ultrafine PM, direct and indirect genotoxicity of PM and their organic extracts on pulmonary cells, J Environ Sci, vol. 71, pp 168–178, 2018;

[16] Núñez-Millacura C., Tapia V., An oxidative stress-mediated positive feedback iron uptake loop in neuronal cell, J Neurochem, vol. 82, pp 240–248, 2002;

[17] Eom, H.-J., Liu Y., Inhalation toxicity of indoor air pollutants in Drosophila melanogaster using integrated transcriptomics and computational behavior analyses. Sci. Rep., vol. 7, p 46473, 2017.

EFFECT OF MOISTURE AND ORGANIC MATTER CONTENT ON N_2O EMISSIONS

Mg.sc.ing. Sindija Liepa[1]
Mg.sc.ing. Luīze Lepiksone[1]
Mg.sc.ing Dace Butenaite[1]
Mg.sc.ing. Jovita Pilecka-Ulcugaceva[1]
Assist.prof. Inga Grinfelde[1]
[1]Latvia University of Life Sciences and Technologies**, Latvia**

ABSTRACT

The increasing economic activity reinforces the importance of climate change on a global scale. Together with the development of the economy and the increase in people's well-being, the emissions of greenhouse gases (GHG) which are released into the atmosphere as a result of human activities, also increase. Nitrous oxide (N_2O) is one of the main greenhouse and ozone (O_3) depleting gases. Seven percent of the anthropogenic greenhouse effect is nitrous oxide. From a molecular perspective, N_2O has a 310-fold greater global warming potential than CO_2 over a 100-year period. Organic soils are the main source of direct emissions of N_2O. Emissions from organic soils account for up to 13% of total N_2O emissions in the European Union, although organic soils cover only 7% of the area of the European Union. Totally 10 mixed soil samples from 10 agricultural plots were collected for the experiment. Soil from each agricultural plot was weighed into two buckets to allow measurements for two moisture regimes - wet aerobic conditions and wet anaerobic conditions. The soil was placed in 3-liter buckets, each bucket containing 1.5 kilograms. Measurements were made with the CRDS device Picarro G2508. The equipment measured the concentrations of N_2O with an average interval of one second and the emission were calculated using Soil Flux software. Descriptive statistical methods, analysis of variance and Kruskal-Wallis test, and multiple pairwise comparisons using the Steel-Dwass-Critchlow-Fligner procedure were used. By analyzing the data it was obtained that the statistically significant differences ($p<0.0001$) of N_2O emissions are between wet organic soil and the other groups.

Keywords: N_2O, GHG emissions, organic soil, agriculture, moisture, Picarro G2508.

INTRODUCTION

The importance of climate change on a global scale is becoming more and more relevant. Along with the development of the economy and the increase in people's well-being, greenhouse gas emissions, which are released into the atmosphere as a result of human activities, also increase. [1] Nitrous oxide (N_2O) is one of the main greenhouse and ozone (O_3) depleting gases. Seven percent of the anthropogenic greenhouse effect is nitrous oxide. From a molecular perspective, N_2O has a 310-fold greater global

warming potential than CO_2 over a 100-year period [2]. Sources of N_2O include the ocean, soil, biomass burning, fertilizer use, and various industrial processes. N_2O emissions from natural sources make up about 60%, while from anthropogenic sources - about 40% of total N_2O emissions [3]; [4]. Humans are mainly responsible for the increase in N_2O concentration in the atmosphere, most of the emissions are related to food production. Agriculture is thus recognized as the largest source of anthropogenic N_2O, accounting for approximately 60% of total anthropogenic emissions. N_2O emissions from agriculture have increased mainly due to the widespread use of nitrogen fertilizers on agricultural land and the increase in livestock farming. Agricultural N_2O emissions are likely to continue to increase as food production will need to increase in the coming decades to feed a growing population [5]. Soils are one of the main biological sources of nitrous oxide (N_2O), while nitrification and denitrification processes are central to the formation of N_2O in soil. How much NO and NO_2 are taken up by plants determines the net exchange of NO_x at the Earth's surface [6]. Organic soils are the main source of direct emissions of N_2O. Emissions from organic soils account for up to 13% of total N_2O emissions in the European Union, although organic soils cover only 7% of the area of the European Union [7]. Drainage or use of organic soils for agricultural purposes often results in large emissions. In order to develop measures to reduce N_2O emissions, in-depth research on N_2O formation in organic soils is necessary, as this process is influenced by many different factors. A better understanding of N_2O processes in soil and the formation of nitrous oxide emissions could allow more accurate determination of the total amount of N_2O and thus the total amount of GHG emissions from organic soils. The nitrogen cycle consists of several stages. [8] Have identified five processes that are central to the nitrogen cycle: ammonification, which includes N_2 fixation, nitrification, denitrification, and nitrite-nitrate interconversion. Atmospheric N_2 is fixed (ammonification) into ammonia (NH_3) to break the N_2 triple bond. In the soil, NH_3 is transformed into ammonium ion (NH_4^+), which can be oxidized to nitrate ion (NO_3^-). This process is called nitrification. During nitrification, nitrite (NO_2^-) and nitrate (NO_3) ions are produced, they are reduced during denitrification, and gradually NO_3^- is reduced to N_2 by four enzymes, creating intermediate products: NO_2^-, NO and N_2O. During the ammonification of NO_3^-, N_2O can also be formed. The general processes of mineralization and assimilation of organic matter complete the movement of reactive nitrogen through the biosphere [9]; [8]. The main sources of N_2O and NO are soils. The formation of N_2O in the soil takes place mainly through the processes of nitrification and denitrification, which are influenced by the physical and chemical properties of the soil: soil moisture, temperature, pH content, oxygen concentration, the amount of available organic carbon and nitrogen, and the C/N ratio of the soil [10]; [11]; [9]. Temperature and humidity play an important role in the processes of nitrification and denitrification, as they determine the activity of microorganisms. In addition, soil temperature and moisture strongly influence not only N_2O production, but also its release into the atmosphere [9].

At low temperatures, the rate of nitrogen conversion is low, and increases with increasing temperature. A study conducted in maize and wheat fields on sandy soil in northern China concluded that N_2O emissions increase exponentially with increasing soil temperature [12]. The same conclusion has been reached by [13] in their study of N_2O emissions from loamy soils in England. It is important to highlight the positive correlation between temperature and denitrification rate: increasing soil temperature stimulates soil respiration (microbial activity), thereby increasing the anaerobic sites

where denitrification can occur [9]; [12]. In mineral soils, N_2O is usually formed in nitrification and denitrification processes, and the speed of these processes largely determines the amount of N_2O emissions. Also in organic soils, nitrification and denitrification are the main processes that generate N_2O [14]. Depending on the soil type, the ability of the soil to produce N_2O varies. Organic (peat) soils with high organic nitrogen content (1-2%) have a high capacity to produce N_2O. Organic agricultural soils have the greatest potential to act as a source of N_2O in boreal regions [11]. When organic soils are drained for agricultural purposes, the decomposition of organic matter is accelerated and large N_2O emissions are produced by nitrification and denitrification [11]; [15]. Large N_2O emissions from drained organic soils have previously been observed, such as 23 kg N ha−1 yr. in the boreal zone, 23 kg N ha−1 yr. in Canadian soils, 56 kg N ha−1 yr. in southern Germany, and 97 kg N ha−1 yr. Ohio, USA. In organic soils, denitrification is more important than nitrification due to N_2O release due to high carbon availability during decomposition of soil organic matter [15].

MATERIALS AND METHODS

Within the scope of the work, data collected in the test fields of the Stende Research Center were used. The research fields is located 6 km from the city of Talsi and 5 km from the Stende research center (Figure 1). Instead of measurements, an organic farming method is used.

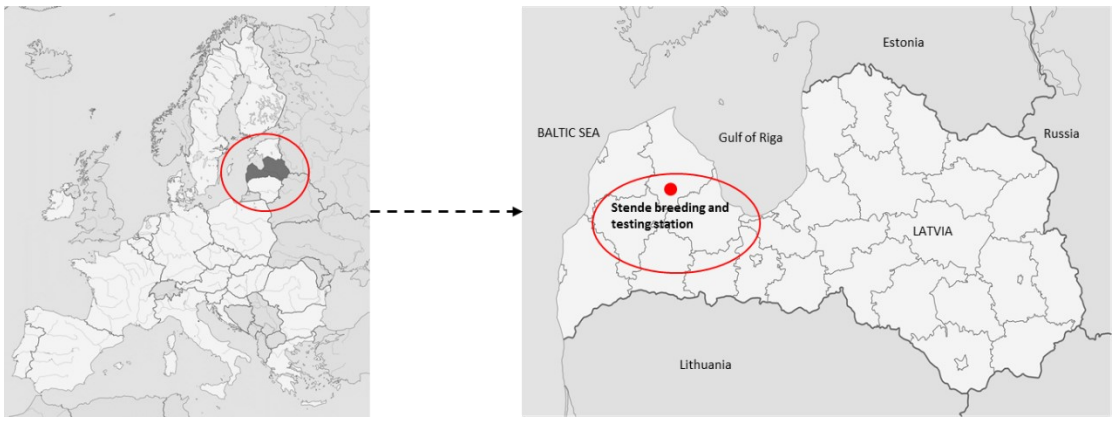


Figure 1. Location of Stende Research Center

The samples were collected on 12.08.2020, while the measurements of GHG gases were carried out in laboratory conditions from August to September 2020. Average soil samples collected from 10 plots. The average soil sample was created in each sample plot by collecting soil samples in five places of the plot (in each corner of the plot and in the middle of the plot). Soil samples were placed in 3 L buckets, each bucket containing 1.5 kg of soil. Samples from each area are weighed in two buckets so that measurements can be made by varying the humidity regime. GHG gas measurements were made using the Picarro G2508 device, to which a plastic bucket with soil was attached (bucket volume – 3 L, surface diameter – 19 cm, ground surface area – 254.46 cm^2). Before taking the measurements, enough water was added to one of the buckets to compensate for evaporation (150 mL), while in the other bucket, enough water was added to create over moistened soil (300 mL). In the course of the measurements, the water in the buckets was regularly replenished, a total of seven times. The equipment measured the

concentrations of five gases - N_2O, CH_4, CO_2, NH_3, and H2O with an average interval of one second (Figure 2).



Figure 2. CRDS device Picarro G5131-i

The study assumes that organic soils are soils with an organic matter content of more than 20%. The rest are defined as mineral soils. Dry soils are defined as those to which enough water was added during the measurement to compensate for evaporation (150 mL), while wet soils are defined as those to which water was added enough to form over moistened soil (300 mL). Codes were assigned to the collected samples depending on the cultivated crop and whether the sample was defined as dry or wet soil (Table 1).

Table 1. Explanation of codes assigned to collected samples

Soil Sample	Code for dry soil	Code for moist soil
Winter wheat organic soil	WW_O_1	WW_O_2
Summer wheat organic soil	SW_O_1	SW_O_2
Oat organic soil	O_O_1	O_O_2
Clover organic soil	C_O_1	C_O_2
Barley organic soil	B_O_1	B_O_2
Buckwheat organic soil	BW_O_1	BW_O_2
Winter wheat sand soil	WW_S_1	WW_S_2
Summer wheat sand soil	SW_S_1	SW_S_2
Oat sand soil	O_S_1	O_S_2
Clover sand soil	C_S_1	C_S_2
Barley sand soil	B_S_1	B_S_2
Buckwheat sand soil	BW_S_1	BW_S_2

RESULTS

The study assumes that organic soils are soils with an organic matter content of more than 20%. The rest are defined as mineral soils. Analysing descriptive statistics data on GHG emissions from organic soils, it is possible to judge the arithmetic mean, standard error, median, mode, standard deviation, variance, range, minimum and maximum values and number of measurements for each gas (N_2O, CH_4, CO_2, NH_3, and H_2O). The number of measurements is the same for all gases. It can be seen that the peak value is the largest for N_2O and the smallest for NH_3. Also, the data range, arithmetic mean, standard error, standard deviation and variance are the largest precisely for N_2O measurements. Both the range, standard deviation, and variance of the data are relatively large for all gases, indicating a large scatter in the data. Also, the fact that all gases have a discrepancy between the arithmetic mean and the median indicates that the data are scattered and not normally distributed.

In general, comparing descriptive statistical data for organic soil with mineral soil, it can be concluded that the content of organic matter has an impact on N_2O emission. In the study, dry soils are defined as those to which enough water was added during the measurement to compensate for evaporation (150 mL), while wet soils are defined as those to which water was added enough to form over moistened soil (300 mL).

Looking at descriptive statistics for GHG emissions from wet soil is similar to analysing descriptive statistics for organic soil. Both the data range, standard deviation, and variance for all gases are relatively large, indicating a large spread of data. Also, the fact that all gases have a discrepancy between the arithmetic mean and the median indicates that the data are scattered and not normally distributed.

Compared N_2O emissions comparing wet and dry soil and when comparing N_2O emissions, there is a large scatter of data from both mineral soil and organic soil (Fig. 3). However, for organic soil and for moist, the dispersion of the data is significantly greater.

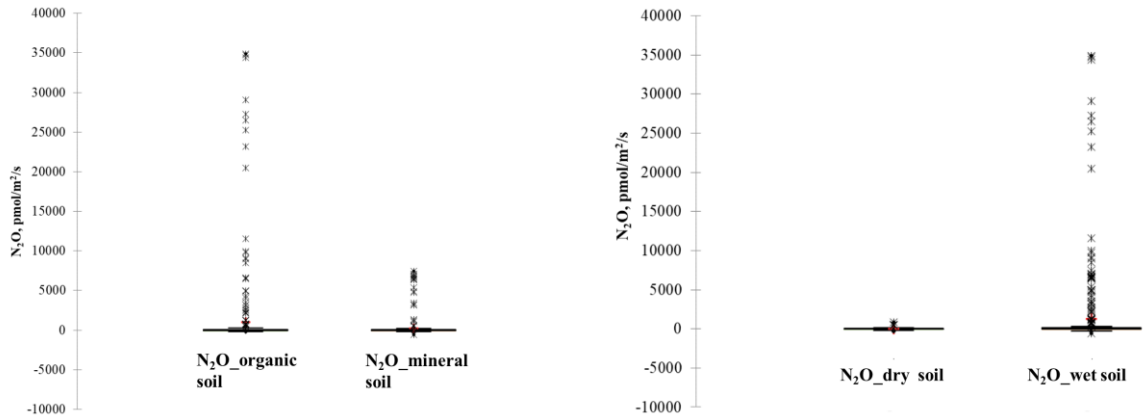


Figure 3. Comparison of N_2O emissions between organic and mineral soil, dry and wet soil

The statistically significant differences ($p<0.0001$) of N_2O emissions are between wet organic soil and the other groups (dry organic soil, wet and dry mineral soil). Which is explained by the high peak value (34920 pmol/m^2/s) for wet organic for the soil. As previously described, it is from wet compared to dry and organic soils compared to mineral soil that the emissions are highest.

The Steel-Dwass-Critchlow-Fligner procedure was used to compare which groups had a significant difference. Using the group comparison, it can be concluded that there is no difference for mineral soil between wet and dry, the values are divided into one group, while if the organic soil is dry or wet, there is a significant difference in N_2O emissions, as they are separated into separate groups after this test.

DISCUSION

The average N_2O emission in mineral soils is 224.9 pmol/m^2/s, while in organic soils it is much higher – 1015.0 pmol/m^2/s. According to the information reviewed in the literature, this can be explained by the decomposition processes of organic matter. Also, in organic soils, denitrification is more important than nitrification due to the release of N_2O due to the high availability of carbon during the decomposition of organic matter in soils [15].

Soil moisture, as the main contributing factor to N_2O emissions in the soil, determines the state of soil aeration and controls the supply of soil microorganisms with oxygen, thus influencing the activity of nitrifying-denitrifying bacteria. As soil moisture increases, the addition of organic carbon promotes the respiration of heterotrophic microorganisms in the soil, resulting in a decrease in the partial pressure of soil oxygen and an increase in denitrification. Many studies have shown that supersaturated moisture content inhibits oxygen and N_2O diffusion, and high soil moisture can create a hypoxic or anaerobic environment that favours denitrification [16].

The literature describes that N_2O emissions from wet soil are higher than from dry soil [15]. Which is also confirmed by the obtained results. The average value of N_2O emissions from wet soil is 1233 pmol/m^2/s, while the emission from dry soil is significantly lower - 7 pmol/m^2/s. It can also be concluded from the literature that denitrification processes dominate in wet soil.

CONCLUSION

Summarizing the results of the research so far, the formation of N_2O emissions in soils is influenced by such factors as: soil moisture, temperature, pH content, soil fauna, oxygen concentration and other factors. The content of organic matter also affects the amount of N_2O emissions, specifically organic soils have a greater potential to produce N_2O gas, because they have a higher content of organic matter and moisture.

In the soils measured during the experiment, the average N_2O emission in mineral soils is 225 pmol/m^2/s, while in organic soils – 1015 pmol/m^2/s. It was established that the content of organic matter has a statistically significant ($p<0.0001$) effect on N_2O emissions. This is also confirmed by the amount of CO_2 (average value in mineral soils – 334 nmol/m^2/s; in organic soils – 440 nmol/m^2/s).

Comparing the N_2O emission in wet and dry soil, the average N_2O emission is significantly higher in wet soils – 1233 pmol/m^2/s, while the emission from dry soil is significantly lower by 7 pmol/m^2/s. A statistically significant difference ($p<0.0001$) was observed between wet organic soil and dry organic soil, wet and dry mineral soil.

In order to judge the processes in depth, continuous measurements in field conditions where soil and air temperatures fluctuate would also be necessary.

REFERENCES

[1] Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S. L., Péan, C., Berger, S., Zhou, B. (2021). Climate change (2021): the physical science basis. Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change, 2.

[2] Zaman, M., Nguyen, M., Šimek, M., Nawaz, S., Khan, M., Babar, M., Zaman, S. (2012). Emissions of Nitrous Oxide (N2O) and Di-Nitrogen (N2) from the Agricultural Landscapes, Sources, Sinks, and Factors Affecting N2O and N2 Ratios. Greenhouse Gases - Emission, Measurement and Management. DOI: 10.5772/32781.

[3] Kudeyarov, V. N. (2020). Nitrous oxide emission from fertilized soils: an analytical review. Eurasian Soil Science, 53(10), pp. 1396-1407. DOI:10.1134/S1064229320100105.

[5] Tian, L., Cai, Y., Akiyama, H. (2019). A review of indirect N2O emission factors from agricultural nitrogen leaching and runoff to update of the default IPCC values. Environmental pollution. 245, pp. 300-306. https://doi.org/10.1016/j.envpol.2018.11.016.

[6] Bouwman, A. F., Boumans, L. J. M., & Batjes, N. H. (2002). Emissions of N2O and NO from fertilized fields: Summary of available measurement data. Global biogeochemical cycles. Volume 16(4), pp. 6-1. https://doi.org/10.1029/2001GB001811.

[7] Leppelt T., Dechow R., Gebbert S., Freibauer A., Lohila A., Augustin J., Drösler M., Fiedler S., Glatzel S., Höper H., Järveoja J., Lærke P. E., Maljanen M., Mander Ü., Mäkiranta P., Minkkinen K., Ojanen P., Regina K., Strömgren M. (2014) Nitrous oxide emission budgets and land-use-driven hotspots for organic soils in Europe, Biogeosciences. 11, pp. 6595–6612. https://doi.org/10.5194/bg-11-6595-2014.

[8] Stein, L. Y., Klotz, M. G. (2016). The nitrogen cycle. Current Biology. 26(3), pp. R94-R98.

[9] Signor, D., Cerri, C. E. P. (2013). Nitrous oxide emissions in agricultural soils: a review. Pesquisa Agropecuária Tropical. 43, pp. 322-338. https://doi.org/10.1016/S1002-0160(12)60029-0.

[10] Del Prado, A., Merino, P., Estavillo, J. M., Pinto, M., & González-Murua, C. (2006). N2O and NO emissions from different N sources and under a range of soil water contents. Nutrient cycling in agroecosystems. 74(3), pp. 229-243.

[11] Koponen, H. T., Duran, C. E., Maljanen, M., Hytönen, J., Martikainen, P. J. (2006). Temperature responses of NO and N2O emissions from boreal organic soil. Soil Biology and Biochemistry. 38(7), pp. 1779-1787. https://doi.org/10.1016/j.soilbio.2005.12.004.

[12] Liu, C., Wang, K., Meng, S., Zheng, X., Zhou, Z., Han, S., Yang, Z. (2011). Effects of irrigation, fertilization and crop straw management on nitrous oxide and nitric oxide emissions from a wheat–maize rotation field in northern China. Agriculture,

Ecosystems & Environment. 140(1-2), pp. 226-233. https://doi.org/10.1016/j.agee.2010.12.009.

[13] Dobbie, K. E., & Smith, K. A. (2001). The effects of temperature, water-filled pore space and land use on N2O emissions from an imperfectly drained gleysol. European Journal of Soil Science. 52(4), pp. 667-673. https://doi.org/10.1046/j.1365-2389.2001.00395.x.

[14] Rochette, P., Tremblay, N., Fallon, E., Angers, D. A., Chantigny, M. H., MacDonald, J. D., Parent, L. É. (2010). N2O emissions from an irrigated and non-irrigated organic soil in eastern Canada as influenced by N fertilizer addition. European Journal of Soil Science, 61(2), pp. 186-196. https://doi.org/10.1111/j.1365-2389.2009.01222.x.

[15] Lee, A., Winther, M., Priemé, A., Blunier, T., & Christensen, S. (2017). Hot spots of N2O emission move with the seasonally mobile oxic-anoxic interface in drained organic soils. Soil Biology and Biochemistry. 115, pp. 178-186. https://doi.org/10.1016/j.soilbio.2017.08.025.

[16] Wei, L., Liu, X., Qin, C., Xing, W., Gu, Y., Wang, X., Li, J. (2022). Impacts of Soil Moisture and Fertilizer on N2O Emissions from Cornfield Soil in a Karst Watershed, SW China. Atmosphere. 13(8), 1200. https://doi.org/10.3390/atmos13081200.

EFFECT OF SOIL GRANULOMETRIC COMPOSITION AND MOISTURE ON THE FORMATION OF N_2O ISOTOPES

Mg.sc.ing. Sindija Liepa[1]

Mg.sc.ing Dace Butenaite[1]

Mg.sc.ing. Jovita Pilecka-Ulcugaceva[1]

Bc.sc.ing. Kristaps Siltumens[1]

Assist.prof. Inga Grinfelde[1]

[1]Latvia University of Life Sciences and Technologies**, Latvia**

ABSTRACT

Nitrous oxide (N_2O) is one of important greenhouse gas (GHG) whose main sources are agricultural soils. N_2O forms in soil as a result of microbial processes, reinforced by the use of nitrogen-containing fertilizers. This study will look at how the formation of N_2O in soil is affected by soil moisture and soil granulometric composition. Soil N_2O isotopes of $\delta^{15}N^{\alpha}$ (central nitrogen position) and $\delta^{15}N^{\beta}$ (end nitrogen position) which could help to identify natural and anthropogenic sources of N_2O emissions and the involvement of microorganisms in N_2O production. N_2O isotopes $\delta^{15}N^{SP}$ and $\delta^{15}N^{bulk}$ can be traced or N_2O produced by nitrification or denitrification. The study used total of 92 soil samples collected in 2020 and 2022. The study uses three types of agricultural soil with a different granulometric compositions. Soil from each agricultural plot was weighted into two samples, each of 1.5 kilograms to provide different humidity conditions – wet aerobic and wet anaerobic. The measurements were performed in a laboratory with the CRDS device Picarro G5131-i. The G5131-i analyzer measures nitrous oxide isotopes $\delta^{15}N$, $\delta^{15}N^{\alpha}$, $\delta^{15}N^{\beta}$, and $\delta^{18}O$ with an accuracy of 0.7 ‰, and N_2O concentration with an accuracy of <0.05 ppb (all measurements are averaged over 10 minutes). The data processing did not use all the data obtained from the Picarro G5131-i, but was selected by evaluating the changes in N_2O concentrations when the concentrations had stabilized. In this research, three types of soil were used, from which it can be concluded that the type of soil, its inherent physical properties and reaction to the moisture regime play an important role in the formation of N_2O isotopes.

Keywords: N_2O isotopes, agricultural soil, moisture, Picarro G5131-i.

INTRODUCTION

For there to be life on earth, there are various important processes in nature based on different chemical elements, one of which is nitrogen (N). Process progress is ensured by the interaction of elements and the factors influencing them. Nitrogen is found in the atmosphere as nitrogen gas (N_2), which accounts for about 78% of the atmosphere, but this type of nitrogen is not available for living organisms. The nitrogen life cycle is a set of several nitrogen compounds transformed by plants and micro-organisms resulting in nitrogen compounds that are necessary for living organisms and that they are able to

absorb. Some of the nitrogen compounds, such as nitrate oxide (N_2O) or nitrates (NO_3^-), are environmental pollutants that pose a threat to the environment, biodiversity, human health, and climate [1]. Nitrous oxide is one of the greenhouse gases.

Soil is the main source of atmospheric nitrogen dioxide, which is based on the interaction of production and consumption processes of existing microorganisms. Various studies are currently being conducted to understand these processes and their relationship with biotic (for example plant-microorganism interactions) and abiotic (for example soil climate) factors. Research has concluded that in order to better understand the flow of N_2O in the atmosphere and soil, it is necessary to better understand the composition and diversity of microorganisms in different soil types, different climatic conditions and different types of land use. Various recent studies have investigated the reduction of N_2O to nitrogen N_2, which increases the understanding of N_2O exchange processes. In these investigated processes, the application of isotope tracking methods was used, at the moment we can conclude that in order for this method to be used more widely, it is necessary to improve the methods of measuring N_2O and N_2 emissions in order to obtain stable and accurate field and laboratory data for different types of ecosystems. To test our conclusions and understanding of these processes, and to investigate N+O feedbacks with changes in environmental conditions, biogeochemical models are currently being improved using what has been studied so far [2].

Soil type has a major impact on greenhouse gas emissions, the main factors being soil structure and soil moisture. Soil structure affects moisture distribution and moisture content, as well as compaction, organic residue distribution, and pore size and continuity. Soil temperature significantly affects the activity of microorganisms that form gases and their emissions. Gas exchange is regulated by the ability of oxygen to enter the soil and the ability of CO_2 and denitrification products (N_2 and N_2O) to escape (Figure 1) [3].

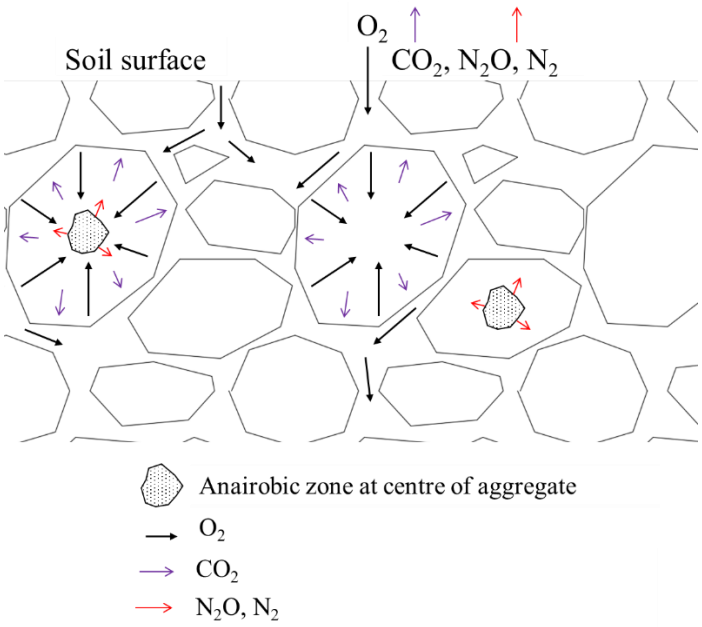


Figure 1. Relationships between stable isotopes and GHG emissions from soil

Soil moisture is the most important parameter of soil emissions, as it controls the functioning of micro-organisms and all related processes. Soil moisture is not the only factor affecting GHG emissions, emissions are also affected by land use, crops, vegetation, plant nutrients and soil temperature, all linked by regional and local climate and hydrology (Fig. 1). Soil temperature is important to explain differences in soil gas emissions. Soil temperature and humidity can explain the 86% variation in N_2O emissions [4]. Microbiological activity is influenced by soil pH. N_2O emissions are reduced only in acidic soils, however no significant correlation between NO and N_2O emissions and pH values is found. The nitrogen (N) and carbon (C) content in soil as well as the use of manure or fertilizers are important, as nutrient availability is most important for the breathing of micro-organisms and plants. N_2O emissions are negatively correlated with the C/N ratio where N_2O emissions are lowest when organic matter degradation is limited. Land use change is critical to GHG emissions from soil, especially when forests, grassland or bogs are converted to farmland [5].

The formation, transport and emission of greenhouse gases into soil is a complex chemical and microbiological process, influenced by temperature, precipitation, soil moisture, soil properties, soil erosion and manual management. Stable isotopes are one way of responding to these changes in GHG emissions production and can also track gas exchange processes in terrestrial ecosystems using stable isotopes [6]. The relationship between stable isotopes and GHG emissions from soil produced in the soil and released into the atmosphere is defined (Figure 1).

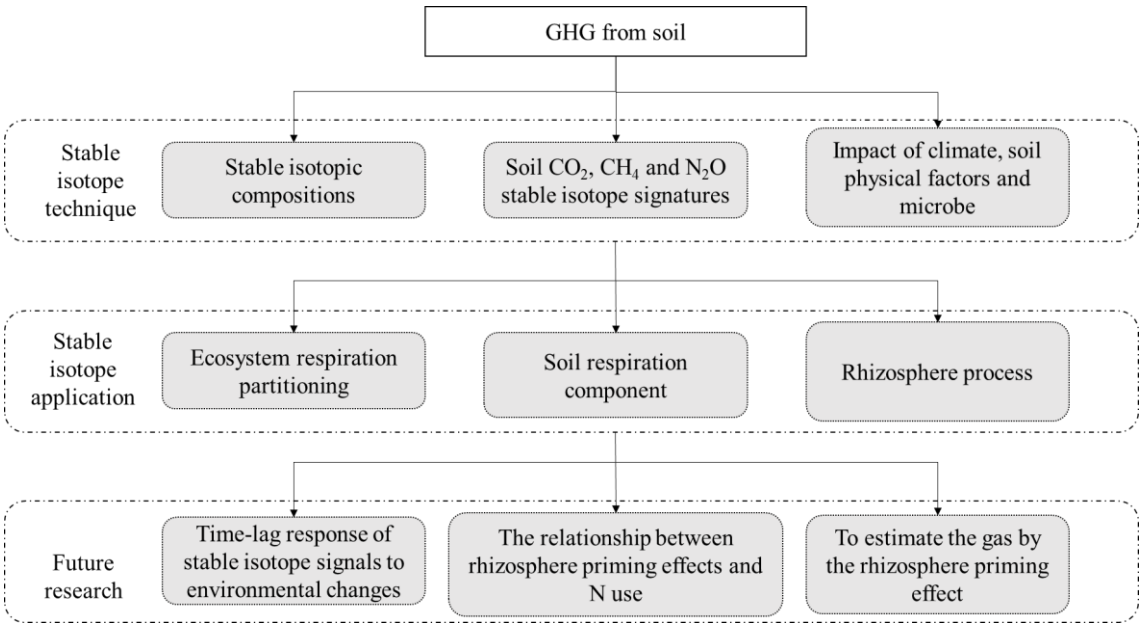


Figure 1. Relationships between stable isotopes and GHG emissions from soil

MATERIALS AND METHODS

This study is conducted by analyzing data from 92 mixed soil samples in 2020 and 2022. Soil samples were collected in August 2020 at the Stende breeding and testing station and at Research and Study farm "Peterlauki" of the Latvia University of Life Sciences and Technologies (Figure 2).

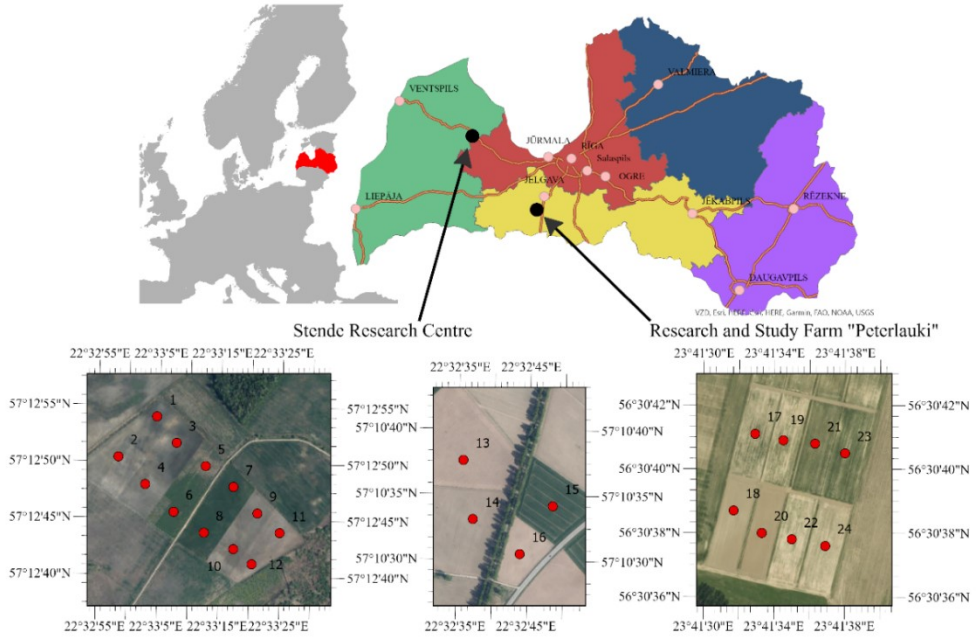


Figure 2. Location of Stende breeding and testing station, Research and Study farm "Peterlauki" and sampling points on the map

The research used dry soil of different granulometric composition - heavy clay, sandy loam and sandy loam with a high content of organic matter (Figure 3).

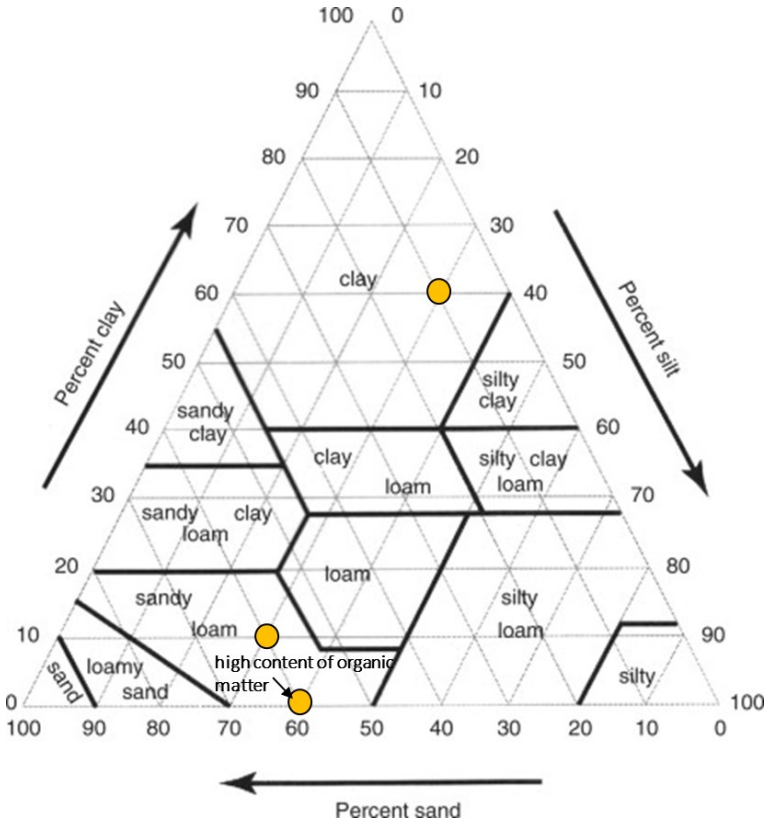


Figure 3. Granulometric composition of the used soil samples

Samples were collected in 16 plots at the Stende breeding and testing station and 12 plots at the Research and Study farm "Peterlauki". Each soil sample was assigned a code such as B_BA_O_CT_1 and B_BA_O_CT_2, B denotes the organic farming type, BA refers to the grown crop, in this sample barley, O refers to the soil type, in this case, organic soil, CT refers to the soil treatment type, which in this case indicates that conventional tillage was used and numbers 1 and 2 denote the humidity regime, 1 refers to normal humidity conditions, 2 refers to wet conditions. These two codes are given to the sample collected from one field. The humidification of the samples was carried out in such a way that wet aerobic conditions and wet anaerobic conditions were formed. Measurements in 2020 for the field samples at the Stende breeding and testing station were taken from 14.08.2020 to 10.09.2020., while for soil samples of Research and Study farm "Peterlauki" measurements were carried out from 30.09.2020 to 27.10.2020, soil samples were moistened regularly. Measurements were made from 14.12.2022 to 30.12.2022. In 2022, samples were moistened regularly, since December is the heating season, then the temperature in the lab was constant throughout the measurements. Moistening, sample weight and evaporative quantity were collected. Measurements were taken at the Scientific Laboratory of Forest and Water Resources with the CRDS device Picarro G5131-i [7].

RESULTS

When visually inspecting δ15NSP data by soil moisture and soil granulometric conditions (Figure 4), it can be observed that the largest dispersion of data for clay soil under the over-moistened conditions is observed. When comparing all soils, clay soil, under both moisture regimes, has the largest data dispersion, the dispersal of such data could be explained by the physical properties of the soil and the response to soil moisturization. Organic soil has the smallest scattering of data δ15NSP values, no extreme values are observed, but deviation values (Outliers) are observed, indicating that these values are deviated and may change the accuracy of the data, these values are considered deviations from the rest of the value model and are not included, such values could be explained by inaccuracies in measurements or measurements immediately after water replenishment.

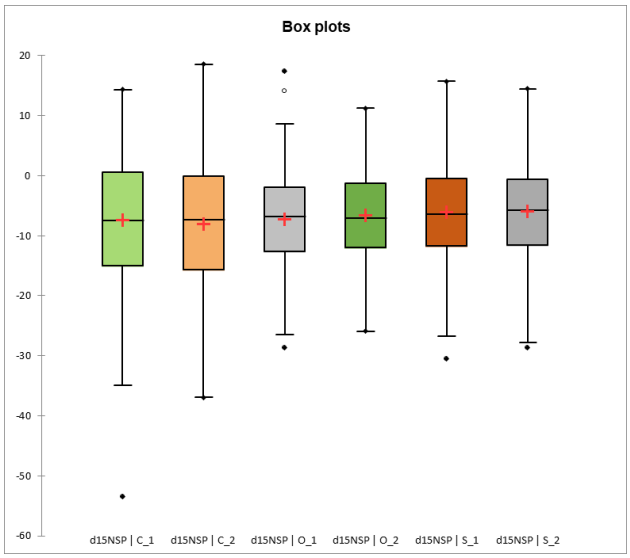


Figure 4. Nitrous oxide isotope $\delta^{15}N^{SP}$ in different soil types and moisture conditions

When analyzing the δ15Nbulk values presented (Figure 5), it can be observed that for organic and sand soil, the data dispersion under the over moistened conditions is greater than under normal humidity conditions and greater under normal humidity conditions, which may be due to the physical properties of clay soil. These data show a lot of extreme values and also values with deviation. The highest extreme minimum value is observed in the moist conditions of clay and organic soil, which is 57 ‰, which would be related to the progress of the denitrification process. For clay and organic soil, the maximum values under normal humidity conditions are observed to be higher than under wet conditions, which in turn would be associated with the nitrification process. In sand soil, this maximum value is lower in normal humidity conditions and higher in wet conditions of 34 ‰ and 36 ‰. This result could be explained by the physical properties of the soil and the processes that occur as a result of wetting.

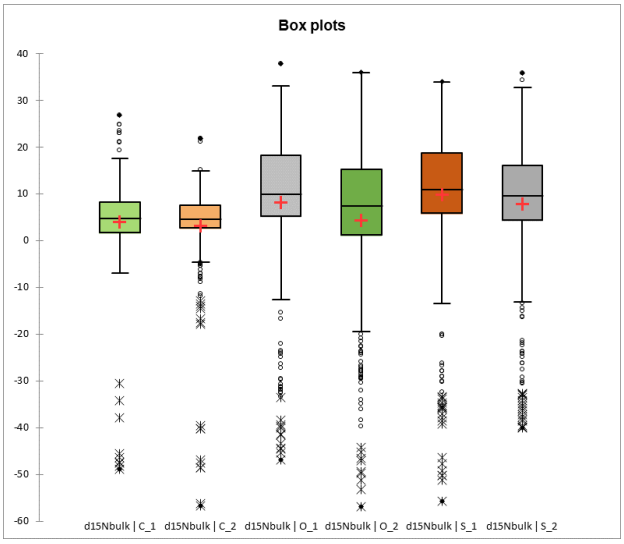


Figure 5. Nitrous oxide isotope $\delta^{15}N^{bulk}$ in different soil types and moisture conditions

DISCUSION

As in the [3] study, this study also confirms that soil type has a strong influence on greenhouse gas emissions, mainly through the influence of soil structure and soil moisture. Differences can be observed in the results between different soil types and different humidity.

Many studies have shown that supersaturated moisture content inhibits oxygen and N2O diffusion, and high soil moisture can create a hypoxic or anaerobic environment that favours denitrification. in this study, it can be seen for the δ15NSP values of the over moistened clay soil, which has the lowest minimum values, which would be explained by the denitrification processes [8].

The δ15Nbulk values show in clay soil data dispersion is lower, while in organic soils it is much higher. According to the information reviewed in the literature, this can be explained by the decomposition processes of organic matter. Also, in organic soils, denitrification is more important than nitrification due to the release of N_2O due to the high availability of carbon during the decomposition of organic matter in soils [9].

CONCLUSIONS

The N_2O is an isotopically complex molecule, whose isotopes δ15NSP and δ15Nbulk can be successfully used to trace sources of soil N2O emissions.

Based on the data analyzed in this work, it can be concluded that soil moisture is one of the most important factors influencing the N2O isotope, such conclusions can also be found in the analyzed literature.

Differences in N2O isotopes even for the same types of soil data can contribute to differences in soil microorganisms.

Three types of soil were used for the research, according to which it can be concluded that the type of soil, its inherent physical properties and reaction to the moisture regime also play an important role in the formation of N2O isotopes.

The Picarro G5131-i device is suitable for measuring N_2O isotopes in laboratory conditions, for their further research. One of the recommendations is to use automatic cameras to be able to provide long-term measurements that would help to evaluate the changes of N_2O isotopes over time. In order to track nitrification and denitrification processes more precisely, it would be necessary to conduct experiments with nitrogen-containing fertilizers. A more in-depth study of the influence of soil microbiological processes would also be necessary in order to be able to more accurately determine the stages of nitrogen fixation and overall nitrification and denitrification.

REFERENCES

[1] Denk, T. R. A., Mohn, J., Decock, C., Lewicka-Szczebak, D., Harris, E., Butterbach-Bahl, K., Kiese, R., & Wolf, B. (2017). The nitrogen cycle: A review of isotope effects and isotope modeling approaches. Soil Biology and Biochemistry, 105, 121–137. https://doi.org/10.1016/j.soilbio.2016.11.015

[2] Butterbach-Bahl, K., Baggs, E. M., Dannenmann, M., Kiese, R., & Zechmeister-Boltenstern, S. (2013). Nitrous oxide emissions from soils: How well do we understand the processes and their controls? In Philosophical Transactions of the Royal Society B: Biological Sciences (Vol. 368, Issue 1621). https://doi.org/10.1098/rstb.2013.0122

[3] Ball, B.C., Scott, A. & Parker, J.P. 1999. Field N_2O, CO_2 and CH_4 fluxes in relation to tillage, compaction and soil quality in Scotland. Soil & Tillage Research, 53, 29–39.

[4] Schindlbacher, A., Zechmeister-Boltenstern, S., & Butterbach-Bahl, K. (2004). Effects of soil moisture and temperature on NO, NO2, and N2O emissions from European forest soils. J. Geophys. Res, 109, 17302. https://doi.org/10.1029/2004JD004590

[5] Oertel, C., Matschullat, J., Zurba, K., Zimmermann, F., & Erasmi, S. (2016). Greenhouse gas emissions from soils—A review. Geochemistry, 76(3), 327–352. https://doi.org/10.1016/J.CHEMER.2016.04.002

[6] Zhu, X. C., Di, D. R., Ma, M. G., & Shi, W. Y. (2019). Stable isotopes in greenhouse gases from soil: A review of theory and application. *Atmosphere*, *10*(7), 1–14. https://doi.org/10.3390/atmos10070377

[7] Butenaite, D., Grinfelde, I., Pilecka-Ulcugaceva, J., Vincevica-Gaile, Z., & Liepa, S. (2021). THE NITROUS OXIDE ISOTOPE MEASUREMENTS FOR SOIL SAMPLES UNDER LABORATORY CONDITIONS. In International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM (Vol. 21, pp. 529–536). https://doi.org/10.5593/sgem2021/5.1/s21.114

[8] Wei, L., Liu, X., Qin, C., Xing, W., Gu, Y., Wang, X., Li, J. (2022). Impacts of Soil Moisture and Fertilizer on N2O Emissions from Cornfield Soil in a Karst Watershed, SW China. Atmosphere. 13(8), 1200. https://doi.org/10.3390/atmos13081200.

[9] Lee, A., Winther, M., Priemé, A., Blunier, T., & Christensen, S. (2017). Hot spots of N2O emission move with the seasonally mobile oxic-anoxic interface in drained organic soils. Soil Biology and Biochemistry. 115, pp. 178-186. https://doi.org/10.1016/j.soilbio.2017.08.025.

EFFECTIVENESS OF SIMPLE ELECTRIC FANS IN REDUCING THE NUMBER OF HOURS WITH HEAT STRAIN INSIDE BUILDINGS

Atlas Ramezani

Marco Manzan

University of Trieste, **Italy**

ABSTRACT

Climate change, marked by rising temperatures, poses significant health risks to indoor-bound individuals. This paper stresses the need for proactive public health measures, especially for vulnerable groups like the elderly and economically disadvantaged who lack access to air conditioning. As heatwaves worsen, traditional solutions, like energy-intensive air conditioning, are problematic due to increased energy use, greenhouse gas emissions, and cost issues. Instead, this paper proposes an affordable solution: electric fans, natural ventilation, and window shadings to combat heat stress indoors.

The study examines the effectiveness of electric fans, window shading, and natural ventilation in mitigating extreme heat's impact. Findings show a notable reduction in heat exposure, even in worst-case scenarios, with electric fans reducing heat strain hours. The methodology employs EnergyPlus and Design Builder software for a comprehensive numerical simulation of a sample building representative of the ones constructed between 1961 and 1975 located in Trieste, Italy. The simulations employ historical weather data, extreme conditions, and future projections to enhance the analysis's depth and relevance.

Keywords: climate change, heat strain, air conditioning, natural ventilation, public health.

INTRODUCTION

The issue of climate change, characterized by a persistent increase in surrounding temperatures, has sparked critical implications for individuals residing in indoor environments. This distressing trend has been reaffirmed by the Intergovernmental Panel on Climate Change (IPCC)'s Sixth Assessment Report in 2021 [1], which stresses the utmost importance of addressing climate changes within the framework of effective policies pertaining to building energy performance [2]. Moreover, it is imperative to prioritize the examination of these effects within risk assessment studies, particularly with regard to their impact on public health. This becomes especially crucial as the occurrence and intensity of heat waves have notably escalated over the course of the past three decades [3], making high temperatures increasingly hazardous. In response to the rising temperatures, the conventional approach has been the widespread implementation of air conditioning (AC) systems. However, it is worth noting that this strategy is not without its limitations. AC systems are responsible for a considerable surge in energy consumption, exacerbating the emission of greenhouse gases.

Additionally, the usage of air conditioners brings forth an additional concern in the form of power outages, which have the potential to undermine the effectiveness of cooling endeavors [4]. Moreover, the installation of external air conditioning units may encounter obstacles due to local regulations. However, the most urgent and significant issue that needs to be addressed is the financial burden imposed by these systems, particularly on low-income households who frequently struggle to meet the expenses associated with their operation [5]. It is crucial to highlight that, fans have emerged as a more economically viable alternative, the deployment of window shading and natural ventilation are two additional cost-effective and straightforward measures that can effectively mitigate the challenges posed by indoor heat stress.

Several investigations have been conducted to analyze the effectiveness of various categories of fans in alleviating thermal discomfort. In a study by Tadepalli et al. [6], experimental analyses were performed on fans mounted on the ceiling, with a focus on their capacity to mitigate thermal discomfort, enhance the utilization rates of fans, and reduce the dependence on air conditioning. In addition to that, economical alternatives like desk or floor mounted fans have also been examined. Nevertheless, the World Health Organization (WHO) has expressed concerns about the effectiveness and safety of electric fans in high-temperature conditions, particularly when the temperatures surpass 35°C. Morris et al. [7] devised a biophysical model to propose the optimal usage of fans for efficient cooling in various regions worldwide, while Tartarini et al. [8] employed the Gagge [9] model to corroborate the safety of electric fans in cooling individuals. Jay et al. [10] further expanded on this by creating a model to evaluate the usability of fans during heatwaves, concluding that the protective advantages of fans may be underestimated by current guidelines.

In this scholarly article, we employ the methodology devised by Tartarini to assess the efficacy of ventilators in indoor settings with inferior thermal properties, acknowledging that individuals residing in inadequately insulated structures often encounter difficulties in accessing conventional cooling techniques. The purpose of this study is to investigate the potential of ventilators and window shutters along with the effect of natural ventilation as economical solutions for alleviating indoor heat stress in such circumstances. In summary, this article delves into the escalating impact of climate change on indoor temperatures and the subsequent health risks, advocating for cost-effective alternatives like fans and shutters. It also reviews recent research on fan efficacy and explores the applicability of ventilators in poorly insulated buildings, offering a solution for those unable to access traditional cooling methods.

MATERIALS AND METHODS

The study utilized numerical simulations to show how electric fans, window coverings, and natural ventilation can effectively alleviate heat stress caused by elevated temperatures. These simulations were performed on a building situated in the north eastern Italian city of Trieste. The research involved modeling the building's physical structure and thermal properties with the assistance of DesignBuilder software. The simulations were executed using EnergyPlus version 9.4, and four different climate datasets were employed for the building simulations. In the subsequent sections, this paper provides an overview of the weather data employed, elucidates the architectural attributes of the building, and delineates the biophysical model utilized in the study which computes the duration of periods characterized by heat strain.

The four weather data that were employed in this paper and were described in Manzan et al. [11], are as follows:

1. TMY: a standard Typical Meteorological Year generated using data between 1995-2022 and is a representation of the mean behavior of the climate.
2. EWY: an Extreme Weather Year for the months from May to September generated for heat-related issues. With the years with the maximum difference between the monthly cumulative distribution function and the long-term.
3. 2003Y: a severe heat wave occurred in the summer of 2003 during the months of July and August that were used to create a direct weather file.
4. FMY: A future Meteorological Year was developed by applying the morphing method using the TMY and projections by the model HadGEM2-ES RACMO22E, 2036-2050, for the RCP 8.5 (a worst scenario case).

The primary characteristics of the building, that is a typical construction of the period spanning from 1961 to 1975, were acquired through the utilization of the Tabula web tool [12]. This building is distinctly characterized by its low thermal mass and a notable degree of transmittance, representing a five-story structure as described in Lupato's work [13]. The building's volumetric capacity measures 3074 cubic meters, providing a total usable surface area of 848.6 square meters, with individual apartments featuring 76 square meters of floor space. To accurately model the building, adjustments were made to its geometry to account for staircases and the presence of two apartments on each floor. For a visual representation, please refer to Figure 1, which illustrates the floor plan accommodating two apartments. It's important to note that this building is oriented towards the south, with apartment 1 exposed to the east, while apartment 2 features a west-facing wall. As described in Manzan et al. [11] to facilitate subsequent references, each apartment is identified by its floor level, commencing with 0 for the Ground floor, followed by an orientation indicator, with A1 denoting eastward and A2 representing westward orientation. Thus, the two ground-floor apartments are respectively referred to as F0_A1 and F0_A2. The opaque and transparent structural components, as well as the parameters related to internal loads, adhere to the specifications outlined by Lupato et al [13]. To ensure consistency in the modelling, characteristics related to internal loads, opaque and transparent surfaces, and output variables were fine-tuned using Python scripts in conjunction with the eppy library. Subsequently, the data underwent further processing and analysis using the same eppy library [14].

To assess the effectiveness of electric fans in reducing internal heat stress, caused by high temperatures, we use a biophysical model. This approach has been explained completely in Manzan et al. [11]. In the course of this study, the outcomes were acquired through the utilization of the "fans heatwaves" algorithm, which furnishes a range of biophysical parameters as output, each corresponding to various air velocities. This approach was employed to effectively depict the influence of fans on the human body. Leveraging environmental variables, including dry bulb temperature t_{db}, mean radiant temperature t_r, air velocity V, and relative humidity RH, in conjunction with individual-specific parameters such as clothing level I_{cl}, and activity level (metabolic rate) M, a comprehensive evaluation was conducted. This assessment aimed to discern the impact of these variables on the dynamics of sensible and latent heat exchanges

between the human body and the surrounding environment, with a focus on the identification of potential heat strain. The pythermalcomfort [15] library also facilitates the extraction of biophysical parameters conducive to the recognition of heat stress. In this context, three specific parameters can be assessed against prescribed threshold values to detect potentially hazardous conditions. These parameters encompass the rate of regulatory sweat production $m_{rsw,}$ the degree of skin wetness w, and the level of skin blood flow m_{bl}. Comprehensive elucidation of the ranges and constraints associated with these parameters is provided in Manzan et al. [11].

Subsequently, the following phase entailed the execution of simulations for each of the weather files, followed by the implementation of post-processing procedures employing the eppy and pythermalcomfort libraries to streamline the analytical processes. In conjunction with the simulations detailed in the work by Manzan et al. [11], which primarily addressed scenarios involving fan_on and fan_off, our study extended these simulations to encompass additional conditions. The condition involved simulations with natural ventilation and window shadings in the presence of a fan and without a fan. The Window Opening Schedule dictates natural ventilation and window shade usage during warm months (May to September). Natural ventilation activates when internal temperatures surpass the 24-degree Celsius Cooling Setpoint and external temperature is lower than internal one, providing relief. Concurrently, exterior window shutters close when solar radiation exceeds 200 W/m^2, mitigating solar heat gains. This strategy optimizes thermal comfort and energy efficiency, aligning with sustainable building practices.

TABLES AND GRAPHS

Table 1, maximum values for physiological parameters and number of hours with heat strain for the apartments and for each weather file l. fan off condition

		F0_A1	F0_A2	F1_A1	F1_A2	F2_A1	F2_A2	F3_A1	F3_A2	F4_A1	F4_A2
TMY	m_{rsw}	74.86	85.58	91.67	105.92	100.69	114.80	106.04	114.59	99.89	108.62
	w	0.58	0.65	0.70	0.70	0.70	0.70	0.70	0.70	0.68	0.70
	m_{bl}	27.56	31.20	33.40	37.72	36.06	40.60	36.95	41.43	36.48	39.77
	n_{hs}	0	0	0	9	5	15	9	16	0	2
EWY	m_{rsw}	71.07	85.75	87.79	104.01	100.70	115.32	103.60	113.88	101.73	115.18
	w	0.62	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
	m_{bl}	26.30	30.52	32.07	39.19	35.14	45.75	37.54	48.29	37.15	40.38
	n_{hs}	0	2	4	28	19	57	28	64	7	27
2003Y	m_{rsw}	73.25	83.64	90.39	101.93	101.93	115.18	104.10	118.21	102.39	114.26
	w	0.61	0.68	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
	m_{bl}	27.08	30.56	33.00	36.98	35.62	40.71	36.68	42.50	37.41	40.64
	n_{hs}	0	0	2	26	15	83	26	95	0	17
FMY	m_{rsw}	90.61	99.70	113.80	124.39	124.43	135.57	124.14	137.08	125.05	131.3
	w	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
	m_{bl}	32.56	36.78	44.24	55.26	52.13	64.33	54.91	66.93	45.37	53.68
	n_{hs}	8	13	27	84	65	155	82	168	21	62

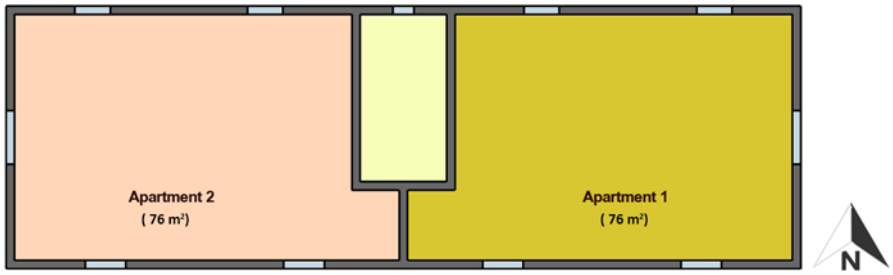


Figure 1, with two flats and a staircase

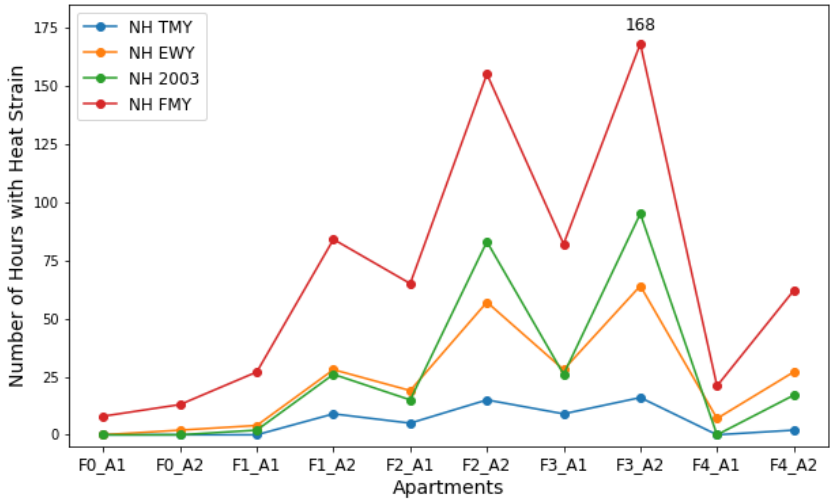


Figure 2, number of hours with heat strain in situations with no shade, no fan, and no natural ventilation

RESULT

Table 1 presents the maximum values of various physiological parameters and the duration of heat strain within residential apartments across different weather files, with the fan off, no natural ventilation, and no window shading condition. Upon examination of Table 1, a notable observation emerges: the highest recorded dry bulb and operative temperatures, along with the consequent peak duration of heat strain, occur in apartments with a western orientation, specifically on the second and third floors. The results depend on particular months, days, and times, when apartments experience the highest temperatures and heat strains. In the specific fan_off condition, the analysis of weather data reveals that the most unfavorable conditions are evident when utilizing the FMY dataset (168 hours), followed by the 2003Y dataset (83 hours), which demonstrated the highest values in relation to heat strain conditions. Additionally, it is worth noting that the EWY dataset depicts a marginally more severe scenario (64 hours) compared to the TMY dataset (16 hours). Another salient observation pertains to the mitigating impact of natural ventilation and window shading on the noticeable reduction of heat strain duration within the apartments, as in the context of window shades and natural ventilation, the absence of heat strains is evident. This effect underscores the significance of considering these environmental factors in the context of heat management.

DISCUSSION

The results of our simulations serve to highlight the potential vulnerability to heat stress in urban areas located within the northern region of Italy, as exemplified by the specific case of the city of Trieste. This phenomenon is especially prevalent in structures characterized by high rates of heat transfer through walls and windows, thereby emphasizing the crucial role that building design plays in achieving thermal comfort.

To conduct our investigation, we employed a variety of meteorological datasets in order to identify instances in which heat stress could potentially occur. As anticipated, we found that the Typical Meteorological Year (TMY) dataset, which is typically used in building energy simulations, proved to be insufficient in accurately identifying extreme temperatures and the potential for heat stress. In light of this, we turned to the Extreme Weather Year (EWY) dataset as a more effective tool for pinpointing critical thermal events. By utilizing the EWY dataset, we were able to observe a substantial increase in the number of hours during which heat stress was experienced. Moreover, our analysis revealed that the year 2003 (2003Y) exhibited a particularly heightened susceptibility to heat waves, which manifested in an elevated number of hours with heat stress. Notably, the results obtained from our study reveal a discernible and substantial impact of climatic change on the frequency and severity of heat strain experienced by individuals. This is particularly evident when we consider the use of the Future Meteorological Year (FMY) dataset for conducting simulations. Utilizing this dataset led to a significant escalation in the number of hours during which individuals were exposed to heat strain, highlighting the urgency and importance of addressing this issue.

One effective strategy that emerged from our research is the implementation of fans as a means of mitigating the health risks associated with elevated external temperatures. It is crucial to emphasize that while fans do provide some degree of relief, they cannot fully replicate the comprehensive thermal comfort that is offered by mechanical air conditioning systems. This distinction is important to bear in mind when considering the effectiveness of different cooling methods and the overall well-being of individuals in a given environment. In the scenario where fans are coupled with window shades and natural ventilation, the occurrence of hours with heat strain is significantly reduced. In the case of Trieste, a city in northeast Italy characterized by relatively moderate temperatures, the total absence of heat strain hours is anticipated. These methods offer a complementary approach to fan usage and have shown promising results in terms of reducing the number of hours individuals are exposed to heat strain. By allowing for the flow of fresh air and the control of solar radiation gains, natural ventilation, and window shutters contribute to creating a more comfortable and conducive environment for occupants.

CONCLUSION

Climate change exerts a profound influence on temperature patterns, thereby posing a formidable challenge, particularly for those individuals who lack the financial means to install air conditioning systems and inhabit inadequately insulated structures. The focus of this investigation is to ascertain the efficacy of employing electric fans, window shutters, and natural ventilation as strategies to ameliorate the deleterious impact of elevated indoor temperatures on residents. This study was conducted within the confines

of a four-story residential building, inclusive of the ground floor, comprising a total of ten apartments.

To rigorously assess the potential impact of these strategies, comprehensive simulations were carried out using the EnergyPlus software in conjunction with four distinct meteorological datasets tailored to the city of Trieste. These datasets encompassed a standard test reference year, an extreme weather year, a recorded year featuring intense heatwaves, and a future weather dataset designed to account for the influence of climate change. In the assessment of elevated temperatures and their influence on building occupants, a sophisticated biophysical model was deployed. This model yielded critical biophysical parameters that are instrumental in identifying instances of heat strain among the residents. The findings gleaned from this investigation have yielded several salient conclusions. Foremost among them is the realization that soaring temperatures present a significant hazard to individuals residing within buildings, even within the context of a city located in northeastern Italy. Furthermore, it has become evident that without effective interventions, the issue of severe heat strain warrants earnest consideration by municipal authorities as they engage in risk assessment and mitigation efforts.

Notably, in the realm of building simulations aimed at gauging the risks associated with elevated indoor temperatures, the utilization of standard Typical Weather Files, conventionally deployed for energy analyses, is ill-suited for this purpose due to their representation of an average year and their consequent failure to account for extreme climatic conditions. Therefore, a recommendation is made for the adoption of extreme weather files when tackling this specific challenge. Moreover, the deployment of future weather files generated through the fusion of Global Climate Model (GCM) and Regional Climate Model (RCM) projections offers valuable insights into the challenges posed by climate change, thereby necessitating their inclusion in the deliberations of risk assessment and mitigation. Specifically, the integration of electrical fans emerged as a highly effective mitigation measure, demonstrating remarkable resilience in nearly all scenarios, including a worst-case projection of escalating external temperatures due to climate change. The addition of window shutters, which serve to diminish incoming radiation, and the implementation of natural ventilation proves efficacious in reducing internal temperatures and, by extension, the associated risks of heat stress for occupants. These findings advocate for the inclusion of these strategies in the guidelines set forth by health authorities to address the challenges posed by heat waves.

In conclusion, our study demonstrates the significant impact of climatic change on the occurrence of heat strain and the importance of adopting effective mitigation strategies. The use of fans can greatly contribute to reducing the frequency and severity of heat strain. Additionally, the integration of natural ventilation and window shutters further enhances occupant comfort and well-being. These findings provide valuable insights for policymakers, architects, and individuals alike, emphasizing the need to prioritize the implementation of these strategies in order to create healthier and more sustainable living environments.

REFERENCES

[1] IPCC, I. P. (2021). Synthesis Report of the Sixth Assessment Report. accessed 20 October 2023: https://www.ipcc.ch/ar6-syr/.

[2] Zhang Deng, K. J. (2023 Jun2). Using urban building energy modeling to quantify the energy performance of residential buildings under climate change. Building simulation, 1-15.

[3] Attia S, L. R. (2021). Resilient cooling of buildings to protect against heat waves and power outages: Key concepts and definition. Energy and Buildings , 239.

[4] IEA, I. E. (2018). The Future of Cooling Opportunities for energy- efficient air conditioning. <https://iea.blob.core.windows.net/assets/0bb45525-277f-4c9c-8d0c-9c0cb5e7d525/The_Future_of_Cooling.pdf> .

[5] Shen, P. (2017). Impacts of climate change on U.S. building energy use by using downscaled hourly future weather data. Energy and Buildings, 61-70.

[6] Tadepalli S, J. T. (2021). Influence of ceiling fan induced non-uniform thermal environment on thermal comfort and spatial adaptation in living room seat layout. Building and environment, https://doi.org/10.1016/j.buildenv.2021.108232.

[7] Morris NB, C. G. (2021). Electric fan use for cooling during hot weather: a biophysical modelling study. The Lancet Planetary Health , 368-377.

[8] Tartarini F, S. S. (2022). Application of Gagge's energy balance model to determine humidity-dependent temperature thresholds for healthy adults using electric fans during heatwaves. Building and Environment, https://doi.org/10.1016/j.buildenv.2021.108437.

[9] Gagge Ap, S. J. (1971). Effective temperature scale based on a simple model of human physiological regulatory response. ASHRAE Transactions , 247-263.

[10] Jay O, C. M. (2015). Should electric fans be used during a heat wave? . Applied Ergonomics , 137-143.

[11] Manzan M, R. A. (2023). Climate change mitigation: analysis of electrical fans usage impact on dwellers heat stress. The 78th ATI Congress. Carpi: Italian Thermotechnical Association.

[12] Tabula. (2023, 10 30). Tabula web tool. Retrieved from building typology EU: https://webtool.building-typology.eu/#bm

[13] Lupato G, M. M. (2019). Italian TRYs: New weather data impact on building energy simulations. Energy and Buildings, 287-303.

[14] eppy. (2023, 10 30). pypi. Retrieved from https://pypi.org/project/eppy/

[15] pythermalcomfort 2.8.10. (2023, 11 13). Retrieved from https://pypi.org/project/pythermalcomfort/

ENVIRONMENTAL PROBLEMS SOLVING AS A FACTOR IN THE FORMATION OF A SUSTAINABLE AND BALANCED DEVELOPMENT PARADIGM

Doctor of Philosophy (D.Sc.), Professor Valentyna Voronkova[1]
Doctor of Philosophy (D.Sc.), Professor Roman Oleksenko[2]
Doctor of Philosophy (D.Sc.), Professor Vitalina Nikitenko[1]

[1]Zaporozhzhia National University, Zaporizhzhia, **Ukraine**
[2]Volodymyr Vynnychenko Central Ukrainian State University, Kropyvnytskyi, **Ukraine**

ABSTRACT

Environmental problem-solving as a factor of sustainable and balanced development is an integral part of every country in the world, based on the interaction of man, nature, society, and the overcoming of crisis factors in an imbalanced world. That is why today it is necessary to move from the economics of aggressive expansion to the economics of sustainable development in order to promote the formation of a stable identity and social sustainability, which requires a fundamentally new development paradigm. The new paradigm of sustainable development as the main driver and megatrend of solving environmental problems includes climate change management and overcoming the destructive effects of climate change, natural resource management, the introduction of renewable energy sources, and environmental technologies that require a transition to a circular economy, which requires a new economic philosophy - overcoming the large-scale destructive effects of the planet. The formation of a new paradigm is based on the idea that the country's future should be purposefully programmed as a balanced one. In order to achieve these objectives, a sustainable development paradigm should be formed which will lead to economic efficiency, inclusiveness, implementation of renewable energy sources, environmental protection, releasing the energy of entrepreneurship, innovation, and achieving sustainable and balanced development based on harmony, prosperity, risk reduction, well-being, and environmental safety.

Keywords: environmental problems, sustainable development paradigm, climate change, renewable energy, circular economy

INTRODUCTION

The relevance of the research topic is that in order to solve environmental problems, stop global warming and prevent the devastating effects of climate change, humanity must stop emitting greenhouse gases into the atmosphere altogether. Humanity has never faced a challenge of this scale before. Each country will have to abandon its usual approaches, as today any activity is accompanied by greenhouse gas emissions, so if we do not change anything, the environmental crisis will not be avoided. Countries and governments are able to invent and apply technologies, and if they act quickly, they will be able to prevent a climate catastrophe. Today, almost any activity is accompanied by greenhouse gas emissions, and if nothing is changed, the world will continue to produce greenhouse gases, climate change will gain momentum,

and its impact on humanity will be catastrophic. Thus, China has announced its intention to become an "ecological civilization" and this concept was incorporated into the Constitution in 2012. It is also striking that China's five-year plan actually reflects this new environmental mentality. Improving resource efficiency is only a step in the correct direction. Equally important is moving toward an economy based on renewable materials, circular material flows, and taxes used to balance demand. The vision of sustainable entrepreneurship is one that "is focused on the preservation of nature, life support, and community in the pursuit of perceived opportunities to bring into existence future products, processes, and services for gain, where the benefit is broadly construed to include economic and non-economic gains to individuals, the economy, and society" [9], [10]. Failing to achieve all of the above, the benefits of increased efficiency will quickly be offset by the combination of recoil and economic growth effects.

MATERIALS AND METHODS

The methods used for the study are analysis and synthesis, abstraction, transition from the concrete to the abstract and vice versa, logical and historical. The axiological, systemic, and synergistic approaches to solving environmental problems are important to our research, as they made it possible to identify the influence of values on the formation of a new paradigm of sustainable development, to define the topic under study as a systemic sphere and to analyze its architectonics as a complex nonlinear phenomenon. The method of cross-cultural analysis played an important role, helping to compare the development of global warming in all countries in order to prevent the devastating effects of climate change and to identify priority areas for shaping the paradigm of sustainable and balanced development for the sake of the planet's survival. In contrast to a simple increase in temperature across the planet, global warming has dramatically increased the instability of the climate system, and warming is only the beginning of growing meteorological uncertainty. The axiological approach considers environmental problems as a complex social, cultural, or economic phenomenon, which requires more and more creative principles in the formation of this paradigm. In our opinion, the axiological approach to solving environmental problems is the use of information and communication technologies to develop praxeological solutions that require the expansion of its cultural functions. The specificity of the axiological approach is that the solution to environmental problems is focused on identifying value and normative aspects, which includes a complex of semiotic understanding (sign system), communication (information and communication sphere of communication), systemic approaches to the analysis of global problems of our time as complex nonlinear forms representing systemic complexities, identification of mental characteristics (way of thinking of a social group), their inherent set of worldview, which allows identifying the most essential aspects of environmental problems. The economy has all the features of a complex system, it contains a huge number of individual parts, which is the basis for the development tendency towards self-organization, which can be represented as a single "super-organism" to be analyzed through a synergistic approach. The informatics approach provided for the collection of information on the environmental problems of our time through new methods of Big Data, Data Mining, and Data Science. The essence of some complex systems is the ability to process and produce information, and the study of complexity has become one of the most promising areas of scientific research, based on heterogeneity, network

organization, interdependence, and adaptation, which are the four regulators of agility. These principles are intended to overlap and complement each other, as ecology is a self-adaptive, complex system that offers a plan for shaping a new world and contributing to the prosperity of the planet. The culture of emergent innovations of the sustainable and balanced development paradigm will make it possible to understand and feel the responsibility of national governments to the world, aimed at long-term changes that will be initiated in solving specific environmental problems, the analysis of which is provided in the scientific study. The authors of the Club of Rome have created a prototype computer model that helps to understand the behavior of economic and environmental systems. The methodology of this study is the World computer model, which was designed to combine data and theories related to growth to develop internally consistent scenarios for the world's development in order to overcome global environmental problems related to resource use and emissions. The model M3 called for profound social innovation through technological, cultural, and institutional changes to avoid increasing the "ecological footprint" in order to move towards sustainability. Exponential growth, coupled with a delayed response, can lead to overstepping the boundaries.

RESULTS

This article is a synthesis of many ideas on environmental issues, the results of their own research, and the cooperation of scientists who consider that they belong to a certain area of the scientific paradigm of sustainable development of modern society, which sheds light on the amazing possibilities and unexplored depths of human survival. We rely on the book by Bill Gates "How to Avert Climate Catastrophe. Where We Are Now and What We Must Do Next" [3], who has spent decades researching the causes and consequences of climate change in order to stop the ecological collapse on the planet. In this book, the author does not only explain why we need to reach zero carbon emissions but also details what we should do to achieve this extremely important goal, as he has his own understanding of innovation and knows exactly the cost of bringing new ideas to market. Analyzing these issues, we rely on research by the Club of Rome, which demonstrates the benefits of significant carbon emission reductions from extended use of products and increased recycling and reuse. The EU Commission has so far abstained from any significant actions and decisions on the circular economy, with most efforts in this area focused on changes to waste directives, and in the context of EU guidelines, eco-design is also a concern. In the "Factor Five" report to the Club of Rome, the authors showed that a fivefold increase in resource efficiency is possible even in the four most power- and water-consuming sectors (construction, industry, transportation, and agriculture). The substantiation of the reports to the Club of Rome is presented in Donella Meadows, Jorgen Randers Dennis Meadows "Limits to Growth. The 30-Year Update" [8], whose contribution was fundamental and whose deep concern for the world and inexhaustible belief in humanity inspired to talk about the prospects for the long-term future of mankind."The Limits to Growth" models scenarios for the global economy and answers the question, 'What can be done to create an environmentally balanced and socially oriented economy that brings prosperity to all? As we have only one planet, we will have to reconsider our worldview, and behavioral and political patterns, learn to look far ahead, adapt better, and plan smarter - otherwise there is no other way. The critical approach and scientific findings of the authors of

"Limits to Growth" are an excellent ground for expanding horizons, forming a new worldview, and changing policies. The Club of Rome scientists used the theory of system dynamics and computer modeling to analyze the long-term reasons and consequences of the planet's growth and the physical economy. Al-Khalili Jim's "What's Next? Everything science knows about our future" [1], Appelo Jürgen "Management 3.0. Agile management. Leadership and team management", [2] James Womack, Daniel Jones's "Lean manufacturing. How Toyota's production system can help prevent material losses and ensure the prosperity of your company"; Drucker Peter F. "Challenges for Management in the 21st Century", which forms the conditions for creating a new paradigm as a factor of sustainable and balanced development. [4] Co-presidents of the Club of Rome Ernst Ulrich von Weizsäcker and Anders Wijkman "Come On! Capitalism, short-sightedness, population and the destruction of the planet. A Report to the Club of Rome", "Come On!" is called the "new Enlightenment 2.0", which means a balance between nature and man, between long-term consequences and tactical tasks. [5] Naomi Klein is the author of three world bestsellers. "Everything is Changing. Capitalism versus the Climate skillfully analyzes how large corporations and free market ideology are blocking already uncertain attempts to combat climate change. Drawing on a variety of opinions, cultural studies, and investigative journalism, the author finds solutions to the problem of climate change and explains how the economic system is connected to this issue.[7] In the work of Stephen Pinker "Enlightenment Today. Arguments for Intelligence, Science, and Progress" in the "Environment" section, he notes that we are wasting the earth's bounty, ignoring its finite nature, and killing our nests with air pollution and garbage, thus hastening the day of reckoning when nature strikes back. [11] Dr. Steven Pinker, a cognitive scientist, argues that Enlightenment ideals such as reason, science, and humanism laid the foundation for modern prosperity and that the ability to empathize and think rationally helped us evolve into rational humans. However, the author argues that the world is falling into an abyss, as progress has begun to work against humanity.[11] Schwab Klaus's paper "The Fourth Industrial Revolution, Shaping the Fourth Industrial Revolution" [12] notes that digital technologies based on computer hardware, software, and networks are becoming more complex, advanced, and can transform entire societies and the global economy. Important scientific discoveries are being made simultaneously in various fields: from DNA sequencing to nanotechnology, from renewable energy sources to quantum computers. It is the synthesis of these technologies and their interaction in the physical, digital, and biological spheres that distinguish the Fourth Industrial Revolution from all previous ones. Urban theorist, and professor at the University of Toronto, Florida Richard in his book "The Crisis of Urbanism. Why Cities Are Making Us Miserable and What the Future Will Look Like"[14] notes that urbanists should think about the new urban crisis and examines the crisis that caused the current type of urbanization and offers options for overcoming the challenge of modern cities.

The main task of scientists is to form a new paradigm of sustainable and balanced development, as the old system, which remains unchanged by the basic principles of production, is losing its position, and a new system of sustainable development based on emergence is on the way. The Internet has played a key role in this by enabling the masses not only to be heard but also to participate in the discussions, deliberations, and governance that were recently the privilege of professional politicians, representing a kind of collective intelligence that demonstrates "emergent democracy." This meta-organism has much higher capacities and intelligence

than the total of its parts, which can emerge from a network of less complex parts properly combined. Environmental problems are a reflection of the natural world and are an emergent property, the result of the activity of molecules, carbohydrates, lipids, proteins, and nucleic acids, which exhibit properties that no individual or government can control. Paradigms are systems of ideas consisting of an emergent system of units and neurons that exist beyond the authority of rulers, ensure development, and are in a state of transition to new ways of finding stability for humanity and developing innovation. The emergent age has replaced the age of authority and led to a better way of organizing intellectual and physical capital. The purpose of the study is to conceptualize the solution to environmental problems as a factor in the formation of a new paradigm of sustainable and balanced development. Research objectives: 1) to analyze the devastating effects of climate change; 2) to reveal the conditions for the formation of sustainable livelihoods and environmental preservation; 3) to formulate the concept of a regenerative city as an identification of new economic and environmental opportunities; 4) provide recommendations on how to adapt cities to climate change. The conceptualization of solving environmental problems as a factor in the formation of a new paradigm of sustainable and balanced development is measured by social wealth and well-being and corresponds to the improvement of quality and increase in all volumes - natural, cultural, labor, and production. For example, sustainable forestry management increases natural capital; the extraction of phosphorus or metals from waste preserves natural capital; modification of buildings reduces energy consumption and improves the quality of construction; and the creation of a new model of circular economy based on reusability is currently being discussed.

1. The devastating effects of climate change

The available renewable energy sources - primarily wind and solar - are capable of making a powerful impact, but humanity is in no hurry to use them to their fullest potential. It has also become clear that getting to zero is not enough. Electricity generation accounts for only 27% of total greenhouse gas emissions. Therefore, to avoid a climate catastrophe, as Bill Gates says, we must get to zero; we must deploy existing tools such as solar and wind energy faster and more efficiently; we must create and bring to market advanced technologies that will help us get there. If we do not stop emitting greenhouse gases into the atmosphere, the temperature will rise, so the only reasonable way out is to reduce them to zero. [3] In November-December 2015, the United Nations Climate Change Conference held in Paris resolved to engage private investors and put innovation on the political agenda. Today, large corporations and free-market ideology are blocking already fragile attempts to combat climate change, and many large green organizations with ties to oil companies are overpromising and under-delivering. However, our work is more than climate change prevention. It's about fundamental changes in the way we exist on this planet, in other words, if the temperature reaches a certain point, unpredictable and potentially irreversible changes can begin to occur that will have a large-scale, destructive effect. After that, the process cannot be stopped, even by reducing carbon dioxide emissions into the atmosphere. It will be a collapse, the consequences of which we cannot control, according to a 2014 report by the American Association for the Advancement of Science, the largest scientific association for the natural sciences, notes Naomi Klein in "Everything Changes. Capitalism vs. the Climate" [7]. The use of fossil fuels has changed our climate to such an extent that it is now necessary to reduce the level of their use. Man-

made natural disasters continue to change the climate, but leaders are not even trying to change the system that makes disaster inevitable. We are already experiencing alarming symptoms due to rising temperatures. In 2020, unprecedented melting of the Greenland ice sheet occurred. In addition, the process of oxidation of the world's oceans is proceeding faster than expected. If we do not prevent further temperature increases, we will face disastrous consequences. Due to the COVID-19 pandemic, the economic activity of the population has decreased and the amount of greenhouse gas emissions have decreased (not 51 billion, but 49-48 billion tons of carbon dioxide).To combat climate change, the world needs new technologies that leave no carbon footprint, because more gases mean higher temperatures. Once they enter the atmosphere, they stay there for a long time: in 1000 years, every fifth molecule of carbon dioxide released today will still be floating in the air, and it will be increasingly difficult for humanity to develop and then survive. Greenhouse gases in the atmosphere will not disappear, so the planet will remain warmer for a long time, even when we reach zero. "It is quite obvious that human activity, especially the burning of fossil fuels and destruction of forests, contributes to the growth of greenhouse gas concentrations in the atmosphere," note the authors of the paper "Limits to Growth. 30 Years Later". The concentration of carbon dioxide (the main greenhouse gas) in the atmosphere is undoubtedly growing exponentially. The concentration of CO2 has been monitored for decades and can be measured retrospectively by analyzing air bubbles preserved in ice masses. Greenhouse gases trap heat that would otherwise radiate from the Earth into space. This is a well-known property of their molecular structure and absorption frequency spectrum. The trapped heat causes the Earth to have a higher temperature than it would otherwise have.

The rationale of biotechnology in this case is similar to industrial applications, to increase the overall efficiency of conversion of agricultural inputs, into products [13]. Due to this these organisations are able to compete on the basis of cost.

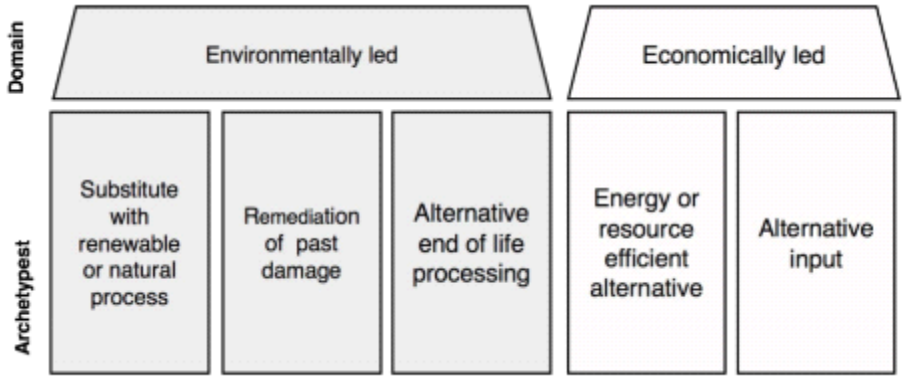


Figure 1. Sustainable biotechnology-driven business model archetypes [13]

As the advantage derived is a cost-based advantage this archetype is classified as ‘economic-led’, the primary advantage of adopting biotechnologies is to reduce costs to be able to compete on price. sustainable biotechnology-driven businesses can reach a sustainable business model through either operating as an environmentally-led archetype or economically-led archetype. Broadly organisations operating an environmentally-led business model archetype facilitate some reconfiguration of the industry value chain they operate in, utilising biotechnology to offer a product or service distinct to those previously available [13].

Some industrial sectors, such as transport logistics. According Kaveckė and

Paužuoliene [6], companies around the world are under pressure to apply sustainable development-based business practices in the value-creation system. The development of the logistics and transport sector leads to increasing freight flows, an increase in the mileage of freight cars and the consumption of diesel fuel, which has an impact on the environment by increasing CO2 emissions. The use of renewable energy sources in the transport sector is still low and the targets have not been met. Companies should therefore step up their efforts to reduce emissions of pollutants harmful to health from vehicles in order to improve these indicators. Organizations seeking to reduce negative environmental impacts should apply green solutions in their activities, thus helping to reduce a wide range of environmental, economic and social problems. In order to move towards more environmentally friendly transport, organizations could implement the following green solutions in their activities: use greener vehicles, alternative fuels, encourage drivers to learn and apply a fuel-efficient driving style, optimize vehicle routes, reduce waste, etc.

2. Conditions for sustainable means of existence and environmental protection.

Natural resources provide the basis for prosperity and well-being. The United Nations Sustainable Development Goals (SDGs) depend on the sustainable management and use of the planet's natural resources. This connection was emphasized in a seminal report by the International Resource Group, Resource Efficiency: Potential and Economic Implications, presented at the G8 meeting in May 2016 in Japan. The report advocates a radical change in the mentality and systems of production and living. Until the world begins to use resources of all kinds with much greater efficiency, Sustainable Development Goals will not be achieved. As a thinking center, Development Alternatives has done groundbreaking work in developing such concepts. Beyond these core goals, it also has an innovative research and development center that produces specialized technologies meeting the criteria of environmental sustainability and poverty reduction. Such technologies include cookstoves and appliances (home wood stoves), electricity generators (gas generators), environmentally friendly and sustainable building materials (earthen bricks, micro-concrete slabs, reinforced concrete components), handmade paper from recycled waste, and other eco-friendly products to create a sustainable living, restore healthy land, water, and forest resources. The TARA (Technologies and Activities for Rural Areas Modernization) Initiative cultivates entrepreneurial ideas and business models for newly established small and medium-sized entrepreneurs. The TARA initiative aims to promote low-carbon activities and inclusive growth through the development of entrepreneurship in the sectors of rural housing, renewable energy, water management, sustainable agriculture and regulation, and waste management. Some analysts consider 2014 as a turning point when renewable energy sources were on the path to the inevitable triumph of wind and solar energy technologies. The world is expanding its renewable energy capacity every year, which is now equal to the combined capacity of coal, natural gas, and oil. However, leaving large reserves of fossil fuels in the ground will also lead to certain consequences and they will turn into "unclaimed carbon assets" worth $6 trillion," Ernst said. Ernst Ulrich von Weizsäcker and Anders Wijkman note. Plant nutrients - nitrogen, phosphate, potassium - must be returned to the agricultural lands that feed cities, binding carbon and holding it in grants and forests, reviving urban agricultural production, providing energy to cities through renewable energy sources, and reconnecting cities with their regional ecosystems. [5]

3. The concept of a regenerative city as the identification of new economic and environmental opportunities.

The concept of a regenerative city includes greening the urban environment and protecting nature from the physical expansion of the city, so that city residents take positive steps to create regenerative urban systems of production, consumption, transportation, and construction. The concept of a regenerative city as an identification of new economic and environmental opportunities includes: 1) enhancing the ecological and other relationships between cities and the natural systems on which they depend; 2) implementing efficient renewable energy systems for human settlements in cities; 3) choosing new lifestyles and environmental opportunities that will encourage people to participate in this transformation process. In recent years, many urban regeneration projects have been implemented in abandoned cities in industrialized countries, focusing on the links between urban populations and nature, between urban systems and ecosystems. Initiatives aimed at resource-saving, regenerative urban development focus on the creation of "eco-districts" in cities in Europe and the United States, such as the "zero energy" district (Beddington in Sutton, South London, eco-districts in Nancy, Fraction; eco-districts in Stockholm and Portland. Over the next decades, significant investments will need to be made in marine protection and dams to withstand sea level rise and intensified precipitation and flooding, especially in large plains where dams will have to be rebuilt over long distances inland along rivers. Experts emphasize the need to avoid construction in regions where the risk of natural disasters due to climate change can be expected in the future. Countries should also take measures to limit urban expansion. When planning road and rail infrastructure, it is necessary to optimize performance to ensure easy access to jobs, shops, hospitals, or natural parks, while minimizing the cost of maintaining infrastructure and CO2 emissions, which can be done by implementing measures to reduce and improve transfer infrastructure and planning for efficient use of land and transportation systems in cities. Refined products will be replaced by more efficient products based on renewable materials from forests and agriculture. Research into the potential of algae is particularly important they can be grown almost anywhere and can produce ten times more biofuels than typical energy substances.

DISCUSSION

The Intergovernmental Panel on Climate Change (IPCC) has recognized the global temperature increase as indisputable, and that without significant policy changes, the trend of global greenhouse gas emissions and related climate change will continue. These changes will lead to widespread impacts and costs across various economic sectors and regions. Cities are particularly susceptible to climate change due to their high population concentration, developed transportation infrastructure, etc. Currently, about half of the world's population lives in cities, and this share will only grow in the future, so the issue of urban adaptation to climate change is becoming increasingly urgent and needs to be resolved.

The projected climate change did not show any dependence on the degree of urbanization of a city. In all cities, there will be a significant increase in the maximum temperature, which will increase the frequency of heat waves, as well as the minimum temperature, which indicates an increase in tropical nights, i.e., intensification of heat stress both during the day and at night.

The impact of heat stress is primarily manifested in the impact on human health: increased mortality and diseases associated with abnormally hot weather (heat strokes, overheating, dehydration, exacerbation of asthma and allergies of various origins, etc.), increased incidence of foodborne diseases, transmissible diseases arising as a result of increased average temperatures.

In this case, the following recommendations can be offered to reduce the city's vulnerability to heat stress: design of urban facilities (buildings and green areas) for better air circulation; increasing the share of vegetation, especially in built-up city centers; planting urban and suburban plant communities; sufficient thermal insulation of buildings; radiation protection for transparent building elements such as windows, verandas, glass walls, and ceilings; rational use of air conditioners; use of light colors and reflective surfaces.

Recent climate change projections show that global warming could intensify the hydrological cycle in the coming decades and increase the magnitude and frequency of intense precipitation events. Flood hazards may also increase with wetter and warmer winters in some regions, with more frequent rainfall and less frequent snowfall.

Recommendations aimed at reducing the city's vulnerability to floods: developing an early warning system for the population living in the area of possible flooding; raising public awareness of the probability of flooding, its causes, consequences, actions during flooding, and evacuation methods; conducting proper planning of the construction of new city districts, taking into account forecasts of possible flooding; modernizing and expanding development of a rainwater management system throughout the city - to create reservoirs for its accumulation and use for economic needs; implementation of measures aimed at strengthening the banks of large reservoirs and watercourses in the city; reducing impermeable surfaces and maintaining/increasing the number of green spaces in the city (in order to increase the area of surfaces through which water can infiltrate into the soil and reduce pressure on drainage systems during heavy rains); using appropriate structures and materials resistant to flooding in the design and construction of new buildings and infrastructure; implementing a complete technical and technological modernization of the existing ground-based hydrometeorological network (meteorological stations and hydrological posts) with the aim to carry out continuous measurements of hydrometeorological parameters affecting the formation of river runoff, opening new and resuming operation of previously closed meteorological stations and hydrological posts with automatic means of measuring hydrometeorological parameters, installing additional automatic rain meters, especially in areas of river runoff formation; developing measures to redistribute the risk of flooding in one area by increasing the risk of flooding in another area that is economically less important for the city; creating natural disaster relief, bio shields to reduce the risk of flooding; construction of rainwater drainage systems from houses and agricultural land.

CONCLUSION

In order to stop global warming and prevent the devastating effects of climate change, humanity must stop emitting greenhouse gases into the atmosphere altogether. The world must rapidly transform its production and consumption systems to have a chance to stay within the 2º C target. The Paris commitments, which amount to USD 100 billion annually starting in 2020, should be used to adapt to the growing climate change, and humanity will devote the next decade to this bold goal, and to develop an

appropriate action plan.

Establish a carbon tax agreed upon by all countries, which will be collected and stored in each country separately, and for most countries, this will be a real salvation. Decentralized energy use is technically feasible and can really help to create jobs where they are needed most - in rural areas of developing countries. Governance policy frameworks need to be changed to encourage the adoption of the necessary technologies. In addition, government support for research, innovation, and demonstration projects should be significantly increased, and investments in low-carbon infrastructure and material efficiency should be actively supported. Biofuels should be part of the solution, and the concept of a bioeconomy is gradually taking hold in many countries, such as Canada, Sweden, and Finland

We need to concentrate the world's passion and scientific potential to implement the clean energy production methods we already have and invent new ones to stop greenhouse gases from entering the atmosphere. Innovation is not a panacea against climate change, but without it, the Earth will become uninhabitable. Technology alone is not enough, but it is necessary. For the next 10 years, governments should focus on the technologies, policies, and market structures that will put countries on the path to zero emissions by 2050.

By investing in science and technology, governments and countries will be able to combine economic recovery from the COVID-19 coronavirus crisis with stimulating innovation to save them from climate catastrophe. Public funding for research and development will accelerate economic growth and reduce emissions, and science and technology is the only area where economic growth is intertwined with carbon-free innovation. The government should accelerate the development of clean energy by adopting regulations to increase competitiveness and stimulate the economy to actively use renewable sources and build integrated power networks.

REFERENCES

[1] Al-Khalili Jim. What's Next? Everything science knows about our future / translated from English by M. Klymchuk. Kyiv: Key Foundation Media, 2018. 248 p.

[2] Appelo, Jürgen. Management 3.0. Agile management. Leadership and team management". Kharkiv : Morning: Fabula, 2019, 432 p.

[3] Gates, Bill. How to avert a climate catastrophe. Where Are We Now and What Should We Do Next / translated from English by Yulia Kostiuk. Kyiv : Laboratory, 2021, 224 p.

[4] Drucker, Peter F. Challenges for the management of the XXI century. Kyiv: KM-BOOKS Publishing Group, 2020. 240 p.

[5] Ernst, Ulrich von Weizsäcker, Anders Wijkman. Come On! Capitalism, shortsightedness, population, and the destruction of the planet. Report to the Club of Rome / translated from English by Y. Sirosh; under the scientific editorship of V. Vovk, V. Butko. K.: Summit-Book, 2019. 276 p.

[6] Kaveckė, I., Paužuolienė, J. (2021). Transporto įmonių aplinkosaugos tendencijos ir galimybės pereiti prie žaliosios logistikos. *Regional formation and development studies: journal of social sciences*, (1), 17-27.

[7] Klein, Naomi. Everything is changing. Capitalism versus the climate / translated

from English by Dmytro Kozhedub. Kyiv: Nash format, 2016. 480 p.

[8] Meadows Donella, Randers Jorgen, Meadows Dennis. The Limits to Growth. 30 years later / edited by Viktor Vovk. Kyiv: Pabulum, 2018. 464 p.

[9] Moya-Clemente, I., Ribes-Giner, G., Chaves-Vargas, J. C. (2021). Sustainable Entrepreneurship: An Approach from Bibliometric Analysis. Journal of Business Economics & Management, 22(2), 297–319.

[10] Munoz, P., Cohen, B. (2018). Sustainable Entrepreneurship Research: Taking Stock and looking ahead. Business Strategy and the Environment, 27(3), 300–322.

[11] Pinker, Stephen. Enlightenment Today. Arguments in favor of reason, science and progress. Kyiv: Nash format, 2019. 560 p.

[12] Schwab, Klaus. The Fourth Industrial Revolution, Shaping the Fourth Industrial Revolution. Kharkiv: Family Leisure Club, 2019. 426 p.

[13] Peppou, G. (2018). Biotechnology-driven business model archetypes: Sustainability, Innovation and Commercial Viability. *Journal of Commercial Biotechnology*, *24*(3).

[14] Florida, R. (2019). Crisis of urbanism. Why cities make us unhappy/trans. from English I. Bondarenko. K.: Our format. 320p.

EXTERNAL COSTS OF ROAD TRANSPORT IN FRAMES OF THE TRANSITION TO A LOW-CARBON ECONOMY

Prof. Dr. Olga Kudryavtseva[1]

Dr. Anastasiia Baraboshkina[2]

[1] Moscow State University, Faculty of Economics, **Russian Federation**

[2] Moscow State University, Faculty of Economics, **Russian Federation**

ABSTRACT

In order to make the transition to a low-carbon economy and sustainable transport system and solve environmental and climate problems, many countries are replacing traditional cars that run on petroleum fuels with electric cars. Unlike vehicles with an internal combustion engine (ICE), electric vehicles` emissions from the operation phase are practically zero, but this is not the case if we consider the full life cycle. In this paper, we briefly describe the electric vehicle market, examine the life-cycle emissions of electric cars and ICE cars. The novelty of this study is in a methodological approach to the economic assessment of the negative impact of emissions from road transport and in a comparative assessment of the external costs of cars that run on traditional and alternative fuels. We applied the methodology of the Organization for Economic Cooperation and Development (OECD), which allows calculating country-specific and time-adjusted value of a statistical life. In this paper the characteristics of Russia`s energy balance and automotive market are considered. We came to results that, in general, in this country electric cars are more environmentally friendly and contribute less to climate change than cars with internal combustion engines. The external costs caused by life-cycle greenhouse gas emissions of an electric car are lower than similar emissions from a traditional car. The external costs caused by emissions of pollutants from the electric car operation phase are lower than external costs caused by emissions from an ICE car. The proposed study could be of interest for policymakers in other countries to develop measures for sustainable transport system.

Keywords: electric cars and road transport, low-carbon development and climate change, life cycle analysis, external costs, greenhouse gas emissions and air pollutants.

INTRODUCTION

The World Economic Forum's annual Global Risks Report 2022 ranks the failure of governments and businesses to take effective action to adapt to and mitigate climate change as one of the biggest risks to the global economy [11]. The transport sector accounts for more than 1/5 of greenhouse gas emissions, the main of which is carbon dioxide (CO2). This is about 80% more than in 1990. The majority of emissions come from road transport - 74.5%, with almost half coming from passenger transport [2].

Transport is one of the main sources of urban air pollution. According to the European Environment Agency, road transport accounts for almost 1/3 of total emissions of nitrogen oxides (NOx), 18% of carbon monoxide (CO), 7.6% of non-methane volatile organic compounds (NMVOC), 7.7% of particulate matter with a

diameter of less than 10 microns (PM10) and 10% of particles with a diameter of less than 2.5 microns (PM2.5) [3].

According to the latest World Health Organization estimates, air pollution causes 4.2 million premature deaths worldwide each year [12].

. One of the main directions for solving environmental and energy problems is the transition to sustainable development, which includes the development of a low-carbon economic model [6], [7]. Electrification of vehicles and an increase in the share of low-carbon and carbon-free energy sources are associated with the achievement of Sustainable Development Goals (SDGs): SDG 7 ("Affordable and clean energy"), SDG 9 ("Industrialization, innovation and infrastructure"), SDG 11 ("Sustainable cities and settlements"), SDG 13 ("Combating climate change") [1].

In Russia, the electric transport market is at the initial stage of development (by the beginning of 2023, 20.7 thousand electric vehicles were registered in the country), ant it has good prospects. According to the "Transport Strategy of the Russian Federation until 2030 with a forecast for the period until 2035" and the "Concept for the development of production and use of electric road transport in the Russian Federation for the period until 2030", the share of electric vehicles in total sales could reach 15% in 2030, with a significant portion coming from passenger and light commercial electric vehicles [9].

Environmental externalities play an important role when comparing the impact of electric vehicles and internal combustion engines on humans and the environment. They include: air pollution; greenhouse gas emissions; noise pollution; resource depletion; waste generation. Electrification of road transport, being an integral part of the transition to a sustainable and low-carbon transport system, has both positive and negative aspects.

A sustainable transport system can be defined as a system that integrates economic, social and environmental dimensions.

The formation of an environmentally sustainable transport system helps to reduce emissions of air pollutants, greenhouse gases and waste within the planet's ability to absorb them, reduce noise pollution, minimize the consumption of non-renewable resources, and develop the recycling and reuse of materials.

As a result of comparing the impact of electric vehicles and cars with internal combustion engines on humans and the environment, five types of environmental externalities were identified. Table 1 shows the definitions of externalities and reveals their features in relation to electric vehicles in comparison with traditional cars.

Table 1. Environmental externalities of electric vehicles in comparison with cars with internal combustion engines

External effect	Definition	Peculiarities
Air pollution	Costs associated with damage to human health, biodiversity, ecosystems, and material objects from substances that pollute the air at the local and	- Direct emissions of air pollutants during the operation of electric vehicles are practically absent (with the exception of emissions of particulate matters). - There are no direct greenhouse gas emissions from the operation of electric vehicles. - The amount of indirect emissions from the operation of electric vehicles (arising from the generation of electricity at power plants, which is

	regional level.	used to charge electric vehicles) strongly depends on the structure of electricity generation. The use of coal as the main fuel, high levels of electricity losses in networks, and outdated generation technologies significantly increase emissions. - The production of electric vehicles is characterized by higher emissions, due to the energy-intensive production of batteries. - Recycling of batteries reduces emissions during the life cycle of electric vehicles. This is due to reducing the negative impact of electric vehicles by using recycled materials in the vehicle manufacturing process instead of mining and processing raw materials.
Greenhouse gas emissions	The costs associated with the negative impacts of greenhouse gas emissions and, consequently, climate change, at the global level.	
Noise	Costs associated with noise-induced discomfort or noise-related harm to human health.	- The spread of electric vehicles can reduce noise levels in the city, but only where the average speed of vehicles is relatively low. This is because at high speeds tire, road and wind noise dominates rather than engine noise.
Resource depletion	Costs to future generations associated with excessive consumption of non-renewable resources (fossil fuels, rare metals, etc.).	- The impact of electric vehicles on metal resource depletion is higher than that of ICE vehicles. - Consumption of fuel and energy resources in the case of electric vehicles is lower and varies significantly depending on the structure of electricity generation.
Waste generation	Costs associated with water and soil pollution.	- Electric cars have less parts than cars with internal combustion engines, and, accordingly, less components to be disposed of, and there is also no risk of oil leakage. - At the same time, the problem of battery recycling is acute. Technological progress and the development of recycling and reuse will help reduce waste.

Source: compiled by the authors

MATERIALS AND METHODS

To assess the external costs associated with air pollution during the operation of electric vehicles and cars with internal combustion engines, it is preferable to use an approach based on the economic assessment of damage (damage cost approach). To assess the external costs associated with greenhouse gas emissions during operation and throughout the entire life cycle of vehicles, it is preferable to use an approach based on the economic assessment of the costs of preventing/mitigating the negative consequences of climate change (avoidance/abatement/mitigation cost approach).

One of the main causes of urban air pollution is direct emissions from internal combustion engines, the predominant part of which occurs as a result of fuel combustion in the engine. Direct emissions from electric vehicles tend to zero, but during their operation, as in the case of traditional cars, emissions of particulate matter of non-exhaust origin occur due to wear of tires, brakes, road surfaces and resuspension of road dust. Indirect emissions are also generated due to the electricity generation at urban power plants.

We used foreign estimates of external costs associated with emissions of pollutants into the atmosphere, based on the damage cost approach, with their subsequent transformation in the country and time context according to the OECD methodology [10].

We adjusted the volumes of pollutants taking into account the structure of the Russian passenger car fleet in terms of environmental classes and the structure of electricity production in four scenarios:

1) "Russia" (the national structure of electricity production is used: 43% natural gas and 16.2% coal); [5].
2) "gas" (the share of natural gas is close to 100%);
3) "coal" (the share of coal approaches 100%);
4) "hydropower" (the share of hydropower is approaching 100%).

While air pollutants harm human health and the environment primarily at the local and regional levels, anthropogenic greenhouse gas emissions have a negative impact on the climate at the global level. In this regard, in addition to quantifying the external costs associated with greenhouse gas emissions at the operational stage, which is necessary for further calculation of the size of the consumer subsidy, we estimate in monetary terms emissions of the full fuel cycle and emissions during the production of vehicles. Emissions during the full fuel cycle (including emissions at the operation stage and the fuel production stage) of electric vehicles are taken from the Argonne National Laboratory database and adjusted to take into account the characteristics of the Russian electricity production structure in each scenario. Emissions during the full fuel cycle of Russian internal combustion engines, as well as the emissions at the production stage of vehicles, are taken from a study of the Moscow Credit Bank.

To estimate the external costs associated with greenhouse gas emissions, we propose to use the avoidance cost approach. This is due to the inability to take into account and quantify all the damage because from climate change due to the scale and variety of its possible negative consequences, the difficulty of choosing a discount rate and other factors. In addition, the emissions trading system is based on the avoidance cost approach.

As an estimate of external costs caused by greenhouse gas emissions, we use a value of 1000 rubles/t CO2-eq.: at this price carbon units were sold during the first trading on the Moscow Exchange in September 2022.

RESULTS

One can see below some results obtained (fig.1, fig.2).

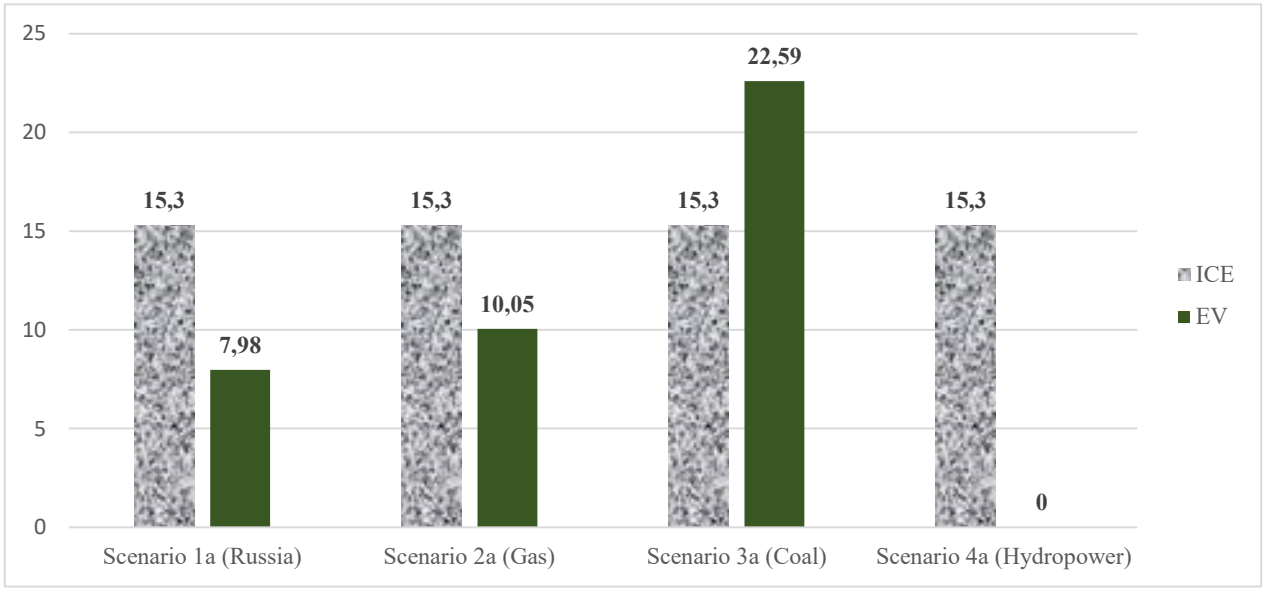


Figure 1 – External costs associated with greenhouse gas emissions during the operation of vehicles, rubles/100 km
Source: compiled by the authors

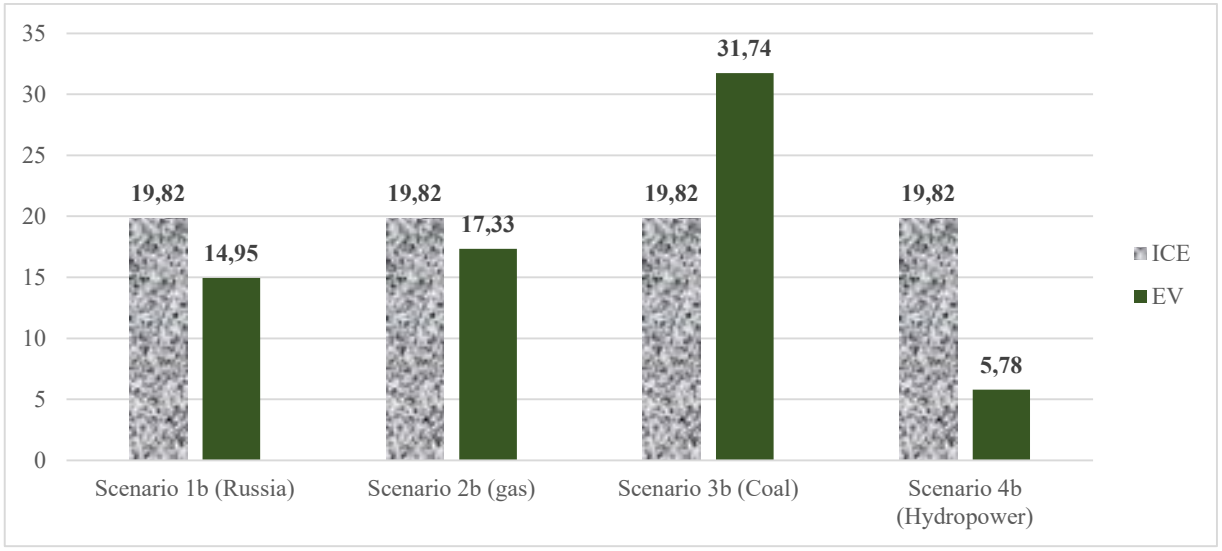


Figure 2 – External costs associated with greenhouse gas emissions during the life cycle of vehicles, carbon footprint (without recycling stage), rubles/100 km
Source: compiled by the authors

DISCUSSION

External costs associated with greenhouse gas emissions are higher at the operating stage and in general during the life cycle of cars with internal combustion engines in all scenarios except the "coal" one. In the "coal" scenario, the external costs of electric vehicles are higher than those of cars with internal combustion engines by 1.5 times (operation stage) and 1.6 times (life cycle). Therefore, the spread of electric

vehicles in cities and regions with an extremely high share of coal in the electricity production structure (for example, Chita) will not be a tool for the transition to low-carbon development, but, on the contrary, will lead to an increase in greenhouse gas emissions. In scenario 4a ("hydropower"), indirect emissions from the operation of electric vehicles (electricity generation) are completely absent. This means that increasing the share of electric vehicles in hydropower-rich regions and cities could make a significant contribution to reducing emissions. However, it is important to consider limiting factors. For example, the Republic of Dagestan, where almost 100% of electricity is generated by hydroelectric power plants, is an energy-deficient region, that will hinder the spread of electric vehicles.

External costs associated with air pollution during the operation stage of vehicles are higher in all scenarios for cars with internal combustion engines. In the "coal" scenario, the difference between the external costs of electric vehicles and cars with internal combustion engines is the smallest, from 5.5 to 7.9 times, depending on the size of the city. In the "hydropower" scenario, the difference between costs is the largest – from 16.2 to 23.1 times, respectively. The gap in the external costs of cars with internal combustion engines and electric vehicles is due, firstly, to the fact that a greater degree of dispersion of emissions when burning fuel at power plants reduces the concentration of harmful substances and, accordingly, the damage. Secondly, only in scenario 3 ("coal") the main fuel is coal, the combustion of which is characterized by the largest volume of emissions of harmful substances. In scenario 4 ("hydro"), for electric vehicles, only non-exhaust particulate emissions occur.

At the beginning of 2023, there were 20.7 thousand electric vehicles among all passenger cars in Russia [8]. It is expected that by 2030 the number of passenger electric vehicles may reach 630 thousand units [4] or 1.3% of the total number of passenger cars. At the beginning of 2023, there were 45.39 million passenger cars among all cars in Russia. Taking into account the average growth of the Russian vehicle fleet for 2019–2021. (1.65%) the number of passenger cars will be 50.1 million units by 2030.

CONCLUSION

Electrification of road transport, being an integral part of the transition to a sustainable and low-carbon transport system, has both positive and negative aspects. Direct emissions of air pollutants from the operation of electric vehicles tend to zero (except for emissions of particulate matter of non-exhaust origin); there are no direct greenhouse gas emissions when operating electric vehicles; the volume of indirect emissions from the operation of electric vehicles (arising from the generation of electricity at power plants, which is used to charge electric vehicles) strongly depends on the structure of electricity generation; electric vehicle production is characterized by higher emissions due to the energy-intensive production of batteries; recycling batteries can reduce emissions during the life cycle of electric vehicles, which is due to the use of secondary raw materials instead of primary ones; the distribution of electric vehicles can reduce noise levels, but only where vehicle speed is relatively low; the impact of electric vehicles on the depletion of metal resources is higher than that of cars with internal combustion engines; the impact on the depletion of fuel and energy resources, on the contrary, is lower and strongly depends on the structure of electricity production; electric vehicles have fewer parts to be recycled and there is no risk of leakage of petroleum products. At the same time, the problem of recycling batteries is acute. We

can come to the conclusion that external costs due to urban air pollution are lower for electric vehicles in all considered scenarios. External costs due to greenhouse gas emissions are also lower for electric vehicles, with the exception of the situation when the share of coal in the electricity production structure approaches 100%. The complete absence of greenhouse gas emissions from electric vehicles is realized with a 100% share of hydropower.

ACKNOWLEDGEMENTS

The research was funded by the Russian Fund for Basic Research within project 23-28-00508 “Methodology for the elaboration of mechanisms for low-carbon development of Russia's economy in new circumstances”.

REFERENCES

[1] Baraboshkina, A. V., & Kudryavtseva, O. V. (2023). External costs of road transport in the context of the transition to a low-carbon economy: Russian experience. Lomonosov Economics Journal, 58(3), 137–156. https://doi.org/10.55959/MSU0130-0105-6-58-3-7

[2] Cars, planes, trains: where do CO2 emissions from transport come from? // Our World in Data.URL: https://ourworldindata.org/co2-emissions-from-transport

[3] Emissions of air pollutants from transport //European Environment Agency. URL: https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-air-pollutants-8/transport-emissions-of-air-pollutants-8

[4] Experts predicted how many electric vehicles there will be in Russia by 2030 // RIA Novosti. https://ria.ru/20211021/elektromobil-1755502699.html

[5] International Energy Agency. Countries, https://www.iea.org/countries/russia

[6] Kudryavtseva O.V., Baraboshkina A.V. Low-carbon development: challenges for Russia // International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM. — 2021. — Vol. 21, no. 5.1. — P. 301–306.

[7] Kudryavtseva, O. V., Kurdin, A. A. (2023). Prospects for low-carbon industrial policy: The case of Russia. Global Challenges of Climate Change, 2, 251–263. https://www.springerprofessional.de/en/prospects-for-low-carbon-industrial-policy-the-case-ofrussia/23719704

[8] Loboda V. The number of registered electric vehicles in Russia exceeded 20 thousand // Avtostat. https://www.autostat.ru/news/54027/.

[9] Transport strategy of the Russian Federation until 2030 with a forecast for the period until 2035. Order of the Government of the Russian Federation dated November 27, 2021 №. 3363-p. http://static.government.ru/media/files/7enYF2uL5kFZlOOpQhLl0nUT91RjCbeR.pdf

[10] The Cost of Air Pollution: Health Impacts of Road Transport. OECD Publishing, 2014. P. 54–55. https://read.oecd-ilibrary.org/environment/the-cost-of-airpollution_9789264210448-en#page4

[11] The Global Risks Report 2022. – World Economic Forum, 2022, 2022, 117 pp

[12] World Health Organization. (2022, December 19). Ambient (outdoor) air pollution. https://www.who.int/ru/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

GHG EMISSION VARIABILITY FROM SOIL IN CONVENTIONAL FARMING SYSTEM

Ph.D. Kristine Valujeva[1]

Mg.sc.env. Inga Grinfelde[1]

PhD Candidate Jovita Pilecka-Ulcugaceva[1]

[1] Latvia University of Life Sciences and Technologies, Scientific Laboratory of Forest and Water Resources, **Latvia**

ABSTRACT

Reducing GHG emissions from soil is crucial for mitigating climate change, promoting sustainable agriculture, protecting ecosystems and biodiversity, ensuring food security, and improving public health. The effectiveness of GHG mitigating strategies may vary depending on local conditions, soil type, and agricultural practices. It is recognized that conventional farming practices may lead to increased GHG emissions compared to more sustainable farming systems. Therefore, the aim of this study is to research the GHG emission variability from conventionally managed soil. The soil flux of N_2O, CH_4 and CO_2 was measured in three conventionally managed monitoring sites in the vegetation periods from 2018 to 2022 using a mobile spectrophotometer Picarro G2508. The average N_2O emission at monitoring sites ranges from 4.1 to 6.6 g $ha^{-1}day^{-1}$, the average CO_2 emission ranges from 73.8 to 122.3 kg $ha^{-1}day^{-1}$, but CH_4 assimilation ranges from 1.7 to 5.1 g $ha^{-1}day^{-1}$. Transitioning to sustainable agricultural practices may help to mitigate the GHG emissions from soil while promoting soil health and long-term sustainability.

Keywords: nitrous oxide, carbon dioxide, methane, agriculture, Picarro G2508

INTRODUCTION

Agriculture is responsible for generating three primary greenhouse gases (GHG): carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The main sources of GHG emissions from agriculture are enteric fermentation (resulting in CH_4 emissions), manure management (contributing to both CH_4 and N_2O emissions), and soil management practices (leading to CO_2 and N_2O emissions). To address the objectives of meeting the global demand for high-quality food and fiber while also reducing GHG emissions and combating climate change, there is a need for coordinated efforts on a global scale. This creates the need for a combination of initiatives, including the adoption of management practices aimed at maximising yield while simultaneously minimizing GHG emissions from soil. Before making recommendations for combination of initiatives, it is important to understand the advantages and disadvantages of traditional management practices.

It is recognized that conventional farming practices may lead to increased GHG emissions compared to more sustainable farming systems [1,2]. Conventional soil tillage significantly affect greenhouse gas (GHG) emissions from soil by accelerating the decomposition of soil organic matter and releasing CO_2 into the atmosphere [3]. It

also may lead to the depletion of soil organic carbon content over time, further contributing to increased CO_2 emissions. Soil organic carbon is a critical component of soil fertility and quality. Disruption of soil structure and aeration results in changes in soil temperature and moisture [2], which in turn may contribute to the formation of N_2O emission. Conventional tillage practices are more likely to reduce CH_4 emissions due to increased soil aeration and the promotion of aerobic conditions [4]. Therefore, the aim of this study is to research the GHG emission variability from conventionally managed soil.

MATERIALS AND METHODS

The monitoring sites are located in central part and southwest of Latvia, Northern Europe (Figure 1). At the Berze monitoring site, the soil is naturally fertile and suitable for agricultural activity. It is classified as a *Calcic Cambisol* with a clay content of 28% at a depth of 0-25 cm and a pH range of 7.5-7.9. The soil at Mellupite monitoring site is *Stagnic Luvisol* with clay content of 12.2% at a depth of 0-45 cm and a pH range of 6.7-7.0. The soil at Auce monitoring site is *Gleyic Cambisol* with clay content of 0.6% at a depth of 0-30 cm.



Figure 1. Locations of monitoring sites: 1, Mellupite monitoring site (56.493361, 22.230326); 2, Auce monitoring site (56.494337, 22.978962); 3, Berze monitoring site (56.713914, 23.375577).

Concentration measurements of N_2O, CO_2, CH_4 were conducted using a portable spectrophotometer known as the Picarro G2508 Gas Concentration Analyzer. A total of 416 measurements were done, each lasting 400 seconds. Comprehensive information about the equipment and the transformation of the data can be found in Valujeva et al., 2017, 2022 [5,6]. The concentrations of N_2O, CO_2, CH_4 were used to calculate soil flux

rates. These rates were determined through the application of a linear model [7], employed within the Soil Flux Processor (SFP) software, which was developed by Picarro Inc. All flux rates were then converted into units of grams or kilograms per hectare per day.

IMB SPSS Statistics version 22 was used for conducting statistical analyses and creating data visualizations. The distribution of datasets was assessed using the Shapiro-Wilk test. Subsequently, to determine yearly differences in GHG emissions from soil among three monitoring sites, the non-parametric Kruskal-Wallis test was used ($p<0.05$). For conducting pairwise comparisons, the Dunn's post hoc tests were applied ($p<0.05$).

RESULTS

N_2O emission varies from 2.52 g ha^{-1} day^{-1} in 2022 to 9.82 g ha^{-1} day^{-1} in 2019. No significant differences in N_2O emission in conventional tillage can be observed between years. CO_2 emission varies from 85.29 kg ha^{-1} day^{-1} in 2021 to 124.25 kg ha^{-1} day^{-1} in 2017. There is also a statistically significant difference between these values ($p<0.05$). CH_4 uptake has decreased over the last three years compared to the period 2017-2019. It has a statistically significant difference between 2019 and 2020, 2021, 2022, between 2017 and 2020, 2021, 2022, and between 2018 and 2022 ($p<0.05$).

Table 1. Mean value and standard error of the mean (SE) for N_2O, CO_2, CH_4 emissions of conventional tillage (CT).

Year	N_2O, g ha^{-1} day^{-1}		CO_2, kg ha^{-1} day^{-1}		CH_4, g ha^{-1} day^{-1}	
	Mean	SE	Mean	SE	Mean	SE
2017	2.54	0.99	124.25	11.46	-5.87	0.73
2018	4.00	0.98	100.69	8.36	-4.50	0.52
2019	9.82	2.98	86.77	7.83	-6.38	0.71
2020	8.90	3.18	99.28	7.24	-3.04	0.40
2021	6.52	1.55	85.29	9.12	-3.14	0.44
2022	2.52	0.54	98.30	7.69	-1.97	0.30
Total	5.49	0.81	98.01	3.57	-3.62	0.20

The higher average N_2O emission is observed in Mellupite monitoring site reaching 6.58 N_2O, g ha^{-1} day^{-1}. N_2O emission is significantly lower for Berze monitoring site comparing to Mellupite monitoring site ($p=0.012$). The largest scattering amplitude is observed at Auce monitoring site.

The higher average CO_2 emission is also observed in Mellupite monitoring site (122.30 kg ha^{-1} day^{-1}). But the lowest average CO_2 emisison is for Berze monitoring site, which significantly differs from other monitoring sites ($p<0.05$).

The higher CH_4 assimilation is for Auce monitoring site (-5.11 g ha^{-1} day^{-1}), which significantly differs from GHG emissions released at Mellupite and Berze ($p<0.05$). Berze has the lowest average CH_4 asimilation (-1.71 g ha^{-1} day^{-1}) and it also significantly differs from Mellupite ($p<0.05$).

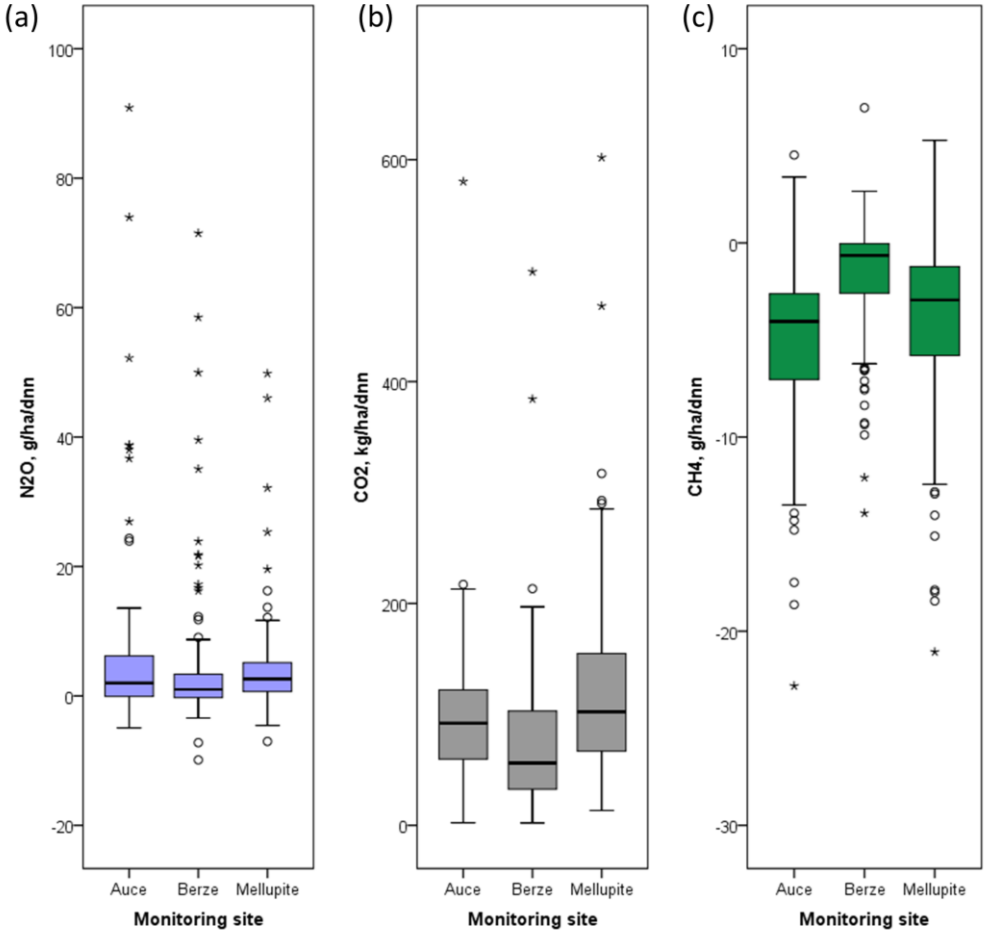


Figure 1. The (a) N_2O, (b) CO_2, and (c) CH_4 emissions from the soil in three monitoring sites.

N_2O fluxes correlated positively with soil moisture, but negatively with soil temperature and CH_4 (Table 1). CH_4 fluxes correlated positively with soil moisture, but negatively with N_2O and CO_2. CO_2 also positively correlated with soil temperature. Soil temperature and soil moisture significantly affects with N_2O fluxes. Soil moisture affects CH_4, but soil temperature affects CO_2.

Table 1. Kendall's Tau correlation coefficients for conventionally managed soil.

Factors	Soil temperature, °C	Soil moisture, %	N_2O, g ha^{-1} day^{-1}	CH_4, g ha^{-1} day^{-1}	CO_2, kg ha^{-1} day^{-1}
Soil temperature, °C	**1.000**	-0.006	**-0.097****	0.022	**0.091****
Soil moisture, %	-0.006	**1.000**	**0.068***	**0.281****	-0.038
N_2O, g ha^{-1} day^{-1}	**-0.097****	**0.068***	**1.000**	**-0.065***	0.062
CH_4, g ha^{-1} day^{-1}	0.022	**0.281****	**-0.065***	**1.000**	**-0.377****
CO_2, kg ha^{-1} day^{-1}	**0.091****	-0.038	0.062	**-0.377****	**1.000**

*Correlation is significant at the 0.05 level
**Correlation is significant at the 0.01 level

DISCUSSION

This study focused on how conventional tillage affects N_2O, CO_2, CH_4 emissions in three different monitoring sites used for intensive agricultural production. *Calcic Cambisol* with clay content of 28% shows lower average N_2O and CO_2 emissions, and almost 3 times lower CH_4 assimilation comparing to other soil types. *Gleyic Cambisol* with clay content of 0.6% shows the higher average CH_4 assimilation rate.

From the correlation analysis we can see that higher soil moisture leads to higher CH_4 and N_2O emissions. But soil temperature is the limiting factor for formation of GHG emissions. Fluctuations in soil temperature affect N_2O emission, the lower the soil temperature, the higher the emission. On the other hand, CO_2 emission has an inverse correlation with soil temperature and as the temperature rises, the CO_2 emission will rise. Although the Krauss et al. (2017) found the positive correlation between N_2O fluxes, soil temperature and water filled pore space [8]. Variability of GHG emissions from soil is difficult to estimate with simple relationships between emissions and soil properties, as, for instance, high soil nitrogen reduces CO_2 emission, but simultaneously increases N_2O emissions [9].

Sustainable agricultural practices that focus on reducing emissions and enhancing carbon sequestration in soil play a crucial role in mitigating the overall impact of agriculture on climate change. These practices may reduce GHG emissions by changing the physical, chemical and microbiological properties of soil, as GHG emissions from soil are related to several soil properties, such as soil pH, soil water content, soil structure, crop types, nutrient management and climate zones [9,10,11]. For instance, CO_2 emission can be reduced by introducing reduced tillage [2]. In our study more sustainable tillage may lead to increased CH_4 assimilation, more stable CO_2 emission and improved soil health.

CONCLUSION

N_2O emission shows variability over the years, however, there are no significant differences in N_2O emissions observed between years when considering conventional tillage practices. This suggests that N_2O emissions from conventional tillage may remain relatively consistent despite yearly fluctuations. CO_2 emission vary noticeably from year to year, with the highest emission observed in 2017. Results show that conventional tillage decreases the CH_4 assimilation over the last three years. GHG emissions from the soil are influenced by multiple factors, including the year, tillage practices, monitoring site, and environmental conditions. GHG emissions from soil can vary significantly both temporally and spatially. Additionally, the correlations highlight the complex interactions between GHG emissions and environmental variables. Environmental factors, such as soil moisture and temperature, play a significant role in influencing GHG emissions from the soil. Transition to more sustainable tillage treatment, namely conservation tillage, minimum tillage may lead to increased CH_4 assimilation, more stable CO_2 emission and improved soil health.

https://doi.org/10.5593/sgem2023V/4.2/s19.28

ACKNOWLEDGEMENTS

The research was funded by 'Assessment of the Impact of Land Reclamation on the Reduction of Climate Change (Flood Risk)', of the Ministry of Agriculture of the Republic of Latvia [No. 18-100-INV18-5-000013; No. 19-00-SOINV05-000017; No. 20-00-SOINV05-000008; No. 21-00-S0INV05-000024; No. 22-00-S0INV05-000005].

REFERENCES

[1] Bhattacharyya, S.S., Leite F.F.G.D., France, C.L., Adekoya A.O., Ros, G.H., de Vries W., Melchor-Martínez, E.M., Iqbal, H.M.N., Parra-Saldívar, R. Soil carbon sequestration, greenhouse gas emissions, and water pollution under different tillage practices, Science of The Total Environment 2022, Volume 826, 154161, https://doi.org/10.1016/j.scitotenv.2022.154161.

[2] Alskaf, K., Mooney, S.J., Sparkes, D.L., Wilson, P., Sjögersten, S. Short-term impacts of different tillage practices and plant residue retention on soil physical properties and greenhouse gas emissions, Soil and Tillage Research 2021, Volume 206, 104803, https://doi.org/10.1016/j.still.2020.104803.

[3] Reicosky, D.C., Archer, D.W. Moldboard plow tillage depth and short-term carbon dioxide release. Soil Tillage Res 2007, 94(1):109–121.

[4] Ho, A., Reim, A., Kim, S.Y., Meima-Franke, M., Termorshuizen, A., de Boer, W., van der Putten, W.H., Bodelier, P.L.E. Unexpected stimulation of soil methane uptake as emergent property of agricultural soils following bio-based residue application. Glob Change Biol 2015, 21: 3864-3879, https://doi.org/10.1111/gcb.12974

[5] Valujeva, K., Pilecka, J., Frolova, O., Berzina, L., Grinfelde, I. Measurement time estimation of CO_2, CH_4, N_2O and NH_3 in closed chambers and recirculation system with Picarro G2508 analyser. In Proceedings of the 17th International multidisciplinary scientific GeoConference SGEM 2017, Albena, Bulgaria, 29 June-5 July 2017, 519-526.

[6] Valujeva, K., Pilecka-Ulcugaceva, J., Skiste, O., Liepa, S., Lagzdins, A., Grinfelde, I. Soil tillage and agricultural crops affect greenhouse gas emissions from Cambic Calcisol in a temperate climate, Acta Agriculturae Scandinavica, Section B — Soil & Plant Science 2022, 72:1, 835-846, DOI: 10.1080/09064710.2022.2097123

[7] Wagner, S.W., Reicosky, D.C., Samuel Alessi, R. Regression models for calculating gas fluxes measured with a closed chamber. Agron. J. 1997, 89, 279-284.

[8] Krauss, M., Ruser, R., Müller, T., Hansen, S., Mäder, P., Gattinger, A. Impact of reduced tillage on greenhouse gas emissions and soil carbon stocks in an organic grass-clover ley - winter wheat cropping sequence, Agriculture, Ecosystems & Environment, Volume 239, 2017, Pages 324-333, ISSN 0167-8809, https://doi.org/10.1016/j.agee.2017.01.029.

[9] Chalco Vera, J., Curti, R. N., Acreche, M. M. Integrating critical values of soil drivers for mitigating GHGs: An assessment in a sugarcane cropping system. Sci. Total Environ 2020, 704, 135420, https://doi.org/10.1016/j.scitotenv.2019.135420

[10] Shakoor, A., Shakoor, S., Rehman, A., Ashraf, F., Abdullah, M., Shahzad, S. M., et al. Effect of animal manure, crop type, climate zone, and soil attributes on greenhouse gas emissions from agricultural soils—A global meta-analysis. J. Clean. Prod. 2021, 278, 124019. doi:10.1016/J.JCLEPRO.2020.124019

[11] Oertel, C., Matschullat, J., Zurba, K., Zimmermann, F., Erasmi, S. Greenhouse gas emissions from soils—A review. Chemie Der Erde 2016, 76 (3), 327–352.

HOW SUSTAINABLE AND GREEN IS TODAY'S MODERN PRINTING INDUSTRY? MYTHS AND FACTS

Prof. Dr. Csaba Horvath[1]

Prof. Dr. Cem Aydemir[2]

Prof. Dr. Semira Yenidogan[2]

[1] Óbuda University, Budapest – **Hungary**
[2] Marmara University, Istanbul – **Turkey**

ABSTRACT

Going green ... So many projects to reduce environmental impact start this way and continue with the first task being to eliminate printed communication and go paperless and digital. All this is not driven by thoughtful environmental considerations, but by an aversion to paper-based communication that is wrongly anchored in the social consciousness. The authors draw attention to the misconceptions that people have about paper-based communication, showing that they are untrue and that they are often used to greenwash the digital world, thus distracting attention from the harmful environmental impact of their own processes. At the same time, they present the facts against the myths, citing scientific sources and reports, as well as their own research. They analyse the real environmental impacts of paper-based communication and the extent to which technology processes meet sustainability requirements. The world of print communication (including the modern printing industry) attaches great importance to sustainability. The Gutenberg galaxy has provided the basis for the development of human knowledge and culture for half a millennium and plans to continue to play this role in the future. It aims to meet the requirements of environmental sustainability, the circular economy and to work with the rest of the supply chain to achieve the UN Sustainable Development Goals (SDGs). The authors detail and analyse these processes in their work.

Keywords: paper based communication, printed media, sustainability, green printing

INTRODUCTION

“Go green”, “Go paperless” and “Save the trees” are common messages as many organisations encourage their customers to switch to electronic transactions and communications. But are these appeals based on fact? These sorts of messages give the impression that electronic communication is more environmentally friendly than paper-based communication.

These statements are often made as part of cost saving initiatives and typically ignore the environmental impact of digital communications. In most countries such statements, made without research and evidence, go against national advertising standards.

The authors aim to use such a high-profile conference on environmental issues to highlight misleading and unsubstantiated environmental claims and assertions against the

paper-based print media, and to take stock of and systematise alliances and collaborations that can help improve the future social perception of paper-based communication.

At the same time making suggestions for the environmental and social sustainability of the five-century-old Gutenberg Galaxy.

METHODS

In a recent publication [1], the authors summarised the technological aspects of the sustainability of the printing industry, focusing on the environmental impacts. This article focuses on the - particularly sensitive - social aspects of the sustainability of paper-based print media. To explore the topic, we reviewed publications, communications, and statements of key players in the print media supply chain over the last 10-12 years and available databases.

First, we summarised the common prejudices and misconceptions that have emerged in public opinion about paper-based communication.

Print and paper: Myths and Facts

When we talk about the sustainability of print and paper, it is so important to separate the facts from the myths. This was helped by the publication of Two Sides [2], which explains misconceptions and their contrasting realities in a simple and understandable (if not scientifically rigorous) way (Table No.1).

Founded in 2008, Two Sides is a not-for-profit, global initiative promoting the unique sustainable and attractive attributes of print, paper, and paper packaging. (www.twosides.info)

Table No.1

	The Myth	The Fact
1	European forests are shrinking.	European forests have been growing by over 1,500 football pitches every day.
2	Planted forests are bad for the environment.	Sustainable forest management preserves biodiversity and safeguards forests for future generations.
3	Paper is bad for the environment.	Paper is highly recycled and naturally sustainable.
4	Only recycled paper should be used.	Virgin fibres from sustainably managed forests are needed to maintain the paper cycle.
5	Paper production is a major cause of global greenhouse gas emissions	Most of the energy used in paper production is renewable and carbon intensity is surprisingly low.
6	Paper production consumes an excessive amount of water	Paper production is dependent on water, yet relatively little is consumed.
7	Electronic communication is better for the environment than paper-based communication	Electronic communication also has environmental impacts
8	Digital is the preferred means of communication.	Many consumers value paper-based communication

The following list provides a more detailed justification of the facts. A more basic factual explanation - supported by data - can be found in the above-mentioned publication [2].

1. In Europe, where almost all primary forests are protected, paper comes from sustainably managed forests where the cycle of planting, growing, and logging is carefully controlled.
2. Well-managed sustainable forests give multiple benefits to society, such as livelihoods, ecosystem services and biodiversity, while helping to tackle climate change. To ensure the long-term health of European forests, sustainable forest management underpins how the paper industry operates and sources its main raw material. Nearly 105 million hectares, 52% of the forest area in Europe, is certified by the Forest Stewardship Council® (FSC®) and the Programme for the Endorsement of Forest Certification™ (PEFC™).
3. Paper is based on wood, a natural and renewable material. Paper is one of the most recycled products in the world and epitomises the circular economy model of make, use, recycle and reuse. In 2020, a total of 56 million tonnes of paper was collected and recycled in Europe – a recycling rate of 74%.
4. Without new virgin fibres from trees, the paper cycle cannot be maintained. Recycled fibres degrade after several uses and the paper industry needs fresh fibre from sustainably managed forests to keep the renewable cycle going.
5. The European pulp and paper industry produces original biobased products using wood, a renewable material. It is also the largest single industrial user and producer of renewable energy in the EU.
6. The pulp and paper industry depends on water in three crucial areas. Firstly, there is rainwater that is essential for trees to grow and, through photosynthesis, transform carbon dioxide to oxygen and cellulose, which provides the industry's primary raw material, wood fibre. Then there is water that is used to make pulp and paper, and finally there is the suitably treated effluent. Since the 1990s, the average water intake per tonne of paper has decreased by 47%.
7. The electronic waste problem is also colossal and growing. In 2019, the industry was responsible for a gigantic 53.6 million metric tonnes (Mt) of e-waste across the world. The ICT industry accounts for 5-9% of electricity use, which is more than 2% of global greenhouse gas emissions (as much as all air traffic). If left unchecked, the ICT footprint could increase to 14% of global emissions by 2040.
8. The value and convenience of the digital revolution must have accepted, but consumers must continue to have a right to receive paper-based communications, particularly bills and statements, without penalties, supplementary charges, or difficulty.

Go paperless … greenwashing actions

Greenwash is defined as "Behaviour or activities that make people believe that a company is doing more to protect the environment than it really is", (Cambridge Dictionary)

Greenwashing is a danger for our industry which, if left unchallenged, threatens the loss of €337 million of value annually for the paper, print and mailing industry in Europe [3].

Two Sides has been actively engaging with organisations found to be making misleading and unsupported environmental claims against print and paper for over 10 years. Their Anti-Greenwash campaign has successfully challenged over 750 global organisations,

primarily service providers like banks, utilities, and telecoms, that subject their customers to repeated Greenwashing messages which are damaging to our industry [3].
It remains vital that Greenwashing is challenged to ensure that the industry's great environmental record is recognised and that the livelihoods of thousands of industry employees, as well as print, paper, and postage volumes, are not damaged by the spread of misleading and opportunistic Greenwash marketing.

SUSTAINABILITY OF THE PAPER BASED COMMUNICATION

Climate change is one of the biggest topics in the modern era with a huge emphasis being put on environmentally friendly actions for people, companies, and countries. This topic is at the forefront for many consumers and will often influence their feelings towards a company and its products. This mind-set from the public has put pressure on, governments and unions, as well as businesses, to promote sustainable practices.

"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."
Sustainable development is the balance of three interconnected dimensions defined in 1992 by The Declaration of Rio on Environment and Development as environmental protection, economic growth, and social development.

The pulp, paper and printing industry are already one of the most sustainable in the world, unfortunately, the industry has somehow gained something of a bad reputation when it comes to sustainability (Figure 1). There has even been schemes to try to limit paper usage by consumers even though managed forests, which are the greatest suppliers of pulp for paper, are often carbon neutral in their efforts. Despite this, companies within the paper-based print product supply chain have made a move to be even more socially responsible.

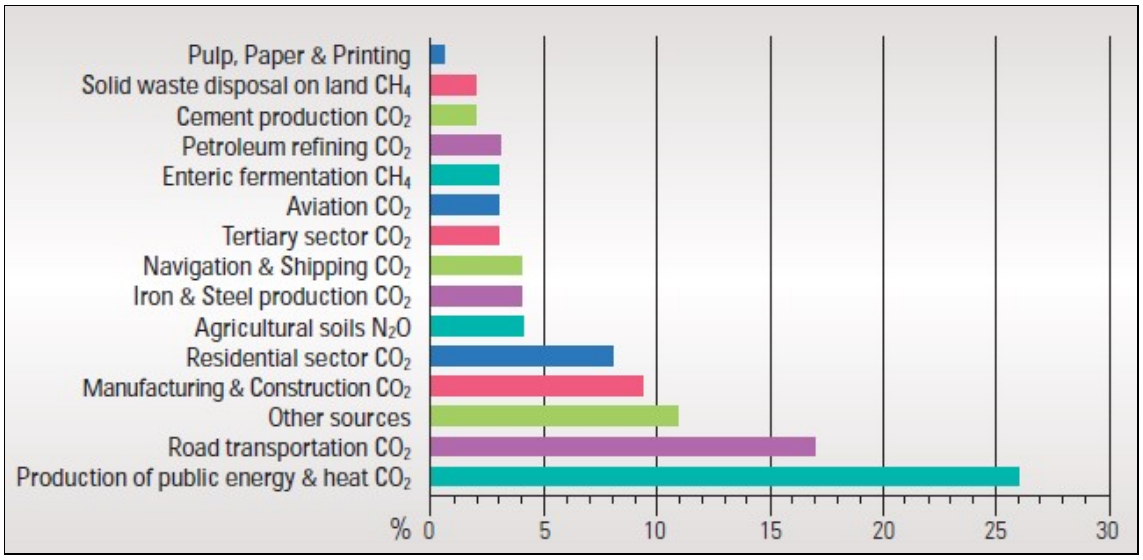


Figure 1: Pulp, Paper & Printing is very small contributor (0.6%) of total European emissions (it is normally classed with manufacturing & construction) [5]

More detailed analyses along the printed product value chain also provide several opportunities to reduce environmental impacts, as the authors have shown in a previous publication [1].

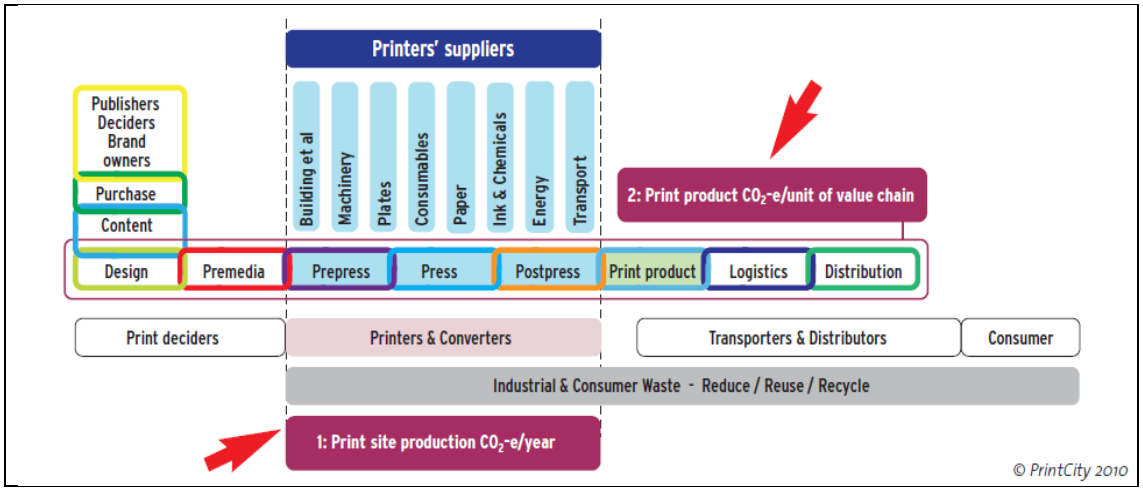


Figure 3: Print media product value chain [5]

The carbon reduction objective can facilitate the transformation of simple supplier/customer relationships to one where common project are defined that can last several years with more durable contractual relations. For example, the reduction of the carbon footprint of a magazine requires all participants in the supply chain to work together – the publisher, paper maker, printer, and distributor. Within this approach carbon reduction objectives can be shared. In some cases, the optimisation of transport to reduce carbon may lead to more distributed printing. This will require a case-by-case evaluation, particularly the origin of the paper used at the different locations. Correctly used, carbon management presents environmental, economic, and commercial advantages. It is a strategic tool for companies to provide them with a clearer vision of the future.
Mapping of Value/Process Streams identifies the multiple sources of CO2e and energy consumption. The most effective optimisation approach is to work across the entire value stream to measure, identify and prioritise areas where improvements can be made. Anything that makes the supply chain more energy efficient generally saves carbon. This approach can use techniques from Lean Manufacturing [6,7].

Carbon Footprint value chain — making it "leaner and greener"
And how can a printing company be environmentally friendly? Obviously because of its commitment to environmental protection and consciousness. The printed products of such a printing company considerably reduce environmental loading and support sustainable development. In addition to the environment-sparing technologies, environmental aspects also determine the internal operation of the printing company and are taken into consideration to an utmost extent.

The exploration of the human–machine environment principally calls for the methods of organizational studies. Lean management is a systemic methodology that identifies, eliminates all forms of losses, as well as all such activities that do not represent any added

value for the customer, client. the lean work methodology has been applied by several companies involved in graphic communication [3].

"The first principle of environmental improvement is to avoid waste. The fundamental principle of Lean is to avoid waste," - asserts the US Environmental Protection Agency that has adopted Lean techniques to improve manufacturing environmental performance [8].

Environmental wastes add no value and can negatively affect production flow, time, quality, and cost — making them prime targets for Lean initiatives. In many cases the costs associated with pollution and wasted energy, water and raw materials can be significant. "Lean Manufacturing" is the elimination of waste in every area of production, including customer relations, product design, supplier networks and factory management." [9]

Waste is anything that does not contribute directly to adding value for the customer. The key metrics are cost and time. Lean manufacturing reduces waste to minimise costs and time while simultaneously improving "Green performance" because any waste reduction provides direct environmental benefits as well as economic efficiency.

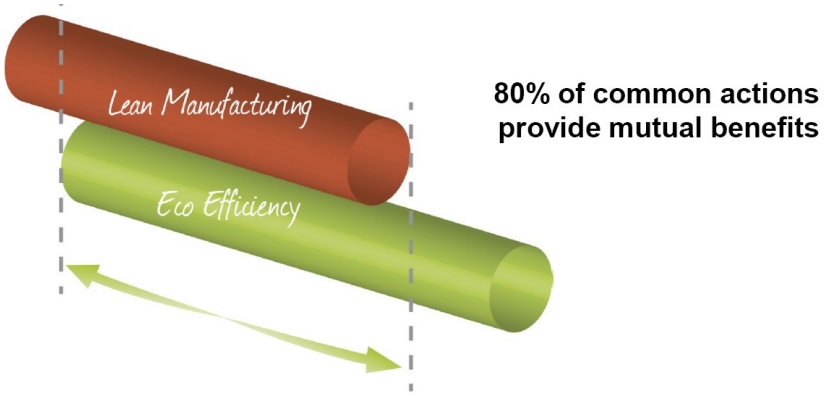


Figure 2: Lean and green strategy [8]

SECTORAL ALLIANCE, COOPERATION AND DISCUSSION

The interest in the social sustainability of print communication motivates all stakeholders in the supply chain to join forces and take collective action, as the following recent examples demonstrate.

Printers' environmental programs are either independent company initiatives or, more commonly, voluntary regional schemes like, Scandinavian Nordic Swan or France's Imprim'vert (Green Printer). The Printing Industries of America has introduced a Sustainable Green Printer Partnership. The Japan Federation of Printing Printing Industries launched the Green Printing movement. The Printers' Association of Australia managed the Sustainable Green Print (SGP) standard and the prestigious 'Environmental Practitioner of the Year' award. The Swiss Association of Swiss Printing Industry (VDS) developed an eco-rating system. The label of British Printing Industry Federation named "Carbon Smart", and the "Print CO2 geprüft" system of printers' federation in Austria (VDMÖ) and in Germany (BVDM) primarily focus on climate protection and reducing carbon footprint [10]. Through the EU Ecolabel, the printing industry can offer to its consumer eco-friendly printed paper products (books, catalogues etc.) from 2021.

In 2021 the Two Sides presented its latest consumer research which revealed many thought-provoking insights into consumer attitudes towards print and paper [3,4,11].

On 18 July 2023, the European Parliament's Committee on Culture and Education adopted by a large majority the own-initiative report on the future of the European book sector by Tomasz Frankowski MEP.
The report promotes books in general and sets out strong messages on printed books and book printing [12].

- Printed books are particularly popular with young people, and this is extremely important for their development.
- Reading in early childhood, especially print books, develops thinking and literacy skills.
- The report calls on the Commission and the Member States to support the sector in the green transition by including financial incentives, funding research and involving all actors in the book market.
- Stresses the environmental friendliness of paper-based products and calls for this to be considered more strongly.
- the whole industry is making a major effort to produce 'greener' products, paying attention to the use of recycled paper, their CO2 footprint and trying to minimize the environmental damage caused.

The new "Printed in Europe" label could also strengthen the interests of the entire European printing industry.

Printers increasingly need to prove their credentials by providing clear issue details to the of their products. If you want to reduce greenwashing and provide your customers with a print-specific tool, you should offer an industry-specific emissions calculator, provided by INTERGRAF has developed to calculate CO2 emissions for the printing industry (2021). This recommendation is the only well-developed international graphical standard for calculating carbon emissions in the printing industry the world and "aims to ensure that everyone on the same basis [13].

CONCLUSION

“Ink on paper” is the most successful communications innovation of the last 2000 years, the one that has lasted the longest and had the profoundest effect on civilisation. Without the technology that is paper there would be no civilisation. Yet most people don’t even think of paper as a technology.
This move to sustainability is highlighted by some of the largest publishers’ devotion to a sustainable approach, with their aims to make a positive social and environmental impact. This plan is based on three pillars: learning for everyone, learning for a better world, and leading responsibly. Common targets and actions can be formulated to European publishers and printers (*Peter Kraus vom Cleef, FEP*).
“Work together to contribute to achieving the United Nations Sustainable Development Goals”, by signing the SDG Publishers Compact, which compels us to prioritise sustainability, raise awareness, and act.

- “Improve our ecosystem together by thinking in networks and reducing our carbon footprint” – for example, by using more AI to “better forecast what we need to print”.
- “Lobby together for our cultural and creative sector”

“Collect together all the research, studies and information about the benefits of reading – and particularly reading in print” – and publish it alongside other stakeholders like booksellers and librarians [14].

ACKNOWLEDGEMENTS

The authors would like to thank INTERGRAF, Two Sides Europe and CEPI (Confederation of European Paper Industries) for making their publications available and allowing access to their databases.

REFERENCES

[1] Aydemir C., Yenidogan S., Tutak D.: Sustainability in the print and packaging industry, Cellulose Chemistry and Technology, Volume 57 (2023), Issue 5-6, pp. 565-577

[2] Print and Paper – Miths & Facts, Two Sides, Daventry, United Kingdom, 2021

[3] Tame, J.: Busting the myths - a European study of consumer perceptions and attitudes toward print and papers, Two Sides Europe, United Kingdom, 2021, p.8

[4] Deemer, J.: Sustainability studies in print – Five printers discuss their journeys to SGP certification, Printing Industries Press, Pittsburgh, USA, 2011, p.124

[5] Wells, N. (ed.): Carbon Footprint & Energy Reduction for the graphic industry value chain, PrintCity GmbH + Co. KG, Gröbenzell, Germany, Wels, N. (ed.)2011, p.34

[6] Wells, N. (ed.): PRINT: seen lean & green, Book 1, PrintCity GmbH + Co. KG, Gröbenzell, Germany, 2012, p.34

[7] Wells, N. (ed.): PRINT: seen lean & green, Book 2, PrintCity GmbH + Co. KG, Gröbenzell, Germany, 2012, p.34

[8] The Lean and Environmental Toolkit (EPA-100-K-06-003), United States Environmental Protection Agency, (www.epa.gov/lean)

[9] Cooper, K., Keif, M. G., Macro Jr. K. L.: Lean Printing: Pathway to Succes, PIA/GATFPress, Pittsburgh, USA, 2007

[10] Horvath, C., Geller, R.: Proposal for an eco-friendly printing standard and EEFP (European Eco-friendly Printer) confirmation label and certification system, 19th SGEM International Multidisciplinary Scientific Geoconference, Proceedings, Nano, Bio, Green and Space: Technologies for Sustainable Future (2019) pp. 339-346

[11] Joubert, D.: Print and paper in a digital world – an international survey of consumer preferences, attitudes and trust, Two Sides, Daventry, United Kingdom, 2019, p.14

[12] Culture and Education committee calls to support the EU book sector and promote reading, Press Releases, 18-07-2023, (https://www.europarl.europa.eu/news/en/press-room/20230717IPR03033/cult-committee-calls-to-support-the-eu-book-sector-and-promote-reading)

[13] INTERGRAF recommendations on CO_2 emissions calculation in the printing industry, Version 2.1 – 2021, INTEGRAF (European Federation for Print & Digital Communication), Brussels, Belgium, 2021, p.6

[14] Smithers (Ed.: Thomas Poetz): European Book market report 2021, Smithers & INTERGRAF, Brussels, Belgium, 2021, p.27.

HYBRID ENERGY SYSTEM FOR FISHING VESSELS CONSIDERING FUTURE ENVIRONMENTAL REGULATIONS: AN APPLICATION "HENSUS" FOR FAST PRELIMINARY POWER SYSTEM CONFIGURING

Marija Koričan[1], PhD

Assoc. Prof. Dr. Nikola Vladimir[1]

Prof. Dr. Krešimir Vučković[1]

Prof. Dr. Tatjana Haramina[1]

Assoc. Prof. Dr. Neven Alujević[1]

[1] University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, **Croatia**

ABSTRACT

In recent years, the maritime industry was shifting towards sustainable practices, focusing on minimising environmental impact and maximising energy efficiency. Fishing vessels are increasingly adopting hybrid energy systems to reduce the consumption of fossil fuels. However, finding the optimal hybrid energy configuration specifically determined for a certain vessel type, its technical specifications, and operational requirements remains a complex challenge. This paper presents the development of an user-friendly application called "HENSUS", i.e. Hybrid Energy System for fishing vessels. The application considers technical characteristics (such as engine power), and operative factors (fuel consumption, working time and average engine load). It contains a comprehensive database of energy sources, from conventional marine fuels to alternative ones (LNG, biodiesel, hydrogen etc.) and full electrification. Through a user-friendly interface, users can input specific vessel details and operational parameters. The application then processes this information to generate a range of optimal hybrid energy configurations. The configurations are evaluated based on the results of the life-cycle cost assessment, which also includes the calculation of carbon tax based on produced tailpipe emissions. The proposed application promotes the adoption of sustainable energy solutions in the fishing industry.

Keywords: optimization, hybrid energy system, fishing vessel, decarbonization, web-based application.

INTRODUCTION

Anthropogenic Greenhouse Gas (GHG) emissions, which are mainly caused by burning fossil fuels and the emissions of carbon dioxide (CO_2), nitrogen oxides (NO_X), sulphur oxides (SO_X), and particulate matter (PM), are the main cause of global warming. The Paris Agreement, adopted in 2015, and the subsequent Glasgow Climate Pact in 2021 represent key milestones in the global effort to combat climate change. By encouraging nations to submit their Nationally Determined Contributions (NDCs) voluntarily, the Paris Agreement seeks to keep global warming far below 2 °C, with a goal of 1.5 °C [1]. The Glasgow Climate Pact expands upon this framework and calls for countries to

strengthen their commitments, improve adaptation strategies, and provide funds to areas that are at risk. A significant step towards resolving a significant contributor to greenhouse gas emissions was taken at COP26 with the agreement to "phase out" wasteful fossil fuel subsidies and "phase down" the use of coal [2].

The marine sector contributes to GHG emissions primarily through the combustion of fossil fuels for propulsion and onboard energy generation in shipping vessels [3]. Approximately 2.9% of the world's emissions resulting from human activity were related to shipping in 2018, accounting for 1,076 million tonnes of CO_2. At the EU level, maritime transport accounts for between 3 and 4% of all CO_2 emissions, or more than 124 million tonnes in 2021 [4]. Studies are periodically conducted by the International Maritime Organization (IMO) to determine the quantity of GHG emissions from the global shipping sector and to appraise the industry's achievements in mitigating its environmental effects. In order to significantly reduce these emissions from international shipping, the IMO set a number of technical and operational measures to deal with challenges in the sector such as decarbonization. Measures like the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP), entered into force in 2013, aim to improve energy efficiency and reduce GHG emissions. By 2023, IMO Member States have adopted further energy efficiency measures – Energy Efficiency Existing Ship Index (EEXI) and the Carbon Intensity Indicator (CII). Through the deployment of EEXI and CII measures, IMO has committed to decreasing the carbon intensity of international shipping by 40% by 2030 in comparison to 2008. Currently, the above-mentioned measures refer to larger fleets, i.e. cargo and passenger ships, of 400 GT and more. By 2025, IMO plans to apply its strategy to the complete fleet, which includes both large-scale and small-scale fisheries [5,6].

DECARBONIZATION OF THE FISHING SECTOR

In order to mitigate these environmental effects and support the long-term sustainability of marine ecosystems, sustainable fishing practices, technology advancements, and regulatory measures are essential. From the extended literature review, it can be noted that these environmental measures include gear retrofit, use of alternative fuels, implementation of renewable energy sources such as photovoltaics, route optimisation etc. [3]. However, the focus of this research is mainly on the modernization of energy systems of fishing vessels, considering the upcoming environmental regulations.

Previous research, presented by Perčić et al. showed that 100% replacement of the existing energy system (mostly diesel) with an alternative option, usually results in very high costs [7]. When a lifecycle analysis is carried out, which includes the production of engines, fuel cells, batteries, etc., and the production process of the desired fuel, the amount of emitted emissions can be greater than that produced by the existing diesel system [7]. This problem could be solved by adopting hybrid energy systems, which aim to maximize efficiency by leveraging the strengths of different energy sources. The adoption of hybrid systems aligns with stringent emission regulations in the maritime sector, promoting sustainability in the fishing industry. Hybridization in the context of fishing vessels refers to the integration of multiple power sources or propulsion systems to enhance efficiency, reduce environmental impact, and provide operational flexibility. Considering various technical characteristics and operational profiles of fishing vessels, and the great influence of weather and environmental factors on the fishing activities

themselves [3], hybrid systems offer flexibility in adapting to different conditions and energy demands by switching between energy sources [8].

Since there are many alternative power options, it is sometimes difficult to choose the optimal solutions. A big challenge is also the diversity of fishing vessels so one solution may be optimal for one vessel but not the other one. This paper presents the software "HENSUS" developed as a tool for quick and simple configuration of hybrid energy systems, user-friendly and approachable to the general public, who may not have specialized expertise in energy systems. The software offers several advantages and addresses key challenges in the maritime industry:

- Customization for vessel-specific requirements – taking into account specific characteristics, working patterns, and power requirements of individual vessels, allowing for the customization of hybrid systems to meet their unique needs.
- Optimization for efficiency – by performing complex calculations and simulations to optimize the hybrid system configuration for maximum energy efficiency.
- Cost savings – by efficiently balancing power sources and incorporating renewable energy options, the software can help identify cost-effective hybrid configurations.
- Environmental sustainability - software can recommend configurations that incorporate energy sources whose implementation reduces emissions, contributing to environmental sustainability and compliance with increasingly stringent emission regulations.

This accessibility can promote the adoption of environmentally friendly technologies in the maritime industry. The software can aid in ensuring compliance with international and regional regulations related to emissions and environmental standards. It can assist fishing vessels in meeting international standards by recommending designs that are compliant with regulations.

SOFTWARE "HENSUS"

The software is developed using a combination of Python and C++, leveraging the strengths of both languages. Python is utilized for developing the Graphical User Interface (GUI) for visualizing calculations and facilitating user input. Meanwhile, C++ is used for the data extraction process from the GUI (Phyton). The entered user data was extracted and passed to the C++ program. Linear optimization and complex calculations were performed using C++. The results of these calculations were then transferred back to Python, where the graphical representation, including graphs, was generated. The Python script was used for sketching the graphs and organizing them into different folders based on the calculated results. The example of the programming code and several equations used in the software are presented in Figure 1. The core of the software incorporates advanced optimization algorithms to determine the optimal hybrid configuration. These algorithms consider a range of factors, including power source mix, storage capacities, lifecycle costs, tailpipe emissions and operational modes, aiming to minimize costs and reduce environmental impact.



Figure 1. Example of programming code

The user interface of the "HENSUS" software is presented in Figure 2. The target group of users are currently fishers of the Croatian fishing fleet, so the entire application is in Croatian. The application can easily be converted into bilingual if there is a demand for it. The interface shows general information about the project - project manager, source of funding and a brief description of activities and goals.

Data entry starts with the user's e-mail address (i.e. contact) and is then directed to the basic information about the ship. In order to make the data easier to archive and later use, the name and registration number of the ship were requested. An important piece of information is the type of ship itself, for example, a purse seiner or a trawler, in order to analyse the obtained data with greater accuracy. Regarding the technical characteristics, the most important information is the power of the main engine and the total power of the auxiliary engines. Data such as overall length, breadth, gross tonnage and similar can be extracted from the ship register according to its name and registration. Data on technical characteristics are crucial for calculating exhaust emissions and determining investment costs and maintenance costs. After specifying all the necessary technical data, the user is directed to input the operating characteristics.

The first operating data that is requested is the average fuel consumption in litres per day. Currently in Croatia, the Ministry of Agriculture can obtain data on the total annual fuel consumption of fishing vessels. However, to choose the optimal hybrid energy system, such information is deficient because it does not provide detailed information about the work profile - the number of working hours, how the number of hours varies depending on the season, the time of day when fishing takes place, etc. [3]. Currently, there is no database for the entire Croatian fleet that monitors fuel consumption in real-time, but the fishers themselves are quite experienced and can estimate daily fuel consumption. In addition to the fuel consumption itself, fishers monitor the operation of the main and auxiliary engines and can estimate the approximate percentage of operation of each engine depending on the type of fishing activity taking place. Entering this type of data will provide enough information to create an operational profile of the ship. Given that the software calculates lifecycle costs (investment, fuel and maintenance costs) in addition to the amount of exhaust gases, the fishers have to choose a certain carbon tax

scenario. In carbon tax scenarios, a pricing mechanism is implemented with the aim of placing a cost on carbon emissions, hence incentivizing businesses and people to reduce their GHG emissions. The amount of permitted emissions will decrease over the years, while the price of carbon credit will increase until zero-emission is reached (carbon credit with the highest cost) [7].

After entering all the requested data, the user confirms the entry and starts the calculation of the optimal hybrid energy system.

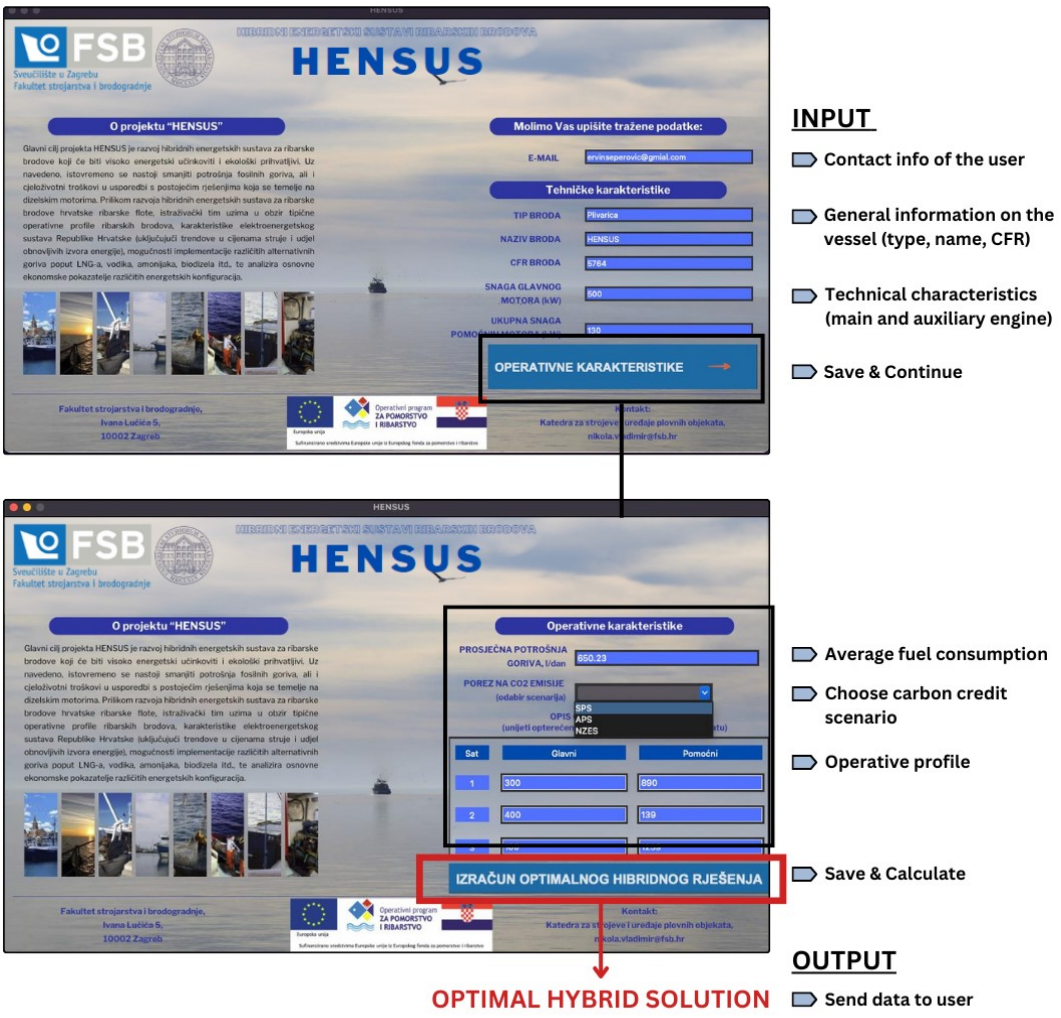


Figure 2. User interface and user guidelines

RESULTS & VALIDATION

The integrated software system, combining a Python GUI for user interaction and C++ for data processing and linear optimization, yields a range of valuable results, for all types of fuels being investigated. An example of the received results is presented in Figure 3.

The software is designed to be adaptable to changing conditions, incorporating real-time data such as vessel operational parameters. This adaptability enhances the software's utility in dynamic maritime environments, allowing vessel operators to make informed decisions based on current conditions. Using the entered data, the software produces results, which are displayed graphically, about a potential hybrid solution for that specific ship. Depending on the operational profile and the total time of operation, the required energy demand of the ship at a given moment and the share of fuels (e.g. diesel, methanol) that are used are estimated. In addition, the software calculates and graphically displays costs by category for each fuel used. The carbon tax is also calculated based on the emissions produced during the use of fossil fuels.

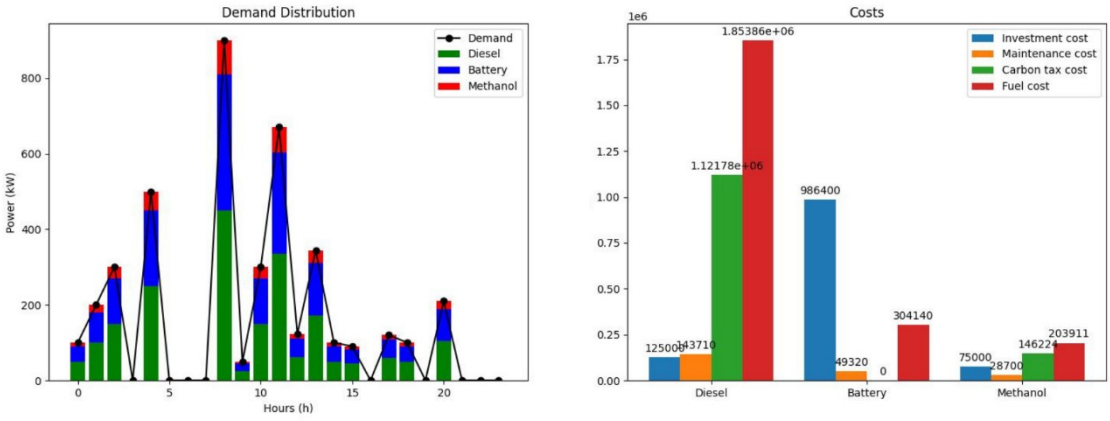


Figure 3. Representation of the results received from the software "HENSUS"

To ensure the accuracy and reliability of the software's output, a validation process is undertaken by scientists specializing in maritime energy systems at the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb. The validation involves comparing the software-generated configurations with empirical data, ensuring that the tool consistently provides viable and efficient hybrid solutions.

CONCLUSION

The development of the "HENSUS" software represents a significant contribution to the ongoing efforts in the maritime industry towards sustainability and decarbonization. The paradigm shift towards minimizing environmental impact and maximizing energy efficiency is evident, particularly in the adoption of hybrid energy systems by fishing vessels. Despite the complexities associated with determining the optimal hybrid energy configuration tailored to specific vessel types, technical specifications, and operational requirements, "HENSUS" addresses this challenge through its user-friendly application. Due to both Python and C++ being integrated, performance and usability are balanced, making the program a useful and dependable tool for ship operators looking to improve environmental sustainability and energy efficiency. By considering vessel types, technical characteristics, and operative factors, it provides a comprehensive database of energy sources, from conventional marine fuels to alternative ones like LNG, biodiesel,

hydrogen, and full electrification. The adaptability of the software to changing operative profiles and its validation process by experts further enhance its reliability. The results received from "HENSUS" are graphically represented, providing users with insights into potential hybrid solutions, energy demand, costs, and the impact of carbon tax. The software application makes a significant step forward towards better cooperation between fishers and scientists by giving fishers an easy-to-use, effective, and scientifically verified method for assessing optimum hybrid energy systems while eliminating challenges such as the large number of fuels that need to be studied.

In the context of broader global initiatives, such as the Paris Agreement and the Glasgow Climate Pact, the "HENSUS" software aligns with the goals of reducing anthropogenic GHG emissions in the maritime sector. The software is a useful tool that promotes good environmental practices in the marine industry and complies with international requirements while also making an easier transition to cleaner energy solutions.

ACKNOWLEDGEMENTS

This investigation has been co-funded by the European Maritime and Fisheries Fund of the European Union within the project “Hybrid Energy Systems for Fishing Vessels – HENSUS,” granted by the Ministry of Agriculture, Directorate of Fisheries, Republic of Croatia (Award No. 324-01/21-01/2273).

REFERENCES

[1] UNFCCC, Paris Agreement, 2016, https://unfccc.int/process-and-meetings/the-paris-agreement (accessed December 1, 2023).

[2] UNFCCC, Glasgow Climate Pact, 2021, https://unfccc.int/process-and-meetings/the-paris-agreement/the-glasgow-climate-pact-key-outcomes-from-cop26 (accessed December 1, 2023).

[3] Koričan M., Vladimir N., Fan A., Investigation of the energy efficiency of fishing vessels: Case study of the fishing fleet in the Adriatic Sea, Ocean Engineering 2023;286:115734, https://doi.org/10.1016/j.oceaneng.2023.115734.

[4] European Commission, Reducing emissions from the shipping sector, 2023, https://climate.ec.europa.eu/eu-action/transport/reducing-emissions-shipping-sector_en (accessed December 1, 2023).

[5] Joung T.H., Kang S.G., Lee J.K., Ahn J., The IMO initial strategy for reducing Greenhouse Gas (GHG) emissions and its follow-up actions towards 2050, Journal of International Maritime Safety, Environmental Affairs, and Shipping 2020;4:1–7, https://doi.org/10.1080/25725084.2019.1707938.

[6] International Maritime Organization, Fourth IMO GHG Study 2020, Full Report, 2020.

[7] Perčić M., Vladimir N., Fan A., Techno-economic assessment of alternative marine fuels for inland shipping in Croatia, Renewable and Sustainable Energy Reviews, 2021;148, https://doi.org/10.1016/j.rser.2021.111363.

[8] Koričan M., Vladimir N., Haramina T., Vučković K., Alujević N., Applicability of hybrid power systems for fishing vessels, 2023 IEEE International Conference on Environment and Electrical Engineering and 2023 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe), IEEE, 2023, p. 1–6. https://doi.org/10.1109/EEEIC/ICPSEurope57605.2023.10194653.

INFLUENCE OF COATED UREA APPLICATION ON SOIL ORGANIC CARBON SEQUESTRATION

PhD. Nicoleta Vicar
Assoc. Prof. Dr. Adina Berbecea
Assoc. Prof. Dr. Alina Lato
PhD. Liliana Brei
Prof. Dr. Isidora Radulov
University of Life Sciences "King Mihai I" from Timisoara, **Romania**

ABSTRACT

The application of nitrogen fertilizers in the form of urea tends to increase acidity, especially on low pH soils, and as a result can lead to increased aluminum toxicity, which can adversely affect not only soil properties such as microbial activity, but also productivity. Application of different types of urea with inhibitors to reduce nitrogen losses would result in a different carbon response to fertilizers applications for the same soil type because of differences in soil micro-environment, including microbial biomass and activity.

The aim of the study was to determine the influence of applying different forms of urea on the content of total nitrogen, organic carbon, phosphorus and assimilable potassium.

The experiment was set up in the Western Plain of Banat, on soil with weak acid pH and medium nitrogen supply. The research was carried out on autumn oilseed rape crops, in the following fertilization variants and application rates: UREE 46% total N; UREE Z 45.7% N total with nitrification inhibitor up to 80%; UREE ZL 45.7% N total with urease inhibitor up to 50%; UREE NDP 45.7% N total with urease inhibitor up to 50% and nitrification inhibitor up to 80%; UREE DMPP 45.7% N total with volatilization reduction up to 95%. For these crops, 300 kg/ha 16:16:16 complex fertilizer and 120 kg/ha UREE were applied, from the described above varieties.

There were no significant differences in soil pH and total nitrogen, available potassium increased significantly, and available phosphorus decreased slightly in all treatments. Application of stabilized and coated urea fertilizers resulted in a moderate improvement in soil SOC.

Keywords: urea with inhibitors, total nitrogen, organic carbon, phosphorus and assimilable potassium.

INTRODUCTION

Soils are the largest carbon reservoirs within terrestrial ecosystems and quantifying soil carbon dioxide flux, as an important component in carbon dynamics, is a priority objective in mitigating climate change. The reduced level of carbon in the soil, which generates losses in the quality and productivity of agricultural land, is already a critical global situation [1]. Farmers everywhere must rise to the challenge of managing the complex relationship between conventional farm practices and halting soil degradation.

The quality of a soil is ensured by the reserve of organic carbon it holds. The world's soil is estimated to contain 3000 Gt of carbon, which is three times the estimated amount of atmospheric C [2]. Thus, even small changes in the soil carbon pool can seriously affect the concentration of CO_2 in the atmosphere, having a high impact on air temperature.

A high level of organic carbon reduces the risk of soil erosion and ensures more stable and larger harvests, especially in the context of droughts. The organic carbon in the soil thus becomes the basis for a resilient and sustainable agriculture. By increasing the amount of carbon stored in the soil, we can considerably reduce the level of CO_2 in the atmosphere, improving the health of the soil at the same time [3]. Due to the impact that the decomposition of soil organic materials has on element cycling in the ecosystem and the uncertainties regarding responses to global change, an increased understanding of the interactions between carbon and nitrogen during decomposition is desirable. [4]

Nitrogen is an essential element for plant growth. A persistent nitrogen deficiency can lead to soil degradation and erosion. When applied in excess, nitrogen can cause surface and groundwater pollution as well as eutrophication.

Due to the stoichiometric relationship between nitrogen and carbon in soil organic matter (SOM) which has the role of maintaining the functional stability of terrestrial ecosystems [5], excessive or reduced N fertilization will have an impact over time on carbon content and quality total organic and vice versa. Numerous studies have shown that nitrogen fertilization can increase, decrease, or have no effect on decomposition rate [6]. Synthetic nitrogen fertilizer can have a direct positive effect on SOM mineralization by altering microbial activity and biomass. The theory of stoichiometric decomposition shows that, although nitrogen is a limiting resource, fertilization with nitrogen mineral fertilizers will increase biomass and microbial activity, thus intensifying the mineralization of soil organic materials [7]. Although many studies have shown that the impact of N fertilization influences soil microbial populations, respiration and enzymatic activities [8], there is insufficient information available on the impact of N fertilization on soil C labile pools.

Because urea has been widely used in agricultural land as a source of nitrogen fertilization, the aim of the article is to present how the application of different forms of urea, with urease, nitrification or volatilization inhibitors, will influence the content of organic carbon and the CN ratio in the soil.

MATERIAL AND METHODS

The experimental study was carried out in the Western Plain of Banat, in an experimental field located on a cambic chernozem soil, with the following characteristics: an upper horizon humus content varying between 3 and 5%, at depths of about 50 cm this decreases to 1.5-2% and at depths greater than 70 cm the humus value is below 1.0%. The pH-value varies between 6.15 and 7.15, the degree of saturation in bases 87-100% and the bulk density can have values between 1.29-1.47 g/cm^3. The C:N ratio varies between 11 and 12 and the total nitrogen content is between 0.12 and 0.17%. The water and aeration properties are good and the high organic matter content results in a good supply of crop nutrients during the growing season.

Soil samples were collected at a depth of 0 - 20 cm, the field crops for this experiment was autumn wheat. Basic fertilization was done with 300 kg/ha complex mineral fertilizer 16:16:16. Urea was applied in the amount of 120 kg/ha, in the following variants:

- Urea (46% N)
- Urea Z (45.7% N with nitrification inhibitor up to 80%)
- Urea ZL (45.7% N with urease inhibitor up to 50%)
- Urea NDP (45.7% N with urease inhibitor up to 50% and nitrification inhibitor up to 80%)
- Urea DMPP (45.7% N with volatilization reduction up to 95%)

Organic matter was determined by the calcination method at 600˚C. The determination of soil organic carbon is based on the Walkley-Black chromic acid wet oxidation method and determination of total soil nitrogen was done by the Kjeldahl method according to European standard ISO 11261:1995.

RESULTS AND DISCUSSIONS

Nitrogen fertilization studies have shown that nitrogen addition can increase, decrease, or have no effect on decomposition rate (OM). A low or unchanged decomposition rate, together with an increased production of plant biomass, can decrease atmospheric CO_2 concentration.

Decomposition of carbon from organic residues is controlled by many factors soil environmental conditions (temperature, moisture, aeration, soil pH, nutrient availability, etc.), substrate quality (chemical composition) and quantity, soil residue pretreatment, application methods and their potential interactions. However, an integrated assessment of the effects of nitrogen fertilization on the processes that influence soil C balance is lacking.

The carbon-to-nitrogen ratio of soil organic matter means the amount of carbon relative to the amount of nitrogen present. There is always more carbon than nitrogen in organic matter. When there is a C:N ratio between 1 and 15 in the soil, there is rapid mineralization and release of N, which becomes available for plant uptake. The lower the C:N ratio, the faster nitrogen will be released into the soil for immediate crop use. A C:N ratio > 35 results in nitrogen immobilization. A ratio of 20-30 leads to a state of equilibrium between mineralization and immobilization. [9].

Numerous researches show that mineral fertilization determines the modification of the organic matter (OM) decomposition rate. A low or unchanged rate of decomposition, together with an increased production of plant biomass, may cause atmospheric CO_2 to fall.

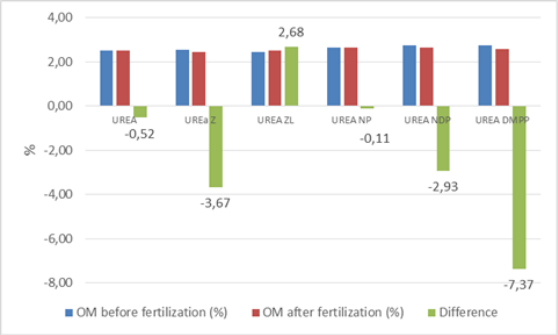


Fig. 1. Soil organic matter modification after different type of urea application



Fig. 2. Soil total nitrogen modification after different type of urea application

Table 1

Variant		Organic matter (OM %)	Organic carbon (OC%)	Total Nitrogen (TN%)	C/N
Before application	UREA	2.52	1.46	0.17	8.58
	UREA Z	2.55	1.48	0.12	12.34
	UREA ZL	2.45	1.42	0.13	10.92

	UREA NP	2.66	1.54	0.18	8.57
	UREA NDP	2.74	1.59	0.14	11.34
	UREA DMPP	2.76	1.60	0.16	9.99
After application	UREA	2.50	1.45	0.19	7.64
	UREA Z	2.46	1.43	0.14	10.20
	UREA ZL	2.52	1.46	0.16	9.11
	UREA NP	2.66	1.54	0.21	7.00
	UREA NDP	2.66	1.54	0.17	9.05
	UREA DMPP	2.57	1.49	0.18	8.27

From table 1 it can be seen that before the application of urea with nitrification or/and ammonification inhibitors, the organic matter content of the soil was between 2.45 and 2.76, the organic carbon between 1.42 and 1.60%, the total nitrogen between 0.12 - 0.17, and the ratio C:N had values between 8.57 and 12.34. There are studies that show that the application of synthetic nitrogen fertilizers can increase the content of organic matter in the soil [3], but also reduce it because it accelerates the mineralization of organic matter [4].

After the application of different types of urea, a decrease in the content of organic matter and organic carbon is observed in all experimental variants by 0.5 to 7.4%, except for the variant fertilized with urea with urease inhibitor. Urease has a role in the decomposition of urea and the transformation of nitrogen into ammonium ion that can be consumed directly by plants, but the presence of urease inhibitors reduced its activity. Koçak [10] shows that urease activities in soils had an important relationship with soil properties like organic matter, texture, pH, cation exchange capacity.

Decomposition of carbon from organic residues is controlled by many factors, such as soil environmental conditions (temperature, moisture, aeration, soil pH, nutrient availability, etc.), substrate quality and quantity (chemical composition), soil residue pretreatment, their application methods and potential interactions. However, there is no integrated assessment of the effects of nitrogen fertilization on the processes influencing the soil C balance [11]. The greatest reduction in organic matter content, with respect to organic carbon, was determined when applying urea with reduced volatilization. The reduction of volatilization by 90% allowed almost the entire amount of nitrogen applied in the form of urea and transformed into ammonium ion to remain in the soil, having a positive effect on the enzyme activity and intensifying the mineralization process of organic matter. Khalafalla and Hamed (2015)[12] show that the addition of urea fertilizer significantly stimulated soil organic carbon decomposition.

The total nitrogen content after the application of different types of urea increases in all experimental variants. When high amounts of urea are applied, an intensification of the hydrolysis process and higher ammonium ion concentrations in the soil are observed. The rapid hydrolysis of urea when applied to the soil surface reduces the time available for urea and ammonium ion to diffuse into the soil. When the diffusion time in the soil is reduced, the ammonium ion will be concentrated in a large amount at the soil surface, and its pH will increase. Factors that affect the intensity of hydrolysis, and which depend on the type of soil and climatic factors, are the type and amount of nitrogen fertilizer applied, the amount of urea enzyme in the soil, soil temperature and soil moisture.

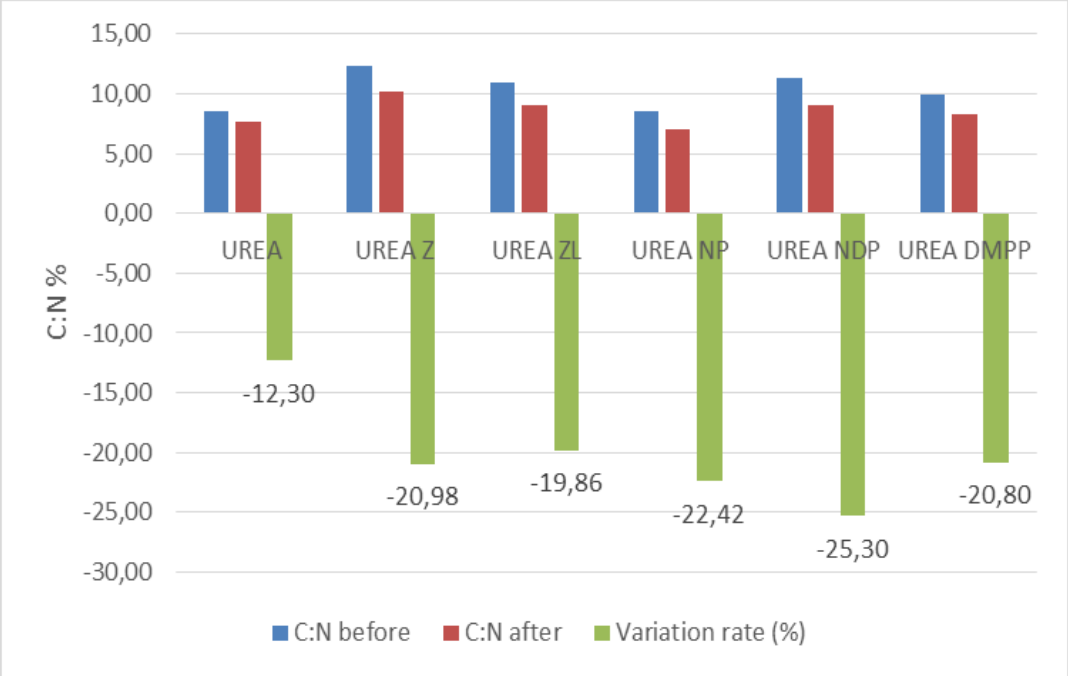


Fig.3. C:N rate modification after different type of urea application

Figure 3 shows a reduction of the C:N ratio following the application of different types of urea. The most significant reduction in the C:N ratio occurs when fertilizing with urea containing both nitrification and urease inhibitors (-25.30%). Bowden et all (2004) [13] show that although nitrogen fertilization increases crop yield and biomass production and thus increases total organic carbon content, numerous studies have reported a decrease in total organic carbon content by accelerating the mineralization of soil organic matter. O'Brien et all (2015)[14] consider that unilateral mineral fertilization, especially in light soils, causes the intensification of mineralization. Changing management practices can cause a relatively small increase or decrease in soil carbon content resulting in significant net exchange of C between the soil C pool and the atmosphere.

CONCLUSION

The introduction of inhibitors in the manufacture of urea determines the reduction of losses by volatilization of the ammonium ion or by leaching of the nitrate ion.

The application of urea with nitrification inhibitors and volatilization intensifies the mineralization rate of organic matter and organic carbon content.

The reduction of the value of the C:N ratio, determines an intensification of the process of mineralization of organic matter, and implicitly an increase of the total nitrogen content in the soil.

ACKNOWLEDGEMENTS

This research paper is supported by the project Consolidation of the research - innovation ecosystem within USVT code CNFIS-FDI_2023-F-0343

REFERENCES

[1.] Powlson, D. S., Whitmore, A. P. & Goulding, K. W. T. Soil carbon sequestration to mitigate climate change: A critical re-examination to identify the true and the false. Eur. J. Soil Sci. 62, 42–55 (2011).

[2.] Moinet, G. Y. K., Hijbeek, R., van Vuuren, D. P., & Giller, K. E. (2023). Carbon for soils, not soils for carbon. Global Change Biology, 29, 2384–2398. h t t p s : //d o i .org/10.1111/gcb.16570

[3.] Button, E. S. et al. Deep-C storage: Biological, chemical and physical strategies to enhance carbon stocks in agricultural subsoils. Soil Biol. Biochem. 170, 108697 (2022).

[4.] Begum R, Jahangir MMR, Jahiruddin M, Islam MR, Rahman MT, Rahman ML, Ali MY, Hossain MB, Islam KR. Nitrogen fertilization impact on soil carbon pools and their stratification and lability in subtropical wheat-mungbean-rice agroecosystems. PLoS One. 2021 Oct 1;16(10):e0256397. doi: 10.1371/journal.pone.0256397. PMID: 34597320; PMCID: PMC8486117.

[5.] Hessen DO, Ågren GI, Anderson TR, Elser JJ, De Ruiter PC. Carbon sequestration in ecosystems: the role of stoichiometry. Ecology. 2004; 85:1179–1192.

[6.] Yokamo S, Irfan M, Huan W, Wang B, Wang Y, Ishfaq M, Lu D, Chen X, Cai Q and Wang H (2023) Global evaluation of key factors influencing nitrogen fertilization efficiency in wheat: a recent meta-analysis (2000-2022). *Front. Plant Sci.* 14:1272098. doi: 10.3389/fpls.2023.1272098

[7.] Mahal NK, Osterholz WR, Miguez FE, Poffenbarger HJ, Sawyer JE, Olk DC, Archontoulis SV and Castellano MJ (2019) Nitrogen Fertilizer Suppresses Mineralization of Soil Organic Matter in Maize Agroecosystems. Front. Ecol. Evol. 7:59. doi: 10.3389/fevo.2019.00059

[8.] DeForest JL, Zak DR, Pregitzer KS, Burton AJ. Atmospheric nitrate deposition, microbial community composition, and enzyme activity in northern hardwood forests. Soil Science Society of America Journal. 2004; 68:132–138.

[9.] Song, M. H. et al. Shifts in priming partly explain impacts of long-term nitrogen input in different chemical forms on soil organic carbon storage. Glob. Chang. Biol. 24, 4160–4172 (2018).

[10.] R. Lal, Soil Carbon Sequestration Impacts on Global Climate Change and Food Security.Science304,1623-1627(2004). DOI:10.1126/science.1097396

[11.] Mostafa Y. Khalafalla and Mahdy H. Hamed: Impact of Nitrogen Fertilization on Soil Organic Carbon Decomposition ALEXANDRIA SCIENCE EXCHANGE JOURNAL, VOL.36, No.4 OCTOBR- DECEMBER 2015.

[12.] Poffenbarger, H. J., Sawyer, J. E., Barker, D. W., Olk, D. C., Six, J., and Castellano, M. J. (2018). Legacy effects of long-term nitrogen fertilizer application on the fate of nitrogen fertilizer inputs in continuous maize. *Agricult. Ecosyst. Environ.* 265, 544–555.

[13.] Bowden RD, Davidson E, Savage K, Arabia C, Steudler P. Chronic nitrogen additions reduce total soil respiration and microbial respiration in temperate forest soils at the Harvard Forest. Forest Ecology and Management. 2004; 196:43–56

[14.] O'Brien, S.L.; Jastrow, J.D.; Grimley, D.A.; Gonzalez-Meler, M.A. Edaphic controls on soil organic carbon stocks in restored grasslands. Geoderma 2015

[15.] Brown, K. H., Bach, E. M., Drijber, R. A., Hofmockel, K. S., Jeske, E. S., Sawyer, J. E., et al. (2014). A long-term nitrogen fertilizer gradient has little effect on soil organic matter in a high-intensity maize production system. *Glob. Chang. Biol.* 20, 1339–1350. doi: 10.1111/gcb.12519

INTERACTION BETWEEN METHANE AND CARBON DIOXIDE EMISSIONS USING METHANE-REDUCING BIOCOVER

Bc.sc.ing. Kristaps Siltumens[1,2,3]

Assoc. Prof. Inga Grinfelde[1,2]

Dr. Juris Burlakovs[3,4]

Mg.sc.ing. Sindija Liepa[1]

Mg.sc.ing. Jovita Pilecka-Ulcugaceva[1,2]

[1] Latvia University of Life Sciences and Technologies, Faculty of Forest and Environmental Sciences, **Latvia**
[2] Latvia University of Life Science and Technologies, Scientific Laboratory of Forest and Water Resources, **Latvia**
[3] University of Latvia, **Latvia**
[4] The Mineral and Energy Economy Research Institute of the Polish Academy of Sciences, Kraków, **Poland**

ABSTRACT

Decomposition of solid waste in landfills causes global air pollution with methane, the most dangerous of the greenhouse gases. The emission potential of this gas is 28-36 times greater than that of CO_2. With the help of methane-reducing Biocover, can find a solution to this problem. In this study, a biocover was developed in the laboratory to reduce methane emissions. When measuring the methane emissions of this biocover, data on the amount of carbon dioxide emissions were also obtained in parallel. The purpose of this study is to clarify the interaction between methane emission reduction and carbon dioxide emission flux. The laboratory experiment consisted of three parts. The first part was the creation of experimental tubes. Three experimental columns with a diameter of 160 mm and a height of 1500 mm were created. Active compost saturated with water at a thickness of 500 mm was used as a source of methane, a permeable layer of sand at a thickness of 300 mm was further formed and finally covered with biocover. Biocover represents 60% of fine-fraction waste, 20% of soil and 20% of compost. The second part was taking measurements. All measurements were performed with the Cavity Ring-Down Spectroscopy (CRDS) gas measurement device Picarro G2508. The third part was the analysis of the obtained data. The obtained data were analyzed by processing the data and obtaining the interaction between these gases. The experiment is planned to be continued by obtaining long-term emission data. This will help to develop more promising future approaches to reduce methane emissions from landfills. This research contributes to the understanding of sustainable environmental management practices and underscores the importance of a holistic approach to address multiple greenhouse gases simultaneously.

Keywords: Air pollution; biodegradation; greenhouse gas mitigation measures; emissions interaction

INTRODUCTION

Landfills are critical components of municipal waste management systems worldwide, serving as repositories for solid waste generated by human activities. However, they are also significant sources of greenhouse gas emissions, primarily methane (CH_4) and carbon dioxide (CO_2)[1]. Methane is a potent GHG with a significantly higher global warming potential than CO_2 over a short time frame, making its management a priority [2]. Carbon dioxide, on the other hand, is a major contributor to the enhanced greenhouse effect and long-term climate change [3]. The coexistence of these two gases in landfill environments leads to complex interactions that impact overall emissions and the environmental footprint of landfills. Understanding these interactions is crucial for developing effective mitigation strategies.

In the process of organic waste decomposition in anaerobic conditions, gases are formed, primarily containing methane and carbon dioxide. The distribution of these gases is approximately 60% methane gas and approximately 40% carbon dioxide [4]. Methane gas has a global warming potential 28 times greater than carbon dioxide over a 100-year period [5].

One approach to mitigate CH_4 emissions from landfills while considering their CO_2 emissions is the implementation of methane-reducing biocovers. Methane-reducing biocovers are engineered systems that utilize microbial communities to promote CH_4 oxidation and reduce emissions. These systems have shown promise in mitigating CH_4 emissions and have the potential to influence CO_2 emissions as well [6]. However, the dynamics of CH_4-CO_2 interactions within these biocovers are complex and multifaceted, necessitating a comprehensive examination of their mechanisms and impacts [7].

The aim of this study is to clarify interaction between methane and carbon dioxide emissions using methane-reducing biocover.

MATERIALS AND METHODS

This research was carried out in a controlled laboratory environment, involving the creation of cylindrical tubes with a diameter of 160 mm and a height of 1500 mm. Inside these tube columns, a layer of water-saturated compost and fine fraction waste was carefully placed at the base, creating a layer with a thickness of 500 mm, which served as the methane source. To distinguish this compost layer from the biocover above it, a 300 mm layer of sand was added on top. Finally, a 400 mm thick biocover was applied to the uppermost section of the tube (see Figure 1). The composition of the biocover was analysed using the CRDS gas measurement device Picarro G2508 (Picarro Inc., USA California). Methane emissions were measured both with and without the biocover system to assess the interaction between methane and carbon dioxide emissions. Each measurement had a duration of 250 seconds [8].

The biocover material was a mixture of fine fraction waste, soil, and compost, prepared in the following proportions: 20% soil (heavy clay), 20% compost, and 60% fine waste fraction. A visual representation of the biocover composition is presented in Figure 2 [9]

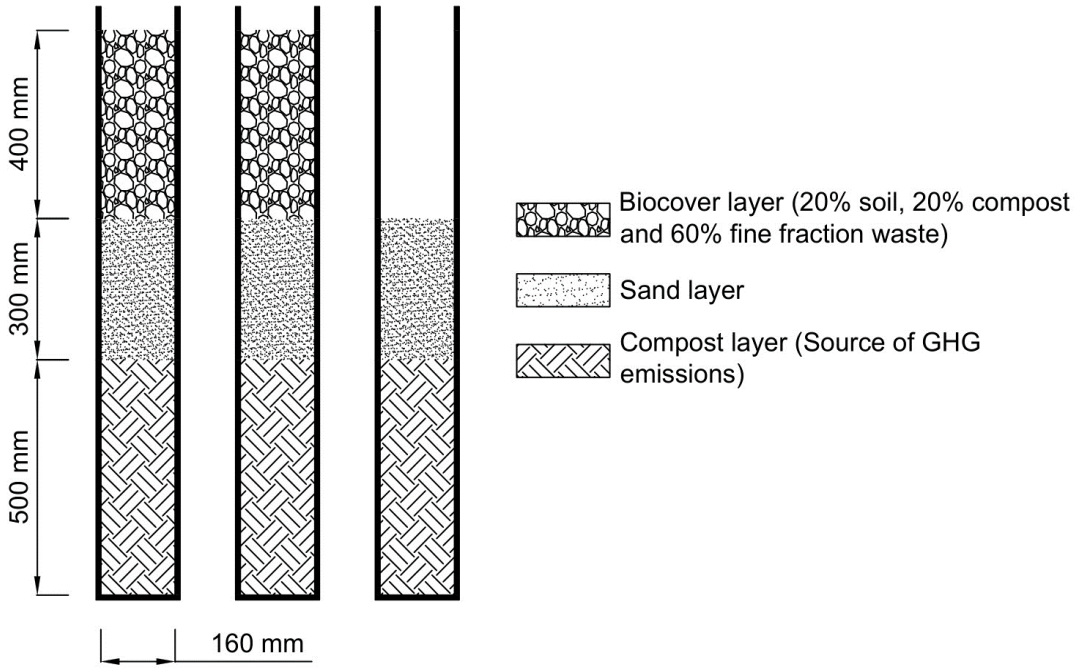


Fig. 1. Schematic representation of experimental tubes



Fig. 2. Coposition of the biocover (20% soil (heavy clay), 20% compost and 60% fine fraction waste).

The experiment was initiated on June 6, 2022, once all the required raw materials had arrived. Initial measurements were conducted two weeks after the setup's installation. This brief waiting period was implemented to allow the biocover to settle and stabilize. Following this settling period, measurements were subsequently carried out on a weekly basis over a span of 16 months, resulting in a total of 123 measurements (see Table 1). In order to maintain a field-relevant level of moisture and prevent drying, 250 ml of water were applied to the constructed columns every week.

Table 1

Split data groups

Group	Measurement time (Five month period)	Experimental Tube	Sample code in data analysis
1	June - November	control	1_1
1	June - November	biocover	1_2
1	June - November	biocover	1_3
2	November – April	control	2_1
2	November – April	biocover	2_2
2	November – April	biocover	2_3
3	April – September	control	3_1
3	April – September	biocover	3_2
3	April – September	biocover	3_3

Before the commencement of the measurement procedures, a suitable lid for the experimental tubes was chosen. This lid featured two ports, one for air intake and another for air discharge, as presented in Figure 3. At the beginning of each measurement, the lid was securely placed on the designated tube, and air was pumped through the air outlet pipe to the CRDS gas measurement device, Picarro G2508 (Picarro Inc., USA, California). The airflow rate within the tube was consistently maintained at 5 ml/s^{-1}. To ensure a closed and controlled measurement environment and prevent the infiltration of ambient air into the measurement equipment, a seal was applied to the pipe cover.



Fig. 3. Test tube column cover, during gas measurements.

RESULTS

The analysis of the data was started by dividing the data into three parts: the start, middle and end of the experiment (see Table 1). This was in line with the difference in emissions from the use of compost as a source of emissions in each of these parts. An analysis of the descriptive statistics was carried out below (see tables 2 and 3).

Table 2

Descriptive statistics data by time groups and bocover type (CH_4 nmol m^{-2} s^{-1})

Sample | Group	Minimum	Maximum	Range	Q1	Median	Q3	Mean
CH_4 nmol m^{-2} s^{-1} | 1_1	3.80	560.00	556.20	30.25	62.85	189.48	156.31
CH_4 nmol m^{-2} s^{-1} | 1_2	3.40	997.00	993.60	5.57	65.55	119.45	201.08
CH_4 nmol m^{-2} s^{-1} | 1_3	6.00	604.00	598.00	26.35	52.00	129.50	142.59
CH_4 nmol m^{-2} s^{-1} | 2_1	10.10	102.00	91.90	13.00	18.00	35.30	33.19
CH_4 nmol m^{-2} s^{-1} | 2_2	4.59	63.00	58.41	8.70	10.10	12.30	14.13
CH_4 nmol m^{-2} s^{-1} | 2_3	0.57	28.90	28.33	4.50	6.10	9.30	8.27
CH_4 nmol m^{-2} s^{-1} | 3_1	4.30	16.30	12.00	6.76	8.60	10.56	9.03
CH_4 nmol m^{-2} s^{-1} | 3_2	0.16	10.60	10.44	2.30	2.70	5.55	3.83
CH_4 nmol m^{-2} s^{-1}| 3_3	-159.00	5.90	164.90	-0.63	2.48	3.68	-15.17

Table 3

Descriptive statistics data by time groups and bocover type (CO_2, µmol m^{-2} s^{-1})

Sample | Group	Minimum	Maximum	Range	Q1	Median	Q3	Mean
CO_2, µmol m^{-2} s^{-1}| 1_1	1.31	63.80	62.49	6.66	18.25	33.60	23.65
CO_2, µmol m^{-2} s^{-1}| 1_2	3.57	59.00	55.43	5.44	11.57	33.50	20.26
CO_2, µmol m^{-2} s^{-1}| 1_3	6.10	118.00	111.90	8.25	11.75	39.75	28.82
CO_2, µmol m^{-2} s^{-1}| 2_1	2.44	7.62	5.18	3.99	4.22	4.67	4.41
CO_2, µmol m^{-2} s^{-1}| 2_2	2.42	9.60	7.18	3.15	3.34	4.22	4.14
CO_2, µmol m^{-2} s^{-1}| 2_3	1.15	7.84	6.69	2.23	2.90	4.84	3.69
CO_2, µmol m^{-2} s^{-1}| 3_1	0.80	6.50	5.70	1.67	2.11	2.64	2.41
CO_2, µmol m^{-2} s^{-1}| 3_2	-0.30	3.89	4.19	1.78	1.98	2.52	2.08
CO_2, µmol m^{-2} s^{-1}| 3_3	1.45	3.95	2.50	2.63	3.02	3.48	2.95

To perform data analysis to understand the interaction between CH_4 and CO_2 emissions, was started by calculating the correlation coefficient between these two variables. The correlation coefficient will help us quantify the strength and direction of the relationship between the two gases. It was calculated using Pearson's correlation coefficient for this purpose. Pearson's correlation ranges from -1 to 1, where:

- A positive value close to 1 indicates a strong positive correlation (as one variable increases, the other also increases);

- A negative value close to -1 indicates a strong negative correlation (as one variable increases, the other decreases);
- A value close to 0 indicates little to no linear correlation [10].

Correlation between CH_4 and CO_2 emissions: Pearson's Correlation Coefficient = 0.134. Based on the calculated correlation coefficient, there is a very weak positive correlation between CH_4 and CO_2 emissions. This suggests that there is a minimal linear relationship between the two gases [11].

In the subsequent data analysis, median values were used to show the average value in the data set. The median is a measure of the central trend that represents the mean value when a dataset is ordered from smallest to largest. This is a value that divides data into two equal sides, with half of the data points falling below and half above it. By establishing a graph for the median interaction between CO_2 and CH_4, a correlation was found between these values (see Figure 4).

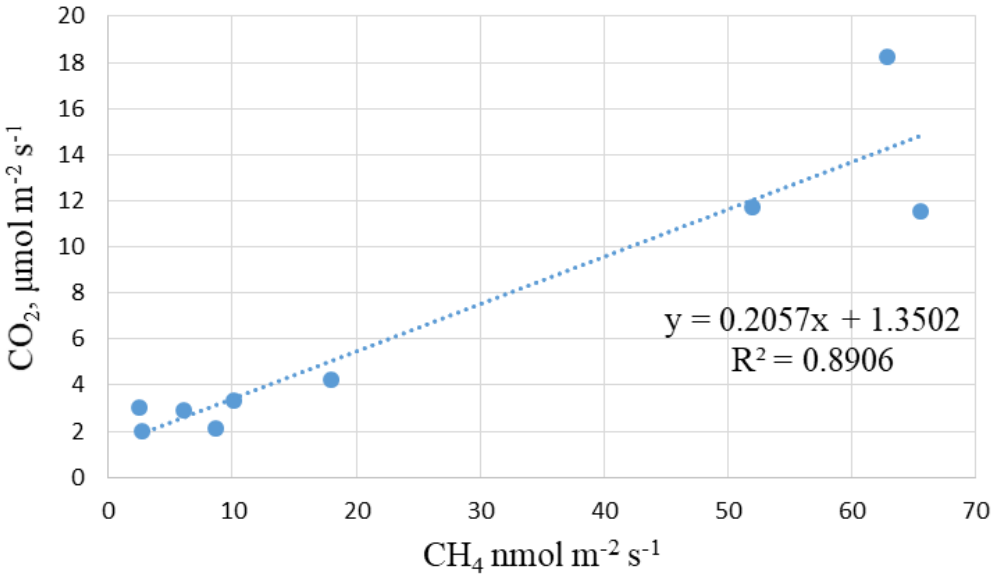


Fig. 4. Graph of CO_2 (µmol m^{-2} s^{-1}) and CH_4 (nmol m^{-2} s^{-1}) emission medians

DISCUSSION

The interaction of methane and carbon dioxide in the biological cover of a landfill is a complex process that involves various factors such as gas concentration, methane oxidation, and gas emissions. Several studies have investigated this interaction using numerical models and field studies to understand the behavior of methane and carbon dioxide in landfills.

Jun Ma research group developed a numerical model to simulate changes in methane, oxygen, and carbon dioxide concentrations during air injection and extraction in landfills [12]. Their study provides insights into the dynamics of gas concentration and the role of air injection and extraction in influencing methane and carbon dioxide levels. Huber-Humer with his research group discussed the measurement of stable isotopes as a precise method for determining methane oxidation in landfill covers [13]. This approach

offers a promising method for assessing methane oxidation and its impact on carbon dioxide levels in landfills. Górka with colleagues highlighted that methane and carbon dioxide are major components of landfill gas, accounting for a significant portion of total gas emissions [14]. Their study emphasizes the dependence of methane and carbon dioxide variations on the composition and age of the waste, as well as landfill operating procedures. Furthermore, Christophersen with researchers emphasized the role of landfill cover soils in providing a suitable environment for methane oxidation, leading to the transformation of methane to carbon dioxide [15]. This highlights the significance of the landfill cover in influencing the interaction between methane and carbon dioxide.

Overall, these studies collectively demonstrate the importance of understanding the numerical results and field observations related to the interaction of methane and carbon dioxide in the biological cover of landfills. They provide valuable insights into the factors influencing gas concentration, methane oxidation, and gas emissions in landfill environments.

CONCLUSION

Laboratory biocover experiments have very high potential because it is possible to check and identify the benefits and disadvantages of this cover. Identify the effectiveness of the biocover of the various materials and their proportions and predict how much the reduction in methane emissions will be. The contribution of this study is that it analyzed the interactions between carbon dioxide and methane. When analyzed, the data initially appeared to have no interaction between them, but after further investigation it was found.

The interaction of the resulting carbon dioxide and methane emissions, in the median values of emissions, shows that carbon dioxide is very important in the methane reduction process. Methane-reducing bacteria in the process transform methane into production and release carbon dioxide into the air. The more methane is reduced, the more carbon dioxide will be released into the air. By comparing the two of these gases, carbon dioxide is a less dangerous gas that doesn't leave as much imprint as methane

The experiment will be continued and studied further. At present, the first results obtained are potentially positive. A number of more promising approaches to methane reduction will also be developed in the future.

ACKNOWLEDGEMENTS

The work was supported by the PASIFIC program GeoReco project funding from the European Union’s Horizon2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 847639 and from the Ministry of Education and Science.

REFERENCES

[1] Zhang C., Xu T., Feng H., Chen S., Greenhouse Gas Emissions from Landfills: A Review and Bibliometric Analysis, Sustainability, vol. 11/issue 8, pp 2282, 2019.

[2] Mønster J., Kjeldsen P., Scheutz C., Methodologies for measuring fugitive methane emissions from landfills – A review, Waste Management, vol. 87, pp 835-859, 2019.

[3] Archer D., Brovkin V., The millennial atmospheric lifetime of anthropogenic CO_2, Climatic Change, vol. 90, pp 283–297, 2008

[4] Aghdam E. F., Scheutz C., Kjeldsen P., Impact of meteorological parameters on extracted landfill gas composition and flow, Waste Management, vol. 87, pp 905-914, 2019.

[5] Skytt T., Nielsen S. N., Bengt-Gunnar J., Global warming potential and absolute global temperature change potential from carbon dioxide and methane fluxes as indicators of regional sustainability – A case study of Jämtland, Sweden, Ecological Indicators, vol. 110, pp 105831, 2020.

[6] Warmadewanthi I.D.A.A., Chrystiadini G., Kurniawan S.B, Abdullah S.R.S., Impact of degraded solid waste utilization as a daily cover for landfill on the formation of methane and leachate, Bioresource Technology Reports, vol. 15, pp 100797, 2021.

[7] Borisova D., Kostadinova G., Petkov G., Dospatliev L., Ivanova M., Dermendzhieva D., Beev G., Assessment of CH_4 and CO_2 Emissions from a Gas Collection System of a Regional Non-Hazardous Waste Landfill, Harmanli, Bulgaria, Using the Interrupted Time Series ARMA Model, Atmosphere, vol. 14/issue 7, pp 1089, 2023.

[8] Grinfelde I., Valujeva K., Zaharane K., Berzin, L., Automated cavity ring down spectroscopy usage for nitrous oxide emission measurements from soil using recirculation system, Engineering for Rural Development, vol. 16, pp 1111–1116, 2017.

[9] Siltumens K., Grinfelde I., Liepa S., Puzule E.P., Burlakovs J. Biocover composition impact on landfill methane emissions reduction, 22nd International Multidisciplinary Scientific GeoConference SGEM 2022, vol. 22/issue 4.2, pp 183-189, 2022.

[10] Siltumens K., Grinfelde I., Liepa S., Burlakovs J., Makejeva S., Reduction of methane emission from landfills with cellulose in biocover, International Multidisciplinary Scientific GeoConference SGEM 2023, vol. 23/issue 4.1, 2022.

[11] Emerson, R.W., Causation and Pearson's Correlation Coefficient, Journal of Visual Impairment & Blindness, vol. 109/issue 3, pp 242-244, 2015.

[12] Jun M., Lei L., Xiao Y., Xunchang F., Xiong Z., Gang Z., Yuzhang B., Simulation of gas concentration during the process of air injection and extraction in a landfill, Environ Prog Sustainable Energy, vol. 39/issue 5, 2020.

[13] Huber-Humer M., Röder S., Lechner P., Approaches to assess biocover performance on landfills, Waste Management, vol. 29/issue 7, pp 2092-2104, 2009.

[14] Górka M., Bezyk Y., Sówka I., Assessment of GHG Interactions in the Vicinity of the Municipal Waste Landfill Site – Case Study, Energies, vol. 14/issue 24, pp 8259, 2021.

[15] Christophersen M., Kjeldsen P., Holst H., Chanton J., Lateral gas transport in soil adjacent to an old landfill: factors governing emissions and methane oxidation, Waste Manag Res, vol.19/issue 6, pp 595-612, 2001.

INTERACTION BETWEEN METHANE AND NITROUS OXIDE EMISSIONS USING METHANE-REDUCING BIOCOVER

Bc.sc.ing. Kristaps Siltumens[1,2,3]

Assoc. Prof. Inga Grinfelde[1,2]

Dr. Juris Burlakovs[3,4]

Mg.sc.ing. Sindija Liepa[1]

Mg.sc.ing. Jovita Pilecka-Ulcugaceva[1,2]

[1] Latvia University of Life Sciences and Technologies, Faculty of Forest and Environmental Sciences, **Latvia**
[2] Latvia University of Life Science and Technologies, Scientific Laboratory of Forest and Water Resources, **Latvia**
[3] University of Latvia, **Latvia**
[4] The Mineral and Energy Economy Research Institute of the Polish Academy of Sciences, Kraków, **Poland**

ABSTRACT

Landfills of municipal waste are important sources of methane emissions. The surface of the landfill area is the interface between the waste layer and the atmosphere. By creating a biocover cover layer, it is possible to reduce methane emissions that would refer to air quality. This innovative biocover technology aims to curtail methane emissions from various sources. The research delves into the effectiveness of this biocover in not only mitigating methane emissions but also its potential influence on nitrous oxide emissions. Through a combination of laboratory experiments, the study unravels the intricate dynamics between methane and nitrous oxide emissions in the context of the methane-reducing biocover.The study created a laboratory biocover experiment. Interaction between methane and nitrous oxide emissions was studied using methane-reducing biocover. The experiment was launched on 6 June 2022. This was done by creating tube columns with a diameter of 160 mm and a height of 1500 mm. The biocover used consisted of 60% of fine-fraction waste, 20% of soil and 20% of compost. Measurements of methane and nitrous oxide emissions were performed with Cavity Ring-Down Spectroscopy gas measurement device Picarro G2508. When performing emission measurements, the flow rate in the tube of the mesurement device was 5 ml/s^{-1}. During the whole experiment, water-saturated compost was used as a source of methane and nitrous oxide. The experimental structure also used sand, which served as a gas-permeable layer and separated biocover from compost (emissions source). The analysis of the data showed a minor interaction between methane emissions and nitrous oxide flow. The results shed light on potential synergies or trade-offs in greenhouse gas reduction strategies, offering valuable insights for optimizing emission reduction efforts while considering the broader environmental implications.

Keywords: Air pollution; biodegradation; greenhouse gas mitigation measures; emissions interaction

INTRODUCTION

Landfills are a critical component of modern waste management systems, but they also present a significant environmental challenge due to the emission of potent greenhouse gases (GHG) such as methane (CH_4) and nitrous oxide (N_2O) [1]. Methane is primarily produced through anaerobic decomposition of organic matter [2], while nitrous oxide results from various microbial processes, including nitrification and denitrification [3]. These emissions contribute substantially to global warming and climate change. Thus, mitigating these emissions from landfills is of utmost importance to address environmental concerns and meet international climate targets [4].

One innovative approach to tackling this issue is the use of methane-reducing biocovers, also known as microbial methane oxidation biocovers. These biocovers consist of microbial communities, often dominated by methane-oxidizing bacteria, which can actively consume methane from landfill gas emissions before it reaches the atmosphere. The application of methane-reducing biocovers has gained increasing attention as a cost-effective and environmentally friendly means to mitigate methane emissions from landfills [4].

While much research has focused on the individual impacts of methane and nitrous oxide emissions in landfill sites, there is a growing recognition of the interconnected nature of these emissions. Recent studies have revealed that the presence of methane-reducing biocovers can influence not only methane but also nitrous oxide emissions [5;6]. The mechanisms underlying this interaction are complex and multifaceted, involving microbial communities, nutrient availability, and environmental conditions [7].

Understanding the intricate relationship between methane and nitrous oxide emissions in the context of methane-reducing biocovers is critical for optimizing landfill gas management strategies. By gaining insights into the simultaneous reduction of methane and nitrous oxide emissions, we can develop more sustainable and efficient landfill gas management practices, ultimately contributing to global efforts to combat climate change and reduce the environmental impact of landfills.

The aim of this study is to clarify interaction between methane and nitrous oxide emissions using methane-reducing biocover.

MATERIALS AND METHODS

This study was conducted in the Scientific Laboratory of Forest and Water Resources of Latvia University of Life Sciences and Technologies, where under controlled conditions three pipe columns were created with diameter of 160 mm and a height of 1500 mm. the first layer of pipe columns was a water-saturated compost mixed with organic waste from a landfill site. The second layer was constructed from sand, which will separate the first layer from the biocover layer. The third layer was biocover layer. The biocover layer was applied to two of the tubes as a third will be left as a control tube to determine emissions without this biocover (see figure 1). In this experiment, a composition was chosen as biocover: 20% soil (heavy clay), 20% compost and 60% fine fraction waste (see figure 2) [8]. The composition was selected based on previous studies where the positive effects of biocover composition on methane emissions are known [8;9].

The source of methane emissions was chosen a water-saturated compost mixed with organic waste from a landfill site because it produces enough methane to conduct an experiment and not pose a hazard to humans.

The scheme of the experimental columns created was as follows: first layer, methane source (500 mm); second layer, gas permeable layer (300 mm); Third layer, methane gas reduction layer or biocover layer (400 mm) (see figure 1).

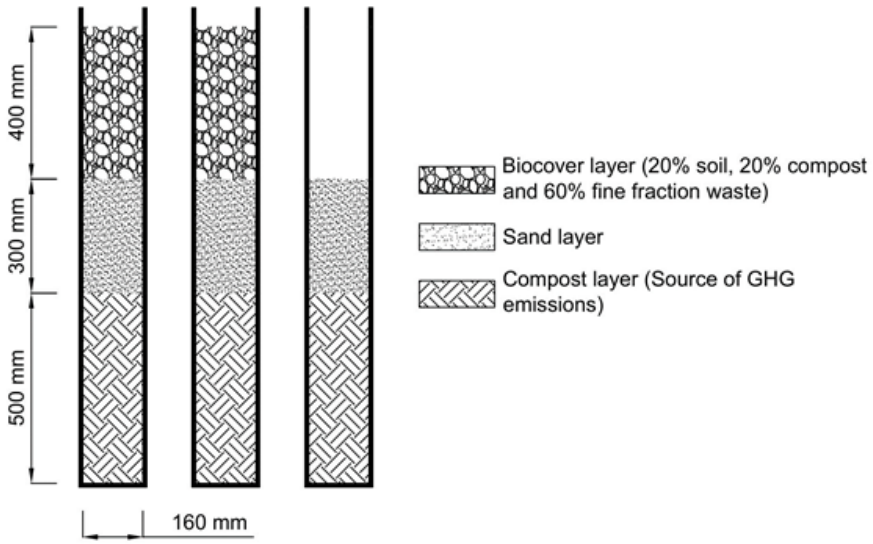


Fig. 1. Schematic representation of experimental tubes



Fig. 2. Coposition of the biocover (20% soil (heavy clay), 20% compost and 60% fine fraction waste).

Measurements of methane and nitrous oxide emissions were made using the CRDS gas measurement device, Picarro G2508 (Picarro Inc., USA, California). This equipment is capable of providing accurate measurements of nitrogen oxide and methane gas at parts-per-billion (ppb). During the measurement process, the air flow rate in the test tube is maintained at 5 ml/s^{-1}.

The establishment of experimental colons was carried out on 6 June 2022. The first measurement of methane and nitrous oxide was made two weeks after the creation. This was done to allow time for the columns created to compact and stabilise (see figure 3). Further measurements were made weekly over 16 months. A total of 123 measurements

were made in 16 months. To mimic field conditions, each week the experimental columns were watered with 250 ml of water.



Fig. 3 Experiment tubes (author-made)

RESULTS

The data analysis commenced with the categorization of data into three segments: the beginning, middle, and end of the experiment, as outlined in Table 1. This segmentation aligned with variations in emissions derived from compost usage across these phases. Subsequently, a comprehensive examination of descriptive statistics was conducted, detailed in tables 2 and 3.

Table 1

Split data groups

Group	Date
1	June 6 - November 6
2	November 6 – April 6
3	April 6 – September 6

Table 2

Descriptive statistics data (CH4 nmol m^{-2} s^{-1})

Sample | Group_Chamber	Minimum	Maximum	Range	Q1	Median	Q3	Mean
CH_4 nmol m^{-2} s^{-1} | 1_1	3.80	560.00	556.20	30.25	62.85	189.48	156.31
CH_4 nmol m^{-2} s^{-1} | 1_2	3.40	997.00	993.60	5.57	65.55	119.45	201.08
CH_4 nmol m^{-2} s^{-1} | 1_3	6.00	604.00	598.00	26.35	52.00	129.50	142.59
CH_4 nmol m^{-2} s^{-1} | 2_1	10.10	102.00	91.90	13.00	18.00	35.30	33.19
CH_4 nmol m^{-2} s^{-1} | 2_2	4.59	63.00	58.41	8.70	10.10	12.30	14.13
CH_4 nmol m^{-2} s^{-1} | 2_3	0.57	28.90	28.33	4.50	6.10	9.30	8.27
CH_4 nmol m^{-2} s^{-1} | 3_1	4.30	16.30	12.00	6.76	8.60	10.56	9.03
CH_4 nmol m^{-2} s^{-1} | 3_2	0.16	10.60	10.44	2.30	2.70	5.55	3.83
CH_4 nmol m^{-2} s^{-1}| 3_3	-159.00	5.90	164.90	-0.63	2.48	3.68	-15.17

Table 3

Descriptive statistics data (N_2O nmol m^{-2} s^{-1})

Sample | Group_Chamber	Minimum	Maximum	Range	Q1	Median	Q3	Mean
N_2O, nmol m^{-2} s^{-1}| 1_1	-0.50	24.30	24.80	0.47	1.46	7.91	5.82
N_2O, nmol m^{-2} s^{-1}| 1_2	0.10	56.90	56.80	3.03	10.89	27.48	17.70
N_2O, nmol m^{-2} s^{-1}| 1_3	0.13	42.90	42.77	1.88	8.36	21.95	13.84
N_2O, nmol m^{-2} s^{-1}| 3_1	-0.36	7.39	7.75	4.40	5.70	6.45	4.95
N_2O, nmol m^{-2} s^{-1}| 3_2	0.06	5.79	5.73	0.45	0.64	0.85	0.96
N_2O, nmol m^{-2} s^{-1}| 3_3	0.23	6.19	5.96	0.30	0.42	3.58	1.64
N_2O, nmol m^{-2} s^{-1}| 5_1	-0.07	7.50	7.57	0.33	0.70	2.45	1.78
N_2O, nmol m^{-2} s^{-1}| 5_2	0.23	2.76	2.53	1.24	1.40	2.14	1.54
N_2O, nmol m^{-2} s^{-1}| 5_3	-0.29	8.63	8.92	1.17	2.77	3.32	2.79

Upon scrutinizing the data extracted from descriptive statistics, a distinct trend emerges. In the first segment, particularly noticeable in cameras equipped with biocover, the highest range and median values for N_2O and CH_4 emissions are evident. This phenomenon is attributed to the initial two months serving as biocover's stabilization period, during which methane-reducing bacteria undergo a maturation process. Consequently, biocover releases an elevated amount of emissions, a pattern observed consistently across all specified positions.

In contrast, when examining the second and third segments, the mean and range values of N_2O and CH_4 emissions in cameras lacking biocover surpass those with biocover. This suggests that biocover effectively mitigates the quantity of these emissions. Notably, other parameters among the determined values, only CH_4 emissions exhibit a correlation, showcasing significant differences between chambers with and without biocover. Chambers featuring biocover demonstrate markedly lower methane emissions. In the case of N_2O emissions, no correlations were identified among the other parameters.

Summarized results of table 1:

- Minimum and Maximum:

Sample Group 1 exhibits a wide range of methane emissions, with the highest maximum value of 997.00 in Chamber 2. Sample Group 2 has lower maximum values compared to Group 1, ranging from 102.00 (chamber with biocover) in Chamber 1 to 63.00 (chamber without biocover) in Chamber 2. Sample Group 3 displays relatively lower maximum values, with the highest at 16.30 in Chamber 1 (chamber without biocover).

- Range:

Sample Group 1 shows the widest range of emissions, with the largest difference between minimum and maximum values in Chamber 2. Sample Group 2 has comparatively narrower ranges, indicating less variability in emissions across its chambers. Sample Group 3 exhibits moderate ranges, with the most substantial difference in Chamber 3.

- Quartiles (Q1, Median, Q3):

Sample Group 1 generally has higher quartile values, suggesting a broader distribution of emissions. Sample Group 2 shows consistent and relatively lower quartile values across its chambers. Sample Group 3 has varying quartile values, with some chambers displaying negative values for Q1 and Q3.

- Mean:

Sample Group 1 has higher mean values, indicating a more pronounced average emission level. Sample Group 2 has lower mean values compared to Group 1, reflecting lower average emissions. Sample Group 3 displays a mix of positive and negative mean values, indicating variability in average emissions.

In summary, Sample Group 1 exhibits higher overall emissions with greater variability, Sample Group 2 demonstrates lower and more consistent emissions, and Sample Group 3 shows moderate emissions with some chambers displaying negative mean values.

During the subsequent data analysis, average values were employed to represent the dataset's mean, while the median, calculated from sorting the data from smallest to largest, acted as a central measure of tendency. Functioning as the point that evenly divides the dataset into two halves, with half of the data points below and half above it, the median interaction of CH_4 and N_2O revealed a nuanced correlation, as illustrated in Figure 4.

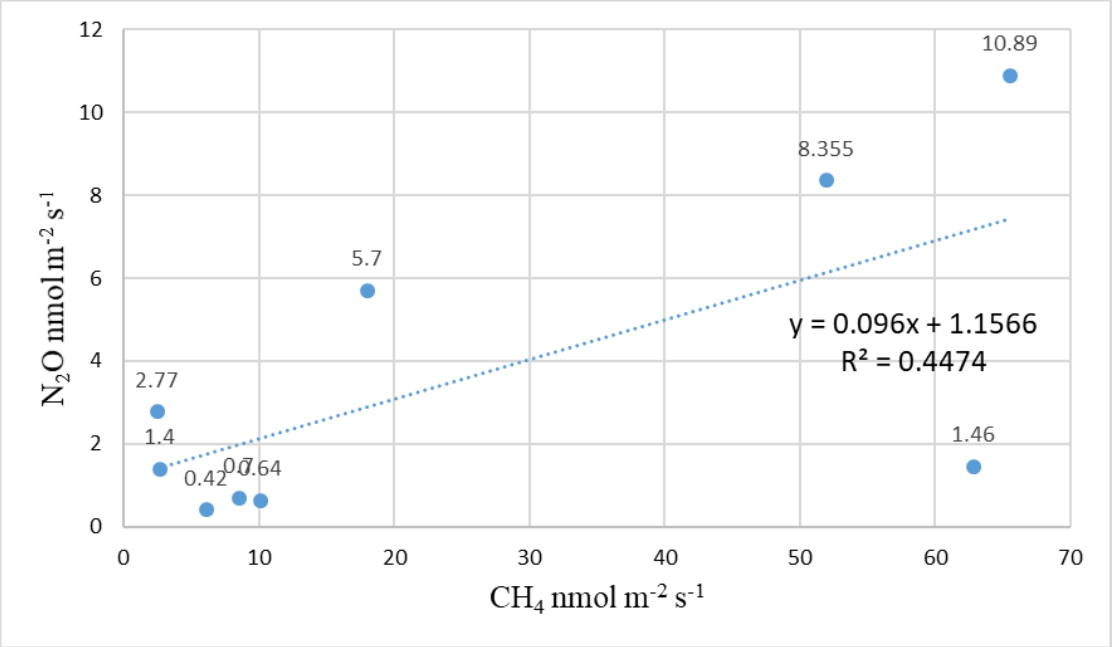


Fig. 4. Graph of N_2O (nmol m^{-2} s^{-1}) and CH_4 (nmol m^{-2} s^{-1}) emission medians

DISCUSSION

The interaction between methane and nitrous oxide emissions from landfill biocover is a critical aspect of waste management and greenhouse gas mitigation. Landfill cover materials have been shown to degrade a wide range of volatile organic compounds, including methane, and nitrous oxide is an intermediate product of microbial nitrogen cycling under specific conditions [10]. Furthermore, research has highlighted the challenges and opportunities associated with biocover systems. For instance, studies have identified issues such as uneven gas distribution and the accumulation of infiltrating water as potential problems in biocover systems, which can lead to variations in gas distribution and the formation of emission hotspots [11]. Viewed from such a perspective, this could be the reason for the large dispersion of the obtained data, which then did not allow determining the precise interaction of these gases.

Additionally, it has been established that soils are a significant source of global nitrogen oxide emissions, accounting for approximately 15% of total emissions [12]. These findings underscore the importance of understanding and mitigating nitrogen oxide emissions from soil systems, including those associated with biocovers.

CONCLUSION

Laboratory biocover experiments hold significant promise as they provide a platform for thorough examination and assessment of the advantages and drawbacks associated with this cover. These experiments enable the identification of the efficacy of biocovers made from different materials and their varying proportions, allowing for predictions regarding the extent of reduction in methane emissions. This study's noteworthy contribution lies in its comprehensive analysis of the intricate interactions between carbon dioxide and nitrous oxide. The interaction between nitrous oxide (N_2O) and methane (CH_4) is a topic of significant environmental importance, particularly in the context of greenhouse gas emissions and their impact on climate change.

The observed interaction between nitrogen oxide and methane emissions, as reflected in the average emission values, indicates a minimal correlation between these gases. The variations in their levels at different concentrations of methane emissions remain poorly understood. Hence, it is imperative to extend this study, conducting more in-depth data analysis with a larger dataset. This approach holds the potential to yield more precise results and unveil established relationships. The ongoing experiment will be extended and thoroughly investigated. Additionally, the exploration of several promising methods for methane reduction will be a focal point in future developments.

ACKNOWLEDGEMENTS

The work was supported by the PASIFIC program GeoReco project funding from the European Union’s Horizon2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 847639 and from the Ministry of Education and Science.

REFERENCES

[1] Nisbet E.G., Dlugokencky E.J., Fisher R.E., France J.L., Lowry D., Manning M.R., Michel S.E., Warwick N.J., Atmospheric methane and nitrous oxide: challenges along the path to Net Zero. Philos Trans A Math Phys Eng Sci, vol. 379/issue 2210, 2021

[2] Molino A., Nanna F., Ding Y., Bikson B., Braccio G., Biomethane production by anaerobic digestion of organic waste, Fuel, vol. 103, pp 1003-1009, 2013.

[3] van Amstel A.R., Swart R.J., Methane and nitrous oxide emissions: an introduction, Fertilizer Research, vol. 37, pp 213–225, 1994.

[4] Pecorini I., Iannelli R., Landfill GHG Reduction through Different Microbial Methane Oxidation Biocovers, Processes, vol. 8/issue 5, pp 591, 2020.

[5] Houhu Z., Weixin L., Zucong C., Yi Z., Yanhong F., Hongling Z., Fei H., Landfill CH4 oxidation and N2O emissions by aged refuse: Effects of wastewater NH_4+-N incubation, heavy metals and pH, Ecological Engineering, vol. 53, pp 243-249, 2013.

[6] Houhu Z., Keqiang Z., Xiaofei Y., Qinfang S., Yi L., Yi Z., Zhao Z., Fan K., Effects of nitrogen conversion and environmental factors on landfill CH4 oxidation and N2O emissions in aged refuse, Journal of Environmental Management, vol. 126, pp 174-181, 2013.

[7] Juha-Kalle M.E., Karhu E.A., Jukka A.R., Mechanically–biologically treated municipal solid waste as a support medium for microbial methane oxidation to mitigate landfill greenhouse emissions, Waste Management, Vol 28/issue 1, pp 97-111, 2008.

[8] Siltumens K., Grinfelde I., Liepa S., Puzule E. P., Burlakovs J., Biocover composition impact on landfill methane emissions reduction, International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, vol. 22/issue 4.2, pp 183-189, 2022.

[9] Huber-Humer M., Röder S., Lechner P., Approaches to assess biocover performance on landfills, Waste Management, vol. 29/issue 7, pp 2092-2104, 2009.

[10] Bogner J., Pipatti R., Hashimoto S., Mitigation of global greenhouse gas emissions from waste: conclusions and strategies from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. Working Group III (Mitigation). Waste Management & Research, vol. 26/issue 1, pp 11-32, 2008

[11] Cassini F., Scheutz C., Skov B. H., Mou Z., Kjeldsen P., Mitigation of methane emissions in a pilot-scale biocover system at the av miljø landfill, Denmark: 1. system design and gas distribution, Waste Management, vol. 63, pp 213-225, 2017.

[12] Hudman R. C., Moore N. E., Mebust A. K., Martin R. V., Russell A. R., Valin L. C., Cohen, R. C., Steps towards a mechanistic model of global soil nitric oxide emissions: implementation and space based-constraints, Atmospheric Chemistry and Physics, vol. 12/issue16, pp 7779-7795, 2012

INVESTIGATING THE IMPACT OF CLIMATE CHANGE IN MEDITERRANEAN SEMI-ARID REGIONS

Ph.D. Georgios Xekalakis[1]
Assoc. Prof. Dr. Christos Anastasiou[2]
Ms. Evi Kazamia[3]
Prof. Yiannis Tsompanakis[4]
Assoc. Prof. Dr. Petros Christou[1, 2]

[1] Frederick Research Center, 1036 Nicosia, **Cyprus**
[2] Frederick University of Cyprus, 1036 Nicosia, **Cyprus**
[3] Troodos Development Company (ANET), 2827 Galata, **Cyprus**
[4] Technical University of Crete, 73100 Chania, **Greece**

ABSTRACT

The Mediterranean basin is distinctly vulnerable to climate change and its associated effects. This vulnerability is noticeably observed in the southern Mediterranean territories, where a perceptible outcome of climate change is the increase of the average temperatures over time, accompanied by water scarcity due to reduced precipitation. Although recent technological advancements have achieved to mitigate to some extend climate change impacts, particularly in stabilizing temperatures and enhancing water resource management, alterations in weather patterns persist. This study presents a realistic climate change scenario in the southern European Mediterranean, namely Cyprus, Greece, Italy, Malta, and Spain, along with selected semi-arid regions like Crete, Murcia, and Sicily, highlighting data spanning during the last three decades. This work aims to outline the principal meteorological factors associated with climate change, aiming to foster a broader understanding of its impact. Additionally, this discussion explores the potential for these regions to utilize the current climatic conditions beneficially, by pivoting towards energy production from alternative, sustainable sources, thereby converting the challenges posed by climate change into opportunities for societal benefit.

Keywords: Mediterranean Climate, Semi-arid Regions, Climate Change Adaptation, Sustainable Energy Transition, Climate Resilience

INTRODUCTION

Climate change has been casting a growing shadow over the Mediterranean regions, imposing several environmental challenges that are expected to escalate in the coming years. The Mediterranean is particularly sensitive to climatic alterations, with the region warming 20% faster than the global average, underscoring the urgency of understanding and mitigating the multifaceted impacts unfolding across these regions [1]. A significant aspect of climate change in the Mediterranean is the rise of mean temperature. This warming trend is anticipated to continue, i.e., air temperatures in these regions are expected to increase between 1.5 to 4 °C 0.5 and 2.5 °C per century [2].

The increasing temperature augments the frequency and severity of heat waves, which have been correlated with a notable rise in mortality rates. For instance, a study revealed that heat waves could lead to a 24.6% increase in total mortality, and a substantial increase in cardiovascular and respiratory mortalities. Such scenarios are particularly pronounced in Mediterranean cities, where urban warming exacerbates the thermal stress on human health, elevating the risks of hospitalizations and fatalities [3].

Moreover, the rise in temperature is accompanied by a decrease in precipitation, which is predicted to fall by up to 30% in Southern Europe for the scenario of 2°C to 4°C global warming. The reduction in precipitation is a harbinger of growing water scarcity, a pressing concern especially in semi-arid and arid environments of the Mediterranean, where water is essential for sustainable development. The frequent droughts occurring in the region are a testament to the escalating water crisis, which imperils not just the ecological integrity but also the socio-economic fabric of these regions [4]. Droughts, accompanied by longer fire seasons, are also one of the main causes of devasting mega-wildfires.

On the other hand, the abundant sunny days characteristic of the Mediterranean climate become a significant resource. The investment in photovoltaic power systems to harness this solar potential is not merely an alternative, but a pivotal strategy for mitigating some of the adverse impacts of climate change. Solar PV installations provide a conduit for clean, renewable energy generation, which is of paramount importance in reducing greenhouse gas emissions, a primary driver of global warming and climate change. The solar infrastructure can also contribute to water conservation by reducing the rate of evaporation, a significant benefit in water-scarce regions. Moreover, the synergy of solar PV panels with vegetation underneath can act as an effective measure against wind erosion in sandy ecosystems, showcasing a blend of ecological and financial benefits [5] [6].

IMPACT OF CLIMATE CHANGE IN EUROPEAN MEDITERRANEAN COUNTRIES

The analysis below delves into an examination of temperature patterns, as shown in Figure 1, across five Mediterranean countries over a quarter-century duration, presenting the potential sign of global warming in this region [7]. The chart delineates a pattern where the mean temperature for each country follows a sinusoidal trend, peaking approximately every three years and reaching a low point every five to six years. There is a noticeable trend of increasing temperatures over time across all five countries, which could be indicative of global warming's local effects. For instance, Malta's average temperature increased from 19.29°C in 1998 to 20.28°C in 2021, and similarly, Cyprus observed an increase from 19.08°C to 19.84°C over the same period. Among the five countries, Malta and Cyprus generally exhibit higher average temperatures compared to Greece, Italy, and Spain. The highest average temperature recorded within this period is 20.35°C in Cyprus during 2010, while the lowest is 12.52°C in Italy during 2005. It is notable that the peak temperatures for Malta, Cyprus, and Spain were recorded in the more recent years (2018-2021), aligning with global trends of rising temperatures.

Figure 2 illustrates a comparison between different Mediterranean countries in terms of their maximum temperatures, populations and, total deaths in 2022 [8]. Malta, with the smallest population of 0.52 million and a high max temperature of 41.5°C, has the highest death rate per 100,000 at 28. Despite having one of the higher maximum temperatures and a large population of 59.11 million, Italy maintains a relatively low death rate of 0.5 per 100,000 individuals.

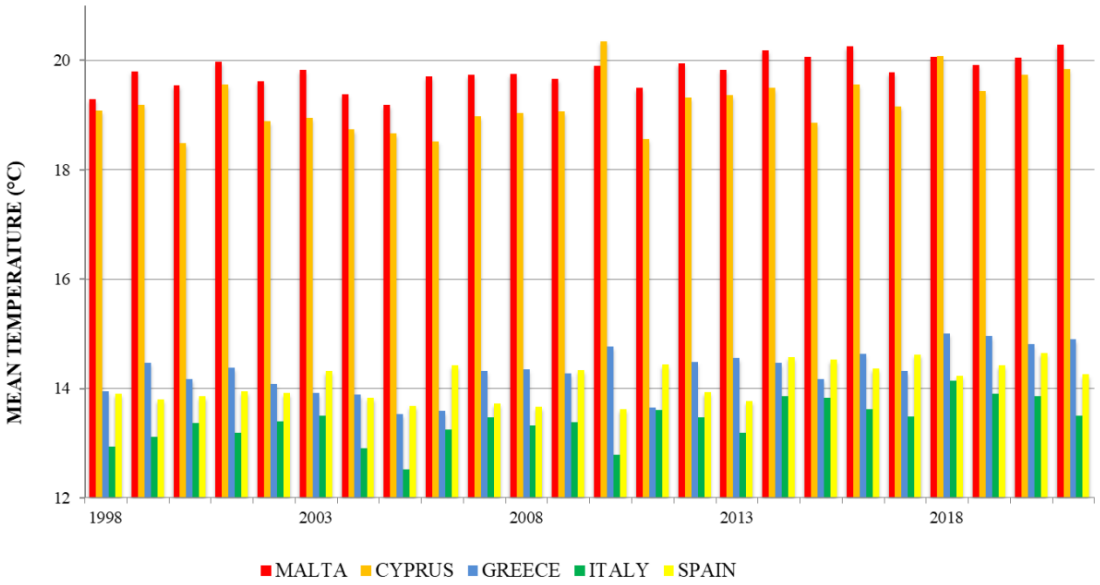


Figure 1. Mean temperature by country in a 25-year period

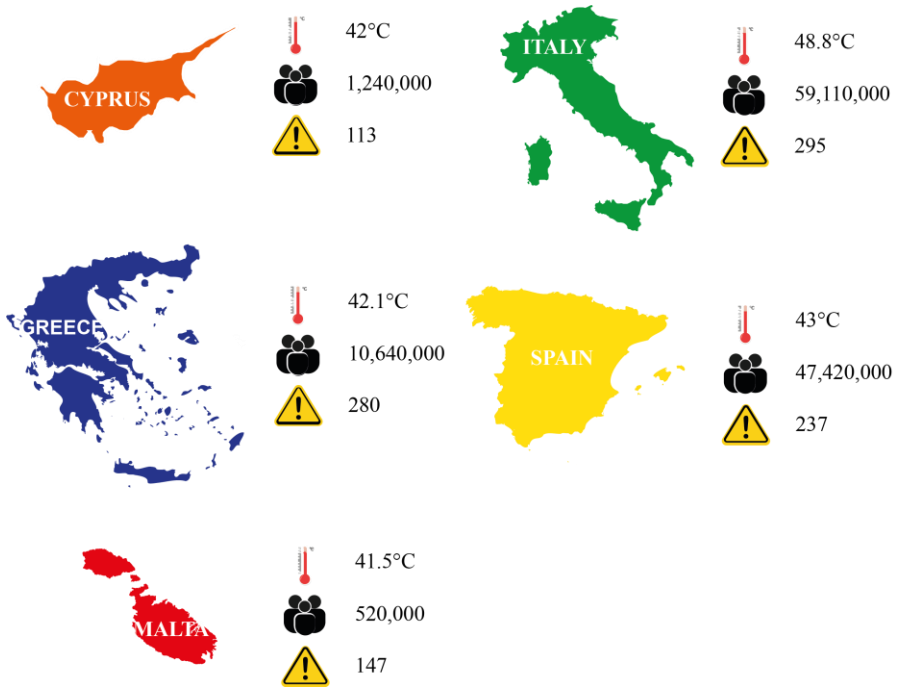


Figure 2. Heat-related mortality rate by country during the summer of 2022

Climate change has intensified various environmental challenges, among which the increased frequency of wildfires stands prominent. Elevated temperatures, predominantly manifesting in the summer months, not only exert an indirect influence, but also bear direct consequences on the ecosystem. The rising temperatures significantly contribute to fire outbreaks, consequently inflicting damage on the region's flora and fauna. Beyond the environmental impact, these blazes pose severe threats to human communities, resulting in substantial property loss and, tragically, loss of life. This cascade of adversities underscores the imperative of addressing the root causes of climate change to foster a more resilient and sustainable future. Table 1 presents the burned and the total forest areas per year from 2010 to 2023 in Cyprus, Greece, Italy and Spain [8].

Table 1. Area (in hectares) burned by country from wildfires during 2010 to 2023

	CYPRUS			GREECE		
YEAR	BURNED	TOTAL	NORM.	BURNED	TOTAL	NORM.
2010	1104	172840	0.6	6472	4132098	0.2
2011	939	172814	0.5	35713	4125626	0.9
2012	2349	172788	1.4	52487	4089913	1.3
2013	2834	172762	1.6	19762	4037426	0.5
2014	436	172736	0.3	14815	4017664	0.4
2015	197	172710	0.1	11613	4002849	0.3
2016	2738	172610	1.6	31707	3991236	0.8
2017	652	172590	0.4	20041	3959529	0.5
2018	417	172570	0.2	12037	3939488	0.3
2019	596	172550	0.3	10736	3927451	0.3
2020	3421	172530	2.0	14915	3916715	0.4
2021	6199	172510	3.6	130744	3901800	3.4
2022	2540	169970	1.5	22480	3771056	0.6
2023	1122	168848	0.7	52801	3748576	1.4
	ITALY			**SPAIN**		
YEAR	BURNED	TOTAL	NORM.	BURNED	TOTAL	NORM.
2010	34280	10090954	0.3	19770	19289250	0.10
2011	36997	10056674	0.4	60060	19269480	0.31
2012	82856	10019677	0.8	189376	19209420	0.99
2013	15776	9936821	0.2	37069	19020044	0.19
2014	13176	9921045	0.1	22001	18982975	0.12
2015	7773	9907869	0.1	63560	18960974	0.34
2016	35246	9900096	0.4	52644	18897414	0.28
2017	140214	9864850	1.4	130925	18844770	0.69
2018	14002	9724636	0.1	12433	18713845	0.07
2019	36887	9710634	0.4	63853	18701412	0.34
2020	53807	9673747	0.6	61099	18637559	0.33
2021	150552	9619940	1.6	84827	18576460	0.46
2022	58751	9469388	0.6	306555	18491633	1.66
2023	58031	9410637	0.6	71271	18185078	0.39

IMPACT OF CLIMATE CHANGE IN SEMI-ARID REGIONS

The semi-arid regions of the Mediterranean, such as Cyprus, Malta, Sicily, Crete, and Murcia [9], are characterized by their distinct climatic conditions, embodying warm to hot summers and mild winters [10], as shown in Table 2. Days with less than 20% cloud cover are considered as sunny. These areas are particularly susceptible to the escalating impacts of climate change, notably experienced through rising maximum temperatures, decreased annual precipitation volumes, and numerous dry days throughout the year.

Table 2. 30-year meteorological data, by region

	CRETE			CYPRUS			MALTA		
MONTH	MAX (°C)	MEAN (°C)	SUNNY DAYS	MAX (°C)	MEAN (°C)	SUNNY DAYS	MAX (°C)	MEAN (°C)	SUNNY DAYS
JAN	21	15	2.8	16	11	6.2	16	14	7.7
FEB	23	16	3	18	12	4.8	14	14	6.9
MAR	26	18	4.9	22	14	7	16	14	8.7
APR	31	23	7.3	27	19	6.9	17	15	10.4
MAY	34	27	12.2	31	24	9.1	20	18	14.1
JUN	38	31	16.8	34	28	9	24	21	18.2
JUL	40	33	18.3	35	31	7.9	26	24	18.8
AUG	38	33	17.5	35	31	7.2	27	25	17.4
SEP	37	30	15.5	32	27	10.8	26	24	14.1
OCT	32	25	10	29	23	12.8	24	22	11.6
NOV	28	21	4.5	23	17	9.1	22	19	9.6
DEC	23	17	2.6	18	13	5.6	19	16	9.5
SUM	-	-	115.4	-	-	96.4	-	-	147

	MURCIA			SICILY		
MONTH	MAX (°C)	MEAN (°C)	SUNNY DAYS	MAX (°C)	MEAN (°C)	SUNNY DAYS
JAN	21	16	13.6	17	12	4.9
FEB	24	17	11.7	18	12	4.8
MAR	27	19	11.4	22	15	7.2
APR	28	22	10.1	26	18	7.4
MAY	32	25	10	31	24	10.3
JUN	36	29	10.5	36	30	14.9
JUL	38	32	11.7	39	33	21.7
AUG	38	33	11.4	39	33	19.6
SEP	35	29	10.8	34	27	11.1
OCT	31	25	11.8	29	23	8
NOV	25	19	12	23	17	5.1
DEC	22	16	13.5	18	13	4.2
SUM	-	-	138.5	-	-	119.2

The percentages provided in Figure 3 indicate the proportion of dry days each region experiences on an average annual basis, for a standard year of 365 days. The data underscores a notable climatic variability among these semi-arid Mediterranean regions.

https://doi.org/10.5593/sgem2023V/4.2/s19.34

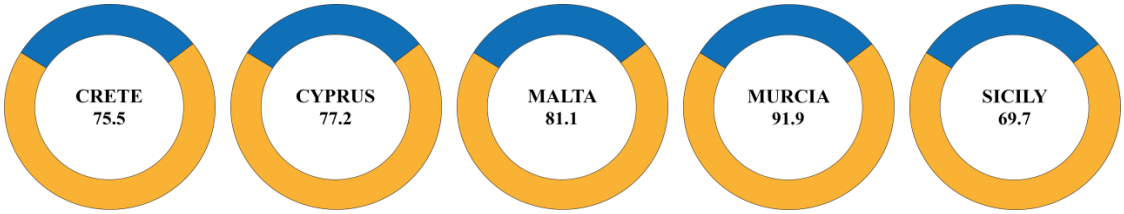


Figure 3. Average annual dry days (%) by region over a 30-year period

Table 3 provides information on the average annual precipitation levels, in millimeters, for the same five semi-arid Mediterranean. These mean precipitation levels are defined for a period of 30 years of data collection [11] [12] [13][14]. In an analysis of meteorological patterns across these five regions, compelling correlations are evident between the annual frequencies of dry days and the associated precipitation volumes. Murcia, with 335.4 dry days, exhibits the least precipitation at 309mm annually, reinforcing the apparent inverse relation between dry days and rainfall. Similarly, Crete, despite having 275.4 dry days, experiences a substantial precipitation of 967mm, indicating occasional heavy rainfall episodes. Sicily, on the other hand, has 254.4 dry days with a precipitation of 715mm, suggesting moderate rainfall spread throughout the year. Cyprus and Malta, with 281.7 and 296 dry days respectively, manifest almost similar precipitation volumes of 470mm and 473mm, potentially implying comparable weather patterns. These regional variations underline the multifaceted nature of climate dynamics, emphasizing the necessity of comprehensive evaluation when interpreting such meteorological data.

Table 3. Average annual precipitation by region over a 30-year period

REGION	CRETE	CYPRUS	MALTA	MURCIA	SICILY
PRECIPITATION	967mm	470mm	473mm	309mm	715mm

Climate change is a reality, with escalating impacts on the environment through heightened climatic and meteorological events. It is imperative for societies to adapt and mitigate these effects to ensure improved living conditions for their citizens. As depicted in the preceding diagrams, the countries mentioned are blessed with abundant sunshine throughout most days of each year. This natural resource could be utilized through the use of photovoltaic (PV) panels in these countries or regions. Solar energy is not only an alternative, but a key strategy to cope with climatic adversities. The integration of solar PV systems is recognized as an important pathway for clean, renewable energy generation and plays a critical role in reducing greenhouse gas emissions, the primary contributor to global warming and climate change. Additionally, solar infrastructure can aid in water conservation by “edging” evaporation rates—a lesser known yet significant benefit, especially in water-scarce regions characteristic of Mediterranean climates, as mentioned in the introduction. Figure 4 illustrates the solar energy capacity across various Mediterranean regions, with Sicily leading in solar energy capacity among the regions listed, followed by Murcia, Cyprus, Malta, and Crete. The disparity in solar energy capacity across these regions may reflect variations in investment, governmental policies, and community engagement towards renewable energy endeavors.

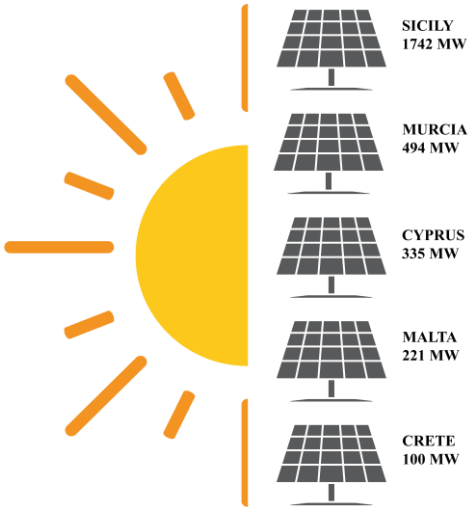


Figure 4. Production of solar power, by region

CONCLUSION

This study sheds some light on how Mediterranean regions are at a higher risk due to the growing impacts of climate change. Higher average temperatures and less rains are the main climate problems in these regions. A careful look at the climate changes in selected Mediterranean countries and dry areas over the last 30 years shows a clear warming trend. The study also highlights the resulting increase in heat waves, water shortages, and wildfires, among other issues, all interrelated with temperature rise.

On a positive note, the study identifies the great solar energy potential due to the sunny weather, which is typical of these regions. The plentiful sunlight presents a valuable chance to shift towards using sustainable energy. By tapping into this green energy potential through the use of solar panels, these regions can lessen some of the negative effects of climate change and move towards a sustainable energy setup.

Furthermore, the connection between solar setups and saving water not only highlights the need to lessen greenhouse gas emissions, but also moves the discussion towards finding practical solutions. By turning the challenges brought by climate change into chances for sustainable development, the Mediterranean regions can lead the way in creating a climate-strong pathway. This is not just about reacting but planning ahead, ensuring a good quality of life and growth for their communities as the climate changes.

ACKNOWLEDGEMENTS

This research work was supported by the ISTOS project. This project has received funding from the European Union's Horizon 2020 research and innovation programme (WIDESPREAD-TWINNING) under grant agreement No. 952300.

REFERENCES

[1] www.unep.org. (n.d.). Climate change in the Mediterranean | UNEPMAP. [online] Available at: https://www.unep.org/unepmap/resources/factsheets/climate-change#:~:text=The%20Mediterranean%20region%20is%20warming.

[2] Christidis, N., Mitchell, D. and Stott, P.A. (2023). Rapidly increasing likelihood of exceeding 50 °C in parts of the Mediterranean and the Middle East due to human

influence. npj Climate and Atmospheric Science, [online] 6(1), pp.1–12. doi:https://doi.org/10.1038/s41612-023-00377-4.

[3] Pyrgou, A. and Santamouris, M. (2018). Increasing Probability of Heat-Related Mortality in a Mediterranean City Due to Urban Warming. International Journal of Environmental Research and Public Health, 15(8), p.1571. doi:https://doi.org/10.3390/ijerph15081571.

[4] Hadri, A., Saidi, M.E.M., El Khalki, E.M., Aachrine, B., Saouabe, T. and Elmaki, A.A. (2022). Integrated water management under climate change through the application of the WEAP model in a Mediterranean arid region. Journal of Water and Climate Change, 13(6), pp.2414–2442. doi:https://doi.org/10.2166/wcc.2022.039.

[5] Gauri Panse-Aglave and Hassan, Q. (2022). A review paper on energy harvesting in arid and semi-arid region via PV cell on irrigation canals. Materials Today: Proceedings. doi:https://doi.org/10.1016/j.matpr.2022.09.427.

[6] Liu, Z., Peng, T., Ma, S., Chen, Q., Song, Y., Zhang, C., Li, K., Gao, N., Pu, M., Wang, X., Bi, Y. and Xiaofan Na (2023). Potential benefits and risks of solar photovoltaic power plants on arid and semi-arid ecosystems: an assessment of soil microbial and plant communities. Frontiers in Microbiology, 14. doi:https://doi.org/10.3389/fmicb.2023.1190650.

[7] tradingeconomics.com. (n.d.). Cyprus Temperature - 2023 Data - 2024 Forecast - 1901-2022 Historical - Chart - News. [online] Available at: https://tradingeconomics.com/cyprus/temperature [Accessed 19 Oct. 2023].

[8] Statista (2023). The statistics portal for market data, market research and market studies. [online] Statista.com. Available at: https://www.statista.com/.

[9] UNESCO (no date) MAB Technical Notes 7 - catalogue.unccd.int. Available at: https://catalogue.unccd.int/1060_1977_unesco_mab_technicalnotes_arid_lands_map.pdf (Accessed: 19 October 2023).

[10] meteoblue. (n.d.). Home. [online] Available at: https://content.meteoblue.com/en [Accessed 19 Oct. 2023].

[11] Data Catalog | Climate Change Knowledge Portal. 2023. Data Catalog | Climate Change Knowledge Portal. [online] Available at: https://climateknowledgeportal.worldbank.org/download-data. [Accessed 20 Oct 2023].

[12] Forestieri, A., Lo Conti, F., Blenkinsop, S., Cannarozzo, M., Fowler, H.J. and Noto, L.V. (2018). Regional frequency analysis of extreme rainfall in Sicily (Italy). International Journal of Climatology, 38, pp.e698–e716. doi:https://doi.org/10.1002/joc.5400.

[13] Tzanakakis, V.A., Paranychianakis, N.V. and Angelakis, A.N. (2020). Water Supply and Water Scarcity. Water, 12(9), p.2347. doi:https://doi.org/10.3390/w12092347.

[14] World Weather & Climate Information. 2023. Average monthly rainfall and snow in Murcia (Murcia), Spain (millimeter). [online] Available at: https://weather-and-climate.com/average-monthly-precipitation-Rainfall,murcia-murcia-es,Spain. [Accessed 20 October 2023].

INVESTIGATIONS OF POTENTIALLY HARMFUL LIMONENE PHOTOOXIDATION PRODUCTS UNDER NO_x AND NO_x-FREE ATMOSPHERIC SIMULATED CONDITIONS

Dr. Alina Giorgiana Negru[1,2,3]
Dr. Claudiu Roman[1,2]
PhD Cornelia Amarandei[1,2,3]
Prof. Dr. Habil. Cecilia Arsene[1,2,3]
Prof. Dr. Habil. Romeo Iulian Olariu[1,2,3,*]

[1] "Alexandru Ioan Cuza" University of Iasi, Institute of Interdisciplinary Research, Integrated Centre of Environmental Science Studies in the North Eastern Region (CERNESIM), **Romania**
[2] "Alexandru Ioan Cuza" University of Iasi, Center with Integrated Techniques for Atmospheric Aerosol Investigation in Romania (RECENT AIR), **Romania**
[3] "Alexandru Ioan Cuza" University of Iasi, Faculty of Chemistry, **Romania**

ABSTRACT

Given the ubiquity of limonene in cleaning and cosmetic products, investigating its gas-phase oxidation products from reactions with OH radicals and ozone has become important for human health. The present study investigates limonene gas-phase reaction with OH radicals under controlled NO_x or NO_x-free conditions using facilities from the 760 L Environmental Simulation Chamber made of Quartz (ESC-Q-UAIC) together with state-of-the-art instruments such as proton-transfer-reaction time-of-flight mass spectrometer (PTR-ToF-MS, model 6000 X2, IONICON). The obtained kinetic results ($k_{limonene+OH} = (16.42 \pm 2.20) \times 10^{-11}$ $cm^3 \times molecule^{-1} \times s^{-1}$), based on the relative rate techniques with 1,3,5-trimethylbenzene and cyclohexene as reference compounds, are in good agreement with the previous kinetic studies. The PTR-ToF-MS mass spectra acquired within the NO_x-free experiments revealed signals at mass-to-charge ratios of 101.060, 139.112, and 169.122, that may be assigned to potentially harmful oxidation products, namely 4-oxopentanal ($C_5H_8O_2$), 4-acetyl-1-methylcyclohexene ($C_9H_{14}O$), and 3-isopropenyl-6-oxo-heptanal ($C_{10}H_{16}O_2$), respectively. Additionally, observed differences between NO_x and NO_x-free experiments highlight that NO_x strongly suppresses the formation of secondary organic aerosols during limonene oxidation and favours the formation of 4-acetyl-1-methylcyclohexene.

Keywords: limonene, OH radicals, gas-phase reaction rate, gas-phase oxidation products, secondary organic aerosols, PTR-ToF-MS

INTRODUCTION

Limonene, one of the most abundant monoterpenes, is a volatile organic compound (VOC) commonly found in residential environments and widely used in cleaning and personal care products due to its pleasant citrus fragrance [1]. Its reaction with indoor and outdoor ozone as well as with hydroxyl radicals leads to various oxidation products. To data, some of the limonene gas phase oxidation products have the potential to cause

* Corresponding author: oromeo@uaic.ro

health-harming effects including oxidative stress, asthma, cell damage and inflammatory responses [2]. The role of atmospheric NO_x may be significant in VOC oxidation, as it modulates the RO_2 radical pathways, thereby influencing the product distribution and the dynamics of secondary organic aerosol (SOA) formation [3]. Low NO_x conditions favor the formation of organic hydroperoxides. Additionally, NO_x can suppress new particle formation from volatile organic compound emissions [4]. While numerous studies, have focused on SOA formation from monoterpene oxidation via ozonolysis [5], there is still a need for further research into SOA formation involving hydroxyl radical oxidation, as indicated by [3].

The present study aims to i) determine the gas-phase reaction rate of limonene with OH radicals, and ii) investigate limonene's gas-phase reaction products under both NO_x and NO_x-free conditions. Additionally, this work provides a detailed analysis of potentially harmful photooxidation products of limonene in both the gas and aerosol phases under various NO_x conditions.

MATERIALS AND METHODS

Experimental setup and relative kinetic method: Gas-phase reaction rate of the limonene toward OH radicals has been determined employing the relative kinetic method and using the ESC-Q-UAIC chamber, a 760-L and 4.2-m-long cylindrical photoreactor consisting of three quartz tubes surrounded by 64 lamps. A detailed description of the chamber is provided elsewhere [6]. Limonene and reference compounds decay in the reactor vessel was monitored by IR spectroscopy using a Bruker Vertex 80 FTIR coupled to a White type mirrors system mounted inside the chamber, providing a total optical path of 492 ± 1 m. The OH radicals were generated *in situ* by photolysis of isopropyl nitrite at 365 nm in the presence of excess NO to suppress ozone formation and potential interference processes. 1,3,5-trimethylbenzene (TMB) with $k_{(TMB+OH)} = (5.86 \pm 0.88) \times 10^{-11}$ $cm^3 \times molecule^{-1} \times s^{-1}$, and cyclohexene (CyHex) with $k_{(CyHex+OH)} = (6.77 \pm 1.69) \times 10^{-11}$ $cm^3 \times molecule^{-1} \times s^{-1}$ were used as reference compounds in the kinetic experiments [7]. Gas-phase IR spectra of limonene, 1,3,5-trimethylbenzene and cyclohexene were recorded at 298 K and 1000 mbar air pressure (**Figure 1**). Individual VOC spectral features were used to monitor the sink of the organic compounds: 890 and 1380 cm^{-1} for limonene, 835 cm^{-1} for 1,3,5-trimethylbenzene, 920 and 1140 cm^{-1} for cyclohexene.

The chemical reactions of the compounds inside the reaction vessel and their specific reaction rates are described by the R1-R4:

limonene + OH	→	products	k_1	(R1)
reference + OH	→	products	k_2	(R2)
limonene	→	reactor walls	k_3	(R3)
1,3,5-trimethylbenzene	→	reactor walls	k_4	(R4)

Prior to the kinetic investigations, all the compounds have been tested to check eventual losses due to wall deposition or photolysis processes. No significant photolysis at 365 nm was observed for the compounds used in this study. The following wall loss coefficients have been determined: $k_3 = (5.65 \pm 0.03) \times 10^{-5}$ s^{-1}, $k_4 = (3.13 \pm 0.01) \times 10^{-5}$ s^{-1}. No wall loss was observed for cyclohexene.

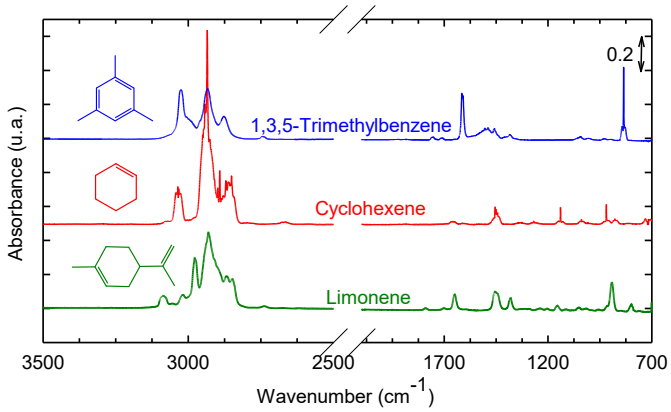


Figure 1. Gas-phase FTIR spectra of — limonene, — cyclohexene, and — 1,3,5-trimethylbenzene at 298 K and 1000 mbar air pressure.

By representing the total decay in time of both references and limonene with respect to the correction mentioned above, the kinetic expression shown in Eq. (1) was used to determine the limonene reaction rate:

$$\ln\left(\frac{[limonene]_{t_0}}{[limonene]_t}\right) - k_3(t - t_0) = \frac{k_1}{k_2}\ln\left(\frac{[reference]_{t_0}}{[reference]_t}\right) - k_4(t - t_0) \quad (1)$$

where: $[limonene]_{t0}$ and $[reference]_{t0}$ are the initial concentrations of limonene and the reference compound at t_0, $[limonene]_t$ and $[reference]_t$ are the concentrations of limonene and reference compounds during the reaction time t, k_1 and k_2 are the gas-phase rate coefficients for the OH radical reactions with the limonene and reference compounds respectively, while k_3 and k_4 are the wall loss rate coefficients for limonene and TMB.

Proton-transfer-reaction time-of-flight mass spectrometry: Investigations on limonene gas-phase and aerosol-phase reaction products under controlled NO_x or NO_x-fee conditions in the ESC-Q-UAIC reactor were performed using a proton transfer reaction mass spectrometer (PTR-ToF-MS, Model 6000X2, IONICON) with a CHemical Analysis of aeRosol ON-line (CHARON) particle inlet. The instrument was operated with H_3O^+ as primary ion at a drift pressure of 2.79 mbar, drift voltage of 450 V, E/N of 116 Td, drift temperature of 100 °C, inlet temperature of 100 °C, and sample flow rate of 200 cm^3 min^{-1}. The ioniTOF 4.2 software was used for instrument control and PTR-MS Viewer 3.4 software for data processing and analysis. The OH radicals were generated *in situ* by: i) photolysis of H_2O_2 at 254 nm for the experiment under NO_x-free conditions, and ii) photolysis of HONO at 365 nm for the experiment under NO_x conditions, since the measurements in the presence of isopropyl nitrite cannot be performed with the PTR-ToF-MS system due to its high proton affinity of 202.1 kcal × mol^{-1} [8].

Chemicals: Substances (purities, manufacturer) used in the present study were: limonene (99%, Sigma-Aldrich), 1,3,5-trimethylbenzen (98%, Sigma-Aldrich), cyclohexene (99.9%, Sigma-Aldrich), NO (99.5%, Linde), and purified dry air (generated from a Kaiser-Zander compressor). Isopropyl nitrite was prepared using isopropanol (99.9% Honeywell), sodium nitrite (98%, Merk) and sulfuric acid (98%, Sigma-Aldrich) according to [9].

RESULTS

The results of the experimental investigation into the gas-phase OH radicals-initiated reaction of limonene under controlled NOx and NOx-free conditions are detailed below. Section 1 presents the results from the relative rate method used to determine the rate coefficient k_1. Section 2 contains the results from investigations using PTR-ToF-MS, which includes both gas-phase and aerosol-phase products from the OH-initiated oxidation of limonene under controlled NO_x or NO_x-free conditions.

1. Kinetic measurements of the gas-phase reaction of limonene with OH radicals

Figure 2 represents the relative kinetic plot obtained by *in situ* FT-IR analysis for limonene in the presence of OH radicals and the reference compounds. The ratio of k_1/k_2 was determined from linear regression analysis of the kinetic datapoints. **Figure 2** insertion represent the measured relative decay of CyHex to TMB due to OH radicals-initiated reactions and correspond to a $k_{CyHex+OH}/k_{TMB+OH}$ of 1.278 ± 0.044, in good agreement with the literature proposed ratio of 1.155 ± 0.337 [7]. The total conversion of limonene during the experiments period was evaluated to 62 %, for TMB at 28% and for cyclohexene at 37%.

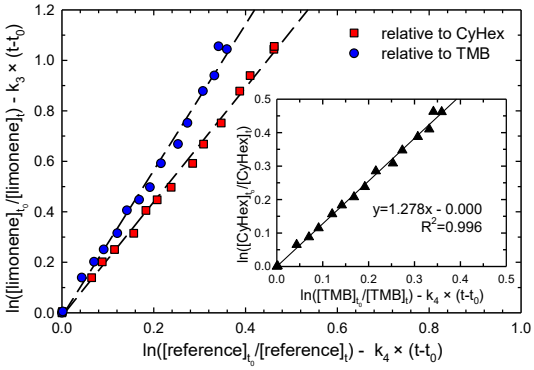


Figure 2. Kinetic data plotted according to Eq. (1) for the reaction of OH radicals with limonene using 1,3,5- trimethylbenzene (blue circle) and cyclohexene (red square) as reference compounds. Insertion represents the second order decay of cyclohexene versus 1,3,5-trimethylbenzene during the gas-phase OH radicals-initiated reaction.

The experimental data obtained from this study are listed in **Table 1**, where k_1/k_2 ratios ($\pm 2\sigma_R$) and gas-phase rate coefficient (k_1) values derived from each reference compound (i) are indicated.

Table 1: Gas-phase OH radicals kinetic results obtained within the present study, reaction rate coefficient, and average atmospheric lifetime for the limonene.

Compound	Reference	$k_1/k_2 \pm 2\sigma_R$	$k_1 \pm \sigma_i$	$\bar{k}_1 \pm \bar{\sigma}$	k_1[a]	τ[b]
			(10^{-11} cm^3×molecule^{-1}×s^{-1})			(hour)
limonene	TMB	2.8923±0.139	16.95±2.67	**16.42±2.20**	**16.50±1.98**	**1.5**
	CyHex	2.2640±0.069	15.33±3.86			

[a][7]; [b] $\tau = 1/([OH] \times \bar{k}_1)$

$$\overline{k_1} = \frac{\Sigma_1^i\left(k_{1,i}\times\left(\frac{1}{\sigma_i^2}\right)\right)}{\Sigma_1^i\left(\frac{1}{\sigma_i^2}\right)} \quad (2) \qquad \sigma_i = k_1\sqrt{\left(\frac{2\sigma_R}{k_1/k_2}\right)^2 + \left(\frac{\sigma_{reference}}{k_2}\right)^2} \quad (3) \qquad \bar{\sigma} = \sqrt{\frac{1}{\Sigma_1^i\left(\frac{1}{\sigma_i^2}\right)}} \quad (4)$$

The average kinetic coefficient ($\bar{k}_1$) resulted from the weighted average of k_1 reaction rate coefficients were estimated according to equation Eq. (2), and their uncertainties derived from Eq. (3) and Eq. (4). The obtained values are given in **Table 1**. Also, the rate coefficient at 298 K for limonene as available from the EUROCHAMP kinetic database [7] is presented in **Table 1**. Assuming the 24h-average concentration of the OH radicals in the atmosphere of 1.13×10^6 cm^{-3} [10] the average tropospheric lifetime of the limonene has been calculated (**Table 1**).

2. Investigation of the products from the gas-phase OH-initiated oxidation of limonene

PTR-ToF-MS mass spectra of limonene **(a)**, limonene + OH products in the gas-phase **(b)**, and limonene + OH products in the aerosol-phase **(c)** obtained in the present study are presented in **Figure 3**. Corresponding background spectra have been subtracted from the spectra (a) and (b).

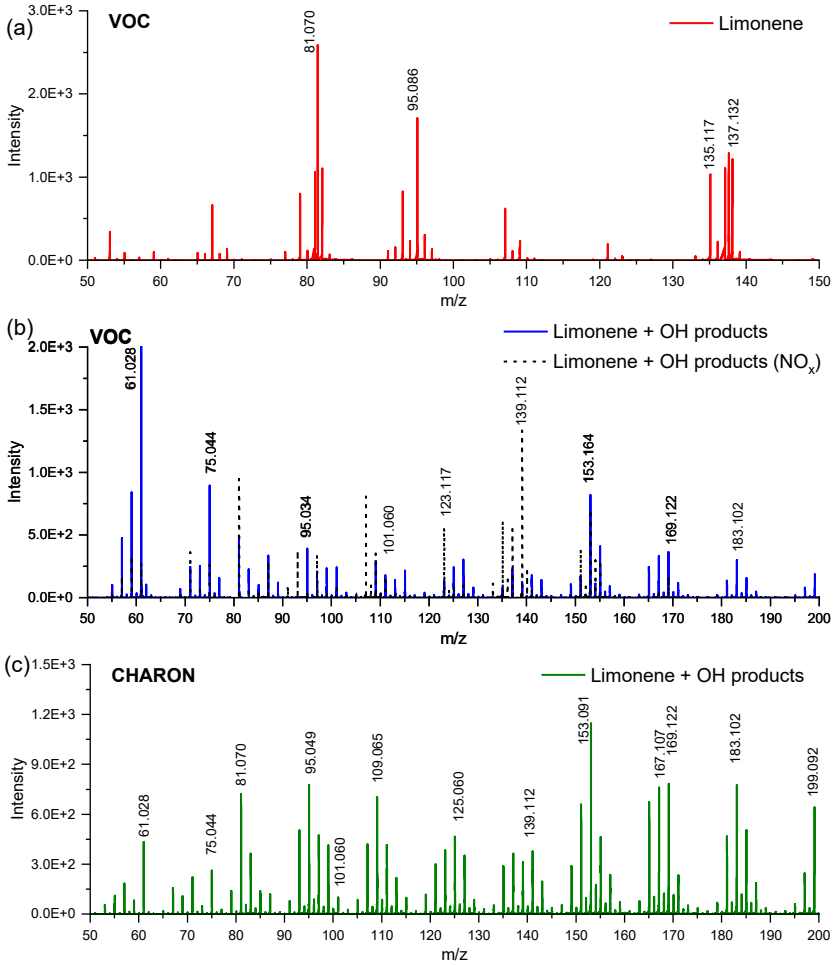


Figure 3. PTR-ToF-MS mass spectra of limonene **(a)**, limonene + OH products in the gas-phase **(b)**, and limonene + OH products in the aerosol-phase **(c)**.

The PTR-ToF-MS spectrum of limonene ($C_{10}H_{16}$, MW = 136 g mol^{-1}) obtained in the gas-phase simulated conditions in the ESC-Q-UAIC reaction chamber (**Figure 3a**) shows distinct signals at mass-to-charge ratios of: 137.132, assigned to the $C_{10}H_{16}H^+$ (M+1), and of 81.070, 95.086, and 135.117 associated with $C_6H_8H^+$, $C_7H_{10}H^+$, and $C_{10}H_{14}H^+$ ionized fragments, respectively. **Figure 3b** highlights the signals of the main gas-phase products generated during the OH-initiated oxidation of limonene in the NO_x-

free and NO_x simulated conditions. Limonene signals were subtracted within this mass spectra. **Figure 3c** presents the mass spectrum of aerosol-phase oxidation products of limonene for the NO_x-free experiment. It is worth mentioning that no signals were observed in the mass spectrum for the aerosol-phase products under NO_x conditions.

Time variation of limonene (95.086 m/z) and interest potentially harmful oxidation products measured by PTR-ToF-MS during experiments performed with OH radicals under NO_x-free **(a)** and NO_x **(b)** simulated conditions are shown in **Figure 4**. The origins of the coordinate systems in the **Figure 4** represent the beginning of reaction. Value of 95.060 m/z was chosen to represent the limonene in order to avoid the contributions from newly formed products with signals not well separated.

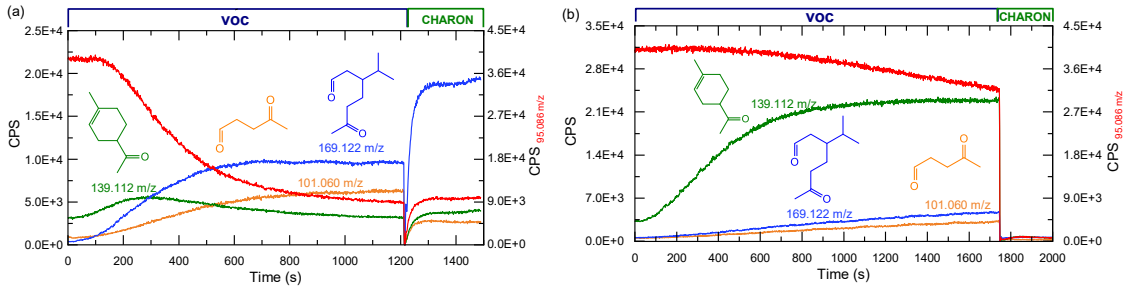


Figure 4. Time variation of limonene (95.086 m/z) and interest oxidation products (101.060 m/z, 139.112 m/z, and 169.122 m/z) measured by PTR-ToF-MS during the experiment performed with OH radical under NO_x-free **(a)** and NO_x **(b)** conditions.

DISCUSSION

The results obtained from the investigations performed into the gas-phase OH radicals-initiated reaction of limonene under controlled NO_x and NO_x-free conditions are discussed below. The experimentally determined OH-reaction rate coefficient ($k_{limonene+OH}$) was (16.42 ± 2.20) 10^{-11} $cm^3 \times molecule^{-1} \times s^{-1}$. Given the 24-hour average tropospheric concentration of OH radicals at 1.13 × 10^6 $radicals \times cm^{-3}$ [10], an average lifetime of 1.5 hours was estimated for limonene. It is expected that this average lifetime to significantly decrease if the reaction rate coefficients for O_3 and NO_3 radicals are included in the assessment. A comparison of the experimental kinetic results with the available literature data reveals a very good agreement with the value of (16.50 ± 3.96) × 10^{-11} $cm^3 \times molecule^{-1} \times s^{-1}$ reported by [11], obtained using both absolute and relative rate determinations.

The investigation into the gas-phase photo-oxidation of limonene revealed distinct degradation pathways under both NO_x-free and NO_x atmospheric conditions as depicted in **Figure 3b**. Under NO_x-free conditions, the gas-phase spectrum shows signals corresponding to a wide range of oxidation products, in contrast to the notably fewer signals observed under NO_x conditions. Both NO_x-free and NO_x conditions presented a notable set of signals at m/z values of 61.028 ($C_2H_4O_2H^+$), 75.044 ($C_3H_6O_2H^+$), 101.060 ($C_5H_8O_2H^+$), 109.065 ($C_7H_8OH^+$), 123.117 ($C_8H_{10}OH^+$), 139.112 ($C_9H_{14}OH^+$), 153.091 ($C_9H_{12}O_2H^+$), and 169.122 ($C_{10}H_{16}O_2H^+$). Among the identified products, 4-oxopentanal ($C_5H_8O_2$), 4-acetyl-1-methylcyclohexene ($C_9H_{14}O$), and 3-isopropenyl-6-oxoheptanal ($C_{10}H_{16}O_2$) have been associated with inflammatory effects in human lung cells [2]. These highlight the importance of further assessing the health implications of such compounds commonly found in personal care products.

PTR-ToF-MS mass spectra acquired from the aerosol phase during OH-initiated oxidation of limonene (**Figure 3c**) revealed a large number of species identified as $C_7H_8OH^+$ (109,065 m/z), $C_9H_{12}O_2H^+$ (153.091 m/z), $C_{10}H_{16}O_2H^+$ (169.122 m/z), $C_{10}H_{14}O_3H^+$ (183.102 m/z), and $C_{10}H_{14}O_4H^+$ (199.092 m/z) for the NO_x-free conditions, in contrast with no products for the NO_x conditions. The observed results suggest that NO_x strongly suppressed the secondary organic aerosol formation, in agreement with literature reported data on NO_x and SO_2 effects SOA formation [3].

In the NO_x-free conditions, as depicted in **Figure 4a**, initiating the generation of OH radicals led to a rapid decay of the limonene signal, accompanied by a significant increase in the signal for 169.122 m/z. The signal for 139.112 m/z, corresponding to 4-acetyl-1-methylcyclohexene increased initially and decrease afterwards due to potentially secondary reactions and losses on reactor walls and photolytic processes. A completely different behavior has been observed for limonene in the presence of NO_x **(Figure 4b)**. Among the potentially harmful products identified in **Figure 4b**, the greatest increase was observed for the 139.112 m/z, while a low increase was observed for 101.060 m/z and 169.122 m/z. These results may suggest that the presence of NO_x leads to a dominant pathway favouring the formation of 4-acetyl-1-methylcyclohexene.

CONCLUSION

This work presents the results from the investigation of limonene OH-initiated oxidation under controlled simulated NO_x and NO_x-free atmospheric conditions. The experiments provided significant information about the OH radicals gas-phase reaction rate and insights into the gas-phase and aerosol-phase products of limonene. The kinetic data derived from the relative rate method, $k_{limonene+OH} = (16.42 \pm 2.20) \times 10^{-11}$ $cm^3 \times molecule^{-1} \times s^{-1}$ using 1,3,5-trimethylbenzene and cyclohexene as references, corroborate very well with prior research findings. The PTR-ToF-MS with CHARON particle inlet measurements revealed that limonene oxidation process leads to a large number of species which are important contributors to secondary organic aerosol formation. Under NO_x-free conditions, predominant gas-phase products included $C_2H_4O_2$, $C_3H_6O_2$, $C_9H_{12}O_2$, and $C_{10}H_{16}O_2H$, while aerosol-phase composition were more complex, including $C_{10}H_{16}O_2$, $C_{10}H_{14}O_3$, and $C_{10}H_{14}O_4$. Under NO_x conditions, the predominant gas-phase species were C_7H_8O, $C_8H_{10}O$, and $C_{10}H_{16}O_2$, with no oxidation products detected in the aerosol-phase. Different contribution from potentially harmful limonene photooxidation products (i.e. 4-oxopentanal ($C_5H_8O_2$), 4-acetyl-1-methylcyclohexene ($C_9H_{14}O$), and 3-isopropenyl-6-oxo-heptanal ($C_{10}H_{16}O_2$)) have been identified in both NO_x-free and NO_x experiments, suggesting different pathway of limonene oxidation. The present study highlights the major role played by NO_x in formation of potentially harmful photooxidation products and SOA via hydroxyl oxidation of limonene. Further researches are planned to: i) identify and quantify other potentially harmful limonene oxidation products and ii) assess the oxidative potential of particles generated in NO_x-free limonene oxidation in order to highlight the health impact.

ACKNOWLEDGEMENTS

This work was supported by a grant of the "Alexandru Ioan Cuza" University of Iasi, within the Research Grants program, Grant UAIC, code GI-UAIC-2022-04. The authors acknowledge the Operational Program Competitiveness 2014-2020, Axis 1, under

POC/448/1/1 research infrastructure projects for public R&D institutions/sections F 2018, through the Research Center with Integrated Techniques for Atmospheric Aerosol Investigation in Romania (RECENT AIR) project, under grant agreement MySMIS no. 127324. A.G.N. thanks the European Social Fund, through Operational Programme Human Capital 2014-2020, project number POCU/993/6/13/153322, project title "Educational and training support for PhD students and young researchers in preparation for insertion into the labor market".

REFERENCES

[1] Nazaroff W.W., Weschler C.J., Cleaning products and air fresheners: exposure to primary and secondary air pollutants, Atmospheric Environment, vol. 38, pp 2841–2865, 2004.

[2] Lipsa D., Barrero-Moreno J., Coelhan M., Exposure to selected limonene oxidation products: 4-OPA, IPOH, 4-AMCH induces oxidative stress and inflammation in human lung epithelial cell lines, Chemosphere, vol. 191, pp 937-945, 2018.

[3] Zhao, D., Schmitt, S.H., Wang, M., Acir, I.H., Tillmann, R., Tan, Z., Novelli, A., Fuchs, H., Pullinen, I., Wegener, R., Rohrer, F., Wildt, J., Kiendler-Scharr, A., Wahner, A., Mentel, T.F., Effects of NOx and SO_2 on the secondary organic aerosol formation from photooxidation of α-pinene and limonene, Atmospheric Chemistry and Physics, vol. 18, pp 1611-1628, 2018.

[4] Hammes, J., Lutz, A., Mentel, T., Faxon, C., and Hallquist, M., Carboxylic acids from limonene oxidation by ozone and hydroxyl radicals: insights into mechanisms derived using a FIGAERO-CIMS, Atmospheric Chemistry and Physics, vol. 19, pp 13037-13052, 2019.

[5] Rosati, B., Teiwes, R., Kristensen, K., Bossi, R., Skov, H., Glasius, M., Pedersen, H. B., Bilde, M., Factor analysis of chemical ionization experiments: Numerical simulations and an experimental case study of the ozonolysis of αpinene using a PTR-ToF-MS, Atmospheric Environment, vol. 199, pp 15-31, 2019

[6] Roman, C., Arsene, C., Bejan, I.G., Olariu, R.I., Investigations into the gas-phase photolysis and OH radical kinetics of nitrocatechols: implications of intramolecular interactions on their atmospheric behaviour, Atmospheric Chemistry and Physics, vol. 22, pp 2203-2219, 2022.

[7] McGillen, M.R., Carter, W.P.L., Mellouki, A., Orlando, J.J., Picquet-Varrault, B., and Wallington, T.J., Database for the kinetics of the gas-phase atmospheric reactions of organic compounds, Earth System Science Data, vol. 12, pp 1203-1216, 2020.

[8] List of proton affinities, Ionicon Analytik Ges.m.b.H., Innsbruck, Austria, 2023.

[9] Atkinson, R., Aschmann, S.M. Carter, W.P. Winer, PM., Pitts Jr., J.N., Alkyl nitrate formation from the NOx-air photooxidations of C_2-Csn-alkanes, The Journal of Physical Chemistry, vol. 86, pp 4563-4569, 1982.

[10] Lelieveld, J., Gromov, S., Pozzer, A., Taraborrelli, D., Global tropospheric hydroxyl distribution, budget and reactivity, Atmospheric Chemistry and Physics, vol. 16, pp 12477-12493, 2016.

[11] IUPAC 2017. Task group on Atmospheric Chemical Kinetic Data Evaluation. Evaluated data sheets available at http://iupac.pole-ether.fr/.

LEVERAGING MODERN LANGUAGES AND TRANSLATIONS FOR SUSTAINABLE ENVIRONMENTAL PRACTICES

Lect. Dr. Raul Pașcalău

Assoc. Prof. Dr. Laura Șmuleac

Prof. Dr. Sorin Stanciu

Prof. Dr. Florin Imbrea

Assoc. Prof. Dr. Adrian Șmuleac

University of Life Sciences" King Mihai I" from Timisoara, **Romania**

ABSTRACT

In an era of globalization and interconnections, addressing environmental challenges requires effective communication and collaboration on a global scale. This abstract highlights the critical role that modern languages and translations play in promoting sustainable environmental practices. By facilitating the exchange of knowledge, ideas, and best practices across linguistic and cultural boundaries, modern languages and translation services empower individuals, organizations, and governments to work together toward a more sustainable future. This interdisciplinary approach explores the significance of multilingualism, the challenges of linguistic diversity, and the opportunities for innovation in the quest for a harmonious coexistence between humanity and the environment. The abstract emphasizes the need for the integration of language expertise and translation technologies into environmental sustainability efforts, ultimately leading to more inclusive, informed, and effective solutions to pressing ecological issues. Modern languages and translations enable people from different linguistic backgrounds to collaborate and share insights on sustainable practices, conservation strategies, and policy development. This collaboration is essential for addressing global challenges like climate change, biodiversity loss, and resource management.

Keywords: languages, environmental, translation, climate, pollution

INTRODUCTION

In our quest for a sustainable future, the imperative to address environmental challenges has never been more pressing. The urgency to mitigate climate change, conserve biodiversity, and ensure environmental equity transcends borders, requiring concerted efforts and collaboration on a global scale. Yet, amidst this shared goal, language diversity stands as both a bridge and a barrier in our collective pursuit of environmental sustainability.

The fusion of modern languages and effective translations emerges as a critical linchpin in our endeavour to address environmental concerns universally. Languages serve as vessels carrying knowledge, ideas, and cultural nuances, but when these insights remain confined within linguistic boundaries, they impede the diffusion of crucial information necessary for fostering sustainable practices worldwide [1].

Consider the disparities: groundbreaking research findings on renewable energy, biodiversity conservation strategies, or innovative eco-friendly technologies often find themselves locked within the confines of a single language, limiting their reach and impact [2]. Effective translation and communication become the conduits through which these valuable insights can transcend linguistic barriers, empowering diverse communities globally to partake in sustainable actions and decision-making.

Moreover, the interplay between modern languages and environmental discourse is not unidirectional. Environmental challenges, in turn, influence language usage, shaping terminology, discourse, and communication styles. New lexicons emerge to encapsulate ecological concepts, reflecting our evolving understanding of environmental issues and the urgent need for sustainable solutions [3].

At its core, the nexus between modern languages, translations, and sustainable environmental practices embodies inclusivity and equity. It ensures that environmental knowledge is democratically accessible, regardless of linguistic backgrounds, thereby fostering a more comprehensive and diverse engagement with sustainability initiatives.

This introduction sets the stage for a journey into the dynamic relationship between language, translation, and the global pursuit of environmental sustainability. It seeks to illuminate the transformative potential inherent in breaking linguistic barriers, envisioning a world where diverse voices collaborate seamlessly in safeguarding our planet for future generations [4].

MATERIALS AND METHODS

Leveraging modern languages and translations for sustainable environmental practices involves a multifaceted approach that incorporates various materials and methods to bridge language gaps and facilitate global collaboration.

Materials:

Multilingual Communication Platforms: Utilizing digital platforms, websites, and social media channels that support multilingual content delivery is crucial. These platforms should be designed to accommodate multiple languages to disseminate environmental information widely.

Translation Software and Tools: Leveraging advanced translation software, such as machine translation tools and computer-assisted translation (CAT) tools, aids in efficiently translating content into different languages while maintaining accuracy.

Educational Materials and Resources: Developing educational materials, such as brochures, manuals, and online courses, in multiple languages enhances accessibility to environmental knowledge and best practices across diverse communities.

Language-specific Glossaries and Terminologies: Creating and updating language-specific glossaries and terminologies related to environmental sciences and sustainability helps standardize and facilitate accurate translations of technical terms [5].

Methods:

Professional Translation Services: Employing skilled translators and interpreters proficient in various languages ensures high-quality translations of environmental documents, reports, policies, and research findings.

Community Engagement and Localization: Engaging local communities and involving bilingual or multilingual individuals in the translation process ensures contextual relevance and resonance with diverse cultural and linguistic backgrounds.

Collaborative Networks and Partnerships: Building collaborative networks with international organizations, NGOs, and institutions working in the environmental sector facilitates the exchange of translated materials and fosters a collective approach to addressing global sustainability challenges.
Transcreation and Adaptation: Going beyond literal translation, transcreation involves adapting content culturally and linguistically to resonate with specific audiences while maintaining the integrity of the environmental message [6].
Accessible Multimedia Content: Using diverse multimedia formats (videos, infographics, podcasts) with multilingual subtitles or voiceovers increases accessibility and engagement across language barriers.
Training and Capacity Building: Providing training sessions and capacity-building programs for translators, environmental professionals, and stakeholders on effective communication strategies and translation practices in the environmental domain.
Continuous Evaluation and Improvement: Regularly evaluating the effectiveness of translated materials through feedback mechanisms and incorporating improvements based on user responses and evolving language trends ensures continuous enhancement.
By integrating these materials and methods, practitioners can effectively leverage modern languages and translations to bridge linguistic gaps, promote cross-cultural understanding, and advance sustainable environmental practices on a global scale.

RESULTS

The results of leveraging modern languages and translations for sustainable environmental practices encompass various positive outcomes that contribute to advancing global environmental stewardship. Here are some notable results:
1. Enhanced Access to Information:
Increased Dissemination of Knowledge: Translation efforts enable the widespread dissemination of environmental research, policies, and best practices across diverse linguistic communities, fostering greater awareness and understanding.
2. Facilitated Collaboration and Communication:
Global Collaboration: Effective translation bridges communication gaps, enabling multinational collaborations among researchers, policymakers, and environmental practitioners to share expertise and coordinate efforts for sustainable solutions [7].
Cross-Cultural Engagement: Improved communication across language barriers fosters inclusive discussions, encouraging diverse perspectives and cultural insights in environmental decision-making processes.
3. Improved Engagement and Empowerment:
Empowering Communities: Multilingual materials empower local communities to actively engage in environmental initiatives by providing accessible information tailored to their linguistic and cultural contexts.
Increased Participation: Language accessibility encourages broader participation in sustainability initiatives, enabling individuals from diverse backgrounds to contribute ideas and actions toward environmental conservation [8].
4. Strengthened Policy Implementation:
Effective Policy Dissemination: Translating environmental policies and regulations into multiple languages enhances compliance and understanding among stakeholders, facilitating better implementation at local and international levels.

Cross-Border Cooperation: Shared multilingual documents and agreements facilitate cooperation among nations, encouraging joint efforts in addressing transboundary environmental challenges.

5. Expanded Educational Reach:

Multilingual Educational Resources: Translation of educational materials and resources supports environmental education programs worldwide, promoting sustainable practices among students and educators in diverse linguistic settings.

Accessible Learning: Increased accessibility to multilingual environmental content fosters a deeper understanding of ecological issues and encourages informed decision-making at all levels of society.

6. Cultural Preservation and Integration:

Preservation of Indigenous Knowledge: Translation efforts aid in preserving and sharing indigenous ecological knowledge and practices, recognizing the value of diverse cultural perspectives in sustainable environmental practices [9].

Integration of Diverse Perspectives: Encouraging multilingual communication integrates diverse cultural approaches to environmental conservation, enriching global sustainability strategies.

7. Enhanced Public Engagement and Awareness:

Increased Advocacy: Communicating environmental issues in various languages amplifies advocacy efforts, rallying broader public support and raising awareness about pressing ecological challenges [10].

Behavioural Change: Multilingual communication campaigns encourage sustainable behaviours and lifestyle changes by reaching diverse audiences with tailored messages.

8. Continuous Improvement and Innovation:

Feedback and Iterative Processes: Feedback mechanisms on translated materials facilitate continuous improvement, allowing for better adaptation of messages and strategies based on user responses and evolving language trends [11].

Innovation in Communication: The intersection of languages and environmental communication encourages innovation in communication strategies, adapting to technological advancements and changing linguistic landscapes [12].

By leveraging modern languages and translations in the realm of sustainable environmental practices, these results collectively contribute to a more interconnected, informed, and proactive global community dedicated to addressing environmental challenges and fostering a sustainable future [13].

CONCLUSION

Leveraging modern languages and translations has emerged as a critical gateway to achieving global environmental sustainability. It serves as a conduit, breaking down linguistic barriers and enabling the widespread dissemination of knowledge, policies, and innovations crucial for addressing environmental challenges.

The integration of languages facilitates inclusivity and empowerment within the realm of environmental conservation. By ensuring accessibility to information across diverse linguistic backgrounds, it empowers communities, individuals, and stakeholders to actively engage in sustainable practices and decision-making processes. Efforts to bridge language gaps foster collaboration and enhance cross-cultural understanding in the pursuit of sustainable environmental practices. Multilingual communication encourages diverse perspectives, knowledge exchange, and cooperative endeavours among global stakeholders, enriching environmental initiatives.

Multilingual approaches play a pivotal role in environmental education, advocacy, and policy implementation. They support educational outreach, facilitate effective advocacy efforts, and enhance the implementation of environmental policies and regulations across borders.

Recognizing the intersectionality between language and environmental discourse is crucial. This connection highlights the dynamic relationship between linguistic diversity, cultural contexts, and the evolution of environmental terminology, fostering a more holistic approach to sustainability.

The process of leveraging languages and translations for sustainability is an ongoing journey marked by continuous improvement and adaptation. Feedback mechanisms, technological advancements, and evolving language trends drive the need for constant refinement and innovation in communication strategies.

Ultimately, the utilization of modern languages and translations underscores the collective responsibility and global impact in safeguarding our planet. It emphasizes the interconnectedness of nations, cultures, and ecosystems, urging a unified commitment to sustainable environmental practices for the well-being of current and future generations.

In conclusion, the convergence of modern languages, translations, and sustainable environmental practices signifies a powerful force driving change on a global scale. By embracing linguistic diversity and fostering effective communication, we pave the way for a more inclusive, informed, and collaborative approach toward achieving a sustainable and resilient future for all.

The convergence of modern languages, translations, and sustainable environmental practices represents a transformative force that transcends geographical, cultural, and linguistic boundaries. This integration stands as a pivotal catalyst in catalysing positive change on a global scale, offering profound implications for the future of our planet.

Embracing linguistic diversity within the realm of sustainable environmental practices is not merely about language translation but honouring and leveraging the richness of diverse linguistic expressions. It acknowledges the wealth of indigenous knowledge, cultural practices, and perspectives that contribute uniquely to environmental stewardship.

The fusion of languages and translations amplifies the reach and impact of environmental initiatives. It dismantles language barriers, ensuring that critical information, scientific findings, and innovative solutions can transcend linguistic confines, reaching individuals and communities worldwide.

By embracing linguistic diversity, environmental communication becomes more inclusive and accessible. It ensures that marginalized communities, minority language speakers, and those with limited access to resources can actively engage in environmental discourse, fostering a more equitable and participatory approach to sustainability.

Multilingualism facilitates knowledge exchange and collaboration among experts, researchers, policymakers, and communities across borders. It encourages the sharing of best practices, lessons learned, and diverse perspectives, fostering a more holistic understanding of environmental challenges and fostering innovative solutions.

The integration of languages and translations contributes to nurturing a global environmental consciousness. It enables the dissemination of environmental values, ethical principles, and behavioural changes necessary to address pressing ecological issues, fostering a collective sense of responsibility towards the planet.

Effective multilingual communication supports the development and implementation of sustainable environmental policies and regulations on a global scale. It facilitates the translation of complex legal and technical documents, ensuring coherence and compliance across diverse linguistic contexts.
By transcending language barriers, the convergence of languages and translations inspires collaborative action. It encourages individuals, organizations, governments, and businesses to unite in a shared commitment toward sustainable practices, recognizing the interdependence of humanity and the environment.
Embracing linguistic diversity in environmental communication acknowledges the need for adaptive responses to environmental challenges. It promotes diverse perspectives on adaptation, resilience, and sustainability, fostering a more comprehensive approach to building a resilient future in the face of environmental changes.
In essence, the convergence of modern languages, translations, and sustainable environmental practices represents a transformative paradigm shift in how we perceive, communicate, and address environmental issues. By harnessing the power of language diversity and effective communication, we pave the way for a more inclusive, informed, and collaborative approach, thereby fostering a sustainable and resilient future for all inhabitants of our planet.

ACKNOWLEDGEMENTS

Support was also received by the project Horizon Europe (HORIZON) 101071300 - Sustainable Horizons -European Universities designing the horizons of sustainability (SHEs)

REFERENCES

[1] Smuleac Laura, Silvica Oncia, Anisoara Ienciu, R Bertici, A Șmuleac, C Pițiga. A study on the possibilities of using groundwater in rural communities in south-western Banat plain, Research journal of agricultural science, Vol 45, No 2, 2013;

[2] Hillman, M., Fawcett, T & Rajan, S.C. The Suicidal Planet: How to Prevent Global Climate Catastrophe. New York: Thomas Dunne, 2007;

[3] Șmuleac Laura, Ciprian Rujescu, Adrian Șmuleac, Florin Imbrea, Isidora Radulov, Dan Manea, Anișoara Ienciu, Tabita Adamov, Raul Pașcalău. Impact of Climate Change in the Banat Plain, Western Romania, on the Accessibility of Water for Crop Production in Agriculture, Agriculture, Vol 10, 2020

[4] Kagawa, F. & Selby, D. (EDS). Education and Climate Change: Living and Learning in Interesting Times. New York: Routledge, 2010;

[5] Læssøe,J. Schnack, K., Breiting, S. & Rolls, S. Climate Change and Sustainable Development: The Response from Education. IALEI, 2009;

[6] Pike, G. & Selby, D. Global Teacher, Global Learner. Londres: Hodder & Stoughton, 1988;

[7] Pașcalău R., Șmuleac L.,. Stanciu S. M, Imbrea F., Șmuleac A., Bakli M., Amara,M., Non- formal education in teaching foreign languages for agriculturists, Research Journal of Agricultural Science, 54 (2), ISSN: 2668-926X, 2022.

[8] Șmuleac A, C Popescu, F Imbrea, G Popescu, L Șmuleac. Topographic and cadastre works for the establishment of an animal farm with NPRD funds, measure 121, Vărădia, Caraș-Severin county, Romania, International Multidisciplinary Scientific GeoConference: SGEM 3, 685-692, 2016;

[9] Șmuleac, L., Rădulescu H., Imbrea F., Șmuleac A., Pașcalău R., Water management to reduce floods in the hydrographic Basin Bega-Timiș, International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 22(3.2), pp. 247–254, 2022 [10] Hamilton, C. Requiem for a Species: Why We Resist the Truth About Climate Change. Londres: Earthscan, 2010;

[11] UNESCO. Education au changement climatique en vue du développement durable. Paris: UNESCO, 2010;

[12] Șmuleac Laura, Simona Niță, Anișoara Ienciu, Adrian Șmuleac, Dicu Daniel, Topographic survey for the monitoring of the impact of the BRUA/ROHUAT pipe on water flow in the irrigation system at Fântânele, Arad County, Romania, International Multidisciplinary Scientific GeoConference: SGEM, Vol 3, 2016;

[13] Pașcalău, R., Șmuleac, L., Stanciu, S., Imbrea, F., Șmuleac, A., Modern translation in climate change nowadays, International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 22(4.2), pp. 351–356, 2022.

MANAGEMENT AND ASSESSMENT OF URBAN GREEN: A DIGITAL DATABASE APPLICATION

Xanthopoulou-Tsitsoni, Valia [1]

Prof. Dr. Andreopoulou, Zacharoula[2]

Papagiannopoulou, Dimitra [3]

Morfopoulos, N. [4]

[1]School of Economics, Aristotle University of Thessaloniki, **Greece**

[2 3] School of Forestry & Natural Environment, Laboratory of Silviculture, Aristotle University of Thessaloniki, **Greece**

[4] BSc Chemical Engineer, Aristotle University of Thessaloniki, **Greece**

ABSTRACT

Green development is a kind of development that considers two factors· social and environmental impacts of development. Information and Communication Technologies (ICTs) are tools that can be used in monitoring of the impacts of climate change. They can demonstrate the effects of climate change and they can contribute to the proper management of urban green via their role as decision-making tools. Urban areas have an important role in urban ecosystems through multifunctional role of trees, such as the reduction of extreme temperatures. A digital database was constructed in the framework of the project LIFE Climate Value of Urban Trees- LIFE18 GIC/IT/001217. This database provides data and significant information about green areas, from four medium-sized cities, and is a key tool in urban green management as it takes into account the assessment of urban green. This online database can be used by both· experts and citizens. Aim of this paper is to describe the digital database (lifeclivut.treedb.eu). Web database app was created to be used as a user-friendly tool for experts such as environmentalists, foresters, urban planners with main aim supporting urban green areas. Foresters and environmentalists can use this web app for proper management and design as in this app exist data about the urban trees (tree height, breast diameter, position, tree health).

Keywords: Climate change, assessment and management of urban green areas, digital database, ICTs

INTRODUCTION

Green IT is a term in IT science that describes its use in the context of the natural environment and natural resources, taking into account both sustainability and sustainable development [1]. New technologies have entered in life significantly and the online services offer an opportunity for a sustainable regional development. The online services offered by the new ICTs are an important decision-making tool [2]. These tools in urban

planning include new methods that contribute to proper management and planning and the decision-making process [3]. Following the proposed Sustainable Development Goals (SDGs) by United Nations, countries have long considered the establishment of sound policy to deal with climate change risk. Governments have continued implementing the infrastructure improvement and introducing ICT to increase the efficiency [4]. Co-movements among the ICT and CO_2 emissions have changed and progressed over the frequency and time domain [5]. The rapid development of modern ICT has led to its application in various sectors such as agroforestry. One of the major benefits of using ICT is the direct dissemination of knowledge to stakeholders through the development of appropriate IT models that can contribute to research and policy making in the agroforestry sector. Reducing energy consumption, increasing environmental awareness, environmental monitoring are some of the benefits of Green Informatics [6]. Sustainable development requires the decoupling of economic growth from environmental impacts and from the use of natural resources [7]. ICT is a tool for green energy and contains energy saving systems as it is correlated to low carbon emissions. In addition, they can contribute to mitigating the effects of climate change through environmental monitoring, simulation through DSS (Discussion Support System). Decision support systems help future environmental scenarios and support sustainable environmental governance [8]. One of the problems that humanity has to face is urbanization. Tools as they play a basic role in supporting urban planning, and proper management are necessary to ensure a high quality of life in cities and to protect urban biodiversity [9]. Urban planners have tried to create urban areas that have elements from nature. Management, design and the protection of urban green areas are necessary for the sustainability and livability of cities [10]. Nowadays, new approaches based on the integration of ecosystem services have been considered as an alternative to traditional spatial planning models. Main aim of these models is to achieve a higher level of environmental performance that is necessary to enhance the quality of life of citizens and preserve resources for future generations [11]. An online database, that could improve the proper management of urban areas, was constructed in the framework of a european project, LIFE CliVut project. The LIFE CliVUT project (LIFE18 GIC/IT/001217) is coordinated for Greece by the Department of Forestry and Natural Environment of the Aristotle University of Thessaloniki and the Forestry Informatics Laboratory also participates. One of the objectives of the project is to mitigate the impact of climate change. The project partners are the University of Perugia, the Municipalities of Bologna and Perugia, the Italian Institute CESAR and the Portuguese Institute ISG. The main objective of the LIFE CLIVUT project is to develop and implement an Urban Green Space Management Strategy, focusing on Climate Change mitigation, taking into consideration the urban greenery conditions in four medium-sized Mediterranean cities. In this online database, data from the monitoring of the trees and dendrometric characteristics are entered. The observation of the growth stages of trees and shrubs was done through the science of phenology. Plant Phenology is the scientific study of their biological stages, such as flowering, leaf development, seed production and senescence in relation to climatic conditions [12, 1]. Environmental factors such as temperature and humidity can affect phenological stages [13]. Leaf development time, flowering onset time, fruit development time, leaf fall time are the main phenological stages [12]. Recording the date of onset of phenological stages and

their correlation with temperature plays an important role in the study of plant phenological stages [14, 15]. The dendrometric characteristics (tree height, breast diameter) are used to extract results about various functions of the trees such as the absorption of CO_2, PM10, about the biodiversity etc. This digital application, in which data about urban trees are entered, contributes to proper management and assessment of urban green areas as it exports results and it is a decision-making tool.

MATERIAL AND METHOD

The online application, a database of trees, was constructed under the European project LIFE CliVut project LIFE18 GIC/IT/001217 and contains the data of the monitoring of the phenological stages of silvicultural urban trees in three Phenological Monitoring Areas (PMAs). PMAs were also created within the same project. Each PMA contains 100 individuals (5 per species), 10 tree species and 10 shrub species. The trees were planted at a distance of 5 meters from each other and the bushes at a distance of 4 meters. The tree database includes data related to tree and shrub inventory, dendrometric characteristics such as tree height, breast diameter. Except for these, data from trees of 10 urban green areas in Thessaloniki were entered. So, this application extracts results about PM10 absorption, CO_2 absorption. Georeferenced data referring to the urban green asset is also available. Plant phenological stages are studied from March to December 2021 till now on a weekly basis according to BBCH scale. The BBCH scale as a standard system for describing the phenological stages of plant growth has been introduced by the Global Phenological Monitoring Network [16].A digital inventory of ten urban green areas of was created. There is information about the trees and shrubs in these areas such as dendrometric characteristics, CO_2 absorption, PM10 absorption and biodiversity. It is an innovative tool that allows the visualization of trees and shrubs and their contribution to the ecosystem.

Till now, only experts could use similar software. They could insert data into the applications and the citizens only could see the results. Now, this database can be used by both· experts and citizens. Citizens also can insert data of trees in this web app via their pc or their mobile phone. Also, this application, which takes into consideration allometric equations universally accepted, calculates directly CO_2 and PM10 absorption.

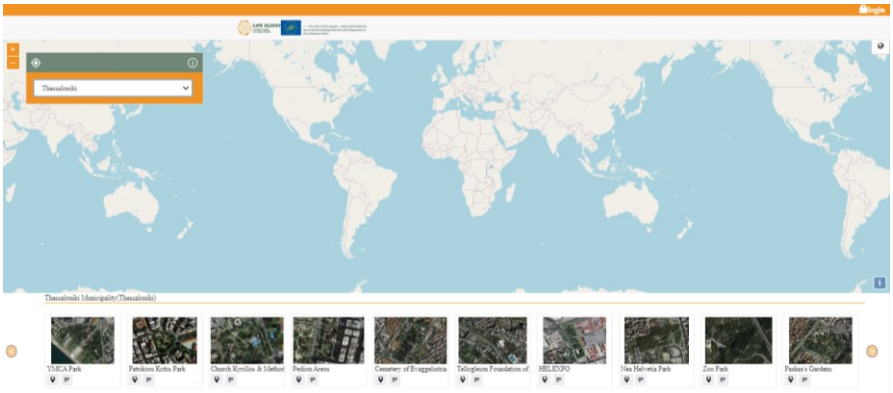


Figure 1. Homepage LIFE Clivut tree database. The ten Census Green Areas in Municipality of Thessaloniki.

https://doi.org/10.5593/sgem2023V/4.2/s19.37

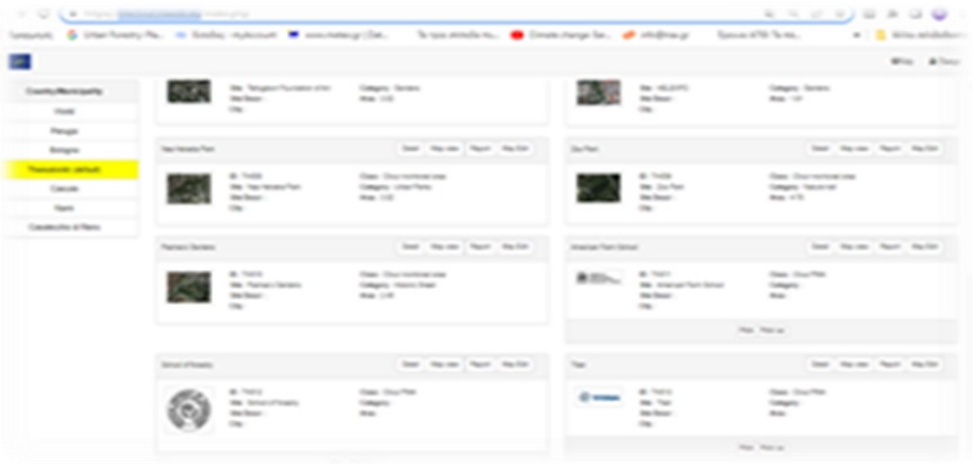


Figure 2. Homepage after login of LIFE Clivut tree database. Details about 10 Census areas in Municipality of Thessaloniki (Number of trees/area, $m^{2,}$ species/area, CO_2).

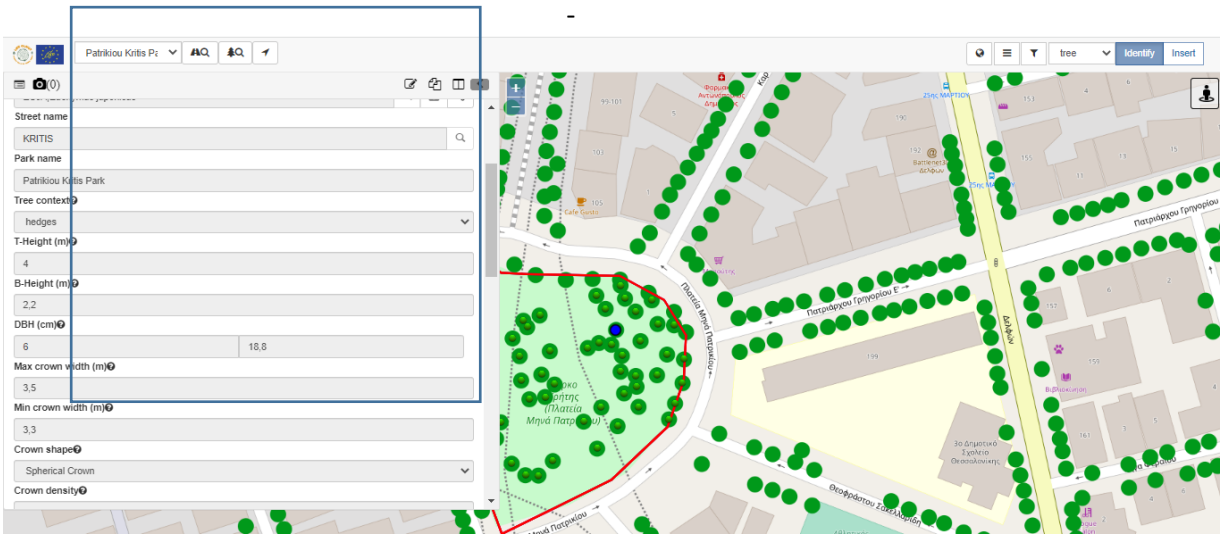


Figure 3. Information of the selected urban tree (tree height, breast diameter, site) this area (blue in Figure).

RESULTS

In the online LIFE Clivut database, the data from the phenological monitoring in the three PMAs are entered (Figure 4).

The growth of trees and shrubs is visible via the web app (Figure 5).

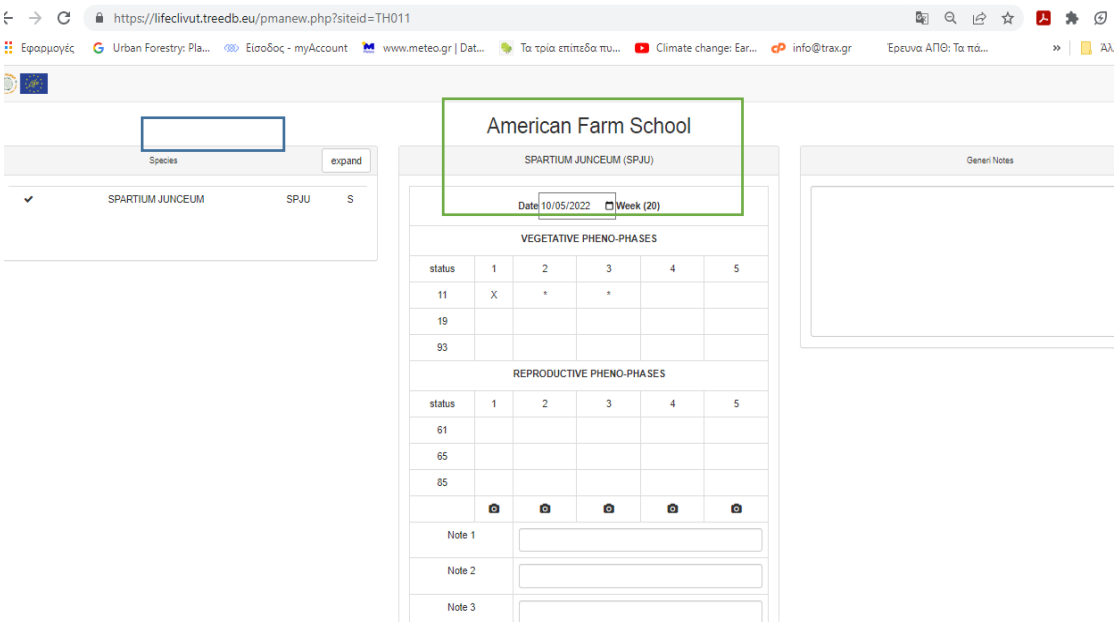


Figure 4. Blue frame shows the species on the left side. On the right side (green frame) are shown the phenological stage, the date and the current stage of the selected species. In this page, data from the phenological monitoring are entered.

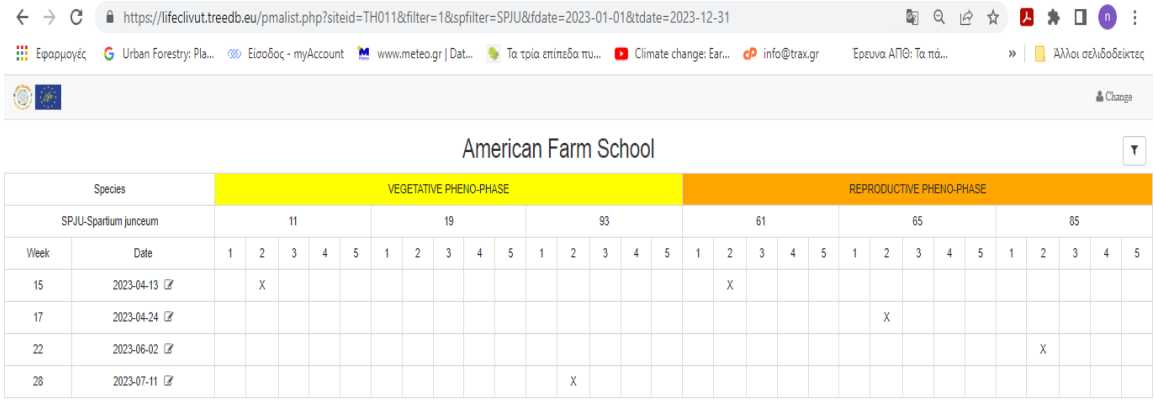


Figure 5. The growth of trees and shrubs. This table shows the species, the vegetative and reproductive phases.

This application shows the phenological stages of each species and provides the possibility for correlations and processing of the data depending on the climatic conditions. Except for the phenological data, data from urban trees in urban green areas are entered in this database.

CONCLUSIONS

The proper management of urban areas must take into account the green elements that exist in them. Green areas must be designed and managed appropriately with a long-term approach to have a healthy urban ecosystem. The decision-making process is an important activity especially in the proper management and assessment of urban green spaces. Therefore, special care should be taken when making decisions about the design of open urban green spaces.

In conclusion, ICT could improve decision-making in this field. Urban green areas are essential components of a city. They guarantee an adequate quality of life by providing several ecosystem services.

ICTs are widely employed for environment and climate monitoring including data from the growth of species. Adaptation to climate change involves taking action to mitigate its effects and proper management for the future. Also, ICTs can be used in promoting sustainable practices.

REFERENCES

[1] Andreopoulou, Z., Papagiannopoulou D., Tsitsoni, T. (2023). Online *app for the evaluation of climate change impact in urban green areas.* Proceedings of the 21st International Conference on e-Society 2023, Portugal, 485-488.

[2] Kirkenidis, Y. and Andreopoulou, Z. (2015). E-learning and the aspect of students in Forestry and Environmental Studies, *Journal of Agricultural Informatics*, 6(1). Available at: https://doi.org/10.17700/jai.2015.6.1.158.

[3] Al-Douri, F.A. (2022). How information and communication tools (ICT) affect the processes and decision-making in professional urban design practice?, *URBAN DESIGN International* [Preprint]. Available at: https://doi.org/10.1057/s41289-022-00196-8.

[4] N'dri, L. M., Islam, M., & Kakinaka, M. (2021). ICT and environmental sustainability: any differences in developing countries?. Journal of Cleaner Production, 297, 126642.

[5] Batool, R., Sharif, A., Islam, T., Zaman, K., Shoukry, A. M., Sharkawy, M. A., ... & Hishan, S. S. (2019). Green is clean: the role of ICT in resource management. Environmental Science and Pollution Research, 26, 25341-25358.

[6] Andreopoulou, Z. Manos, B. Polman, N. and Viaggi D. (Eds.) (2011). *Agricultural and Environmental Informatics, Governance and Management*: *Emerging Research Applications*. IGIGLOBAL.

[7] Hilty, L., Lohmann, W., & Huang, E. M. (2011). Sustainability and ICT-an overview of the field. Notizie di POLITEIA, 27(104), 13-28.

[8] Andreopoulou, Z., (2016). Green ICTs for Climate Change Mitigation and Energy Sustainability: EU Challenge. Calitatea, 17(S1), p.492.

[9]Kopucki, R. and Kiersztyn, A. (2015). Urban green space conservation and management based on biodiversity of terrestrial fauna – A decision support tool. *Urban Forestry and Urban Greening*, 14(3), pp.508-518.

[10] Baycan, T., Van Leeuwen, E., Rodenburg, C. (2002). Development and management of green spaces in European cities: a comparative analysis. *Research memorandum*, 2002, p.25.

[11]Pantaloni, M., Marinelli, G., Santilocchi, R., Minelli, A., Neri, D. (2022). Sustainable Management Practices for Urban Green Spaces to Support Green Infrastructure: An Italian Case Study. Sustainability, 14(7): 4243.

[12] Davi, H., Gillmann, T., Cailleret, M., Bontemps, A., Fady, B., Lefevre, F. (2011). Diversity of leaf unfolding dynamics among tree species: new insights from a study along an altitudinal gradient, *Agric For Meteorol*, 151(12):1504-1513.

[13] Rousi, M., Heinonen, J. and Neuvonen, S. (2011). Intrapopulation variation in flowering phenology and fecundity of silver birch, implications for adaptability to changing climate, Forest Ecology and Management, 262(12), pp. 2378–2385. Available at: https://doi.org/10.1016/j.foreco.2011.08.038.

[14] Tiwari, P., Verma, P. and Raghubanshi, A.S. (2021). Forest phenology as an indicator of climate change: Impact and mitigation strategies in India, Springer Climate, pp. 185–205.

[15] Papagiannopoulou, D. and Tsitsoni, T. (2022). The phenological stages of forestry species under the impact of climate change• Early data. Environmental Science and Toxicology, 6(1), 069-073.

[16] Meier, U. et. al. 2009. Phenological Growth Stages of Roses (rosasp.): Codification and description according to the BBCH scale, *Annals of Applied Biology*, 154(2), pp. 231–238.

PRECIPITATION AND TEMPERATURE CHANGES IN SLOVAKIA DURING THE GROWING SEASON IN 1961-2020

Ing. Martin Minárik[1]

Assoc. Prof. Dr. Ján Čimo[1]

Dr. Vladimír Kišš[2]

[1] Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture in Nitra, **Slovakia**

[2] Faculty of European Studies and Regional Development, Slovak University of Agriculture in Nitra, **Slovakia**

ABSTRACT

The impact of climate change is felt by people all over the world, but this change is more pronounced in Europe. In Slovakia, which is in Central Europe, we feel these changes in all areas of the economy, but most significantly in agriculture. We experience extremely high temperatures more and more often, and frequent periods of drought alternate with extreme intensity of precipitation. The aim of this paper is to compare these changes in temperature and precipitation with a reference period - the sixty-year climate normal (1961-2020). Based on data from 81 meteorological stations, maps of temperature and precipitation deviations from the climatic norm were created by interpolation for selected decades (1961-1970, 1991-2000 and 2011-2020) in the growing season (April - October). By overlaying the map outputs of temperature and precipitation, new attributes were created that comprehensively evaluate locations in Slovakia. The results show that in the 1960s the summer months were normal in terms of precipitation and subnormal in temperature, in the 1990s the areas were mostly normal in temperature and in April especially above normal in terms of precipitation. On the contrary, the last decade is characterized by above-normal temperatures throughout the entire period and below-normal precipitation at the beginning of the growing season and above-normal precipitation in the autumn months. With this contribution, we can help farmers visualize the development of temperatures and precipitation, and thus they will be able to better adapt to the development of climate change.

Keywords: climate change, temperature changes, precipitation changes

INTRODUCTION

Humanity is constantly evolving, and our activities are leaving their mark on global ecosystems. Along with a rapidly growing population, the demands on the provision of life's necessities are also increasing. This includes increasing consumption of food, water, energy, minerals, and consumables. It can be said that there is a general attitude that the

future is a distant point and does not need to be addressed. This way of life has led us into the events of global change. What makes it so unprecedented in its impact is that it is so closely linked to human activity. The global change now underway, with its extremes, is a direct consequence of human activity on the planet [1].
Among the visible manifestations of global climate change is the poleward movement of vegetation, which in turn causes the movement of fauna (e.g., insects, amphibians, birds, fish, and mammals). The budding and flowering of trees is occurring earlier, and the flight and arrival of migratory birds is changing. The water in the seas and oceans is warming, sea levels are rising and flooding is more frequent [2].
The effects of climate change can be seen most clearly in the air temperature. In Slovakia, stations monitoring climate change are evenly distributed throughout the country. Over the period 2009 - 2019, an increase in average winter temperatures was recorded at the Sliač station. The most pronounced increase in mean annual temperature has occurred over the last 30 years. The Slovak Environmental Agency notes that over the period 1881 to 2016, the average annual air temperature increased by approximately 1.73 °C. As regards precipitation, annual totals have started to be presented in the State of the Environment Report since 2010. Since this period, average annual precipitation has been on a downward trend. In 2016, this decrease represented about 0.5% reduction compared to the climatic normal of 1961-1990 [3].

MATERIALS AND METHODS

Our area of interest is in the south of Slovakia in the Danube Lowland. Specifically, the micro-regions of “Bratislava a okolie”, “Dolné Považie”, “Dolná Nitra” and “Podunajsko”. The location within Slovakia can be seen on the map in Figure 1.

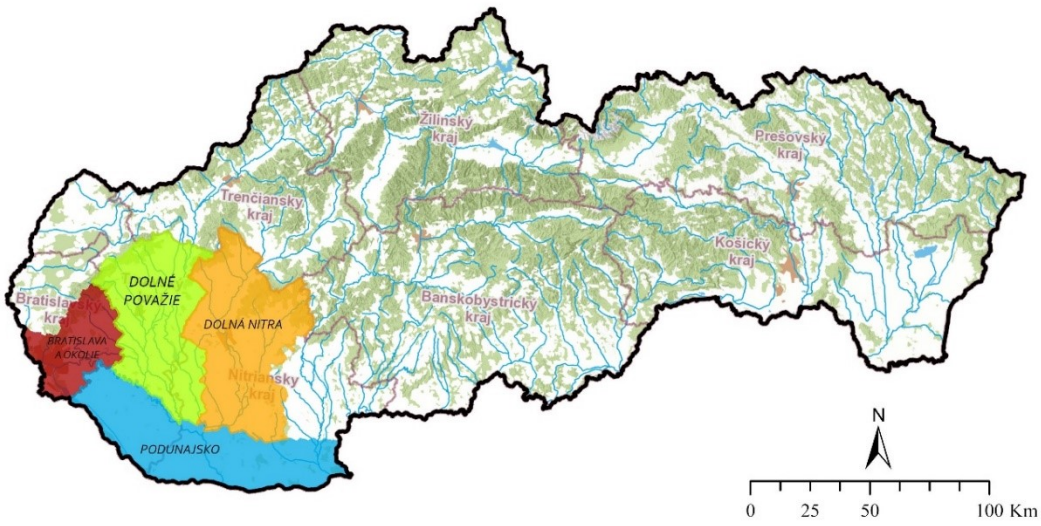


Fig 1: Map of Slovakia showing the micro-regions (*Minárik, 2023*)

These areas were selected on the basis that they contain the largest areas of intensively farmed agricultural land. The area is also characterised by a high population density. From a technical point of view, it should be noted that western Slovakia has the highest density of meteorological and climatological stations from which data were taken.
Input data on average air temperatures and precipitation totals were provided by the Slovak Hydrometeorological Institute in Bratislava and Online Agrometeorology

laboratory of Slovak university of Agriculture. These data covered the period 1961 - 2020. Since in practice climate normal are used to assess the course of climatic and meteorological phenomena, our data are divided into two climate normals. The use of a 30-year climate normal ensures a more stable course of climatic phenomena. To develop our comparison, we selected 10 climate stations that cover our selected area.
The collected data were processed in ArcGIS Pro by Esri. Interpolation was used to calculate missing values at locations where measured data from climate stations are not available. In the ArcGIS Pro environment, the Topo to Raster interpolation method was chosen for this case. We reclassified the result of the interpolation into the appropriate classes. Subsequently, map outputs were produced for each period separately.
Next, we needed to express the amount of soil moisture available for transpiration of agricultural crops in the growing season. This quantity can so far only be expressed by empirical formulas that express the relationship between rainfall and potential evaporation. The most used is the hydrometric Seljanin coefficient (HMC), which represents the ratio of rainfall (R) to the tenth of the temperature sum over a period with $t_d \geq 10.0$ °C. The hydrometric Seljanin coefficient is usually calculated for months when the average monthly temperature is above 10.0 °C. At lower temperatures, the relationship between potential evaporation and the temperature sum changes and the values of the coefficient increase. The formula for calculating the hydrometric Seljanin coefficient is:

$$HMC = \frac{\sum R}{0{,}1\ TS10}$$

where: HMC – hydrometric Seljanin coefficient
$\sum R$ – sum of rainfall
0,1 TS10 - the tenth of the temperature sum over a period with $t_d \geq 10.0$ °C

RESULTS

The result of our work is a comparison of the average air temperature and average precipitation for the growing season in our selected location. We also compared the changes in moisture availability available for plant transpiration over the growing season. For this work, we compared the changes in two periods of climatic normals, namely 1961 - 1990 and 1991 - 2020. A clear graphical comparison of the changes in temperature and precipitation is provided by the maps in Figures 2. a) - d).
From Figures 2. a) and 2. c), the temperature distributions for the different periods are evident. While in the period 1961 - 1990 the average temperature during the growing season in the southern part of the territory was in the range of 15.0 - 15.5 °C, in the period 1991 - 2020 the average temperature in this part of the territory reached values above 16.5 °C. In the northern part of the area, the average temperature between 1961 - 1990 was no more than 15,0 °C. Between 1991 - 2020, the temperature was already in the range of 15,5 °C to 16,5 °C. This represents a 3,0 - 10,0 % increase in average air temperature during the growing season.
Figures 2. b) and 2. d) show the evolution of precipitation totals in our area. Most of the territory had an average rainfall in the range of 48.0 - 51.0 mm between 1961 - 1990. The south-eastern part of the territory around Štúrovo and Komárno had average rainfall totals only up to 48.0 mm. The northern parts had the richest rainfall totals, and their average

values were higher than 54.0 mm. In contrast, between 1991 - 2020, most of the area recorded average rainfall totals ranging from 54.0 to 57.0 mm. In the central part, there is an area where rainfall reached 51.0 - 54.0 mm. The northernmost part of the area is also the richest in rainfall with an average rainfall of over 57.0 mm. The average rainfall over most of the area has increased by about 11.0 % compared to the past.

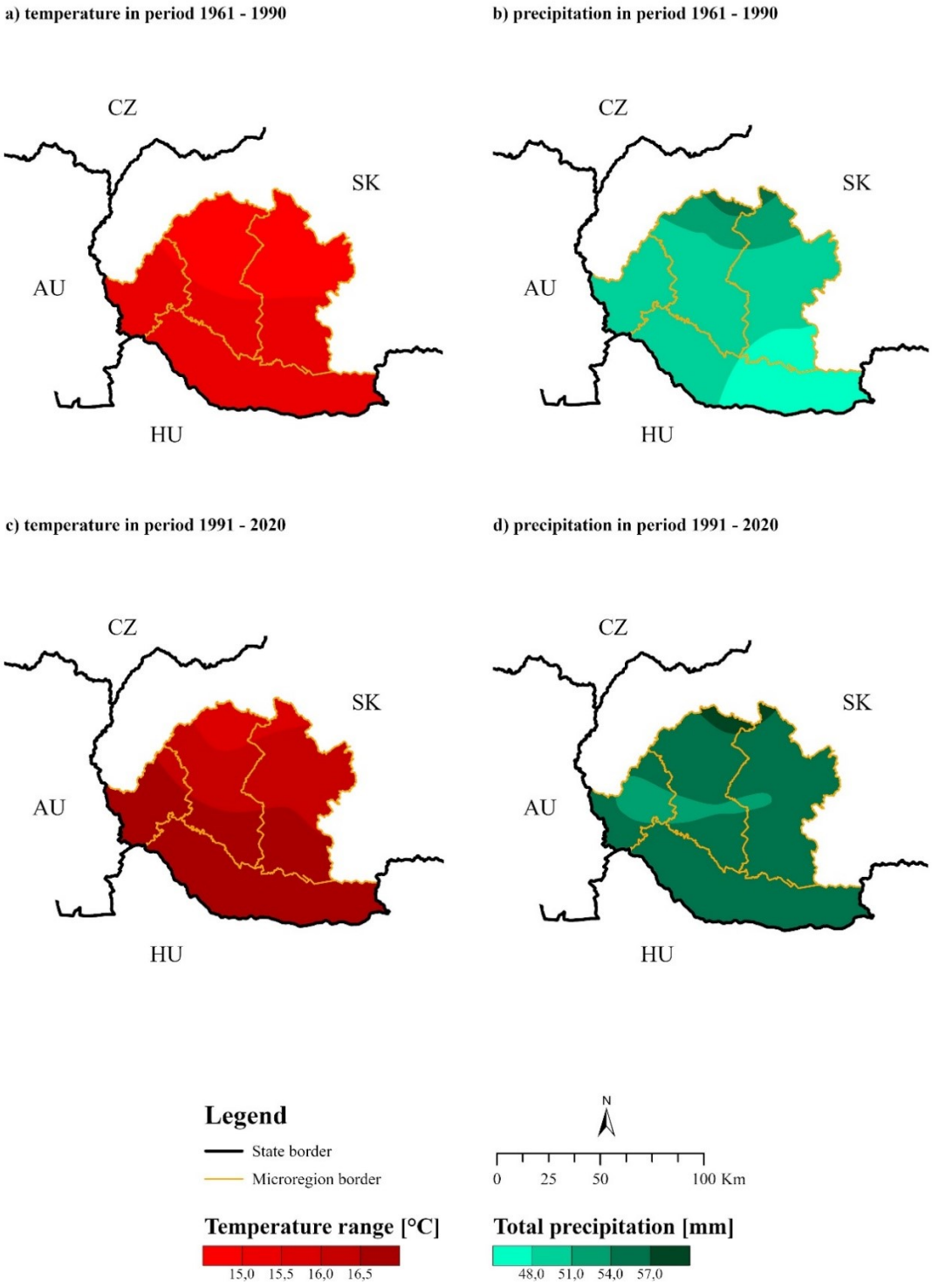


Fig 2: Changes in average temperatures and precipitation totals (*Minárik, 2023*)

Regarding the moisture supply required for transpiration of plants during the growing season, the Tables 1 and 2 show the results of the comparison. The tables show the individual coefficients for the months during the growing season for the selected stations. Coefficients higher than 1.0 are shown in red. This means that there is sufficient soil moisture in the soil during that period. The yellow colour shows coefficients with a value lower than 1.0. This phenomenon occurs when evaporation is higher than precipitation and therefore there is insufficient soil moisture in the soil. The values shown in green represent a coefficient equal to 1.0, which means that rainfall and evaporation are in equilibrium.

It is evident that, on average, September was the least soil moisture deficit at all the selected stations between 1961 - 1990. At the stations Bratislava, Hurbanovo and Nitra this situation also occurred in July. During the other months, the selected stations were sufficiently supplied with soil moisture, as the rainfall exceeded the evaporation rate.

On the contrary, in 1991 - 2020 the driest period moved one month earlier, and thus August was on average a month when the evaporation rate was higher than the rainfall rate. At Bratislava station this situation lasted on average from June to August. As can be seen, the balance between precipitation and evaporation occurred in only three situations, namely at the stations Hurbanovo, Nitra and Jaslovské Bohunice (green colour). The rest of the growing season was sufficiently moisture-protected.

Table 1: Hydrometric Seljanin coefficient in period 1961 - 1990

Station	1961-1990						
	IV.	V.	VI.	VII.	VIII.	IX.	X.
Bratislava, airport	1,17	1,21	1,20	0,89	1,06	0,86	1,21
Hurbanovo	1,24	1,19	1,10	0,84	0,99	0,83	1,06
Nitra	1,27	1,21	1,18	0,85	1,02	0,86	1,18
Piešťany	1,36	1,50	1,36	1,03	1,14	0,99	1,34
Jaslovské Bohunice	1,29	1,31	1,26	1,02	1,08	0,88	1,23

Table 2: Hydrometric Seljanin coefficient in period 1991 - 2020

Station	1991-2020						
	IV.	V.	VI.	VII.	VIII.	IX.	X.
Bratislava, airport	1,02	1,17	0,98	0,91	0,91	1,20	1,31
Hurbanovo	0,90	1,21	1,00	1,02	0,83	1,17	1,40
Nitra	1,06	1,20	1,00	0,97	0,83	1,22	1,42
Piešťany	1,16	1,22	1,24	1,09	0,92	1,29	1,54
Jaslovské Bohunice	1,04	1,23	1,04	1,00	0,94	1,30	1,48

DISCUSSION

Our results are consistent with those of other authors whose data have been analysed in other studies. For example, Blahušiaková states in her dissertation that in Slovakia the temperature increase is most pronounced between April and August. As far as the winter half-year is concerned, the highest warming is observed in December and January. In the future, average temperatures are expected to increase in all seasons of the year. For example, by 2025, temperatures are expected to increase significantly in March and October. Major changes in the distribution of precipitation will occur in different seasons of the year, where it is expected to decrease slightly during the summer. This decrease will mainly be observed in the southern part of Slovakia. A slight increase in precipitation is expected in the rest of the country, especially in the north and in winter. The increase in precipitation is not as significant as in the case of average temperatures [4].
Marková and Monoši report in their paper that between 1181 - 2018, the average air temperature in Slovakia increased by about 1.7 °C. There has also been a decrease in annual atmospheric precipitation averaging 0.5 %. In the south of Slovakia, this decrease has been as much as 10.0 % in places. The intensity of potential evaporation has also increased. All these changes have caused a decrease in soil moisture and a change in climate variability, particularly in rainfall [3].
Rataj, Galambošová and Macák state in their study that, based on air temperature measurements since the 19th century, average air temperatures in both the warm and cold half of the year have increased by approximately 2.0 °C. The temperature increases since 1980 has been significantly higher in the whole era of meteorological measurements in Central Europe. Precipitation totals have not followed a significant trend since the end of the 19th century in Central Europe, but their variability has increased. Increased average temperatures and uneven or below-average rainfall have contributed to soil drought [5].

CONCLUSION

The aim of our work was to evaluate the changes in mean temperature, mean precipitation and moisture supply required for plant transpiration during the growing season. The changes were investigated in the territory of the micro-regions “Bratislava a okolie”, “Dolné Považie”, “Dolná Nitra” and “Podunajsko”. The results show that already during the two periods studied (1961 - 1990 and 1991 - 2020), changes can be observed in all three parameters studied.
The average temperature during the growing season in most of the area increased by 3.0 - 10.0 % compared to the past. While in the past the average temperatures reached a maximum of 15.5 °C, nowadays it is more than this value. In the southern part, average temperatures are even above 16.5 °C.
As far as rainfall is concerned, there is also an increasing trend. In the past, the average rainfall during the growing season was a maximum of 51.0 - 54.0 mm. The southern parts of the area were even drier, with average rainfall of up to 48.0 mm. At present, average rainfall is increasing, reaching above 51.0 mm during the growing season.
Comparing the change in moisture availability at the selected stations, it is evident that most of the growing season is sufficiently wet, i.e., the amount of rainfall is higher than the amount of potential evaporation. The change occurs in the period when moisture is scarce, potential evaporation is higher and rainfall is lower. In the past, this period fell mainly in September, but nowadays it is shifting to August. Some stations are also vulnerable to this soil moisture deficit situation in other months of the growing season.

ACKNOWLEDGEMENTS

This publication was supported by the Cultural and Educational Grant Agency no. KEGA 026SPU-4/2023.

REFERENCES

[1] Marek V. Michal et al., Klimatická změna, príčiny, dopady a adaptace, book, Czech republic, 2022, ISBN 978-80-200-3362-8.

[2] Behringer Wolfgang, Kulturní dějiny klimatu, czech book, Czech Republic, 2010, ISBN 978-80-7432-022-4.

[3] Marková I., Minoši M., Analysis of Selected Indicators of Climate Change Asseessment in the Territory of the SR (for the Purposes of Supporting the Development of Rescue Services), In Krízový manažment, pp. 16-24, ISSN 1336-0019, available on: <https://drepo.uniza.sk/bitstream/handle/hdluniza/546/1638890133-Markova-Monosi.pdf?sequence=1&isAllowed=y>.

[4] Blahušiaková Andrea, Impact of the regional climate change on the hydrological regime with regard to extremes, dissertation, Czech Republic, 2019, available on: <https://dspace.cuni.cz/bitstream/handle/20.500.11956/115542/150046663.pdf?sequence=1&isAllowed=y>.

[5] Rataj, V., Galambošová, J., Macák, M.: Precision Farming and Climate Change. Životné prostredie, 2019, 53, 2, p. 108 – 115, available on: <http://publikacie.uke.sav.sk/sites/default/files/2019_2_108_115_Rataj_a_kol.pdf>.

THE DISTRIBUTION OF TUNGSTEN IN JELGAVA CITY AT 2022 AND 2023

PhD Candidate Jovita Pilecka-Ulcugaceva[1]

PhD Candidate Anda Bakute[1]

PhD Candidate Maris Bertins[2]

Bc. sc. ing. Kristaps Siltumens[1]

Assoc. Prof. Inga Grinfelde[1]

[1] Latvia University of Life Sciences and Technologies, **Latvia**
[2] University of Latvia, **Latvia**

ABSTRACT

Every year, cities are becoming more populated and urban traffic more intense. Urban air quality is deteriorating and causes for pollution are being sought and solutions to improve the quality of life in urban areas. Atmospheric deposits, vehicles, traffic and de-icing products are the main sources of snow pollution in cities. Snow, located near roads and streets with intense traffic, is a very useful tool for identifying the risks of traffic-related metals in the environment. In many countries, in winter, they use tires with studs made of tungsten-based material. The tires wear out to fine particles that disperse in the environment, particularly in the vicinity of roads and streets. In the environment, tungsten can also come from the incineration of waste and industry. Due to low concentrations of tungsten in the natural environment, this can be a potentially good identifier for traffic and other anthropogenic contamination. The aim of the study is to identify the risk of spreading tungsten in different areas in Jelgava. This study studied the harvested snow in 2022 and 2023. Snow was harvested at 59 monitoring points 5 m from the road or street section in Jelgava, Latvia. Tungsten concentrations were determined by ICP-MS. The average concentration of tungsten was 0.154 µg/L in 2022 and 0.342 µg/L in 2023. Five groups of tungsten distribution from low pollution risk to high pollution risk were divided using the hierarchical clustering method. The spatial distribution of divided risk groups in urban areas highlights the impact of the transport corridor and private buildings on the urban distribution of tungsten.

Keywords: tungsten, ICP-MS, air pollution, snow, traffic in the city

INTRODUCTION

In most cities, traffic is the largest contributor to particulate matter in the air, and traffic, as such, is considered one of the primary sources of environmental pollution in urban areas [6], [9]. In regions with cold climatic conditions, the study of snow becomes an essential topic of environmental research [6]. Snow can be used to monitor local air pollution caused by road traffic [6].

Snow is a good collector of organic and inorganic matter. Snow acts as a natural filter for various chemical elements, particles, and dust, especially those resulting from anthropogenic activities (for example, industry and road traffic) [1], [6], [9].

Snowflakes accumulate more atmospheric pollutants than raindrops because of their larger surface area and slower falling speed [6]. The snow also absorbs dust from the material spread on the road in winter. Using tires with studs causes additional wear on the driving part and the studs containing tungsten. This dust enters the snow and the surrounding environment, especially during winter [2], [4]. The concentration of tungsten decreases rapidly with the distance from the roadway, which indicates an indisputable source of pollution from the road [4]. In general, street dust consists of road wear material and sand that is spread, as well as tire and brake wear, engines (combustion and friction), and vehicle corrosion [1].

Due to the low concentration of tungsten in the natural environment, it can be a suitable identifier of road and traffic pollution [4]. Tungsten is released naturally into the atmosphere through wind-blown dust from the soil, or it can enter waters by leaching. Several studies have reported an increased content of tungsten in road dust rainwater runoff from the road and roadside soils, which is associated with wear of tire studs, wear and tear of cars, and intensive traffic flow [1], [6], [3]. In processes of anthropogenic origin, tungsten can still occur, for example, in ore processing processes, as a result of the production of hard metals, during the production and use of tungsten carbide, as well as as a result of the combustion of household waste, when tungsten escapes into the atmosphere [7], [8].

The aim of the study is to identify the risk of spreading tungsten in different areas in Jelgava.

MATERIALS AND METHODS

The study was carried out in the administrative territory of Jelgava City. The total area of Jelgava is 60.56 km^2 see Figure 1. One of Latvia's largest rivers, Lielupe [10], flows through Jelgava. In early 2022, the city of Jelgava had a population of 54694 [12]. The exact location and location of the control monitoring point and snow sample collection can be found in Grinfelde et al., 2021.

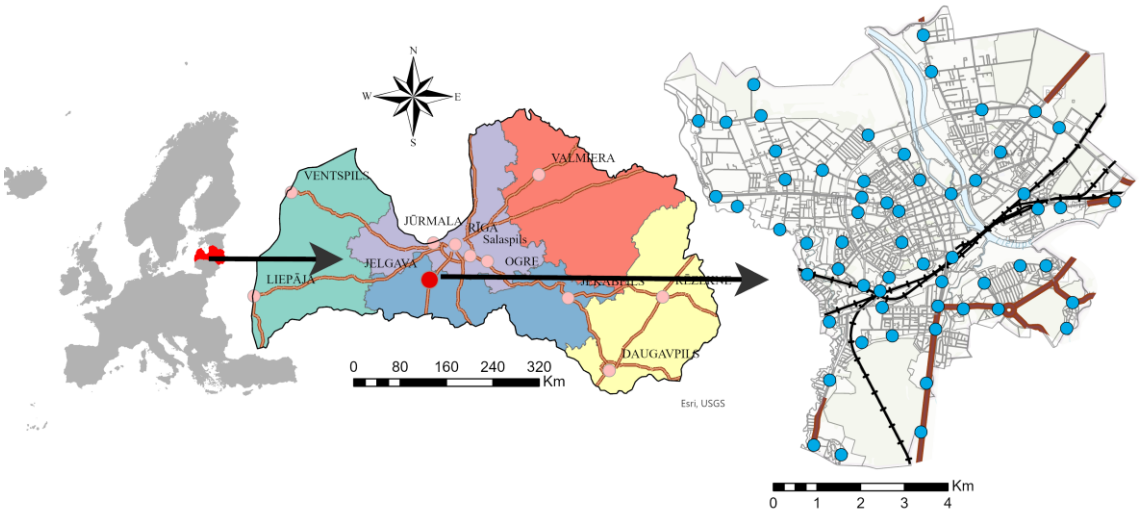


Figure 1. The geographical location of Jelgava.

Public weather data from the "Latvian Environment, Geology, and Meteorology Centre" [11] meteorological observation station "Jelgava" (56 ° 33 ′ 24,954 ″ N and 23 ° 57 ′ 50,679 ″ E) were used to describe climatic conditions during sampling. Snow samples were collected on February 4, 2022. The average air temperature on the sampling day was -2.33 °C, snow cover was 5.8 cm, and rainfall was 1.4 mm. Snow samples were collected after an 8-day exposure period. Snow samples were collected on January 9, 2023. The average air temperature on the sampling day was -2.48 °C, the average snow cover was 4 cm, and the rainfall was 0 mm on the sampling day. Snow samples were collected after a 6-day exposure period.

Snow samples were collected about 5 m from the roadway. A steel ring with an inner diameter of 25 cm was used for sample collection. Snow was collected from the ring using disposable dust-free nitrile gloves. The entire snow cover was collected from the steel ring. The snow was collected in sterile plastic containers and immediately transported to the laboratory.

Samples were analyzed using an inductively coupled plasma mass spectrometer ICP-MS, Agilent 8900 ICP-QQQ. Snow samples were analyzed according to the method described by Grinfelde et al., 2021.

Cluster analysis was performed for normalized (0-100) 2022 and 2023 data series. Agglomerative hierarchical clustering (AHC) analysis using Euclidean distance calculation and Ward's method.

RESULTS

In 2022, the minimum value for tungsten in the territory of Jelgava is 0.050 µg/L, the maximum value is 4.352 µg/L, and the median is 0.050 µg/L. the minimum value in 2023 for tungsten in the territory of Jelgava is 0.060 µg/L, the maximum value is 0.960 µg/L, and the median is 0.179 µg/L see Figure 2.

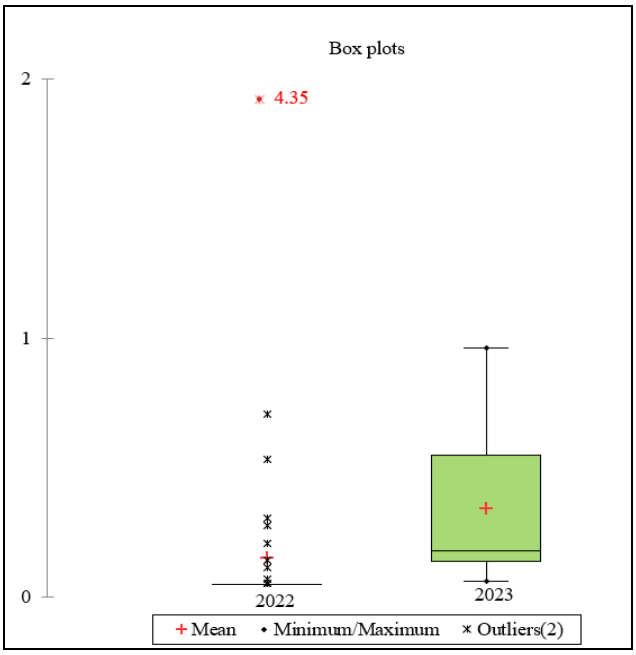


Figure 2. Variation of tungsten by year.

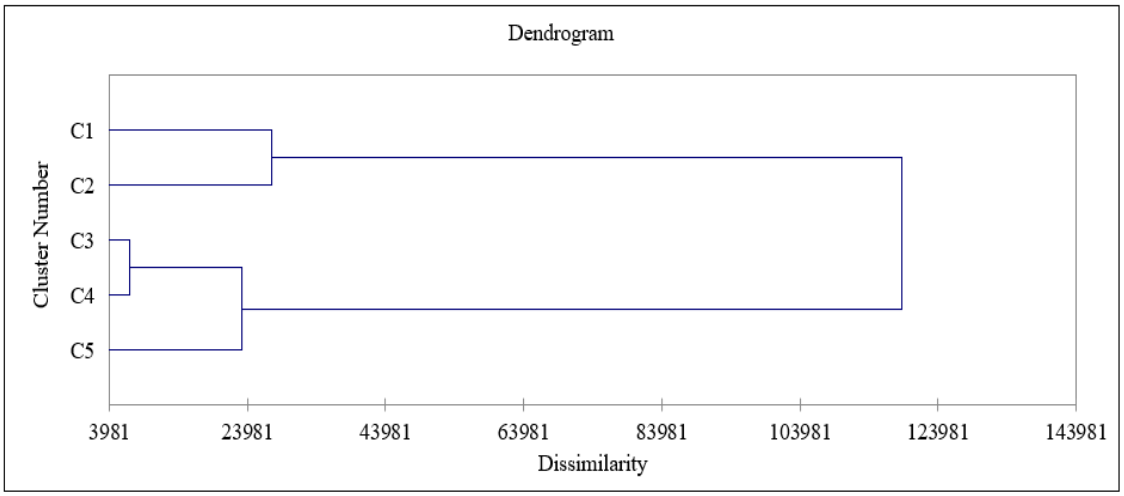


Figure 3. Hierarchical cluster analysis of tungsten.

Cluster analysis resulted in five vanadium contamination risk groups. The first cluster has a mean value of 0.119 µg/L and a median of 0.097 µg/L. The mean value of the second cluster is 2.311 µg/L, and the median is 2.311 µg/L. The mean value of the third cluster is 0.246 µg/L, and the median is 0.251 µg/L. In the fourth cluster, the mean value is 0.351 µg/L, and the median is 0.355 µg/L. In the fifth cluster, the mean value is 0.443 µg/L, and the median is 0.445 µg/L.

The minimum, maximum, average, and median values of tungsten are summarized in Table 1. The results were obtained after cluster analysis for the city of Jelgava for 2022 and 2023. See Table 1 for the breakdown by year.

Table 1. Descriptive statistics of tungsten by clusters.

Cluster by year	Minimum (µg/L)	Maximum (µg/L)	Mean (µg/L)	Median (µg/L)	Risk level
2022 | 1	0.050	1.009	0.093	0.050	Low risk
2022 | 2	4.165	4.483	4.352	4.406	Extremely high risk
2022 | 3	0.050	0.310	0.087	0.050	Medium risk
2022 | 4	0.050	0.288	0.072	0.050	Medium-high risk
2022 | 5	0.050	0.050	0.050	0.050	High risk
2023 | 1	0.050	0.250	0.144	0.143	Low risk
2023 | 2	0.260	0.280	0.270	0.270	Extremely high risk
2023 | 3	0.290	0.520	0.405	0.405	Medium risk
2023 | 4	0.530	0.740	0.635	0.635	Medium-high risk
2023 | 5	0.750	0.990	0.870	0.870	High risk

DISCUSSION

In a study conducted in Sweden, tungsten concentrations increased in winter but were much lower in summer. Average values of tungsten in road runoff in winter were 9.18 µg/L, in summer 1.06 µg/L in Svaneberg, in Norsholm they were 0.58 µg/L in summer, and 5.77 µg/L in winter. Tungsten is often neglected in road runoff studies, although it

is often used in tire studs. [4]. Our research shows the significant impact of transport corridors. The exceptionally high risk of contamination with tungsten appears in the main transit direction to Lithuania, where the highest tungsten concentrations appear at the border of the settlement, where the median value in 2022 was 4.406 µg/L.

Bourcier et al. In a 1980 study, tungsten was 15,000 µg/L in rainwater samples from roads containing street dust [5]. In the city of Jelgava, dust is regularly collected from asphalted streets. The study shows that unpaved streets are at high risk of tungsten contamination. An analysis of pollution from incineration (MWI) plants in Barcelona, Spain, concluded that tungsten concentrations in fly ash from MWI plants ranged from 13 to 17 µg/g [14]. As a result of burning, tungsten probably enters the atmosphere from the city's heat energy producer and heating equipment of private houses in the southwestern part of the city. This is evidenced by complex studies in Jelgava [14]. Tungsten concentrations in melted snow samples collected in Poland were 1.70 µg/L at the airport, 2.59 µg/L near the highway, and 1.93 µg/L at a distance of 1.5 m from the entrance in the parking lot [9]. The study conducted in Jelgava in 2022 and 2023 showed that the average tungsten concentration ranged from 0.072 µg/L to 4.352 µg/L.

CONCLUSION

Tungsten concentration in snow during the observation period from 2022 to 2023 in the city of Jelgava ranges from 0.050 µg/L to 4.483 µg/L.

Tungsten concentrations in Jelgava city territory differ significantly, and the influence of transport corridors and heating systems is marked.

Tungsten concentration in snow during the observation period from 2022 to 2023 in the city of Jelgava ranges from 0.050 µg/L to 4.483 µg/L.

Tungsten concentrations in Jelgava city territory differ significantly, and the influence of transport corridors and heating systems is marked.

The study identified five levels of risk of tungsten contamination in the air. In low-risk areas, tungsten concentrations correspond to the natural background of tungsten pollution. The tungsten source can be transport and heating systems in medium and medium-high-risk areas.

The spatial distribution of tungsten in the city over the years requires the collection of more extended data series to be able to make accurate statements about the sources of vanadium pollution and their impact on air quality in urban areas.

Future work should be done on methods to help identify and differentiate between diffuse and point sources of tungsten air pollution.

REFERENCES

[1] Peltola P., Tyre stud derived tungsten carbide particles in urban street dust, Boreal Environment Research, vol. 11, pp 161-168, 2006.

[2] Furberg A., Arvidsson R., Molander S., Dissipation of tungsten and environmental release of nanoparticles from tire studs: A Swedish case study, Journal of Cleaner Production, vol. 207, pp 920-928, 2019.

[3] Bäckström M., Karlsson S., Allard B., Metal Leachability and Anthropogenic Signal in Roadside Soils Estimated from Sequential Extraction and Stable Lead Isotopes. Environmental Monitoring and Assessment, vol. 90, pp 135–160, 2004.

[4] Bäckström M., Nilsson U., Håkansson K., Allard B., Karlsson S., Speciation of Heavy Metals in Road Runoff and Roadside Total Deposition, Water, Air and Soil Pollution, vol. 147, pp 343–366, 2003.

[5] Bourcier D. R., Hindin E., Cook J. C., Titanium and tungsten in highway runoff at Pullman, International Journal of Environmental Studies, vol. 15:2, pp 145-149, 1980.

[6] Bućko M. S., Magiera T., Johanson B., Petrovský E., Pesonen L. J., Identification of magnetic particulates in road dust accumulated on roadside snow using magnetic, geochemical and micro-morphological analyses, Environmental Pollution, vol. 159/issue 5, pp 1266-1276, 2011.

[7] Keith L. S., Wohlers D.W., Moffett D. B., Rosemond Z.A., ATSDR evaluation of potential for human exposure to tungsten, Toxicology and Industrial Health, vol. 23/issue 5-6, pp 309-345, 2007.

[8] Ushakova E., Menshikova E., Karavaeva T., Puzik A, Volkova M., Vaganov S., Assessment of trace elements pollution in snow piles removed from residential areas in Perm, Russia, Journal of Water and Land Development, No.56, pp 109-117, 2023.

[9] Adamiec E., Wieszała R., Strzebońska M., Jarosz-Krzemińska E., An attempt to identify traffic related elements in snow, Geology, Geophysics & Environment, vol. 39, pp 317-329, 2013.

[10] Grinfelde I., Pilecka-Ulcugaceva J., Bertins M., Viksna A., Rudovica V., Liepa S., Burlakovs J., Dataset of trace elements concentrations in snow samples collected in Jelgava City (Latvia) in December 2020, Data in Brief, vol. 38, Article number 107300, 2021.

[11] The Latvian Environment, Geology and Meteorology Centre is a governmental service under the Ministry of Environmental Protection and Regional Development of Latvia. Temperature and other statistical parameters. Available at: https://www.meteo.lv/meteorologija-datu-meklesana/?nid=461 (in Latvian). Last accessed 16.08.2023.

[12] Central Statistical Office. Available at: https://stat.gov.lv/lv/statistikas-temas/iedzivotaji/iedzivotaju-skaits/247-iedzivotaju-skaits-un-ta-izmainas (in Latvian). Last accessed 16.08.2023.

[13] Pilecka J., Grinfelde I., Valujeva K., Straupe I., Purmalis O., The temporal and spatial analysis of transport impact on trace elements in snow samples, In International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, Bulgaria, vol. 18/ issues 4.2, pp 671–677, 2018.

[14] Williams M., Todd D., Roney N., Crawford J., Coles C., McClure P. R., Garey J.D., Zaccaria K., Citra M., Toxicological Profile for Manganese, Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles, 2012.

THE GOOD, THE BAD AND THE EFFECTIVE? TRENDS IN SUSTAINABILITY REPORTING IN NEW ZEALAND-LISTED COMPANIES

Assoc. Prof. Dr. Michaela Balzarova[1]

Kathryn Bell[2]

[1] University of Canterbury, **New Zealand**
[2] The Alliance – **Christchurch, New Zealand**

ABSTRACT

This paper examines sustainability reporting trends of 50 NZX-listed companies, focusing on their effectiveness, transparency, and accountability. As sustainability reporting remains largely voluntary, unregulated, and inconsistent, this study investigates the current status quo in ESG/sustainability reporting in New Zealand. As a result, it provides managerial advice on what currently constitutes effective sustainability reporting. This paper of qualitative nature explores reporting practices across five key criteria: report type, adopted reporting frameworks, type of adopted governance within an organisation, type of adopted assurance and trends in social disclosures. The findings point to improvements in the quality of sustainability reporting in New Zealand, however, find that most organisations fall short of international standards. The study underscores the necessity for a balanced disclosure of material issues, suggesting the adoption of the GRI and integrated reporting frameworks need to deliver a comprehensive picture of a company's value creation. Additionally, it offers key recommendations for making sustainability reporting more meaningful. This includes disclosure of both positive and negative impacts, data sources, methodologies, and key assumptions used. Furthermore, it identifies the importance of stakeholder engagement to assess and address organisational material impacts, the necessity to adopt clear measurable sustainability goals, and the use of third-party verification for the enhanced reports' credibility.

Keywords: ESG reporting, sustainability reporting, New Zealand

INTRODUCTION

As businesses worldwide seek alignment with a wider pool of stakeholder expectations, sustainability reporting has become important to convey information related to the organisation's environmental, social, and governance (ESG) performance. Driven by the demand for enhanced transparency, several reporting trends have emerged. At the forefront is the significant shift towards integrated reporting. This approach offers a comprehensive view by merging financial and sustainability data, enhancing the depth and breadth of disclosures [1]. Accompanying this shift is the widespread adoption of reporting frameworks, particularly the Global Reporting Initiative (GRI), the Sustainability Accounting Standards Board (SASB), and focusing on the United Nations Sustainable Development Goals (SDGs). Evidence suggests that adopting an integrated reporting approach can improve sustainability reporting overall [2]. The use of widely recognised reporting frameworks aim to set benchmarks for sustainability disclosures that intends drive towards enhanced consistency and credibility in the reporting

landscape [3], [4]. However, the continuous increase of new reporting frameworks has created tensions between traditional and new approaches that focus on materiality topics in sustainability reporting [5]. Our literature identified several trends that shape sustainability reporting practices. These trends evolve around practices related to (1) Assurance, (2) Board Diversity, (3) Frameworks, (4) Communication, (5) Impact, (6) Indicators, (7) Materiality and (8) Practice orientation. (1) Assurance in sustainability reporting is not always represented by a credible verification process [6]. Companies with better sustainability performance are more likely to use third parties to ensure their sustainability reports [7]. (2) Board diversity: A diverse board structure that includes women can positively impact sustainability reporting and gender policies disclosed in CSR or sustainability reports [8]. (3) Frameworks fall short in their comparability, specifically in inter-firm and inter-temporal comparisons. This inconsistency arises as indicators are frequently added or removed without clear explanations, leading to difficulties in comparing data across different firms and time periods [9]. (4) Communication: Sustainability reporting is often perceived with a substantial amount of skepticism. This is particularly evident among the top 24 Fortune 500 Global companies, which tend to employ 'fantasy-type' narratives and 'rhetorical vision' in their sustainability communications, casting doubts on the authenticity and reliability of their reports. [10]. Rahim and Omar (2017), however, found that managers of Malaysian public listed companies viewed online communication for sustainability reporting positively [11]. (5) Impact: Positive relationships between sustainability reporting disclosure and business characteristics were found, along with a positive correlation between sustainability reporting & market value [10]. Studies also found that transparency & legitimacy are the main reasons for the publication of sustainability reports. The quality of sustainability reporting positively impacts risk and access to finance. (6) Indicators: There is a growing emphasis on the importance of reporting on social values, guidelines, and the accuracy of disclosures in sustainability reporting. The trend of including performance indicators in sustainability reports is on the rise, with social indicators related to labor being commonly reported. However, there is a concern that some companies may strategically report on less relevant indicators, potentially obscuring their true level of commitment to sustainability. [12]. (7) Materiality: Another evolving facet of sustainability reporting is the dynamic interplay between traditional and contemporary approaches to materiality. The studies by [12], [13] suggest that there is a need for a new and more effective method for materiality analyses in practice. This trend is manifested in the emergence of the "meta-materiality" method, which integrates a multitude of perspectives into the materiality assessment process [5]. Even though the materiality assessment poses a challenge for many companies, it is not always directly recognized and can, therefore, quickly lead to inaccuracies in published reports. There are some reports that draw unjustified conclusions based on materiality assessments due to a lack of available information and low-quality data that is used [5]. The problem with these results represents the neglect of stakeholders' different perspectives, which allows focus on only a small portion of issues [5]. Nevertheless, further studies show that the more emphasis a company puts on its materiality analysis, the better the stakeholders are represented in the sustainability report, which then provides more meaningful insights into a company's performance with regard to handling its own ESG ambitions [14]. (8) Practice orientation includes a focus on environmental practices such as emissions and consumption, a lack of realism in listed firms' sustainability reporting, and the increasing integration of the circular economy into sustainability efforts

(Székely & Brocke, 2017). There are obstacles to sustainability reporting, such as cost reduction and low efficiency. Overall, sustainability reporting is gaining momentum in the private sector and is increasingly seen as responsible business practice due to its global impact. Failure to communicate this impact can result in litigation and reputational damage [15]. Additionally, there are key trends shaping global sustainability reporting, as identified by [15]. These include regulatory developments, standardization, integrated reporting, stakeholder engagement, and technological innovation. Regions like New Zealand have instituted and implemented mandatory climate-related disclosure legislation in 2023 for financial institutions with turnover over NZD 1 Billion. This regulation declares New Zealand the first country to make climate risk reporting mandatory for certain companies and to pioneer and champion this change (Threlfall et al., 2020). 80% of NZX's top 100 companies reported on some SDG aspects. Large firms in New Zealand have stronger uptake of voluntary sustainability reporting (Proxima, 2019). However, there was significant variation in the standard and type of information voluntarily reported (Proxima, 2019).

The research conducted by Nilipour et al. (2020), which involved examining 264 reports from New Zealand companies, revealed that over a 10-year period, the readability of these reports improved by only 6.5 percent. [16]. Furthermore, [16] concluded that there is a significant negative correlation between the average readability score and the quality of reporting. This finding underscores the importance for organisations to produce reports that are easy to read and understand. [16]. Momin et al. (2022) concluded that using visuals in reports improves the reading experience for NZX companies as photos draw on the reader's emotions. In contrast, tables and figures draw on the logical side of them [17]. From the Australasian perspective, [18] suggest that as companies in regions like Australia and New Zealand mature. They noted a clear evolution in engaging management, decentralizing reporting, zeroing in on materiality, and aptly deploying KPIs. [19] showed that assurance rates for sustainability reports among the top Australasian companies remain low, which can enhance the perception of greenwashing and reduce the reporting quality.

In conclusion, the realm of sustainability reporting is undergoing a transformative phase. With advancements in integrated reporting, the development of comprehensive frameworks, and a renewed focus on materiality, businesses are now better equipped to meet stakeholder expectations, fortify their corporate reputation, and make meaningful contributions towards a sustainable future.

METHODS AND FINDINGS

This report assesses the sustainability reporting quality of NZX50 companies as of 18/03/23 (NZX, 2023). It examines key factors such as report type, framework, assurance practices, social disclosures, and governance metrics (Table 1). The type of report played a significant role in the ranking system, with Integrated Reporting (IR) being the preferred method. IR best aligns ESG results and targets with a company's financial performance, according to [2]. Sustainability reporting was second-ranked, while annual reporting was the least preferred due to its varying ESG detail. The analysis found that only 32% of NZX50 companies utilised IR to communicate with stakeholders (Table 2). On the other hand, the bottom third of companies relied solely on annual reporting, with limited sustainability reporting. The report analyses firms' reporting frameworks and identifies that combining multiple reporting frameworks is

preferred to create a more robust and transparent report. From the NZX50 reports, 38% used the Global Reporting Initiative framework, 44% used Task Force on Climate-related Financial Disclosures (TCFD), 44% mentioned the Sustainable Development Goals, 12% highlighted the External Reporting Board requirements, and 30% used other frameworks (Table 2).

Table 1 Grading Rubric for NZX50

Key Criteria	Metric	Rating
Report Type	Sustainability Report	0.75
	Integrated Reporting	1.00
	Annual Report	0.25-0.75
	Maximum Rating	1.00
Key Criteria	Metric	Rating
Reporting Framework	GRI	0.45
	SDG	0.15
	TCFD	0.30
	XRB	0.05
	Other	0.05
	Maximum Rating	1.00
Key Criteria	Metric	Rating
Governance	Clear goals	0.25-0.70
	Industry Benchmarking	0.05-0.15
	Remuneration Structure	0.05-0.15
	Maximum Rating	1.00
Key Criteria	Metric	Rating
Assurance	Entire Report Assured	1.00
	GHG	0.25
	Carbon	0.25
	Maximum Rating	1.00
Key Criteria	Metric	Rating
Social Disclosures	Diversity	0.05-0.25
	Wage Equity	0.05-0.25
	Modern Slavery	0.05-0.25
	Safety	0.05-0.25
	Maximum Rating	1.00
	Maximum Total Rating	5.00

Assurance was identified as a crucial factor for ensuring transparency and integrity in ESG reports [20]. This paper supports the research by [20] that a significant shortage in third-party assurance in NZX50 reporting exists. The analysis identified that only 14% of reports fully assured the organisation's ESG performance, but 30% of GHG and 42% of carbon statements were independently assured. It was interesting to note that all seven companies that sought full assurance were from the Electrical (service & supply) and Banking sectors. The rubric was developed to capture the social impacts of organisations within ESG reporting. Critical social disclosures were identified as Diversity, Wage Equity and Modern Slavery. The detail assessed the reporting shared, from a mention (5%) to detailed metrics (25%) for each category. Across all 50 reports, the average score for all social disclosures was 37%, highlighting a significant gap in the quality and inclusion of social factors in the NZX50 reporting. Modern slavery was the weakest criterion, receiving a mention in only 24 reports, with an average score of 8% and no reporting getting full marks (see Table 3). Finally, governance factors were examined to incentivise, analyse, and develop ESG targets. Clear goals, industry benchmarking, and remuneration structure were identified as crucial metrics for successful governance, helping ensure that ESG targets are met and leading to positive organisational change. Despite improvements in sustainability reporting, New Zealand is still behind the international standard, and existing frameworks make comparative performance assessment difficult. While 58% of reports had clear goals, only 18% included industry benchmarking or CEO remuneration tied to ESG performance.

Table 2 Analysis of NZX Top 50 Companies by Market

Analysis of NZX Top 50 Companies by Market Capitalisation			
Key Criteria	Metric	Reports	%
Report Type	Sustainability Report	16	32%
	Integrated Reporting	16	32%
	Annual Report	27	54%
Reporting Framework	GRI	19	38%
	SDG	22	44%
	TCFD	22	44%
	XRB	6	12%
	Other	15	30%
Assurance	Entire Report Assured	7	14%
	GHG	15	30%
	Carbon	21	42%
Social Disclosures	Diversity	41	82%
	Wage Equity	39	78%
	Modern Slavery	24	48%
	Safety	30	60%
Governance	Clear goals	28	56%
	Industry Benchmarking	9	18%
	Remuneration Structure	9	18%

Table 3 summarises the findings of the analysis of NZX50 reporting and shows that Integrated Reporting (IR) and Sustainability reporting are the preferred methods to communicate ESG performance to stakeholders amongst the top reporters, while reporting via Annual reports remains the default option for the non-reporters. GRI, SDG, and TCFD have gained traction, with many top reporters using all three frameworks. Multiple reporting frameworks are also crucial to creating a more transparent report. This study highlights a significant shortage in third-party assurance in NZX50 reporting, with only 14% of reports having full assurance. Additionally, the report identifies a significant gap in the quality and inclusion of social factors in NZX50 reporting, with an average score of 37% for all social disclosures. Governance factors are also crucial for incentivising, analysing, and developing ESG targets, but only 18% of reports included CEO remuneration tied to ESG performance. Overall, the findings highlighted the need for companies to improve their ESG reporting to achieve a more sustainable future.

DISCUSSION

For NZX-listed companies sustainability reporting presents an avenue to showcase leadership within their respective sectors. This study confirmed that reporting used as a tool for communication with stakeholders must be paired with effective corporate governance and incentives to create meaningful change [21]. The issues of enhanced transparency via independent verification seem a little embedded in practice. In the absence of verification, external stakeholders may find it challenging to assess the actual quality of a company's sustainability reports. Additionally, beyond the immediate focus on a product or service, vagueness can lead to perceived greenwashing, which is associated with deceptive practices and can harm the entire brand [22]. Moreover, greenwashing can sow confusion and diminish consumer willingness to pay across the board [22].

Across many regions globally, there's an escalating imperative for companies to include specific sustainability metrics and environmental stewardship details within their annual disclosures. This heightened focus contributes to improved strategic integration and perceived credibility, demonstrated by minimal variation when comparing the periods before and after an intervention, such as the introduction of regulation [23]. To further bolster corporate reputation, NZX-listed organisations should expand their disclosures beyond carbon footprint to encompass a broader spectrum of sustainability metrics. Such comprehensive reporting will benchmark performances against industry peers, affirm dedication to sustainable operations, and gain the trust of stakeholders through externally assured reports.

The study of [24] identified the presence of “organisational hypocrisy” in corporate sustainability reporting due to a lack of explanatory clearness of the information and the explicit formulation of the demands the company makes on its stakeholders in order to make the pro-environmental changes [24]. Avoiding such outcomes can be achieved by transparent materiality assessment that embraces consultation with a variety of stakeholders who are impacted by the company's operations or have a significant interest in its activities. Some potential stakeholders that could be consulted include (1) Co-operative Members who are already active and engaged with companies. (2) Customers engaging with both local and international clients to address concerns over

product quality and the environmental and social footprint of the company. (3) Employees soliciting insights across various departments, from procurement to sales,

Table 3 Full Grading Rubric for NZX 50 company

			Report Type				Reporting Framework						Assurance				Social Disclosures						Governance				
#	CODE	NAME	SR	IR	AR	RATING	GRI	SDG	TCFD	XRB	Other	RATING	Yes	GHG	Carbon	RATING	Diversity	Wage Equity	Modern Slavery	Safety	RATING	Clear goals	Industry Benchmarking	Remuneration Structure	RATING	Total Rating
			0.75	1	0.25-0.75		0.45	0.15	0.3	0.05	0.05		1	0.25	0.25		0.05-0.25	0.05-0.25	0.05-0.25	0.05-0.25		0.25-0.70	0.05-0.15	0.05-0.15		5
14	CEN	Contact Energy Limited		1.00		1.00	0.45	0.15	0.30		0.05	0.95	1.00	0.25	0.25	1.00	0.25	0.25	0.05	0.25	0.80	0.70		0.15	0.85	4.60
8	SPK	Spark New Zealand Limited	0.75	1.00		1.00	0.45		0.30	0.05		0.80	1.00	0.25	0.25	1.00	0.25	0.25	0.05	0.25	0.80	0.70	0.05	0.15	0.90	4.50
4	MEL	Meridian Energy Limited (NS)		1.00		1.00	0.45	0.15	0.30	0.05		0.95	1.00	0.25	0.25	1.00	0.25	0.25	0.15	0.25	0.90	0.25		0.15	0.40	4.25
2	ANZ	ANZ Group Holdings Limited	0.75	1.00		1.00	0.45	0.15	0.30			0.90	1.00	0.25	0.25	1.00	0.15	0.25	0.15		0.55	0.70			0.70	4.15
28	VNT	Ventia Services Group Limited	0.75		0.50	0.75	0.45	0.15		0.05		0.60	1.00	0.25	0.25	1.00	0.25	0.25		0.25	0.75	0.70		0.15	0.85	3.95
1	WBC	Westpac Banking Corporation	0.75			0.75	0.45	0.15	0.30	0.05	0.05	0.65	1.00	0.25	0.25	1.00	0.25	0.25	0.25		0.75	0.70	0.05		0.75	3.90
24	GNE	Genesis Energy Limited (NS)	0.75	1.00		1.00	0.45	0.15	0.30	0.05		0.95		0.25	0.25	0.25	0.25	0.25	0.05	0.25	0.80	0.70		0.15	0.85	3.85
50	KMD	KMD Brands Limited		1.00		1.00	0.45	0.15	0.30		0.05	0.95		0.25	0.25	1.00	0.25	0.25	0.25	0.25	0.75	0.70	0.15		0.85	3.80
11	ALD	Ampol Limited		1.00		1.00	0.45	0.15	0.30			0.90	1.00	0.25	0.25	1.00	0.05	0.25	0.05	0.25	0.60	0.25	0.05		0.30	3.80
45	WHS	The Warehouse Group Limited		1.00		1.00	0.45					0.45		0.25	0.25	0.50	0.25	0.25		0.25	0.75	0.70			0.70	3.40
5	AIA	Auckland International Airport Limited	0.75		0.50	0.75		0.15	0.30	0.05		0.50		0.25	0.25	0.50	0.25	0.25	0.15	0.25	0.90	0.70			0.70	3.35
26	AIR	Air New Zealand Limited (NS)	0.75		0.50	0.75		0.15	0.30	0.05		0.50		0.25		0.25	0.25	0.25		0.25	0.75	0.70			0.70	2.95
31	SKC	SkyCity Entertainment Group Limited		1.00		1.00	0.45					0.45				0.00	0.25	0.25	0.05	0.25	0.80	0.70			0.70	2.95
3	FPH	Fisher & Paykel Healthcare			0.50	0.50	0.45	0.15	0.30			0.90			0.25	0.25	0.05	0.05	0.05	0.25	0.40	0.70		0.15	0.85	2.90
30	PCT	Precinct Properties Limited (NS)		1.00		1.00	0.45		0.30		0.05	0.80			0.25	0.25	0.05	0.05	0.05	0.25	0.40	0.25	0.15		0.40	2.85
44	THL	Tourism Holdings Limited		1.00		1.00			0.30		0.05	0.35		0.25	0.50	0.50	0.05			0.25	0.30	0.70			0.70	2.85
20	CNU	Chorus Limited (NS)	0.75			0.75		0.15	0.30		0.05	0.50				0.00	0.25	0.25	0.05	0.25	0.80	0.70			0.70	2.75
21	FBU	Fletcher Building Limited	0.75		0.75	0.75	0.45	0.15	0.30		0.05	0.95			0.25	0.25	0.05	0.05	0.05	0.25	0.40	0.25		0.05	0.30	2.65
10	MCY	Mercury NZ Limited (NS)		1.00		1.00	0.45		0.30			0.75				0.00	0.25	0.25			0.50				0.00	2.25
9	EBO	Ebos Group Limited	0.75			0.75	0.45	0.15			0.05	0.65				0.00	0.05	0.05	0.05	0.25	0.40	0.25		0.15	0.40	2.20
36	KPG	Kiwi Property Group Limited	0.75			0.75		0.15			0.05	0.20		0.25		0.25	0.05	0.05			0.10	0.70	0.15		0.85	2.15
16	POT	Port of Tauranga Limited		1.00		1.00			0.30			0.30			0.25	0.25	0.05			0.25	0.30	0.25			0.25	2.10
32	FRW	Freightways Group Limited	0.75			0.75		0.15				0.15			0.25	0.25				0.25	0.25	0.70			0.70	2.10
12	MFT	Mainfreight Limited	0.75			0.75	0.45	0.15	0.30		0.05	0.95				0.00	0.05				0.05	0.25	0.05		0.30	2.05
37	PFI	Property for Industry Limited	0.75			0.75	0.45		0.30			0.75		0.25	0.25	0.50				0.25	0.30				0.00	2.05
39	VSL	Vulcan Steel Limited			0.25	0.25						0.00		0.25	0.25	0.50	0.25		0.05	0.25	0.55	0.70			0.70	2.00
48	SPG	Stride Property Ltd			0.50	0.75						0.45		0.25		0.25			0.05	0.25	0.30	0.25			0.25	2.00
29	SUM	Summerset Group Holdings Limited	0.75	1.00		1.00		0.15	0.30		0.05	0.05		0.25		0.25	0.05		0.05	0.25	0.35	0.25			0.25	1.90
49	ARV	Arvida Group Limited		1.00		1.00					0.05	0.05				0.00	0.25	0.25	0.05	0.25	0.80				0.00	1.85
23	GMT	Goodman Property Trust (NS)			0.50	0.50	0.45				0.05	0.50			0.25	0.25	0.05			0.25	0.30				0.00	1.55
34	MNW	Manawa Energy Limited		1.00		1.00			0.30			0.30				0.00	0.05				0.05				0.00	1.35
15	ATM	The a2 Milk Company Limited			0.50	0.50		0.15			0.05	0.20				0.00	0.05		0.05	0.25	0.35	0.25		0.05	0.30	1.35
17	VCT	Vector Limited (NS)			0.50	0.50		0.15				0.15				0.00	0.25	0.05		0.25	0.55				0.00	1.20
13	IFT	Infratil Limited			0.50	0.50			0.30		0.05	0.35				0.00	0.05	0.05	0.05		0.05	0.25			0.25	1.15
22	TEM	Templeton Investment Trust Plc	0.75			0.75		0.15				0.15				0.00	0.05	0.05	0.05		0.15				0.00	1.05
47	RBD	Restaurant Brands New Zealand Limited			0.25	0.25						0.00				0.00	0.05	0.25		0.25	0.55		0.05		0.00	0.80
7	FCT	F&C Investment Trust PLC			0.25	0.25		0.15	0.30			0.45				0.00					0.00				0.05	0.75
41	ARG	Argosy Property Limited			0.25	0.25						0.00			0.25	0.25	0.05				0.05				0.00	0.55
43	DGL	Delegat Group Limited			0.25	0.25						0.00				0.00	0.05		0.05	0.05	0.15				0.00	0.40
19	RYM	Ryman Healthcare Limited			0.25	0.25						0.00				0.00	0.05		0.05	0.05	0.10				0.00	0.35
38	HGH	Heartland Group Holdings Limited			0.25	0.25						0.00				0.00		0.05			0.05		0.05		0.05	0.35
42	SKL	Skellerup Holdings Limited			0.25	0.25						0.00				0.00	0.05		0.05		0.10				0.00	0.35
25	JPG	JPMorgan Global Growth & Income plc			0.25	0.25					0.05	0.05				0.00					0.00				0.00	0.30
33	PPH	Pushpay Holdings Limited			0.25	0.25						0.00				0.00	0.05				0.05				0.00	0.30
35	VHP	Vital Healthcare Property Trust			0.25	0.25						0.00				0.00	0.05				0.05				0.00	0.30
46	HFL	Henderson Far East Income Limited			0.25	0.25						0.00				0.00	0.05				0.05				0.00	0.30
6	AFI	Australian Foundation Investment			0.25	0.25						0.00				0.00					0.00				0.00	0.25
18	TCL	The City of London Investment Trust Plc			0.25	0.25						0.00				0.00					0.00				0.00	0.25
27	BIT	The Bankers Investment Trust Plc			0.25	0.25						0.00				0.00					0.00				0.00	0.25
40	BGP	Briscoe Group Limited			0.25	0.25						0.00				0.00					0.00				0.00	0.25
		Total # of Reports	16	16	27.00		19	22	22	6	15		7	15	21		41.00	39.00	24.00	30.00		28.00	9.00	9.00		
		% of Reports	32%	32%	54%		38%	44%	44%	12%	30%		14%	30%	42%		82%	78%	48%	60%		56%	18%	18%		

for a holistic view of operational risks and improvement opportunities. (4) Suppliers who provide feedback on procurement policies and their alignment with sustainability objectives. (5) Local Communities that enhance an understanding of the impacts on communities surrounding the sourcing and processing locations. (6) NGOs and Advocacy Groups gleaning inputs from organizations with environmental and social focuses. (7) Industry Bodies and Regulators adhering to sustainability reporting standards and expectations set by industry and regulatory groups. Furthermore, post-consultation on the identified most significant sustainability matters should be prioritized and woven into NZX-listed organisations' governance and strategy. The sustainability reporting process should then prioritize identifying key issues, establishing measurable goals, and tracking progress through defined KPIs. This study revealed differences in companies' maturity to report on sustainability aspects. Similarly to [18] findings, the maturity was significantly related to "deeper embedding and routinisation of sustainability reporting" [18]. According to [18] organisations striving to transition to a mature firm shall focus on four steps. First, the management needs to be included to enable the second step, related to the decentralization of the reporting. This is followed by the materiality process approach, and lastly, the adequate utilization of KPIs for precise and reasonable target setting.

CONCLUSION

This paper investigated NZX-listed organisations and their reporting practices showcased via corporate sustainability reports. This research identified the adoption of an integrated reporting framework embedded in the Global Reporting Initiative (GRI) standards, which were complemented by a robust materiality assessment and alignment with the Sustainable Development Goals (SDGs) at the forefront of transparent sustainability practices. The way companies implement sustainability aspects varied in this study quite strongly. Analysis of NZX50 companies revealed a deficiency in social factor reporting, with an average coverage of only 37%. Governance aspects, vital for setting and incentivizing ESG goals, were also often underreported, with a scant 18% of reports linking CEO compensation to ESG outcomes. Lastly, it is expected that utilising the GRI Standards and SDG frameworks will ensure global standard alignment and enhance inter-firm and inter-termporal comparability.

REFERENCES

[1] W. C. Adams, "Conducting Semi-Structured Interviews," in *Handbook of Practical Program Evaluation*, John Wiley & Sons, Ltd, 2015, pp. 492–505. doi: 10.1002/9781119171386.ch19.

[2] M. Montecalvo, F. Farneti, and C. de Villiers, "The potential of integrated reporting to enhance sustainability reporting in the public sector," *Public Money & Management*, vol. 38, no. 5, pp. 365–374, Jul. 2018, doi: 10.1080/09540962.2018.1477675.

[3] R. Hahn and M. Kühnen, "Determinants of sustainability reporting: a review of results, trends, theory, and opportunities in an expanding field of research," *Journal of Cleaner Production*, vol. 59, pp. 5–21, Nov. 2013, doi: 10.1016/j.jclepro.2013.07.005.

[4] R. G. Eccles and M. P. Krzus, *One Report: Integrated Reporting for a Sustainable Strategy*. John Wiley & Sons, 2010.

[5] S. Jørgensen, A. Mjøs, and L. J. T. Pedersen, "Sustainability reporting and approaches to materiality: tensions and potential resolutions," *Sustainability Accounting, Management and Policy Journal*, vol. 13, no. 2, pp. 341–361, Jan. 2021, doi: 10.1108/SAMPJ-01-2021-0009.

[6] O. Boiral and I. Heras-Saizarbitoria, "Sustainability reporting assurance: Creating stakeholder accountability through hyperreality?," *Journal of Cleaner Production*, vol. 243, p. 118596, Jan. 2020, doi: 10.1016/j.jclepro.2019.118596.

[7] "Corporate Sustainability Performance and Assurance on Sustainability Reports: Diffusion of Accounting Practices in the Realm of Sustainable Development - Braam - 2018 - Corporate Social Responsibility and Environmental Management - Wiley Online Library." Accessed: Nov. 10, 2023. [Online]. Available: https://onlinelibrary.wiley.com/doi/full/10.1002/csr.1447
[8] K. Furlotti, T. Mazza, V. Tibiletti, and S. Triani, "Women in top positions on boards of directors: Gender policies disclosed in Italian sustainability reporting," *Corporate Social Responsibility and Environmental Management*, vol. 26, no. 1, pp. 57–70, 2019, doi: 10.1002/csr.1657.
[9] A. Cardoni, E. Kiseleva, and S. Terzani, "Evaluating the Intra-Industry Comparability of Sustainability Reports: The Case of the Oil and Gas Industry," *Sustainability*, vol. 11, no. 4, Art. no. 4, Jan. 2019, doi: 10.3390/su11041093.
[10] M. Hossain, Md. T. Islam, M. A. Momin, S. Nahar, and Md. S. Alam, "Understanding Communication of Sustainability Reporting: Application of Symbolic Convergence Theory (SCT)," in *Business and the Ethical Implications of Technology*, K. Martin, K. Shilton, and J. Smith, Eds., Cham: Springer Nature Switzerland, 2022, pp. 257–280. doi: 10.1007/978-3-031-18794-0_14.
[11] Universiti Utara Malaysia, N. Rahim, N. Omar, and Universiti Teknologi MARA, Kedah, "Online Communication and Sustainability Reporting: The Managerial Issues," *JKMJC*, vol. 33, no. 3, pp. 231–249, Sep. 2017, doi: 10.17576/JKMJC-2017-3303-14.
[12] A. Calabrese, R. Costa, N. L. Ghiron, and T. Menichini, "Materiality Analysis in Sustainability Reporting: A Method for Making it Work in Practice," *European Journal of Sustainable Development*, vol. 6, no. 3, Art. no. 3, Oct. 2017, doi: 10.14207/ejsd.2017.v6n3p439.
[13] M. Guix, M. J. Bonilla-Priego, and X. Font, "The process of sustainability reporting in international hotel groups: an analysis of stakeholder inclusiveness, materiality and responsiveness," *Journal of Sustainable Tourism*, vol. 26, no. 7, pp. 1063–1084, Jul. 2018, doi: 10.1080/09669582.2017.1410164.
[14] "Materiality Assessment Is an Art, Not a Science: Selecting ESG Topics for Sustainability Reports - Jilde Garst, Karen Maas, Jeroen Suijs, 2022." Accessed: Nov. 10, 2023. [Online]. Available: https://journals.sagepub.com/doi/full/10.1177/00081256221120692
[15] D. Meech and T. Bayliss, "International developments in sustainability reporting," Ministry of Business, Innovation and Employment (New Zealand), Report, Jun. 2021. Accessed: Nov. 10, 2023. [Online]. Available: https://apo.org.au/node/312998
[16] A. Nilipour, T.-A. D. Silva, and X. Li, "The Readability of Sustainability Reporting in New Zealand over time," *Australasian Accounting, Business and Finance Journal*, vol. 14, no. 3, pp. 86–107, Jul. 2020, doi: 10.14453/aabfj.v14i3.7.
[17] M. Momin and S. Chong, "An analysis of the use of visual elements in workplace diversity disclosure," *Pacific Accounting Review*, vol. 35, no. 2, pp. 336–363, Jan. 2023, doi: 10.1108/PAR-06-2022-0089.
[18] M. B. Farooq and C. de Villiers, "Understanding how managers institutionalise sustainability reporting: Evidence from Australia and New Zealand," *Accounting, Auditing & Accountability Journal*, vol. 32, no. 5, pp. 1240–1269, Jan. 2019, doi: 10.1108/AAAJ-06-2017-2958.
[19] H. Al-Shaer and M. Zaman, "CEO Compensation and Sustainability Reporting Assurance: Evidence from the UK," *J Bus Ethics*, vol. 158, no. 1, pp. 233–252, Aug. 2019, doi: 10.1007/s10551-017-3735-8.
[20] P.-C. K. Hsiao, T. Scott, and Z. Zang, "A snapshot of sustainability assurance market in New Zealand," *Pacific Accounting Review*, vol. 34, no. 5, pp. 669–686, Jan. 2022, doi: 10.1108/PAR-08-2021-0142.
[21] H. Hartikainen, M. Järvenpää, and A. Rautiainen, "Sustainability in executive remuneration - A missing link towards more sustainable firms?," *Journal of Cleaner Production*, vol. 324, p. 129224, Nov. 2021, doi: 10.1016/j.jclepro.2021.129224.
[22] C. Santos, A. Coelho, and A. Marques, "The greenwashing effects on corporate reputation and brand hate, through environmental performance and green perceived risk," *Asia-Pacific Journal of Business Administration*, vol. ahead-of-print, no. ahead-of-print, Jan. 2023, doi: 10.1108/APJBA-05-2022-0216.
[23] G. Mion and C. R. Loza Adaui, "Mandatory Nonfinancial Disclosure and Its Consequences on the Sustainability Reporting Quality of Italian and German Companies," *Sustainability*, vol. 11, no. 17, Art. no. 17, Jan. 2019, doi: 10.3390/su11174612.
[24] C. Higgins, S. Tang, and W. Stubbs, "On managing hypocrisy: The transparency of sustainability reports," *Journal of Business Research*, vol. 114, pp. 395–407, Jun. 2020, doi: 10.1016/j.jbusres.2019.08.041.

THE IMPACT OF CLIMATE CHANGE ON TEMPERATURES AND PRECIPITATION IN THE REGIONS OF SLOVAKIA IN 1961-2020

Dr. Vladimír Kišš

Ing. Martin Minárik

Dr. Jakub Pagáč

Dr. Andrej Tárník

Assoc. Prof. Dr. Martin Prčík

Slovak University of Agriculture in Nitra, **Slovakia**

ABSTRACT

Climate change affects everyday life, especially extremely high temperatures and long-term droughts alternating with intense rainfall. Changes in rainfall distribution and increasing temperatures force farmers to adapt to new conditions. In our contribution, we compared temperature deviations from the climatic normal and the percentage of precipitation from the climatic normal. For the complexity of the data comparison, a 60-year normal was created for 81 stations in Slovakia. Data interpolation created maps were superimposed on each other and created new areas comparing the complex development of temperatures and precipitation in individual regions of Slovakia (Bratislava, Trnava, Nitra, Trenčín, Žilina, Banská Bystrica, Prešov and Košice region) for the decades 1961-1970, 1991-2000 and 2011-2020 and in individual months of the year. The tables show the percentage development of the area of newly created areas in individual regions and decades. To see how currently warmer and drier areas have invaded, especially in winter, when there is an insufficient layer of snow cover in the southern regions, which affects soil moisture especially in spring. With this contribution, we can help farmers visualize the evolution of temperatures and precipitation over decades, which will also indicate future developments and they can better adapt to the impacts of climate change.

Keywords: climate change, precipitation, temperature

INTRODUCTION

Climate change is happening now – and even if we effectively reduce global emissions, it will continue to impact our lives. Flooding, droughts, heatwaves and other climate-related hazards are becoming more intense, longer and more frequent. These hazards carry significant health and economic impacts. While all Europeans are affected by climate change, some communities and regions are more vulnerable. Global mean near-surface temperature between 2013 and 2022 was 1.13 to 1.17°C warmer than the pre-industrial level, which makes it the warmest decade on record. European land temperatures have increased even faster over the same period by 2.04 to 2.10°C [1]. In Europe there has been a pattern of increasing seasonal rainfall north of the Mediterranean basin and decreases in southernmost Europe. This pattern is stronger and more widespread in winter, and weaker in summer when Eastern and Western Europe

also experience dry conditions [2]. Extreme weather, including recent heatwaves in many parts of the EU are already causing economic losses for farmers and for the EU's agriculture sector. Future climate change might also have some positive effects due to longer growing seasons and more suitable crop conditions, but these effects will be outweighed by the increase in extreme events negatively affecting the sector [3]. The aim of this work is to combine temperature and precipitation deviations from the climatic norm, create new categories and compare changes within the regions of Slovakia.

MATERIALS AND METHODS

The territory of interest of this work is the Slovak Republic (Figure 1). In terms of global climate classification, the territory belongs to the northern temperate climate zone with a regular alternation of four seasons and changeable weather with a relatively even distribution of precipitation throughout the year. The climate of Slovakia is influenced by the prevailing westerly air flow in moderate latitudes between permanent pressure formations, the Azores pressure high and the Icelandic pressure low. As a result of the alternation of air masses during the year and the fact that the territory of Slovakia is very divided vertically, there are regionally very different climatic regions in our territory. Mountain ranges, especially high ones, form significant climatic divides and, together with the rugged terrain, significantly influence individual climatic elements, especially air temperature, atmospheric precipitation, air humidity, cloudiness, sunshine and wind conditions, etc. Therefore, lowlands, basins, valleys, slopes and ridges of mountain massifs have a different climatic character. The shape of Slovakia's territory, elongated in the west-east direction, also conditions the differences in temperature and precipitation between western and eastern Slovakia [4].

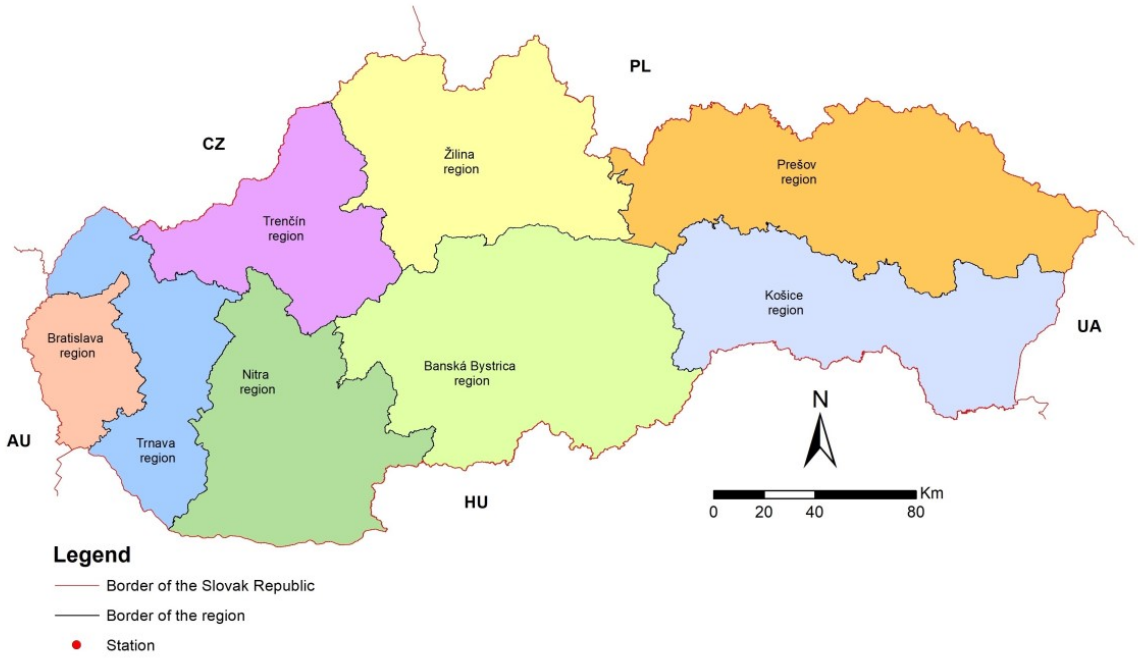


Figure 1 Regions of Slovakia

From the provided daily meteorological data from the Slovak Hydrometeorological Institute, we processed monthly average temperatures and monthly rainfall totals. From the processed data, a 60-year climate norm 1961-2020 was created, with which the decades 1961-1970, 191-2000 and 2011-2020 were compared, and temperature and precipitation deviations from the norm were calculated. ArcGIS software was used for analytical work, in which data was processed using Spatial Analyst Tools. Since the data were tied to points (meteorological stations), we had to use a suitable interpolation method to convert point data to area data. The entire territory of the Slovak Republic was chosen as the area for which the data were spatially added. When using meteorological data, the Topo to Raster method was the most suitable, so it was also used in this case. When working with raster data, other tools were used for data reclassification (Reclassify) and converting raster data to vector (conversion Tools - Raster to Polygon). The conversion of raster data was necessary due to the overlay of temperature and precipitation spatial data, which was helped by the analysis tools (Analysis Tools), specifically the tools under the overlay group (Overlay) and the union function (Union). Subsequently, new categories were created, which are listed in Table 1. The newly created maps of Slovakia were divided by region and these new areas were compared.

Table 1 Categories of deviation from climatic normal

Category	Description	Category	Description
23	very dry-cold	45	normal-hot
33	dry-cold	46	normal-very hot
34	dry-normal	53	wet-cold
35	dry-hot	54	wet-normal
36	dry-very hot	55	wet-hot
43	normal-cold	64	very wet-normal
44	normal		

RESULTS

The results of our work prove climatic changes in individual regions of Slovakia (Table 1 and Table 2). In the winter months, a change is visible, especially in January and February in the Bratislava region, when in the years 1961-1970 the area of dry-cold, dry-cold, and normal-cold prevailed, while in the last decade 2011-2020 normal, wet-normal, and very wet-normal. In the other regions (Trnava, Nitra, Tenčín, Žilina, Banská Bystrica and Košice region) we observe the transition of areas in the years 1961-1970 from dry-cold, dry-normal, and normal-cold to the current (2011-2020) normal to wet-normal areas. The exception is the Prešov region, where normal and normal-cold areas prevailed, which changed to wet-normal to very wet-normal areas. In December, a change occurred in the districts of Trnava, Nitra, Trenčín and Žilina, when in the past normal to normal-cold areas prevailed, which has changed and now dry-normal, dry-hot, normal, and normal-hot localities prevail. In the Bratislava region, there are currently normal areas (1961-1970 dry-cold prevailed). In the Banská Bystrica,

Prešov and Košice regions, there were even wet-cold and wet-normal localities in the past, while now dry-normal and dry-hot localities are starting to appear.

Table 2 Deviation from climatic normal (Bratislava, Trnava, Nitra and Trenčín region)

Bratislava region												
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
1961-1970	23 33 43	23 33 43	43 44	44	43 44	44 54	43 44	43 53	34	44	44 54	33 43
1991-2000	44	34 44	44 54	44 54	44	44	44 54	34 44	44 54	44	44 54	44 54
2011-2020	44 54 64	44 54	44 45	35 45	44	44	45 55	45 46	44 45 54	44 54 64	34 44	44
Trnava region												
1961-1970	33 43	33 43	44	44	43 44	44	43 44	43	34	44	44 54	43
1991-2000	44	34 44	44	44 54	44	44	44 54	34 44	44 54	44	44	44
2011-2020	44 54	44	34 44 45	34 35 44 45	44 45	45 46	45 46	45 46	44 45 54 55	44 54	34 44	35 44 45
Nitra region												
1961-1970	33 43	33 43	44	44	43 44	44	43 44	43	34 44	44	44 54	43 44
1991-2000	44	34 44	44	44 54	44	44	44 54	34 44	44	44 54	44	44
2011-2020	44 54	44 54	44 45 54	34 35 45	44 45	35 45 46	45 46	45 46	44 45 54 55	44 54	34 44	34 35 44 45
Trenčín region												
1961-1970	33 34 43	33 34 43	44	44	44	44	43 44	43 44	34 44	34 44	44 54	43 44
1991-2000	44	34 44	44 54	44 54	44	44	44	34 44	44	44	44	44
2011-2020	44	44 54	44	34 35 44 45	44	45 46	44 45	45 46	44 45 54	44 54	34 44	34 35 44 45

Table 3 Deviation from climatic normal (Žilina, Banská Bystrica, Prešov and Košice region)

Žilina region												
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
1961-1970	33 34 43 44	33 34 43 44	34 44	44	44	44	43 44 54	43 44	34 44	44	44 54	43 44
1991-2000	44	44	44 54	44 54	44	44	44	44	44	44 54	44	34 44
2011-2020	44 45	44 54	44 45	44 45	44	45 46	44 45	44 45 46	44 45 54	44 54	34 44	34 35 44 45
Banská Bystrica region												
1961-1970	33 34 43 44	33 34 43 44	44	44	33 34 43 44	44 54	43 44 54	43 44 53 54	34 44	34 44	44 54 64	43 44 53 54
1991-2000	44	34 44	44	44 54	44	44	44	34 44	44	44 54	44	44
2011-2020	44 54	44 54	44 45 54	34 35 44 45	44	45 46	44 45 54 55	45 46	44 45 54	44 54	44	34 35 44
Prešov region												
1961-1970	43 44	43 44	44	34 44	34 44	34 44	44	43 44	34 44	34 44	44 54 64	43 44 54
1991-2000	44	34 44	44 54	44 54 64	44	34 44	44	44	44 54	44	44	44
2011-2020	44 54 64	44 54	44 45	35 44 45	44 45 54	44 45 46	44 45 54	44 45 46 55	44 45 55	44 54	44	34 44 45 54
Košice region												
1961-1970	33 43	33 43	44 54	44	34 44	34 44	43 44	43 44	34 44	34 44	44 54	44 54
1991-2000	44	34 44	44	44 54	34 44	44	44	44	44	44	44	44
2011-2020	44 54	44 54	44 45	34 35 44 45	44	45 46	44 45 55	35 36 45 46	44 45	44 54	44 45	34 44 45

In the summer and autumn months, there is a significant change in all regions in July and August, when the transition from normal and normal-cold areas (normal and dry-normal in the Prešos and Košice regions) to normal-hot to normal-very hot areas is

visible. In September, in all regions except the Košice region, we observe a transition from dry-normal to wet-normal to wet-hot. In the Bratislava region, areas went from normal to very wet-normal in November. In other regions, we observe a transition from dry-normal to wet-normal.

DISCUSSION

The authors did not deal with the problem of combining two assessments - deviation of temperature from the climatic normal and deviation of precipitation from the climatic normal. There is a more extended evaluation of the development of temperature in particular and the development of precipitation in the territory of Slovakia in a certain time interval, which is also connected with the development of drought or the development of growing seasons. The development of drought according to several indices was determined by [5], while in the work they point to the alternation of dry and wet periods. Despite the alternation of these periods, it is shown that there was no statistically significant change in the total amount of annual precipitation [6], but their distribution changes [7]. The change was also noted by Zeleňáková et al. [8], who investigated changes in trends in annual precipitation and temperature time series and concluded that the sharp shift in precipitation at the highest climate station, Lomnický peak, began around 1985, and the sharp shifts in temperature began around 1970. In addition to the change in the distribution of precipitation, the occurrence of snow cover also changes, which is caused by a change in temperature [9]. From the perspective of increasing temperature growing seasons are getting longer - they start earlier and end later [10].

CONCLUSION

In this work, we focused on the comprehensive development and assessment of precipitation over a 60-year period and compared this development for the decades 1961-1970, 1991-2000 and 2010-2020. The results show an increase in temperature in the summer and autumn months in several regions of Slovakia, especially in the last decade. In the winter months, an increase in temperature is also visible, but also a higher amount of precipitation, which is due to the fact that the snowfall has changed to rain. An increase in precipitation is also observed in the autumn months. Thanks to this comprehensive assessment, it is possible to better understand the development of temperature and precipitation conditions in individual regions of Slovakia.

ACKNOWLEDGEMENTS

This publication was supported by the Cultural and Educational Grant Agency no. KEGA 031SPU-4/2021 and by the Grant Agency of SUA in Nitra no. 19-GASPU-2021.

REFERENCES

[1] EEA, Climate change impacts, risks and adaptation, Available online: https://www.eea.europa.eu/en/topics/in-depth/climate-change-impacts-risks-and-adaptation (accessed on 13.11.2023).

[2] Met Office, Rainfall across Europe disrupted by climate change, Available online: https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2022/rainfall-across-europe-disrupted-by-climate-change (accessed on 13.11.2023).

[3] EEA, Climate change threatens future of farming in Europe, Available online: https://www.eea.europa.eu/highlights/climate-change-threatens-future-of (accessed on 13.11.2023).

[4] SHMÚ, Klimatické pomery Slovenskej republiky [Climatic conditions of the Slovak Republic], Available online: https://www.shmu.sk/sk/?page=1064 (accessed on 13.11.2023) [In Slovak].

[5] Nagy P., Zelenakova M., Kapostasova D., Hlavata H., Simonova D., Identification of dry and wet years in eastern Slovakia using indices, IOP Conf. Series: Earth and Environmental Science, 444, 2020.

[6] Repel A., Zeleňáková M., Jothiprakash V., Hlavatá H., Blišťan P., Gargar I., Purcz P., Long-Term Analysis of Precipitation in Slovakia, Water, 13(7):952, 2021. https://doi.org/10.3390/w13070952.

[7] Minárik M., Čimo J., Kišš V., Change in the Amount of Precipitation in Slovakia Induced by Climate Change, Veda mladých 2023 - Science of Youth 2023, pp. 6-16, 2023. https://doi.org/10.15414/2023.9788055226217.

[8] Zeleňáková M., Purcz P., Blišťan P., Vranayová Z., Hlavatá H., Diaconu D.C., Portela M.M., Trends in Precipitation and Temperatures in Eastern Slovakia (1962–2014), Water, 10(6):727, 2018. https://doi.org/10.3390/w10060727.

[9] Vojtek M., Faško P., Šťastný P., Some Selected Snow Climate Trends in Slovakia with Respect to Altitude, Acta Met. Univ. Comenianae, XXXII, pp. 17 – 27, 2003.

[10] Kišš V., Pagáč J., Tárník A., Čimo J., Changes in Vegetation Period Length in Slovakia under the Conditions of Climate Change for 1931–2110, Sustainability, 14(19):12220, 2020. https://doi.org/10.3390/su141912220.

THE POTENTIAL ROLE OF MODERN TECHNOLOGY IN PROMOTING NATURE-BASED SOLUTIONS ADDRESSING GLOBAL CLIMATE CHANGE

Denis Vasiliev[1]
Lennart Bornmalm[2]
Rodney Stevens[2]
Richard Hazlett[3]
[1] Turiba University, **Latvia**
[2] Gothenburg University, **Sweden**
[3] Pomona College, **USA**

ABSTRACT

Global heating is happening at an unprecedented speed. As a result, both human society and natural ecosystems are facing significant challenges. Numerous tools and policies are being implemented both for climate change mitigation and adaptation. Substantial amount of funding has been pledged by international governments and private corporations to support these efforts. One of particularly promising tools that tends to gain popularity for addressing climate change are Nature-based Solutions. These tools can be used for both climate change mitigation and adaptation. Additional benefits provided by the application of Nature-based Solutions include support of biodiversity and associated ecosystem services, which in turn foster well-being of the human society. Implementation of the solutions, however, is challenging and requires stakeholder support, thorough research, multi-stakeholder collaboration and financial resources. Implementation and management of Nature-based Solutions for climate change may take several decades until they reach their full potential. This makes stakeholder engagement and attraction of essential investments particularly problematic. Application of modern technologies can support implementation of the solutions and help overcoming the above listed challenges. However, the use of information technologies in design, management and implementation of the Nature based Solutions tends to be limited, in particular in the Global South, where resource constraints and lack of awareness and/or skills may discourage stakeholders from use of the technologies. Thus, we discuss opportunities for application of modern technologies for implementation of Nature-based Solutions and the ways to lower financial and other barriers to their application.

Keywords: biodiversity, artificial intelligence, machine learning, mobile technology, sustainable development

INTRODUCTION

Global climate change is a major threat to both humanity and the natural environment. Diverse strategies have been developed to address the processes and effects of this change. An important component of some of these strategies is the implementation of Nature-based Solutions, defined as “Nature-based Solutions are actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal

challenges effectively and adaptively, simultaneously benefiting people and nature" [1]. Different types of Nature-based Solutions serve different purposes, including disaster risk reduction, climate mitigation and climate adaptation. In recent years Nature-based Solutions for climate mitigation have become increasingly popular, with multiple ambitious governmental and private programmes aiming to develop large scale forest plantations for carbon sequestration currently underway. Roll out of these programmes and recent developments in carbon markets make substantial financial resources available for implementation of Nature-based Solutions. Implementation of the solutions, however, remains challenging. Stakeholder support for their development is not always easy to secure. Conflicts of interests may hinder Nature-based Solutions projects. Lack of evidence-based value estimates and high levels of uncertainty associated with development of the projects may also undermine the support for their implementation. The uncertainty stems from the fact that the ecosystems of Nature-based Solutions often can often reach their full potential several decades after project initiation. Identification of the ecosystem capacity to maintain biodiversity and ecosystem service flows is particularly problematic. Changing climatic conditions create uncertainty both over the capacity of Nature-based Solutions to maintain biodiversity over long term and over the ability of ecosystem itself to adapt to changing conditions.

Problems associated with implementation of Nature-based Solutions may be addressed by application of information technologies. There is a broad range of technical tools that if implemented correctly can greatly facilitate Nature-based Solutions projects. The technologies include web and mobile applications, geo-information systems, big data, cloud computing, and artificial intelligence tools. Application of these tools is often considered to be expensive and overly complicated. However, recent technological developments have greatly increased accessibility the tools, making them affordable and easier to use. Adoption of the tools may also be hindered by lack of awareness of their potential applications in Nature-based Solutions projects. Thus, there is a clear need for synthesis of their potential applications in the context of implementation of the solutions addressing global climate change. In this paper we focus on the lower cost or free technologies as Nature-based Solutions projects may not have substantial funds that could be devoted to application of the technological tools. This might be particularly true in the Global South where Nature-based Solutions projects can have the greatest contributions to local community wellbeing and where financial resources and skills may be in short supply.

METHODOLOGY

Conceptual research methodology was used in present study. This methodology helps identify solutions to real-world problems through interdisciplinary research. Theory synthesis, theory adaptation, typology, and modelling are four main methods of conceptual research. Here theory adaptation approach is used as it allows proposing novel insights by exploring concepts not synthesised in existing literature. Innovative application of evidence and theoretical knowledge from multiple disciplines allows developing suggestions for improvement of existing practices. In the present study application of a broad range of technologies in Nature-based Solutions addressing climate change is discussed. The tools are discussed with a particular emphasis on low cost and easy to use solutions, emphasising the necessity to use them in the context of implementation of Nature-based Solutions projects in the Global South.

WEB AND MOBILE TECHNOLOGIES

Mobile and web applications are relatively easy to develop, however, full potential of use of these applications for fostering Nature-based Solutions projects may not be fully realized. One particularly troublesome problem that may hinder implementation of Nature-based Solutions is negative perceptions of the projects by local communities [2]. This may happen due to lack of transparency and understanding of the benefits associated with the projects [2]. One of the most straightforward ways to increase project transparency is through open and detailed communications. Developing a project website can be particularly helpful in these circumstances. The effectiveness of the website can be enhanced through integration of a blog and either email or chat communication capabilities. This would allow reducing misunderstandings by allowing convenient ways of communication. Developing and maintaining presence on social media may be another way of communications improvement.

Another problem that may be resolved with the help of the technologies is lack of engagement of local communities in development of the Nature-based Solutions. Here mobile app development may be particularly helpful. Mobile apps are often used for biodiversity assessments and monitoring of environmental condition changes. Indeed, public participation in conservation programs has proven to be very effective, with remarkable examples of citizen participation in insect surveys in Europe [3] and roadkill monitoring [4]. Mobile apps can be used throughout the process of Nature-based Solution project implementation. These applications may be particularly useful at planning stages when information about sites where the solutions are expected to be implemented is collected. Citizen engagement may also be particularly useful in site selection for the Nature-based Solutions, evaluating where the project may have the greatest contribution to biodiversity conservation and ecosystem resilience. As was mentioned above, one of the most significant problems in Nature-based Solutions projects is uncertainty in biodiversity outcomes, especially under changing climate. This problem, to some extent, can be addressed through ongoing monitoring of biodiversity changes, thereby helping to implement timely conservation interventions. In addition, monitoring of biodiversity loss causes at this stage may be particularly helpful, such as monitoring of illegal harvesting and roadkill. All these activities can be greatly facilitated through community participation, which in turn can be enhanced by mobile application use. The applications for certain conservation purposes are already developed and are readily available for download and use. A remarkable example of such applications includes the Lukim Gather app developed in collaboration with UN's development agency [5]. In more specific cases mobile applications tailored to specific needs can be developed. Today, it is also possible to develop cross-platform applications that may act as a website and may simultaneously be applicable for both Android and iOS operating systems. This provides an opportunity to develop versatile applications with a single code base, making application development much more affordable. The frameworks for development of such applications tend to be open source, meaning that no cost is involved in software acquisition. One of such frameworks is React Native, which not only allows developing cross-platform applications, but also perfectly integrates with TensorFlow.js – a machine learning framework that significantly enhances functionality of the mobile applications and equips them with such capabilities as computer vision, speech recognition, object detection and other functions. These capabilities are particularly useful for biodiversity

assessments, change detection and detection of illegal resource harvesting. Finally, what is remarkable – these frameworks are relatively easy to use and therefore do not require the scale of investment usually essential when native mobile apps are being developed.

GIS, BIG DATA AND ARTFICIAL INTELLIGENCE

Application of GIS is widespread in Nature-based Solutions projects. However, these applications may be limited to spatial planning, quantification of carbon sink and stock values, wildlife habitat assessment and change detection. These applications are doubtlessly important but may suffer from inaccuracy and lack of holistic understanding of ecological processes affecting the capability of ecosystems to maintain biodiversity, as well as a lack of consideration of social factors that may determine long term persistence of the ecosystem. Thus, more advanced applications of GIS and Artificial Intelligence tools need to be considered in this context. One particularly important aspect determining capacity of Nature-based Solutions ecosystems to maintain biodiversity is an understanding of ecological processes operating at a range of spatial and temporal scales. These processes are, to a large extent, determined by landscape composition and configuration, which in turn is affected by anthropogenic activities and global climate change. Indeed, ecological processes operating at a range of spatial and temporal scales and responsible for maintaining biodiversity and determining ecosystem resilience can be facilitated by multi-scale landscape connectivity [6], which may be further supported by fitting the Nature-based Solutions to the ecosystem design [7]. Obtaining relevant data to identify ecosystem design requires utilization of remotely sensed imagery with different spatial resolution, ranging from low resolution satellite imagery to high resolution imagery captured by unmanned aerial vehicles. Analysis of three-dimensional landscape structure may further enhance understanding of its capacity to maintain biodiversity. These data can provide important insights into geodiversity and three-dimensional structure of forest canopy, which in turn can help determine habitat diversity (e.g., diversity of ecological niches) and predicting capacity of ecosystems to buffer species from adverse impacts of climate change (which may be facilitated by diversity of micro-climatic conditions) [8]. The three-dimensional structure of the landscape can be obtained from Light Detection and Ranging (LiDAR) imagery, providing insights that may be essential to verify the capacity of the landscape to maintain biodiversity and flow of ecosystem services obtained from both two- and three-dimensional imagery. Such data may be obtained through field surveys. Iteration of all these data across resolution scales and spatial dimensions may be particularly problematic. However, deep learning technique called multi-view data fusion can be applied here to facilitate integration of geospatial data [9]. This approach may not only help integrating data across spatial scales and dimensions, but also can be applied to develop time series through integration of imagery collected at diverse spatial scales.

Another important aspect that needs to be considered in Nature-based Solutions projects is the reduction of future uncertainty. Investors tend to expect that the investments in such projects ultimately deliver social, ecological and climate benefits. Application of artificial intelligence tools can help develop predictions of future landscape pattern change. Such predictions can be obtained through application of certain types of neural networks (such as one-dimensional convolutional networks, Long Short-Term Memory convolutional networks or generative-adversarial networks) to landscape data series obtained through analysis of remote sensing imagery.

However, developing predictions solely based on extrapolation of trends obtained solely through landscape pattern change analysis may not be sufficient here. Integration of human dimension is essential to gain better understanding of how landscape pattern may change with time and how this may affect future capacity of Nature-based Solutions ecosystem to maintain biodiversity and deliver ecosystem services. Here decision analysis and multi-objective optimization may be applied, and multiple possible development scenarios created. These tasks are complex and may be especially challenging when Nature-based Solutions are implemented at large spatial scales. A broad range of machine learning tools exist that can facilitate these tasks, including for example application of random-forest algorithms for multi-objective optimization [10].

Building modes and scenarios for Nature-based Solutions projects with application of GIS and artificial intelligence tools may be problematic due to large volumes of data that need to be processed. Processing geo-spatial data itself requires significant computational resources due to the large size of the files containing remotely sensed data. Furthermore, application of machine learning algorithms heavily depends on powerful hardware to effectively train the models. Software capable of processing big data is likely to be essential for these purposes. Luckily software itself is freely available, including very powerful and reliable frameworks such as Hadoop and Spark. Solving problems associated with hardware, such as lack of storage capabilities or processing speed may be more problematic and may be resolved in one of two ways. The first solution is to obtain multiple computers and integrate them into clusters. In addition, computers may be equipped with Graphics processing units that can facilitate machine learning processes extensively. However, on premise solutions may be costly and may not be justified if only one project is being implemented. Alternative solutions include cloud computing. Costs associated with utilization of cloud services depend on the number of resources used. This may help optimize project costs and can help upscaling and downscaling, which may be more problematic with on premise solutions.

INFORMATION TECHNOLOGIES AND RELATIONSHIP MANAGMENT

Problems in Nature-based Solutions implementation often arise due to lack of public support. Key decision makers may also hinder implementation of the projects. Securing stakeholder support is therefore critical task in Nature-based Solution projects. These tasks may be challenging especially when the projects are large and involve communications at scale. Luckily, multiple technological tools were developed to support marketing communications activities and can be readily used in Nature-based Solutions projects. These tools range from simple customer relationship management (CRM) systems to sophisticated applications based on artificial intelligence. Simple CRM systems may help with stakeholder relationship management, by automatization of regular emailing and personalization of communications. When communicating with representatives of general public it may be possible to automatically generate email content using AI-powered language models, such as ChatGPT. Although this strategy may be risky, and the content should in any case be verified by a human. Natural language neural networks can also power chatbot technologies that can facilitate telecommunications with large number of people. In addition, tools based on artificial intelligence can be particularly useful in key decision maker identification. One recent technology that allows analyzing connections on social media to identify stakeholders that are likely to be connected to each other or have similarities is based on application

of Graph Neural Networks. Such tools may be particularly useful when Nature-based Solutions project managers need to identify groups of key decision makers that may be lobbied for securing project support. Other very important set of artificial intelligence powered tools include application of Natural language neural networks for sentiment analysis that may allow identifying public support or opposition towards the Nature-based Solutions project without the need for reading each email or social media post. All these tools can be either readily used or developed for specific purposes using open-source frameworks, thereby do not require significant investments. Lack of skills or resources may be compensated through establishment of cross-disciplinary international partnerships.

CONCLUSION

The aim of this paper was to synthesize potential applications of moder technologies in the context of implementation of Nature-based Solutions addressing global climate change. Both the most basic technologies (such as websites, mobile applications and CRM systems) and more advanced tools powered by artificial intelligence can potentially facilitate implementation of the solutions. Application of the modern technologies can help overcome the most significant barriers that practitioners willing to implement Nature-based Solutions face. The tools can help reducing uncertainty in benefit delivery, thereby substantially increasing chances of receiving key decision maker and investor support. Technologies are also capable of reducing opposition and securing public support for the projects. Even most basic tools such as mobile applications can significantly increase chances of project success through facilitating local community engagement in planning, implementation and management of the Nature-based Solutions. Technologies can help solve complex problems, such as identification of most appropriate locations for Nature-based Solutions and developing scenarios that can help secure the appropriate persistence of these measures under changing environmental conditions. All of these technologies are freely available, at least regarding their basic functions, and their application usually does not require additional investment in software acquisition. Lack of skills can be compensated through partnership establishment. Thus, the technologies can be utilized not only in developed countries in projects with significant funding but also in the Global South where resources may be limited. Thus we argue for a more widespread use of technologies in Nature-based Solutions projects across the globe.

REFERENCES

[1] IUCN, *Nature-based Solutions*. Available from: https://www.iucn.org/our-work/nature-based-solutions [Accessed on 21 of October 2023], 2023.

[2] Huxham M. et al.: Rawls in the mangrove: Perceptions of justice in nature-based solutions projects. People and Nature, vol. 5(5), pp 1497-1511, 2023.

[3] Carpaneto, G.M. et al. The LIFE Project "Monitoring of insects with public participation" (MIPP): aims, methods and conclusions. Nature Conservation, vol. 20, pp 1-35, 2017.

[4] Vercayie, D. and Herremans, M. Citizen science and smartphones take roadkill monitoring to the next level. Nature Conservation, vol. 11, pp. 29-40.

[5] UNDEP: *Mobile Application, a new tracking tool for conservation*. Available from: https://www.undp.org/papua-new-guinea/news/mobile-application-new-tracking-tool-conservation [Accessed on 4 of November 2023].

[6] Dilts, T.E. et al.: Multiscale connectivity and graph theory highlight critical areas for conservation under climate change. Ecological Applications, vol. 26(4), pp. 1223-1237 (2016).

[7] Vasiliev, D. and Greenwood, S.: Making green pledges support biodiversity: Nature-based solution design can be informed by landscape ecology principles. Land Use Policy, vol. 117, 106129 (2022).

[8] Morelly, T.L. et al.: Climate-change refugia: biodiversity in the slow lane. Frontiers in Ecology and the Environment, vol. 18(5), pp. 228-234 (2020).

[9] Huang, X., Cao, Y., Li, J., An automatic change detection method for monitoring newly constructed building areas using time-series multi-view high-resolution optical satellite images. Remote Sensing of Environment, vol. 244, p. 111802 (2020).

[10] Qu, Q. et al.: A Comprehensive Review of Machine Learning in Multi-objective Optimization. 2021 IEEE 4th International Conference on Big Data and Artificial Intelligence (BDAI), Qingdao, China, 2021, pp. 7-14, doi: 10.1109/BDAI52447.2021.9515233.

THE RIGHTS OF FUTURE GENERATIONS IN ITALIAN-EUROPEAN ENVIRONMENTAL LAW

PhD Giovanna Di Benedetto

University of Camerino, **Italy**

ABSTRACT

The work analyzes the rights of future generations in a perspective of solidarity within Italian-European environmental law, in a similar way to what was done in the German legal system.

The analysis is conducted through a survey of the Italian-European regulatory framework, also with specific reference to the objectives of European social policies and through the jurisprudential comparative analysis with the legal system of the Federal Republic of Germany. In particular, with specific reference to a recent environmental dispute brought before the German Constitutional Court (Case Neubauer, et all v. Germany), within which the rights of future generations to live in a healthy environment are recognized.

In the aforementioned case, the complainants allege that the German government has not introduced a legal framework sufficient to reduce the emission of greenhouse gases and has not limited the increase in global temperature, according to the parameters agreed in the Paris Climate Agreement of 2015.

The ruling of the German Constitutional Court is relevant since it considers it inadequate to achieve the objectives set by the international obligations on the reduction of greenhouse gas emissions assumed by the federal law on climate protection of 2019. The aforementioned law is considered partly unconstitutional because it does not sufficiently protect people from future violations and limitations of the rights of freedom following the gradual intensification of climate change.

In particular, in a perspective of solidarity, in a not local but global conception of the environment, with the recognition of the progressive and dangerous climate change, the German Constitutional Court notes that the German legislator has not distributed the CO_2 emission balance proportionally and therefore, an adequate distribution of the sacrifice among current and future generations.

In particular, the German Court writes: "one generation must not be allowed to consume large portions of the CO_2 balance by supporting a relatively smaller share of the reduction effort, if this would leave subsequent generations with a drastic reduction burden and expose their lives to serious losses of liberty".

The European and sometimes national regulatory framework still appears to be unsatisfactory with respect to the sustainable development objectives. So, the task of the national courts is that, as in the case of the German Constitutional Court, to evaluate the national regulatory provisions on climate protection, in the light of the principle of solidarity towards future generations, adopting an environmental approach that is not limited in time and in space but global.

Keywords: future generations rights, solidarity, sustainability.

INTRODUCTION

The ecological transition has placed the issue of the future dimension of the rights and freedoms of generations yet unborn at the center of the international legal debate.

A correct approach to the ecological and technological transition, which has been underway for some time, must take into adequate consideration, from a solidarity perspective, the interest of future generations in living in a healthy environment.

In particular, future generations must be guaranteed that they will not face the negative consequences of reckless choices made for production purposes with a harsh impact on the environment.

However, the inadequate consideration that European legal systems give to the rights and freedoms of future generations with regard to climate change was noted.

METHODS

The analysis is conducted through a survey of the Italian-European regulatory framework, through comparative jurisprudential analysis with the legal system of the Federal Republic of Germany.

In particular, the investigation is conducted with specific reference to a recent environmental dispute brought before the German Constitutional Court (Neubauer case, et all v. Germany), in which the right of future generations to live in an environmentally healthy to apply in a solidarity perspective.

RESULTS

The European and sometimes national regulatory framework still appears unsatisfactory with respect to the sustainable development objectives.

The measures adopted to date, for the purpose of achieving the climate objectives set within the Paris Agreement, are insufficient and detrimental to the interests of future generations.

The task of national judges, therefore, is that, as in the case of the German Constitutional Court, to evaluate national regulatory provisions regarding climate protection, in light of the principle of solidarity towards future generations, adopting an environmental approach that is not limited in time and in space but global.

The failure to guarantee climate protection and the adoption of insufficient and inadequate measures to stem climate change constitute a violation of the fundamental rights of citizens and in particular of future generations, due to violation of the principle of proportionality.

DISCUSSION

The theme of ecological transition is closely connected to the theme of maintaining good living conditions over time and space.

This is in order to maintain optimal living conditions on the planet.

In this regard, the case Case Neubauer, et all v. Germany concerns the appeal brought by young adults and adolescents before the German Federal Constitutional Court, before which the Federal Law on climate change is being challenged [1].

In particular, the part of the Climate Law is contested in which it omits adequate forecasts in order to achieve emissions neutrality, without burdening future generations with the burden of climate mitigation.

The intense consumption of natural resources has significantly affected the environment and life expectancy of the planet.

In particular, the impact on the environment and therefore on the climate occurs through the exponential increase in the emission of gases in the form of carbon dioxide, together with the simultaneous decrease in oxygen in the atmosphere.

The appellants noted, in particular, that the German national climate targets for annual greenhouse gas emissions permitted by the year 2030 and foreseen by the Federal Climate Change Act were not sufficient.

The insufficient forecast for the purposes of reducing gas emissions led to a violation by omission of the fundamental rights of the appellants, compromising the conservation of the living conditions of future generations.

Such an insufficient forecast of emissions reduction would have led to the need to adopt more drastic measures for future generations, to avoid disastrous environmental scenarios capable of irreversibly compromising terrestrial and marine ecosystems.

It was contested that the climate objectives allowed up to the year 2030, foreseen by the Climate Law, were not sufficient to achieve the neutrality objectives set out in the Paris Agreement.

A correct evaluation of the Federal Law and objectives must take into consideration the European regulatory framework.

The European Union has, in fact, progressively assumed competence in the field of climate change.

Pursuant to art. 191 of the Treaty on the Functioning of the European Union, in fact, the Union is required to maintain a "high level of protection, prevention and precaution" in its environmental and climate policy.

The German Climate Protection Act expressly pursues the objective of ensuring the implementation of European climate objectives and legislation.

In this sense, consider that the Union joined the Paris Agreement on 5 October 2016, assuming with it the climate objectives contained therein.

In particular, the Agreement provides that the increase in global temperature must be kept below the threshold of 2 degrees C., compared to pre-industrial levels and setting the maximum increase limit at 1.5 degrees C.

However, the parties to the Agreement do not make concrete commitments to reduce temperatures through binding quantitative objectives.

The Agreement provides, however, that the adhering parties must prepare climate plans at national level.

The Union has therefore set the objective of reducing greenhouse gas emissions on European territory for a total share of 40%, compared to the year 1990, to be achieved by the year 2030.

Although Germany has not presented a specific national climate plan, it actively participates in the Paris Agreement as a member of the European Union.

In execution of the aforementioned obligations undertaken at the European level, the German legislator issued the Federal Law on climate change of 12 December 2019.

With the aforementioned Law, in implementation of the objective set at European level of a 40% reduction in emissions, Germany made a commitment to reduce greenhouse gas emissions compared to the reference year 1990. for a share equal to 55%, by the target year 2030.

However, such forecasts did not take into account, following studies conducted on the climate, recent scientific findings regarding the negative consequences of greenhouse gases on ecosystems and the progressive increase in global temperature.

In particular, the aforementioned forecasts did not take into adequate consideration the climate obligations assumed by Germany and the European Union with the Paris Agreement to limit the increase in global temperature to below 2 degrees C. and preferably within 1.5 degrees C. compared to preindustrial levels.

In this way, the Union would not only have failed to fulfill its obligations under the Paris Agreement but would also have failed to fulfill its supervisory obligations, undertaken with the aforementioned Article 191 of the Treaty on the Functioning of the European Union.

There is, however, as already observed in the Netherlands v Urgenda Foundation case of 20 December 2019, on each State a concrete duty to act for the climate, failure to comply with which constitutes a violation of human rights.

In particular, the duty of protection in light of climate change, existing on each European State and specifically on the Federal Republic of Germany, pursuant to the combined provisions of Articles 2 and 8 of the European Convention on Human Rights.

A State party to the Convention on Human Rights, in fact, is obliged to adopt adequate measures if there is a real or immediate risk to life (article 2) or to respect for life (article 8) or to the well-being of persons and at the same time the State is aware of such a risk.

In this sense, based on the concrete risk of disastrous climate changes that could endanger the lives and well-being of people, States assume positive obligations to undertake concrete actions to prevent future violations of these rights.

From this perspective, the conclusions of the Dutch Supreme Court, in the aforementioned case Holland v. Urgenda Fundation, appear to be acceptable and applicable to the case in question, according to which to determine what each State must do to fulfill its obligations relating to climate neutrality, it must reference to standards scientifically accepted by the international scientific community.

In other words, beyond just fulfilling the European obligations deriving from joining the Paris Agreement on the climate, Germany and the European Union in general should have, in accordance with recent scientific findings on the climate and on any drastic

consequences in case of inadequate climate action, adopt more incisive measures to achieve climate neutrality.

The innovative scope of the ruling in question seems to be identifiable precisely in the reading that the Constitutional Judges give to the art. 20a of the Constitution, with specific reference to the protection of the natural foundations of the life of future generations.

In particular, the Court states that the State, aware of its responsibility towards future generations, is required to protect the natural foundations of life and therefore of ecosystems.

In this sense, the Court obliges the State to pursue the protection of the environment and the achievement of climate neutrality, in an intergenerational solidarity perspective, in the awareness acquired from recent scientific research of the partial or complete irreversibility of the effects of the progressive deterioration of ecosystems.

This is because, in the Court's conclusions, future generations should not be forced to adopt radical measures in order to achieve an ecosystem balance compatible with life.

An element that characterizes the problem of the environment and its integrity is the conflict of interest existing between present generations together with their ability to intensely and destructively benefit from natural resources and future generations.

It should be noted that intergenerational solidarity connected to environmental protection is present in numerous European constitutions, now constituting a consolidated European common ground.

The principle of intergenerational solidarity is therefore located in the fundamental core of the supreme values that are the basis of the European democratic systems placed at the foundation of all rights and freedoms.

The Constitutional Court, in an axiological reading of the Climate Law, found that the Legislator had not adequately and proportionally distributed the sacrifice budget in the supply of emissions between the present generation and future generations.

In particular, the Court notes that the present generation should not be allowed to consume large portions of the carbon dioxide budget, bearing a relatively smaller share of the reduction effort, compared to future generations, in violation of the principle of proportionality.

Since this would imply implicitly placing a drastic burden of reduction on future generations, exposing their lives to serious losses of freedom.

The principle of environmental solidarity towards future generations must therefore be recognized as having a axiological dimension in all European systems [2].

It should be noted, in this regard, that although the recent amendment to the Italian Constitutional Charter has provided for the inclusion of the rights of future generations with respect to the environment, in article 9, it seems possible to establish an action that is still inadequate for full environmental sustainability.

The common legal heritage of European principles and in particular the recognition, already carried out by the German Constitutional Court, of the rights of future generations, seems destined to have a significant impact on the ecological transition process underway in Italy and Europe.

CONCLUSION

The decision of the Federal Constitutional Court which recognized at a constitutional level the need to programmatically aim for climate neutrality must be shared.

In this sense, the ruling recognizes the constitutional relevance of the objectives set within the Paris Agreement.

The central aspect of the federal judge's decision can be found in the application of the concept of sustainable development which includes attention to intergenerational equity.

The Constitutional Court has established, for the first time in the European panorama, that the failure to guarantee climate protection and the adoption of insufficient measures constitute a violation of the fundamental rights of citizens and in particular of future generations.

This definitively compromises the expectations, rights and freedoms of future generations, placing the burden of taking effective climate action on them.

The German Constitutional Court notes that the German legislator did not proportionally distribute the CO2 emission budget and therefore, an adequate distribution of the sacrifice between current and future generations.

In particular, the German Court writes: "one generation must not be allowed to consume large portions of the CO2 budget by supporting a relatively smaller share of the reduction effort, if this would mean leaving subsequent generations with a drastic reduction burden and exposing their lives to serious losses of freedom".

Intergenerational solidarity connected to environmental protection is present in numerous European constitutions and constitutes consolidated European common ground.

The principle under discussion is therefore located in the fundamental core of the supreme values that underlie European democratic systems.

The principle of environmental solidarity towards future generations must therefore be recognized as having a fundamental axiological dimension in all European systems [3].

ACKNOWLEDGEMENTS

This work is a product developed within the research project funded by the European Union - NextGenerationEU, MUR - Promotion and Development Fund - D.M. 737/2021, ESCOP4Green – Enhancing Sustainable Consumption and Production for the Green transition.

REFERENCES

[1] Ruggeri L., Caterini A.E., Produzione e consumo sostenibili fra politiche legislative e prassi adattive, Italy, 2022;

[2] P. Perlingieri, I principi del sistema ordinamentale, Il diritto civile nella legalità costituzionale, Italy, 2020, pp 207-221;

[3] M. Pennasilico, La sostenibilità ambientale nella dimensione civil-costituzionale: verso un diritto dello sviluppo umano ed ecologico, Rivista quadrimestrale di diritto dell'ambiente, Italy, 3, pp 4-10.

THE USE OF WEB MAPS IN MANAGING CRISES CAUSED BY CLIMATE CHANGE

Assoc. Prof. A. Bluszcz[1]

Assoc. Prof. K. Tobór-Osadnik[2]

Assoc. Prof. A. Manowska[3]

Ing. A. Kelíšek, PhD[4]

[1,2,3,] Silesian University of Technology, Faculty of Mining, Safety Engineering and Industrial Automation/ Department of Safety Engineering, **Poland**
[4,] University of Žilina, Faculty of Security Engineering, Department of Crisis Management University of Žilina, **Slovakia**

ABSTRACT

Climate change may increase the frequency and severity of floods in many regions of the world, including Poland and Slovakia. Crises may be caused by, among others: increased rainfall, rapid melting of snow, river floods, and floods in urban areas. The article focuses on the problems occurring in Poland and Slovakia, which will have to adapt their infrastructure and policies to cope with the changing climate and increased flood risk. The article concerns aspects of crisis management using geo-informatic tools in flood situations resulting from climate change. The publication indicates events in Poland and Slovakia that resulted in flooding of urban areas. This scientific text explores the causes and impacts of floods, highlighting key sources of information and discussing mitigation strategies. Analyzes of these events were presented in terms of planning and implementation of crisis management actions and cooperation in border areas. The publication presents selected critical infrastructure facilities and identifies them in the QGIS software. Quantum GIS is free software, the Open Source Geographic Information System, enabling, among other things, the identification of critical infrastructure facilities based on available GIS Open data from the examined region. The practical use of geomatics tools was also proposed to identify places potentially at risk in the future and to develop web maps, which may be a useful tool for determining buffer zones and planning appropriate actions depending on the qualified level of risk in a given buffer. The publication may be a valuable example of the use of available IT systems in crisis management for both theoreticians and practitioners in the field of crisis management and many related industries.

Keywords: geomatics, crisis management, critical infrastructure.

INTRODUCTION

Climate change has various negative effects, including floods caused by sudden heavy downpours or melting snow. These phenomena cause injuries to people within the flood reach and significant economic, environmental, and cultural heritage damage. In Europe, the number of moderate to severe flash floods has more than doubled in recent years since the end of the 1980s. Climate change is an aggravating factor, causing changes in rainfall patterns and weather patterns, rising sea levels, and, consequently, more frequent and more severe floods. In response to the increasing frequency of floods, the EU adopted the Floods Directive in 2007 and Member States started implementing flood risk management plans. However, many challenges remain, including in spatial planning and event prediction as well as in developing risk management plans in given regions.
The article indicates examples of flood events in Poland and Slovakia and presents geoinformatics tools for preparing web maps, which can be a useful tool for planning actions for crisis management services [1].

EVENTS IN POLAND AND SLOVAKIA THAT RESULTED IN FLOODING OF URBAN AREAS.

Floods are natural hydrological events that occur globally, affecting communities, economies, and ecosystems. Slovakia and Poland located in Central Europe, are no exception to this phenomenon. The country's varied topography, climate, and river systems make it susceptible to both riverine and flash floods. This scientific text explores the causes and impacts of floods in Poland and Slovakia, highlighting key sources of information and discussing mitigation strategies. Several factors cause floods in Poland and Slovakia [2].
In July 1997, southern and western Poland, the Czech Republic, eastern Germany, northwestern Slovakia, and eastern Austria were underwater. As a result, 114 people died (56 people in Poland) and all material damage was estimated at $4.5 billion.
The situation was dangerous. Several huge rivers flooded: the upper Vistula and Elbe, Odra, Nysa Kłodzka and Łużycka, Oława, Olza, Bystrzyca, Bóbr, Mała Panew, Szprotawa, Ślęza, Widawa, Szprotawa and Skora. There was water everywhere.
2010 - extensive flooding in Central Europe. At the turn of May and June 2010, there was a flood in the following regions: Poland, the Czech Republic, Slovakia, Hungary, Ukraine, Austria, Germany and Serbia. The largest flood wave in 160 years was recorded on the Vistula River, and the water level on this river exceeded the 1997 level in many places. From May 14 to 18, 2010, there were heavy rains and the water level in Poland in the upper Vistula basin rose. Flood embankments were breached near Czechowice-Dziedzice, Chełm Śląski, Oświęcim, Kraków and Sandomierz. Then the threat appeared in the Lublin, Podkarpackie, and Masovian voivodeships. There were over 1,300 landslides in Małopolska. The first flood wave lasted several days and over 30,000 people were evacuated. Water flooded over 550 hectares of land. The Odra River also overflowed or became saturated and the embankments broke in many places. 14 alarm levels were exceeded at the water gauges along the entire river and 4 warning levels were exceeded. 10 flood alarms were announced. On May 21, the flood wave reached Oława, where it reached the level of 1997, i.e. 766 cm. The fight against the element continued in Oława, Kotowice, Siedlce, Łany, Wrocław, Brzeg Dolny and Ścinawa. The embankments were maintained thanks to the work of hundreds of firefighters and the local population. On May 22, at 1:01 p.m., Kozanów was flooded, the water broke the temporary embankment

near Ślęza, and Psie Pole and Polanowice were flooded. Things weren't easy in other voivodeships either. About 70 percent area of Lesser Poland was flooded. About 12,000 people suffered and at least 4,000 were evacuated.
One of the primary causes of flooding in Slovakia is heavy precipitation. The country experiences a wide range of precipitation patterns, including rain and snow. Intense rainfall events, particularly during the spring and summer months, can lead to a rapid inflow of water into river basins, increasing the risk of floods [3]. The winter season in Slovakia brings substantial snow accumulation in the mountainous regions. As temperatures rise in the spring, the snowmelt can lead to a sudden surge of water in rivers and streams, potentially causing floods [4]. Slovakia's complex river system, including the rivers Danube, Váh, and Bodrog basin, is prone to overflow during periods of heavy rainfall or rapid snowmelt. The confluence of these rivers can lead to extensive flooding in low-lying areas [3]. Floods in Slovakia are a recurring natural hazard that can have significant socioeconomic and environmental impacts. Understanding the causes, effects, and mitigation strategies is essential for safeguarding the country against future flood events. We can understand the term mitigation strategies as implementing effective floodplain management strategies, including land-use planning and zoning regulations, can help reduce the risk of flooding and protect vulnerable areas [5]. Developing and maintaining early warning systems, which provide timely information to residents and authorities, can help mitigate the impact of floods by enabling proactive evacuation and response measures [6]. Restoration projects, such as revitalizing river channels and constructing levees, can help control floodwaters and prevent extensive damage [7]. The situation is different in individual municipalities and regions. Damages associated with floods are estimated to grow in the EU in the long term [8]. The reason is their more frequent and intense occurrence, which is related to climate changes, but also socio-economic changes associated with urbanization and densification of cities. "Societal changes in recent decades have also led to more people living in floodplains, which increases the potential damage caused by river floods," states the [9]. "Climate change is expected to increase the amount and frequency of precipitation in the future, so flood losses and the number of people affected by river floods in Europe will also increase." [10]. In the following text, we present brief statistics of floods in Slovakia for the past two decades. In April 2000, as a result of persistent rain and melting snow, the levels of the Torysa, Ondava, and Ladomírka rivers rose so that they declared the third level of flood activity. The level of the Torysa near Sabinov was at a height of 230 centimeters, while its normal level is below 150 cm, the level of the Ondava near Stropkov was 290 centimeters. In July 2001, floods claimed one human victim in the Prešov area, a 25-year-old man from the village of Jarabina died after being electrocuted in a flooded basement. In August 2002, floods affected the whole of Central Europe, including the territory of Slovakia. The floods affected the Pohronie region, and later the Danube basin, especially the Bratislava city districts of Devín and Devínska Nová Ves. In July 2004, an emergency arose in seven villages after a windstorm that hit the Trenčín district. The floods mainly affected Trenčianske Stankovce, Melčice-Lieskové, Adamovské Kochanovce, Krivosúd-Bodovka, Trenčianska Turná, Veľké Bierovce and Mníchova Lehota. In July 2005, a cloudburst and evening intense rain in the Prešov region caused flooding in Vranovsko, Prešov, and Stropkovo districts. The most damage to municipal property was on roads, bridges, and stream regulation. Around 200 houses were flooded in Bystrom nad Topľou, one family was evacuated. In September 2005, about 40 cellar spaces of family houses, 70 yards and gardens, and about 30 wells with drinking water were flooded after a strong

cloudburst that affected the village of Michaľany in the Trebišov district. In June 2006, approximately 40 municipalities in the districts of Prešov, Bardejov, and Stará Ľubovňa, Kežmarok, and Svidník declared the third level of flood activity after heavy rains. An hour-long storm combined with cloudbursts and heavy rain caused flooding in parts of several villages in the Veľký Krtíš district and caused great damage. In August 2007, torrential water flooded villages in Zamagurie and Spiš region. The city of Spišská Stará Ves and the village of Matiašovce were among the most affected. In May 2008, the third level of flood activity was declared in the village of Smižany in Spiš, which was hit by a burst of clouds accompanied by hail. The rolling water and mud flooded several parked cars on the estate, as well as the basements of several family houses. The third level of flood activity due to increased flow levels was declared in 17 villages of the Bardejov district and the Kežmarok district. A flooded river in the village of Čirč (Stará Ľubovňa district) claimed 2 lives. In March 2009, the Myjava river overflowed its banks and flooded family houses in the Turá Lúka district. Several family houses were flooded in the village of Podbranč on the course of the Myjava River. In May 2010, the Chotčianka stream caused extensive damage in the village of Bukovce, Stropkov district, tearing down part of a concrete bridge, flooding the yards and cellars of family houses, and destroying a multi-purpose playground. In August 2010, thousand-year water rushed through the waterways of the upper Nitra and hit the town of Handlová as well as the villages of Handlovská dolina. Flooding was also reported by Žiar nad Hronom, Prievidza, and Martin. In June 2011, during the flash flood, the villages of the Small Carpathians were the most affected, a significant peak values were recorded. The greatest damage was caused in Píla na Gidra and the village of Horné Orešany. Material damage was also caused in other villages such as Častá, Modra, Svätý Jur and Pezinok. In June 2013, the Danube overflowed in Slovakia and caused floods in the area of Bratislava, where it mainly affected the local part of Devín. The level of the Danube reached a height of 10.34 m and a flow rate of 10.735 m^3/s. The mayor of Bratislava declared a state of emergency in the Slovak capital. In May 2015, intense and heavy rainfall in the form of storms, accompanied by hail, strong wind, and strong lightning activity were the cause of typical flash floods on tributaries in the upper Hron and Rimava basins. Flows reached the value of 10-year water. In June 2020, torrential and heavy rainfall in the form of stormy downpours, accompanied by hail, strong wind, and intense lightning activity were the cause of typical flash floods, especially on smaller streams in the Hrona, Ipľa, Slanaj, and Rimava basins. Intense rainfall was the cause of many local floods. The flood events caused great material damage, as they were also accompanied by the occurrence of flood events outside the streams, such as water running down the slopes, mudflow, flooding of cellars, etc [11]. From the above examples, Slovakia and Poland, like many other regions prone to flooding, face the challenge of adapting to a changing climate. Ongoing research and adaptation efforts are crucial to address the evolving nature of flood risks. Some potential areas for future research and adaptation include continuously monitoring and assessing climate change impacts on precipitation patterns, snowmelt rates, and river flow is essential for understanding how floods in Slovakia and Poland may evolve in the future [12]. Developing comprehensive flood risk maps and assessing vulnerability in different regions can guide land-use planning and flood mitigation strategies [13]. Given the transboundary nature of many rivers in Slovakia and Poland, there is a need of cooperation with neighbouring countries is vital for coordinated flood risk management and prevention [14]. Also, encouraging public participation and community resilience

building is key to improving awareness, preparedness, and response to floods in Slovakia, Poland, and all European regions.

IDENTIFICATION OF CRITICAL INFRASTRUCTURE FACILITIES FOR THE STUDIED AREA

Critical infrastructure systems such as energy supply, energy raw materials and fuels, communications, ICT networks, financial, food supply, water supply, health care, transport, and rescue, ensure the continuity of public administration operations, production, storage, storage, and use of chemical and radioactive substances, including pipelines of hazardous substances. Critical infrastructure plays a key role in the functioning of the state and the lives of its citizens. As a result of events caused by forces of nature or resulting from human activities, critical infrastructure may be destroyed, or damaged, and its operation may be disrupted, which may pose a threat to the life and property of citizens. At the same time, such events hurt the economic development of the country. Hence, the protection of critical infrastructure is one of the priorities facing the Polish state. The essence of tasks related to critical infrastructure is not only to ensure its protection against threats but also to ensure that any damages and disruptions in its functioning are as short-term as possible, easy to remove, and do not cause additional losses for citizens and the economy.

Critical infrastructure protection is all activities aimed at ensuring the functionality, business continuity, and integrity of critical infrastructure to prevent threats, risks, or vulnerabilities and to limit and neutralize their effects, as well as to quickly restore this infrastructure in the event of failures, attacks and other events disturbing its proper functioning.

THE USE OF GEOMATICS TOOLS IN THE FLOOD RISK ASSESSMENT PROCESS

Planning anti-crisis activities should be based on the implementation of IT tools. An example of a functional tool is Quantum GIS, which enables the preparation of up-to-date information on the current location of crisis events to take appropriate actions to prevent or remove the effects of events [15-16].
The flood risk classification procedure for the examined critical infrastructure facilities was carried out according to the following stages:

- preliminary assessment of flood risk in the study area
- identification of critical infrastructure facilities in the examined area
- flood risk assessment for the examined critical infrastructure facilities along with the development of buffer zones,
- development of flood risk maps
- development of flood risk management maps in the studied area

The process of identifying areas of particular flood risk from the river was carried out for the city of Gliwice, where the Silesian University of Technology is located, Silesian Voivodeship, Poland. The Hydro postal service was used for this purpose.

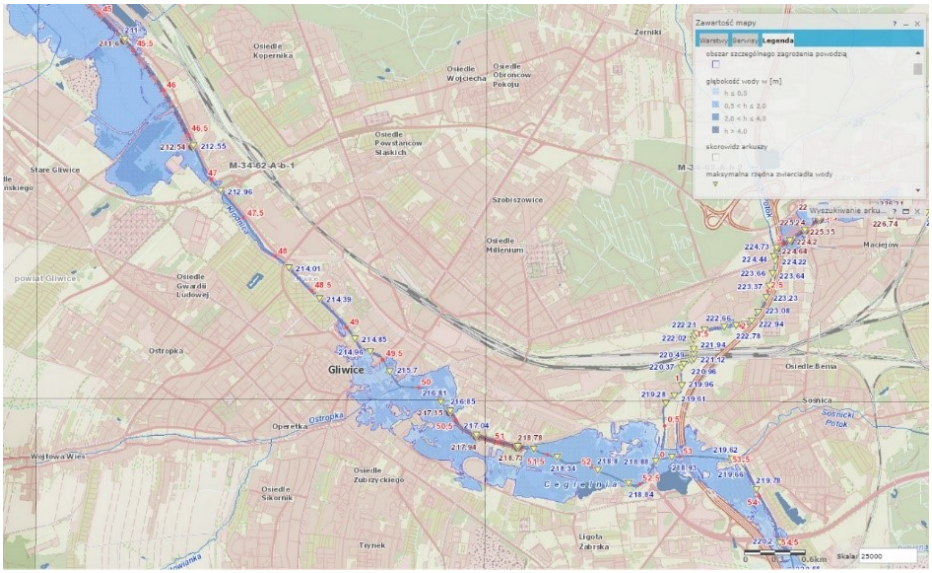


Fig 1. Flood hazard map in Gliwice, Poland
Source: https://wody.isok.gov.pl/imap_kzgw/?gpmap=gpMZP

Areas in the city of Gliwice, Poland particularly at risk of flooding along the Kłodnica River are marked in Figure 1. Blue color means water depth: light blue - depth below 0.5 m, 0.5 to 2 m, 2 m-4 m, and navy blue - water depth above 4 meters.

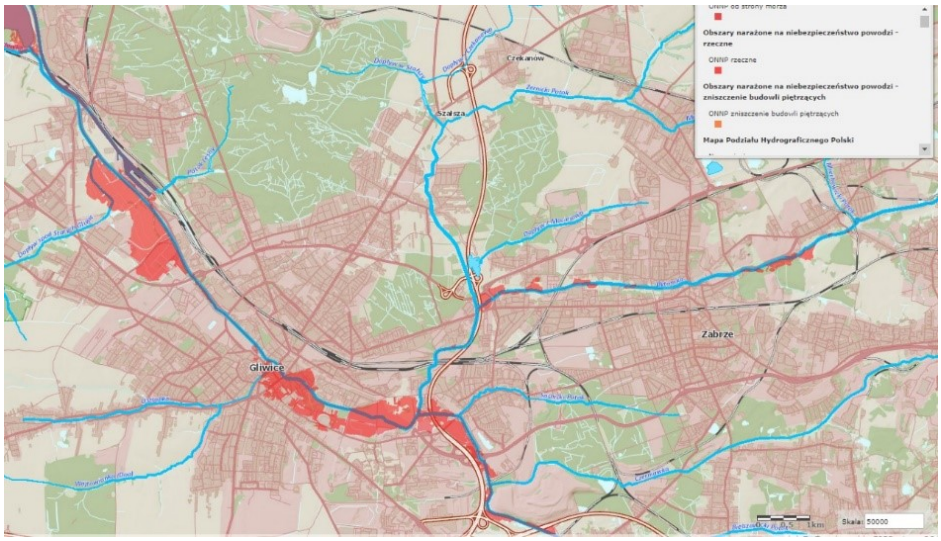


Fig 2. Preliminary flood risk assessment in Gliwice, Poland
Source: https://wody.isok.gov.pl/imap_kzgw/?gpmap=gpMZP

Areas at risk of river floods and destruction of dam structures are marked in red on the map.
Flood risk assessment was calculated for selected critical infrastructure objects such as hospitals, airports, trains roads, and the energy industry situated in Gliwice, Poland.
Risk value was accessed according to the following formula:

$$R = P \times S \quad (1)$$

Where:
R – risk value,
P – parameter of the probability of occurrence of a flood crisis,
S - value of potential losses, consequences,

When assessing probability and impact, the Risk matrix, presented in Table 1, are applicable.

When using 3-point scales to assess the probability and impact of risks, the matrix allows to identify three types of risk values (Table 1):
- low (blue color),
- medium (grey color),
- high (red color).

Table 1: Risk matrix

PROBABILITY	1	HIGH			
	2	MEDIUM			
	3	LOW			
RISK VALUE			A	B	C
			LOW	MEDIUM	HIGH
			CONSEQUENCES		

Source: based on [17]

Table 2 Risk classification for selected critical infrastructure

Type of critical infrastructure object	Probability	Potential losses, consequences	Risk value
Public Trains – transport infrastructure	high	high	high
Hospitals – oncology hospital	high	high	high
Other hospitals – infrastructure	low	high	low
Airport- transport infrastructure	low	high	low
Coal industry – energy infrastructure	low	high	low



Fig 3. Flood risk assessment for selected critical infrastructure in Gliwice, Poland for selected critical infrastructure
Source: own elaboration QGIS

Based on maps of areas exposed to flood risk, it is possible to prepare useful maps using QGIS software. Using the geoprocessing tools; buffer, it is possible to designate risk zones for selected critical infrastructure facilities. In the tested example, the quick search tool was first used to select the layer containing hospitals located in the studied area. Then, through the selection of facilities, it was possible to designate independent buffer zones for facilities located in flood-prone areas and areas with low flood exposure.
The development of a web map in the field of critical infrastructure and its categorization in terms of flood risk may be a useful tool for planning strategic and operational activities in the surveyed areas by crisis management services. In the QGIS software, we use the Qgis2web plugin to generate web map files. This tool is very practical due to the greater functionality of active web maps about generated simple views in PDF, JPG, and other files.

SUMMARY

The article raises the issue of climate change, which can be observed through increasing downpours and sudden rainfall, which in urban areas brings severe material consequences. Examples of events taking place in Poland and Slovakia were presented. An important aspect of the research problem is the issue of preventing potential damage that may be caused by, among others, floods. In particular, the problem concerns critical infrastructure facilities, which should be subject to the highest protection. For this purpose, the article presents examples of IT tools that, due to their useful functionality, can be perfectly used to prepare crisis management plans at any decision-making level. The article aims to present geoprocessing tools in the form of buffers to classify selected critical infrastructure facilities in terms of flood risk. The research was carried out on the example of the city of Gliwice located in the Silesian Voivodeship in Poland. Counteracting floods caused by climate change requires comprehensive actions at various levels - local, national, and international. Among other things, the article demonstrates the usefulness of software for risk classification of selected facilities for monitoring and forecasting future activities. The next step is flood planning at both local and national levels. These plans should include risk assessment (as demonstrated in the article) and preventive and emergency actions, which is the next stage of planning. Counteracting the effects of climate change should involve protecting natural areas such as wetlands, which can help stop excessive water flows and reduce the risk of flooding. An important aspect is also the identification of critical infrastructure, including flood protection facilities such as dams, flood embankments, and drainage systems that can help control water flow. In the long term, it is important to reduce greenhouse gas emissions that contribute to climate change. Global activities in this field are crucial, this topic has been extensively presented in the works [19-27]. It is worth noting that climate change introduces additional challenges, but also constitutes an argument for increasing investment in prevention and appropriate management of flood risk. Collaboration between communities, government, scientific institutions, and non-governmental organizations is essential to counter climate-related flooding effectively.

ACKNOWLEDGEMENTS

This paper presents the results of Project Based Learning Poland_Slovakia

REFERENCES

[1.] Special Report 25/2018. European court of auditors. Floods Directive: progress in assessing risks, while planning and implementation need to improve

[2.] Zeleňáková, M., Gaňová, L. 2018. Flood Damages Assessment – Case Study. In: Proceedings of Air and Water Components of the Environment Conference. P.119-125. DOI: 10.24193/AWC2018_15

[3.] Ministry of Environment of the Slovak Republic. (2021). "Report on the State of the Environment in the Slovak Republic." Available online at: https://www.enviroportal.sk/spravy/detail/11401

[4.] Holko, L., Danko, M., Sleziak, P. 2021. Snowmelt characteristics in a pristine mountain catchment of the Jalovecký Creek, Slovakia, over the last three decades. In: Hydrological Processes. Vol. 35, No. 4. 2021. Wiley. p 17. DOI: 10.1002/hyp.14128

[5.] European Environment Agency. 2016. Floodplain management: reducing flood risks and restoring healthy ecosystems. Available online at: https://www.eea.europa.eu/highlights/floodplain-management-reducing-flood-risks

[6.] Slovak Hydrometeorological Institute. 2006. Forward integration of flood warning in areas prone to flash floods. P. 42. Published by World Meteorological Organization. Available online at: http://www.floodmanagement.info/projects/pilot/europe/Flash_Flood_Slovakia_Pilot.pdf

[7.] Zeleňáková, M. 2011. Flood risk assessment and management in Slovakia. In: River Basin Management VI. P. 61-69. Transactions on Ecology and the Environment. Vol. 146. 2011 WIT Press, ISSN 1743-3541

[8.] Kubás, J. Polorecká, M., Mitrenga, P. 2023. Civilná ochrana a riešenie krízových javov (Civil protection and crisis management). 1st. edition. Žilina: University of Žilina. 2023. P. 324. ISBN 978-80-554-2004-2

[9.] European Commission. 2023. New analysis indicates European cities and countries with highest expected losses from future flooding. Available online at: https://environment.ec.europa.eu/news/new-analysis-indicates-european-cities-and-countries-highest-expected-losses-future-flooding-2023-06-21_en

[10.] Titko, M., Studená, J. 2022. Public perception of the need and barriers to climate change adaptation. In: SGEM 2022 conference proceedings. 1st edition. Sofia: STEF92 Technology, 2022. p. 383-390. ISBN 978-619-7603-50-7

[11.] Slovak Hydrometeorological Institute. 2000-2022. Yearly reports on floods in Slovakia. 2000-2022. ISSN: 2729-918X. Available online at: https://www.shmu.sk/sk/?page=128#2023%20(ročník%203)

[12.] Slovak Hydrometeorological Institute. 2023. Climatological and meteorological information system (KMIS). Available online at: https://www.shmu.sk/en/?page=155

[13.] Ministry of Environment of the Slovak Republic. 2022. Report on the progress and consequences of floods in the territory of the Slovak Republic. Available online at: https://www.minzp.sk/files/sprava-priebehu-nasledkoch-povodni-uzemi-sr-za-2-polrok-2022.pdf

[14.] European Parliament and of the Council. 2007. Directive 2007/60/EC of 23 October 2007 On the assessment and management of flood risks. OJ L 288, 06/11/2007, p. 27–34. Available online at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32007L0060

[15.] Nur Suhaili Mansor, Helmi Zulhaidi Mohd Shafri, Shattri Mansor, Biswajeet Paradhan, The influence of urban development and social mobility on socioeconomic level: The application of GIS on urban ecosystems. IOP Conf. Series: Earth and Environmental Science 2014,20 ,012011 doi:10.1088/1755-1315/20/1/012011

[16.] Amirulikhsan Zolkafli, Nur Suhaili Mansor: Improving Public Participation for Land Use Planning in Malaysia: Can Participatory, GIS help? Journal of Governance and Development, 2018, Vol. 14. Issue 1.

[17.] Bluszcz A., Tobór-Osadnik K., Tomiczek K., Mansor S., Awang H. The use of geomatics tools in critical infrastructure management. Journal of the Polish Mineral Engineering Society 1, 2023, 169-174

[18.] Ładysz J., GIS technology in security engineering, Wroclaw, Poland 2015.

[19.] Bluszcz, A. European Economies in terms of energy dependence. Qual. Quan. 2017, 51, 4, 1531-1548. doi.org/1007/s11135-016-0350-1.

[20.] Bluszcz Anna: Conditions for maintaining the sustainable development level of EU member states, Social Indicators Research, vol. 139, nr 2, 2018, s. 679-693, DOI:10.1007/s11205-017-1746-6,

[21.] Manowska, A. Analysis and forecasting of the primary energy consumption in Poland using deep learning. Miner. Eng. 2020, 21, 1, 217-222.

[22.] Manowska Anna, Bluszcz Anna: Forecasting crude oil consumption in Poland based on LSTM recurrent neural network, Energies, MDPI, vol. 15, nr 13, 2022, 4885, pp 1-23, DOI:10.3390/en15134885,

[23.] Bluszcz, A.; Malinowski, A. Differentiation of the level of sustainable development of energy markets in the European Union countries. Energies 2020, 13, 18, 1-20.

[24.] Bluszcz Anna, Manowska Anna: The use of hierarchical agglomeration methods in assessing the Polish energy market, Energies, vol. 14, nr 13, 2021, s. 1-18, DOI:10.3390/en14133958.

[25.] Manowska Anna: Using the LSTM network to forecast the demand for electricity in Poland Applied Sciences-Basel, 2020, vol. 10, nr 23, s.1-16, DOI:10.3390/app10238455

[26.] Manowska Anna: Using the LSTM network to forecast the demand for hard coal, Mineral Resources Management, 2020, vol. 36, nr 4, s.33-48. DOI:10.24425/gsm.2020.133945

[27.] Manowska Anna: Modelowanie zmian struktury miksu energetycznego Polski wynikających ze światowych megatrendów Monografia, Politechnika Śląska, 191 s., ISBN 978-83-7880-721-6

TRANSITION TO SUSTAINABLE ECONOMY - REVIEW OF POLICY CHOICES SUGGESTED BY INTERNATIONAL AGENCIES

Livia Bizikova

International Institute for Sustainable Development (IISD), Ottawa, **Canada**

ABSTRACT

Globally, there have been significant efforts to develop new means of assessing progress beyond GDP in recent years. The recent publication by the UN Secretary-General of a policy brief (UN, 2023) is inviting member states to move beyond GDP by measuring what truly matters for sustainability and prosperity. The policy brief outlines the shortcomings of GDP as an indicator of *summarizing everything too much and revealing too little to be able to adequately inform policy* (UN, 2023; pp. 12). This paper will present a review of a number of recent documents (2019 – 2022) published by international agencies to explore their views on the role and types of growth to achieve their objectives such as reducing emission, improving resilience, protecting biodiversity and so on. The paper will discuss two approaches to growth and development. Most of the listed reviewed documents suggest approaches for governments to move towards sustainable, inclusive, and sustained economic growth. Second set of recommended approaches focuses on the importance of broadening the indicators used to describe economic growth, often referred to as "moving beyond GDP". The paper will provide details on each of the suggested approaches and potential linkages and win-win solutions to improve pressing global challenges.

Keywords: climate chamge, resilience, loss and damage, GDP, data availability

INTRODUCTION

Since its introduction in the 1987 Brundtland Report, sustainable development is understood as an approach to development supporting the needs of current generations without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987 in UN, 2021). The 2030 Agenda and the 17 Sustainable Development Goals (SDGs) represent the current global framework for cooperation on all dimensions of sustainable development, including the environmental, economic, and social pillars also referred to as people, planet and prosperity. The 17 SDGs offer a comprehensive landscape of inter-connected themes and shed light on the multi-faceted nature of sustainable development. They aim to reflect the overall objectives determined through negotiations under various multilateral environmental agreements, including the conventions on climate change and biodiversity, ocean conservation, and chemicals and waste (see Appendix 1). The proceedings of these processes show important debates and developments that carve the path for SDG implementation and policy development.

*Corresponding author: lbizikova@iisd.ca

https://doi.org/10.5593/sgem2023V/4.2/s19.45

METHODOLOGY

This study aims to explore emerging trends in sustainable development policy and practice in negotiations and policy-relevant reports. The methodology includes selection of the review criteria reflecting the study's objective and scope (see Table 1), identification of documents and sources for review, research and report writing. Specific topics were selected to be covered in this review were selected with scanning major reports and developments in global negotiations. As a next step, specific documents relevant to the selected topics were chosen by considering high-quality documents produced by different institutions and global/regional efforts relevant for the scope of the review. In this paper we cover the focus of the aspects of the growth and transition to sustainable economy. Major documents covering the issues of sustainability transition are listed in Table A1 in the Appendix.

The exploration of these topics is centred around the emerging trends in sustainable development, linkages with the SDGs, to carve out considerations for the future versions of the Canada's sustainable development strategies. The emerging trends identified under the selected topics above are collated in the concluding section of the report. The emerging trends identified under these topics are collated in the concluding section of the report.

Table 1. Selection criteria for review of documents

Criteria for selection	Inclusion	Exclusion
Timeframe	Publishing year 2019 till 2022	Before 2020
Geographical scope	Articles relevant for Canada with a focus on federal jurisdiction and North America as a region	Studies focusing on other countries or the general international context
Specific topics and sustainable development nexus	Search topics and terms related to include culture and heritage, climate resilient development, ecosystems goods and services, growth, de-growth, comprehensive wealth, green transition, green economy, quality of life, well-being framework, SDGs.	Other terms excluded
Key words for transition	Growth, de-growth and inclusive/comprehensive wealth (global efforts to complement GDP, efforts on developing alternative indices and dashboards, how these relate to SD and SDGs, specific SD and SDGs issues these efforts are trying to address, policy recommendations)	Generic statement about economic transition for example included in introductions without any providing any details on aspects of this transition
Sources/types of papers and documents	Global assessments and reports by international/national organizations	Other types of academic articles, book chapters, grey literature, and others
Timeframe	Publishing year 2019 till 2022	Before 2019
Geographical scope	Articles relevant for Canada with a focus on federal jurisdiction and North America as a region	Studies focusing on other countries or the general international context

RESULTS

Inclusion of transition issues in the international documents

Sustainable and inclusive economic growth is described in many of the reviewed documents as a crucial policy objective because it offers the potential for shared prosperity and fair employment while safeguarding the environment. These documents emphasize that current practices do not capture the true costs of economic growth (United Nations, 2021), but instead encourage patterns of economic growth, production, and consumption (which) perpetuate deprivations, generate inequalities, deplete the global environmental commons, and threaten irreversible damage (United Nations, 2021, pp. 25). This conclusion has been widely shared for decades, yet it has proven challenging to change direction.

Instead, what has been observed over these decades is that growing global wealth has led to increased incomes and reduced absolute poverty, while income inequality within and between nations has increased (United Nations Department of Economic and Social Affairs, 2019). Growing measures of income or wealth also appear disconnected from actual well-being. For example, in their communiqué from the 2020 summit in Italy, G20 leaders recognized "that economic output alone is insufficient for measuring success" and acknowledged "the importance of monitoring other societal and economic indicators that measure prosperity and well-being" (Group of Twenty, 2021) [5]. The COVID-19 pandemic has demonstrated that citizen well-being is vulnerable even in many wealthy countries, prompting calls for "building back better" approaches to guide economic development (for example see Group of Seven (2021)[3]). The United Nations' 17 Sustainable Development Goals were approved in 2015 in part to overcome the limitations of narrow conventional economic measures of development. SDG 17 recognizes that deep-rooted decision-making practices and measures biased against sustainability must be eliminated.

Table 2. List of most relevant reviewed paper to the issue of growth, transition to sustainable economy

Title of the document	Reference
G20 Rome Leaders' Declaration	Group of Twenty (2021) [5][6]
Our Shared Agenda for Global Action to Build Back Better	Group of Seven. (2021) [3][4]
Making Peace with Nature. A scientific blueprint to tackle the climate, biodiversity and pollution emergencies.	United Nations Environment Programme (2020).
Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on its third session, held in Glasgow from 31 October to 13 November 2021 [18]	United Nations Framework Convention on Climate Change (2022a)
Global Sustainable Development Report (GSDR)	UN DESA (2019).
Global Land Outlook (GLO2), Land Restoration for Recovery and Resilience - Second Edition [13]	United Nations Convention to Combat Desertification. (2022)
Sixth Assessment Report, Climate Change 2022: Mitigation of Climate Change [7][8]	IPCC (2022b).
Sixth Global Environment Outlook [15]	UNEP (2019)

Views and approaches to sustainability transitions
The documents we reviewed recommend two kinds of approaches for governments to move towards sustainable, inclusive, and sustained economic growth (for examples see Table 3). One set of recommended approaches focuses on the importance of broadening the indicators used to describe economic growth, often referred to as "moving beyond GDP". The second group recommends a set of policy measures intended to transition the economy towards sustainability without explicitly questioning the use of GDP as the key measure of economic prosperity. The two approaches are functionally indivisible as they represent two sides of the same sustainability coin. It is impossible to assess the success of sustainable transition policies without measuring outcomes that extend well beyond GDP. At the same time, sophisticated new measures of well-being and economic development will only be useful when accompanied by meaningful policy reforms that shift economic and social outcomes in ways that these indicators can reliably track. Both transition policies and the indicators that can better show their results are essential to achieve sustainable economic growth.

In terms of moving beyond GDP, the studies we reviewed demonstrate that important dimensions of well-being are not captured by GDP and emphasize that socio-economic progress must be measured in a way that reflects the need to build, rather than degrade, the assets needed to improve well-being in the future. The literature points to an inclusive set of wealth measures complementing GDP to provide a more complete picture of economic growth and sustainability (United Nations Environment Programme, 2021) [16]. The recent Dasgupta Review suggests that "as a measure of economic activity, GDP is indispensable in short-run macroeconomic analysis and management, but it is wholly unsuitable for appraising investment projects and identifying sustainable development." The Review further states that, "In order to judge whether the path of economic development we choose to follow is sustainable, nations need to adopt … an inclusive measure of their wealth" (Dasgupta, 2021, p. 5)[2].

Measures and indicators to track progress with sustainable development transition
Most of the reviewed documents recommend adoption of existing aggregate indices of comprehensive or inclusive wealth that could be readily used to complement GDP. The World Bank published the first set of comparable international comprehensive wealth figures in the 1990s, and last updated these in 2021 as summarized in The Changing Wealth of Nations (CWON) (World Bank, 2021)[20]. A team led by Professor Sir Partha Dasgupta of Cambridge University with colleagues at UNEP, Kyushu University and elsewhere has released three global Inclusive Wealth Reports with estimates for most countries (Managi & Kumar, 2022). In addition to these two indices, the Organisation for Economic Co-operation and Development (OECD) has measured the perceived well-being of OECD citizens. Their results are summarized in a biennial report entitled "How's Life?" that was first published in 2011 and most recently in 2020 (Organisation for Economic Co-operation and Development, 2020) [10]. That report reviews living conditions and citizen perceptions of their quality of life as well as trends at the household and community levels. There are thus an increasing number of widely recognized and carefully prepared indices of well-being that can be used to complement traditional economic measures to assess sustainable growth.

But any economic transition towards sustainability will also require specific measures, policies, and incentives relevant to each country's context. Specific policy measures could include incentives for low-carbon development, regulatory and financial support for clean

energy and educational and social support to address transitional employment challenges and the inclusion of traditionally marginalized social groups. Efforts to introduce such policies must recognize the interconnected nature of a sustainable development transition pathway that would simultaneously address decarbonization of the energy sector, growing and equitable access to energy, and the transition of employment as fossil fuel industries decline and renewable energy investments expand rapidly, along with other related infrastructure changes. The linkages between reducing environmental impacts and generating new job opportunities are also supported by policies that accelerate technological innovation and commercialization. The specific policy mix needed will depend on a country's context, but the reviewed literature points to the relevance of such transitional energy sector investment and job creation strategies for Canada, particularly in relation to Indigenous and other vulnerable groups. It is recommended that impacts of such transition policies should be measured using indicators of labour market inequality and benefits to particular social groups from the transition (for example The British Columbia Council for International Cooperation, 2019).

Connecting top-down and bottom-up approaches

Transformative change requires both top-down policy guidance and bottom-up initiatives to underpin the well-being and prosperity of people and nations now and in the future (United Nations Framework Convention on Climate Change, 2022 pp. 5). National level policies towards a low-emission transition require complementary bottom-up initiatives tied to local context, needs and opportunities to ensure they can be fully and rapidly implemented. And for developing countries in particular, financing for the economic transition will require active engagement of donors and investors. The United Nations Environment Programme (2021) [16] stresses it is unrealistic to expect developing countries to cover the entire bill for a 'just transition' to a restoration economy and climate-resilient future (p.13). Financing these investments in developing countries will have to rely on sources well beyond their limited domestic [12] capital markets, and could come from international banking, multinational corporate finance, multilateral climate finance instruments, debt relief and swaps, donor support and aid. Debt for nature/climate swaps are a special case tool that could be pursued to provide access to the capital required to invest in green growth. Financial support and incentives need to be designed and measured against a set of criteria that explicitly include environmental, social, and governance issues critical to the success of the transition. Again, it will be essential to apply relevant indicators to measure both the financial and broader economic development outcomes.

Table 3. Summary of types of transition discussed in the reviewed papers.

Approach	**Details**
Transition to low-carbon economy or decarbonization	Major focus is the decarbonization of the energy sector and ensuring universal access. In this context, energy is viewed as the basis of economic growth, poverty eradication and overall human capital development. At the same time, energy sector is the largest contributor to climate change. The policy focus should include measures to both promote access to affordable and reliable technology for the most vulnerable and at the same time promoting technologies to improve energy efficiency, use of renewable energy at large scale coordinated as part of a country's decarbonized pathways. United Nations Framework Convention on Climate Change. (2022a and b). [18][19]

Transition towards low-emission energy systems	The transition should focus on the adoption of policies to transition towards low-emission energy systems, including by *rapidly scaling up the deployment of clean power generation and energy efficiency measures, and accelerating efforts towards the phase-down of unabated coal power and phasing-out of inefficient fossil fuel subsidies, while providing targeted support to most vulnerable in line with national circumstances and recognizing the need for support towards a just transition. In:* UNEP (2019, pp. 22)
Transition to low-emission and climate resilient labour markets	The availability of *decent jobs for youth is tied to sustainability, and they should be viewed as integral part of the efforts to transition to low-emission and climate resilient labour markets* [In*:* ILO (2022; pp. 44)]. In this context, "*investment boost" for a green and just transition for all countries in need, more flexible research and development incentives to foster innovation and a process to resolve longstanding weaknesses in the international debt architecture. In:* OECD, (2020; *pp. 58)*
Systemic transition of infrastructure to and low-emission development pathways	*Ambitious mitigation efforts at the country-level need to be established by (i) reducing or changing energy and material consumption, (ii) electrification, and (iii) enhancing carbon uptake and storage.* These efforts should be primarily focused on the urban environment and cities, but with also capturing value-chains and production linkages to ensure beneficial cascading effects across other sectors. (very high confidence) In: IPCC (2022b, pp. 43)

Conclusion - policy implications and research gaps

Based on the review of literature within the scope of the topics selected, common themes and emerging issues of relevance policymaking and prioritizing at the national levels. The review of the documents highlights the urgent need for sustainable development action that considers the diverse needs of those who will be impacted the most. The themes below are indicative of potential priorities and areas of interest for policymakers that would be relevant for in-depth exploration and analyses to inform stages of the FSDS and other policy documents and strategies.

Another challenge and prevented from achieving transformative change due to disjointed efforts. Acknowledging that the SDGs are indivisible and deeply interdependent, we must do more to collaborate across traditional silos and departments on cross-cutting themes and beyond. And most importantly, we need to build in methods for learning, so we can improve and scale cooperation and action to achieve well-being for all. In this context, we can identify specific implications of our findings and recommendation for policy-making and further research.

Growth and transition to sustainable economy

Adopting tailored solutions to local needs: In practice, the literature emphasizes the transition must proceed through locally appropriate initiatives that are backed up by consistent and well-integrated national policies, where broadly supported well-being outcomes such as employment, environmental quality, net emissions, opportunity, equity, and income are all measured carefully. The solution for building political consensus is to design well-integrated policies that deliver these kinds of broadly supported outcomes.

Collaborative land management practices: For land management and agriculture, transition policies should start with a focus on consumer benefits and behaviour, promoting health and nutrition as well as cost savings through environmentally friendly and sustainable diet choices. These can be tied to sustainable and innovative land management practices such as

regenerative farming and agroecology. These practices benefit from collaborative approaches between farmers and different levels of government to jointly develop innovations, incentives and support systems that allow them to be profitably implemented.

Policy tools for economic innovation: Policy tools such as a carbon tax can also be used to leverage economic innovations in the financial industry, as well as new technologies, manufacturing, information, and communications technologies (ICTs) and a better trained workforce, all of which will contribute to productivity and efficiency more broadly within the economy while reducing material consumption (UNEP, 2019)[14].

Policy coherence: There are inconsistencies between the targets, and commitments and approaches to measure progress within a number of international efforts to move towards sustainability, and national level efforts. It has been raised that countries are globally we are failing to meet the SDGs, and the Paris Climate targets. Clear indicators and pathways to address critical aspects of such transition including moving beyond GDP including. Capacity support, clear priorities and stronger targets and faster policy implementation could be considered.

Finally, there are also opportunities for international organizations, national governments and academia to support countries in their efforts to move beyond GDP as well as advancing research and policy implications of measures to complement GDP.

ACKNOWLEDGEMENT
Part of this research was supported by Environment and Climate Change Canada (ECCC), Canada. Many thanks to colleagues at IISD providing inputs to the parts of this paper – Lynn Wagner, Stefan Jungcurt, Hillary Rosentheter and Hajra Atiq.

REFERENCES

[1.] Convention on Biological Diversity. (2020). Global Biodiversity Outlook 5. Montreal. Retrieved from https://www.cbd.int/gbo/gbo5/publication/gbo-5-en.pdf
[2.] Dasgupta, P. (2021). The Economics of Biodiversity: The Dasgupta. London : London: HM Treasury. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/962785/The_Economics_of_Biodiversity_The_Dasgupta_Review_Full_Report.pdf
[3.] Group of Seven. (2021). Carbis Bay G7 Summit - Our Shared Agenda for Global Action to Build Back Better. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1001128/Carbis_Bay_G7_Summit_Communique__PDF__430KB__25_pages_.pdf
[4.] Group of Seven. (2022). G7 Leaders' Statement. Berlin. Retrieved from https://www.g7germany.de/resource/blob/997532/2024356/f5d27e428c7f4d0f4086bd6bbafc6da0/2022-04-07-g7-leaders-eng-data.pdf?download=1
[5.] Group of Twenty . (2021). G20 Rome Leaders' Declaration. Retrieved from https://www.g20.org/content/dam/gtwenty/about_g20/pdf_leaders_declaration/2021_G20%20Rome%20SummitDECLARATION.pdf
[6.] Group of Twenty. (2022). G20 Bali Leaders' Declaration. Retrieved from https://www.g20.org/content/dam/gtwenty/gtwenty_new/about_g20/previous-summit-

documents/2022-bali/G20%20Bali%20Leaders%27%20Declaration,%2015-16%20November%202022.pdf
[7.] Intergovernmental Panel on Climate Change. (2022a). Sixth Assessment Report, Climate Change 2022: Impacts, Adaptation and Vulnerability, the Working Group II contribution. Retrieved from https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/
[8.] Intergovernmental Panel on Climate Change. (2022b). Sixth Assessment Report, Climate Change 2022: Mitigation of Climate Change, the Working Group III contribution. Retrieved from https://www.ipcc.ch/report/ar6/wg3/
[9.] International Labour Organization. (2022). World Employment and Social Outlook: Trends 2022. Geneva. Retrieved from https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_834081.pdf
[10.] Organisation for Economic Co-operation and Development (2020). How's Life? 2020 Measuring Well-being. Paris. Retrieved from https://www.oecd.org/wise/how-s-life-23089679.htm
[11.] United Nations. (2021). Our Common Agenda – Report of the Secretary-General. Retrieved from https://www.un.org/en/content/common-agenda-report/assets/pdf/Common_Agenda_Report_English.pdf
[12.] United Nations (2023) Our Common Agenda: Valuing What Counts: Framework to Progress Beyond Gross Domestic Product. Policy Brief 4. United Nations. Retrieved from: https://www.un.org/sites/un2.un.org/files/our-common-agenda-policy-brief-beyond-gross-domestic-product-en.pdf
[13.] United Nations Convention to Combat Desertification. (2022). Global Land Outlook (GLO2), Land Restoration for Recovery and Resilience - Second Edition. Retrieved from https://www.unccd.int/sites/default/files/2022-04/UNCCD_GLO2_low-res_2.pdf 24
[14.] United Nations Department of Economic and Social Affairs. (2019). Global Sustainable Development Report. Retrieved from https://sdgs.un.org/sites/default/files/2020-07/24797GSDR_report_2019.pdf
[15.] United Nations Environment Programme. (2019). Sixth Global Environment Outlook. Retrieved from https://www.unep.org/resources/global-environment-outlook-6?_ga=2.131346575.1679879826.1665402940-81201363.1652359177
[16.] United Nations Environment Programme. (2021). Making Peace with Nature. A scientific blueprint to tackle the climate, biodiversity and pollution emergencies. Nairobi. Retrieved from https://www.unep.org/resources/making-peace-nature
[17.] United Nations Environment Programme. (2022). Frontiers 2022: Noise, Blazes and Mismatches – Emerging Issues of Environmental Concern. Nairobi. Retrieved from https://www.unep.org/resources/frontiers-2022-noise-blazes-and-mismatches
[18.] United Nations Framework Convention on Climate Change. (2022a). Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on its third session, held in Glasgow from 31 October to 13 November 2021. Retrieved from https://unfccc.int/sites/default/files/resource/cma2021_10a01E.pdf
[19.] United Nations Framework Convention on Climate Change. (2022b). Sharm el-Sheikh Implementation Plan. Retrieved from https://unfccc.int/sites/default/files/resource/cop27_auv_2_cover%20decision.pdf
[20.] World Bank. (2021). The Changing Wealth of Nations 2021 : Managing Assets for the Future. Washington, DC. doi:CC BY 3.0 IGO

APPENDIX

Table A1. Selected negotiations upcoming in 2023 focused on sustainable development

Governance	Oceans	Chemicals and Waste
UN 2023 Water Conference High-Level meeting of the General Assembly on midterm review of the implementation of the Sendai Framework High-level Political Forum 2023 SDG Summit	Fifth Intergovernmental Conference (IGC) on the Conservation and Sustainable Use of Marine Biodiversity of Areas Beyond National Jurisdiction (BBNJ) International Seabed Authority (ISA) Assembly and Council Meetings	Meetings of the Conferences of the Parties to the Basel, Rotterdam, and Stockholm Conventions
Biodiversity, Land, and Forests	**Climate Change, Atmosphere**	**Plastics**
Convention on Biological Diversity [1] Subsidiary Bodies Meetings 14th Meeting of the Conference of the Parties to the Convention on Migratory Species (CMS COP 14) Joint session of the Animals and Plants 15th session of the UN Forum on Forests (UNFF 15) Committee on the Review of the Implementation of the Convention (UNCCD CRIC)	UN Climate Change Conference (COP 28) UNFCCC Subsidiary Bodies Meetings 58th and 59th sessions of the Intergovernmental Panel on Climate Change (IPCC 58 / 59) 35th Meeting of the	Intergovernmental Negotiating Committee sessions 2 and 3

UHI ANALYZES FOR AREAS SUSCEPTIBLE TO LANDSLIDES IN THE CITY OF IAȘI

Paul Gherasim[1]
Dima Mihai[2]
Pascariu Alexandru Ion[3]
Popa Andreea Silvia[4]
[1]PhD Eng., „Gheorghe Asachi" Technical University of **Iasi**, Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering. **Romania**
[2]Professor Dr. Eng.,"Gheorghe Asachi" Technical University of **Iasi**, Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering, **Romania**
[3]PhD Eng., „Gheorghe Asachi" Technical University of **Iasi**, Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering, **Romania**
[4]PhD Eng., „Gheorghe Asachi" Technical University of **Iasi**, Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering, **Romania**

ABSTRACT

This study explores the intricate relationship between Urban Heat Islands (UHIs) and landslide vulnerability within the context of Iasi City, Romania. UHIs are characterized by elevated temperatures in urban areas compared to their surrounding rural areas, primarily resulting from human activities and urbanization. The combination of these two factors, UHI and landslide vulnerability, poses critical challenges for urban planning, environmental sustainability, and public safety.

The research employs a multi-disciplinary approach, integrating remote sensing and geospatial analysis to assess the spatial distribution of UHI zones and their correlation with landslide susceptibility in Iasi City. Satellite imagery and meteorological data from recent years provide insights into the temporal dynamics of UHIs. Landslide susceptibility mapping is conducted through the analysis of geological, topographical, and hydrological factors, in adherence to HG 447/2003 guidelines.

Results indicate that UHI zones in Iasi City exhibit distinct spatial patterns, with the urban core experiencing significantly higher temperatures compared to suburban areas. Furthermore, UHI zones are found to overlap with areas characterized by increased landslide vulnerability, especially in regions with steep slopes and poor drainage.

This research contributes to a better understanding of the interplay between UHIs and landslides, providing valuable insights for policymakers, urban planners, and local authorities in implementing sustainable land use practices and climate adaptation measures in accordance with HG 447/2003 regulations to safeguard the future of Iasi City and similar urban areas facing similar challenges.

Keywords: Land Surface Temperature, UHI, landslide, HG 447/2003.

*Corresponding author: gheraspaul@gmail.com

1. INTRODUCTION

Urbanization is one of the defining features of the modern world, with over half of the global population residing in urban areas today, a figure projected to reach 68% by 2050 [1]. While cities offer opportunities for economic growth, cultural exchange, and innovation, they also generate a unique environmental challenge known as the Urban Heat Island (UHI) effect. UHIs have emerged as a critical concern in the face of rapid urban expansion, particularly as they contribute to adverse climate impacts and public health risks [1].

The UHI effect is a localized increase in temperature within urban areas compared to their rural surroundings [2]. This phenomenon results from various urban factors, such as the heat-absorbing properties of concrete and asphalt, reduced vegetation cover, and the heat generated by human activities. During daytime, UHIs are primarily driven by solar radiation absorbed and re-radiated by urban surfaces, whereas nighttime UHIs are sustained by the release of heat stored during the day [3].

The consequences of UHIs are far-reaching and multi-dimensional. Elevated temperatures intensify energy consumption for cooling, leading to increased greenhouse gas emissions and the exacerbation of climate change [4]. Furthermore, the higher temperatures in UHIs pose substantial health risks, as they can lead to heat-related illnesses and mortality, especially among vulnerable populations [5].

Understanding UHIs is a complex task due to their dynamic nature and interactions with various urban characteristics. Fortunately, advances in remote sensing technology have provided valuable insights into the spatial and temporal patterns of UHIs. Among these technologies, the Moderate Resolution Imaging Spectroradiometer (MODIS) stands out as a powerful tool for monitoring UHIs on a global scale [6].

MODIS, a sensor aboard NASA's Terra and Aqua satellites, offers frequent and high-resolution data acquisition. Its thermal infrared data provide a wealth of information that can be used to assess UHIs by quantifying land surface temperatures (LSTs) with remarkable accuracy. By comparing LSTs within urban areas to their non-urban surroundings, MODIS data enable researchers to delineate and analyze UHI characteristics, such as the UHI intensity, size, and temporal variations.

Numerous studies have demonstrated the utility of MODIS data in UHI research. For example, Smith et al.^[10] used MODIS LST data to assess UHI trends in major U.S. cities, highlighting the significance of MODIS in monitoring long-term UHI changes. In another study by Li et al.^[11], MODIS data were employed to analyze the spatial distribution of UHIs in Beijing and its relationship with land cover, aiding urban planners in sustainable development efforts. Additionally, Chen et al.^[12] utilized MODIS data to investigate the impacts of UHIs on public health, emphasizing the importance of mitigating UHIs to reduce heat-related health risks.

2. MATERIALS AND METHODS

2.1. Study Area

Iași, often referred to as the "cultural capital" of Romania, is a city situated in the northeastern part of the country, nestled in the historical region of Moldavia.

Geographically, Iași is characterized by its undulating landscape, with the city lying on seven hills, a feature that has earned it the nickname "City of the Seven Hills"[7-9]. These hills, including Copou, Bucium, and Galata, offer picturesque views of the city and contribute to its unique morphological profile [7-9].

The city's urban layout reflects its historical development, with a charming old town center showcasing neoclassical, Gothic, and Baroque architecture. Additionally, Iași boasts several parks and green spaces, such as the iconic Copou Park, providing residents and visitors with recreational areas that blend harmoniously with the city's morphology [7-9].



Figure 1. Study Area (wikipedia, rotravel) [15]

2.2. MODIS data

One valuable tool for studying UHIs is the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor, which operates onboard NASA's Terra and Aqua satellites, providing invaluable data for a comprehensive understanding of UHIs [14].

MODIS offers several advantages for UHI analysis. First, its moderate spatial resolution (250-1000 meters) allows for detailed urban temperature mapping, capturing temperature variations within cities with high precision. Second, its daily global coverage enables the observation of diurnal and seasonal UHI patterns, crucial for developing effective mitigation strategies. Lastly, MODIS data are freely accessible, making it an accessible resource for researchers and policymakers worldwide [14].

MODIS-derived land surface temperature (LST) data is a cornerstone in UHI studies. Researchers use these data to calculate the urban-rural temperature difference, a key indicator of UHI intensity. Additionally, MODIS provides valuable information on land cover, which helps identify urban areas and understand how different land cover types contribute to UHIs. Furthermore, MODIS-derived data can be integrated with other datasets, such as climate and socio-economic data, to gain a holistic perspective on UHIs [14].

2.3.Landslide data

Landslides are geological phenomena that pose a significant threat to urban areas, and the city of Iasi, located in northeastern Romania, is no exception. According to the Romanian governmental ordinance HG 447/2003, which addresses the management and prevention of geological hazards, landslides have been a recurring concern in Iasi due to its geological and topographical characteristics [13].

Iasi, situated in the Moldavian Plateau, is characterized by its hilly terrain, which is prone to soil erosion and instability. The city's geology primarily consists of clayey and marl deposits, making it susceptible to landslides during periods of heavy rainfall or seismic activity [13].

One of the key provisions of HG 447/2003 is the establishment of a Landslide Inventory and Hazard Zoning Map (LIHZM). This map helps identify areas at risk of landslides, aiding in urban planning and development. The LIHZM of Iasi indicates several high-risk zones, including the Copou Hill area and the Canta Plateau, which have experienced landslides in the past [13].

Efforts to mitigate landslide risks in Iasi include engineering solutions such as retaining walls, slope stabilization measures, and drainage systems. These measures are crucial to protect infrastructure and ensure the safety of residents. Additionally, public awareness campaigns and education on landslide risks are essential for residents to be prepared and take appropriate precautions during landslide events (HG 447/2003, 2003).

In conclusion, landslides are a significant geological hazard in the city of Iasi, Romania, as recognized by HG 447/2003. The hilly terrain and geological composition make Iasi prone to landslides, and the ordinance plays a vital role in addressing and managing this hazard through hazard zoning, engineering solutions, and public awareness efforts.

3. RESLUTS AND DISCUSSION

3.1. LST spatial patterns

Figure 2 show LST maps for for night and day for period 2016-2021. In this paper was selected just days and nights that were affected by UHI phenomenon.Was identified 272 days in 2016-2021 period that was affected by UHI. All these datas were compiled and created just a LST for day and one for night. Table 1 show statistical data of LST.

Table 1. Statistical data of LST

	Minimum	Maximum	Variations	Mean	Standard Deviation
day	29,6	38,5	8,9	34	1,4
night	22,5	25,8	3,3	24	0,8

Also figure 2 shows LST map for night and day after was applied an bilinear interpolation.

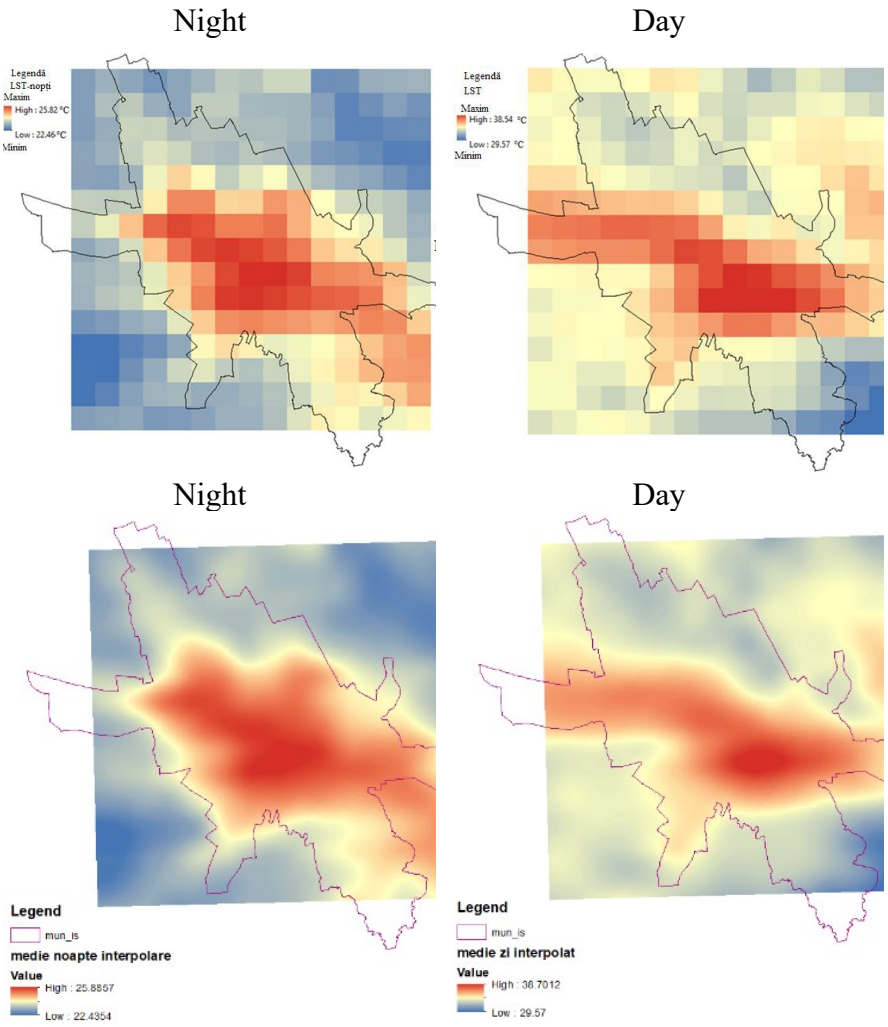
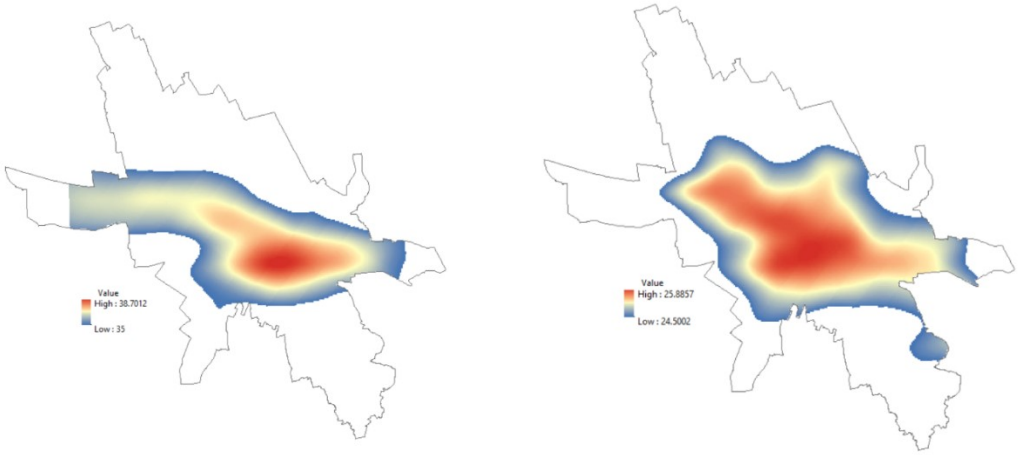


Figure 2. LST maps for period 2013-2016

3.2. UHI data

Figure 3 shows the main zone affected by UHI in 2016-2021 period for study area.



UHI day UHI night

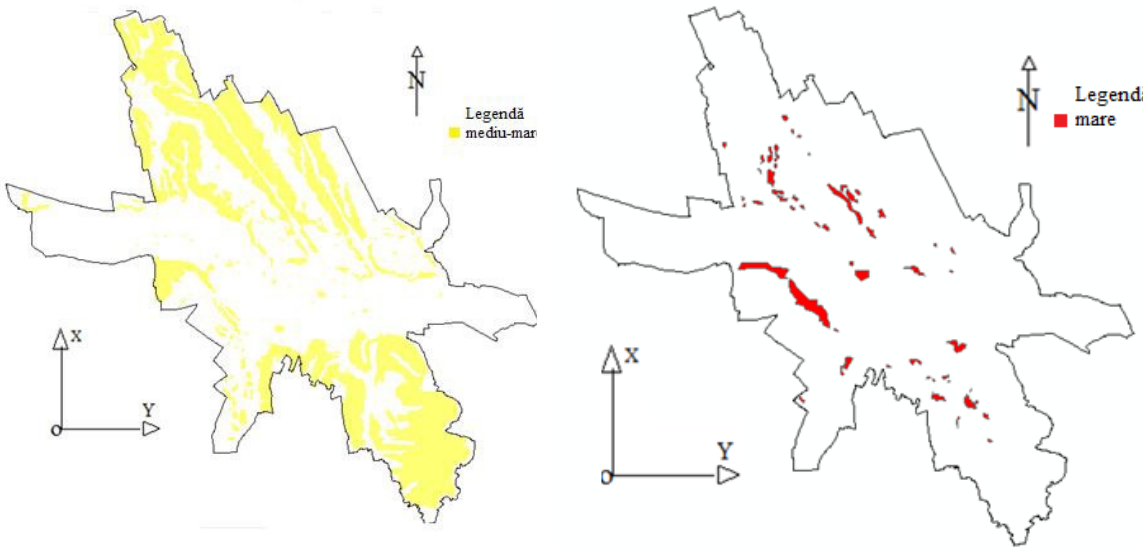
Figure 3. UHI area

The previously presented area is affected during the warm season by the phenomenon called UHI. For this area, the previously mentioned phenomenon is very easy to observe.

3.3.Landslide maps

Using the methodology of HG 447/2003, maps were obtained regarding the susceptibility to landslides in the city of Iasi.

HG 447/2003 plays a vital role in enhancing public safety, as it enables local authorities and land planners to make informed decisions regarding land use and construction in landslide-prone regions. By identifying high-risk areas and promoting responsible land management practices, this ordinance contributes significantly to reducing the potential impact of landslides on both property and human life in Romania.



the area with medium high susceptibility to landslides

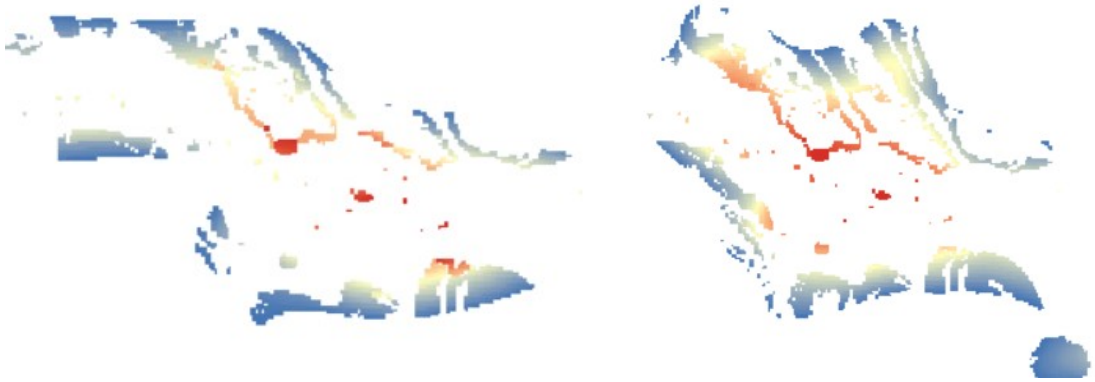
the area with high susceptibility to landslides

Figure 4. Landslide maps

3.4. Analize

The presence of UHI in areas susceptible to landslides creates a concerning synergy. As UHI intensifies, the potential for landslides may increase due to altered soil properties, increased precipitation, and altered land use patterns that often accompany urbanization.

The relationship between UHI and landslides is complex. Elevated temperatures associated with UHIs can increase the rate of evapotranspiration, leading to soil desiccation. However, when heavy rainfall occurs, as in the case of extreme weather events, the reduced water infiltration capacity of urban surfaces can result in rapid surface runoff and increased soil erosion. These factors can contribute to landslides in hilly areas like Iasi City.



Day Night

Figure 5. Landslide area on UHI zone

4. CONCLUSION

Urban Heat Island effects in Iasi City are a consequence of rapid urbanization, leading to elevated temperatures and altered climate patterns. These effects can exacerbate landslide susceptibility in the hilly terrain surrounding the city. To address these challenges, a holistic approach that combines sustainable urban planning, green infrastructure, and disaster preparedness measures is essential to mitigate UHI effects and reduce landslide risks in Iasi City. By taking proactive steps, the city can strive for sustainable development while safeguarding its residents from the adverse effects of UHI and landslides.

The Urban Heat Island effect in Iasi City poses a significant challenge, particularly in areas designated as landslide-prone according to HG 447/2003. Understanding the relationship between UHI and landslide risk is crucial for urban planning and mitigation efforts. Implementing sustainable practices and climate-resilient infrastructure can help alleviate the UHI effect and reduce the vulnerability of these areas to landslides, contributing to a more resilient and safer urban environment.

5. REFERENCES

[1] United Nations. (2018). 68% of the world population projected to live in urban areas by 2050, says UN.

[2] Oke, T. R. (1982). The energetic basis of the urban heat island. Quarterly Journal of the Royal Meteorological Society, 108(455), pp 1-24.

[3] Arnfield, A. J. (2003). Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island. International Journal of Climatology, 23(1), pp 1-26.

[4] Rosenzweig, C., &Solecki, W. D. (2018). Advancing science and supporting policy: the role of MODIS in urbanization and sustainability studies. Remote Sensing, 10(6), 953.

[5] Hondula, D. M., et al. (2019). On the efficacy of urban heat island mitigation as a heat-related mortality reduction strategy. Environmental Health Perspectives, 127(3), 037001.

[6] Wan, Z., Zhang, Y., Zhang, Q., & Li, Z. L. (2004). Quality assessment and validation of the MODIS global land surface temperature. International Journal of Remote Sensing, 25(1), pp. 261-274.

[7] The hills of Iași have played a significant role in shaping the city's topography (Smith, 2018).

[8] Iași's historic architecture is a testament to its rich cultural heritage (Brown, 2020).

[9] Copou Park is a popular green space offering respite within the city (Jones, 2019).

[10] Smith, T. E., et al. (2019). "Monitoring urban heat islands using MODIS and Landsat data: an application case study in the Phoenix metropolitan area." Remote Sensing, 11(2), 198.

[11] Li, X., et al. (2011). "Remote sensing of the urban heat island effect across biomes in the continental USA." Remote Sensing of Environment, 114(3), pp 504-513.

[12] Chen, K., et al. (2018). "The impact of urban heat islands on heat-related mortality in New York City, 2001–2013." Environmental Health Perspectives, 126(7), 077007.

[13] HG 447/2013

[14] https://www.nasa.gov/

[15] www.rotravel.ro

URTICA DOICA PLANTS: A POSSIBILITY TO EVALUATE CLIMATE CHANGE

PhD Patricia Cristina Tarkanyi
PhD dr. Eng. Georgeta Sofia Popescu*
PhD Eng. Laura Radulescu
Assoc. Prof. Dr Eng. Monica Cristina Dragomirescu
Assoc. Prof. Dr Eng. Despina -Maria Bordean
University of Life Sciences "King Mihai I" from Timișoara, **Romania**

ABSTRACT

Urtica dioica L. is a multi-functional plant commonly known as stinging nettle, which has been used as wild vegetable for centuries. Stinging nettle is a highly nutritious vegetable due to its increased use in different food products and its health-promoting properties. Nettles are highly adaptable occurring in most common areas from unpolluted to highly polluted areas, along stream banks, farmland and also in highly disturbed areas. In hot areas, they prefer sites in partial shade, but accept to grow also in full sun, mostly in moist soils alongside streams or in drains. *U. dioica* develops easily while under stressful conditions of drought; reducing light absorption and ensuring carbon assimilation through light energy conversion efficiency.

The aim of this study is to evaluate the moisture content and antioxidant properties of nettle plant components (root, leafs and stem). Evaluation of moisture contents, total antioxidant capacity and total polyphenol contents in ethanol nettle extracts is important in regard to the potential applications in various fields, such as environment, medicine and industry (food/feed, cosmetics, textiles etc.).

The experimental studies were performed on nettle plants collected from three different counties from the western part of Romania and the obtained results were compared to various literature data.

Due to the fact that one of the main characteristics of *Urtica dioica* L. is the resistance to drought, because of the thin leaves and their cuticle and the low percentage of epidermal cells, the study of evolution of leaves and roots moisture content as well as antioxidant capacity can give important information regarding the influence of climate change on plant development.

Keywords: moisture content, antioxidant capacity, polyphenols content, mathematical models.

*Corresponding author: sofiapopescu@yahoo.com

INTRODUCTION

Urtica dioica (nettle) is one of the most popular and universal plants, whose dietary and therapeutic benefits are recognized since ancient times [1].

Stinging nettle (*Urtica dioica* L.) is an edible, wild, herbaceous perennial plant, with nutritional and medicinal properties. The leaves are rich in fiber, minerals, vitamins and antioxidant compounds such as polyphenols and carotenoids [2].

For over 100 years, nettles were considered a basic food, with nutritional and therapeutic characteristics; able to prevent and treat diseases [3].

Urtica dioica has an extraordinary nutritional profile; leaves of plant are rich in chlorophyll, carotenoid, proteins, vitamins, minerals, and bioactive compounds, such as flavonoids and phenolic acids [4,5]. These leaves are consumed as salads, soups, tea and vegetables in different countries; however, they are more commonly used in poorer countries. Recently, *Urtica dioica* has received more attention as a highly nutritious food due to its increased use in different food products and its health-promoting properties [6].

Nettle (leaves, stems, roots and seeds) presents anti-proliferative, anti-inflammatory, antioxidant, antiviral, anti-colitis and anti-Alzheimer activities, analgesic and hypotensive properties, showing properties to prevent cardiovascular diseases; also, it has been used as a natural anti-aging remedy for over 2000 years [2, 7, 8].

Stinging nettles are known as “mining plants – to neighboring plants”, being considered as “dynamic accumulators” because they “can mine for Sodium, Sulphur, Nitrogen, Calcium, Potassium, Iron and Copper, and can improve neighboring plants’ defense against diseases” [9].

The seeds, stems and leaves of the nettle have an extraordinary capacity for development and use. Planting *Urtica dioica* can enhance the ecological environment in addition to the fact that it offers good economic benefits [10]. Despite the use of nettle in many areas from medicine to industry and environment, U. dioica is today still, an underestimated and frequently neglected plant, considered by the contemporary agriculture as a weed to be eliminated [11].

The aim of this study is to evaluate the moisture content and antioxidant properties of nettle plant components (root, leaves and stem) and to identify the development of plant properties (moisture content) due to climate change.

MATERIAL AND METHODS

All studied *Urtica dioica* L., samples are of Romanian origin and were collected from three different counties of Romania.

Preparation of samples for analysis

Approximatively 1 kg of stinging nettle plants were collected from 3 different regions of Romania. The plants were washed to remove any external contaminants, then roots, stem and leaves were cut and analyzed separately. The different plant components were cut and distinctly homogenized to certify typical and uniform samples.

Analysis of samples

The moisture content (MC) was determinate using thermogravimetric method, total antioxidant capacity (TAC) using CUPRAC method (cupric ion-reducing antioxidant capacity) and total polyphenols content (TPC) using Folin Ciocalteu method as described by Bordean, 2016. All analyses were performed in triplicate and the mean values were reported [12].

The experimental data were compared to literature data and statistically evaluated.

Experiment 1: The plant samples from the 3 Romanian regions were analyzed separately (roots, stem and leaves) and the experimental results regarding MC, TAC and TPC, were compared with data presented by different scientific articles.

Experiment 2: The plant samples collected from Timisoara area in 2 consecutive years were analyzed regarding plant MC and the data were statistically evaluated in accordance to the climate data specific for the evaluated months and years (Romania Weather History, for Timisoara "Traian Vuia" Airport Station) [13].

Statistical Analysis

The data were statistically evaluated using PAST Version 2.17c [14] and MVSP.

Results and Discussions

The results of the first experiment are presented in table 1 and figure 1.

Table 1

Nettle parts moisture content, total antioxidant capacity and total polyphenols content

Samples	H2O [%]	TAC [µM Trolox/100 g FW]	TPC [mg GAE/g FW]
NR1 (FIA)	70.46	1002.25	11.98
NL1 (FIA)	78.53	5186.96	34.53
NS1 (FIA)	79.41	1101.09	12.40
NR2 (VAD)	68.46	880.13	13.81
NL2 (VAD)	91.07	5582.75	57.00
NS2 (VAD)	88.50	829.96	24.04
NR3 (GORJ)	69.37	487.96	13.81
NL3 (GORJ)	69.38	7445.87	71.25
NS3 (GORJ)	85.88	2621.40	24.04

Legend: H2O= moisture content of plant samples (%); TAC = total antioxidant capacity; TPC= total polyphenols contents; FW = fresh weight; NR = nettle roots; NL = nettle leaves, NS= nettle stems; 1...3 = collection areas; FIA = Timis County; VAD = Hunedoara County; Gorj = Gorj County

All measurements were performed in triplicate and the antioxidant capacity of each extract was expressed in (µM Trolox/100 g FW). The total polyphenol content was expressed in mg Gallic Acid/100 g FW.

As we can observe the highest TAC and TPC are given by the ethanolic leaves extracts.

Figure 1 shows the correlation between the analyzed parameters: moisture content and TAC ($y_{TAC} = 38.813 \cdot x_{H2O} - 230.17$), respectively moisture content and TPC ($y_{TPC} = 0.45897 \cdot x_{H2O} - 6.5452$). The equations obtained using Generalized linear model show the correspondence between moisture content and TAC and TPC, indifferent of the plant part or origin of analyzed samples.

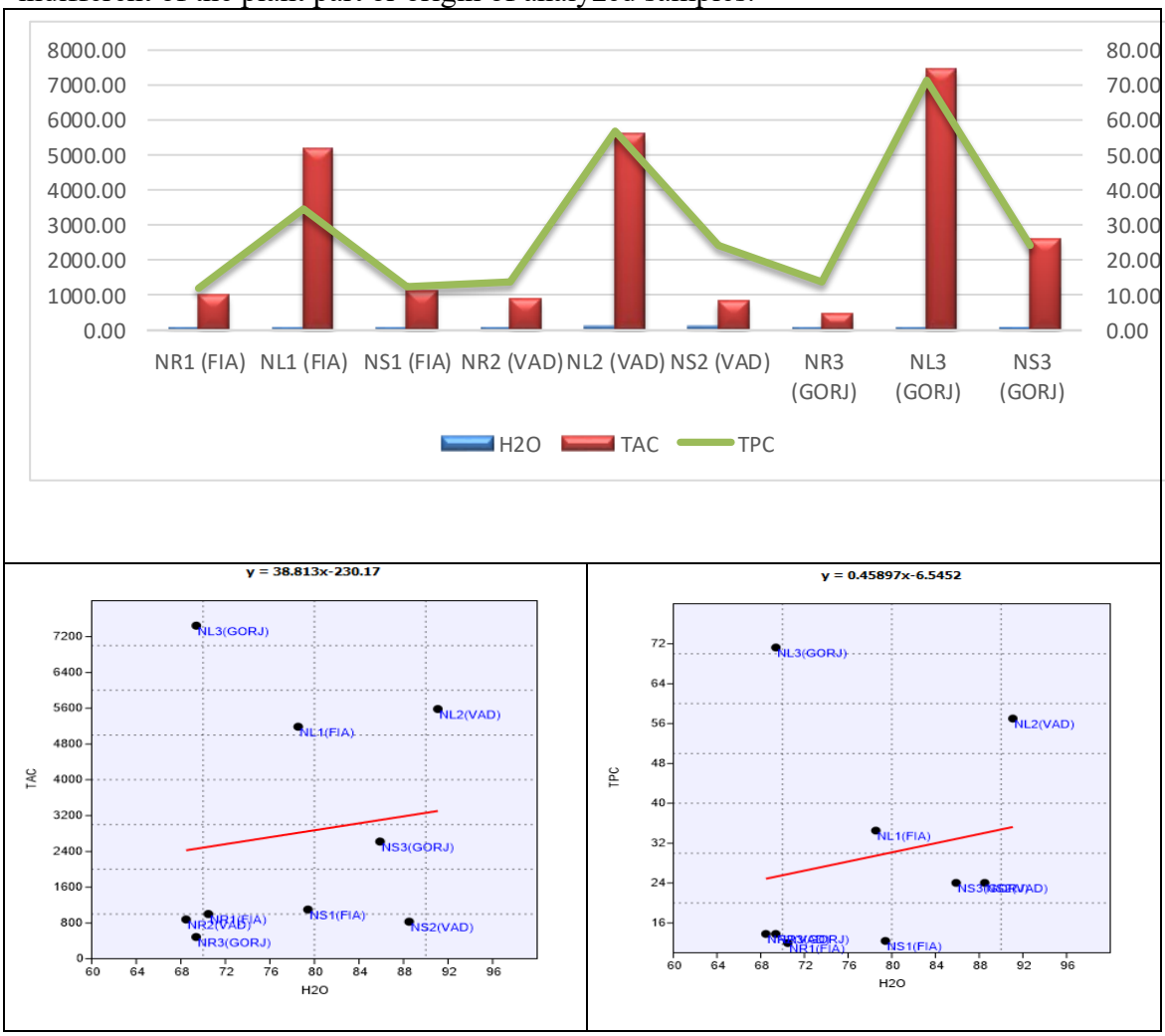


Figure 1 Graphical representation of analyzed nettle parts samples

Legend: H2O= moisture content of plant samples (%); TAC = total antioxidant capacity; TPC= total polyphenols contents; NR = nettle roots; NL = nettle leaves, NS= nettle stems; 1...3 = collection areas; FIA = Timis County; VAD = Hunedoara County; Gorj = Gorj County

Table 2

Nettle plant parts Moisture content and climate parameters for July and October 2022 and 2023

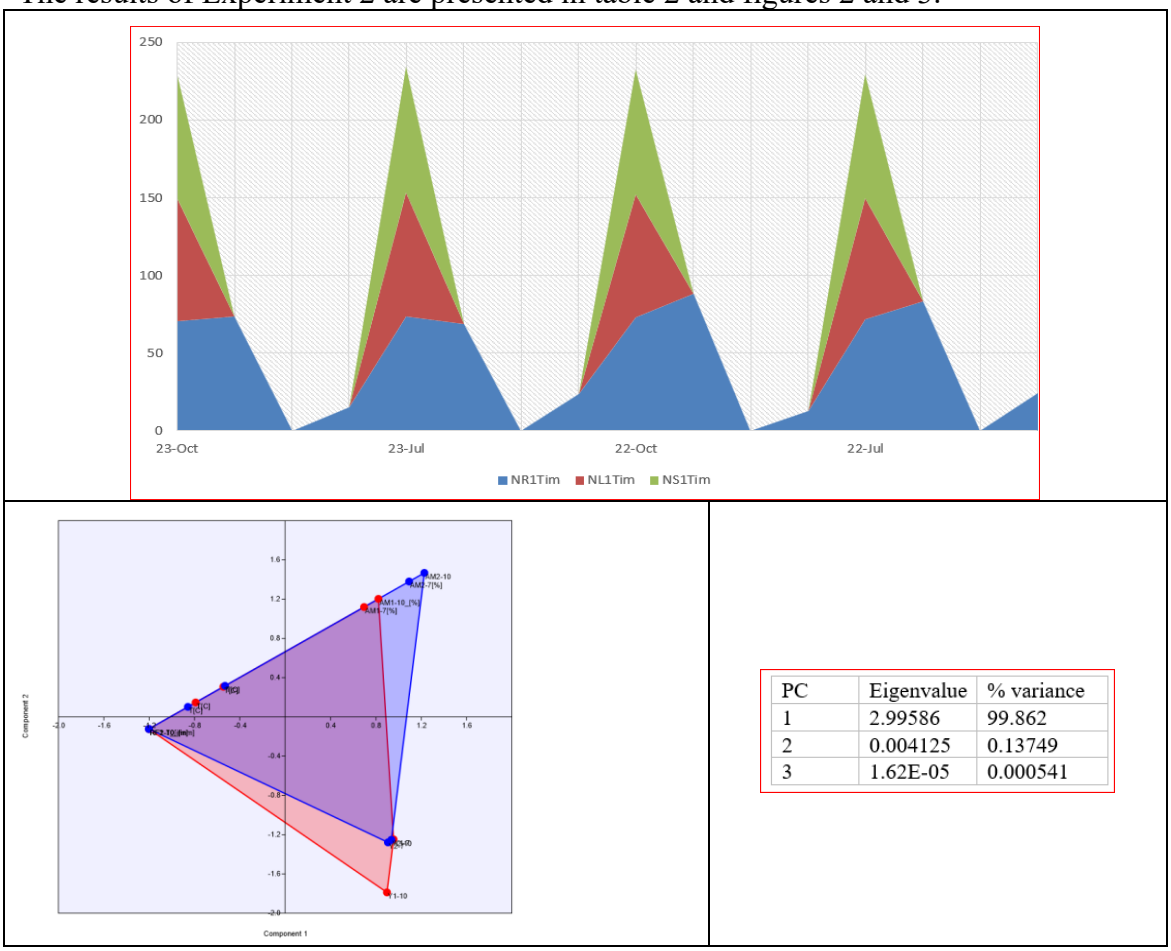
Date (Year-Month)		Code	NR1Tim	NL1Tim	NS1Tim
23-Oct	Oct23Nettle Moisture [%]	Y1-10	70.46	78.53	79.41
	Humidity [%]	AM1-10	73.32*		
	Rainfall[in]	RF1-10	0*		
	Temperature[◦C]	T	14.93*		

23-Jul	Jul23Nettle Moisture [%]	Y1-7	73.55	79.67	81.41
	Humidity [%]	AM1-7	68.73*		
	Rainfall[in]	RF1-7	0*		
	Temperature[◦C]	T	23.8*		
22-Oct	Oct22Nettle Moisture [%]	Y2-10	72.86	79.16	80.57
	Humidity [%]	AM2-10	87.99*		
	Rainfall[in]	RF2-10	0*		
	Temperature[◦C]	T	12.46*		
22-Jul	Jul23Nettle Moisture [%]	Y2-7	71.73	78.22	79.35
	Humidity [%]	AM2-7	83.12*		
	Rainfall[in]	RF2-10	0*		
	Temperature[◦C]	T	24.31*		

** Romania Weather History, for Timisoara Traian Vuia Airport Station [13]*

Legend: NR1Tim = nettle roots from Timis County; NL1Tim= nettle leaves from Timis County, NS1Tim= nettle stems from Timis County

The results of Experiment 2 are presented in table 2 and figures 2 and 3.



PC	Eigenvalue	% variance
1	2.99586	99.862
2	0.004125	0.13749
3	1.62E-05	0.000541

Figure 2 Nettle fingerprints based on Moisture content variations for July and October 2022 and 2023

Legend: NR1Tim = nettle roots from Timis County; NL1Tim= nettle leaves from Timis County, NS1Tim= nettle stems from Timis County

Figure 2 shows the variations of moisture content in the different parts (root, leaves and stem) of the studied plant samples based on the climate parameters specific to the collection months of the samples. The climate parameters are atmospheric humidity, rainfall quantity and average monthly temperature. As we can observe the fingerprints are different even if the variations are very small.

From applying the principal component analysis, we observe that the variations are given by the dissimilarities of climate parameters, mostly the difference of temperature and atmospheric humidity.

If we investigate further by applying spatial interpolation using Kriging algorithm, we will discover that the highest influence is created by the temperature differences from one year to another (red area - figure 3).

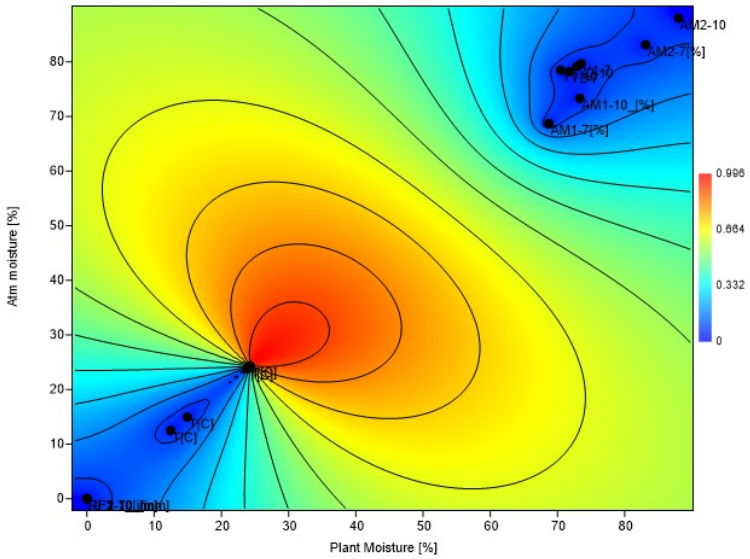


Figure 3. Spatial interpolation based on plant moisture and atmospheric humidity

Legend: Y1-10 = Oct23Nettle Moisture [%]; Y1-7= Jul23Nettle Moisture [%]; Y2-10 = Oct22Nettle Moisture [%]; Y2-7 = Jul22Nettle Moisture [%]; AM1-10 = Atmospheric Humidity [%]; RF1-10 = Rainfall [in]; T= Temperature [◦C];

The obtained results can be explained by the fact that Urtica dioica L. has the capacity to adapt to shady areas and drought conditions during cultivation, ability which is attributed to an increase in water distribution in the roots and a decrease in water distribution in stems and leaves (Table 2), which is proving the high adaptability to the environment, observation confirmed by Liu, Y. Q., cited by Zhang et al, 2023 [15].

CONCLUSIONS

Urtica dioica can be used as an important source of natural antioxidants and polyphenols, and/or a good source of proteins, fiber, minerals and vitamins. *Urtica dioica* leaves show very high concentration of bioactive compounds, antioxidants, and antioxidant activity. The antioxidant properties of *nettle leaves* and its extract can be utilized in the food and pharmaceutical industries. Incorporation of extract of *Urtica*

dioica powder and extracts as functional ingredients can increase the quality and shelf-life, and due to the presence of chlorophyl, the color of different foods.

The high capacity to adapt to different climatic parameters makes this plant o great source of informations regarding climate change. The variations of moisture content in the different parts (root, leaves and stem) of the studied plant samples based on the climate parameters specific to the collection months of the samples can help create specific fingerprints.

If we apply different mathematical models, we can create a database of various nettle fingerprints precious to evaluate and interpret climate change. As we can observe spatial interpolation of data based on the moisture content of nettle plants and the variations of temperature from one month to another and from one year to another is an important tool to evaluate temperature influence on plant development.

ACKNOWLEDGEMENTS

The research was performed with the support of the Interdisciplinary Research Platform belonging to the University of Life Sciences "King Michael I" from Timisoara.

This research paper is supported by the project Institutional Development Fund (FDI), domain 6, by National Council for the Financing of Higher Education (CNFIS), CNFIS-FDI-2023-F-0307

REFERENCES

[1] Kavalali G., The Genus Urtica, Ed. Taylor & Francis Ltd, New York, 2003: 10.

[2] Said, A.A.H., Otmani, I.S.E., Derfoufi, S., Benmoussa, A., 2015. Highlights on nutritional and therapeutic value of stinging nettle (Urtica dioica L.). International J. Pharm. Pharmacist. Sci. 7 (10), 8–14

[3] Singh, M., Kali, G., 2019. Study on morpho-anatomical and histo-chemical charaterisation of stinging nettle, Urtica dioica L. in Uttarakhand, India. J. Pharmacogn. Phytochem. 8 (3), 4325–4331.

[4] Rafajlovska V., Kavrakovski Z., Simonovska J., Srbinoska M. Determination of protein and mineral contents in stinging nettle. Qual. Life. 2013; 7:26–30. doi: 10.7251/QOL1301026R.

[5] Grauso L., de Falco B., Lanzotti V., Motti R. Stinging nettle, Urtica dioica L.: Botanical, phytochemical and pharmacological overview. Phytochem. Rev. 2020; 19:1341–1377. doi: 10.1007/s11101-020-09680-x

[6] Maietti A., Tedeschi P., Catani M., Stevanin C., Pasti L., Cavazzini A., Marchetti N. Nutrient composition and antioxidant performances of bread-making products enriched with stinging nettle (Urtica dioica) leaves. Foods. 2021; 10:938. doi: 10.3390/foods10050938.

[7] Jan, K.N., Singh, S., 2017. Stinging nettle (Urtica dioica L.): a reservoir of nutrition and bioactive components with great functional potential. J. Food Meas. Char. 11 (2), 423–433

[8] Chrubasik, J.E., Roufogalis, B.D., Wagner, H., Chrubasik, S., 2007. A comprehensive review on the stinging nettle effect and efficacy profiles. Part II: nettle radix. Phytomedicine 14 (7-8), 568–579

[9] https://ww3.brighton-hove.gov.uk/sites/brighton-hove.gov.uk/files/Benefits%20of%20stinging%20nettles%20for%20environment%20May-June%202016.pdf

[10] Di Virgilio, N., Papazoglou, E. G., Jankauskiene, Z., Di Lonardo, S., Praczyk, Wielgusz, M. K. (2015). The potential of stinging nettle (Urtica dioica l.) as a crop with multiple uses. Ind. Crops Products. 2015, 68. doi: 10.1016/j.indcrop.2014.08.012

[11] De Vico, G., Guida, V., &Carella, F. (2018). Urtica dioica (Stinging Nettle): A neglected plant with emerging growth promoter/immunostimulant properties for farmed fish. Frontiers in physiology, 9, 285.

[12] Despina-Maria Bordean, Analiza produselor agroalimentare – Partea I-a, Editura ArtPress Timișoara, ISBN 978-973-108-721-4, p. 176, 2016

[13] https://www.wunderground.com/history/monthly/ro/ghiroda/LRTR

[14] Hammer O., Harper D.A.T, Paul D.R., Past: Paleontological statistic software package for education and data analysis. Palaeontol.Electron.2001,4, pp9. Available online: https://palaeo-electronica.org/2001_1/past/issue1_01.htm

[15] Zhang Y, Zhang X, Zafar MH, Zhang J, Wang J, Yu X, Liu W, Wang M. (2023). Research progress in physiological effects of resistant substances of Urtica dioica L. on animal performance and feed conversion. Frontiers in Plant Science, 14. Jun 28;14:1164363. doi: 10.3389/fpls.2023.1164363. PMID: 37448866; PMCID: PMC10336547.

WATEP CONFLICTS RELATED TO CLIMATE CHANGE AND POPULATION EXPLOSION

Assoc. prof. Dr. Georgi Bardarov

Sofia University "St. Kliment Ohridski", **Bulgaria**

ABSTRACT

The second half of the twentieth and the beginning of the twenty-first century are marked by two processes that pose a serious threat to the sustainable development of the world in the near future. These are the population explosion in certain parts of the world and climate change.

At the beginning of the second millennium the world population was only 300 million, today it exceeds 8 billion and by the middle of this century it will reach 10 billion. At the same time, throughout human history, people have lived and worked in an identical way, now for the first time we have industry, transport, industrial animal husbandry that seriously pollute the natural environment, the consequences of it are unpredictable and they are bound to affect people. And this is already occurring, with increasingly acute drinking water shortages catalysing existing ethno-religious conflicts and generating new ones. The ones we have analyzed in this paper are along the Nile and in the Middle East along the Tigris, Euphrates and Jordan rivers. Already more than half of African countries are in water stress, and nearly a third in water disaster, including one, Uganda, which according to UN projections is expected to have a population growth between 2000 and 2050 of 302%! And when we talk about climate change and water conflicts, we need to act immediately so that tomorrow is not too late!

Keywords: climate change, population explosion, water conflicts

INTRODUCTION

In the 21st century, the world is undergoing a drastic demographic transformation. It also determines large territorial demographic disparities. On the one hand, in the developed world (Europe, USA, Canada, Japan, etc.) there is an increasingly lower birth rate, an accelerated aging of the population and a serious deficit of young, active population. In the near future, Southern European countries are expected to have an average life expectancy of 90 years and a fertility rate below 1. On the other hand, the developing world, especially sub-Saharan Africa, South and South-West Asia is experiencing its demographic explosion and there is an accumulation of a very young population. The average age of the population in most sub-Saharan African countries is 15-16 years. This generates many problems, from the large volume of the refugee wave to Europe to the acute scarcity of vital resources such as water in Africa and South-West Asia. The situation is compounded by climate change, which is related to global

temperature increases and changes in rainfall patterns in parts of Africa and Asia. In some areas there is a serious reduction in rainfall, in others a serious increase, which is reflected in droughts, crop reduction, famine, thirst and catastrophic floods. Even today there are more than 100 active military conflicts in Africa, and this situation will catalyse some of them and generate new ones related to the scarcity of water resources. Water conflicts have marked human development through all its stages. In the early XXI century as a result of nearly two centuries of industrialization and technological progress, many parts of the planet are witnessing extraordinary changes in climate patterns such as rising average temperatures, reduced rainfall, melting glaciers, and increased intensity of climate disasters. The ones we have analyzed in this paper are along the Nile and in the Middle East along the Tigris and Euphrates rivers.

The methods used in this study are scientific synthesis, comparative analysis, descriptive, historical, cartographic, mathematical and statistical.

Climate Change is the variation in the global and regional climates over a period of time. The term refers changes in the variations and the average state of the atmosphere over long periods of time, ranging from decades to million of years. These changes can be caused by processes internal to the Earth, external forces (such as change in the solar radiation intensity) or human activity. The conservative forecasts expect by 2100 the average temperature of the planet to increase by 1,8° C to 4° C from the levels in 2000, but other estimates indicate that we may see temperatures rise by as much as 6° C. Sea level is expected to rise between 0,18 and 0.59 meters.

The long-term projected changes of the climate include more intense and longer droughts, more intense tropical storms, frequent heat waves and heavy rainfall. In particular, most affected areas will be the Arctic (ice sheet lost, change in eco systems), Sub-Saharan Africa (water stress, crop reduction), Small Island States (coastal erosion and inundation) and the Mega deltas in Asia (flooding from seas and rivers). The described changes will result in food and water shortages, forced migration and economic losses [2]. In these consequences will create new or will contribute significantly to existing ethnic, social and political tensions and as a result will make conflicts, including violent ones, more likely.

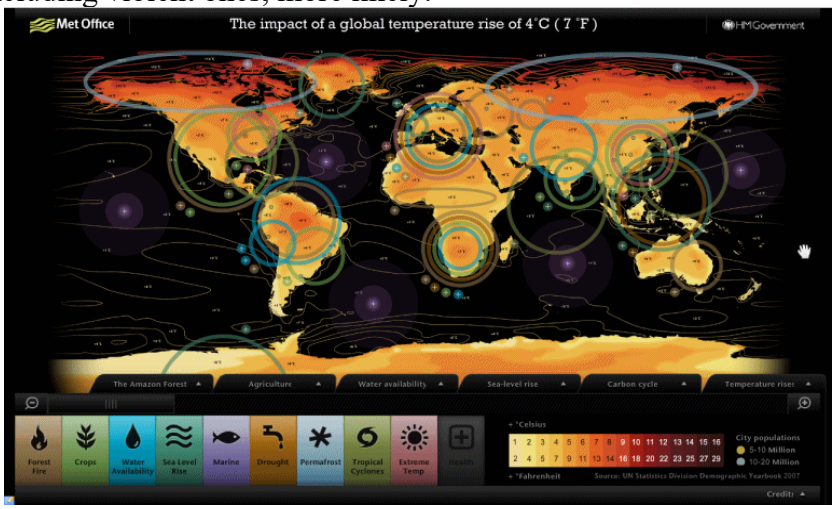


Figure 1. The impact of a global temperature rise of 4°C
Source: IUBS (International Union of Biological Sciences)

This map from the International Union of Biological Sciences shows how the Earth will change if global temperatures rise by 4 degrees Celsius by the end of the century. As we can see the whole planet will be affected. This translates into rising global ocean levels, melting permafrost, tropical cyclones, crop reduction, acute drinking water shortages, etc.

All this will be reflected in the following consequences for the planet: By 2050, an estimated 75 to 250 million people (climate migrants) will face increasing water scarcity, yields in some countries will drop by up to 50%. The food security of many African countries will be threatened. Densely populated areas around major river deltas in Asia are at increased risk of flooding. Rising sea levels in small island states will lead to flooding, greater destruction from storms, increased erosion, etc [6]. According to the International Panel on Climate Change, threatened food security will lead to malnutrition. Small island states will be planted under the threat of extinction. However, globally, there is still debate in political and scientific circles about whether we can talk about global climate change or whether this is speculation [1].

Whether there is global climate change or cyclicity significantly influenced by pollution, the consequences for the planet are unpredictable. The situation is further complicated by the population explosion in Africa and Asia.

Since the beginning of the nineteenth century, the world has successively gone through the so-called demographic transition. The demographic transition is a transition from a traditional to a modern type of reproduction. The traditional type of reproduction that humanity has had from its inception until the industrial age is defined by an excessively high birth rate (52-53‰) globally, but also an excessively high death rate (50-51‰), as a result of which natural increase has been low, the world's population has increased very slowly, and for long periods has even been reduced. At the beginning of the new era, the entire population of the Earth would be concentrated in a single modern country, the largest Muslim country, Indonesia, about 270 million; at the beginning of the second millennium again, the entire population of the Earth would be concentrated in a single modern country, the USA, just over 300 million. It was not until 1820 that the planet's population reached 1 billion, and now it is over 8 billion. The modern type of reproduction is characteristic of the early nineteenth century to the present. It consists of a parallel decline in fertility and mortality globally, with the first phase, known as the "population explosion", accelerating the decline in mortality while fertility remains very high. In the recent fourth phase, in which the developed world finds itself today, the birth and death rates are levelling off, natural increase is zero and even negative, life expectancy is rising steadily and the population is ageing rapidly. However, a large part of the developing world is still in the first phase of a demographic explosion, its population is increasing at a very rapid rate and it is accumulating an excessively large young population that needs resources for survival, development and fulfilment.

Table 1. Demographic growth in the World (1950-2050)

Region	1950	2010	2050
World	2.6 billion	6.8 billion	9.2 billion
Developing countries	1.7 billion	5.6 billion	7.9 billion
North Africa	44 million	164 million	248 million
Sub-Saharan Africa	184 million	849 million	1.9 billion
Middle East	44 million	218 million	344 million
Asia	1.4 billion	3.8 billion	4.7 billion

Source: US Census bureau, 2011

As we can see from this table, the population in the developing world will increase from 1.7 billion to 7.9 billion in just a century, from the middle of the 20th century to the middle of the 21st century, and in sub-Saharan Africa in the same period from 184 million (less than one Nigeria today) to 1.9 billion!!!

This means the accumulation of too many young people in territories with serious shortages of drinking water, widespread famine, multiple military conflicts, brutal dictatorial regimes, high unemployment, including youth unemployment which reaches and exceeds 80% and extremely high levels of illiteracy, around and above 90% [7].

According to the World Bank and the World Health Organization, in order to exist normally, the human body needs between 100 and 200 litres per day or between 32 and 76 m per year. These quantities include only water needed for personal needs. However, water is also needed for agriculture, industry, electricity, which in total makes between 1,700 to 2,500 cubic meters of water per year for drinking, hygiene and Industrial needs. From 1,000 to 1,700 cubic meters we talk about water stress, and below 1,000 cubic meters about water disaster. The water access situation is very serious in Africa.

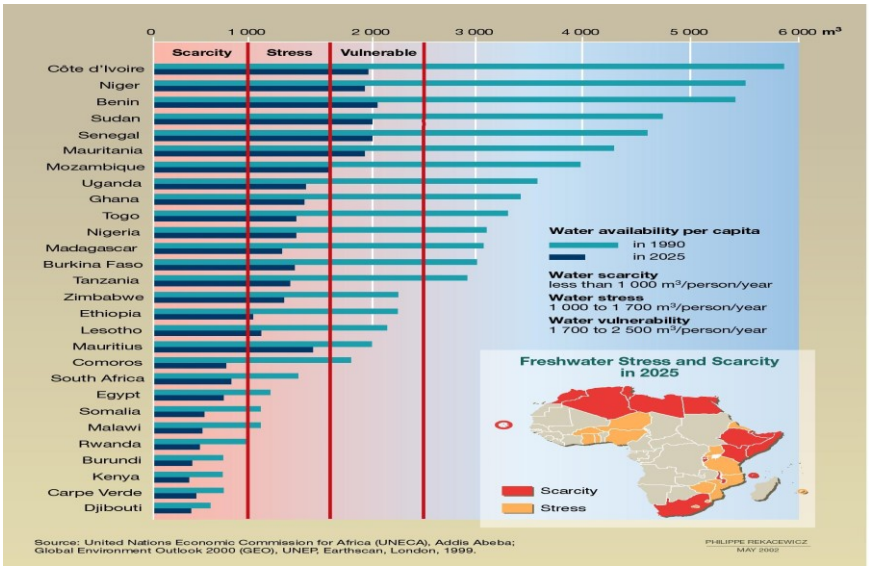


Figure 2. Water availability per capita in Africa (1990-2025)
Source: UNEP/GRID-Arendal, 2002

In this map we see how water availability in Africa is changing between 1990 and 2025. Already in 1990 half of African countries have water stress. In 2025, two-thirds will be under water stress and half will be in a water catastrophe

Most affected will be countries in the Nile region, sub-Saharan Africa and the Middle East, which are now experiencing their own demographic explosion.

Table 2. Estimated population growth in the Nile region and Southwest Asia (2000-2050)

Country	2000	2050	Growth 2000-2050
Egypt	65.2 million	137.8 million	101%
Ethiopia	64.2 million	238.2 million	246%
Kenya	30.5 million	66.1 million	127%
Sudan	34.2 million	79.3 million	121%
Uganda	23.9 million	96.3 million	302%
Turkey	68.9 million	101.9 million	49%
Iraq	22.7 million	56.3 million	126%
Syria	16.5 million	33.7 million	101%

Source: US Census bureau, 2011

All these countries will have a population growth of over 100 percent in just 50 years. A Uganda would have a growth of a whopping 302 percent, If they are in water stress with a population of 23.9 million what are they going to do with a population of nearly 100 million?

According to our point of view, in the 21st century we will talk less and less about ethno-religious conflicts, we will witness more and more conflicts related to the most important resource on our planet, water. As the population grows, so does the need for water for domestic use and for food-irrigation of agricultural areas. Between 1950 and 1990, the Earth's population doubled and water consumption increased by 300%; if these rates continue, we will soon be using 100% of the world's available water supply.

In Africa, the Nile region is very harsh and has the potential for severe conflict. All countries along the Nile suffer from water scarcity, with less than 1,100m³ per capita per year-the minimum amount needed for normal life, and separately the demographic pressure is extremely strong. Many key water sources are shared by two or more countries, conflicts arise both between countries along the Nile (Egypt-Ethiopia, Egypt-Sudan) and within countries (Sudan).

The situation in Darfur-South Sudan is particularly grave. The genesis of the conflict is ethnic, but it is being catalysed very rapidly by climate change, the encroachment of the Sahara desert to the south and water scarcity. In 40 years, the desert Sahara has advanced southward by 100 km, or 2.5 km per year in the period to 2017, This process has been accompanied by land degradation due to overexploitation of the grasslands. The number of livestock farmed has increased from 27 million to 135 million! For years, nomadic Arabic-speaking tribes from the north tried to take the land and livelihoods of the settled Fur, Masalit and Zaghawa. The leading cause is the advancing desert and scarcity of resources, mainly water in northern Sudan. Nomadic tribes are tacitly tolerated by the government in Khartoum [5]. The conflict dates back more than 30 years, but escalated most seriously after 2013.

Over a period of 5 years, the victims of the conflict amounted to 300,000 and the refugees to 2.5 million. Since the beginning of the conflict the victims are about 2 million, the raped women hundreds of thousands, the refugees over 4 million. The UN describes the situation as the biggest humanitarian crisis in history. "This is Africa!" is the most common definition of this conflict. According to UNICEF, about 80 newborns die every day in the state. The Covid pandemic, the refugee crisis in Europe, the violence of the Islamic State, the war in Ukraine and the escalation of the conflict between Palestinians and Jews have shifted the focus from the grave problem in Sudan, and today we can say that this is the greatest forgotten war of our time. Refugee camps in neighbouring Chad of people fleeing the escalating violence and mass ethnic cleansing in Darfur are overcrowded, over a million people live on the bare grassland and the daily ration of water is one cap.

Although our Middle East focus is on the hostilities in Syria and especially the ferocious escalation of the Palestinian-Israeli conflict in 2023, in view of the ever diminishing water resources in the region we can foresee new military conflicts arising in the future. At the end of the twentieth century, there are 500 million people living there, and this figure is expected to double by 2050. There are three rivers that have shaped human history in the Middle East region - the Jordan, the Tigris, the Euphrates. They are the only source of water in the region and in this mostly arid region, artificial irrigation is the only way to produce enough food to sustain life. The waters of the Tigris and Euphrates are shared by Iran, Iraq, Syria and Turkey. For these countries, water conflicts have become deeply emotional and symbolic. Although on their way to the Persian Gulf the Tigris and Euphrates collect the waters of different tributaries, the bulk of their waters come from Turkey-88% for the Euphrates and 50% for the Tigris. According to some estimates, 85% of Syria's water comes from the Euphrates, and Iraq gets almost all of its water from the two rivers alone. In recent years, all three countries have built dams on the Tigris and/or Euphrates, with Turkey has been the most active with the GAP project. GAP includes the construction of 22 dams on the Tigris and Euphrates and irrigation systems spanning more than 2 million hectares. This project will completely change the natural landscape, desert valleys will be turned into water reservoirs, canals will cross the land and barren fields will become flower gardens. For Iraq and Syria it is a matter of survival. In 1998 Turkey and Syria were facing war precisely because of a conflict over water resources. And given the climate change, demographic situation and political instability in the region, such a conflict is not excluded in the future [4].

As cynical as it may sound, climate change can also be a means of defusing military conflict. New Moore Island in the Bay of Bengal, disputed for 30 years by India and Bangladesh, was covered by water because of rising world ocean levels. A problem that went unsolved for almost 30 years has been solved by global warming.

The Indian island of Goramara is disappearing little by little. It used to be home to 40 000 people, but today the population is just 4 000. It is now 1.8 square kilometres - half the size it was 20 years ago. Although some of the other residents say they would move elsewhere, they cannot afford it. A more serious natural disaster would be fatal for them. Rice is the staple food for the people of Goramara, but rice fields are flooded with salt water very often. When a field is destroyed, it takes from three to five years before rice can be planted there again. The reason is sea level rise caused by climate change.

And what about the inhabitants of Kiribati, Seychelles, Solomon Islands and Maldives? All three island states are threatened with extinction due to rising global ocean levels [3]. The president of the Maldives even held a cabinet meeting underwater to alert the world that everything in the Maldives could soon be underwater. And the Kiribati government is buying land from neighbouring mountainous Fiji to evacuate its population from coastal areas.

CONCLUSION

Today, humans extract around 60 billion tonnes of resources from nature every year - an 80% increase in just a few decades. Man-made greenhouse gas emissions have doubled since 1980, adding at least 1.7 degrees to global temperatures. Every year we dump up to 400 million tonnes of heavy metals, toxic and other waste into our oceans and rivers, 75% of the land, 40% of the oceans and 50% of the rivers "suffer serious consequences from the degradation" of human activity. "The Red Data Book" catalogues about 100,000 species, about 1/4 of which are classified as endangered. More than 2 billion people still rely on wood as their main source of energy and about half of all medicines come from plants and animals. According to WWF's latest report, The Living Planet Report 2020, wildlife populations have declined by an average of 68% over the past four decades. It estimates a decline of over 4,392 species observed between 1970 and 2016. The report warns that ecosystem destruction threatens around a million species - 500,000 animals and plants and 500,000 insects - with extinction in the coming decades and centuries. A 2021 UN report on the state of nature and humanity's impact on the environment concludes that the most destructive creatures in history are us humans. All of this is compounded by the demographic explosion in sub-Saharan Africa, reflected in increasingly severe water shortages and making living conditions impossible in vast areas of Africa and Asia. This, in turn, will stimulate increasing refugee flows from the affected territories, catalyse existing and generate new military conflicts.

In the twentieth century we got used to talking about ethno-religious conflicts. In the twentieth century, we became accustomed to associating conflicts with illiteracy, poverty, ethnic and religious differences. In the 21st century we must forget these clichés. In the 21st century, conflicts will intensify, but they will move to a social basis.

REFERENCES

[1.] Atanasova A., Ecological urbanism-some facts and issues, International Multidisciplinary Scientific GeoConference: SGEM, Vol. 20/issue 6.1, pp. 549-554, 2020.

[2.] Bates B., Kundzewicz Z. W., Wu S., Palutikof J. P., Climate Change and Water, Technical Paper VI of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, Switzerland, 2008.

[3.] Diamond J., Collapse: How Societies Choose to Fail or Succeed, Viking Penguin, UK, 2005.

[4.] Gat A., War and Strategy in the Modern World: From Blitzkrieg to Unconventional Terrorism, UK, Routledge, 2018.

[5.] Kler M., Resource Wars: The New Landscape of Global Conflict, New York, USA, Owl Books, reprint edition 2002.

[6.] Kler M., All Hell Breaking Loose: The Pentagon's Perspective on Climate Change, New York, USA, Henry Holt and Co, 2019

[7.] Tsvetkov K., Factors, dimensions and consequences of refugee crisis in Europe since the beginning of the 21st century, E-journal Geography, Bulgaria, Vol. 7, pp. 79-92, 2023.

APPENDIX

IUBS (International Union of Biological Sciences) – (https://tropicsu.org/four-degree-interactive-map/)

UN – Climate change (https://unfccc.int/news/antonio-guterres-2021-is-the-year-to-reconcile-humanity-with-nature), 2021.

UNEP/GRID-Arendal (https://www.grida.no/resources/7031), 2002.

US Census Bureau ((https://www.census.gov/library/visualizations/2011/demo/world-population--1950-2050.html), 2011.

WWV – Living Planet Report 2020
(https://www.worldwildlife.org/publications/living-planet-report-2020).

SECTION

RENEWABLE ENERGY SOURCES AND

CLEAN TECHNOLOGIES

A PROPOSAL OF MARINE SHORT RANGE TRANSPORTATION, IN MEDITERRANEAN SCENARIO, TO REDUCE CO_2 EMISSIONS AND IMPACT ON ENVIRONMENT

Prof. Valerio Ruggiero [1]

[1] University of Messina, Italy

ABSTRACT

The Mediterranean Sea can be taken as a good example of the advantage of people transportation by water, in order to reduce pollution. This is mainly due to historical reasons, in fact the ashore private transportation along coasts of Italy, France, Spain, Slovenia, Croazia etc, has been developed during centuries on the basis of Roman Empire roads, and furtherly with development of railways, offering basically 2 different ways of transport. But recent solutions and studies shows the possibility to give a significant contribution to the reduction of emissions by the use of appropriate vessels. In fact, the present generation of propulsion system in marine application, and the developments of hybrid propulsion, with new technologies for batteries, makes possible to build a vessel with a significant reduction of pollution.

The author, after studying also, as a benchmark, the transportation used on main Italian Lakes, and using his experience with other vessel, also hydrofoil and fast vessels, consider a case study of transportation applied to Ligurian an Tirrenic sea, by the use of a fleet of fast vessels, capable to carry 350-400 passengers at an average speed of 22-24 knot, comparing the fuel consumption and the cost of each vessel with the average capability and price of a train and comparing the fuel consumptions of the vessels with the total amount of fuel used by the amount of private cars used to move the same amount of people. The study takes in consideration also the average sea condition, to demonstrate that especially in the area considered, a similar service can guarantee a long-term usage. The result of the study shows how is possible to adopt a significant benefit for the environment, due the possibility now offered to use e-fuels, or green fuels, to reduce the ashore facilities, no need of bridges, tunnels, road etc.

Keywords: Hybrid propulsion, passenger transportation, clean propulsion, CO_2 emissions, Passenger vessels.

INTRODUCTION

The Europe and the Mediterranean are sharing the problem of being a strongly anthropized area with a relevant density of populations, historically the mankind establish a living are along the coast or nearby fresh water sources like lakes, rivers, etc. As consequence of this situation, it's possible to examine the presence of a large number of cities and town along the shore line.

A simple geographical map of Mediterranean shows the almost continuous line of towns distributed along the coast nowadays. The present system for transportation of people among these areas on short distance, below 50-60 km, on daily basis commuting, is

based on two main solutions: by rail or by road. Both these solutions are basically following the same trails old by centuries, sometimes more, if simply look at the path of modern roads overlapping it at a map of roads build during Roman Empire. Moreover, there is a geological situation connected to the orography of the coasts in north part of Mediterranean



I. Fig.1: Relief Map of Mediterranean Sea (from Creative Commons)

Its clear that the construction of new roads or new railways has to deal with the presence of mountains and hills, with an impact on the costs of realization.

As consequence of these two factors: Cities and Orography, a possible solution is the use of the sea, to create a system of transportation capable to move significant amount of people on a short distance.

A system like this is already used in other part of the world, obviously it will be too simple take as example similar transportations from coast to islands or among islands, this cannot be considered a significant example because it is “obliged” due to the logistic situation. This study then focused on the example of ferries working “in parallel “with roads and trains like for example on lakes on northern Italy, where the total volume of passengers moved yearly by “Gestione Governativa Navigazione Laghi” is of about 8 millions/year.

A new element must be included in this research: the technological innovation due to the green transition, with the need for a propulsion system capable to reduce the CO2 emissions and deal with electrical propulsion and use of new batteries. Etc.

In same similar scenarios these possibilities have been already studied by the Author [1-3] and in other papers [4-6]

The paper then focused on the study of a specific situation of publica transportation in Ligurian sea, on a distance of 30-40 km, with specific attention to the environment impact and the expected reduction of CO2 emissions and cost reduction compared to train and roads.

MATERIALS AND METHODS

The area of interest is the Gulf of Genoa, with specific attention to the public transport among Savona and Genova on one side and Genova and the "riviera of Levante", there is a serious problem due to the situation of the highway and the railroad, with a severe impact on traffic and transportation, especially during summer and touristic season.

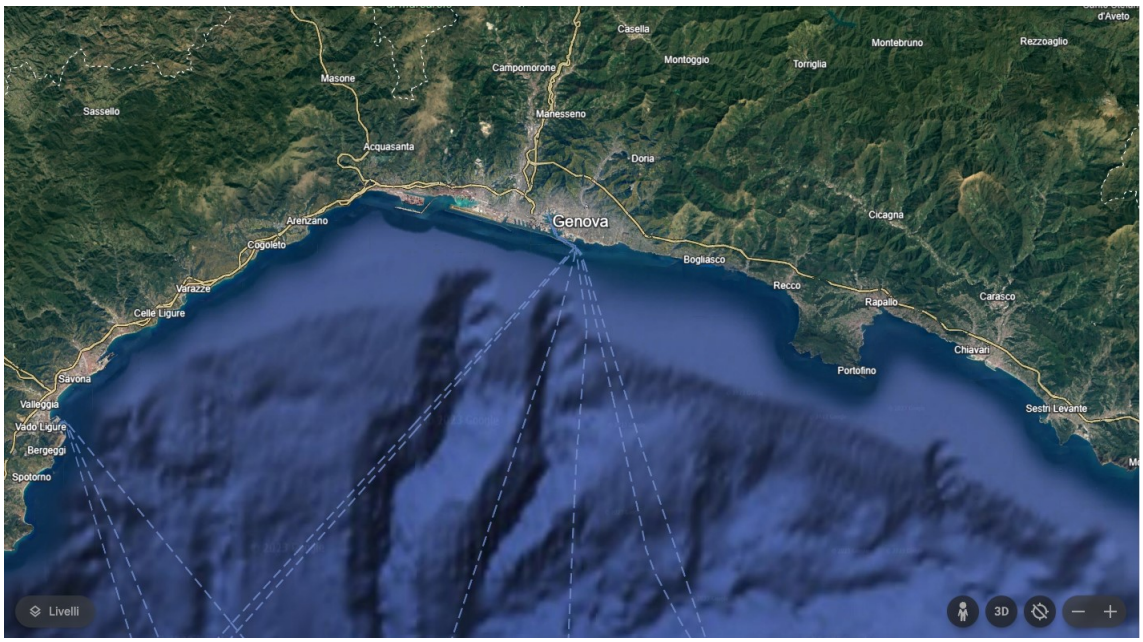
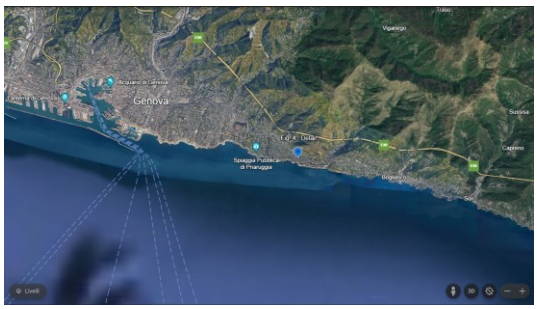


Fig.2) Area of interest, from Savona on the west to Sestri Levante on the east, with highlighted in yellow the A10 Highway (east) and the A12 Highway (west).

The rail lines serve the commuting to and from Genova, in both directions with trains.

Actually, on commuting basis the trains used have an average capacity of 300 passengers and an average cost for each of 4.5-5 million of euros according to the Italian railways site.

As it possible to see the urbanization of the area doesn't allow the construction of a new rail line, the Figg. 3-4 shows a detail of the actual railroad, with also the connection from Genova to Rome, is a 2 rails line, one for each direction, running among houses etc.





Figg. 3-4) The railroad and connections.

https://doi.org/10.5593/sgem2023V/4.2/s17.49

The situation of movements using highways is similarly critical, the orography gives strong limitations to the path, because the need of building new bridges, tunnels with high costs of maintenance and also high costs of realization of a new highway.

It is estimated a cost of building new highways in the area of 2000 million of euros for 19-20 km of highway, depending on the path chosen [7-8].

Obviously, the consequence of moving large amount of people by private cars, is also the need to realize parking at destination, capable to recover all the cars used.

With this consideration it s obvious that the capacity of a single train, 300 pax, can be compared at 250-300 cars, assuming a certain percentage of car sharing with all the problems, related also the limitations of private vehicles according to the different classes of emissions EU3-EU4-EU5 etc. decided lately by several Public administrations.

As consequence of these analysis the paper aims at a proposal of solution to reduce the stress on public transportation, by the use of fast ferries, capable to carry around 400 passengers on a route along the sea, with an important reduction in costs compared to new highways, and train.

The use of the sea has also the great advantage that, historically, the towns were build around the port area and then developing to the exterior, so the use of the port, with existing piers allow to carry the people/passengers directly “in the heart of Town”, making the commuting more efficient than the use of private car, the storage parking, then buses or metro inside the town.

RESULTS

Starting from the above premise the study decide to focus on the possibility to adapt a previous preliminary study of the author [9] to evaluate the benefits of a transportation system, introducing new elements in the study, like the analysis of costs for realizing one vessel, compared with costs for one single train with capability of 300 pax, and the reduction of CO2, compared to number of cars required to carry the same amount of people on the same distance.
The study takes also in consideration the latest resolutions from IMO about the classification of e-fuels or green fuels [10-11].

HYPOTHESIS OF PROJECT

The vessel considered is a catamaran in aluminum alloy, with propulsion system of hybrid mixed type, with waterjets operated by electric motors of 1800 kW each, and power generation provided through 4 internal combustion engines, of 900 kW about, using efuels. The propulsion at low speed (below 5 knots) during maneuvering is actuated by 2 x 400 kWh battery packs, capable to be recharged or in 2-3 hour during the night stop of ship, or by the onboard generators. The size of battery packs can be adapted to the various solutions of use, to increase the possibility of navigate at zero emissions.

Table 1) Main Dimensions

L.o.a. Length over all	41 m.
Beam	10.5. m
Construction material	Aluminum alloy
Engines power	2000 kW
Cruise speed	25 knots

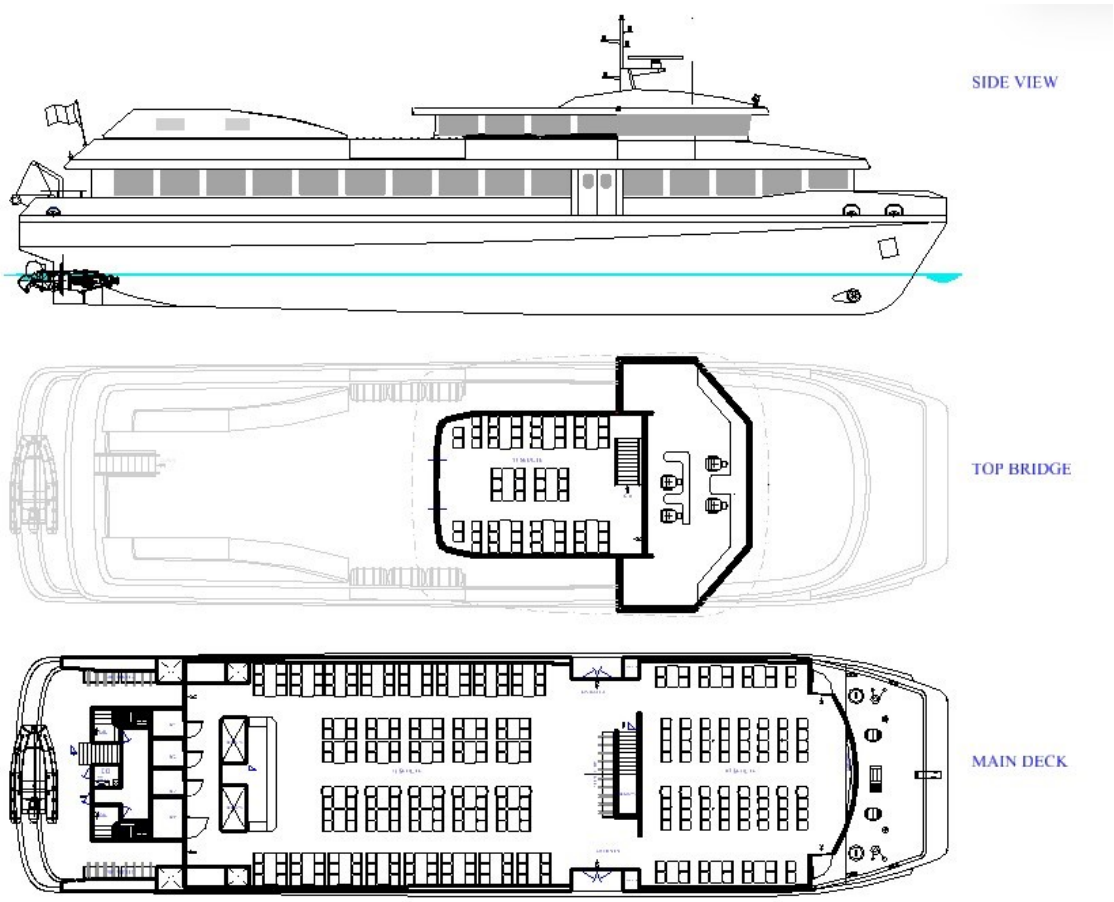


Fig.5) – General arrangement

The proposal of route is according to the following stops, marked with a red dot on the map, and corresponding to cities of interest, for number of citizens, presence of school, Universities, touristic attractions:

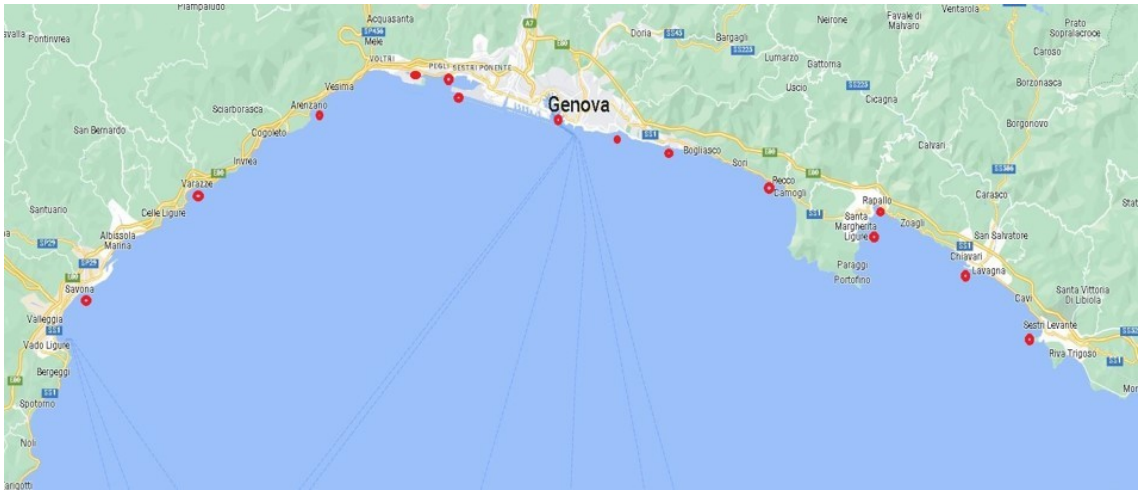


Fig. 6) Maps of ports connected by the service

With the following travel time:

Tab 2) Distance between ports and corresponding travel duration

PORTS	NAUTICAL MILES	TIME OF TRAVEL
SAVONA-VARAZZE	5	14’ about
VARAZZE-ARENZANO	6,5	19’ about
ARENZANO-GE AEROPORTO	7	20’ about
GE AEROPORTO-GE FIERA	7,5	22’ about
GE FIERA-RECCO	9	28’ about
RECCO-SANTA MARGHERITA LIGURE	12	30’ about
SANTA MARGHERITA-RAPALLO	1,5	6’ about
RAPALLO-LAVAGNA	5	15’ about
LAVAGNA-SESTRI LEVANTE	3	10’ about

As it’s possible to see verifying on any navigation software, the distance between center of Savona port and center of Genova by car is 45 mins, with a travel time of minimum 45’, compared to the 60-70’ mins required by the travel by sea. Time travel by train, according Railroads is comparable, with a travel time of 48 mins with Intercity train and 71’ with economical train, depending from.
The economic study of tickets, allows to make a good comparison: 45 km by highway, with private cars, can have an estimated cost of 15 euros, (ACI - Italian Automobile Club data), plus 5 euros of Highway, without considering the cost of parking in town.
Train ticket costs span between 5.80 euro and 11 euro.
On the opposite line: east bound, from Sestri Levante to Genova, the situation of time, distance and costs presents the same data.
With this information, without considering any public contribution, is possible to estimate a ticket cost for each passenger on the ship around 5 euros.

CONCLUSION

The proposal described can lead to the following conclusions: the cost of realization of a similar kind of vessel can be estimated in 13 millions of euros analyzing the international market of similar ships, this amount is comparable to the cost of 2.5 trains capable each of carrying 300 people, realizing a cost for passenger of 70% more about.

The power used is 1600 x 2 kW spammed on a 60' trip, a private car can be considered using an average power of 30 kW, regardless the type of propulsion system adopted: diesel, petrol, hybrid, BEV (in this case depending from the source of generation), this means an usage of around 6750 kWh, more than double the use of the vessel. In addition to this must be taken in consideration the possibility for the larger engines adopted on the vessel to work using green fuels like green methanol, reducing to CO2 impact to zero.

The study above is focused on the comparison "more cautious" economically, neglecting for a precise choice the evaluation of costs of building new highways or new railroads, because as already mentioned in this case the spread between costs for building more ships and the costs of building only few kilometers of highway is larger.

The great advantage of this proposal, that is a concept, and a preliminary study is that the "main mean" is the Sea, is already usable, with minimal impact of logistic solutions to make the project work.

The paper describes a case study as an example of feasibility, due to need of strong scientific basis already available, but are obvious the similarities with other scenarios in Europe, similarly ready to be adopted.

REFERENCES

[1] Ruggiero V., Zangrandi M., Repetti G., "Proposal of a coastal ferry using last hybrid technology for green transportation in touristic areas**",** NAV 2022 Technology and science for the ships of future - 20th edition, 15-17 giugno 2022 Genova, DOI: 10.3233/PMST220056

[2] Ruggiero V., "The future developments of Hybrid and electrical propulsion for small vessel, according to new possibilities offered by Industry 4.0"**,** ISM 2021 - – International Conference on Industry 4.0 and smart manufacturing. November 2021, Linz (Austria), DOI: 10.1016/j.procs.2022.01.294

[3] Ruggiero V., "New methodology to approach project of small hybrid propulsion passenger ferries for Italian scenario**",** SPEEDAM 2020 International Symposium on Power Electronics, Electrical Drives, Automation and Motion.24-26 Giugno 2020, Sorrento (NA), Proceedings ISBN: 978-1-7281-7018-3 **,** DOI: 10.1109/SPEEDAM48782.2020.9161881

[4] Mauro F., Nasso C., la Monaca U., Bucci V.

"A simulation model for hybrid-electric inland waterway passenger vessels"

(2018) Technology and Science for the Ships of the Future - Proceedings of NAV 2018: 19th International Conference on Ship and Maritime Research, pp. 388 - 397,

DOI: 10.3233/978-1-61499-870-9-388

[5] Bucci V., Mauro F., Marino A., Bosich D., Sulligoi G.

"An innovative hybrid-electric small passenger craft for the sustainable mobility in the Venice Lagoon"

(2016) 2016 International Symposium on Power Electronics, Electrical Drives, Automation and Motion, SPEEDAM 2016, art. no. 7525941, pp. 1388 - 1395,

DOI: 10.1109/SPEEDAM.2016.7525941

[6] Padolecchia D., Utzeri S., Braidotti L., Marino A.

"A Hybrid-Electric Passenger Vessel for Inland Waterway"

(2023) 2023 IEEE International Conference on Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles and International Transportation Electrification Conference, ESARS-ITEC 2023, DOI: 10.1109/ESARS-ITEC57127.2023.10114841

[7] Delibera numero 128, del 21 Dicembre 1993 - Riprogrammazione regione liguria - interventi ANAS, Presidenza del Consiglio dei Ministri Dipartimento per la programmazione e il coordinamento della politica economica (archiviato il 19 agosto 2018).. Pubblicata su Gazzetta Ufficiale n. 62 del 6 marzo 1994

[8] Gronda di Genova, online analisi costi benefici e analisi giuridica | mit, su *www.mit.gov.it*.

[9] Ruggiero V., Morace F., "Innovative use of hybrid propulsion system in fast passenger ferries over 300 passengers and 20 knots"**,** HSMV 2020 **-**12th Symposium on High Speed Marine Vehicles. 15-16 Ottobre 2020, Napoli, ISBN: 978-1-64368-125-2

[10] AA.VV. IMO Air pollution and energy efficiency team "Air Update on the IMO Future Fuels & Technology Project", may 2023. https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/FFT%20Project/Final%20study%20output_presentation.pdf

[11] Ram, V.; Salkuti, S.R. An Overview of Major Synthetic Fuels. *Energies* **2023**, *16*, 2834. https://doi.org/10.3390/en16062834

AN ANALYSIS OF AN INNOVATIVE, ENERGETICALLY INDEPENDENT SALES SYSTEM (VENDING MACHINE) FOR COLD AND HOT PRODUCTS

Ioan Mihail Savaniu
Oana Tonciu
Ancuta Neagu
Magdalena Culcea
Technical University of Civil Engineering Bucharest, Bucharest, **Romania**

ABSTRACT

In the current energetical context, there is a need to diversify energetically independent applications. The presence of energetically independent vending systems is necessary in the smart cities of the future and beyond. Energetically independent vending equipment must ensure the delivery of cold or hot products with low energy consumption. Reduced energy consumption and the use of environmentally friendly sources lead to reduced greenhouse gas emissions and at the same time to higher energy autonomy. The paper presents the results obtained from testing the innovative experimental sales system developed to study the energetic efficiency of this equipment. The innovative sales system is a complex system that integrates energy production and storage, cooling and heating systems. The fully automated system allows cold storage of products and their subsequent delivery, cold or hot, on demand. The vending system was powered by electrical energy from an array of photovoltaic panels. The results obtained, summarized in the paper, lead to the possibility of developing stand-alone vending equipment with significant reduction of greenhouse gas emissions in urban agglomerations.

Keywords: renewable sources, vending machine, energy efficiency, environment

INTRODUCTION

In the context of urban development in the recent years and the COVID 19 pandemics, the necessity to develop automated sales systems for food products has increased. The use of such vending machines is necessary both for ensuring food safety and healthy eating. In SMART cities, building a vending machines network which is adapted to the location area and the food preferences of the users has become essential. The easy placement and the fast relocation of such systems is possible if energetically independent systems are used. In this context, the present work presents the development of a study platform for automate vending systems which sell hot or cold food products and which are energetically independent. The energy independence is assured by a photovoltaic panels array which provides the energy needed by the vending machine while reducing the greenhouse effect gases.

Thus, according to ref [1], communities are moving towards healthier products in vending machines due to the lower prices of the sold products. In case energy-

*Corresponding author: mihai.savaniu@utcb.ro

efficient systems are used, the prices of products will be lower than for similar products in the hospitality system. Energy-independent vending systems equipped with photovoltaic panels have several advantages such as: reduced electricity costs, the possibility to be located anywhere, easy relocation, ease of installation, independence from the local electricity grid, environmentally friendly and reduced CO2 emissions [2,3]. The market for energy independent vending systems is in its infancy but it is expected to grow significantly in the coming years. According to Ref. [4,5], the global smart vending machine market will reach USD 21.4 billion by 2030. The global, post COVID-19, smart vending machine market, which is USD 9.2 billion in 2022, is estimated to reach a value of USD 21.4 billion by 2030, growing at a Compound Annual Growth Rate (CAGR) of 11.1% during the analysis period 2022-2030. The heated products market is estimated to grow at 11.4% CAGR and reach USD 22.1 billion by 2030. Given the continued post-pandemic recovery, the growth of the snacks segment shows a CAGR of 10.3% for the period 2022-2030.

The energetic independence of the sales system ensures the creation of a green product with a low impact on the environment and also allows its placement in areas where electricity cannot be provided from other sources. Taking into account the existing models, we developed an autonomous vending machine that would allow the analysis of the operation of a system for selling cold and/or hot products that would be powered with the help of solar panels. In order to study the problems that arise in the case of the creation of such equipment, we designed and created a prototype called SVIEE which is an energetically independent vending system. The trading of products with the help of automatic systems allows getting closer to the customer. The customer does not have to travel long distances, with the help of means of transport that emit CO2, to procure certain products. Also, trading with the help of vending machines allows these machines to be fed at night, when fuel consumption for transporting goods from the warehouse to the point of sale is reduced and the impact of CO2 emissions is lower.

MATERIALS AND METHODS

The research was carried out on the SVIEE energetically efficient vending machine prototype installed at The Technical University of Civil Engineering of Bucharest (TUCEB), illustrated in Figure 1. In the article Study on Energy Efficiency of an Off-Grid Vending Machine with Compact Heat Exchangers and Low GWP Refrigerant Powered by Solar Energy [6] the research on the efficiency of the thermally insulated enclosure and the refrigeration system of the experimental model developed for the study of energetically independent vending systems was presented. In the article Neural-Network-Based Time Control for Microwave Oven Heating of Food Products Distributed by a Solar-Powered Vending Machine presents a novel research on the use of a neural network-based time control system for microwave oven heating of food items within a solar-powered vending machine [7].The studied SVIEE prototype has the following subsystems: photovoltaic panel array; solar energy storage battery array; command and control system; thermally insulated enclosure; cooling system; product heating system; resistance structure.

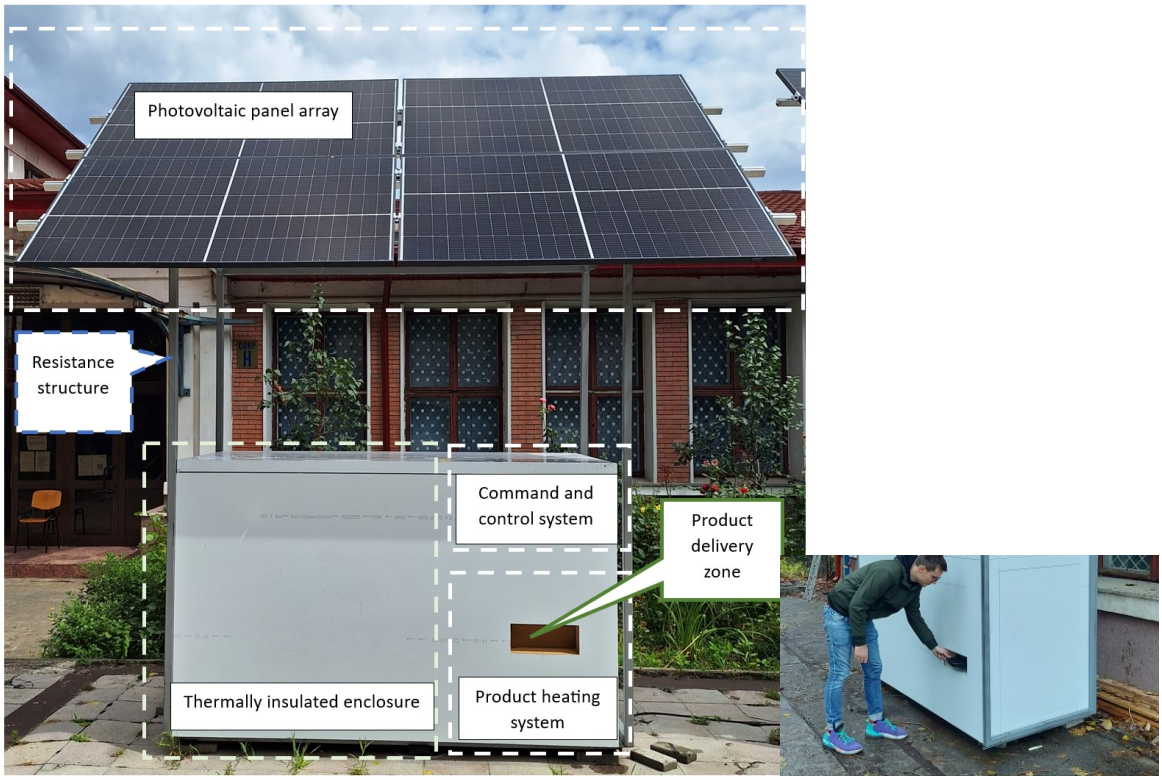


Figure 1. Prototype SVIEE energy independent vending system

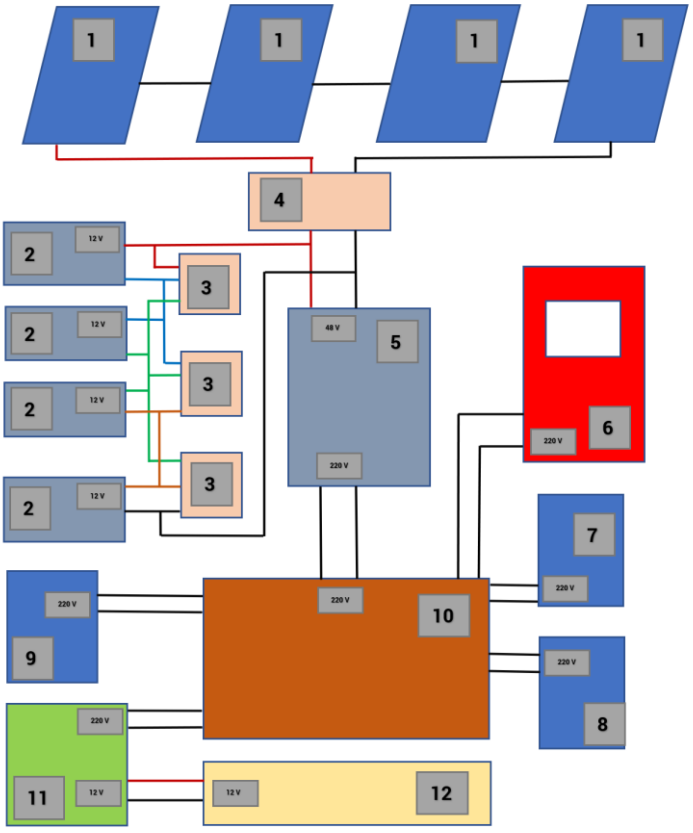


Figure 2. Electrical system of the SVIEE vending machine.

Components illustrated in Figure 2 of the electrical system of the energetically independent vending machine: 1—solar panels, type TSM, 405 DE09. 08, maximum power 405 W; 2—accumulators, type Victron GEL 12 v 130 AH; 3—battery balancer, type Victron; 4—MPPT, type Victron 150/70 Tr; 5—inverter, type Victron Phoenix 5000 W 48 V–230 V; 6—microwave oven, type M2A/28A vending machines; 7—compressor, type Embraco NEU6181U; 8—vaporizer, type Guyan GNKF 850 YAN; 9—condenser, type ELCO; 10—command and control system, manufactured by us; 11-Voltage converter; 12 – Product delivery system. The energy flow produced by the array of photovoltaic panels sent to the battery bank is managed by the MPPT type charge controller. MPPT controllers are known for their efficiency in converting the voltage from the photovoltaic panels to the battery charging voltage. The DC/DC conversion efficiency of these systems is 98% [8]. A battery balancer integrated between the four batteries was used to balance the charging or discharging of the battery bank. For heating the products delivered by the energetically independent vending machine, a microwave oven specially built for model M2A/28A vending machines [9] was adopted and installed. This microwave oven is in the category of those without a rotating table and is equipped with two mirror-mounted magnets.

The SVIEE prototype works properly if food products packed in plastic recipients are inserted inside it and kept in the thermally insulated enclosure until a user wants to buy a product. From the thermally insulated enclosure, the plastic recipients are taken by the displacement system and introduced into the microwave oven. The microwave oven is used to heat the product if a hot product is desired, or the product is directly sent to the user without the use of the microwave oven if a cold product is expected. The delivery is performed in the frontal delivery area, as it can be noticed in figure 1.

The SVIEE prototype is equiped with a complex sensors system connected to the internet. The values measured by the sensors are continuously sent to a server. The collected data are stocked in the server to be analyzed either in real-time using an internet browser or they can be downloaded as a database. The collected data include: the temperature inside the thermally insulated enclosure, the outside air temperature, the cooling system consumption [W], the heating system consumption [W], the displacement system consumption [W], data collected by the photovoltaic system through the MPPT solar charge controller (Baterry [mV]; Baterry injected current [mA]; Solar voltage [mV]; Solar power [W]; etc).



Figure 3. The prototype server data interface

RESULTS

After performing several tests using the SVIEE prototype, we collected data regarding the way in which the automated, energetically independent vending system which sells hot or cold products works. From the complex multidisciplinary data, in this paper, we present a synthetic analyze of the electric energy consumption of the refrigerating system which keeps the product cool until an user places an order and the heating system which warns up the delivered product. The presented data is extracted from the database in which the SVIEE energetically independent vending machine prototype stores the data provided by its embedded sensors.

The period of time we analyzed was during the month of july 2023, the hotest month in 2023 when the mean outside air temperature was 29,4^{0}C and the maximum outside air temperature was 40,5 ^{0}C. The mean relative humidity was 51.4% and the maximum relative humidity was 93,4%.

For the tests we considered two types of products packed in plastic trays with a size of 187 mm X 137 mm X 37 mm. The heated products are: P1 – boiled rice; P2 - pasta with tomato sauce.

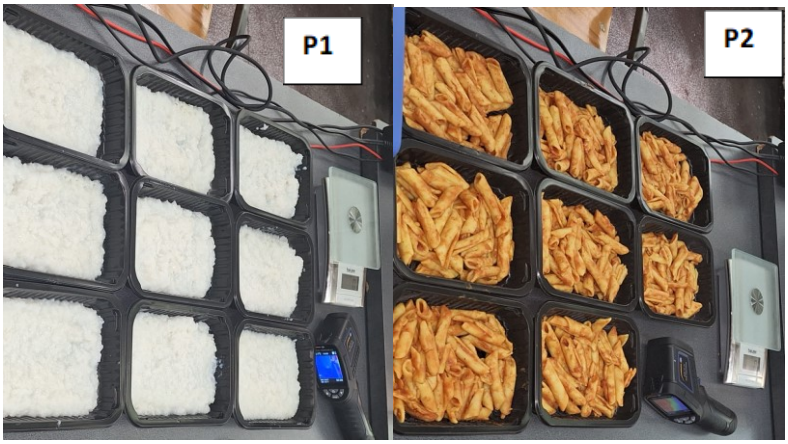


Figure 3. Plastic recipients prepared with tested products.

In order to fulfill the purpose of the research which is to evaluate the impact on the level of CO2 emissions when delivering hot products using an automated, energetically independent selling system, we performed tests for several days considering three working scenarios.

In the first scenario, the vending system was used to deliver plastic trays containing pasta with tomato sauce weighting 191 grames including the tray. In the refrigerating enclosure, 192 trays were stored. The trays were delivered on customers requests and the customers could ask for different heating times. The data acquired between 08.07.2023 and 10.07.2023 are presented in table number 1.

Table number 1

	Number of delivered trays P2 (pieces)	Heating time (sec)	The energy used for heating (Wh)
1	55	10	268,95
2	60	20	778,20
3	72	30	1581,84
Total	187	-	2628,99

During the above mentioned time interval, the refrigeration system consumed 4740.80 Wh, while the auxiliary control and delivery systems used 582 Wh. In scenario number 1, the total amount of electrical energy used was 7951,79 Wh for the delivery of 187 products, resulting a mean consumption per product of 42,52 Wh.

In the second scenario, the vending machine was used to deliver plastic trays filled with boiled rice weighting 241 g including the tray. In the refrigerating enclosure, 192 trays were stored. The trays were delivered on customers requests and the customers could ask for different heating times. The data acquired between 10.07.2023 and 12.07.2023 are presented in table number 2.

Table number 2

	Number of delivered trays P1 (pieces)	Heating time (sec)	The energy used for heating (Wh)
1	45	10	213,75
2	92	20	1181,28
3	43	30	913,32
Total	180	-	2308,35

During the above mentioned time interval, the refrigeration system consumed 5671,86 Wh, while the auxiliary control and delivery systems used 562 Wh. In scenario number 2, the total amount of electrical energy used was 8542,21 Wh for the delivery of 187 products, resulting a mean consumption per product of 47,45 Wh.

In the third scenario, the vending machine was used to deliver both boiled rice trays which weighted 241 grames including the tray and pasta with tomato sauce weighting 191 grames including the tray. In the refrigerating enclosure, 96 trays with pasta were stored and 96 trays with boiled rice. The trays were delivered on customers requests and the customers could ask for different heating times. The data acquired between 12.07.2023 and 14.07.2023 are presented in table number 3.

Table number 3

	Number of trays (pieces)	Heating time (sec)	Energy used for heating (Wh)
Pasta tray -P2			
1	24	10	115,2
2	52	20	661,44
3	10	30	216,2
Total	86	-	992,84
Rice tray -P1			
1	28	10	126,56
2	58	20	731,38
3	8	30	168,88
Total	94	-	1026,82
Total P1+P2	180	-	2019,66

During the above mentioned time interval, the refrigeration system consumed 7358,20 Wh, while the auxiliary control and delivery systems used 556 Wh. In scenario number 3, the total amount of electrical energy used was 8907,04 Wh for the delivery of 180 products, resulting a mean consumption per product of 49,48 Wh.

During the testing period, the photovoltaic panels array produced enough electrical energy to cover the needs of the energetically independent vending machine. The data acquired by the photovoltaic system are presented in table number 4.

Table number 4

Date	Yield (Wh)	Max. PV power(W)	Max. PV voltage (V)	Min. battery voltage (V)	Max. battery voltage (V)	Photovoltaic panels operatin time (min)
14/07/2023	5430	1277	76.04	47.84	56.89	919
13/07/2023	6140	1163	73.27	48.04	56.7	918
12/07/2023	4540	1133	74.75	48.85	56.88	937
11/07/2023	4880	1330	76.86	48.85	56.97	939
10/07/2023	5290	1450	74.48	48.8	57.09	933
09/07/2023	4290	1134	74.83	49.09	57.09	940
08/07/2023	4410	1781	75.67	49.24	56.96	925

During the testing period, the photovoltaic panels array produced 34980 Wh of electrical energy and used only 25401 Wh which leads to the conclusion that the system is sustainable from an energetical point of view and can function energetically independent.

CONCLUSION

To contribute to reducing climate change, the EU established ambitious objectives to reduce the greenhouse effect gas emissions. The EU desires to achieve climate neutrality by 2050. This objectiv and also the reduction of greenhouse effect gas emissions by 55% till 2030 are written in the European climate law. To achieve these objectives, the EU launched several initiatives. One of them is the Effort Sharing Regulation brougt up to date as part of the legislative package called Get 55 [10]. The energetically independent vending system called SVIEE is part of this approach and contributes to the improvement of the hot or cold products trade. The testing showed that we produce more energy than we consume.

The Green Deal Industrial Plan enhances the competitiveness of Europe's net-zero industry and is accelerating the transition to climate neutrality. It does so by creating a more supportive environment for scaling up the EU's manufacturing capacity for the net-zero technologies and products required to meet Europe's ambitious climate targets.[11] The developed technology presented in this article fits in the EU strategy.

The SVIEE prototype consumed 25,401 Wh of electrical energy during the testing period from 08.07.2023 to 14.07.2023. The energy was produced using only the embedded photovoltaic panels array. We took as a reference the electrical energy label of a Romanian electrical energy supplier which informed us that in 2022 [12], in order to produce 1 kWh of electrical energy, the level of specific emissions was 223.25 grames. This information was used to calculate the level of emissions for the energetically independent vending machine. We conclude that the use of the SVIEE prototype reduced the CO2 emissions by 5670,78 grames which is the equivalent of 46 km traveled by a new, medium class vehicle in 2019 with 122.1 gCO2/km emissions [13].

ACKNOWLEDGEMENTS

This work is part of the Competitiveness Operational Program Innovative Energy Efficient Sales Systems for Urban Use (acronym, SVIEE MySMIS code 121420), a project co-financed by the European Regional Development Fund.

REFERENCES

[1] Hasan, H.; Faris, M.A.-I.E.; Mohamad, M.N.; Al Dhaheri, A.S.; Hashim, M.; Stojanovska, L.; Al Daour, R.; Rashid, M.; El-Farra, L.; Alsuwaidi, A.; et al. Consumption, Attitudes, and Trends of Vending Machine Foods at a University Campus: A Cross-Sectional Study. Foods 2021, 10, 2122. https://doi.org/10.3390/foods10092122

[2] Available online: https://www.anker.com/blogs/solar/solar-powered-vending-machines (accessed on 20 october 2023).

[3] Available online: https://ecofriend.com/solar-energy-powers-awesome-vending-machines.html (accessed on 20 october 2023).

[4] Available online: https://www.researchandmarkets.com/reports/3301146/intelligent-vending-machines-global-strategic?gclid=EAIaIQobChMI8pqNmdrogAMVxepRCh08qALVEAAYASAAEgIz8vD_BwE#product--toc (accessed on 20 october 2023).

[5] EU green public procurement criteria for food, catering services and vending machines https://circabc.europa.eu/ui/group/44278090-3fae-4515-bcc2-44fd57c1d0d1/library/9cd7f542-d33c-43f6-91af-b3838c08c395/details (accessed on 20 october 2023).

[6] Calotă R, Savaniu M, Girip A, Năstase I, Georgescu MR, Tonciu O. Study on Energy Efficiency of an Off-Grid Vending Machine with Compact Heat Exchangers and Low GWP Refrigerant Powered by Solar Energy. Energies. 2022; 15(12):4433. https://doi.org/10.3390/en15124433

[7] Savaniu IM, Chiriță A-P, Tonciu O, Culcea M, Neagu A. Neural-Network-Based Time Control for Microwave Oven Heating of Food Products Distributed by a Solar-Powered Vending Machine with Energy Management Considerations. Energies. 2023; 16(19):6953. https://doi.org/10.3390/en16196953

[8] Victron Energy. MPPT Solar Charger Manual; Victron Energy, B.V., Ed.; Victron Energy Manuals Publishing House: Almere, The Netherlands, 2021.

[9] Available online: http://www.chinaxhwb.com/ (accessed on 20 July 2023).

[10] Available online: https://www.europarl.europa.eu/news/ro/headlines/society/20180208STO97442/emisii-reduse-de-co2-in-ue-obiective-nationale-pentru-2030 (accessed on 20 october 2023)

[11] Available online: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/green-deal-industrial-plan_en (accessed on 20 october 2023)

[12] Available online: https://www.enel.ro/content/dam/enel-ro/informatii-utile/reglementari/Ethicheta/etichetaee/Report/2022/Eticheta_PL_EE.pdf (accessed on 20 october 2023)

[13] Available online: *https://www.europarl.europa.eu/news/ro/headlines/society/20190313STO31218/emisiile-de-co2-de-la-autovehicule-date-si-cifre-infografic* (accessed on 20 october 2023)

BIOMASS UTILIZATION AS SUSTAINABLE ENERGETIC ROOT

Lect. Dr. Simona Gavrilaș[1]

Assoc. Prof. Dr. Eugenia Țigan[1]

Assoc. Prof. Dr. Oana Brînzan[1]

Lect. Dr. Radu-Lucian Blaga[2]

[1] "Aurel Vlaicu" Univerity of Arad, Faculty of Food Engineering, Tourism and Environmental Protection, **Romania**
[2] "Aurel Vlaicu" Univerity of Arad, Faculty of Economics, **Romania**

ABSTRACT

The effect of climate change on current life is becoming more visible daily. Our capacity to be resilient to these changes is an act of responsibility for the future. Several directions could serve this purpose. The present study aims to determine the current state of the art in unconventional energy sources. Mainly, the focus will be on biomass. Biopower sources are an element of renewable energy alternatives, along with solar, wind, tide, wave, ocean, and geothermal. The statistics underline an increasing trend of these resource contributions to the total power input. The paper aims to determine the benefits of utilizing biomass as a renewable energy alternative. The key characteristics of such an approach will be examined, emphasizing their advantages and the potential for enhancing performance. There were limitations in accessing valuable information from the field. Through it, biomass-type resources present an increased interest due to their particular property to act in a double sense, unlike the other non-traditional ones. The extent of their application will be ascertained based on the available data.

Keywords: renewable resources, agriculture crops, green power, cogeneration systems, durable exploitation

INTRODUCTION

Access to biomass has been critical to the survival and evolution of humanity throughout history. Autotrophic plants provide us with oxygen and food, essential for survival. Furthermore, they have been a fuel source for thousands of years, furnishing the energy needed for societal progress. In short, life on Earth would not be possible without biomass.

Biomass comprises organic materials from plants and animals, but plants, wood, and waste are the primary sources of biomass feedstocks. The energy generated through biomass is primarily from photosynthesis, which converts carbon dioxide and water into carbohydrates that can be transformed into heat, electricity, or biofuels. Additionally, biomass from human activities, such as manure, crop waste, logging residues, energy crops, and so on, is considered essential for energy production. Energy can be obtained from biomass via various methods, including direct burning, pyrolysis, gasification, and anaerobic decomposition. However, it is essential to consider that crops used to produce

biomass for biofuels, such as ethanol and biodiesel, often involve intensive agricultural practices, lack variation in planting, and rely on only a few types of plants. These crops also require high amounts of pesticides, and their sustainability is debatable.

This paper will review recent research into biomass valorization as a raw material for green energy. The benefits of incorporating this concept in line with present trends concerning the design of sustainable systems will be emphasized. To highlight the potential advantages of adopting this technological approach, we will analyze recent statistics on total energy production in Romania. Objective assessments will be conducted to provide clear and concise findings.

ASPECTS OF BIOMASS USE. BIOMASS AND THE ENVIRONMENT

Since the beginning of the Industrial Revolution, burning fossil fuels has increased atmospheric CO_2 levels by over 50%. It continues to rise, as reported at the World Economic Forum Met Office on 22.03.2021, WEF. Formation of fossil fuels takes millions of years and is finite, subject to depletion through overuse. By the Paris Agreement, nearly all countries have stressed the need to limit global warming to 1.5°C by the end of this century. In the session and meeting Reports of the Paris Climate Change Conference in November 2015, the UNFCCC's Secretariat mentioned that greenhouse gas emissions must peak before 2025 and decline by 43% no later than 2030 to reach this target. A scientist's primary concern is the risk of amplifying climatic feedback loops. A positive response to global warming occurs when initial warming triggers a chain reaction that exacerbates the warming [1]. The relationship between cumulative CO_2 emissions from the present day and warming due to CO_2 emissions relative to preindustrial levels is closely related to the transient climate response to cumulative carbon emissions [2]. It has been estimated that the remaining carbon budget linked to a 1.5°C global warming is 260 Gt CO_2 as of the beginning of 2023. This amount may be depleted in 6.5 years [3]. In response to the emissions gap, we must swiftly implement a more ambitious emissions drawdown with near-term requirements to achieve carbon neutrality before 2050 [1].

Biomass production and consumption play a significant role in regulating the climate by participating in the carbon cycle. During this cycle, carbon moves between the atmosphere, hydrosphere, biosphere, and lithosphere. It is involved in plant photosynthesis, plant and animal decomposition, animal respiration, and various human activities. Throughout these stages, carbon gets sequestered in different forms of biomass and is released into the atmosphere through biomass burning. As long as biomass materials are sustainably farmed and utilized, they can help to reabsorb and sequester carbon at a higher rate than the quantity released into the atmosphere by natural and human activities.

Biomass is an excellent source of renewable energy that is clean and sustainable. It is crucial to maintain a healthy environment by having a diverse and steady supply of trees, crops, and other plants. Many biomass feedstocks can be harvested from marginal lands or pastures, which does not affect the production of food crops. Unlike other renewable energy sources like wind or solar, biomass energy is stored within the organism and can be harvested when needed. In the medium term, biomass waste is expected to be the primary source of biomass for energy [4].

Biomass feedstocks, such as forests, may be rendered non-renewable if not replenished as quickly as they are utilized. Moreover, most biomass requires arable land

to develop, implying that land used for biofuel crops will be unavailable for growing food or providing natural habitats.

We must acknowledge that biofuel production significantly impacts land-use change, which is one of the primary causes of biodiversity loss. It is essential to recognize that clearing land for biofuel crops can substantially reduce local biodiversity, particularly affecting plant species richness and vertebrate abundance [5]. For example, using degraded land instead of clearing more land for biofuel production can mitigate these effects and promote sustainable practices.

Having the necessary skills and expertise is essential when using land for food production and biofuel. Moreover, as the demand for food increases, so does the need for water and energy. We need better business models and strategies to determine how much food and fuel can be produced from the limited land resources. Researchers, as Valentine et al. emphasized a decade ago, in 2012, the importance of sustainable intensification over expanding agricultural land to prevent harm to carbon sinks and biodiversity.

Biomass contains 50% water, making its energy density lower than fossil fuels. However, the water can be eliminated during biomass processing into pellets, increasing its energy density and making it more efficient for transportation. It is considered uneconomical to transport biomass beyond a distance of 160 kilometers from its processing site [6].

On the other hand, the harmful consequences of biomass burning necessitate consideration. When released into the atmosphere, the pollutants generated by biomass burning can create smog and potentially surpass the number of pollutants released by fossil fuels unless captured and recycled.

It is important to note that not all biomass energy can be considered carbon neutral without proper evaluation. The outcome depends on various factors such as the duration of the study, the kind of biomass, the agricultural or forest management techniques, the processing technology used, the distance between processing and the location where the biofuel is utilized, and the combustion technology. As such, assessing the sustainability of biomass production and utilization on a case-by-case basis is crucial.

Biomass is an energy source for many countries, but low returns for producers hinder the widespread adoption of supporting technologies. High-efficiency biomass technologies, such as fluidized bed combustion, co-firing with fossil fuels, Combined Heat and Power Systems (CHP) cogeneration, and gasification, are experiencing a rapid increase in demand worldwide. These biomass-based CHP plants for industry or district heating boast an overall efficiency range of 70% to 90%, according to The International Energy Agency report, IEA, published in May 2012.

CHALLENGES AND PERSPECTIVES IN THE USE OF BIOMASS AS A SUSTAINABLE ENERGY SOURCE

Biomass exploitation poses challenges compared to alternative renewable energy sources due to its unique characteristics. One of these concerns relates to the availability and sustainability of organic matter. Over-harvesting or over-exploitation can lead to deforestation, habitat destruction, and soil degradation [7].

Regarding technological maturity and efficiency, it can be stated that biomass-transforming technologies, including steam bio-methane reforming and gasification, are

readily available for market uptake. However, some strategies are still at low readiness levels [8]. It is essential to utilize cutting-edge and emerging methodologies and systems, such as artificial intelligence, machine learning, remote sensing and Geographic Information Systems (GIS), life cycle assessment (LCA), and bioenergy with capture and carbon storage (BECCS) that could be even more suitable, to achieve the widespread implementation of carbon-neutral bioenergy [9].

While biomass is considered carbon-neutral (the CO_2 released is offset by the one absorbed during plant growth), converting it into energy can release greenhouse gases, primarily if not correctly managed. As energy systems decarbonized, it was used as raw material for biofuels, and production was more evenly distributed amongst the communities [10].

Extending the proportion of these crops can be challenging for those typically grown on arable land and water resources. Impacts can generate surrounding food security and land use conflicts. As the need for alternatives to fossil fuels increases, the new biofuels industry offers agriculture a new income stream. However, expecting it to develop ideally without requiring improvement and optimization is unrealistic. Accordingly, the focus should not exclusively be on the issue of food or fuel. Instead, the more significant challenge of meeting future demands requires improving biofuels and land-based solutions, as Karp et al. highlighted in 2011. One possible solution to this challenge involves establishing bioenergy buffer strips (BBS): narrow areas of land along arable fields and waterways converted to warm-season grasses and short-rotation woody crops for bioenergy purposes. Implementing them could greatly enhance pollination service and natural enemy control in arable crops as beneficial organisms thrive in and near the BBS. A correlation between crop management and species richness was discovered in bioenergy crops across a diverse range of subgenus. As a result, that could be an innovative energy production strategy that encourages reconsidering bioenergy feedstock's sustainable production and balances ecological services with farmers' incomes within land constraints, according to Ferrarini et al. study from 2014. The integration of perennial biomass crops (PBCs) into farming systems and landscapes could support the objectives of the Common Agricultural Policy (CAP) (2023-2027), provided that specific policy measures are in place to encourage farmers and land managers to allocate their less productive and less profitable land for uses that provide verifiable reductions in greenhouse gas emissions [11].

Biomass has a lower energy density than fossil fuels, necessitating a sizeable quantity to obtain significant energy. Additionally, its transportation from production to utilization sites is frequently necessary, as Tumuluru et al. mentioned in their study in 2010. For this type of energy resource to become viable, its supply chain must be efficient, well-defined, and optimized, from collection and transport to storage and distribution (logistics) [12]. For energy uses, it is presented nowadays as one of the significant possibilities as an alternative to fossil. However, due to some constraints caused by its low density, low heating value, and geographic dispersion, all the elements must be carefully understood to allow an efficient operation and design of the supply chain [13].

As a renewable energy source, it has both challenges and promising perspectives. Thus, carbon neutrality is essential in reducing net greenhouse gas emissions. Certification schemes and standards are being developed to verify the sustainability of biomass feedstocks.

Such resources can be locally sourced, reducing dependence on imported fuels and providing economic opportunities for rural communities involved in its production. As a result of energy security and climate change drivers, three markets for crop feedstocks have been expanding: bioenergy (electricity, heat), biofuels (diesel, petrol, and aviation fuel substitutes), and biomaterials (feed, materials, chemicals). As can be seen, it can be used for primary, intermediate, or peak energy generation, depending on the technology used. Its versatility is valuable for balancing different energy needs.

Another promising perspective is that the biomass industry can stimulate economic growth in rural areas by creating agriculture, forestry, and biomass processing jobs, including waste management [14]. Biomass waste streams, including agricultural residues and municipal solid waste, are increasingly utilized for energy production fuel (biogas and biomethane) through anaerobic digestion and incineration processes. For economic and political issues, many researchers proposed corresponding suggestions regarding the biomass project [15], supported by government incentives (input tariffs, tax credits, renewable energy mandates, and research and development grants) that are crucial in stimulating biomass energy development.

The ability of biomass-derived biofuels (especially bioethanol and biodiesel) to replace fossil fuels offers a perspective worth considering. For example, Ganguly et al., 2018, suggested the possibility of producing biofuels from woody biomass as an alternative application for this unused resource, simultaneously replacing petroleum-based fuels. Biomass can also be considered raw material for various chemicals and biomaterials that can substitute petroleum-based products. That is why plastics obtained from biological sources (algae) have similar structural, chemical, and physical characteristics to those derived from petroleum-based sources. Algal biomass could also be blended with conventional plastics to reduce reliance on petroleum-based sources [16].

Worldwide, the emerging trend of hybrid renewable energy sources integration in modern power systems is increasing due to privileged prices, clean electricity supply, baseload power, and intermittency issues associated with other renewable energy supply systems [17]. Using biomass at the same time as non-renewable resources for energy production is part of the transition strategy to reduce emissions while using existing infrastructure. Biomass is a resource that allows a gradual transition to a more renewable energy mix. However, optimal planning hybrid systems is difficult and complex, especially considering different alternatives and sustainability aspects [17,18].

METHODOLOGY

A methodical analysis of the current research published in the domain was considered a base for the documentation. Its principal role was to determine the interest in the topic. The central knowledge base accessed was ScienceDirect. Due to the specifics of the publication, only the most representative references were included in the final manuscript.

The source of the factual data considered as references for processing was the EU energy statistical pocketbook and country datasheets. According to the specifications on the European Commission Energy, Climate Change, Environment web page, the newest report is from August 2023. The evaluation considered the tendencies during three decades, 1990-2021.

RESULTS

The database used is a comprehensive one. In the case of coal, both hard and brown were considered. The renewable class included hydro, wind, biogases, solar, and liquid biofuels. Analyzing the information base, around 56% of the total energy production was obtained from natural gas sources at the beginning of the monitoring. In the end, a decrease of almost 24% was observed.

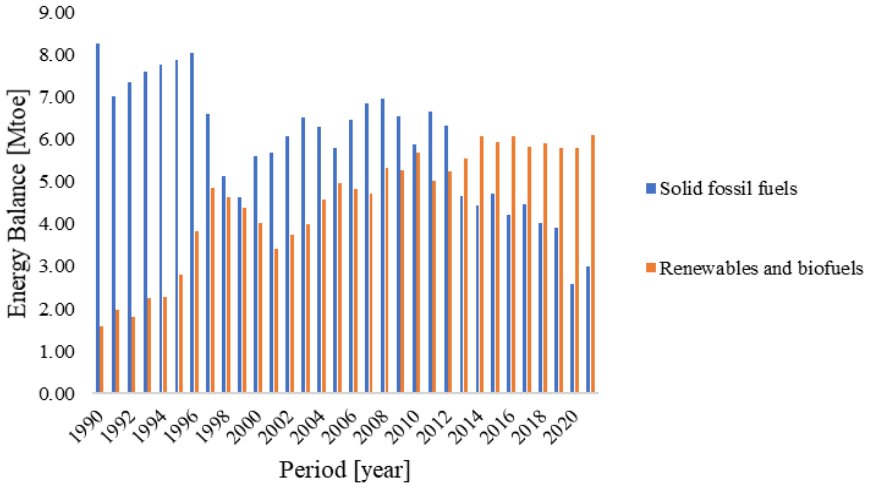


Figure 1 Energy production course

[data source: energy statistical country datasheets]

As Figure 1 presents at the beginning of the interval, the balance between the raw material used for energy strongly slopes towards the solid fossil fuels. Ten years later, the differences between the two sources discussed gradually decreased, arriving as of 2014 to an opposite situation.

DISCUSSION

Despite the release of carbon into the atmosphere during combustion, biomass is perceived as net carbon-neutral owing to plant's carbon absorption in their growth process. Burning biomass yields a substantial potential for slashing carbon emissions. Compared to fossil fuels, biomass usage can aid in reducing climate change and improving air quality.

Although the data in the energy statistic datasheet does not specify the interesting trend for biomass as a raw material for energy, the ascending development of the renewable sources area can be observed. Such consideration can be a starting point for younger farm entrepreneurs to be involved in designing and implementing business plans in the domain. The vision could economically improve small rural communities' status [19] and bring environmental and public health benefits.

CONCLUSION

Biomass is a renewable energy source from organic matter, including wood, energy crops, and agricultural waste. Its deployment helps decrease dependence on finite resources, such as fossil fuels, and enhances the sustainability of energy resources

in the long run. The investigation into the significance of biomass for energy production is essential from various angles, encompassing existing ecological issues and future social requisites. By comprehending and endorsing biomass exploitation in energy-generating processes, we aid the sustainable and accountable progression towards a cleaner and ecologically considerate energy origin.

Sustainability, carbon neutrality, and versatility make biomass essential to the renewable energy mix. At the same time, its exploitation requires careful management and technological development to address its challenges effectively, but also global collaboration and knowledge sharing to develop and promote new technologies. Integrating biomass with other renewable sources and promoting responsible resource management is essential to realizing its potential in transitioning to a more sustainable, energetic root.

Biomass has significant potential as a source of hydrogen, which can be extracted and used as an alternative energy source. However, the primary debate revolves around sustainability, which is currently highly technological and economically demanding.

ACKNOWLEDGEMENTS

The study is intended as a deepening activity in the **ERASMUS+**, *Project 2019-3-TR01-KA205-080177-"Green Thinking Entrepreneur Youth"* to support the young in designing possible ecological alternatives in their entrepreneurial approach. The project funds supported attendance at the SGEM Conference 2023 in the framework of dissemination activity.

REFERENCES

[1.] Ripple, W.J.; Wolf, C.; Lenton, T.M.; Gregg, J.W.; Natali, S.M.; Duffy, P.B.; Rockström, J.; Schellnhuber, H.J. Many risky feedback loops amplify the need for climate action. *One Earth* **2023**, *6*, 86-91, doi:https://doi.org/10.1016/j.oneear.2023.01.004.

[2.] Rogelj, J.; Forster, P.M.; Kriegler, E.; Smith, C.J.; Séférian, R. Estimating and tracking the remaining carbon budget for stringent climate targets. *Nature* **2019**, *571*, 335-342, doi:https://doi.org/10.1038/s41586-019-1368-z

[3.] Forster, P.M.; Smith, C.J.; Walsh, T.; Lamb, W.F.; Lamboll, R.; Hauser, M.; Ribes, A.; Rosen, D.; Gillett, N.; Palmer, M.D.; et al. Indicators of Global Climate Change 2022: annual update of large-scale indicators of the state of the climate system and human influence. *Earth Syst. Sci. Data* **2023**, *15*, 2295-2327, doi:https://doi.org/10.5194/essd-15-2295-2023.

[4.] Casau, M.; Dias, M.F.; Matias, J.C.; Nunes, L.J. Residual biomass: a comprehensive review on the importance, uses and potential in a circular bioeconomy approach. *Resources* **2022**, *11*, 35, doi:https://doi.org/10.3390/resources11040035.

[5.] Tudge, S.J.; Purvis, A.; De Palma, A. The impacts of biofuel crops on local biodiversity: a global synthesis. *Biodiversity Conservation* **2021**, *30*, 2863-2883, doi:https://doi.org/10.1007/s10531-021-02232-5.

[6.] Ieropoulos, I.; Greenman, J. The future role of MFCs in biomass energy. *Frontiers in Energy Research* **2023**, *11*, 1108389, doi:https://doi.org/10.3389/fenrg.2023.1108389.

[7.] Hoogwijk, M.; Faaij, A.; Van Den Broek, R.; Berndes, G.; Gielen, D.; Turkenburg, W. Exploration of the ranges of the global potential of biomass for

energy. *Biomass bioenergy* **2003**, *25*, 119-133, doi:http://dx.doi.org/10.1016/S0961-9534(02)00191-5.

[8.] Buffi, M.; Prussi, M.; Scarlat, N. Energy and environmental assessment of hydrogen from biomass sources: Challenges and perspectives. *Biomass and Bioenergy* **2022**, *165*, 106556, doi:https://doi.org/10.1016/j.biombioe.2022.106556.

[9.] Hiloidhari, M.; Sharno, M.A.; Baruah, D.; Bezbaruah, A.N. Green and sustainable biomass supply chain for environmental, social and economic benefits. *Biomass Bioenergy* **2023**, *175*, 106893, doi:https://doi.org/10.1016/j.biombioe.2023.106893.

[10.] Smyth, C.; Hudson, B.; Metsaranta, J.; Howard, C.; Fellows, M.; Kurz, W. Fire-killed forest biomass for mills and communities and bioenergy GHG impacts. *Biomass Bioenergy* **2023**, *175*, 106877, doi:https://doi.org/10.1016/j.biombioe.2023.106877.

[11.] Clifton-Brown, J.; Hastings, A.; von Cossel, M.; Murphy-Bokern, D.; McCalmont, J.; Whitaker, J.; Alexopoulou, E.; Amaducci, S.; Andronic, L.; Ashman, C. Perennial biomass cropping and use: Shaping the policy ecosystem in European countries. *GCB Bioenergy* **2023**, doi:https://doi.org/10.1111/gcbb.13038.

[12.] Tiwari, S.; Ahmed, W.; Sarkar, B. Multi-item sustainable green production system under trade-credit and partial backordering. *Journal of cleaner production* **2018**, *204*, 82-95, doi:https://doi.org/10.1016/j.jclepro.2018.08.181.

[13.] Nunes, L.; Causer, T.; Ciolkosz, D. Biomass for energy: A review on supply chain management models. *Renewable Sustainable Energy Reviews* **2020**, *120*, 109658, doi:https://doi.org/10.1016/j.rser.2019.109658.

[14.] Liu, M.; Sun, Z.; Li, Q.; Wei, Z.; Liang, B. Driving and Influencing Factors of Biomass Energy Utilization from the Perspective of Farmers. *International Journal of Heat Technology* **2021**, *39*, doi:https://doi.org/10.18280/ijht.390130

[15.] Ma, L.; Yu, J.; Zhang, L. An analysis on barriers to biomass and bioenergy development in rural China using intuitionistic fuzzy cognitive map. *Energies* **2019**, *12*, 1598, doi:https://doi:10.3390/en12091598.

[16.] Cheah, W.Y.; Er, A.C.; Aiyub, K.; Yasin, N.H.M.; Ngan, S.L.; Chew, K.W.; Khoo, K.S.; Ling, T.C.; Juan, J.C.; Ma, Z. Current status and perspectives of algae-based bioplastics: A reviewed potential for sustainability. *Algal Research* **2023**, 103078, doi:https://doi.org/10.1016/j.algal.2023.103078.

[17.] Ullah, Z.; Elkadeem, M.; Kotb, K.M.; Taha, I.B.; Wang, S. Multi-criteria decision-making model for optimal planning of on/off grid hybrid solar, wind, hydro, biomass clean electricity supply. *Renewable Energy* **2021**, *179*, 885-910, doi:https://doi.org/10.1016/j.renene.2021.07.063.

[18.] Zappa, W.; Junginger, M.; Van Den Broek, M. Is a 100% renewable European power system feasible by 2050? *Applied energy* **2019**, *233*, 1027-1050, doi:https://doi.org/10.1016/j.apenergy.2018.08.109.

[19.] Lozano, F.J.; Lozano, R.; Lozano-García, D.F.; Flores-Tlacuahuac, A. Reducing energy poverty in small rural communities through in situ electricity generation. *Discover Sustainability* **2023**, *4*, 13, doi:https://doi.org/10.1007/s43621-023-00128-8.

ENERGY SECURITY OPPORTUNITIES ARISING FROM SDGs AND THE RECOVERY AND RESILIENCE PLAN

Dipl. Ing. Lenka Kazimírová[1]

Assoc. Prof. Dr. Denisa Čiderová[1]

Dipl. Ing. Simona Sakáčová[1]

Dipl. Ing. Jozef Čerňák[1]

[1] University of Economics in Bratislava, **Slovak Republic**

ABSTRACT

The issue of energy self-sufficiency is currently crucial. The concept of energy self-sufficiency is closely related to the concept of energy security; yet, there are many definitions for the term energy security. The essence of all of them is for a country to secure enough energy resources to cover its needs. If a country can secure these resources on its own without depending on imports from other countries, one refers to energy self-sufficiency. Energy self-sufficiency can be achieved in a number of ways such as reducing energy demand, improving fuel efficiency, securing physical infrastructure networks, increasing storage capacity, or increasing the use of renewable energy sources.

Fundamental forms of energy self-sufficiency are external self-sufficiency, internal self-sufficiency, and energy consumption; overall, energy self-sufficiency consists of four components: availability; affordability; energy and economic efficiency; and environmental stewardship.

Low energy self-sufficiency has a significant economic and social impact, which is reflected in a country's balance of payments and employment, it can lead to economic crises and price instability. Lack of access to reliable and affordable energy can result in food insecurity; health problems; limited access to education, social and economic development.

The linkages between energy, food self-sufficiency, and self-sufficiency of water resources are considered in terms of the so-called WEF Nexus (Water-Energy-Food Nexus) that focuses on the interconnectedness of water, energy and food systems to promote sustainable development and address global climate change.

Based on the application of scientific methods in relation to the investigation of energy self-sufficiency (the "E" Matrix in the framework of the WEF Nexus) on the background of quantitative & qualitative sustainable development and CSR trends, the main aim of our paper is to assess energy self-sufficiency in the context of the WEF nexus as well as in the light of the United Nations 2030 Agenda Sustainable Development Goals (SDGs) in order to formulate opportunities arising from the European Union Recovery and Resilience Plans. When documenting quantitative & qualitative sustainable development trends in the context of the WEF Nexus, our paper addressed the United Nations 2030 Agenda (alias *"SDG diplomacy"*) as well as the NextGenerationEU Agenda (alias *"Green Deal diplomacy"*).

https://doi.org/10.5593/sgem2023V/4.2/s17.52

Keywords: United Nations 2030 Agenda Sustainable Development Goals (UN SDGs); *CSR-SDG Correspondence Index*; Water-Energy-Food (WEF) Nexus; CJEU *Case C-121/21 R Czech Republic v Poland (Turów case)*; Visegrád (V4) countries.

INTRODUCTION

"Energy efficiency improvement must more than double its pace – annual energy-intensity improvement rate: 1.4% actual (2015-2020), 3.4% needed (2020-2030)."
"1 in 3 people worldwide struggle with moderate to severe food insecurity." [12b] Fig.2, Fig.3

The issue of energy self-sufficiency is currently crucial. The concept of energy self-sufficiency is closely related to the concept of energy security; yet, there are many definitions for the term energy security. The essence of all of them is for a country to secure enough energy resources to cover its needs. If a country can secure these resources on its own without depending on imports from other countries, one refers to energy self-sufficiency. Energy self-sufficiency can be achieved in a number of ways such as reducing energy demand, improving fuel efficiency, securing physical infrastructure networks, increasing storage capacity, or increasing the use of renewable energy sources. The historical region of Silesia spreads across three contemporary European Union (EU) member states: Poland, Czechia, and Germany. The so-called Turów case (**Case C-121/21 R Czech Republic v Poland** in **Tab. 1**) relates to the "dispute about the operations of PGE's Turów lignite mine in south-western Poland, close to the borders with Germany and the Czech Republic. By 2020 at the latest, operations at Turów had grown so much in extension and depth as to impact negatively on underground water levels across the Czech border, severely limiting or even cutting off supply to some villages. As a result, the Czech Republic sued Poland at the European Court of Justice (CJEU), which issued an injunction to close the mine in May 2021. Poland openly defied the injunction, having also extended PGE's mining license until 2044 the month before. In response to this defiance, in September 2021 the European Commission imposed financial penalties (€0.5 m per day) on Poland, which again refused to comply. This head-on confrontation with the EU reflects the importance of the Turów mine for Poland's energy production and supply." [15]

Tab. 1 Two sides of argumentation in Case C-121/21 R Czech Republic v Poland (Turów case)

Facts of the case	**Case C-121/21 R Czech Republic v Poland (Turów case)**
Visegrád perspective	
Argumentation of PL	*"According to a Polish law of 2008, the validity of a lignite mining concession may be extended once for a period of six years without any environmental impact assessment where that extension is motivated by rational management of the deposit without extending the scope of the concession. On 24 October 2019, the operator [PGE Górnictwo i Energetyka Konwencjonalna S.A.] submitted an application to extend that concession for six years. […] By a decision of 20 March 2020, the Polish Minister for Climate granted permission for lignite mining until 2026."*

Argumentation of CZ	*"Taking the view that Poland had infringed EU law, the Czech Republic brought an action for failure to fulfil obligations before the Court of Justice on 26 February 2021."*
EU perspective	
CJEU Justification	*"Poland has not sufficiently established that the cessation of lignite mining activities at the Turów mine would pose a real threat to its energy security, to the supply of electricity to Polish consumers or to cross-border electricity exchange. Furthermore, the purported harm alleged by Poland resulting from the impossibility of carrying out important projects and investments in the energy field cannot, in any event, take precedence over considerations relating to the environment and human health."*

Legend: CJEU – Court of Justice of the European Union; CZ – Czechia; EU – European Union; PL – Poland.
Source: abridged from [1]

The collision between PGE's operations at Turów and the EU's decarbonisation policy (**Tab. 2**) is framed by Thielemann & Berrocal [15] as follows: "On the one hand, this is depicted as constraining PGE's, and thus Poland's energy production by requiring the abandonment of fossil fuels in favour of more sustainable energy sources. Specifically, EU policy implies the cessation of mining at Turów. On the other hand, operations there are portrayed as ensuring the region's stability and welfare, in both economic and social terms, and as contributing to the energy security of Poland as a whole, since the lignite extracted is used to generate electricity in a nearby power station.".

Tab. 2 PGE's two framings of the Turów case

	Framing 1		Framing 2
	(*alias* Visegrád perspective of "An 'Alliance within the Alliance'" [14])		(*alias* EU perspective of "An Alliance" [14])
Problem	Environmental policies (decarbonisation) vs. economic, social & political effects (welfare & prosperity of Turów region, Polish energy security)	Problem	Legal & moral status of CJEU injunction: legitimate vs. illegitimate
Causes (agents)	EU (Green Deal)	Causes (agents)	CJEU
Evaluation	Emotive lexis (negative re EU Green Deal; positive re PGE approach) Other evocation of emotions ("take away our livelihood")	Evaluation	Emotive lexis (negative re injunction's effects) Other evocation of emotions (references to improper interference in Polish affairs)
Remedies	Solution: 'Green Deal Polish-style'	Remedies	Not specified

Legend: CJEU – Court of Justice of the European Union; PGE – PGE Górnictwo i Energetyka Konwencjonalna S.A. (PGE Elektrownia Bełchatów S.A.).
Source: [14]; adapted from [15]

Be it Framing 1 or Framing 2 of the PGE's campaign, the underlying perception was the one of policy-making (i.e. the EU Green Deal in terms of Framing 1) and/or institutional framework (i.e. the European Commission/CJEU in terms of Framing 2) being imposed by the supranational EU. In the course of developments, a new impetus was registered in the bilateral talks between the Czech government and the Polish government: "In February 2022, a bilateral agreement was reached as a result of which the Czech Republic dropped its lawsuit over Turów, thereby rendering the CJEU's injunction and the Commission's fines null and void, as well as committing itself to make no further financial claims related to the issue. In return, the Polish state paid compensation." [15]

The linkages between energy, food self-sufficiency, and self-sufficiency of water resources are considered in terms of the so-called WEF Nexus (Water, energy, food nexus) that focuses on the interconnectedness of water, energy and food systems to promote sustainable development and address global climate change. This brings us now to the WEF Nexus Index and its Energy pillar, in particular.
Throughout the 2019-2022 COVID-19 era, top scores and bottom scores of the WEF Nexus Index Energy pillar relate to the ensuing intervals in the respective years: in 2019 between 93.2 (Iceland, rank 1) and 35.4 (Jordan, rank 134); in 2020 between 93.6 (Norway, rank 1) and 34.8 (Benin, rank 134); in 2021 between 94.0 (Norway, rank 1) and 34.6 (Benin, rank 136); in 2022 between 94.3 (Norway, rank 1) and 35.1 (Benin, rank 135). Subject to data availability, trends in the Energy pillar in the 2019-2022 time span indicate rather divergence among the territories covered. This can be documented by the fact that the score of 50.4 (Slovak Republic in 2019) was linked to rank 90, whereas almost identical score of 50.3 (Hungary in the years 2021-2022) related to ranks 102 and 105, respectively (**Tab. 3**). Similarly, the same rank 94 of the Slovak Republic in the years 2021-2022 correlates with the scores of 51.8 and 52.4, respectively.

Tab. 3 The Energy pillar (2019-2022) of the Water-Energy-Food (WEF) Nexus Index from the Visegrád (V4) perspective

Energy pillar	CZ	HU	PL	SK
2019 Score	57.1	49.4	55.5	50.4
2019 Rank	58th	98th	70th	90th
2020 Score	55.7	48.5	54.6	49.3
2020 Rank	64th	99th	69th	97th
2021 Score	58.8	50.3	56.4	51.8
2021 Rank	60th	102nd	72nd	94th
2022 Score	59.2	50.3	56.7	52.4
2022 Rank	56th	105th	71st	94th

Source: [13]

Among the Visegrád countries (*alias* V4: Czechia, Hungary, Poland, the Slovak Republic summarised between 2019 and 2022 in **Tab. 3**) the scores of Czechia and Poland are ranking higher on the one hand, and those of the Slovak Republic and of

Hungary are ranking lower, on the other hand. In more detail, the WEF Nexus Index Energy pillar comprises two sub-pillars: Energy access and Energy availability, itemised more in detail in Part *Materials and Methods*.

Based on the application of scientific methods in relation to the investigation of energy self-sufficiency (the "E" Matrix in the framework of the Water-Energy-Food (WEF) Nexus) on the background of quantitative & qualitative sustainable development and CSR trends, the main aim of our paper is to assess energy self-sufficiency in the context of the WEF nexus as well as in the light of the United Nations 2030 Agenda Sustainable Development Goals (SDGs) in order to formulate opportunities arising from the European Union Recovery and Resilience Plans. When documenting quantitative & qualitative sustainable development trends in the context of the WEF Nexus, our paper addressed the United Nations 2030 Agenda (alias *"SDG diplomacy"*) as well as the NextGenerationEU Agenda (alias *"Green Deal diplomacy"*).

MATERIALS AND METHODS

"Energy is important to access water, and water is a key means to generate energy." [4] (for the entire WEF nexus see SDG 2, SDG 6 and SDG 7 in **Fig. 1**)

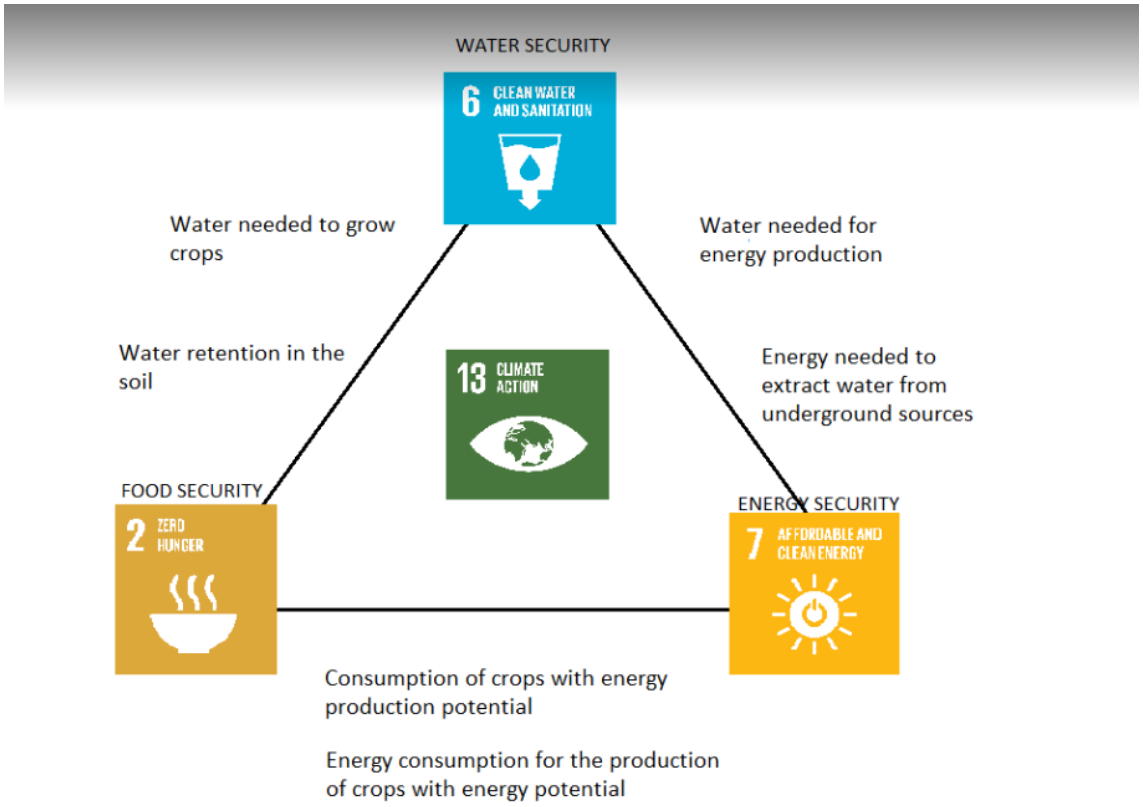


Fig. 1 The Water-Energy-Food (WEF) Nexus in a clockwise constellation
Source: own illustration by authors based on UN SDGs.

Designed as a composite indicator covering 21 relevant country-level indicators across three WEF Nexus pillars of equal weight in response to "a call to move from 'nexus

thinking' to 'nexus action'" [13], the WEF Nexus Index is in the framework of our paper limited to the WEF Nexus Energy pillar (**Tab. 4**).

Tab. 4 Indicators in the Energy pillar of the Water-Energy-Food Nexus Index

Energy-access sub-pillar indicators:	**Unit**	**Energy-availability sub-pillar indicators:**	**Unit**
Access to electricity	% of population	Electric power consumption	kWh/capita
Renewable energy consumption	% of total final energy consumption	Energy imports, net	% of energy use
Renewable electricity output	% of total electricity output		
CO_2 emissions	metric tons per capita		

Source: [13]

In fact, the WEF Nexus Index [13] "should not be viewed in isolation but as an entry point into the underlying hierarchical dataset", with a parallel complementary quantitative and qualitative nexus assessments recommended. Dzebo & Shawoo [3] identified a need to conduct a global assessment of synergies just like trade-offs between key SDG targets from a climate change perspective with the use of a cross-impact matrix in order to address current research gaps and to assess interactions.

Therefore, among 29 SDG Targets (merged into 21 categories) on the background of the shortlisted applicable 5 SDG Targets our paper reflects both the WEF Nexus Index Energy pillar (Energy-access & Energy-availability sub-pillars) [13] and the ensuing SDG targets of the respective matrix [3]:

- SDG Target 2.4 – By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality;
- SDG Target 7.1 – By 2030, ensure universal access to affordable, reliable and modern energy services;
- SDG Target 7.2 – By 2030, increase substantially the share of renewable energy in the global energy mix;
- SDG Target 7.3 – By 2030, double the global rate of improvement in energy efficiency;
- SDG Target 8.4 – Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead.

Adapted from our earlier reflection [2], in the context of "An 'Alliance within the Alliance'" [14] we ranked the Pareto-optimal *(win-win)* scenario as superior to both the "zero-sum" (*win-lose* & *lose-win*) outcomes and the Nash equilibrium (*lose-lose*) in Tab. 5.

Tab. 5 Pareto-optimal scenario/the Nash equilibrium applied to *the "E" & "W" of the WEF nexus* in the practice of Czechia and Poland in the Turów case context from the EU perspective

1.	**Pareto-optimal scenario** *(win-win)* Poland: energy security Czechia: water security	*(win-lose)* Poland: energy security Czechia: water insecurity	2.
2.	*(lose-win)* Poland: energy insecurity Czechia: water security	**Nash equilibrium** *(lose-lose)* Poland: energy insecurity Czechia: water insecurity	2.

Source: adapted from [2]

RESULTS

Based on a 3-level-impact scale stretching from weak impact to strong impact and vice versa, the respective matrix applied the red colour to indicate (restricting: "constraining (–1)"; "counteracting (–2)"; "cancelling (–3)") negative values and the blue colour to indicate (promoting: "enabling (+1)"; "reinforcing (+2)"; "indivisible (+3)") positive values as displayed correspondingly within the "E" Matrix in Tab. 6.

Tab. 6 "E" Matrix with reference to SDG Targets 2.4, 7.1, 7.2, 7.3, 8.4

"E"	2.4	7.1	7.2	7.3	8.4	Σ out: (down)
8.4	Moderately blue "reinforcing" (+2)	Weakly blue "enabling" (+1)	Weakly blue "enabling" (+1)	Strongly blue "indivisible" (+3)	-	25
2.4	-		Moderately blue "reinforcing" (+2)	Moderately blue "reinforcing" (+2)	Moderately blue "reinforcing" (+2)	24
7.1	Moderately blue "reinforcing" (+2)	-	Moderately blue "reinforcing" (+2)	weakly red "constraining" (–1)	Moderately red "counteracting" (–2)	24
7.3	Weakly blue "enabling"	Weakly blue "enabling"	Moderately blue	-	Moderately blue	22

	(+1)	(+1)	"reinforcing" (+2)		"reinforcing" (+2)	
7.2	Weakly red "constraining" (–1)	Moderately blue "reinforcing" (+2)	-	Moderately blue "reinforcing" (+2)	Weakly blue "enabling" (+1)	13
Σ in: (right)	22	16	23	11	11	-

Source: abridged and adapted from [3]

As shown in **Tab. 6**, the SDG Target 8.4 represents almost a double in the total score of outward influence when compared with the SDG Target 7.2 in the 2023 study [3]. In the WEF context the total score of outward influence is the outcome of a combination of both "promoting" SDG Targets as well as "restricting" SDG Targets in the case of individual SDG Targets 2.4, 7.1 and 7.2, but not 7.3 and 8.4, where all the SDG Targets considered were identified as more or less "promoting" only. Analogically, the individual SDG Targets 2.4 and 7.2 symbolise roughly a double in the total score of inward influence when compared with individual SDG Targets 7.3 and 8.4.
Besides "promoting" linkages **Tab. 6** reveals a number of weakly to moderately "restricting" interactions. As neither "restricting" (on the negative scale), nor "promoting" (on the positive scale), i.e. as (0), in terms of mutual outward/inward influence were individual SDG Targets 2.4 and 7.1 categorised by the 2023 study [3].

Tab. 7 "E" Matrix with reference to SDG Targets 2.4, 7.1, 7.2, 7.3, 8.4 in terms of WEF outward & WEF inward influence

SDG Target	WEF outward ("pull") influence Σ		SDG Target	WEF inward ("push") influence Σ
2.4	24	>	2.4	22
7.1	24	>	7.1	16
7.2	13	<	7.2	23
7.3	22	>	7.3	11
8.4	25	>	8.4	11

Source: based on [3]

Overall (**Tab. 7**), the inward influence in the WEF context of the individual SDG Target 7.2 exceeds its outward influence in the WEF context; however, the opposite is true as regards the other individual SDG Targets 2.4, 7.1, 7.3 and 8.4 in the respective "E" Matrix.

In **Tab. 8** we cover the opening and the closing years of both four-year intervals for the four Visegrád countries based on data attached to the *Sustainable Development Report 2023*, showing the respective particular SDG Score for SDG 2, SDG 7 and SDG 8 together with the overall SDG Ranks.

Tab. 8 Overall SDG Score and particular SDG 2, SDG 7 and SDG 8 scores for individual Visegrád countries (pre-COVID interval & COVID interval)

SDG Score	Interval	CZ	HU	PL	SK
SDG 2	Pre-COVID (2015-2018)	60.4 – 63.1	70.2 – 73.2	65.3 – 67.8	69.6 – 74.4
	COVID (2019-2022)	61.2 – 62.1	70.3 – 71.7	65.8 – 67.7	71.2 – 72.6
SDG 7	Pre-COVID (2015-2018)	74.9 – 75.3	73.4 – 74.5	70.6 – 71.2	74.0 – 74.8
	COVID (2019-2022)	76.0	73.9	71.2	77.2
SDG 8	Pre-COVID (2015-2018)	84.2 – 85.9	80.2 – 83.0	82.6 – 85.5	75.7 – 79.5
	COVID (2019-2022)	85.9 – 88.0	81.7 – 84.6	85.3 – 86.9	79.4 – 81.5
Overall SDG Rank	Year	CZ	HU	PL	SK
17 SDGs	2015	24 out of 34	32 out of 34	21 out of 34	27 out of 34
	2018	13 out of 156	26 out of 156	32 out of 156	24 out of 156
	2019	7 out of 162	25 out of 162	29 out of 162	27 out of 162
	2022	13 out of 163	21 out of 163	12 out of 163	24 out of 163

Legend: CZ – Czechia; HU – Hungary; PL – Poland; SK – Slovak Republic.
Source: [5; 7; 8; 11; 12a]

Based on the 2022 overall SDG Rank the Visegrád countries may be clustered into two categories: Czechia (13 out of 163) & Poland (12 out of 163) on the one hand; and Hungary (21 out of 163) & the Slovak Republic (24 out of 163) on the other hand.

DISCUSSION

"Embracing the SDGs as an overarching framework for policymaking and action and linking them with the regular macroeconomic monitoring foreseen in the European Semester, can support the design and implementation of plans that enable the sustainability transition in Europe." [10b]

As the so-called Country-Specific Recommendations (CSRs) symbolise an integral part of the so-called European Semester, linking CSRs with SDGs has the potential to boost better alignment of the United Nations 2030 Agenda with the NextGenerationEU Agenda, too.
Achievement of SDG 8 in Czechia (**Tab. 9**) was linked to a CSR reference throughout the period considered. Similarly, SDG 7 ranking among top-5 according to the SDSN INDEX Dashboard for 2020 (2019-2020 & 2022) and in 2022 SDG 2 (ranked among bottom-5 according to the SDSN INDEX Dashboard for 2020 and regressing from "Significant challenges" in 2020 to Major challenges in 2021) were addressed by CSRs, too.

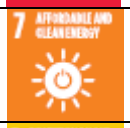
Tab. 9 Assessment and trends of SDG 2, SDG 7 and SDG 8 in Czechia relevant to CSRs

SDG	SDG (CZ)	SDG assessment (CZ)	SDG trend (CZ)	Trend assessment (CZ)	Addressed by CSRs (CZ)	SDG (CZ)
	SDR2020	SDR2020	SDR2020	SDR2020	SDSN2021	SDR2021
SDG 2		Significant challenges		Moderately improving	NO	
SDG 7		Significant challenges		Moderately improving	YES	
SDG 8		Achieved		On track or maintaining SDG trend	Not required	

Source: [9; 10a; 10b]

In Hungary (**Tab. 10**) SDG 8 (moving from the "On track or maintaining SDG trend" in 2020 to the "Moderately improving trend" a year later) was marked by continuous CSR reference throughout the period, followed by SDG 2 and SDG 7 with the exception of the year 2021. Unlike SDG 2 ranking among bottom-5 according to the SDSN INDEX Dashboard for 2020, SDG 7 ranking among top-5 according to the SDSN INDEX Dashboard for 2020 progressed from the Stagnating trend (2020) to the Moderately improving trend (2021).

Tab. 10 Assessment and trends of SDG 2, SDG 7 and SDG 8 in Hungary relevant to CSRs

SDG	SDG (HU)	SDG assessment (HU)	SDG trend (HU)	Trend assessment (HU)	Addressed by CSRs (HU)	SDG (HU)
	SDR2020	SDR2020	SDR2020	SDR2020	SDSN2021	SDR2021
SDG 2		Major challenges		Stagnating	YES	
SDG 7		Significant challenges		Stagnating	YES	
SDG 8		Challenges remain		On track or maintaining SDG trend	YES	

Source: [9; 10a; 10b]

Also in Poland (**Tab. 11**) SDG 8 (moving from the "On track or maintaining SDG trend" in 2020 to the "Moderately improving trend" in the next year) was associated with continuous CSR reference throughout the period, followed by SDG 7 (with the exception of the year 2021) and SDG 2 on a biannual basis in 2020 & 2022.

Tab. 11 Assessment and trends of SDG 2, SDG 7 and SDG 8 in Poland relevant to CSRs

SDG	SDG (PL)	SDG assessment (PL)	SDG trend (PL)	Trend assessment (PL)	Addressed by CSRs (PL)	SDG (PL)
	SDR2020	SDR2020	SDR2020	SDR2020	SDSN2021	SDR2021
SDG 2		Significant challenges		Moderately improving	NO	
SDG 7		Major challenges		Stagnating	YES	
SDG 8		Challenges remain		On track or maintaining SDG trend	YES	

Source: [9; 10a; 10b]

As seen in Hungary, SDG 8 (shifting from "Significant challenges" in 2020 to "Challenges remain" in 2021) was connected with a continuous CSR reference throughout the period in the Slovak Republic (**Tab. 12**). The top-5-ranking SDG 7 according to the SDSN INDEX Dashboard for 2020 and moving from the "Stagnating trend" in 2020 to the "Moderately improving trend" in 2021 came next (with the exception of 2021) in the frequency of CSR reference across the period considered. The bottom-5-ranking SDG 2 according to the SDSN INDEX Dashboard for 2020 followed, with regularity of CSR reference across the period considered in the years 2019-2020.

Tab. 12 Assessment and trends of SDG 2, SDG 7 and SDG 8 in the Slovak Republic relevant to CSRs

SDG	SDG (SK)	SDG assessment (SK)	SDG trend (SK)	Trend assessment (SK)	Addressed by CSRs (SK)	SDG (SK)
	SDR2020	SDR2020	SDR2020	SDR2020	SDSN2021	SDR2021
SDG 2		Major challenges		Stagnating	NO	
SDG 7		Significant challenges		Stagnating	YES	
SDG 8		Significant challenges		On track or maintaining SDG trend	YES	

Source: [9; 10a; 10b]

CONCLUSION

Progress of the V4 countries towards the SDGs in the last 5 years may be summarised as follows:

- CZSDG2, CZSDG8, HUSDG8, SKSDG2 have been progressing towards SDG achievement and their status is better than across the EU;
- HUSDG7, PLSDG8, SKSDG8 have been progressing towards SDG achievement;
- HUSDG2 has been progressing towards SDG achievement, but its status is worse than across the EU;
- Status of CZSDG7, HUSDG7 is worse than across the EU;
- PLSDG7, SKSDG7 have been moving away from SDG achievement;
- PLSDG2 has been moving away from SDGs and its status is worse than across the EU.

In this context, the CSRs outlined for the years 2023-2024 address:

- In Czechia energy support measures with the consideration of fiscal affordability and incentives for energy savings, namely: "Reduce reliance on fossil fuels. Increase the deployment of renewables with additional investments in electricity grids and direct deployment of renewable capacity. Streamline permitting procedures for renewables and make the grid fit to accommodate access to renewables through additional reforms, removing restrictions for small-scale renewables and setting up a one-stop shop, boosting grid flexibility and creating conducive conditions for energy communities. Increase the energy efficiency of district heating systems and of the building stock by incentivising deep renovations and renewable heat sources, easing administrative access to subsidies for both households and industry, and capacity building and skills in public authorities. Promote the uptake of zero-emission vehicles and boost the availability of high-capacity charging and refuelling infrastructure through new reforms to create enabling conditions for and remove existing barriers to the deployment of vehicles and infrastructure. Step up policy efforts aimed at the provision and acquisition of the skills needed for the green transition.";
- In Hungary energy support measures with the consideration of fiscal affordability and incentives for energy savings, namely: "Reduce overall reliance on fossil fuels by accelerating the deployment of renewables, including wind energy, geothermal and sustainable biomethane, in particular by streamlining the permitting procedures, while conducting regular environmental impact assessments and by creating a supportive and predictable regulatory environment. Phase out subsidies for fossil fuels. Reform balancing energy market rules and tariff setting to allow for cost recovery and an optimum use of the grid and, where necessary, upgrade the electricity infrastructure, including grid and storage capacities. Diversify imports of fossil fuels to significantly decrease dependence on Russia, including by strengthening cooperation with other Member States, including where necessary on infrastructure. Improve energy efficiency, in particular in buildings, and continue efforts to reduce overall gas consumption. Adjust the current system of regulated energy prices to encourage energy saving while providing targeted support for low-income households. Step up policy efforts aimed at the provision and acquisition of the skills needed for the green transition.";

- In Poland energy support measures with the consideration of fiscal affordability and incentives for energy savings, namely: “Accelerate the phase-out of fossil fuels and the deployment of renewable energy. Reform the legal framework for grid connection permitting and for renewable energy sources, including energy communities, biomethane and renewable hydrogen. Implement measures to promote energy savings and gas demand reductions. Scale up investment in energy efficiency for buildings and decarbonise the heat supply in district heating to address energy poverty. Further promote sustainable public transport modes. Step up policy efforts aimed at the provision and acquisition of the skills needed for the green transition, including for building renovation.”;
- In the Slovak Republic energy support measures with the consideration of fiscal affordability and incentives for energy savings, namely: “Reduce the economy’s reliance on fossil fuels, in particular natural gas in industry and heating, and diversify imports of fossil fuels. Accelerate the deployment of renewables, particularly for wind, solar, geothermal and renewable gases, in line with relevant sustainability criteria. Simplify permitting and administrative procedures for deploying renewables, including by establishing ‘one-stop shops’ and ‘go-to’ areas. Modernise the electricity network and make the procedures for connecting renewables to the grid more efficient and less costly. Accelerate and incentivise deep renovations of public and private buildings, address energy poverty through housing renovations for low-income households, and step up policy efforts aimed at the provision and acquisition of the skills needed for the green transition.”;
- Synergetic implementation of the RRPs across the V4 countries [6].

ACKNOWLEDGEMENTS

The authors would like to thank the research projects: “Nová vízia ekonomickej diplomacie SR ako nástroja proexportnej politiky do roku 2023 / New vision of economic diplomacy of the Slovak Republic as a tool of export promotion until 2023” funded by the Foundation of the Ministry of Economy of the Slovak Republic (July 2021 – July 2022); and KEGA project No. 003EU-4-2022 for providing their support.

REFERENCES

[1] Court of Justice of the European Union, Poland must immediately cease lignite extraction activities in the Turów mine, Order of the Vice-President of the Court in Case C-121/21 R Czech Republic v Poland, Press Release No. 89/21, 21 May 2021, Luxembourg, 2021.

[2] Čerňák, J., Čiderová, D., Benashvili, G., Sustainable Economic Development From Global Perspective: Transregional European Union Economic Diplomacy and “Green Deal Diplomacy”. In SGEM 2022: 22nd International Multidisciplinary Scientific GeoConference, pp. 205-214, 2022.

[3] Dzebo, A., Shawoo, Z., Sustainable Development Goal interactions through a climate lens: a global analysis, Stockholm Environment Institute, Sweden, 2023.

[4] Holmatov, B., Lautze, J., Uhlenbrook, S., The nexus across water, energy and food (WEF): Learning from research, building on evidence, strengthening practice, Natural Resources Forum, 47(4), pp 817–841, 2023.

[5] Kroll, Ch., Sustainable Development Goals: Are the rich countries ready?, SDSN, Bertelsmann Stiftung, 2015.

[6] Official website of the European Union (https://european-union.europa.eu/index_en) and of its European Commission, Country Pages, https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility/country-pages_en, Belgium.

[7] Sachs, J., Schmidt-Traub, G., Kroll, C., Lafortune, G., Fuller, G., SDG Index and Dashboards Report 2018, Bertelsmann Stiftung and SDSN, USA, 2018.

[8] Sachs, J., Schmidt-Traub, G., Kroll, C., Lafortune, G., Fuller, G., Sustainable Development Report 2019, Bertelsmann Stiftung and SDSN, USA, 2019.

[9] Sachs, J., Schmidt-Traub, G., Kroll, C., Lafortune, G., Fuller, G., Woelm, F., The Sustainable Development Goals and COVID-19. Sustainable Development Report 2020, Cambridge University Press, United Kingdom of Great Britain and Northern Ireland, 2020.

[10a] Sachs, J., Kroll, C., Lafortune, G., Fuller, G., Woelm, F., The Decade of Action for the Sustainable Development Goals: Sustainable Development Report 2021, Cambridge University Press, United Kingdom of Great Britain and Northern Ireland, 2021.

[10b] SDSN. Transformations for the Joint Implementation of Agenda 2030 for Sustainable Development and the European Green Deal – A Green and Digital, Job-Based and Inclusive Recovery from the COVID-19 Pandemic, 2021.

[11] Sachs, J., Lafortune, G., Kroll, Ch., Fuller, G., Woelm, F., From Crisis to Sustainable Development: the SDGs as Roadmap to 2030 and Beyond. Sustainable Development Report 2022, Bertelsmann Stiftung, SDSN, Cambridge University Press, United Kingdom of Great Britain and Northern Ireland and USA, 2022.

[12a] Sachs, J. D., Lafortune, G., Fuller, G., Drumm, E., Implementing the SDG Stimulus. Sustainable Development Report 2023, SDSN, Dublin University Press, France and Ireland, 2023.

[12b] United Nations, The Sustainable Development Goals Report 2023 – Special Edition, USA, 2023.

[13] Simpson, G. B., Jewitt, G. P. W., Becker, W., Badenhorst, J., Masia, S., Neves, A. R., Rovira, P., Pascual, V., The Water-Energy-Food Nexus Index: A Tool to Support Integrated Resource Planning, Management and Security. Front. Water 4(825854), 2022. Retrieved from: https://www.wefnexusindex.org

[14] Szemlér, T., The European Dimension: The V4 and the EU: An "Alliance within the Alliance". In Alexei, D. Voskressenki; Boglárka, Koller (eds.) The Regional World Order: Transregionalism, Regional Integration, and Regional Projects across Europe and Asia, Lexington Books, pp. 77-86, United States of America, 2019.

[15] Thielemann, N., Berrocal, M., Framing the Energy Transition: The Case of Poland's Turów Lignite Mine, International Journal of Strategic Communication, 16 July 2023.

ANNEX

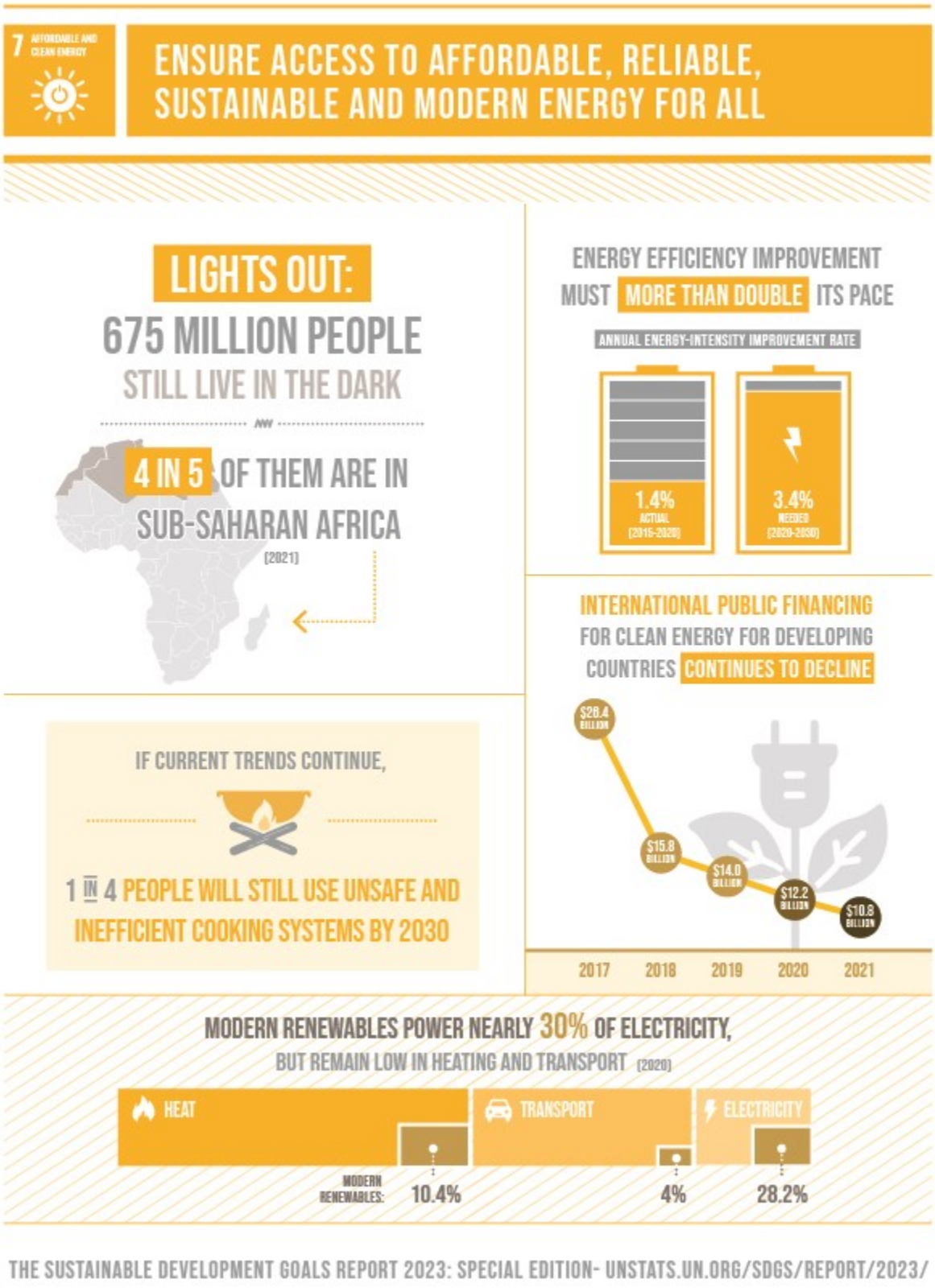


Fig. 2 Status quo of SDG 7 on the global level (2023) Source: [12b]

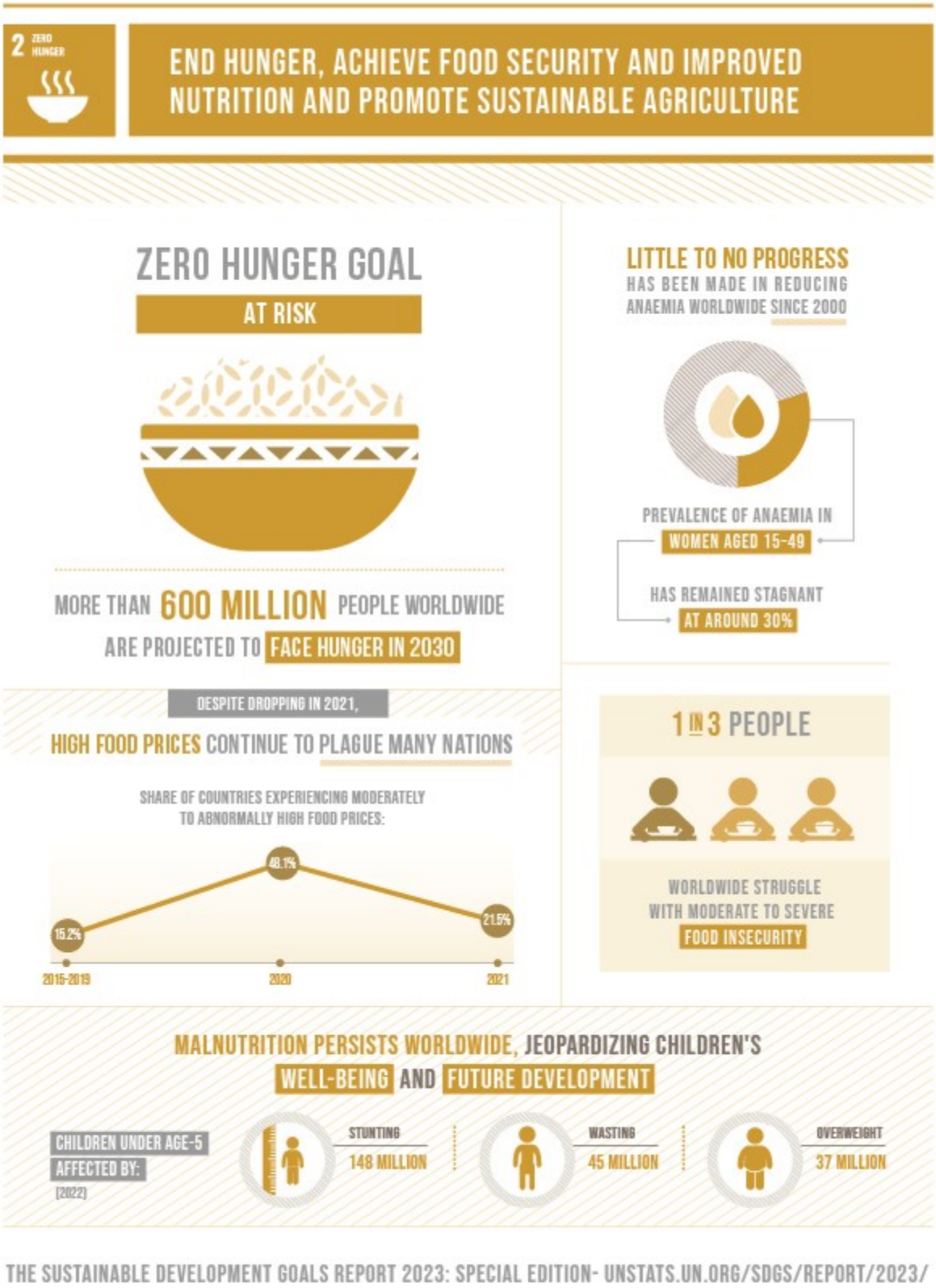


Fig. 3 Status quo of SDG 2 on the global level (2023) Source: [12b]

GREEN BONDS AS LONG -TERM SOURCE OF FINANCE FOR RENEWABLE ENERGY INVESTMENTS

Assoc. Prof. Dr. Meltem Gurunlu[1]

[1] Istanbul Arel University, **Turkey**

ABSTRACT

In a context where clean energy has become almost an imperative, investments in renewable energy projects play an important role for achieving the sustainability of scarce resources needed for the well-being of future generations. Driven by the fact of climate change and the very need for reduction of carbon dioxide emissions all around the world, renewable energy economy has expanded with increasing participation of investors and new types of innovative financial techniques. One of the most striking innovative financial techniques is green bonds, started with the issuance of the "climate awareness bond" by the European Investment Bank in 2007. International Capital Market Association's (ICMA) publication of the Green Bond Principles (GBPs) in 2014, further motivated the expansion of the green bond market. Green bonds, are fixed-income securities which are issued to finance exclusively positive impact generating projects related to environment and climate change. In this study, it is aimed to investigate the development of global green bond markets with their related advantages, disadvantages, and policy implications. A green policy proposal will be made for enhancing the financing of renewable energy projects.

Keywords: Renewable energy investments, green bonds, sustainable finance, renewable energy finance, corporate finance

1.INTRODUCTION

Especially over the last decade, it has been evidenced that there is a future-promising and fast-moving trend towards renewable energy investments. Countries are competing to be a major player in the production of renewable energy due to exponentially increasing environmental problems, concerns over energy security and technological developments reducing cost and increasing efficiency of the renewable energy constructions. It is estimated that renewable energy investment of $5 trillion per year is needed by 2030 for attaining environmental policy targets set by United Nations [1]. Fostering of effective energy transition calls for more renewable energy investments in the form of solar photovoltaics and wind power which should account for nearly 70% of global electricity generation in 2050 [2]. If it is considered that currently, around 80% of global energy and 66% of electrical generation are supplied from fossil fuels, contributing approximately 60% of the greenhouse gas (GHG) emissions responsible for climate change [3], then there is a long path to go for achieving the target set for fostering effective energy transition by 2050. Despite many countries have already started this above-mentioned clean energy transition, the acceleration and expansion of renewable energy investments necessitates more financing sources with less costs. Hence, the central motivation of this study is finding a stable long-term source of finance for renewable energy investments to overcome the obstacles associated with

continuous growth in clean energy-friendly non-fossil fuel energy investments. In this context of the rising importance of renewable energy as an imperative for clean energy, this study aims to investigate the following questions; "Could the green bonds which were initiated by European Investment Bank's issuance of "climate awareness bond" in 2007, be a cure for stable long-term finance need of renewable energy investments? What are the advantages, disadvantages, and related green policy implications?"

2. DEVELOPMENTS IN THE GREEN BOND MARKETS

Green Bonds have been popularized instruments for financing projects which have benefits on environment. Unlike traditional fixed-income securities, the issuer of green bonds guarantees to use the generated proceeds only in financing of investments which have positive environmental or climatic impacts. A "green bond" is also different from a traditional bond by its green labelling process under recommended guidelines which means an assurance to use the proceeds from bond issuance to fund or re-fund "green" investments or pro-environment business activities in a transparent manner [4]. A green bond is also a fixed-income financial instrument which provides capital from external investors in the form of debt obligation. The issuer of bond or debtor, raises a fixed amount of capital from external investors (lenders or creditors) over a fixed period known as the bond's maturity with an agreed amount of interest (coupons). At the end of its maturity, the principal is repaid along with the interest payments. [5].

According to MSCI Global Green Index (Morgan Stanley Capital Investments), green bond's revenue should be used in five categories "alternative energy, energy efficiency, pollution prevention and control, sustainable water, and green building" [6]. The World Bank also, in its Green Bond program emphasizes the transformation to non-fossil fuel clean and renewable energy, low-carbon emitting and climate-friendly economic growth and divides the related environment-friendly projects into two groups; mitigation and adaptation projects. According to the World Bank's definition, green bond's proceeds are used for financing or re-financing eligible projects aimed at achieving climate mitigation and adaptation goals, or other environmental goals. Mitigation projects are immediately needed because they are targeted at reducing the levels of "Greenhouse Gas" (GHG) emissions (an approaching big threat triggering climate change and effecting all countries in the world). Mitigation projects include solar and wind installations, funding for GHG reducing technologies, modification of power plants and to reduce GHG emissions, mass transportation efficiency by non-fossil fuel electricity cars, waste management (methane emissions) and establishment of energy saving green buildings; and increasing forestation activities to reduce carbon emissions. On the other hand, World Bank's adaptation projects are aimed at modifying traditional systems to prioritize important areas like, protection against flooding, food security improvement and implementing climate-resilient agricultural systems and sustainable forest management avoiding deforestation [7].

The first green bond issuance (600 million EUR) in the world is made by the European Investment Bank in 2007, followed by the world bank's issuance of 440 million USD worth climate-focused green bonds to meet the demand from Scandinavian pension funds. In 2010, this amount reached to 4 billion USD by the green bond issuances made by International Finance Corporation (IFC). After the statement of International Capital Market Association's (ICMA) Green Bond Principles (GBPs) in 2014, an expansion in

the green bond markets, has been observed. The growth in Green Bonds issuance hit to a high level of 36.7 billion USD in 2014.In 2021, this figure peaked at approximately 582 billion USD and decreased slightly in 2022, when green bonds issued amounted to 487 billion USD dollars. 2022 capital markets activity was hit globally following Russia's invasion of Ukraine which caused energy price spikes, inflation, and rising interest rates. Green bond issuance in the first half of the year 2023 rose by 22.2% to 351.9 USD compared to the same period in 2022, the biggest ever half year of issuance, outstripping the previous record, set in the second half of 2021, when 296.6 billion USD was issued [8]. In the following figure, the evolution in the value of green bonds issued globally in between 2014-2022 can be seen [9].

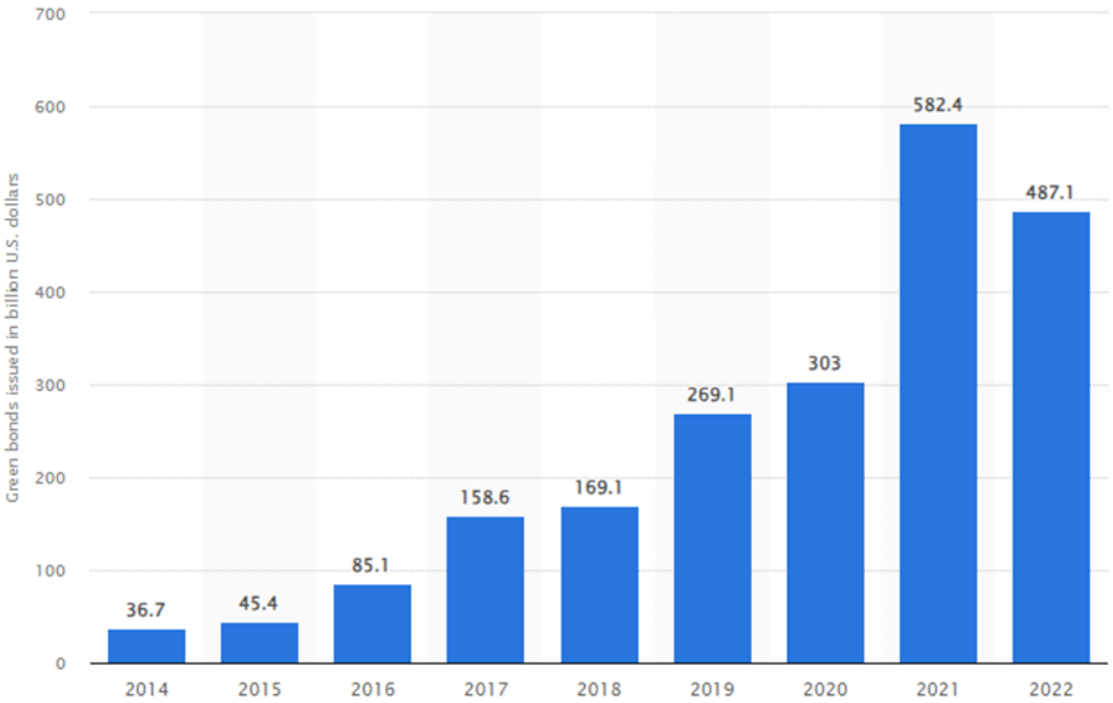


Figure 1. Value of green bonds issued worldwide from 2014 to 2022

(in billion U.S. dollars)

Another figure in the below paragraph depicts the use of proceeds of green bonds by sectors. Accordingly, in between the years 2014 and 2022, more than one third of global green bond revenues were earmarked for financing of the energy sector's renewable energy projects. Second was the buildings, followed by the transportation sector [10].

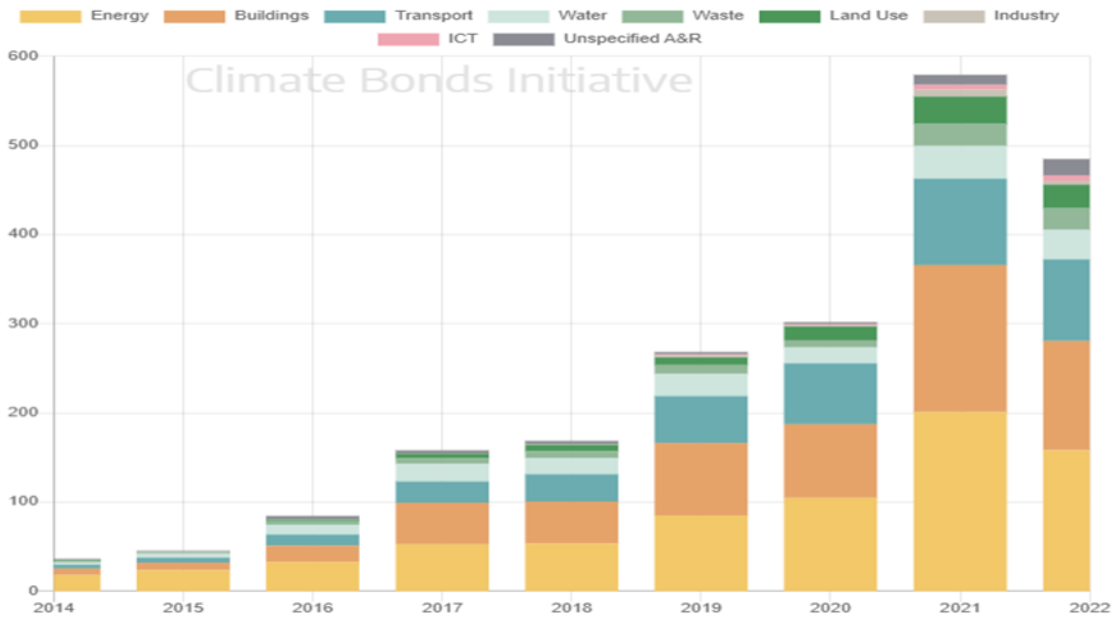


Figure 2. Use of Proceeds of Green Bonds by Sectors

From 2014 to 2022, the United States ranked first in the issuance of green bonds, with 380 billion USD, followed by China, Germany, France, and supranational green bond issuances. **[11]**. In terms of regions, in 2022, Europe was the forerunner with 229 billion USD worth of green bonds as it has been for the last six years. Then comes the Asia-Pacific region with green bonds issuance of 133 billion USD in 2022. It is notable that green bond issuance in all regions decreased in 2022 in comparison with the peak in the year 2021. That is attributable to the effects of Ukraine-Russia war and rising worldwide inflation after the pandemic of COVID 2019 [12].

Total impact bonds consist of Green bonds (bonds with proceeds allocated for projects focusing on environmental benefit), Social bonds (bonds with proceeds allocated for projects focusing on social benefits of the society), Sustainability bonds (bonds with proceeds allocated for projects focused on environmental and social benefits, Sustainability-linked bonds (with an obligation to achieve key indicators based on sustainability performance). Among total impact bonds, green bonds make the 81% of the total issuances.[13].

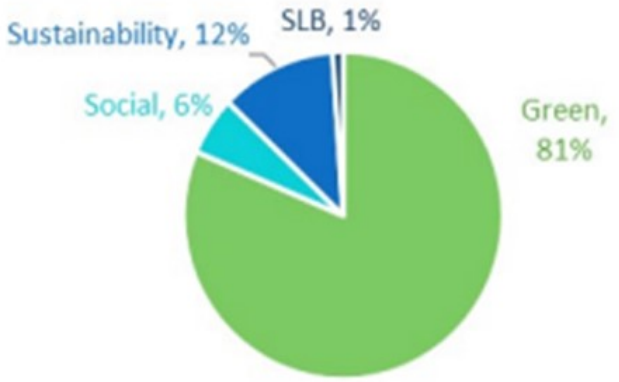


Figure 3. Green, Social and Sustainable Bond Issuance by Type of Instrument (%), 2023

3. DISCUSSION: ADVANTAGES AND DISADVANTAGES FOR GREEN BONDS

Although green bonds do not have a long history, their popularity is rising day by day. The main purpose of green bonds is to provide long-term financing opportunity for environment-friendly investments such as renewable energy and green structuring which commonly have high initial upfront costs and long payback periods with greater expected rate of return by the investors. Green bonds differ from traditional fixed income securities in that they undertake to use the generated proceeds for projects which have positive environmental or climatic impacts. Although green bond markets have grown substantially after its first introduction in 200, reaching to nearly 500 billion USD in 2022 and become a primary instrument for hedging climate change risk, yet its market share is far below the share of conventional bonds. Despite stagnations in the global markets due to high inflations and interest rates, it is anticipated that green bond issuance will be 14% to 16% of total global bond issuance, in 2023 [14].

As green bond investors generally invest for the long-term, there is less liquidity for green bonds when they are compared with conventional bonds. For attracting more investors, there are many incentives related to the green bonds such as tax privileges for issuers and investors of green bonds, credit enhancements and guarantees, green securitization, green bond indices, ratings and stock exchange segments and cross-border investment in green bonds through international collaboration [15]. Another advantage brought by green bonds is that, they decrease the volatility in the bond markets, because investors of green bonds usually apply “buy and hold until maturity” strategy, creating more stable cash flows for renewable energy investments which bear certain risks like a sudden lowering of oil prices, endangering the stability of the cash flows to be generated by the renewable energy investments.

Also, in recent years, due to the increasing perception of climate change’s risks and challenges as common priorities by many stakeholders in the society, Environmental, Social, Governance (ESG) reporting standards of companies and green investing practices have been improved, bringing more transparency to the financial sector for attracting more funds for green investments and green bonds.

Some disadvantages for green bonds can also be mentioned. For example, absence of unified standards for each country may question the greenness of the bond may increase the reputational risk factor for the issuer. There are gaps in country legislations which limits the enforcement power of green bonds for its issuers. This lessens the compatibility of green bonds with their conventional counterparts. Labelling requirement for green bond issuance brings extra costs to the issuer which are needed for reporting, verification, and monitoring of the processes. On breach of the agreed green clauses of the green bond issuance, issuers are obliged to pay a penalty for green default, damaging the issuers' reputation in the financial markets.

4. CONCLUSION

Principles and standards about green bonds should be harmonized and the gaps in this area should be fulfilled because investors have the right to monitor effectiveness of their investments on climate change and reduction of carbon dioxide emissions and greenhouse gases (GHGs). Governments can support professional bodies to work collaboratively on the generally agreed and applicable standards and principles which can fit the dynamics of the market. ICMA's The Green Bond Principles (2014) present voluntary guidelines developed around the design and reporting characteristics of green bonds. The Climate Bonds Standard (CBS) by Climate Bond Initiative (CBI) provides guidelines made by academics and experts for which climate-related investments can be associated with green bonds. A common definition about what truly makes a green bond is needed to ensure the investors about its greenness.

Another strategically important policy implementation needed to be done by the governments is the public issuance of green bonds which can be exemplified by green sovereign bonds green municipal bonds and establishment of green development banks. Moreover, the policies related to green bond market development can be promoted through securitization. Securitization provides aggregation of smaller loans given by banks for renewable energy projects and transfer of them to long-term institutional investors via issuing green bonds backed by the portfolio of smaller loans. Securitization is more favorable for renewable energy projects due to their low risks and stable income generation over the long term.

For future research direction, the existence of a green premium can be investigated through focusing on the spread differentials between green bonds and conventional bonds. Pricing mechanism of green bonds should be investigated more. Is there a premium for green bonds? or does it pay to be green for bonds?

REFERENCES

[1] World Economic Forum, The Ways and Means to Unlock Private Finance for Green Growth, Green Investment Report, 2013, pp:1-38, Available: http://reports.weforum.org/green-investing-2013/required-infrastructure-needs/ (Accessed 03.12.11.2023).

[2] World Economic Forum, Fostering Effective Energy Transition, Insight report, 2023, pp:3-66, Available:https://www.weforum.org/publications/fostering-effective-energy-transition-2023/ (Accessed 03.12.2023).

[3] United Nations Environment Programme, Emission Gas Report, 2021, Available: https://www.unep.org/resources/emissions-gap-report-2021 (Accessed 01.10.2023).

[4] International Capital Markets Association (ICMA), Green Bond Principles: Voluntary Process Guidelines for Issuing Green Bonds, 2021, pp:1-9, Available: https://www.ifc.org/content/dam/ifc/doclink/2022/the-green-bond-principles-202206.pdf (Accessed 01.09.2023).

[5] Organization for Economic Cooperation and Development (OECD), Green bonds: Mobilising the Debt Capital Markets for a Low-carbon Transition, Policy Perspectives Report,2017,Available:https://www.oecd.org/environment/cc/Green%20bonds%20PP%20%5Bf3%5D%20%5Blr%5D.pdf (Accessed 03.12.2023).

[6] Morgan Stanley Capital Investments (MSCI), Global Green Bond Index, 2023 Available:www.msci.com/documents/10199/242721/Barclays_MSCI_Green_Bond_Index.pdf/6e4d942a-0ce4-4e70-9aff-d7643e1bde96 (Accessed 02.12.2023).

[7] The World Bank Green Bond Process Implementation Guidelines, 2017, Available: https://pubdocs.worldbank.org/en/217301525116707964/Green-Bond-Implementation-Guidelines.pdf (Accessed 03.12.2023)

[8] Gardiner, J., Green bonds boom in the first half of the 2023, Bloomberg, Available: https://www.bloomberg.com/professional/blog/green-bonds-boom-in-first-half-of-2023/ (Accessed 03.12.2023)

[9]Statista, Green Bonds Issued Worldwide, 2023, Available: https://www.statista.com/statistics/1289406/green-bonds-issued-worldwide/ ,(Accessed 03.12.2023).

[10] Climate Bond Initiative (CBI), Use of Green Bond Proceeds, 2023, Available: https://www.climatebonds.net/market/data/#use-of-proceeds-charts (Accessed 02.12.2023).

[11] Statista, Green Bonds Issued Worldwide by countries, 2023, Available: https://www.statista.com/statistics/1284029/green-bonds-issued-worldwide-by-country/#:~:text=Between%202014%20and%202022%2C%20The,value%20was%20the%20fifth%20highest (Accessed 02.12.2023).

[12] Statista, Value of Green Bonds Issued Worldwide by Region, 2023, Available: https://www.statista.com/statistics/1294449/value-of-green-bonds-issued-worldwide-by-region/(Accessed 01.12.2023).

[13] World Bank, Green, Social, and Sustainability (GSS) Bonds Market Update, Report,2023Available:https://thedocs.worldbank.org/en/doc/98c3baab0ea4fc3da4de0e528a5c0bed-0340012023/original/GSS-Quarterly-Newsletter-Issue-No-2.pdf (Accessed 03.12.2023).

[14] Standard & Poor Global Ratings, Global Sustainable Bonds 2023 Issuance to Exceed 900 billion, 2023, Available: www.spglobal.com/esg/insights/featured/special-editorial/global-sustainable-bonds-2023-issuance-to-exceed-900-billion#:~:text=Despite%20stagnating%20global%20bond%20issuance,of%20total%20issuance%2C%20in%202023. (Accessed 03.12.2023).

[15] Mutlucan, O.,Green Bonds: Can Green Bonds be an Alternative to Regular Bonds?, Published Thesis, Sorbonne University Press, France, 2017, pp:26-27

INVESTIGATION OF ORGANIC WASTES CONVERSION INTO USEFUL ENERGY RESOURCES USING PYROLYSIS PROCESS

Assoc.Prof. Dr. E.David[1*]
Prof. Dr. J.Kopac[2]
Dr.R-M Marinescu[3]
Drd. A. Armeanu[1]

[1]National Research and Development Institute for Cryogenic and Isotopic Technologies, Rm.Vâlcea, **Romania**

[2]Faculty of Mechanical Engineering, University of Ljubljana, Ljubljana, **Slovenia**

[3]National Institute for Research and Development in Microtechnologies –IMT Bucharest, Ilfov, **Romania**

ABSTRACT

The depletion of fossil fuels is a major concern for the world because of the demand for energy that has increased rapidly with population growth and urbanization. For sustainable development, energy producing industries are trying to find suitable substitutes for petroleum fuel that are environmentally friendly and economically feasible. Biomass ,such as bio-oil and biochar production, could be a possible alternative energy source. Production of biochar and bio-oil from chicken manure(CM) by the pyrolysis process could be a robust approach for organic waste recycling. In this work, experiments were conducted to examine the effect of pyrolysis temperature on the quality of chicken manure biochar (CMB) and to identify the optimal pyrolysis temperature for the conversion of CM into biochar. As the maximum pyrolysis temperature gradually increased from 350 to 650^{O}C, the biochar yield, total nitrogen content in biochar, organic carbon (OC) content, and cation exchange capacity (CEC) of the produced biochar decreased ,while the pH value, ash content and BET surface area of the biochar increased. The generated biochar showed yields of 44.87–61.15% reported to raw material mass, organic carbon of 320–370 g/kg, pH value of 9.4–11.7, BET surface area of 2.65–6.35 m^2/g and CEC of 50.21– 31.45 $cmol_c$/kg. The maximum transformation of organic carbon from CM to biochar occurred at 550 ^{O}C, however 80.5% of N contained in CM was lost to volatile compounds at this temperature. To produce CMB for use as fertilizer, a temperature value of 350 ^{O}C should be selected in pyrolysis process while for environmental applications, 550^{O}C is a suitable temperature value. The obtained results suggest that chicken manure could be used as potential feedstocks for slow pyrolysis process to produce high-value products useful as energy resources.

Keywords: Energy resources; Organic wastes; Chicken manure; Pyrolysis; Biochar;

* Corresponding author: Elena.David@icsi.ro; elenadavid2004@yahoo.com

INTRODUCTION

Generation of renewable energy and bio-products from organic wastes can be a sustainable strategy to substitute the energy provided from fosil and to address to climate change challenges [1].Chicken manure (CM), a solid waste resulting from breeding of chickens, can be used as a feedstock for biofuels and industrial chemicals production [2]. Physically, CM is a mixture of bedding materials (e.g., wood shavings, saw dust, and straw), excreta, feather, feed waste, and chemical treatments (e.g., alum, sodium bisulphate, etc.).Through a thermochemical conversion technology ,such as pyrolysis, organic materials are heated in the absence of oxygen, and can be transformed into biochar, bio-oil, and syngas [3]. Biochar is the black solid product remaining after pyrolysis of biomass, it is porous, enriched with organic carbon (OC), and with good adsorption capacity for water and nutrients, and is an ideal material as amendment or for soil fertility enhancement [4]. Bio-oil is the dark brown liquid product resulting from the condensation of pyrolysis volatiles at room temperature. It has a calorific value (~20 MJ/L), representing 50-60% of that of diesel and can be transformed into a bio-fuel used in furnaces and stationary engines for heating and electricity generation [5]. The gaseous product represents the non-condensable fraction of pyrolysis vapors. It is a mixture of CO, CO_2,H_2, CH_4, C_{2-7}, and other hydrocarbons and can be used as a substitute for natural gas for heating and electricity generation and as a raw material in many chemical processes [6].The annual wastes of CM is of million dry tons, of which the majority is disposed of through land application as an organic fertilizer [7]. Thermochemical conversion of CM for biochar and biofuels production by pyrolysis process may be a value-added approach to reuse of this organic waste [8-10].Usually ,the yields of biochar, bio-oil, and gas fraction are 35%, 30%, and 35% of the dry feedstock biomass, respectively [11]. However, the heat rate, pyrolysis temperature, pyrolysis time, carrier gas conditions, and feed characteristics, such as density, particle size, moisture content influence product yields and characteristics [11]. Of these factors, the temperature during pyrolysis process is critical in determining the yield and quality of product, mainly for biochar [11].The aim of this work was to identify the optimal pyrolysis temperature for converting CM into biochar and bio-oil by comparing the quality characteristics of products from pyrolysis process of CM at different temperatures.

MATERIALS AND METHODS

Chicken manure from a local farm, was collected using a proper procedure according to the rules and regulations of the Department of Environment. Two kilos of the CM sample was dried at the temperature of 100–105 ^{O}C for 24 h, using an oven, to remove the moisture and to reduce its pungent smell. Then, the samples were grinded and sieved prior to initiating the pyrolysis experiments. These methods were used to obtain a standard size (ASTM) at approximately 0.5–1.0 mm. Finally, 50 g of sample was used to perform the pyrolysis experiments. The CM sample was placed in a ceramic crucible (Θ = 60 × h=30 mm) and pyrolyzed in a horizontally tube furnace in the inert atmosphere (60 ml/min,N_2 gas) by heating at 5 ^{O}C/ min .The furnace was set at a temperature ranging from 350 to 650 ^{O}C. At the set temperature , the pyrolysis volatiles were condensed and collected in vessels as liquid fraction (position 10 on Fig.1). Uncondensable gases were captured in a tank (position 11 on Fig.1). The

pyrolysis temperature was maintained until no visible vapors entered into the condenser, this indicating completion of pyrolysis process. Figure 1 shows the system used for pyrolysis experiments.

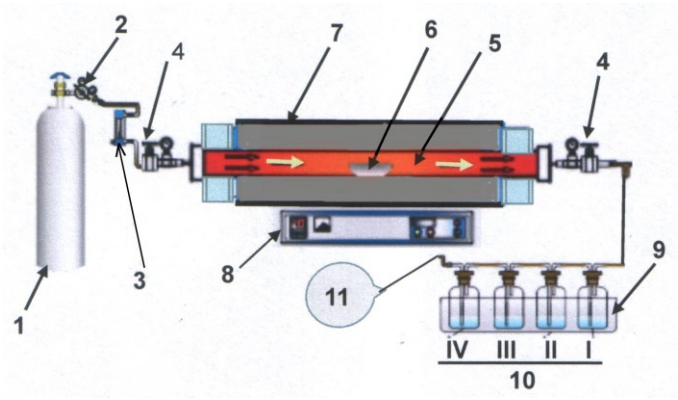


Figure 1. The laboratory pyrolysis system: (1) cylinder with N_2 gas;(2) pressure gauge; (3) flowmeter; (4)gas flow regulator ; (5)horizontally tube furnace; (6) ceramic crucible; (7) electric furnace; (8) regulator and temperature controller; (9) cooling bath (water with ice);(10) vessels for cooling and capturing liquid pyrolysis product; (11) tank for gas collection

The reaction pyrolysis time between start and end of visible vapors from the reactor was recorded. After each pyrolysis experiment , the whole system was cooled to room temperature under nitrogen flow. The chicken manure biochar (CMB) in the ceramic crucible was weighed, transferred into a plastic bag and stored at room temperature for chemical characterization. Bio-oil was collected, weighed and stored in glass bottles for characterization. Chicken manure biochar samples were characterized . The apparent density of CM biochar was measured following the ASTM D-285 method, the ash content of CMB was measured following the standard ASTM D – 2866 method, total organic carbon (TOC) content of MCB was determined using a Mettler Toledo analyzer, the stability of MCB carbon against mineralization was established using the dichromate oxidation method [12]. pH value, electrical conductivity (EC) , water holding capacity (WHC), cation exchange capacity (CEC) were also determined, using specific standards. Extractable nutrients were determined with a Shimadzu 5000A TC/TN analyzer. BET surface area of CMB was measured by N_2 adsorption at 77 K using a Micromeritics ASAP 2000 automated adsorption apparatus and surface acidic groups of biochar was measured using the base titration methods [13]. The composition of the bio-oil was determined by using a GC/MS spectrometer from Agilent Technologies, USA. The identified compound peaks were compared with reference peaks from the NIST mass spectral data library.

RESULTS

The yield and organic carbon content of CMBs produced at various pyrolysis temperatures are given in Table 1. As the pyrolysis temperature increased, the required pyrolysis time was reduced, while the biochar yield and the OC content of biochar decreased, and the ash content of the biochar increased. At 350 ^{O}C, the pyrolysis was complete in 30 min, yielding 29 g OC/kg, biochar being 61.15% of the feed mass. At 650 ^{O}C, however, the pyrolysis time reduced to 10 min, and the biochar yield decreased

to 44.87% (Table 1). Relative to other organic materials, CM has generally higher ash contents and consequently produces more biochar by pyrolysis.

Table 1. Yield of CMB from chicken manure by pyrolysis at various temperature.

Temperature (^{O}C)	Pyrolysis time(min)	Biochar yield(%)	Ash(%)	OC(%)
350	30 ± 2	61.16 ± 0.25	46.65 ± 0.12	36.88 ± 0.50
400	21 ± 2	55.16 ± 0.25	49.56 ± 0.42	37.18 ± 0.25
450	17 ± 1	50.47 ± 0.15	53.75 ± 0.32	36.15 ± 0.52
500	15 ± 1	48.53 ± 0.31	57.35 ± 0.45	35.28 ± 0.45
550	13 ± 1	47.66 ± 0.18	58.76 ± 0.15	34.58 ± 0.46
600	12 ± 1	46.63 ± 0.22	60.43 ± 0.16	33.48 ± 0.41
650	10 ± 1	44.87 ± 0.17	60.65 ± 0.11	32.55 ± 0.33

Values are means ± standard deviations of triplicate measurements.
[a],% of dry mass of CM ;[b], % of CMB mass;[c],OC – organic carbon content

Water holding capacity (WHC), BET surface area ,cation exchange capacity (CEC) and acidic functional groups of biochar generated from chicken manure at different pyrolysis temperatures are showed in Figure 2.

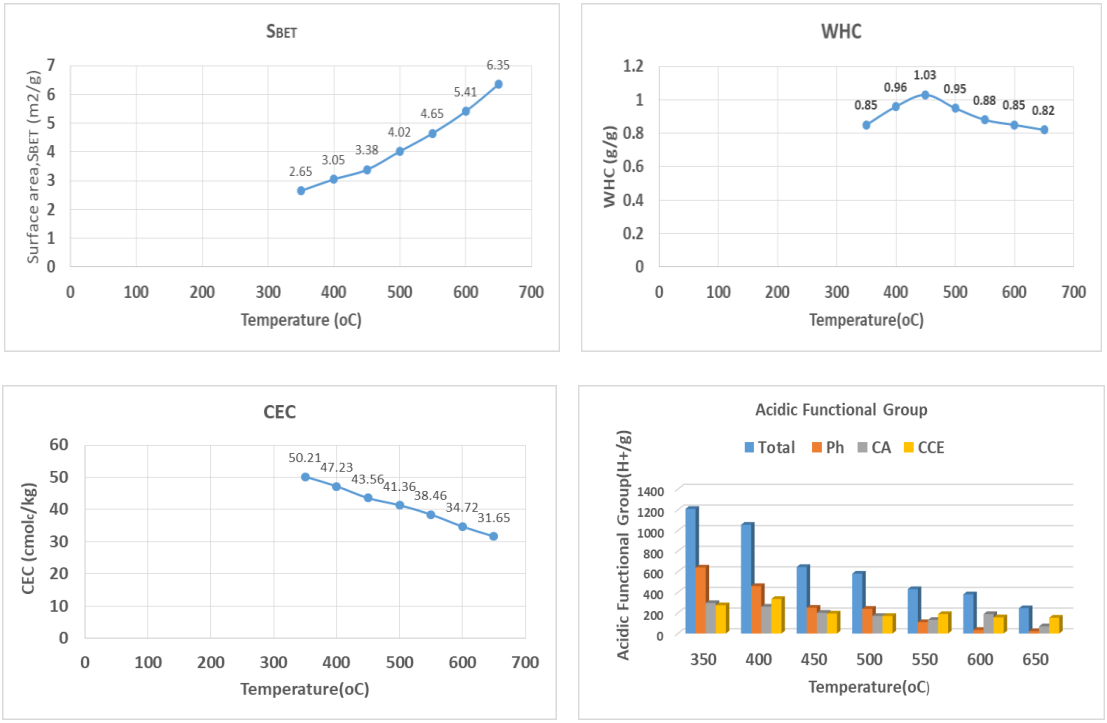


Figure 2. Variation of water holding capacity (WHC), surface area (S_{BET}), cation exchange capacity (CEC) and acidic functional groups of biochar generated from chicken manure at different pyrolysis temperatures.

Table 2 shows the ultimate composition of the organic phase of bio-oil resulted from chicken manure pyrolysis.Table 3 summarizes the list of some notable compounds found in the organic phase of chicken manure-derived bio-oil resulted at 550 °C. The identified compounds of the bio-oil phase with relative areas greater than 1% are presented in this table.

Table 2. The ultimate analysis of bio-oil phase (BO) resulted from pyrolysis of chicken manure

Bio-oil sample	C (wt%)	H(wt%)	N (wt%)	S (wt%)	O(wt%)	HHV(MJ/kg)
BO_{350}	57.35	5.42	4.38	0.1	32.75	23.15
BO_{400}	59.85	7.41	5.25	0.2	27.29	26.84
BO_{450}	61.55	7.86	5.32	0.1	25.17	29.01
BO_{500}	63.58	8.02	6.15	0.1	22.15	31.14
BO_{550}	63.75	8.12	5.84	0.2	22.09	32.26
BO_{600}	55.36	6.84	4.61	0.2	32.99	28.73
BO_{650}	62.83	5.62	4.22	0.2	27.13	29.68

Table 3. The main organic compounds identified in bio-oil phase resulted from chicken manure pyrolysis at 550^{O}C (heating rate of 5 ^{O}C/min).

Organic compound	Relative area(%)	Retention time(min)
Octadecanoic acid	8.3	27.6
3,5-dimethyl cyclohexanone	7.1	2.6
(Z)-9-hexadecen -1-ol	5.7	30.0
Phenol	5.3	5.5
2-ethyl hexanol	4.7	3.0
1,2-dimethyl cyclohexane	4.3	3.3
Hexadecanoic acid,methyl ester	4.2	27.1
3,5-dimethyl –cyclohexanone	3.4	2.4
3-methyl phenol	3.2	7.9
3-ethyl phenol	3.1	10.3
Indole	2.7	13.4
Heptadecane	2.5	23.1
2,3-dimethyl phenol	2.4	9.8
Decane	2.3	2.9
2-methyl phenol	2.2	7.3
Ethyl-cyclohexane	2.2	2.4
Pentadecane	2.2	18.6
9-octadecenoic acid-methyl ester	2.1	29.5
1,2-dimethy-cyclohexane	1.9	3.2
2-methyl phenol	1.6	7.3

The carbon balance for the slow pyrolysis products obtained from chicken manure at various temperature(350 -650 ^{O}C), a heating rate of 5 ◦C/min is presented in Figure 3.

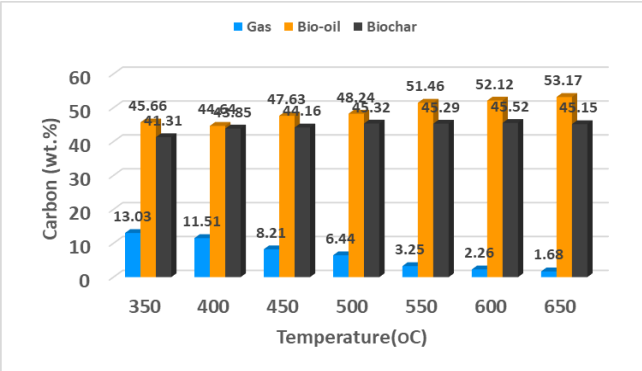


Figure 3. Carbon balance of products obtained from slow pyrolysis of chicken manure (temperature: 350-650 ^{O}C, heating rate: 5 °C /min)

DISCUSSION

Although CMB that was generated at lower pyrolysis temperature had higher OC content (Table 1), the OC was unstable and the majority was oxidized. Almost 62.85% of the OC in CMB generated at 350 ^{O}C pyrolysis temperature was unstable (it was oxidized by dichromate to CO_2). The percentage decreased to 14.75% for the CMB from 550 ^{O}C pyrolysis and further to 13.26% for the CMB obtained at 650 ^{O}C. The apparent density of biochar samples ranged from 0.51 to 0.57 g/cm^3 and this was independent of the pyrolysis temperature. The WHC of CMB samples varied from 0.85 to 1.08 g/g (85% to 108%), see Fig.2. The CEC value of CMB varied from 51.11 to 31.45 cmol$_c$/kg, this decreasing with the increase the pyrolysis temperature (Fig.2). The BET surface area of raw CM was 0.91 m^2/ g and after pyrolysis, it increased, but less than one order of magnitude (Fig. 2).

Functional groups such as hydroxyl, carboxyl, carbonyl, ether, and lactone were developed on biochar during pyrolysis reactions. The CMB had 245–1209 μmol H^+/g of acidic surface functional groups, decreasing as the pyrolysis temperature increased (Fig. 2).Of the total acidic functional groups in the CMB,carboxylic groups are in the range 70 μmol/g to 295 μmol/g, the phenol groups in the range 22 μmol/g to 640 μmol/g, while the cyclic carboxylic esters are in the range 153 μmol/g to 274 μmol/g. The amount of phenols, carboxylic and cyclic carboxylic groups decreased as the pyrolysis temperature increased (Fig.2). Cation exchange capacity (CEC) of biochar is usually influenced of this surface functional groups, when the unstable organic carbon from biochar is oxidized the amount of acidic functional groups increases and CEC also increases. The pH value of CMB was in the range 9.4-11.7 and the value increased with the pyrolysis temperature . The high pH value showed that the ash in CMB contained major components such as Na^+,K^+,Ca^{2+},Mg^{2+}, HCO_3^-,CO_3^{2-} and generally the biochar is alkaline. Electrical conductivity (EC) was determined for extract 1:5 biochar/water and the value varied from 22.68 to 30.95 Ds/m. The EC value increased with the pyrolysis temperature due to increasing of ash content. Considering this high alkalinity , CMB could be applied to soil at a controlled rate to improve its properties. The raw CM contained 30.52 g/kg N, 14.92g/kg P, 41.63g/kg K,42.88g/kg Ca, 11.23g/kg Mg, 16,35g/kg S, respectively. After CM pyrolysis these elements enriched, except for nitrogen (N), and the total amounts increased with the pyrolysis temperature. The total N content of CMB decreased with the increase of pyrolysis temperature. The biochar obtained at lower temperature (350^{O}C) has higher N content, while the biochar resulted from high temperature(650^{O}C) contains lower N amount.

Table 2 shows the ultimate composition of the organic phase of bio-oil generated from chicken manure by pyrolysis. The carbon content of bio-oil increased with the increase of the pyrolysis temperature till 550^{O}C, after which, the carbon content decreased slightly. The hydrogen content also increased in the same way because of a greater degree of cross-linking and the development of higher molecular weight compounds [14]. Like hydrogen and carbon contents, the nitrogen levels also increased in bio-oils produced at higher temperatures. Due to significant levels of oxygen in the bio-oils, for fuel use, it must be upgraded by different techniques for the removal of compounds containing oxygen[15, 16,17].The HHV of chicken manure-derived bio-oil showed a increasing trend from 23.15 MJ/kg at 350 ^{O}C to 32.26 MJ/kg at 550 ^{O}C. The bio-oil produced at 550 ^{O}C exhibited an higher HHV value, this means 550 ^{O}C is the optimal temperature of pyrolysis.The complexity of temperature-dependent reactions in pyrolysis process, such as fragmentation ,decomposition, and re-polymerization result in a

large variety of organic compounds that are present in bio-oil composition. Table 3 shows a list of some compounds found in the bio-oil phase generated at 550 ^{O}C. The identified compounds in bio-oil phase with relative areas greater than 1% are listed in this table. Bio-oil produced at 550 ^{O}C revealed octadecanoic acid, 3,5-dimethyl cyclohexanone, (Z)-9-hexadecen -1-ol, phenol, 2-ethyl hexanol, 1,2-dimethyl cyclohexane, hexadecanoic acid,methyl ester, 3-methyl phenol , 3-ethyl phenol ,indole, etc., this represent a few major components (Table 3. The carbon balance for the slow pyrolysis products at a temperature range of 350 - 650 ^{O}C, a heating rate of 5 ^{O}C/min is presented in Fig.3. With the temperature increase the carbon content in bio-oil and biochar products increased [18]. About 41-45 wt.% of carbon in the feedstock was retained or fixed in the biochar, indicating a good degree of carbonization of biochar. Similarly, the carbon content of bio-oil was found in the range of 45-53 wt.% and the lowest carbon content was found to be in gas fraction, in the range of 1.6-13 wt.%.

CONCLUSION

Increasing the pyrolysis temperature from 350 to 650 ^{O}C decreased the biochar yield, OC content, N content, and CEC, while increasing the carbon stability and BET surface area of the biochar product. To obtain the best quality biochar with an average yield, a lower pyrolysis temperature should be selected. In addition to ensuring biochar production, a lower average pyrolysis temperature is easier to achieve and maintain. Our results suggest that in the temperature range 350-650^{O}C, 350^{O}C is the appropriate pyrolysis temperature to convert CM into biochar for agricultural applications. However, if CM pyrolysis is aimed at carbon capture and energy production, pyrolysis should take place at 550-650^{O}C to convert most of the feedstock to stable OC in biochar, thus producing more bio -oil and synthetic gas. The pyrolysis temperature is the key factor that determines the yield and quality of biochar from the slow pyrolysis of CM. The yield, total nitrogen content, organic carbon (OC) content and CEC value of the biochar obtained from CM decreased with the increase of the pyrolysis temperature in the range of 350-650 ^{O}C, while the carbon stability, BET surface areas, pH value and electrical conductivity (EC) increased. The biochar produced at 350 ^{O}C had the highest yield, nitrogen content and CEC value, while the biochar obtained at 550 ^{O}C had the highest amount of stable organic carbon (OC). The biochar produced at 550-650 ^{O}C can be activated thermal and chemical for transformation into activated carbon for environmental applications.

Besides, the bio-oil produced at elevated temperatures (500-650 ^{O}C) was rich in acids, alcohols and phenols. The gaseous product obtained at 650^{O}C also presented bigger yields of H_2 and CH_4 with an HHV of 8.35 MJ/Nm^3. The obtained results suggest that chicken manure could be used as potential feedstocks for slow pyrolysis process to produce high-value biochar for soil fertilizer or further it can be transformed into activated carbon for environmental applications as well as bio-oil and pyro-gas for energy and fuel applications

ACKNOWLEDGEMENTS

The authors acknowledges the financial support from the Ministry of Research, Innovation and Digitization from Romania, Program: Core; Project no. PN 23 15 04 02 /2023-2026.

REFERENCES

[1] Demirbas A., Biomass resource facilities and biomass conversion processing for fuels and chemicals, Energy Convers. Manage.,2001, 42pp 1357–1378.
[2] Kyakuwaire, M., Olupot, G., Amoding, A., Nkedi-Kizza, P., Basamba, T.A., . How safe is chicken litter for land application as an organic fertilizer? A review. Int. J. Environ. Res. Public Health 2019, 16(19), 3521
[3] Kim S.S., Agblevor F.A., Lim J., Fast pyrolysis of chicken litter and turkey litter in a fluidized bed reactor, J. Ind. Eng. Chem.,2009, 15,pp 247–252.
[4] Chan K.Y., van Zwieten L., Meszaros I.,Downie A., Joseph S., Agronomic values of green waste biochar as a soil amendment, Aust. J. Soil Res.,2007 , 45,pp629–634.
[5]Mohan D., Pittman C.U.,Steele P.H., Pyrolysis of wood/biomass for bio-oil: a critical review, Energy Fuels ,2006,20,pp 848–889.
[6] A. van der Drift, H. Boerrigter, Synthesis Gas from Biomass for Fuels and Chemicals,ECN-report: ECN-C-06-001, Energy Research Center of the Netherlands, Petten, The Netherlands, 2006.
[7]Sharpe R.R., Schomberg H.H., Harper L.A., Endale et al., Ammonia volatilization from surface-applied poultry litter under conservation tillage management practices,J.Environ.Qual.,2004,33,pp. 1183–1188.
[8] Demirbas A.,Biofuels from agricultural residues,EnergySources A.,2008,101–109.
[9]Verheijen F.,Jeffery S.,Bastos A.C.,van der Velde M., Diafas I., Biochar Application to Soils, EUR 24099 EN, Office for the Official Publications of the European Communities, Luxembourg, 2009.
[10]Novak J.M.,Busscher W.J.,Laird D.A.,Ahmedna M.,Watts D.W., Niandou M., Impact of biochar amendment on fertility of a southeastern Coastal Plain soil,Soil Sci., 2009, 174,pp. 105–112.
[11] Laird D.A.,Brown R.C.,Amonette J.E.,Lehmann J., Review of the pyrolysis platform for coproducing bio-oil and biochar, Biofuels Bioprod. Bioref.,2009, 3,pp.547–562.
[12]Schumacher B.A., Methods for the Determination of Total Organic Carbon (TOC) in Soils and Sediments, NCEA-C-1282,U.S.Environmental Protection Agency,National Exposure Research Laboratory, Washington, DC, 2002.
[13]Boehm H.P., Some aspects of the surface chemistry of carbon blacks and other carbons, Carbon 1994 , 32,pp759–769.
[14] Nanda, S., Azargohar, R., Kozinski, J. A., Dalai, A. K., Characteristic studies on the pyrolysis products from hydrolyzed Canadian lignocellulosic feedstocks. BioEnergy Research, 2014,7(1), 174-191.
[15]Hansen, S., Mirkouei, A., Diaz, L. A., A comprehensive state-of-technology review for upgrading bio-oil to renewable or blended hydrocarbon fuels. Renewable and Sustainable Energy Reviews, 2020,118, 109548.
[16]Yaashikaa, P. R., Kumar, P. S., Varjani, S. J., Saravanan, A. (2019). Advances in production and application of biochar from lignocellulosic feedstocks for remediation of environmental pollutants. Bioresource technology, *292*, 122030.
[17] Zhang, B., Feng, H., He, Z., Wang, S., Chen, H. (2018). Bio-oil production from hydrothermal liquefaction of ultrasonic pre-treated Spirulina platensis. Energy Conversion and Management, 159, 204-212.
[18].Tomczyk, A., Sokołowska, Z., Boguta, P. Biochar physicochemical properties: pyrolysis temperature and feedstock kind effects. Reviews in Environmental Science and Bio/Technology, 2020,19(1), 191-215.

NEW ASPECTS OF EXPLOSIVE CHARACTERISTICS OF HYBRID MIXTURES OF DUST/GAS DISPERSIONS

Ing. Matouš Helegda[1]
Ing. Iris Helegda[1]
Ing. Jan Skřínský, Ph.D.[2]
Ing. Kateřina Kubrická[1]
doc. Ing. Jiří Pokorný, Ph.D., MPA, dr. h. c.[1]

[1] Faculty of Safety Engineering, VSB-Technical University of Ostrava, Czech Republic
[2] Energy Research Centre, VSB-Technical University of Ostrava, Czech Republic

ABSTRACT

A small amount of flammable gas mixed with dust can cause a large explosion with serious consequences. In this study, explosions of hybrid mixtures will be performed in an explosion chamber with a volume of 0.02 m^3 and 1.00 m^3. Research into testing the explosion characteristics of hybrid mixtures is usually conducted under standard conditions. Testing the explosion characteristics of hybrid mixtures at higher initial temperatures has already been presented in several earlier studies.

Hybrid mixtures are created and occur, for example, in biomass gasification technology, which is located at VSB-TU Ostrava, where synthetic gas is the output of the entire technology. In technology, the hybrid mixture can be created in a “hot filter”, where a working temperature of 450 °C is required. This technology is not unique, similar gasification technologies are found in other academic or industrial fields in the world. However, they may differ slightly from each other. Given that there is currently a noticeable shift away from fossil fuels and the search for different alternatives, it is possible that these gasification technologies will increase in the world.

With this, the risks resulting from the use of these technologies will also increase, i.e. the risks of fires and explosions (and not only from potential hybrid mixtures created in these technologies).

In this study, the effect of further increasing the initial temperatures will be presented. It was found that as the temperature increases, the values of the explosion characteristics decrease. This has a major impact on the determination of explosion characteristics in industrial plants (e.g. in the food industry or biomass gasification technologies) where non-standard conditions occur.

Keywords: hybrid mixture, dispersion, gas, explosion

INTRODUCTION

The formation of an explosive hybrid mixture, or an explosion, can occur by mixing an amount less than the lower explosive limit (LEL) in the case of pure gas and the minimum explosive concentration (MEC) in the case of pure dust. There is no applicable existing standard for determining safety characteristics for hybrid mixtures. The study [1] published the first international series of comparative explosion tests of a hybrid mixture of cornstarch and methane in 0.02 m3 explosion chambers. The results should have an impact on the new standard and may lead to additional data for later explosion prediction purposes of these flammable systems. The results from this study were taken into account in our experiments.

There are relatively few studies that describe the effect of initial temperature on the explosion parameters of hybrid mixtures. The aim of the work [2] is a comparison and the role of burning velocity in the validity of the hybrid mixtures obtained in the explosion chambers used in European Standard EN 14034 (1.0 m^3 and 0.20 m^3) and explore the influence of the initial temperature (50 °C) on the explosion parameters of the gas and dust mixtures.

In work [3] was used the vessel of 0.20 m^3 volume to carry out hybrid mixture explosion parameters however not at standard temperatures, but at 100 °C. Corn-starch dust was chosen for experimental explosions. One flammable gas (methane) was used. The maximum explosion pressure of steady state methane–air and corn-starch air mixtures were measured in wide range of equivalent ratios.

Article [4] determined the coal dust, lycopodium, and niacin hybrid mixtures with methane and hydrogen in 1 m^3 and 0.20 m^3 chambers. The results show a significant increase of normalised maximum rates of pressure rise in a 0.20 m^3 chamber compared with a 1 m^3 chamber caused by higher turbulence levels in the smaller chamber. It was also shown that the permanent spark could be used for easily ignitable dusts and, in some cases, can produce even higher rates of pressure rise than chemical igniters.

In this work was used the vessel of 0.20 m^3 and 1.00 m^3 volume to carry out hybrid mixture explosion parameters at standard temperatures, and higher initial temperatures at 50 C° and 100 °C. The result of the study is a comparison of individual measurements. Corn-starch dust was chosen for experimental explosions. One flammable gas (methane) was used. The maximum explosion pressure of steady state methane–air and corn-starch air mixtures were measured in wide range of equivalent ratios.

MATERIALS and METHODS

A hybrid mixture of methane and cornstarch was measured. The methane concentration was chosen to be 9% by volume. Corn starch was chosen as a representative substance, whose hybrid mixtures are the subject of research at the German BAM Institute (and not only there), which also aims to create a certain form of methodology for testing hybrid mixtures. The particle-size-analysis, elemental analysis, and moisture content analysis was used to determine the solid material characterisation. The results of the dust sample analysis are listed in Figure 1 and Table 1-2.

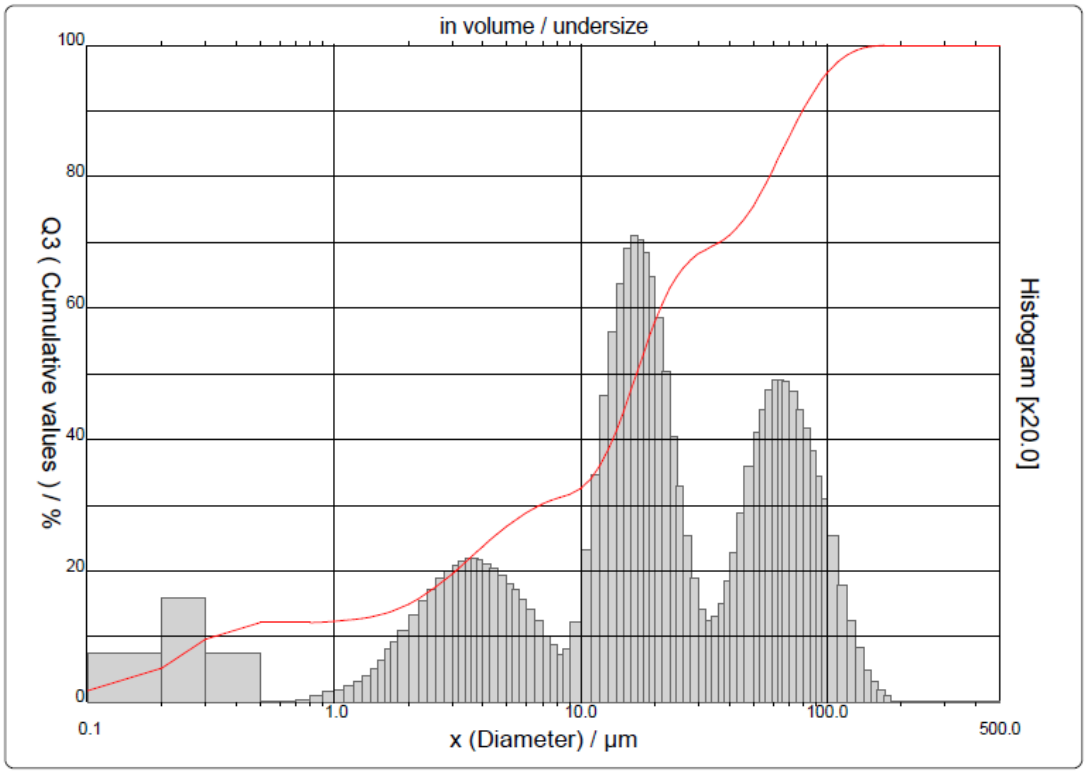


Figure 1: Particle size distribution

Table 1: Moisture content

Parameter	Value Vol. %	Value Vol. %	Value Vol. %	Mean value Vol. %
Moisture	3.0	3.1	3.1	3.1

Table 2: Elemental analysis of the samples

%C	%H	%N	%O	%H_2O	%VM	%FC	%Ash	HHV MJ/kg	LHV MJ/kg
Dry ash-free (daf)					As received (ar)			dry	ar
51.9	6.1	0.3	41.6	7.8	78.1	92.8	0.4	20.80	19.40

The experimental setup is described by Janovsky et al., 2019 [4]. Fundamental explosion characteristic values of the hybrid mixtures were determined experimentally according to the combination of EN 14034 and EN 15967 [5], [6] and [7]. For testing, the explosion vessels were heated to the desired initial temperature. The experimental setup is described in Figure 2.

https://doi.org/10.5593/sgem2023V/4.2/s17.55

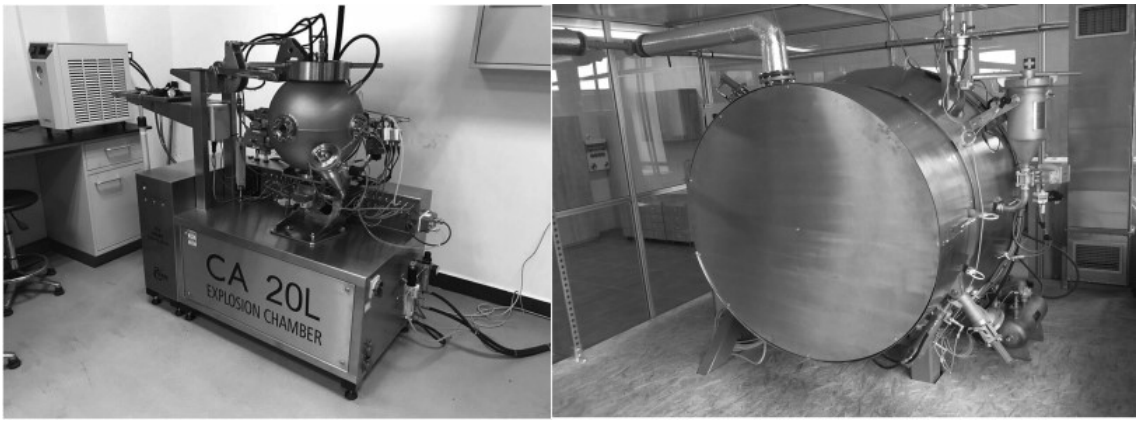


Figure 2: Experimental set-up CA 20L and CA 1M3 [4]

The first experimental technique for the study of explosions in the dissertation is a specific variant of the 1 m^3 explosion chamber. It is a spherical container with an internal diameter of 1240 mm. The material and components used are suitable for the use of the equipment for experiments at atmospheric initial pressure and initial temperature (up to 200 °C). The maximum operating pressure is 3 MPa, while the chamber was subjected to a hydraulic test of 4 MPa. The inner surface of the autoclave is covered with a protective layer of nickel (purity 99.9%) with a thickness of at least 0.5 mm. The autoclave is equipped with electric jacket heating. For this reason, the shell is covered with 80 mm thick thermal insulation and a cover. The system enables the measurement of explosion parameters of three states of substances – dust dispersion, gaseous mixture and liquid vapour mixture in air or oxygen atmosphere and hybrid mixtures [8].

The second experimental technique for the study of explosions in the dissertation is a specific variant of the 0.20 m^3 explosion chamber. The body of the explosion chamber consists of a spherical, double-walled container made of stainless steel, with an internal diameter of 0.362 m and a volume of approximately 0.20 m^3. For easy cleaning of the internal surface, the container is equipped with an opening with an internal diameter of 0.145 m, with a flange and a manually closable lock for locking the lid. The container is also equipped with a glass opening, allowing easy observation of the events inside the autoclave. The used material and autoclave components are suitable for using the device for experiments at atmospheric pressure and initial temperature up to 160 °C and a maximum operating pressure of the autoclave of 3 MPa [9].

RESULTS

As part of the measurements, the explosion characteristics of a hybrid mixture of methane and cornstarch were determined. Comparison of the explosion characteristics of hybrid mixtures at different initial temperatures (20 °C, 50 °C, 100 °C), at a methane concentration of 9 % by volume in the hybrid mixture, different volumes of explosion autoclaves (0.20 m3, 1 m^3), different initiation energies (chemical ignitors 2 kJ and 5 kJ), shown in the Figures see below.

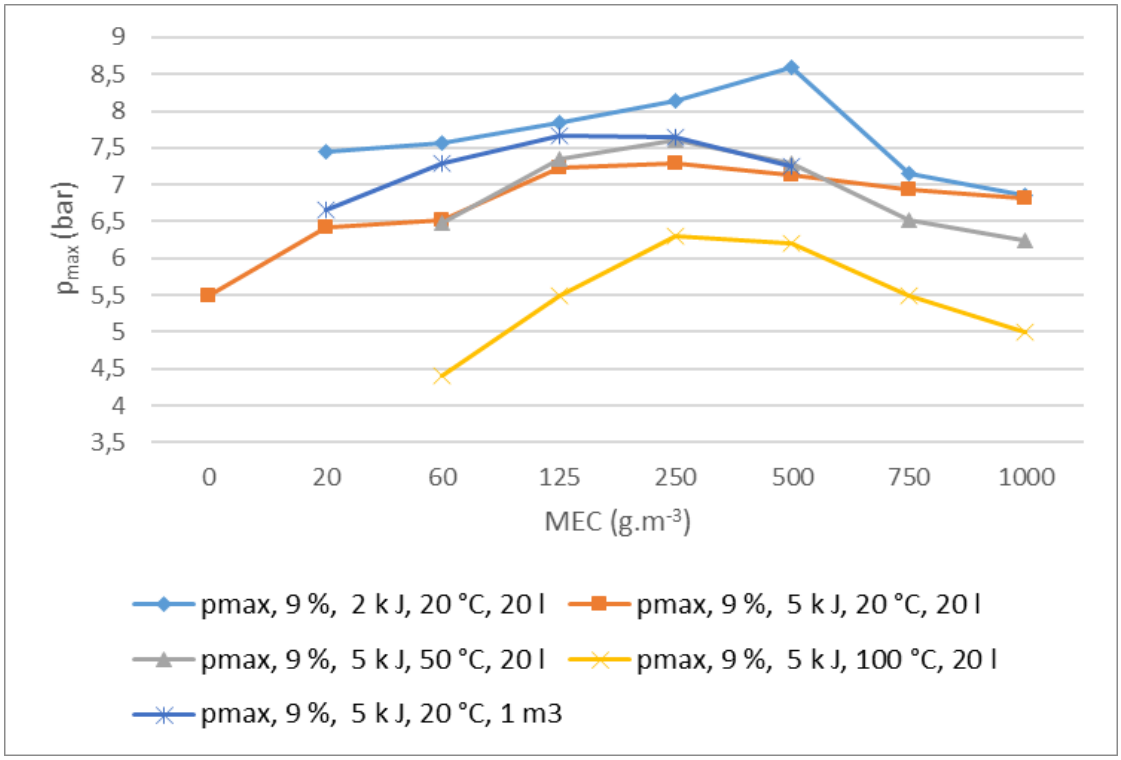


Figure 3: Comparison of the maximum explosion pressure of a hybrid mixture of methane and cornstarch

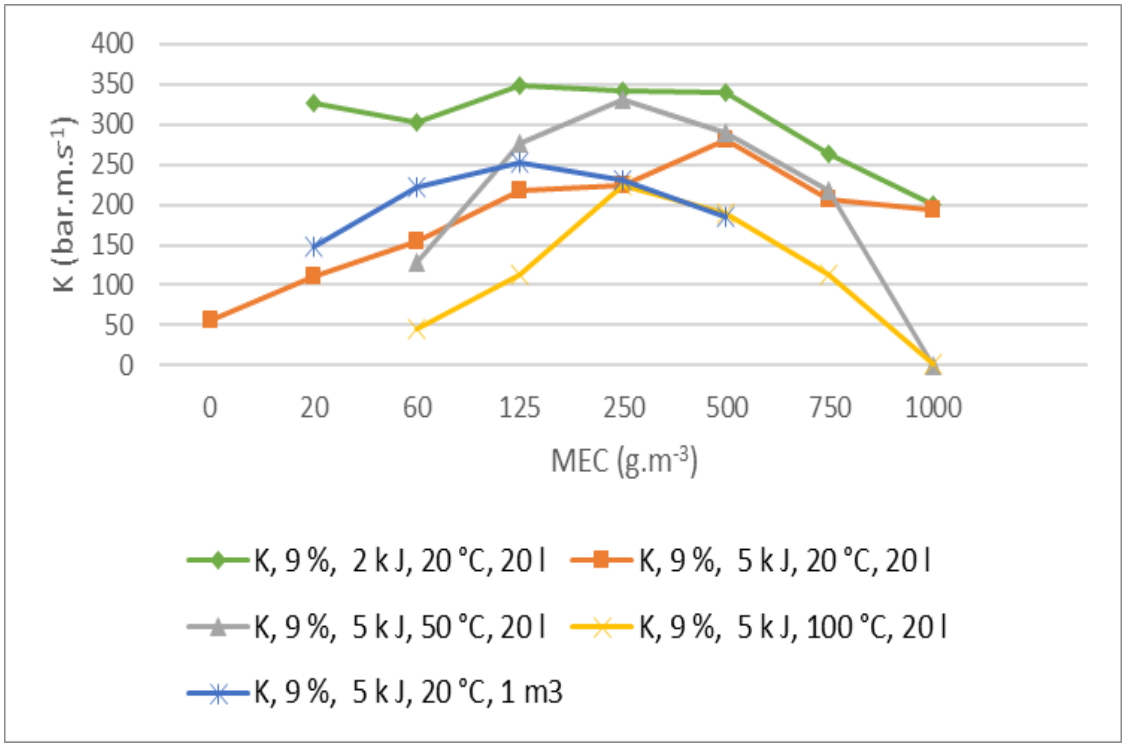


Figure 4: Comparison of the cubic methane constant of a hybrid mixture of methane and cornstarch

DISCUSSION

From the above comparison, it can be seen that the initiation energy has a great influence on the explosion parameters of the hybrid mixture. Paradoxically, higher values of explosion parameters were measured with chemical ignitors of 2 kJ. This may be due to less "overexcitation" or turbulence of the hybrid mixture before initiation than in the case of using a 5 kJ ignitor, when using a 2 kJ ignitor the mixture is not subject to such turbulence caused by the chemical initiator and its explosion is more laminar.

The cubic constant (K) values of the hybrid mixture decrease with increasing temperature.

From the context of the study, it follows that a 1 m^3 explosion chamber is more suitable for testing explosions of hybrid mixtures. The same finding is stated, for example, in the publication Janovsky et al., 2019 [4], which states that it is due to a lower effect of turbulence (the difference between the initiation delay time for gases – 2 minutes, and for dusts – 60 ms). Since the procedure is according to the dust standard, the explosion of the hybrid mixture is therefore more enhanced by turbulence in the 0.20 m^3 chamber than in the 1 m^3 chamber, which increases the explosion parameters. Permanent spark initiation appears to be suitable for easily ignitable dusts, where higher explosion parameters have been measured for these dusts. However, a permanent spark as an initiation source generated lower explosion parameters for less flammable dusts, and therefore chemical initiators are considered necessary for these types of dust.

Similar findings are mentioned by ASTM standards E1226:2019 (Standard Test Method for Explosibility of Dust Clouds) and E1515:2022 (Standard Test Method for Minimum Explosible Concentration of Combustible Dusts), which are used to determine explosion parameters mainly in the USA.

CONCLUSION

The aim of the work presented here is a comparison of explosion characteristics in the validity of the hybrid mixtures obtained in the explosion chambers used in European Standard EN 14034 and explore the influence of the initial temperature on the explosion parameters of the gas and dust mixtures. In this work was used the vessel of 0.20 m^3 and 1.00 m^3 volume to carry out standard procedures to determine hybrid mixture explosion parameters such as maximum explosion pressure and cubic constant.

From the comparison of the explosion testing results of the methane + cornstarch hybrid mixture for different initial temperatures (20 °C, 50 °C and 100 °C), it was found that the p_{max} value of methane decreases with increasing temperature. The same observation applies to the value of the cubic constant K. The p_{max} values measured in a 0.20 m^3 explosion chamber and 1 m^3 at 20 °C do not differ much from each other. The values of the cubic constant K determined at 20 °C in an explosion chamber volume of 1 m^3 are mostly lower than those measured in an explosion chamber with a volume of 20 l. With increasing temperature, the p_{max} value of corn starch decreases. The same applies to the value of the cubic constant K.

The K values of the hybrid mixture decrease with increasing temperature, while the values for the explosion chamber volume of 1 m^3 are significantly lower than for the explosion chamber volume of 20 l.

Ideas for future research on hybrid mixtures arising from this publication could be to carry out experiments at a concentration of methane that would be lower than its lower explosive limit, as well as at initial temperatures of 0 °C and lower in a 20 l container.

Another area of research mentioned could be focusing on testing the explosions of hybrid mixtures at a higher initiation temperature than 100 °C (for example at 150 °C) and monitoring the next trend in the development of the values of the explosion parameters of hybrid mixtures in an explosion chamber with a volume of 1 m^3.

ACKNOWLEDGEMENTS

This work was supported by the Student's Grant Competition, VSB – TU Ostrava, reg. no. SP2023/014, under the project "Verification of the effectiveness of overpressure ventilation of protected escape routes by the selected fire model".

REFERENCES

[1] SPITZER S. H., ASKAR E., BENKE A., CLONEY CH., D'HYON S., DUFAUD O., DYDUCH Z., GABEL D., GEOERG P., HEILMANN V., JANKUJ V., JIAN W., KRAUSE U., KRIETSCH A., MYNARZ M., NORMAN F., SKRINSKY J., TAVEAU J., VIGNES A., ZAKEL S., ZHONG S., 1st international round robin test on safety characteristics of hybrid mixtures. Journal of Loss Prevention in the Process Industries, vol. 81, pp. 104947, 2023. DOI: https://doi.org/10.1016/j.jlp.2022.104947.

[2] HELEGDA M., HELEGDA I., SKŘÍNSKÝ J., KUBRICKÁ K., POKORNÝ J. Laminar burning velocity for hybrid mixtures of corn starch dust and methane gas at high initial temperatures. 22nd International Multidisciplinary Scientific GeoConference SGEM 2022 Proceedings, Volume 22, Issue 4.2, pp 559-566, 2023.

[3] HELEGDA I., HELEGDA M., SKŘÍNSKÝ J., KUBRICKÁ K., PODKUL M. New aspects of explosion characteristics of selected hybrid mixtures. 23rd International Multidisciplinary Scientific GeoConference SGEM 2023 Proceedings, 2023.

[4] JANOVSKY, B., SKRINSKY J., CUPAK J., VERES J. Coal dust, Lycopodium and niacin used in hybrid mixtures with methane and hydrogen in 1m^3 and 20 l chambers, Journal of Loss Prevention in the Process Industries, Volume 62, pp., 2019.

[5] EN 14034-1+A1. Determination of explosion characteristics of dust clouds – Part 1: Determination of the maximum explosion pressure p_{max} of dust clouds. European Committee for Standardization, 2011, 24 pp. Classification code 38 9604.

[6] EN 14034-2+A1. Determination of explosion characteristics of dust clouds –Part 2: Determination of the maximum rate of explosion pressure rise $(dp/dt)_{max}$ of dust clouds. European Committee for Standardization, 2011, 28 pp. Sorting code 38 9604.

[7] EN 15967. Determination of the maximum explosion pressure and the maximum rate of pressure rise of gases and vapours. European Committee for Standardization, 2022, 36 pp. Sorting code 38 9662.
[8] OZM Research, s.r.o. Explosion chamber CA 1M3 for measuring explosion parameters of dust dispersions, gases and vapors at standard and elevated temperatures - User manual for installation, operation, maintenance and troubleshooting. Available on request from: http://www.ozm.cz/en/.
[9] OZM Research, s.r.o. Explosion chamber CA 20-L for measuring explosion parameters of dust dispersions, gases and vapors at standard and elevated temperatures - User manual for installation, operation, maintenance and troubleshooting. Ver. 2 (January 21, 2016), Available on request from: http://www.ozm.cz/en/.

SOLAR TRACKER SYSTEM FOR MONITORING THE MAXIMUM SUN POTENTIAL THAT CAN BE PRODUCED IN A SPECIFIC PLACE

Prof. Dr. Răzvan Bogdan Itu[1]

Prof. Dr. Alexandra Șoica[1]

Prof. Dr. Lorand Bogdanffy[1]

[1] University of Petroșani, **Romania**

ABSTRACT

Power grids have been the mainstay of power systems for more than a century, supporting economic activity by bringing power to homes, industry and services. As the transition to green energy advances, the role of electricity will become more important, making power grids even more special to society and economies. The energy sector is going through essential changes such as decarbonization, digitalization, climate change etc. and as a solution, governments, industries and other stakeholders will need to establish new policies, regulations and updated market models for a new system in the future. Therefore, our purpose was to develop a system that can track the sun from sunrise to sunset, which can be placed in a specific location to record and store data about the maximum potential sun that can be produced. The solar tracker is guided by two step-by-step motors, creating horizontal and vertical movement so that the rising sun will fall perpendicular to the solar panel. The two motors are controlled with the mobile phone which stores data about the amount of energy that is produced. A prototype was made using parts from reused materials such as bicycle wheel, concrete mixer crown, computer elements, parts for chairs, etc. The system is independent of electricity, so it can be placed anywhere without being connected to an outlet. The motors and the data controller are powered by the energy produced by the solar panel in the form of a closed circuit. The data is used to estimate whether investments in solar panel systems in a specific area are profitable and can provide information about the energy produced daily, weekly, monthly or annually. The advantage of the project is that we can control it with our mobile phone and all data is automatically stored without losing any information due to its own power supply.

Keywords: solar tracker, green energy, independent system, sun potential, reused materials

INTRODUCTION

Power grids have been the mainstay of power systems for more than a century, supporting economic activity by bringing power to homes, industry and services.

As transitions to green energy advance, the role of electricity will become more important, making power grids even more special to society and economies.

The energy sector is going through essential changes such as decarbonization, digitalization, climate change, etc. and as a solution, governments, industries and other

stakeholders will have to establish new policies, regulations and updated market designs for a new system in the future.[3]

It is very difficult to live in a modern society without a reliable supply of electricity. The difficulties caused by the Covid-19 pandemic have reminded us of the importance of electricity in all aspects of our lives from keeping medical equipment in hospitals functional and IT systems available for teleworking and video conferencing. Following the studies, it was demonstrated that the effects of a prolonged interruption of the electricity supply far exceed the supply system or the value of the lost energy purchase itself.

Renewable energy sources such as wind and solar photovoltaic systems have become much cheaper than thermal energy generation and are increasing their share of supply. This development is welcome as countries seek to decarbonise the electricity sector.

According to IEA the International Energy Agency in the STEPS, global solar PV deployment continues to expand from around 220 GW in 2022 to about 500 GW in 2030, but planned manufacturing expansion means that the utilisation rate of solar manufacturing remains below 40% through to 2030. The scope to make fuller use of solar manufacturing capacity represents an enormous opportunity to accelerate the deployment of solar PV around the world and accelerate energy transitions [8].

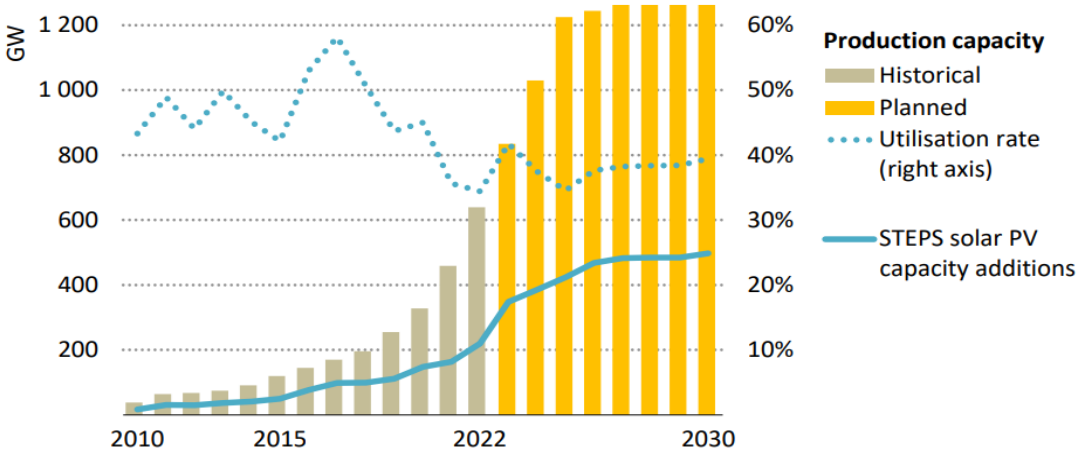


Fig.1 Global solar module manufacturing and solar PV capacity additions in the STEPS, 2010-2030 [8]

Solar energy is the most abundant renewable energy on earth. Every day, the earth's surface receives a sufficient amount of energy to meet the ever-increasing need for electricity for many years, without affecting the environment.[6],[7]

Solar energy is exploited either through photovoltaic systems that transform solar radiation into electric current, or through solar thermal energy that produces electricity in a similar way to coal, gas and nuclear power plants, etc.

The use of solar energy appeared as a necessity of society to produce clean energy, offering numerous technical, environmental, ecological and financial advantages. Among the new solar energy conversion methods, photovoltaic solar cells have become the most popular. They are widely used for various applications, but they face significant limitations such as the land surfaces used for the implementation of solar panels, their fixed orientation, orientation that prevents the capture of sunlight

throughout the day, this being realized only in certain hours of the day when the angle of incidence matches the optimal alignment of the panels.[2]

Thus, the energy efficiency obtained from solar systems is determined by the daily variations of sunlight.

Among the modern solar energy conversion methods, photovoltaic solar cells are the most popular and widely used for a variety of solar energy applications. Although a solar photovoltaic panel has proven to be one of the most efficient sources of green energy, collecting sunlight has become very expensive.

Solar energy, unlike the energy obtained from fossil fuels, is renewable and does not emit harmful emissions that affect the environment and human health, which makes it an attractive choice for reducing carbon emissions and preventing climate change. The electricity production obtained by the photovoltaic panels will be diminished if they are not directed towards the sun.[1]

Photovoltaic systems are often installed as fixed flat systems with predefined angles. This work focuses on building a solar tracking system that can accurately measure sunlight from sunrise to sunset.

The key to the successful implementation of energy policies is the inclusion of people at the center of all transitions to green energy. An increasing number of countries are allocating substantial financial means to support projects based on the transition to clean energy by individuals. Following the studies, it has been shown that Italy has implemented a national recovery and resilience plan in which it has allocated 2.2 billion EURO to support energy communities and self-consumption, which has led to an increase in the amount of green energy produced individually and used or loaded into the national energy system. This produced a decrease in energy production through other classical methods.[5]

The system designed, uses sensors and motors to follow the course of the sun on the sky and to change the location of the solar panels depending on the location of the sun at a certain moment. This allows the maximum possible daytime amount of sunlight to be recorded, resulting in a very high production of electricity.

MATERIALS AND METHODS

The goal of our research was to create a completely autonomous system, with low costs using reusable materials, a system that will store solar energy throughout the day. Thus, we managed to create a solar tracker prototype, independent from the use of electricity, controlled with a mobile phone and capable of producing and storing energy. Wishing to use materials with the lowest possible cost and which do not affect the environment, we decided to create the prototype using parts of various household components, which could be reused.

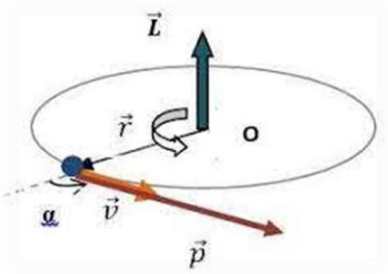


Fig.2 Theory of the moment of force

The principle according to which this project was carried out was based on the theory of the moment of force (fig. 2).[4]

To make the prototype we used a solar panel, two step-by-step motors, a car battery, an Arduino Uno board, sensors and reusable materials. Reused materials for this prototype were a bicycle wheel, concrete mixer crown, elements from a central unit of a computer, parts from an office chair, etc (fig. 3).



Fig.3 Parts from an office chair , Bicycle wheel, Concrete mixer crown, Elements from a central unit of a computer

The solar tracker is moved by two step-by-step motors. These motors made the system move horizontally and vertically, so that the sunrise will fall perpendicular to the solar panel. The two motors were programmed with the help of the Arduino board, which offered the possibility of creating an application and a database.

The application gives the possibility to guide the system or to restart it in case of an error with the help of the mobile, and to create a database that will store information about the amount of energy that is produced.

The chair leg provided stability to the project by becoming its base. The step-by-step motors were mounted on it, which actuated the bicycle wheel and the crown of the concrete mixer, thus realizing the movement of the system horizontally and vertically. For its stability, an iron frame was also created, on which the computer case containing the sensors and control plates was attached. A solar panel was placed at the top of the system, and a battery was installed at its base.

The system is electrically independent, so it can be placed anywhere without being plugged into an electrical outlet. The motors and the data controller will be powered by the energy produced by the solar panel in the form of a closed circuit. The data will be used to estimate whether investments in solar panel systems are profitable and can provide information on the energy produced on a daily, weekly, monthly or yearly basis.

The task of the system is to capture solar rays and produce energy. In order to increase the efficiency of this solar tracker so that it records and produces energy even on sunny or cloudy days, changing the orientation of the panel was considered. Thus, on sunny days, the panel is programmed to follow the position of the sun in the sky so that

its surface collects all its rays, and on cloudy days, a search algorithm was created that controls the orientation of the panel to extract the greatest possible power from the light.

Thus, with the help of a controller that combines an open-loop sun monitoring system with a dynamic feedback controller built on an active search algorithm, it helped to increase the possibility of producing electricity regardless of the weather.



Fig.4 Solar tracker

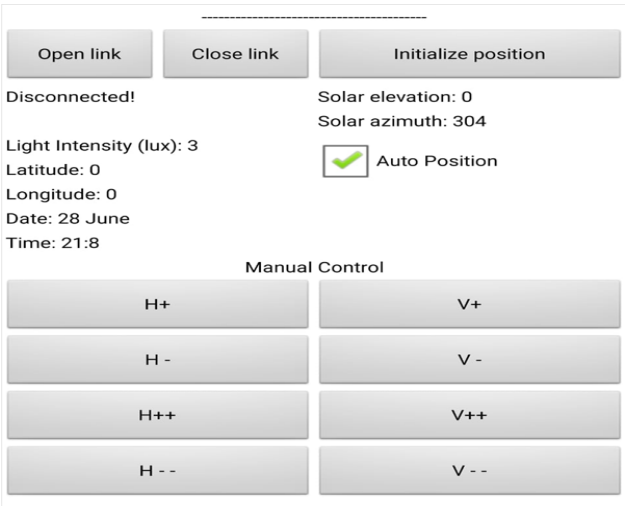


Fig.5 The application that control the system with the phone

RESULT

After the tests, it was found that the system is independent of electricity, so it can be placed anywhere, it does not need to be connected to the outlet. The motors and the data controller will be powered by the energy produced by the solar panel in the form of a closed circuit.

The data will be used to estimate whether investments in solar panel systems are profitable and can provide information on the energy produced on a daily, weekly, monthly or yearly basis. The advantage of the project is that we can control with the mobile phone and all data will be stored automatically without losing any information due to its own power supply.

Following the tests carried out on the prototype, it was established that it produces electricity, it can support itself independently, without the need to connect it to an outlet, and the data recorded by it were exported in the form of a graph that can be seen in figure number 6.



Fig.6 Values recorded in the database

DISCUSSION

Future trends in the electricity sector such as energy transition and climate change require a rethinking of traditional ideas for ensuring electrical security. Many countries have begun to implement policy rules and practices that address unconventional ideas in the energy sectors, offering important options for obtaining electricity.

Thus, our idea to create an independent system for producing and storing electricity represents a way to fulfil the current requirements in the field of electricity.

CONCLUSION

The paper presents the results obtained following the development of a system that follows the sun from sunrise to sunset, which was placed in a certain location to record and store data about the maximum potential of the sun that can be produced. The solar tracker is made of 90% recyclable materials. The prototype was built through two ideas, one to develop a system that can be used by investors who want to build large scale systems and the second was to reuse materials that are easily to obtain from the house surroundings that are usually thrown. As it was seen due to the energy demand and the energy outlook the next years are concentrated to develop more systems that use renewable sources and, in the future, will be more investments in this field.

The system is powered by the energy produced by the solar panel in the form of a closed circuit. The data is used to estimate whether investments in solar panel systems in our area are profitable and can provide information on the energy produced on a

daily, weekly, monthly or yearly basis. The advantage of the project is that we can control it with our mobile phone and all data is stored automatically without losing any information thanks to its own power supply.

Starting from the program interface guided by the phone, it can be adapted through different sort of sensors by recording and storing other types of data, connecting different sensors. Due to its accessibility the system can by changed and can by improved through the investors demands and can by adapted to meteorological phenomenon as hail, wind, snow, frost etc.

REFERENCES

[1] A.A.O., T.Y., I.A.A., M.A.K., H.A., M.A., M. R., An experimental study on hybrid control of a solar tracking system to maximize energy harvesting in Jordan, Solar Energy, Volume 263, October 2023, 111931

[2] U.M., N.T., Dual-axis solar tracking system with different control strategies for improved energy efficiency, Computers and Electrical Engineering, Volume 111, Part A, 2023,108920

[3] S.S.H.D., B.F., Comparison, evaluation and prioritization of solar photovoltaic tracking systems using multi criteria decision making methods, Sustainable Energy Technologies and Assessments, Volume 55,2023,102989

[4] R.B.I., Elemente teoretice de mecanica punctului material și solidului rigid, Universitas, 2022, ISBN 978-973-741-871-5

[5] IEA (2023). Empowering people – the role of local energy communities in clean energy transitions, https://www.iea.org/commentaries/empowering-people-the-role-of-local-energy-communities-in-clean-energy-transitions

[6] IEA. (2017a). Getting Wind and Sun onto the Grid, https://www.iea.org/reports/getting-wind-and-solar-onto-the-grid

[7] IEA (2023). Electricity security matters more than ever, https://www.iea.org/reports/power-systems-in-transition

[8] World Energy Outlook 2023 https://breakthroughenergy.org/our-work/

THE CARBON BORDER ADJUSTMENT MECHANISM (CBAM): A QUALITATIVE LEAP IN ENVIRONMENTAL TAXATION FOR A WORLD IN ECOLOGICAL TRANSITION

PhD Elisabetta Ceroni

University of Camerino, **Italy**

ABSTRACT

The purpose of this paper is to analyse the Carbon Border Adjustment Mechanism (CBAM), as a significant step forward in the testing of good practices in environmental taxation. The main objective of this mechanism is in fact to shift the focus from the mere obtaining of tax revenues towards the achievement of climate objectives.

The European Commission has introduced this tool aware of its leading role in the environmental field, aiming to influence the decisions of third countries in the fight against the global climate emergency.

However, the CBAM raises concerns about its potential use as a tool for European market protectionism, creating tensions with the world's main economic players.

Despite the critical issues, the CBAM proposal could accelerate the convergence of legal systems and foster scientific evidence regarding the relationship between global warming and greenhouse gas emissions, in addressing global environmental challenges.

In a world where global emergencies require global responses, CBAM can therefore become an important tool to prevent the circumvention of law enforcement mechanisms and penalize non-virtuous behavior.

In this context, environmental taxation, now supported in many countries by direct constitutional coverage, can play a strategic role in the implementation of international commitments, promoting an ecological transition with an eye to sustainable development and the effective allocation of resources.

Keywords: Carbon Border Adjustment Mechanism (CBAM); environmental taxation; protectionism; climate change; global emergency; carbon leakage.

INTRODUCTION

As part of the European Green Deal agreements that focus on the challenge we face with the climate and the environment, the European Commission launched a development strategy to gradually transform the European Union into a fairer, more prosperous society characterised by a modern, competitive and resource-efficient economic system.

The carbon adjustment mechanism at the borders established by EU Regulation 2023/956 and issued by the European Parliament and Council on May 10, 2023, is part of the European Green Deal. More specifically, it falls under the "Fit for 55", a comprehensive package of measures that the Commission proposed to orient the European Union towards

a 55% reduction in greenhouse gas emissions by 2030, with an outlook of achieving climate neutrality in all the industries of the economy by 2050 [1].

The European Commission introduced the CBAM aware of its key role in the environmental field, with the aim of influencing third country decisions in combating the global climate emergency [15].

The European Green Deal also aims to protect citizens' health and well-being from environmental risks and their consequences.

This paper explores how CBAM addresses these challenges and how it can impact international dynamics.

The analysis centres around the crucial problem of "carbon leakage" and non-virtuous behavior that could hinder the achievement of global climate goals.

METHOD

Interdisciplinary analysis of CBAM and environmental outlooks.

This paper seeks to critically assess CBAM's potential impact on international trade, taking into account the risk that this tax system will be used as a tool of protectionism for the European market.

It is crucial that the CBAM not decline into a protection measure, but should become a solution for ensuring that all industries, both European and foreign, are on a level playing field with the same rules on environmental criteria.

This involves an interdisciplinary methodological approach [13]. Potential conflicts with the world's major economic players will be taken into consideration, while assessing CBAM's positive effects in fostering convergence between legal systems, also in order to inspire scientific research to delve deeper into the link between global warming and greenhouse gas emissions.

Through a critical analysis, the economic drivers that could lead to the phenomenon of "carbon leakage" will also be examined, evaluating the role of CBAM as an abatement mechanism, together with the practical implications that the obligations required by CBAM will have on the operations of import companies.

Against this backdrop, positive law once again takes on its primary role in harmonising the socioeconomic system's needs for growth and development with an increasingly rigid ecological context, accentuated by more intense industrial development [3].

One can see how the implementation of economic theories developed at a time when legal related to keeping the environment intact did not influence the planet's global balance so significantly today require us to flesh out more suitable solutions to mitigate the potential conflict between growth and development needs on the one hand, and the principles of health and environmental sustainability on the other.

The environmental protection outlook is evolving into an interpretative approach that goes beyond the mere sphere of legal science. It therefore highlights the need to embrace a cross-disciplinary view that involves not only law, but also philosophy, sociology and especially proactive citizens within a constantly changing ecological system.

The bodies of the European Union are clearly working constantly in this direction by always conducting research and fostering solutions meant to safeguard the Earth's resources and especially their reuse.

The ecological transition is therefore a key step towards the desired modernisation of the production system, characterised by a more advanced and mature conception in business and economic planning [14].

In this context, the phrase "the polluter pays" is rising to the fore in contemporary debate. On the basis of that principle, the operator responsible for environmental damage or causing imminent threat of such damage shall be financially liable for costs associated with prevention and restoration activities [17].

Integrating this picture are the principle of prevention and the precautionary principle which hold that the entity that wields control over the polluting sources is called to implement preventive environmental protection measures. This involves taking appropriate action to prevent damage or threats to the environment in accordance with current legal standards.

RESULTS

Benefits and concerns in the balance between competitiveness, environment and global development.

CBAM emerges as a controversial tool with clear benefits, but also considerable concerns. Indeed, on the one hand, the implementation of such a system could accelerate alignment and harmonisation between legal systems, oriented towards achieving the objectives set by the European Union; on the other hand, there are those that fearit could be used as an instrument of protectionism, creating tensions with the main economic players on the world stage.

In fact, CBAM is a mechanism that - although initially conceived as an environmental tool - plays the fundamental role of addressing the challenges of "carbon leakage" and potential non-virtuous behavior [9].

Implemented by applying carbon tariffs to imported products, it acts as a significant deterrent for companies and therefore a counter-incentive for those companies that might be tempted to move production to areas with less stringent environmental regulations.

Against this backdrop, globalisation has facilitated the expansion of international trade activities, resulting in a significant increase in carbon dioxide emissions. Nevertheless, the phenomenon of globalisation could be a major strength in the search for solutions to environmental problems, due to how easily research, studies and knowledge can be disseminated and shared internationally.

However, developing countries may suffer disadvantages from a carbon border tax, as "environmentally friendly" practices are often costly and difficult to implement for developing nations. Thus, the impact of such a tax could have repercussions on the competitive edge of foreign companies, encouraging them to consider the ecological footprint of their production.

The current proposal of the European Union seems to focus mainly on improving competitiveness within, to the detriment of the effectiveness of climate policy and development prospects. It is therefore likely that legislative changes will be needed not only to address the effectiveness of climate policy and compliance with the rules of the World Trade Organization (WTO), but also to consider the impact on European trading partners and, in particular, developing countries [16]. Indeed, it is thought that many developing countries will face additional export costs due to CBAM. The European Union

should therefore carefully evaluate the negative implications for these countries and take action to conceivethe mechanism in such a way that also fosters their development.

To this regard, one proposal is that developing countries be exempt from CBAM and that the European Union should provide them with targeted support, for example by enhancing their ability to implement CBAM and reduce carbon emissions in the industries involved, thus contributing to the decarbonisation of their manufacturing enterprises.

DEBATE

Practical implications of CBAM on international trade.

The CBAM mechanism is designed to operate in parallel with the European Union Emissions Trading Scheme (EU ETS) and aims to ensure that imported goods are subject to a cost for their carbon emissions [5].

Aiming to reduce air pollution, the EU ETS implements the "polluter pays" principle, requiring stakeholders to obtain a permit for every ton of CO^2 emitted. In essence, the new CBAM mechanism can be considered an equivalent system to the EU ETS, but geared towards third-country producers [4].

This mechanism has an impact on important industries, such as cement, fertilisers, iron and steel, hydrogen, aluminium and electricity, creating a European carbon tax on the import of carbon-intensive goods, with the aim of mitigating so-called "ecological dumping", that is, the relocation of production to countries that allow higher greenhouse gas emissions [12].

The instrument seeks to eliminate the disparity in production costs between non-EU companies resulting from the less rigorous commitment of some third countries in combating carbon emissions.

CBAM is often identified as a new environmental customs duty, but from a technical point of view it does not constitute a traditional customs duty. Rather, it represents an ecological tax on import, that is, an autonomous resource of the European Union aimed at preventing polluting production in third world countries that could threaten competitiveness, especially for European companies subject to strict environmental regulations.

The Commission’s introduction of CBAM is legally grounded in Articles 191 and 192.1 TFEU, which require the Union to make a real contribution to the objective of safeguarding, protecting and improving the quality of the environment. Consequently, the CBAM cannot be considered a mere tool to generate tax revenue, having originated with the primary goal of combating climate change and to encourage the achievement of the environmental objectives set by the European Union [11]. Indeed, this mechanism strives to influence companies’ and countries’ behaviour to reduce greenhouse gas emissions. Its implementation has been designed to foster the adoption of sustainable business practices.

CBAM is part of a broader framework of initiatives to promote ecological transition, as a key tool to encourage virtuous behaviour and align trade policies with environmental objectives.

As mentioned above, the risks of protectionism associated with CBA are significant. While it is designed to protect the environment and promote climate goals, CBAM could be twisted, generating trade tensions and widening global divisions. If implemented without adequate international coordination, it could favour domestic producers at the

expense of outsiders, creating trade discrimination and disrupting the important global supply chains that still exist today, especially in carbon-intensive industries.

Producers in countries that do not adopt strict environmental policies could suffer an increase in the cost of export to the European Union, and therefore this could lead to a reduction in the competitiveness of these countries' products on the European market. The dynamics of international trade are complex and quite often characterised by geopolitical crises.

The introduction of the CBAM mechanism has imposed specific mandatory declarations, responsibilities and obligations on import companies in terms of product traceability and production methods [7].

As a collateral effect, CBAM has also led to a change in leading companies' internationalisation strategies and in the determination of their corporate compliance.

Today's new challenge for import companies is to evaluate suppliers not only on the basis of price and product quality, but also in relation to the mode and process of production.

There is talk of due diligence of the product, as the CBAM requires the importer to carry out a series of inspections and audits in order to provide the competent authorities with the necessary information and certifications relating to the customs classification of the product.

Customs compliance becomes crucial, requiring verification of whether the identification code provided by the foreign company meets European criteria [8].

In light of the above, there is a clear paradigm shift, with the focus shifted from assessing product quality to thoroughly examining the production process and the environmental impact of the product itself.

The introduction of CBAM therefore makes it imperative to track the production chain in detail and requires a scrupulous selection of suppliers.

In addition to assessing product quality, timing and delivery costs, it is therefore essential to consider the production process and pay particular attention to the direct emissions generated during the production of goods subject to CBAM, and indirect emissions related to the use of electricity in the manufacture of such products.

In this context, it becomes essential to monitor and counter any attempts to circumvent the provisions of the regulation, including the risk that economic operators make minor changes to their goods without changing their essential characteristics, or artificially fragment shipments in order to circumvent the obligations laid down therein [1].

It is equally essential to monitor situations where goods could be sent to a country before being imported into the European Union market, so-called triangulation, to try to evade the responsibilities foreseen.

The implementation of CBAM therefore raises a number of questions and reflections on the exponential complexity in terms of implementing the legislation that is destined to increase. Today we are talking about steel products, therefore made of 100% steel, which could be considered "simple" to be classified. However, in the future the problem will arise when the legislation will come to encompass products only partly composed of steel. In this specific case, the manufacturer of the goods made of multiple materials will undoubtedly have a harder time complying with the obligations and obligations of CBAM's mandatory declarations.

The European Commission is in fact considering extending the new provisions to other goods liable to carbon leakage and specifically, to those undergoing complex

manufacturing processes, using different raw materials, such as steel or plastic parts, or finished goods such as cars, machines, electronic devices and toys.

A further problem arises from the standpoint of the effectiveness of the measure. We will have to understand whether the values entered will be such as to equalise European costs to those of third-party importers, because if the costs are higher it would entail blocking the market [6]. On the contrary, if costs are low it would mean having a complex and ineffective tool. The real concrete risk could be that of a reduction in steel and aluminum importation and, therefore, a penalisation of the entire manufacturing sector.

CONCLUSIONS

This paper aims to promote a debate on the role and impact of the Carbon Border Adjustment Mechanism as a fiscal tool designed to address climate and environmental challenges related to international trade.

Its introduction as part of the European Green Deal highlights the commitment of the European Commission in pursuing global climate goals and influencing the decisions of third world countries.

It has also sought to explore its economic and environmental implications in order to investigate the effects of this mechanism and the formulation of coherent strategies and policies in the context of the transition to a more sustainable and low-carbon economy. However, a number of concerns have emerged, in particular regarding the potential misuse of CBAM as a tool for protectionism, and potential trade tensions with the world's main economic players [2].

The need to guarantee environmental protection and integrity, considered to be core values of the European Union's action in the pursuit of fundamental principles - which are also reflected in the Italian Constitution - requires a continuous commitment to the creation and implementation of policies and instruments aimed at environmental sustainability and compliance with global environmental standards.

Despite its problems, as the implementation of CBAM raises crucial issues, including environmental protection, prevention of "carbon leakage" and support to developing countries, such a mechanism could accelerate the alignment of legal systems and promote ecological transition, ensuring a level playing field for European and foreign industries in terms of environmental criteria.

In addition, we in a context of global emergencies requiring joint responses, it is only through a joint commitment between all States that climate objectives can be fully achieved.

CBAM can therefore become a key tool in promoting ecological transition and ensuring effective resource allocation in the interest of the planet. However, the challenge remains intricate, requiring continued commitment and effective global governance [10].

Finally, it should be noted that the complexity of the practical implementation of CBAM, as far as obligations and their fulfilment for companies - already emerging in the current experimental period in effect since October 1, 2023 - requires continuous assessment and adaptation of regulations, with particular attention to the practical challenges and dynamics of international trade.

REFERENCES

[1] J. BACCHUS, *Legal Issues with the European Carbon Border Adjustment Mechanism*, CATO Briefing Paper, 2021), 125, pp. 1-7.

[2] F. BENINTENDE, F.J. ARANDA SERNA, *Effects of the European Green Deal within custom borders. Consequences of CBAM*, Revista de Direito Brasileira, Florianopolis, SC, v. 33, n. 12, Set/Dez. 2022, pp. 117-130.

[3] CATERINI E., *Sostenibilità e ordinamento civile*, Napoli, Edizioni Scientifiche Italiane, 2018.

[4] CORTE DEI CONTI EUROPEA, Relazione speciale. *Il principio "chi inquina paga" non è uniformemente applicato nelle diverse politiche e misure dell'UE*, 2021.

[5] P. DÈ CAPITANI DI VIMERCATE, *L'Emissions Trading Scheme: aspetti contabili e fiscali*, in Dir. Prat. Trib., 2010, 15 ss.

[6] EICKE L., WEKO S., APERGI M. - MARIAN A., *Pulling up the carbon ladder? Decarbonization, dependence, and third-country risks from the European carbon border adjustment mechanism*, in Energy Research & Social Science, Vol. 80, 2021.

[7] EUROPEAN COMMISSION, July 14, 2021, *Carbon Border Adjustment Mechanism: Questions and Answers*, https://ec.europa.eu/commission/presscorner/detail /en/ qanda_21_3661

[8] L. LOBARDI, *Manuale di tecnica doganale e commercio estero*, Bruxelles, 2002, pagg. 12 ss.

[9] On the important role that setting a price on carbon plays in the fight against climate change A. MAJOCCHI, *Carbon Pricing. La nuova fiscalità europea e i cambiamenti climatici*, Bologna, Il Mulino, 2020.

[10] C.A. MAURO, *Transizione ecologica e modelli dell'economia*, Rivista di diritto amministrativo, fasc. n. 1/2023 pp. 290-306.

[11] M. MEHLING, H. VAN ASSELT, K. DAS, S. DROEGE, C. VERKUIJL, *Designing border carbon adjustments for enhanced climate action*, in American Journal of International Law, 113, 3, 2019, p. 433 ss.

[12] EUROPEAN PARLIAMENT, 2022, Bruxelles, *Meccanismo di adeguamento del carbonio alle frontiere,* https://www.europarl.europa.eu/doceo/document/TA-9-2022-0248_IT.html.

[13] P. PERLINGIERI, *Il diritto civile nella legalità costituzionale secondo il sistema italo-europeo delle fonti*, IV, Attività e responsabilità, Napoli, 2020.

[14] G. PETRILLO, *Next Generation UE e nuovo sistema di risorse proprie: un passaggio decisivo verso la costituzione di un muovo modello fiscale europeo?*, in Riv. Dir. Trib. Online, 7 dicembre 2021.

[15] REGOLAMENTO (UE) 2021/1119 of Parlamento europeo e del Consiglio, del 30 giugno 2021, establishing the framework for achieving climate neutrality and amending the regulation (CE) n. 401/2009 and the regolation (UE) 2018/1999, G.U. L 243 of 9.7.2021, p. 1.

[16] V. RUBINO, *Sviluppo sostenibile ed effettività*, n. 34, 16/12/2020; p. 229.

[17] U. SALANITRO, *Il principio "chi inquina paga": "responsibility" e "liability"*, in Giornale di diritto amministrativo, n. 1, 2020, p. 33 ss.

THE ENERGY TRANSITION PATHWAY FOR ALASKA

Assoc. Prof. Art Nash

University of Alaska, Fairbanks, **USA**

ABSTRACT

As the only arctic state in America, Alaska is the least dense in population, while consuming more energy (per capita) than any other state. A quarter of that energy presently is provided for by renewable resources, despite a long standing goal out of the legislature to provide half of the state's domestic energy through renewable energy resources by 2025. Of the non-renewable energy produced in the state, natural gas provides half the energy, primarily for the largest urban area. Most of the state's crude petroleum production has been shipped outside the state for refining on America's West Coast, while most domestic coal is low in energy content. Yet several types of capital need to be addressed to shift from non-renewable to renewable energy sources.

Keywords: energy transition, renewable energy, Alaska

INTRODUCTION

Alaska has a wide variety of needs when it comes to energy. Though there are only three quarters of a million residents according to the 2020 U.S. Census, geography truly drives a relatively large amount of energy consumption. Alaska has a fifth of the area of the rest of the contiguous 48 states, Ranging from 55 to
71 degrees in latitude, Alaska's boundaries range from temporal rainforest to frigid arctic climes. The land mass covering such an expanse means that there is a large difference in temperature degree days between the north and south regions, as well as vast distances between communities. Thus it isn't surprising that the majority of the state's energy usage is primarily dedicated to transportation year round, space heating in winter and particularly the fishing and tourism industries in the summer. Transitioning to renewable energy resources (and the selection of which technologies get utilized) will be influenced by seasonality.

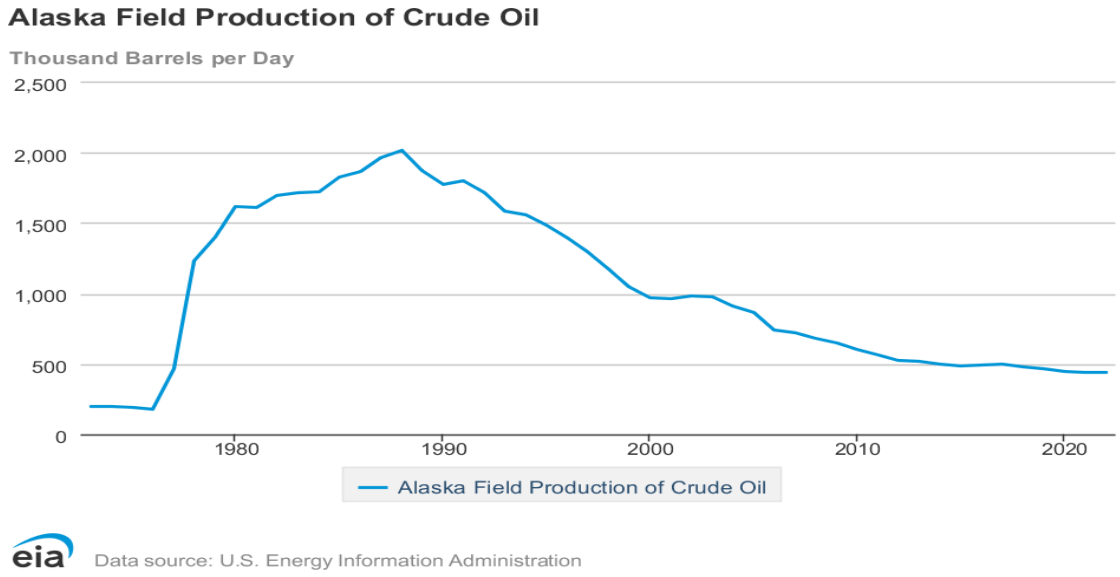
DISCUSSION

With many of the communities being remote, transitioning from non-renewables to locally generated renewables contributes to an advantageous change[2] given the high petrol commodity prices which have neared $100/barrel in the early 2020's (as well as the gradual reductions over the past four decades in production of Alaska's petrol). One of the catalysts for change will most certainly be the decline in cheap and accessible natural gas supplied to the state's urban center where almost half of Alaskans live. While abundant natural gas supplies over the last half century

have allowed Anchorage to have some of the lowest electrical rates in the nation, the tribally owned Fire Island wind project has been a pioneering project as easy to access reserves are about played out.

A number of efforts over the years have been made to bring the stranded natural gas on the North Slope to market in Anchorage as well as to prep it for foreign export as liquid atural gas, but such a project would mean looking at a pipeline or trucking project which would have a large private, but also public investment required. As it is, the majority of the state budget is dependent on the fossil fuel industries, which means as the fluctuations take place in the fossil fuel commodity markets, Alaska's state financial health can be drastically effected. There is no state income tax, few municipal taxes beyond property levies, and residents in fact receive annual dividend check from state permanent fund investments of revenues from petrol extraction.

Table 1:



These challenges, along with a sparse population among which to spread energy production and distribution costs, means that often there is a strategy to use the fuel in closest prximities to communities, even if it is high in carbon or low energy density. Bringing in fuels from Seattle or Anchorage can be quite costly, but setting up the infrastructure needed proves difficult and costly as many in those communities have no road access. Thus, sea barges or airlift flights in some villages might be the only way to get installation equipment in to set up renewable energy generation items (such as cranes, earth movers, modular foundations, etc.). And then delivery of generators and turbines that are essential can run into formidable weather and a short barge traveling season, which complicate getting parts into these enclaves- especially after coastlines are filled with ice for the entire winter.

Such geographic challenges not only make it difficult at times to access planning expertise and drive up the cost of studies to evaluate technology appropriateness, but also can make for costly operations when it comes to parts and maintenance. The

physical lay of the land and local environment can determine not only very different comparative advantages between certain technologies and types of energy generation,but also the realized efficiencies that will be obtainable.

It should be mentioned that as technologies have changed, so have the renewable resources which Alaska has utilized locally and for export. Whereas this last half century petrol oil has dominated the state's extraction industry and energy production for domestic use and export revenues, the century prior a renewable biofuel was center stage. Whales harvested for rendered blubber oil supplied energy for lighting; eventually electrical power filled this niche. In addition, much of Alaska's transportation energy needs a hundred years ago were taken care of by renewable biomass as the interior state areas around the large river systems were cut bare of trees so that the cordwood could be used in the steamships and barges that ran throughout the Interior of the state out to the oceans until desiel became the fuel of choice for ships[1]. During the mid twentieth century, Alaska's only nuclear device was located in the Interior where temperatures would drop as low as -50F below. This nuclear device, used for space heating and electricity was similar to those used in nuclear submarines of the time, and after a decade it was decommissioned. While providing renewable energy, the fuel source was encapsulated/buried and left in place with continued concern by locals of radioactive contamination in the local environment.

Trees were used not only for major transportation ventures but also in most of the homes for space heating. Eventually with the evolution of ship engines, the riverboats used petrol as the energy density of fuel oil was much more dense than wood. In Southeast Alaska during the twentieth century, industry and home energy was largely provided by cheap electricity from renewable, hydro electricity due to the temperate rainforest climate and massive amounts of annual precipitation. As the 20th century came to an end, the dams were aging out and a historical reliance on electrical heating required more diesel generators to be added to supply needed energy. It should be mentioned that in the second decade of the twenty-first century climate patterns are seemingly changing so as to bring more sun and less precipitation to Southeast Alaska.

Changes in climate are more extreme in the arctic; the farther north, the more average degrees increase in annual temperatures. Ironically, it affects fossil fuel extraction. Thus climate variations that are being experienced in the twenty-first century have implications on what type of renewables will be viable in various locations- as well as what viability there is to continue non-renewable energy extraction.

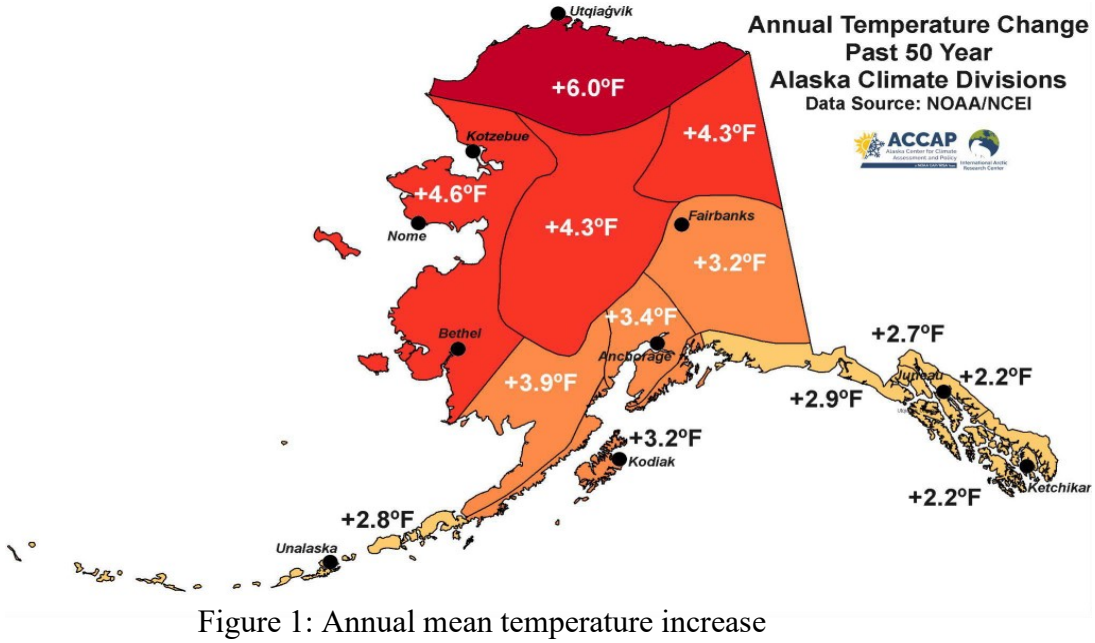
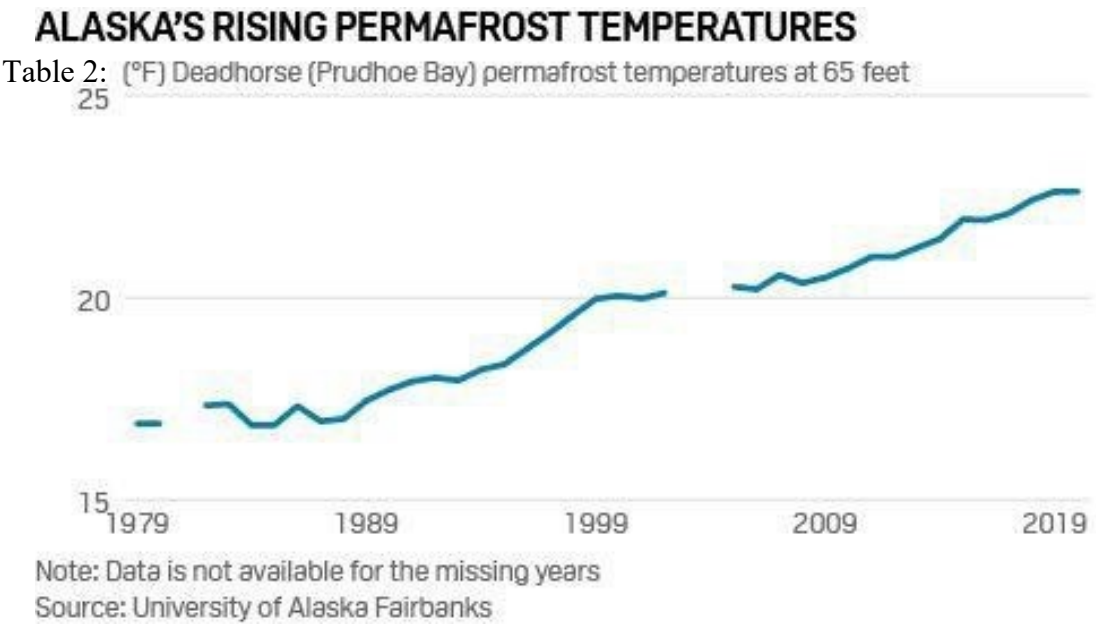


Figure 1: Annual mean temperature increase

As seen above, the most extreme mean increases of 6 degrees occur up on Alaska's North Slope where the Prudhoe Bay oil fields are near Deadhorse, Alaska. The changes in permafrost (soils that are frozen for more than 24 consecutive months) are a concern for the petroleum drillers due to soil instability in the drilling process. Thus the changes in Alaska's cryosphere from warming may create difficulties in future oilextraction.

Table 2:



Once the oil is brought out of the ground, it enters an eight hundred mile pipeline to deliver the commodity to what has up to this point been the most northern ice-free port in North America. With the warming of permafrost along the route from the North Slope to Prince William Sound, scientists have observed slumping slopes and

migrating frozen debris lobes, which will continue to be hazards for transporting oil.

If the current trajectory of climate changes continue as they have been proceeding in Alaska, one of the major concerns will be degradation of infrastructure along coasts and river banks. Erosion from warmer ocean water melting permafrost shores and migration of soils from rising sea and river levels are a concern for those enclave communities, many of which were originally settled very near to river banks or coasts. As citizens they are encouraged to switch over to renewable energy technologies, the very real need for stable soils to provide stout foundations for wind turbines or solar arrays may become more crucial.

Thus with the keen differences between Alaska and other states in geography and logistical challenges, the transitions to renewables may take longer than in the lower 48 states. Oil will for some time, most likely, be the fuel for long distance transportation (though there have been exploatory projects highlighted to use hydrogen rather than petrol in long distance ship runs). The remote, enclave nature of many communities will make it difficult to justify the construction of power line interties[3] because of not being cost effective. In many locations of the state the intricate hodgepodge of land parcel ownership between federal, state, tribal and private holders can make larger renewable energy projects difficult due to right of ways and easement permissions. The short summers and construction season are also a hindrance to completion of large construction projects. The lack of economies of scale and industry clusters to provide support and expertise around large energy projects leads to few advantages.

Yet while these logistical challenges often deal with financial, infrastructural, and natural resource allocation capitals/assets, there are a few capitals on the social side that can limit the effectiveness on renewable projects[5]. Neal Flora, retired sociologist from the University of Iowa, has mapped out seven capitals that need to beconsidered when moving a project forward to better community usage of clean, affordable energy.



In some communities there may be flexibility in ‘increasing’ the socially related

capitals (political, social, human and cultural) needed to have stakeholders be well heard, community cohesiveness and the labor skills to transition to renewable energy usage. In other communities, however, there may be as great difficulty in 'moving the needle' to installing a hydro dam/penstock, wind turbine or large array of solar panels let alone to continue their operation and maintenance due to a deficit in the social assets (and inability to flex them). Zoning committee decisions, political considerations among utility board members, social lobbying from non-renewable energy constituents and a lack in human workforce skills around renewables have stymied contracts, installations, and efficient use of new energy systems in some Alaskan communities.

From the cultural capitals aspect, for the last half century Alaska has been able to grow primarily due to fossil fuel extraction- whether for domestic use such as Cook Inlet natural gas, or for a few amount of years around the turn of the 21st century when petroleum from the Alaska Pipeline was exported to Asia. That impact has figured strongly in the common culture of Alaska, whether it be from 'imported' residents who came to Alaska due to their expertise in the oil industry, related support firms or from indigenous residents whose tribal corporations and members have been integrated into petroleum service enterprises running from security to engineering.

Yet for several historical reasons going back to the Arab Oil crisis five decades ago, federal legislators, NGO's, non-profits and multi-national corporations are very invested and applying leverage on Alaskan arctic fossil fuel reserves; particularly when it comes to the Alaska National Wildlife Refuge which is located on the North Slope of the State. It is not an understatement to note that the whole nation periodically has had constituents eyeing this portion of Alaska with diametrically opposed efforts over the last several decades to either develop it for U.S. energy security or leave it pristine without any development. In some regards, the tundra laden allotment of just over 19 million acres has been a national hotspot of concern for many interest groups throughoutthe U.S.

CONCLUSION

Alaska has abundance wind, tidal, river, and even solar resources for its domestic energy needs. The goal of contributing half of the state's energy use with renewables by 2025[4] isn't realistic when currently the share of renewables is about a quarter of the state's energy stock. However, with several decades of declines in North Slope oil production and easily accessible natural gas stocks near Anchorage, there is an opening in interest as well as investment opportunities to line up renewable projects.

In the first couple months of 2024, several pieces of legislation are slated to be introduced when the Alaska citizen legislature convenes. Bill(s) proposing incentives for neighbors forming co-ops for small-scale renewable energy projects will be proposed, which may be in the form of solar, wind or hydroelectric projects. A renewable portfolio standard set for utilities with the goal of getting to four fifths

of Alaska's energy coming from renewable sources by 2040 is in the works. And another senate bill has been drafted to establish a green bank that could provide loads to individuals or utilities for renewable power generation. What these bills will look like in terms of incentives vs. regulatory compliance through state government remains to be seen at the end of the legislative session (which normally lastsfour months, providing there are no special sessions called).

Time will tell, and guaranteed efforts that drive the transition to greater renewable energy contributions will not be simply from the innate motivations of individual state residents. It will require a holistic gathering of all sorts of assets in order to create the community development needed!

REFERENCES

[1] Brewer, J.P., Vandever, S. and Johnson, J.T. "Towards Energy Sovereignty: Biomass as Sustainability in Interior Alaska", Sustainability Science 11(1) :pp. 25-26, 2017.

[2] Koss, G. E&E News. Accessible at: https://www.eenews.net/articles/cash-strapped-alaska-looks-to-senate-energy-bill-for-help, September 13, 2016.

[3] McCallum, C. S., Kumar, N., Curry, R., McBride, K., & Doran, J. Renewable electricity generation for off grid remote communities; Life Cycle Assessment Study in Alaska, USA. Applied Energy, 2021.

[4] United States Energy Information Administration- quick facts for Alaska. Accessible at: https://www.eia.gov/state/?sid=AK#:~:text=The%20state%20has%20a%20non,alternative%20energy%20sources%20by%202025,

[5] University of Nebraska-Lincoln, "Community Capitals Framework as a Measurement of Community Development". Accessible at https://agecon.unl.edu/cornhusker-economics/2015/community-capitals-framework

THE HYDROGEN CONCENTRATION ON NETWORKS FOR GAS SUPPLY

Assoc. Prof. Dr. Martin Boyadjiev

University of Mining and Geology, **Bulgaria**

ABSTRACT

Restrictions on the planet's carbon footprint are becoming a motivating measure to limit the use of fossil fuels in the European Union. One of the measures to decarbonize the economy is to reduce the use of hydrocarbon fuels (oil, gas, coal). Increasing the potential for hydrogen use in energy is a key point in the conversion of fuels into energy.

How the concentration of hydrogen is reflected in the gas supply is an analysis that the energy sector must consider to determine the safe operation and quality of operation of the appliances. Increasing the concentration of hydrogen in gas mixtures by up to 5% does not change the key parameters that determine the interchangeability of used gases in the gas industry. At hydrogen concentrations above 15 % in the gas mixtures, the gas-dynamic properties of the gas also change, which also affects the design parameters of the gas supply systems.

The article has described the possibilities for transport of the hydrogen in gas networks mixed with natural gas. Options for hydrogen production using alternative energies to meet the Green Deal criteria are described. The specifics of the transport and distributed gas pipelines in Bulgaria have been examined. According to their technical parameters, with the aim of high safety, a scheme of mixing hydrogen with natural gas is proposed. Based on the materials of the pipelines and the technical means of management and maintenance, the permissible concentrations of hydrogen are given. To achieve the possibility of a simplified assessment of the influence of hydrogen.

Keywords: hydrogen, natural gas, networks, gas supply

INTRODUCTION

The reduction of the carbon footprint on the planet becomes a motivating measure to limit the use of fossil fuels (oil, gas, coal) in the European Union. One of the measures to decarbonize the economy is to reduce the use of hydrocarbon fuels at the expense of the simplest chemical element - hydrogen. The increase in the possibilities of using hydrogen is considered to be a key moment in the conversion of fuels in the energy sector. This "weight" of his, despite being the lightest chemical element, is fueled more by environmental and geostrategic motives. It is expected that its role will strengthen after 2035, and the intervention according to European strategies will be at the expense of natural gas. At the same time, the main source for the production of hydrogen (due to better economic conditions) is precisely natural gas. High hopes are placed on systems known as fuel (hydrogen) cells that produce electricity and heat from hydrogen.

The main changes are expected to be in the direction of changing the fuel base in the energy and transport sectors. The task is to limit fossil fuels at the expense of an

increasing share of hydrogen (green and blue), obtained during electrolysis or reforming, respectively, from water or natural gas. The expectations of the European community by 2040 that the reduction of greenhouse gases will be 5 Gt compared to the current situation. In the process of replacing non-renewable fossil fuels with hydrogen produced by the two main technologies, at least three problems are identified. One is related to obtaining significant enough quantities of this gas, and the others are related to its transmission, distribution and use by consumers. The present report deals with the last two questions and problems related to them.

OPPORTUNITIES FOR USING HYDROGEN IN GAS SUPPLY SYSTEMS

European politicians are increasingly recognizing the important role that hydrogen will play in existing gas networks to achieve decarbonisation targets with minimal disruption to consumers. Existing gas infrastructure is a vital asset for energy supply and security of supply, capable of long-term and reliable energy storage. Blending hydrogen with natural gas in existing gas supply systems is the possible advantage for companies in the gas sector. Some insight into the market can be obtained by studying the theory of disequilibrium, as a balanced center of gravity presented by [1]. Technologically, in the supply chain from the production of hydrogen to its burning at the consumers, three technical-technological tasks are distinguished, corresponding to the chain of production and supply of customers.

The first problem is related to transport, where the sub-problems are divided into the linear (pipeline) part, gas storages and compressor stations. In the transmission network, research is in the direction of: development of standards based on ASME B 31.12 to prepare specifications of allowable equipment, technical means for high pressure hydrogen injection in transportation systems, research and investigation of membrane technologies to protect the steel pipelines of high concentration of hydrogen in the transfer. In terms of storage, a promising direction is the possibility of capturing carbon dioxide from thermal power plants and, in combination with hydrogen, to obtain methane, which can be traditionally stored and used in gas transportation systems. At the compressor stations, the research is of interest to establish the effect of an increased concentration of hydrogen during the operation of the gas turbine units. In gas distribution, the analysis of the intensity of hydrogen diffusion processes in pipes is fundamentally important for establishing the criteria for limiting the amount of hydrogen used in urban networks. A separate type of research is devoted to its influence on gas facilities. In the use of gas-hydrogen mixtures (H2NG) by consumers, the efforts of the scientific community are aimed at establishing the influence of the mixture on the combustion process in order to preserve the design power of the gas appliances and the quality of the combustion process. The possibility of using hydrogen in transport also belongs to this segment of research. The models adopted there are based on internal combustion engines using hydrogen as fuel or on the basis of hydrogen cells to obtain electricity for electric cars and heavier vehicles. The technology for obtaining hydrogen-oxygen mixtures in our country at the beginning of the new millennium, known as "Brownian gas" after the name of its developer, became famous, is a third form, but it is not based on scientific-theoretical popularity and currently does not find distribution and applicability. Hydrogen injection in gas supply systems Hydrogen is a gas that differs greatly in its physico-chemical characteristics from natural gas and other

biogases that are compatible in the gas network. Its pure use, in concentrations above 90%, can impair the mechanical properties of steel pipelines, gas storage facilities and customer installations. It can certainly be argued that pure hydrogen is not compatible with existing grids. Nevertheless, hydrogen may be transferred to gas networks if it is in quantities at the network entry point mixed with natural gas that do not adversely affect the interoperability of the gas supply network. This stems from the interpretation of articles under Directive (EU) 2018/2001 of the European Parliament of the Council of December 11, 2018 to promote the use of energy from renewable sources. These possibilities are yet to be detailed in standards and working documents of network operators, so that other gases can also be fed into the network as "additional gas" to natural gas ("main gas") in existing gas supply networks. In addition, the supplemental gas must be injected in a manner that meets the requirements of the public natural gas supplier at the point of entry. This means that hydrogen can be supplied as far as permitted and as far as possible to guarantee the safety and interoperability of the input network in question, of any transmission network along the chain, as well as of the storage facilities connected to the affected sections of it. On the other hand, the network operator is not required to increase the hydrogen resistance of the existing network. In this case, the minimum availability and minimum injection capacity rules do not apply. Measures requiring the network operator to take actions to increase the capacity of its network are also not applied. This means that while there may be sufficient capacity for the gas in the system, the gas that is injected into the system may not necessarily be compatible with that system.

GAS DISTRIBUTION SYSTES

The transportation system includes components such as pipelines, gas turbines, compressors, compressor stations, etc. Their characteristics mainly depend on the material from which they are made, and for pipes it is steel. When tested in hydrogen mixed gases, they show the ability to work with up to 30% hydrogen-natural gas (H2G) mixture, while any increase in these amounts above these levels or levels of 50% lead to critical corrosion activity towards the system components (Ekhtiari et al., 2022).

Turbines and compressor stations operate with a 10-20% H2G mix. However, manufacturers recommend lower hydrogen concentrations on the order of 1 to 5%, at most 5% to 7%(Ekhtiari et al., 2022). Major turbine manufacturers such as General Electric recommend H2G up to 5%, while Siemens mandates 15% and Mitsubishi Hitachi Powers report the highly efficient operation of their turbines up to 30% (“How pink hydrogen could add to the nuclear renaissance,” n.d.).

In compressor systems, up to 20% concentration of hydrogen in the composition of natural gas does not negatively affect the system, but requires a degree of suitability in terms of the materials used and the ability of hydrogen to migrate. Therefore, lower concentrations in the order of 7-10% are recommended [4].

In general, the transport system in which mixtures between injected hydrogen and natural gas will be used requires material replacement and the use of alloyed and nitrided steels for the resistance of the material when working with the hydrogen-containing mixture [3].

An important factor is the calorific value of the mixture, as that of hydrogen-natural gas is lower than that of natural gas. This parameter leads to the need for adjustments,

regarding the appliances at the end customers. (Melaina, M., Antonia, O., Penev, M., 2013.).
It was found that above 20% H2G the density changes significantly. The lower density affects the flow rate by increasing it and with it the pressure. The delivery of larger quantities is necessary to satisfy the required flow rates of consumers, which is directly related to the ability of pipes and appliances to withstand the new pressures [2].

RESULTS

The requirement for the use of 32% renewable energy specified in the Directive on energy from renewable sources and the requirement for an annual increase in the share of renewable energy sources in heating and cooling compared to what was achieved in 2020. with 1.3%, puts the issue of using hydrogen in an important position for their implementation. There are many technical, legislative and other barriers to overcome for this implementation. An example of this can, as usual, be taken from Germany. What has been achieved there shows that some of the pan-European barriers can be overcome more quickly at the national level, before waiting for the Directives from the EU. Gaps and inconsistencies at the regulatory level relate to: - The lack of a single definition of renewable gases of non-biological origin – the only existing definition applies only to fuels from the transport sector. To overcome this barrier, Germany includes hydrogen produced by electrolysis of water with BE in the definition of biogas (Energy Industry Act). - Having a single guarantee of origin system for renewable gases of non-biological origin would encourage end-users to buy renewable hydrogen. In this regard, Ordinance No. RD-16-1117 of October 14, 2011 is a good basis that can be applied in similar future situations. - Adoption of standards for permissible concentration of hydrogen in the gas mixture. Based on the current research and future projects in this direction, the definitions of gas quality can be developed at the national level to be admitted, including norms for the concentration of hydrogen in gas mixtures.

INFLUENCE ON THE OPERATION OF GAS APPLIANCES

In order to ensure the safety and determine the performance of a system with increasing hydrogen concentration, an effort is needed to develop regulatory studies and limitations. In the University of Mining and Geology, together with the gas sector, a number of studies have been launched in this context. These projects aim to develop and publish detailed research on the impact of natural gas and hydrogen blends on end-use applications, particularly in the residential and commercial sectors. Our task is to explore the possibility of the widespread adoption of H2CH4 (hydrogen in natural gas) mixtures and their impact on domestic and commercial gas appliances. According to the European standard EN 16726: 2015, Gas infrastructure. Quality of gas. Group H "it is not possible to set a limit value for hydrogen valid for all parts of the European gas infrastructure, therefore a case-by-case analysis is recommended". Eligibility thresholds vary for the UK from 0.1% to 6 and 10% in France and Germany respectively. For the current levels of hydrogen in mixtures of hydrogen with natural gas, no additional safety requirements are indicated. For increased hydrogen concentrations, the prospect is to increase the requirements for monitoring, sensors and safety rules in installations. Additional restrictions arise related to national regulations or areas of application. For example, the calorific value of the gas after injection changes. In Germany, there is a

formal agreement for the monitoring and billing of H2NG mixtures where the calorific value can be determined with gas quality measuring devices (gas chromatographs are currently used). The EU Gas Appliances Directive 90/396/EEC and the derivative Gas Appliances Regulations ((EU)2016/426), which cover all Member States, already set out (in a general format) the requirement to demonstrate the safety of any gas appliance that will be sold in the EU. The gas appliance regulations apply equally to all gaseous fuels that will be used in a gas appliance – hydrogen, biogas, natural gas, propane and/or butane. The conducted research showed that, for the time being, the operation of gas appliances with the used mixtures of hydrogen and natural gas up to 20% by volume of hydrogen is possible without adapting the devices.

Table 1. Effect of hydrogen concentration % H2 d, kg/m3 Hlcv kWh Hgcv kWh Wlcv MJm3 Wgcv MJ/m3

% H2	d, kg/m3	Hlcv kWh	Hgcv kWh	Wlcv MJm3	Wgcv MJ/m3
0	0,67	9,156	10,165	43,73	48,546
5	0,641	8,69	9,65	42,547	47,235
10	0,608	8,22	9,13	41,333	45,89
15	0,575	7,75	8,61	40,08	44,5
20	0,542	7,29	8,09	38,793	41,59
25	0,51	6,82	7,57	37,46	41,59
50	0,345	4,48	4,979	29,93	33,23

The table presents the results of a study of hydrogen concentration in a methane mixture. The step is through 5 percent, and the variations studied are from 0 to 50 percent hydrogen content in the methane mixture. Indicators such as: density, d (kg/m3), upper and lower limit of heat of combustion, H (kWh) and lower and upper value of Wobbe number, W (MG/m3) were evaluated. The calculations made are based on the methodology and requirements of the BDS ISO 6976 standard, and software used for these purposes by the Natural Gas Association.

CONCLUSION

Gas distribution and supply networks made of high-density polyethylene do not show activity about the concentration of hydrogen in the H2G mix and there is no major corrosion hazard. Rather, in networks, the risk is of diffusion, migration, and leakage of gas into the atmosphere (Gondal, 2019; Gondal et al., 2018). Therefore, the implementation of systems to detect hydrogen leakage and create explosive conditions is of great importance, and it is necessary.
Table 2 shows the effect of hydrogen on the various elements of the system at different percentages of hydrogen in the systems.

ACKNOWLEDGEMENTS

The author expresses his sincere gratitude to the gas companies from the "Natural Gas" Association, who accepted the topic of decarbonization and environmental protection as their mission and, in this sense, provided full support and sympathy for the conducted research and analysis. We gratefully accept proposals for follow-up activities and results, believing that real results in scientific activity can only be obtained if they are related to applied projects that benefit society as a whole.

REFERENCES

[1] Juli Radev, Empirical analysis of the demand for natural gas by households in Europe, Journal of Economic Studies, p.154-183, 2012.

[2] Gondal, I.A., Masood, S.A., Khan, R., 2018. Green hydrogen production potential for developing a hydrogen economy in Pakistan. International Journal of Hydrogen Energy 43, 6011–6039.

[3] Georgiev, L., Lakov, N., 2011. Analysis of opportunities for production of electrical energy from different energy sources. Presented at the IX ScPrS, FNTS, Sofia, Bulgaria, pp. 135–141.

[4] The European Green Deal, 2019.

[5] Radev July, Model of the demand for natural gas by households in Europe, magazine Economic alternatives, 2011, No. 1, pp. 58-81.

[6] European Hydrogen Safety Panel [WWW Document], n.d. URL https://www.clean-hydrogen.europa.eu/get-involved/european-hydrogen-safety-panel-0_en (accessed 4.22.23).