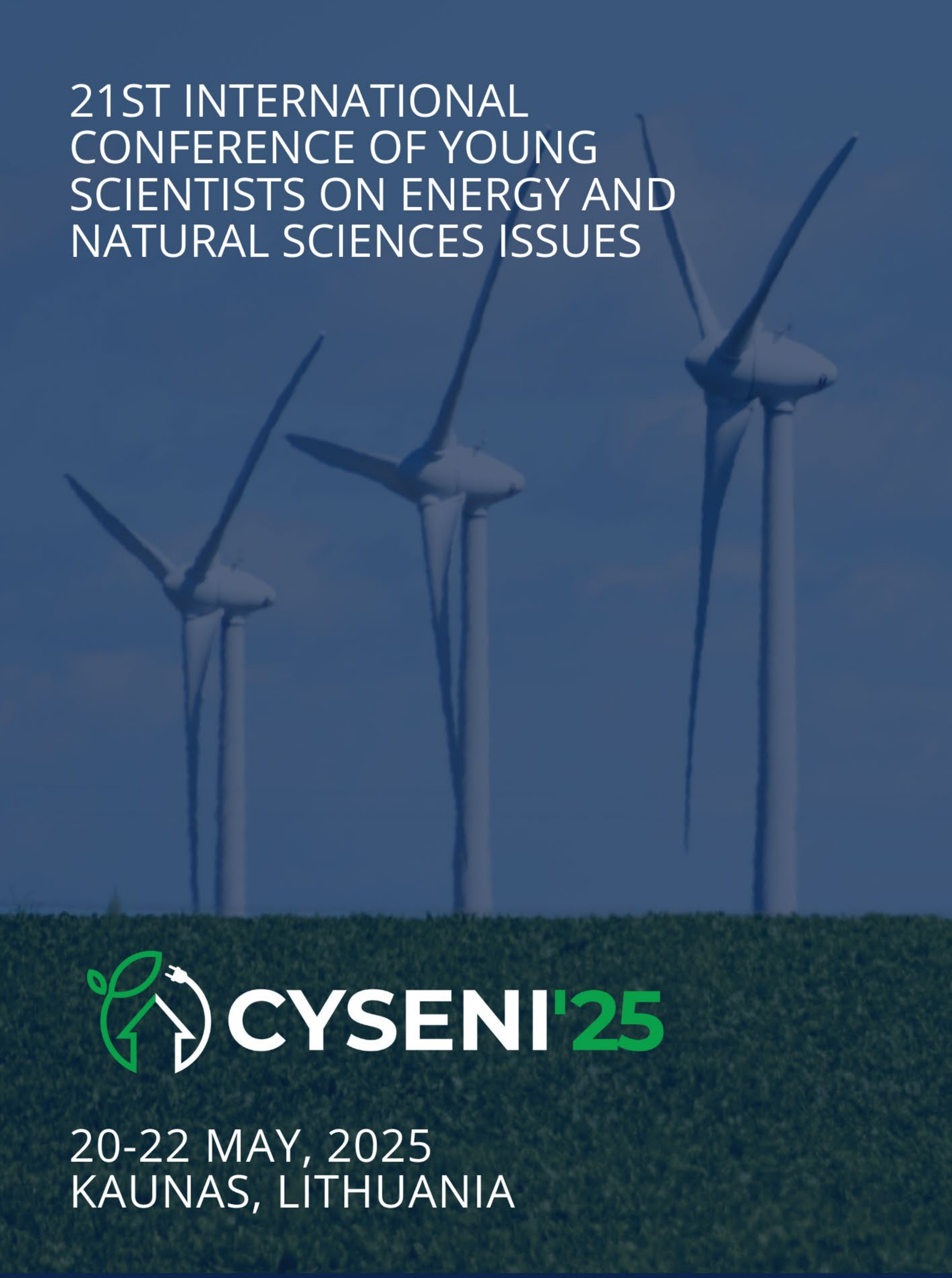
21ST INTERNATIONAL CONFERENCE OF YOUNG SCIENTISTS ON ENERGY AND NATURAL SCIENCES ISSUES



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Dear Colleagues,

The International Conference of Young Scientists on Energy and Natural Sciences Issues (CYSENI 2025) has been organized already for the 21st time since 2004, which became an annual tradition. We are very proud to bring together talented young scientists to participate in the 21st CYSENI conference. We expect that this will contribute to exchange of ideas, improved knowledge of young researchers, development of their acquired abilities and contribute to increasing level of exercised research activities. The initiative for such an event came from young and enthusiastic researchers of Lithuanian Energy Institute (LEI). They realised that there are a lot of young, smart and science-oriented young people and they do need a place to share their views, generated ideas and present the latest research results.

The conference once again has brought together young researchers and scientists to discuss recent trends in energy and natural sciences sectors worldwide. We are pleased that young scientists further found the conference valuable to present their up to date research results and share scientific experience. We thank all the contributors who made this conference possible. This includes all people from scientific and organising committees.

We would like to thank all participants for their contribution to the Conference and submission of their research papers. Moreover, special thanks to Keynote speakers: Martin Obligado, Zoltán Hózer, Antonio Froio, David Pérez, Ignitis Group.

Sincerely,
Conference Organizers

PLENARY SPEAKERS

- **SPEAKER | Martin Obligado**

Professor at Centrale Lille Institute:
HYDRODYNAMICS OF BUBBLE COLUMNS

- **SPEAKER | Zoltán Hózer**

Head of the Fuel and Reactor Materials Department at the HUN-REN Centre for Energy Research:
DEVELOPMENT OF ACCIDENT TOLERANT FUEL FOR NUCLEAR POWER PLANTS

- **SPEAKER | Antonio Froio**

Professor of Nuclear Power Plants at the Energy Department in Politecnico di Torino, Italy:
OPEN-SOURCE MULTIPHYSICS MODELLING OF FOR LIQUID BREEDING BLANKETS: THE NEMOFOAM SOLVER

- **SPEAKER | David Pérez**

Coordinator of the Low2HighDH project:
THE FUTURE OF DISTRICT HEATING IN THE EU: CHALLENGES AND STUDIED SOLUTIONS

- **SPEAKER | Ignitis Group**

Ignitis Group Representatives:
CREATING A 100% GREEN & SECURE ENERGY ECOSYSTEM

Martin Obligado
Professor at Centrale Lille Institute:
HYDRODYNAMICS OF BUBBLE COLUMNS

Bubble column reactors, where gas is injected at the bottom of an initially stagnant liquid, are widely used in chemical engineering. These reactors often operate in the heterogeneous regime, characterized by a strongly polydisperse distribution of bubble sizes, high gas concentrations (15 to 40% by volume), and strong velocity fluctuations (up to 50% of the mean). Owing to such flow complexity, no reliable scaling rules are available for reactor designers. This problem dramatically hampers optimization and process control. In particular, extrapolation between laboratory-scale and industrial-sized columns (with diameters ranging from 5 to 10 m and heights between 20 and 40 m) is not controlled, and therefore simulations yield realistic results only through ad hoc adjustments depending on the size of the column.

In this work, the hydrodynamics of bubble columns are revisited with a focus on the increase in the apparent relative velocity between phases observed in the heterogeneous regime. We report experiments in an air-water bubble column of diameter 0.4 m using a new Doppler probe that provides access to bubble velocities conditioned by the void fraction. In the first part of the seminar, we will derive and test a new scaling for the liquid velocity. Using our data and results from the literature, we will show that such scaling appears to hold for a wide range of operating conditions and bubble columns of varying sizes.

Later, we focus on the characterization of meso-scale structures corresponding to high (clusters), low (voids), and intermediate gas concentrations relative to the mean gas holdup. These structures are identified using Voronoï tessellations built from the phase indicator function. The resulting conditional bubble velocity data demonstrate that meso-scale structures drive the transport of both phases in the heterogeneous regime. The unconditional relative velocity is recovered from conditional relative velocities weighted by the probability of bubble presence in a given structure. These results provide a physical basis for the swarm factors introduced in simulations. They also offer a way to connect relative velocity enhancement with the characteristics of meso-scale structures, advancing our understanding of scaling rules.

Finally, some preliminary work on the unsteady properties of these flows and their numerical modeling will be briefly discussed. Overall, this work aims to present an overview of the current state of the art in upscaling bubble columns in the heterogeneous regime.

Zoltán Hózer
Head of the Fuel and Reactor Materials Department at the HUN-REN Centre for Energy Research:

DEVELOPMENT OF ACCIDENT TOLERANT FUEL FOR NUCLEAR POWER PLANTS

The analyses of the Fukushima accident highlighted that the scenario and the extent of damage to the units were heavily influenced by the materials used in the reactor core. The production of hydrogen primarily occurred due to the chemical interaction between steam and zirconium components of the fuel assemblies. The release of radioactive fission products into the environment was facilitated by the hydrogen explosions, which compromised the containment integrity.

To prevent Fukushima-like accident scenarios, several measures were implemented in nuclear power plants (e.g., additional diesel generators, hydrogen re-combinators, spent fuel pool cooling make-up, etc). One significant action was the proposed replacement of traditional nuclear fuel with so-called Accident Tolerant Fuel (ATF). The primary objective of ATF is to prevent or mitigate the release of radionuclides from the reactor in the event of an accident.

The development of ATF currently focuses on several technical solutions. The zirconium cladding used in today's fuel rods is being replaced by alternatives such as chromium-coated zirconium tubes, FeCrAl alloys, or SiC tubes. New pellet designs include additives to UO_2 fuel to increase grain size. Silicide-type fuels, with their high thermal conductivity, can achieve lower temperatures and store less energy at the onset of an accident. In micro-cell fuel designs, additional barriers within the pellets help prevent the transport of radionuclides.

ATF must demonstrate reliable performance not only during accidents but also under normal operating conditions. The requirements applied to the traditional nuclear fuel may not be fully applicable to ATF, and some new operational limits might be necessary. Before the routine loading of ATF into nuclear power plants, extensive testing must be conducted in out-of-pile and in-pile facilities. Lead test assemblies must be loaded first into selected nuclear power plants for further evaluation.

Several international projects have been launched to support the development, testing, and qualification of ATF. Selected research activities will be illustrated using results from projects involving the Lithuanian Energy Institute (LEI) and HUN-REN EK.

Antonio Froio
Professor of Nuclear Power Plants at the Energy Department in Politecnico di Torino, Italy:

OPEN-SOURCE MULTIPHYSICS MODELLING OF FOR LIQUID BREEDING BLANKETS: THE NEMOFOAM SOLVER

One of the challenges for future fusion power plants is the demonstration of a closed fuel cycle, i.e. producing in-situ more tritium than needed to operate the machine. The component devoted to such aim is the Breeding Blanket (BB), which however is nonexistent in present day fusion experiments. Among the several options being considered for the design of a BB, liquid breeders are considered the most promising option, at least in the longer term. Possible liquid breeder materials are liquid metals (LM; e.g. molten PbLi eutectic) or molten salts (MS, e.g. LiF-BeF mixtures), which could serve simultaneously as a breeder, neutron multiplier, and coolant. The design and analyses of these systems is therefore a multiphysics problem, as neutronics, chemistry, thermal-hydraulics and structural mechanics are interlinked; additionally, the flow of LMs or MSs in a magnetic field is affected by magnetohydrodynamics (MHD), influencing the flow pattern, heat transfer, and tritium transport.

This work presents nemoFoam, an open-source solver developed within the OpenFOAM framework, which allows coupled neutronics and MHD simulations, to determine in a self-consistent manner the neutron and photon fluxes, the power deposition, the Tritium Breeding Ratio, and flow and temperature fields. Several dedicated models for MHD turbulence are developed and presented. The code development, verification and application is presented, together with the future perspectives.

David Pérez
Coordinator of the Low2HighDH project:

THE FUTURE OF DISTRICT HEATING IN THE EU: CHALLENGES AND STUDIED SOLUTIONS

The presentation will explore District Heating (DH) in the EU, focusing on policies, challenges to decarbonise, and solutions from the Low2HighDH project.

It will begin with an overview of DH in the EU, covering CO2 emissions, fuel distribution, and key directives. The challenges of meeting climate neutrality goals (2020-2050) will be discussed, looking at biomass as a potential replacement of fossil fuel, along with its advantages and limitations, with a specific focus on Lithuania's historical adoption and policy drivers.

The Low2HighDH project will then be introduced, outlining its objectives, contributions, and initial application results. Technical solutions for integrating Low-Grade Renewable Energy Sources (LGRES) with High-Temperature DH will be presented, along with case studies discussed in Low2HighDH project. The presentation will conclude with financial strategies to support the transition to sustainable DH systems in the EU studied in our project.

Ignitis Group

Ignitis Group Representatives:

CREATING A 100% GREEN & SECURE ENERGY ECOSYSTEM

Ignitis Group is a renewables-focused integrated utility and the largest listed company in the Baltic states. In this presentation three speakers from Ignitis Group will present on what Ignitis Group is doing on:

– sustainability strategies and their implementation (Valentas Neviera, Head of Group Sustainability at Ignitis Group)

– developing a low-carbon electricity generation portfolio focusing on green generation and green flexibility technologies (Agota Greičiūnienė, Asset Performance and Optimisation Manager at Ignitis Renewables)

– innovations in energy sector (Algirdas Dučinskas, Battery Energy Storage Program Manager at Ignitis Group)

CONFERENCE PAPERS

1. ENERGY SCIENCES

1.1. Renewable Energy Sources

RISK OF DIESEL COMBUSTION IN THE REFRIGERATION SYSTEM WHEN WORKING WITH FLAMMAMBLE REFRIGERANTS – A CASE STUDY OF EUTECTIC REFRIGERATION SYSTEM

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ABSTRACT

Refrigeration and heat pump technology is undergoing a radical transformation related to the transition to natural refrigerants. The new European F-Gas Directive dramatically reduces quotas for placing hydrofluorocarbons (HFC) on the market, while a new restriction proposal submitted to European Chemicals Agency under European REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) regulations for per- and polyfluorinated alkyl substances (PFAS) threatens to outright ban virtually all the current HFC and HFO refrigerants.

Natural refrigerants are being proposed as alternative refrigerants as they have zero or near-zero GWP and most crucially do not create PFAS. Hydrocarbons (HC) is a large family of natural refrigerants that have excellent thermodynamic properties and are predominantly used in domestic refrigerators (R600a) as well as small commercial refrigeration systems (R290). In this study, a specific eutectic refrigeration system (ERS) for a transport refrigerator, working with R1270 refrigerant is analysed. [1] In such systems the evaporation temperature at the end of temperature pull-down can reach -60°C. For single-stage vapor compression systems running with R1270 refrigerant this means a lower than atmospheric vapor pressure at the end of the pull-down cycle, creating a risk of diesel combustion.

This study aims to examine these risks associated with diesel combustion during normal operation of low temperature refrigeration systems and to evaluate potential additional risk reducing measures that could be implemented in the system, by incorporating a combination of theoretical modelling and preliminary testing. A mass flow model based on the Saint-Venant and Wantzel equation is used to calculate the mass flow through a hole. A mathematical model for air infiltration into the low-pressure side of the refrigeration system is developed and the volume fraction of refrigerant R1270 in the compressor suction line is calculated while also comparing it to the UFL (upper flammability limit) to assess whether flammable mixture can form in the compressor suction line during normal operation. A psychrometric approach is used to analyse the effects of non-condensable gas infiltration to the high pressure side and to determine if UFL can be reached with traditional safety switches. To better understand the variation of relevant parameters in ERS with non-condensable gas infiltration, tests on a prototype ERS working with R1270 refrigerant were performed.

When considering the air infiltration through a hole into the low-pressure side, it should be noted that the simulation was performed up to an evaporation pressure of 0.3 bar (abs), but such a low evaporation pressure is not used during normal operation. Even low-temperature ERS do not require an evaporation temperature lower than -60°C-60℃, which corresponds to 0.56 bar (abs). By ensuring an efficient design of the evaporator and effective control of the expansion valve, the evaporation pressure in ERS will not go below 0.6 bar (abs). The diameter of the hole significantly affects the volume fraction ψ_2, but even with a twice-increased hole diameter and 0.3 bar (abs) evaporation pressure, the volume fraction of R1270 in the mixture at the compressor inlet exceeds the UFL of R1270 refrigerant more than 3 times. Considering the recommended hole diameter of D=0.8 mm [2] and the lowest possible evaporation pressure (which is limited by a low-pressure switch at 0.5 bar (abs)), the ψ_2ψ₂ exceeds the UFL of R1270 by more than 9 times. On the other hand, the size of the compressor significantly affects the volume fraction, but even the smallest compressor considered would not reach the upper flammability limit if the system is equipped with low pressure protection. However, if the safety low pressure switch is disconnected (e.g. when the liquid line is closed, and the compressor is used to isolate the refrigerant on the high-pressure side) an explosive mixture could form in the compressor at low pressure. As for the high-pressure side, testing confirmed that subcooling in the condenser is a reliable indicator of the presence of non-condensable gas in the system.

The tests of the protection system will continue, but based on the theoretical study and preliminary tests, it can be concluded that diesel combustion conditions are not met during natural operation of a properly designed ERS equipped with standard protection devices (low pressure switch, high pressure switch and discharge line thermostat). Furthermore, a subcooling-based fault detection system, which calculates the supercooling of the refrigerant in the condenser, allows detection of the infiltration of non-condensable gas and turning off the refrigeration system well in advance of the emergence of diesel combustion conditions.

Keywords: eutectic refrigeration system, diesel combustion, air infiltration

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OPTIMIZATION OF GRID CONNECTED HYBRID RENEWABLE ENERGY SYSTEM WITH ENERGY STORAGE

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ABSTRACT

The growing demand for energy sustainability and renewable energy sources drives the development of hybrid renewable energy systems (HRESs), which are increasingly adopted in commercial and industrial sectors [1]. HRESs integrate multiple generation, storage, and consumption technologies into a single system, aiming to enhance efficiency and benefits compared to single-source energy systems [2].

This study investigates the application of an HRES in two industrial companies, combining wind and solar power with energy storage. The analysis focuses on balancing power generation with energy demand while optimizing storage capacity. Real-world data are used to construct solar and wind power generation profiles, and various capacity scenarios are examined. A mathematical model is developed to determine the optimal storage capacity based on specific power requirements, ensuring an efficient and cost-effective system design [3].

Results highlight the complex interplay between renewable energy sources, storage, and load profiles in shaping system performance and economic viability. The findings indicate that low HRES generation (from photovoltaic (PV) or wind) leads to a higher reliance on grid-imported energy, reducing cost-effectiveness. Conversely, when combined with battery storage, larger PV and wind turbine capacities decrease grid dependence and improve economic outcomes. The study also reveals a direct relationship between financial and environmental benefits in renewable energy systems. Configurations with wind turbines are significantly more cost-effective in reducing CO_2 emissions and achieve higher total reductions than PV-only systems. However, PV-only configurations exhibit diminishing returns, where the cost per tonne of CO_2 avoided rises sharply as emissions reductions increase. These findings underscore the need to carefully consider priorities when designing and implementing HRESs in industrial applications.

Keywords: hybrid renewable energy systems, optimisation, solar and wind generation, industry.

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TRACTOR THREE-POINT HITCH FOR MOBILE SOLAR PANELS

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ABSTRACT

The electrification era in agriculture commenced with the extensive adoption of electricity in the sector, aiming to lower carbon emissions and enhance sustainability. This transition is being rapidly advanced through technological innovations and the incorporation of renewable energy sources, particularly solar energy. These initiatives aim to achieve carbon neutrality within the European Union by 2050, aligning with the Net Zero Target outlined in the European Green Deal. An analysis of literature and commercial mobile solar panel applications reveals that all are designed in a towable format and mounted on trailers. In this study, the solar panels were mounted on a three-point hitch system for mobility. This approach offered several advantages, including ease of transport on roads, simplified operation and control via hydraulics, dynamic load transfers of the panel weight to the rear axle, and reduced slippage during movement [1]. Mobile solar panels are engineered to fold compactly optimizing space utilization and providing protection from external damage factors. As a result, the folding system enabled the transportation of two solar panels, 200 cm wide and with a total power of 500 W, within a compact width of just 8 cm. Preliminary calculations indicate that, considering the maximum equipment width (2.55 m), and weight and size of novel panels (half-cut technology with 550 W maximum power), it is feasible to transport up to 50 solar panels, corresponding to a total installed capacity of 27.5 kW. Consequently, one of the sustainable development goals of the United Nations "affordable and clean energy" would be covered by using folded and mobiled by tractor's three-point hitch presented for the first time in the literature as an alternative system.

Figure 1 Three point hitched solar panel (work condition (left) and road condition (right).

Keywords: Photovoltaic, Transport Agriculture.

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1.2. Hydrogen energy and fuel cell technologies

METHANE DECOMPOSITION USING CHLORIDE-DERIVED ACTIVATED CARBON CATALYSTS FOR ENHANCED DECOMPOSITION

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ABSTRACT

As much as 900 megatons of carbon dioxide is emitted with the use and production of hydrogen, as estimated by the International Energy Agency [1]. Catalytic methane decomposition is a promising process for hydrogen production with solid carbon as a byproduct instead of carbon dioxide, which is one of the products of steam methane reforming – the primary method of hydrogen production currently. One of the main challenges of catalytic methane decomposition is manufacturing of catalysts that would be not only effective but also possessing a long lifetime. Chloride-derived catalysts offer a way to manufacture small crystallite sizes and, therefore, more active catalysts [2]. In this study, chloride-derived carbon-supported Ni, Fe catalysts were compared to corresponding samples based on precipitation synthesis methodology. Ni and Fe were chosen because of them being among the most prospective catalysts for methane decomposition [3]. 80 grams of charcoal per litre of 1 M solution were impregnated with $NiCl_2$ and $FeCl_3$ for two types of catalysts. The activated charcoal used is DARCO®, with the specific surface area measured to be 1388 m^2/g by the BET method. EDS shows metal loading on the catalysts to be 8.79 (±1.51) wt% Fe and 8.04 (±1.23) wt% Ni, not accounting for the weight of the chloride ions. Catalyst activity was measured in 30 vol% CH_4 in Ar atmosphere at temperatures up to 1050 °C, and stability was evaluated at 850 °C for 4 hours, GHSV being 24000 $mL \cdot h/g_{cat}$. The structure and composition of the catalysts pre- and post-experiments were investigated with XRD, and EDS measurements. Chloride-derived counterparts indicate better catalytic activity and stability compared to those of traditional synthesis methods.

Keywords: Catalytic Methane Decomposition, Sustainable Catalysis, Sustainable Hydrogen.

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BINDERLESS, SINTERED TUNGSTEN OXIDE ELECTRODES FOR DECOUPLED ACIDIC WATER ELECTROLYSIS

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ABSTRACT

Decoupled water electrolysis is a way to potentially simplify hydrogen generation systems by removing the need for gas separation systems or membranes. [1] However, the traditional way of creating the electrodes by coating a conductive material, like carbon felt, with the active material and a binder comes with multiple problems: low volumetric density of the active material, low availability of the material because of it being coated by the binder and electrode degradation during cycling. By creating conductive tungsten oxide–carbon composite electrodes with high open porosity and hierarchical pore structure, it should be possible to mitigate these problems.

Samples were sintered using spark plasma sintering (SPS) from dry-milled WO_3 (Somaterials WO3-113-M monoclinic) and carbon black (Printex) with WO_3/C mass ratios of 95:5, 90:10, 80:20 and 70:30. They were characterized with XRD in combination with Rietveld analysis to get information on their phase contents and crystalline parameters, then tested using chrono chronopotentiometry (CP) in 0.5M H_2SO_4 solution against RuO_2 coated titanium electrode, cycles limited to between -2 and 1.5V at constant current of 50mA. Scanning electron microscopy was used to evaluate the microscopic inner morphology of sintered samples from their fractured shards. It was not possible to reliably do cyclovoltammetry (CV) measurements for the whole sample, so inks were made from crushed, dry-milled samples and 20mg/ml solution of PVDF in NMP for a final sample/binder mass ratio of 9:1 and sample concentration of 180mg/ml, the powder being dispersed with ultrasound probe homogenizer. It was then used to impregnate carbon felt pieces.

XRD showed that the main phase in the samples sintered at 900°C corresponds to nonstoichiometric tungsten oxide with small amounts of WO_2, which increased with higher carbon content in the sinterable powder, ranging from practically 0% to 5% at the highest concentration. From XRD data, the main phase is formed in needle-like crystallites, with an approximate length of 200nm in the 010 hkl direction. During CP HER cycles, the WO_2 reacts, turning into roughly 20nm H_4WO_5 crystallites, which could be the cause of enough volume change to explain the cracking of the samples that had the largest starting carbon content.

As can be seen in Figure 1, samples with higher starting carbon content had significantly higher specific capacity, calculated from CP cycle times, which might be explained by higher open porosity, meaning a higher amount of material available for intercalation of H^+. Additionally, for all tested samples, their capacity steadily increased during CP cycling; for the sample with a 70:30 starting ratio, it happened for more than 300 cycles. Differences between calculated total efficiency for a whole cycle between different samples was negligible, in all cases being above 55%.

In figure 2 the CV results are presented, which show that the material created during sintering does exhibit differences in both CV peak locations and the specific capacitance, though they are small and do not directly correlate with the starting composition or the crystalline composition of the samples.

By controlling the SPS parameters and carbon content, it is possible to create stable, useable electrodes for decoupled electrolysis in an acidic environment containing almost purely a single nonstoichiometric tungsten oxide phase without any witnessed capacity decrease during CP cycling.

STRUCTURE AND ELECTROCATALYTIC ACTIVITY OF ZIRCONIUM NITRIDE COATINGS ON STAINLESS STEEL

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ABSTRACT

With the rapid development of renewable energy sources in the world, efficient ways of storing electrical energy in chemical compounds are being sought. Hydrogen generation from aqueous solutions remains a priority research direction in this field. The world is trying to turn to renewable energy and green hydrogen, but currently hydrogen production is still mostly depending on fossil fuel. Low-emissions hydrogen produced by water electrolysis is expected to remain expensive in the short term, but costs are projected to fall significantly [1]. However, hydrogen handling and storage present many technological challenges, therefore, other so-called Power-to-X technologies that turn electricity into carbon-neutral chemical compounds have attracted enormous interest. In this regard, the electrochemical synthesis of green ammonia is particularly promising.

Electrochemical production of green ammonia requires stable and efficient electrocatalysts and industrial scale-up to compete with traditional ammonia synthesis using natural gas. Among the many materials studied for this purpose, currently a lot of research is focused on transition metal nitrides. In these materials metal and nitrogen bonding consists of covalent, ionic and metal bonds [2]. Metallic bonds influence that material have small electrical resistivities and high corrosion resistivity. Covalent bonds influence materials high stress tolerance which gives material high hardness. Ionic bonds points to similar electronic structure to precious metals like Pt and Pd due to contraction of metal d-bands and an expansion of the parent metal lattice. Zirconium nitride (ZrN) has been recently identified as a promising material for electrocatalytic processes of oxygen and nitrogen reduction in aqueous solutions as cheaper and efficient alternative to precious metals [3].

The aim of this work was to prepare ZrN coatings on AISI 304 type stainless steel and to study their structure, composition, morphology and electrocatalytic activity in aqueous solutions.

ZrN coatings were synthesized by pulse direct current magnetron sputtering. Magnetron sputtering is proved to be fast and efficient way to obtain ZrN coatings of desired thickness of about 250 nm. Structure and stoichiometry are known to influence significantly the electrocatalytic properties of ZrN. Therefore, the deposition of non-stoichiometric ZrN electrocatalysts was tailored by varying the ratio of Ar/N2 in gas atmosphere and applying 200-350 W power. The characterization of prepared electrocatalyst samples was done by scanning electron microscopy and energy-dispersive X-ray spectroscopy (SEM-EDX), Raman spectroscopy, X-ray diffraction spectroscopy, profilometry, and UV-vis spectroscopy. Electrochemical measurements were performed in 0.1 M KOH electrolyte in a three electrode cell consisting of ZrN/stainless steel substrate as working electrode, Ag,AgCl|KCl(sat) as a reference electrode, and Pt wire as a counter electrode. The experimental results show that the prepared ZrN coatings are highly stable and active electrocatalysts in hydrogen evolution reaction (HER). The catalyst requires low overpotentials of 560 mV to reach 10 mA/cm^2 with long-term durability at pH 13. Tafel slope was estimated to be 130-140 mV/dec, thus, suggesting that the Volmer’s step (water dissociation/electrochemical adsorption) is the rate-determining of HER.

Keywords: ZrN thin films, magnetron sputtering, water electrolysis, electrochemical ammonia synthesis.

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AMPROSE - GREEN AMMONIA PATHWAYS FOR A DECARBONIZED ENERGY SYSTEM IN THE BALTIC-NORDIC REGION

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ABSTRACT

The AMPROSE project "Prospects for Green Ammonia in Sustainable Energy Development", funded by the Baltic-Nordic Energy Research Programme (2024–2026), explores the potential role of green ammonia (NH_3) in accelerating the transition to sustainable energy systems and cleaner energy. Traditionally used in agriculture, ammonia is gaining attention as a clean energy alternative and a hydrogen carrier, particularly within the maritime sector. However, traditional ammonia production by the Haber-Bosch (H-B) process is highly energy-intensive. It emits a significant amount of CO_2 into the atmosphere due to its dependence on fossil fuels for hydrogen production. AMPROSE suggests using a combination of different methods to address these challenges, focusing on integrating renewable energy sources such as wind and solar into a green NH_3 production and supply. This research aimed to investigate the influence of green ammonia costs on electrolytic hydrogen and assess its impact on the energy markets in the Nordic and Baltic regions under varying future scenarios. The project also includes an experimental component aimed at developing low-cost, readily available materials for the electrochemical synthesis of ammonia. This experimental aspect leads to progress toward a proof-of-concept system where production is 10^{-7} mol·cm^{-2}s^{-1}, efficiency is more than 50%, and the system deteriorates by only 0.2% every 100 hours. Proton-conducting electrochemical cells (PCECs) are identified as a promising technology, enabling decentralised and flexible ammonia production that can complement large-scale Haber–Bosch facilities. In addition, AMPROSE aims to provide evidence-based recommendations to policymakers and stakeholders on strategically using green ammonia to support climate neutrality regionally and globally. The project aligns with key policy frameworks such as the European Green Deal, Nordic Vision 2030, and Lithuania and Norway's national energy and climate plans. Combining materials research with system-wide modelling, AMPROSE highlights ammonia as a crucial pathway to decarbonising energy systems across the Baltic-Nordic region.

Keywords: Green ammonia, Electrochemical synthesis, Proton-conducting electrolysis cells (PCEC), Techno-economic analysis.

1.3. Fusion Energy, Nuclear Fission and Radiation Protection

MODELLING OF RADIONUCLIDE TRANSFER THROUGH THE CONCRETE BARRIER CONSIDERING GRADUAL BARRIER DEGRADATION

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ABSTRACT

Radionuclide migration assessment is an important part of any nuclear waste installation safety assessment. In most cases, a long-term assessment of radionuclide migration needs to be performed. Such assessments need to consider various processes, which must be accurately represented. These processes can vary heavily: pH changes induced by leaching of concrete minerals, concrete decalcification and degradation, radionuclide migration etc.

Radionuclide migration, in a nuclear waste repository, heavily depends on processes such as radionuclide sorption and concrete degradation. An accurate representation of these processes, however, can be difficult due to the need to use reactive transport modelling, for both radionuclide migration and concrete degradation.

Sorption modelling in concrete is generally done using Kd sorption values. This is due to the complexity of concrete mineralogical composition, which leads to difficulties modelling surface complexation and cation exchange. Due to this, it is difficult to model potential change in concrete capability to retain radionuclides. To circumvent this issue, concrete degradation is modelled instead, using reactive transport modelling, as outlined by Jacques 2014 [1]. Concrete degrades in 4 stages, each with distinct pH and mineralogical changes. These changes determine the change of Kd values in concrete, that can be linked to each stage separately. In previous work [2] concrete degradation was linked with each degradation stage, and the change was stepwise, with a sharp change in Kd value. Realistically, the change in Kd value in any engineered barrier system is a gradual process and dependent on pH change of the concrete barrier.

In this study, concrete degradation and radionuclide migration and retention are modelled using a PHREEQC based water flow and reactive transport modelling program HP1 [3]. Using previous work, concrete degradation stages are determined and immediately set for the calculation. However, in this work, Kd values are updated over the entire degradation stage, instead of immediate change in after a new degradation stage is achieved. This is achieved by modelling the change of pH in the degrading concrete barrier. The change in pH is then used to determine discrete time steps when Kd value changes. This leads to a more accurate representation of ongoing processes of Kd dependence on the state of the concrete barrier [3]. Using this data, two different radionuclides, one of low sorption and one of high sorption in concrete are put in as a constant contaminant flux infiltrating into the top of the barrier and migrating through the barrier and finally leaching out. Kd values are coupled to the pH value of the barrier. Contaminant flux out of the barrier is measured as evaluation of the performance of the model. When Kd is changed in a model, radionuclides are immediately released into the water flux, leading to sharp increases in contaminant flow from the bottom of the barrier. In the case of immediate Kd change, this flux can increase by an order of magnitude. This sharp increase accounts for a 9.51% increase in total contaminant release from the barrier.

Keywords: radionuclide migration, sorption, concrete degradation

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HYDROGENATION OF ZIRCONIUM ALLOYS AND MEASUREMENT OF HYDROGEN CONTENT

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ABSTRACT

Ensuring the integrity of nuclear fuel cladding under accident conditions is a critical aspect of nuclear power plant safety. Zirconium alloys are widely used as cladding materials due to their favourable properties; however, their susceptibility to hydrogen absorption and high-temperature oxidation can lead to embrittlement, significantly compromising safety. This research focuses on investigating hydrogen uptake and oxidation behaviour in zirconium claddings, particularly under Loss-of-Coolant Accident (LOCA) scenarios.

A hydrogenation system and measurement techniques were developed to precisely control and quantify hydrogen absorption in zirconium alloys. A high-temperature three-zone tube furnace, integrated with a gas inlet and a vacuum system, was used for the hydrogenation process. The pressure change during hydrogenation was continuously monitored, where a decrease in pressure indicated active hydrogen uptake by the zirconium samples. Once hydrogen absorption was complete – as evidenced by the pressure stabilization – the sample holder was retracted into the cold zone of the furnace to terminate the process. High-temperature steam oxidation tests were conducted on both unhydrogenated and hydrogen-precharged samples to assess the impact of hydrogen content on oxidation kinetics and embrittlement. Furthermore, hydrogen distribution was examined in samples representative of conditions observed during real-world reactor incidents.

Results indicate that hydrogen uptake plays a crucial role in cladding embrittlement, with a clear transition from ductile to brittle behaviour occurring above 3000 ppm hydrogen content. Additionally, oxidation kinetics remained largely unaffected by initial hydrogen concentration, but the mechanical integrity of the cladding was significantly reduced. These findings provide valuable data for refining accident modelling codes and developing improved fuel cladding materials with enhanced accident tolerance.

Keywords: nuclear safety, zirconium alloys, LOCA, hydrogen embrittlement, steam oxidation

HIGH TEMPERATURE OXIDATION TESTS OF ZIRCONIUM FUEL CLADDING

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ABSTRACT

The primary application of zirconium alloys is in the nuclear industry, where they are used as fuel claddings and structural components of fuel assemblies. The fuel cladding plays an important role in preventing the release of fission products from a nuclear power plant into the environment, under both normal and accident conditions. Zirconium alloys developed for fuel claddings have excellent corrosion resistance and very good mechanical properties under normal operating conditions. However, high temperature and corrosive atmosphere may develop in incident and accident scenarios, which can lead to the rapid oxidation of the cladding. Oxidation can cause deterioration of the mechanical properties of the cladding and, in extreme cases, even the loss of cladding integrity.

The kinetics of oxidation depends on several factors, one of which is the oxidizing atmosphere. The oxidation of the zirconium cladding takes place in the steam atmosphere during a Loss of Coolant Accident (LOCA). In the event of a reactor vessel failure during a severe accident, high temperature air oxidation of the cladding may occur. Understanding these processes is essential for the safe operation of nuclear power plants.

High temperature oxidation experiments were performed over a wide temperature range (800 – 1200 °C) and in different atmospheres (steam, air, steam-air mixture) to investigate the oxidation behaviour of Zr cladding under accident conditions. The ring samples from a fuel cladding tube were oxidized under isothermal conditions for varying durations. The extent of the oxidation was calculated on the basis of the mass increase. The experimental results showed that the samples were only slightly oxidized at 800 °C in both steam and air atmospheres. Above 900 °C, the zirconium samples oxidized faster in air and in steam with high air content (50%) than in pure steam, and in most cases, a porous, non-protective oxide layer formed on the surface. The formation of a non-protective oxide layer can lead to increased oxidation and earlier embrittlement of the cladding. The results provide important data for developing models that support nuclear power plant (NPP) accident analysis.

Keywords: zirconium alloys, oxidation behaviour, high temperature oxidation, fuel cladding

ADVANCES IN FUSION NEUTRONICS: SYSTEMATIC LITERATURE REVIEW ON NEUTRON TRANSPORT, ACTIVATION, AND BENCHMARKING IN EXPERIMENTAL AND COMPUTATIONAL STUDIES

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ABSTRACT

Neutronics plays a crucial role in fusion energy R&D, shaping reactor performance, material integrity, and radiation safety. This literature review covers current neutronics activities across major fusion facilities, including material irradiation centers and experimental reactors. It highlights key considerations such as neutron transport, shielding, activation, tritium breeding, and irradiation effects, emphasizing their impact on next-generation reactor designs.

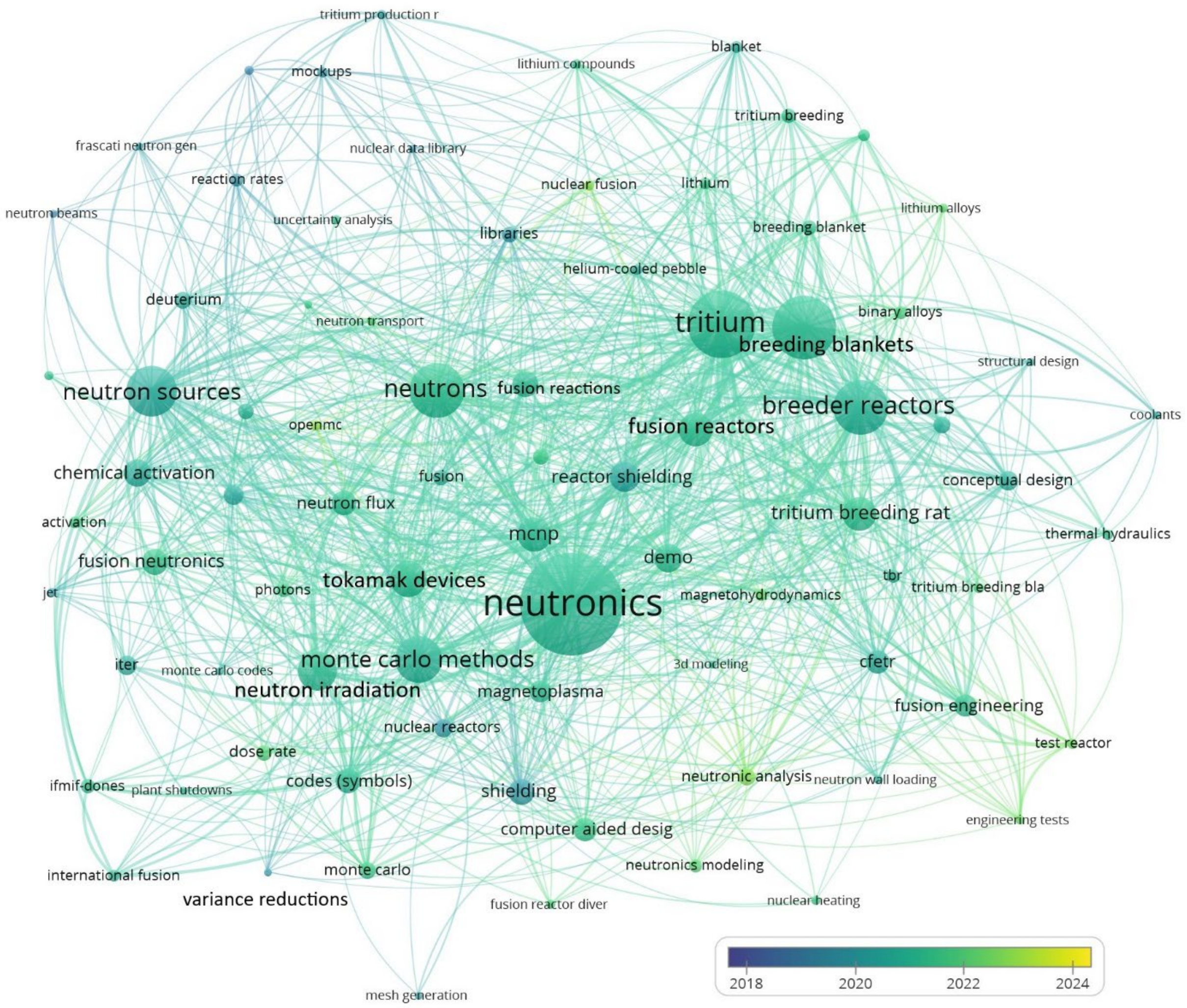

Figure 1 Keyword Co-occurrence Map in Fusion Neutronics Research (2018–2025).

Methodologically, a bibliometric analysis focusing on the 2018–2025 publication window is performed, categorizing documents into eight classifications.Among them six classifications have been further considered: (1) citation analysis, (2) authors' networks, (3) high-impact journals, (4) co-authorship collaboration among institutions, (5) co-authorship among countries, and (6) keyword concurrence analysis (Figure 1). A systematic review of the selected literature complements these bibliometric findings, revealing emerging trends, knowledge gaps, and research collaborations in fusion neutronics. The results emphasize the growing complexity of reactor configurations, the continual evolution of computational methods, and the importance of multidisciplinary collaboration. While in research focusing on tritium breeding and blanked design, complex multi-physics simulations coupling thermal-hydraulics, neutronics and structural effects is trending, in full reactor and system integration efforts, on the other hand, multi-physics coupling that covers magnetoplasma, neutronics, structural and thermal-hydraulics is dominating, especially in concepts like DEMO, CFETR (Chinese Fusion Engineering Test Reactor), and other advanced test reactors. By mapping the state of the art in fusion neutronics, this study identifies key areas for future investigation such as advanced materials development, improved tritium breeding strategies, and refined neutron transport modelling. Monte Carlo methods, such as MCNP, OpenMC, Serpent, continue to dominate for reactor shielding, activation, and flux analysis. In Figure 1, MCNP is shown in dark green to highlight its long-standing dominance, while OpenMC appears in light green-yellow to illustrate its recent rise in usage. Additionally, the size of each ball corresponds to the frequency with which that keyword appears in the analyzed literature. At the same time hybrid approaches that combine deterministic and stochastic codes are emerging to speed up large, 3D or time-dependent calculations. Notably, ongoing research efforts focus on the development of variance reduction and shutdown dose calculation tools and methodologies, CAD-to-MC conversion tools and capabilities that enable computations directly within CAD environments. In parallel, high-energy (14 MeV) neutron cross sections for structural and breeder materials remain an active area of refinement, guided by both experimental measurements and theoretical evaluations. Furthermore, continuous updates to nuclear data libraries, such as FENDL, ENDF, JEFF, and TENDL are integrating improved scattering, reaction rate, and helium production data relevant to fusion applications. The growing need for automated methods to test and validate nuclear data and libraries, is identified.

Keywords: Fusion neutronics, neutron transport, Monte Carlo simulations, shutdown dose rate, tritium breeding.

1.4. Energy Efficiency, Reliability and Security

THE ECOLOGICAL FOOTPRINT OF DISTRICT OF HARIPUR: HOW INCOME INFLUENCES ENVIRONEMNTAL IMPACT

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ABSTRACT

Sustainability is also the name of the balance between bio-capacity and ecological footprint. Biocapacity is the amount of natural resources that Earth needs to support life. These resources include farmland, grazing land, built-up land, fishing grounds, and forest land. Similarly, an ecological footprint is a pattern of the use of natural resources. In 2022, the world's biocapacity was 1.51 gha per person, while the ecological footprint per capita was 2.58. This imbalance shows that there is a growing ecological deficit because people use up resources faster than the earth can replace them. An increase in urbanization significantly affects natural resources because anthropogenic activities degrade land and contaminate the land, water and soil [1]. Since 1970, it has been observed that bio-capacity is decreasing over time, whereas the ecological footprint is increasing. In this study, the Global Footprint Network's ecological calculator was used to assess the environmental impact of the living standards of 20 inhabitants from different income stratum. This study reveals that finance affects the ecological footprint. Twenty people with low incomes had an average ecological footprint of 4.26 global hectares (gha) per person. In the same way, the average EF for people with middle incomes was 5.16 global hectares (gha) per person, and it was 7.13 global hectares (gha) for people with high incomes. The average ecological footprint per capita for Haripur District was 5.50 global hectares (gha) per person. The carbon footprint accounts for 66% of the total ecological footprint. Lithuania has a biocapacity of 5.97 gha and an ecological footprint of 6.43 gha per person. In contrast, Pakistan has a biocapacity of 0.36 gha per person and an ecological footprint of 0.73 gha per person. With a biocapacity deficit of -0.46 gha in Lithuania and -0.37 gha in Pakistan, both nations are suffering. The average ecological footprint per person in Haripur, on the other hand, is 5.50 gha, which is many times higher than the average for Pakistan as a whole. Pakistan must work hard in the future to close the ecological footprint gap, which is many times greater in some areas. Resolving this problem will benefit the environment and support sustainable resource management. The study aimed to determine the ecological footprint of the inhabitants of Haripur district, Pakistan, based on their socioeconomic status. The district is divided into three units: Haripur tehsil, Ghazi tehsil, and Khanpur tehsil. The participants were given information about their ecological footprint, bio-capacity, environmental aspects of activities, and their adverse impact on the environment. The questionnaires were divided into three categories: food, housing, and transportation. The food section asked about the amount of animal-based food consumed, housing type, size, and number of people in the household, energy efficiency of the house and appliances, and the percentage of electricity use from renewable energy. The transportation section asked about weekly car or bicycle usage, fuel economy, carpooling trends, and public transport usage. The study found that approximately 31% of Pakistan's electricity generation comes from renewable resources [2]. The data was manually entered into the Global Footprint Network's ecological footprint calculator, providing information on personal earth footprint, number of earths needed, ecological footprint, carbon footprint, and percentage of carbon footprint.

Table 1 Demographic information of inhabitants in sample for study.

Demographic information of the participants (n=60)					
	Gender	**Age**	**Occupation**	**Socioeconomic status**	**Living area**
Variables/frequency	Male/49	Less than 40 year/24	Private sector/35 Private sector/14	Low/20 Middle/20	Rural/27
	Female/11	More than 40 year/36			Urban/33
			Business/11	High/20	

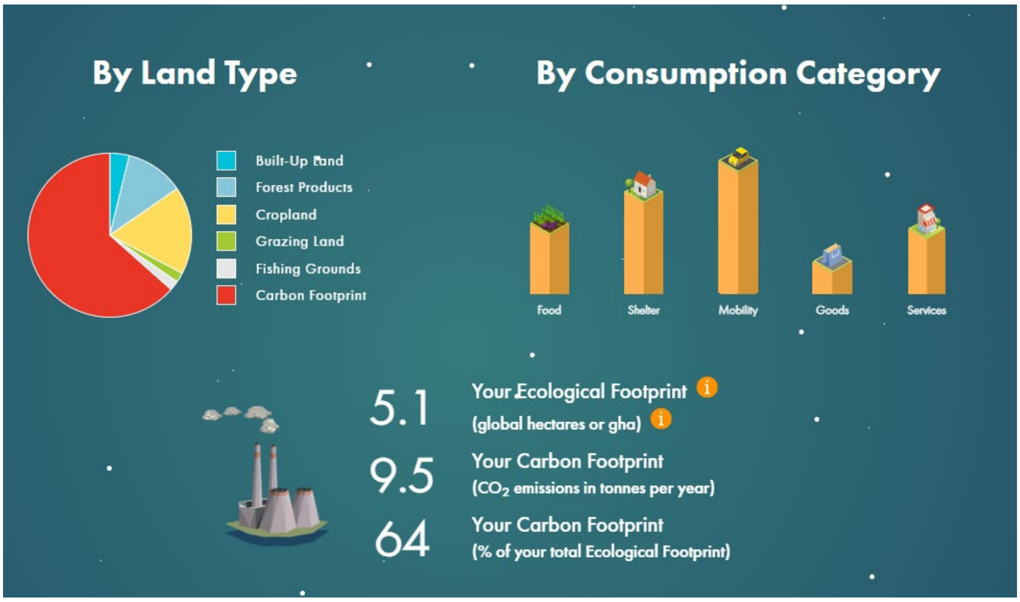

Figure 1 Illustrate results of footprint calculator for each inhabitant [3]**.**

Table 2 Illustrates information about each ecological footprint, earth need and carbon footprint for each section.

	Low-Income	Middle-Income	High-Income	Overall
Needs Earths	2.60	3.17	4.38	3.3
Ecological footprints(gha)	4.26	5.16	7.13	5.2
Carbon footprint (t/year)	8.86 t/year	9.57t/year	13.10t/year	10.50t/year
% of Carbon Footprint in E.F	69%	65%	63%	66%
By land type (gha)				
Built-up land	0.16	0.20	0.30	0.22
Forest products	0.51	0.68	1.07	0.75
Croplands	0.55	0.81	1.07	0.81
Grazing land	0.02	0.07	0.10	0.06
Fishing grounds	0.03	0.08	0.10	0.07
Carbon footprint	2.98	3.35	4.51	3.61
By Consumption Category (gha)				
Food	0.42	0.67	0.81	0.63
Shelter	2.33	2.07	2.45	2.28
Mobility	0.50	0.80	1.69	0.99
Goods	0.42	0.87	1.14	0.81
Services	0.56	0.74	1.03	0.77

Keywords: Sustainability, Ecological footprint & Bio-capacity.

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INFLUENCE OF GLAZING PERFORMANCE ON THE ENERGY EFFICIENCY OF A SINGLE-FAMILY HOUSE

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ABSTRACT

The main objective of the study is to determine how the glazing characteristics of the façade of a single-family dwelling affect the thermal energy consumption for heating and overheating of the building. This study builds on previous studies carried out in 2024, which showed that the simulated thermal energy consumption of the building is similar to that measured during the operation of the building, following the analysis of the results of the first LT-PH3 passive single-family house monitoring in Lithuania carried out in 2016-2020. A survey of manufacturers identified the dominant algorithm for the selection of glazing elements for single-family houses, as well as the three most frequent combinations of the heat transfer coefficient (Ug) and the total solar transmittance (g) values of glazing elements. The study evaluated the effect of each glazing combination on the thermal performance of the building depending on its orientation. It was determined that the solar transmittance through the windows has a significant influence on the thermal performance of the building and that neglecting it leads to energy consumption increases of more than 1.5 times. Therefore, despite the higher prices, all three types of glazing used on the market today do not ensure a corresponding reduction in heating costs. The study also confirmed that the south orientation of the main façade of the building, where most of the windows are located, with the use of shading measures, provides the highest solar heating efficiency and the lowest percentage of overheating.

Figure 1 Influence of changing the orientation of the south façade of the LT-PH3 single-family dwelling on the heat consumption for heating (kWh/(m²a)) in different scenarios of the glazing units Ug and g values.

Keywords: building orientation, PHPP, Passive House, heat consumption, energy performance, overheating, glazing, shading.

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NAVIGATING DATA PRIVACY IN AI-ENHANCED BUILDING ENERGY SYSTEMS

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ABSTRACT

The integration of AI and advanced technologies into building energy management systems has shown potential for improving energy efficiency and generating savings. A significant amount of data is being collected from buildings to design and train AI models that predict energy consumption and occupants' behavior. This raises privacy concerns and highlights risks like data breaches, occupant's personal information, and unauthorized access. Therefore, balancing utilizing energy data for AI-driven solutions and protecting occupant privacy is important. This study presents a systematic review of recent literature addressing the privacy challenges associated with collecting, analyzing, and sharing building energy data. Various privacy-preserving methods have been proposed and evaluated. Federated learning enables decentralized model training without sharing raw data, maintaining strong privacy with minimal accuracy loss. Differential privacy offers formal privacy guarantees by introducing calibrated noise, while synthetic data generation allows for developing and testing AI systems without using real occupant data. Additionally, data minimization, aggregation, and privacy risk assessment frameworks support ethical and secure data practices. This review examines current approaches and provides a comparative understanding of their effectiveness, limitations, and applicability. It aims to guide the selection of appropriate privacy-preserving techniques and promote responsible and ethical AI deployment in buildings.

Keywords: AI, Buildings, Data, Energy, Privacy.

ARTIFICIAL INTELLIGENCE FOR SUSTAINABLE CRYPTOCURRENCY MINING: BITCOIN ENERGY FORECASTING

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ABSTRACT

Bitcoin remains the most prominent cryptocurrency, attracting significant attention due to its energy consumption. Prior studies forecasted that Bitcoin's annual energy consumption would rise significantly, with predictions reaching up to 284 TWh per year—comparable to Italy's total energy usage. However, as of January 2025, empirical data suggests that Bitcoin's actual annual energy consumption is approximately 175.87 TWh, closer to Poland's energy consumption. This discrepancy highlights the impact of several factors influencing Bitcoin's energy usage.

Technological advancements, particularly in mining hardware efficiency, have significantly reduced energy consumption per hash. Additionally, the increasing adoption of energy-efficient mining practices, including the use of renewable energy sources—now estimated at nearly 40% of total Bitcoin mining operations—has mitigated overall energy demand. Studies have shown that Bitcoin mining's integration with renewable energy can support grid decarbonization by providing flexible load response capabilities and incentivizing further investment in clean energy infrastructure. Some projections estimate that Bitcoin's future mining operations may continue this trend, reducing reliance on fossil fuels and improving sustainability metrics.

Market fluctuations also play a role, as mining activity adjusts dynamically with Bitcoin's price, affecting overall energy consumption trends. Recent advancements in dynamic pricing models and reinforcement learning (RL) techniques have opened new avenues for optimizing Bitcoin mining strategies. Reinforcement learning algorithms can be leveraged to develop self-optimizing mining frameworks that dynamically adjust computational power, energy consumption, and profitability based on real-time electricity prices, mining difficulty, and market conditions. By training deep reinforcement learning (DRL) agents, miners can make autonomous decisions to maximize profitability while minimizing energy costs, especially by aligning mining activity with periods of low electricity demand or high renewable energy generation. Such AI-driven adaptive mining approaches could enhance sustainability by reducing grid strain and incentivizing greener energy usage through intelligent workload scheduling.

Furthermore, the shift of other cryptocurrencies, such as Ethereum, from Proof-of-Work (PoW) to Proof-of-Stake (PoS) has further differentiated Bitcoin's energy demands from the broader cryptocurrency sector. Research suggests that PoS mechanisms offer a more energy-efficient alternative, potentially influencing Bitcoin's long-term sustainability strategy.

Recent life cycle assessments (LCA) indicate that the environmental footprint of Bitcoin mining varies significantly based on geographical location and electricity mix. Studies suggest that site-specific energy strategies, such as utilizing waste heat recovery and optimized hardware efficiency, could further mitigate its carbon footprint. These findings indicate that previous growth projections overestimated Bitcoin's energy trajectory, and future studies must integrate technological, economic, and AI-driven models, including reinforcement learning-based optimization techniques and dynamic pricing frameworks, to refine energy consumption forecasts.

This study underscores the need for continuous monitoring of cryptocurrency energy consumption trends and the exploration of alternative consensus mechanisms to improve energy efficiency. Reinforcement learning and other AI-driven optimization methods could provide novel solutions for balancing profitability, sustainability, and energy grid stability. Policymakers should consider the role of Bitcoin mining in energy transition strategies, particularly in regions with high renewable energy potential, to maximize environmental benefits while maintaining blockchain security and decentralization.

Keywords: cryptocurrency, energy consumption, reinforcement learning, energy-efficient mining

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OPTIMAL COMPOSITION OF LITHUANIAN ENERGY COMMUNITIES

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ABSTRACT

Energy communities play an increasing role in providing energy to consumers. This study comprehensively analyzes energy communities (see Figure 1), possible member types, compositions, and load distribution in Lithuania.

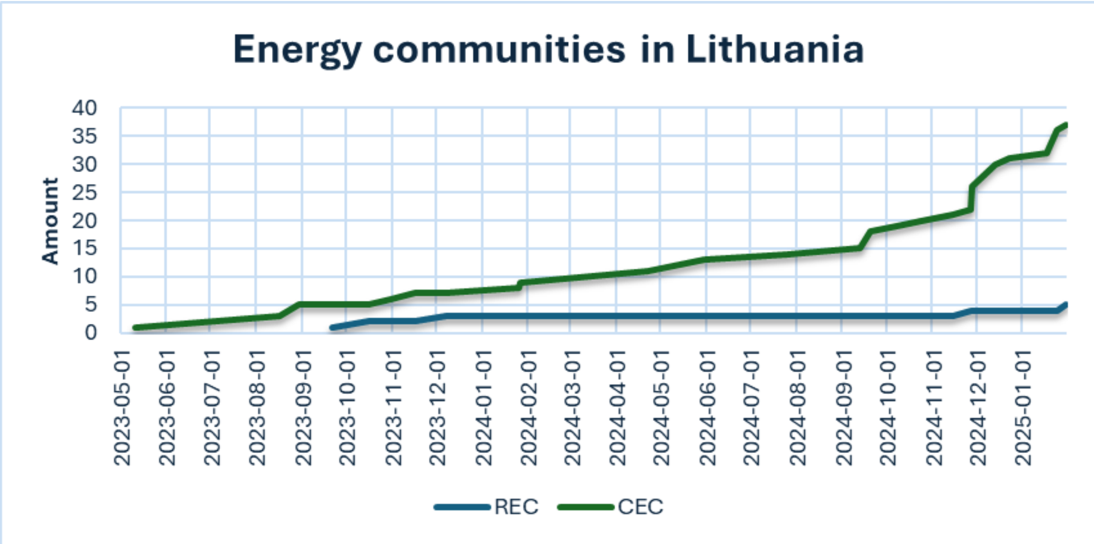

Figure 1 Energy Communities in Lithuania as of February 1, 2025, including Citizen Energy Communities (CEC) and Renewable Energy Communities (REC) (developed by the authors).

Using MATLAB R2024b-based modeling, the research uses a Stochastic Random Solution Generator (SRSG). It evaluates different types of energy communities, considering members energy consumption patterns. The study aims to identify the most effective energy community configurations that minimize relative deviation from the average load while maintaining a stable energy supply. The first focus is on determining the energy community made of each possible member and calculating the difference between reserved power from the energy distribution network in personal and as an energy community (see Table 1). The results demonstrate significant reductions of reserved power from 125 to 67 kW, highlighting an energy community's efficiency gains and load-balancing benefits.

Table 1. Power distribution (kW): individual (blue), initial energy community (red), where 1 is garden houses, 2 - polyclinic, 3 - societies, 4 - religious organization, 5 - apartment association, 6 - private house, 7 - garages community, 8 - union, 9 - art association and 10 - apartment (developed by the authors)

Power/Member	1	2	3	4	5	6	7	8	9	10	In total
Maximum	0,25	39,88	1,64	9,26	3,55	0,36	2,69	15,90	28,99	2,79	**66,12**
Minimum	0,00	2,06	0,05	0,72	0,61	0,04	0,04	2,94	6,15	0,00	14,46
Average	0,03	6,23	0,23	1,55	2,28	0,16	0,34	7,55	11,46	0,16	29,98
Reserved	3	40	7	10	7	7	3	16	29	3	**125,00**

By leveraging numerical simulations, the study provides insights into how different community compositions impact load use efficiency. The results contribute to understanding efficient energy community design principles in Lithuania, highlighting the potential advantages of well-structured collaborations and enhancing grid stability. Using version 1 of SRSG, the minimal amount of each member type varies between 1 and 50. The best minimal relative deviation from the average load was reached while iterating 1000000 times – 0,2527. At the same time, the initial energy community has 0,3399 as minimal relative deviation from the average load.

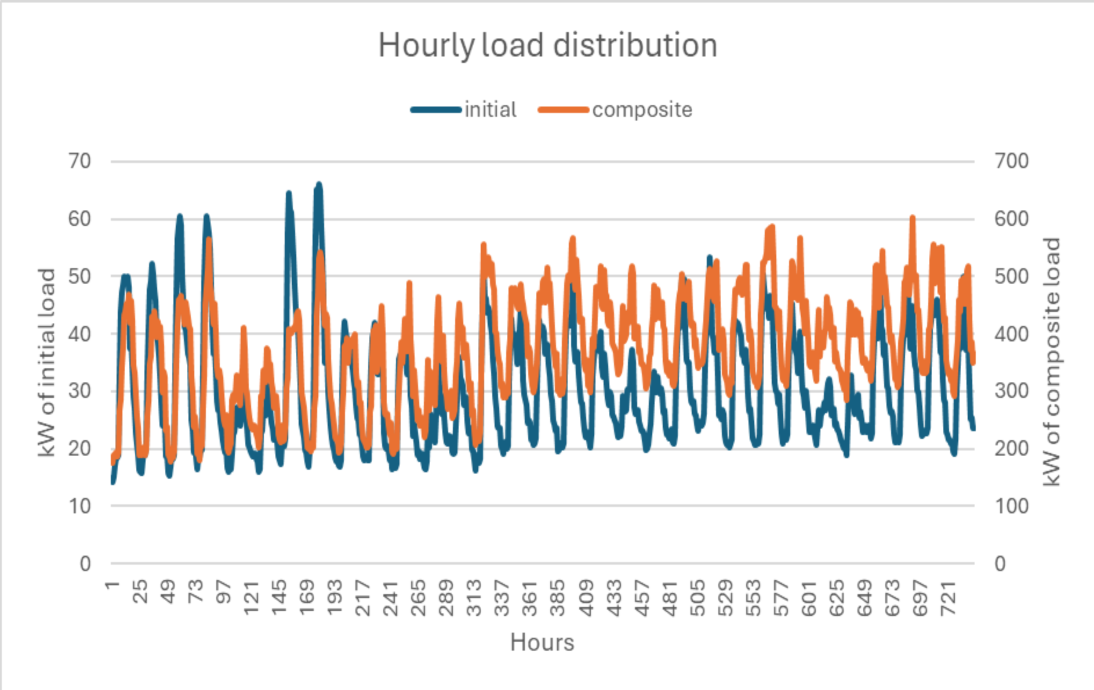

Figure 2 Hourly load of initial energy community with one member of each 10 types (blue) and composite energy community using stochastic random solution generator and selection based on the lowest relative deviation from the average with 42 garden houses, 1 polyclinic, 42 societies, 8 religious organizations, 38 apartment associations, 27 private houses, 1 garages community, 14 unions, 12 art associations and 14 apartments (orange) in Lithuania (developed by the authors).

The findings offer digital energy community concept for policymakers, grid operators, and community organizers seeking to implement resilient and efficient energy-sharing systems in Lithuania. This research supports the development of optimized renewable energy communities (REC) and citizen energy communities (CEC), promoting a transition toward decentralized and sustainable energy management strategies. The growing importance of enhancing local energy resilience and independence underlines the need to integrate and explore energy sustainability at local and regional levels. It can be done using an energy community framework to get additional benefits for community members and ensure a resilient, efficient, and sustainable energy future.

Keywords: Renewable Energy Community, Citizen Energy Community, Digital Energy Community, Power Balance, Modelling, MATLAB.

ENERGY EFFICIENCY ANALYSIS OF CLIMATE-NEUTRAL BUILDING DESIGN IN THE LITHUANIAN CONTEXT

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ABSTRACT

The reduction of greenhouse gas emissions and adherence to stringent energy performance standards have increasingly focused attention on the building sector. In this context Europe's ambition to become a climate-neutral continent underscores the need to investigate the design criteria and performance metrics that could define climate neutral buildings. Although the highest energy performance classification for buildings in Lithuania is A++, this rating denotes high energy efficiency but does not automatically ensure climate neutrality, which requires addressing factors such as carbon emissions from energy sources and building operations. This research forms part of the Applied Research project “Climate Neutral Buildings in Lithuania,” which contributes to the preparatory phase for proposals under the Horizon Europe Mission on “Climate Neutral and Smart Cities”. By employing IDA-ICE modeling software, the study seeks to develop a numerical algorithmic model that evaluates and enhances the energy efficiency of high-performance residential building designs and identifies the necessary conditions to achieve climate neutrality in the Lithuanian context.

The study employs IDA-ICE simulation software to construct an algorithmic model that quantitatively assesses the energy performance of high-efficiency buildings. The methodology involves:

* Developing a detailed virtual representation of an A++ class building.

* Incorporating comprehensive simulation parameters that represent energy consumption profiles, thermal dynamics, and renewable energy integration under Lithuanian climatic conditions.

* Utilizing dynamic simulation techniques to evaluate thermal performance, energy flows, and interactions among building systems.

The study concludes that a simulation-based algorithmic model can serve as a quantitative tool for evaluating energy performance in high-efficiency buildings. The results demonstrate that the model can predicts building performance across a range of climatic scenarios, thereby enabling the identification of effective strategies for reducing energy consumption and emissions. A detailed, dynamic simulation framework is essential for the quantitative assessment of design modifications aimed at achieving reduced carbon footprints. Finally, these findings contribute to the foundational knowledge required to establish energy performance metrics for climate-neutral building standards, in alignment with European objectives for climate neutrality.

Keywords: Energy Efficiency, Climate-Neutral Buildings, IDA-ICE Simulation, Thermal Performance, Renewable Energy Integration, Carbon Emissions

EQUIVALENT CIRCUIT MODELS FOR LITHIUM-ION BATTERY CELL AGING ESTIMATION: REVIEW AND DEVELOPMENTS

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ABSTRACT

Lithium-ion batteries are widespread in home appliances, portable electronics and electric vehicles. The high energy density boasted by lithium-ion batteries allows them to be compact, while also effective for energy storage. The long-life cycling of these batteries makes them appealing not only for commercial electronics, but also for use in grid energy storage. However, the aging process of a lithium-ion battery, described by the degradation of energy storage capacity and output current, inhibits long-term usage of these batteries and poses safety risks for the consumer.

Real-time monitoring of key battery quality indicators such as the state of charge (SOC) and state of health (SOH) is essential for optimizing the remaining useful life and determining the end-of-life of a battery, which in turn decreases resource consumption for replacement manufacturing. Various models, simulating the working processes within a battery, have been proposed in scientific literature over several decades with the goal of estimating the quality of the battery and predicting its remaining lifespan. These models range from material level electrochemical process simulations to entire battery module aging approximations using readings of individual cells.

This study focuses on equivalent circuit models (ECM) which are used to model lithium-ion batteries at the cell level utilizing time-dependent measures of current, voltage and impedance. These models are characterized by relatively simple mathematical expressions and realization, which allows for implementation within battery management systems (BMS) for real-time diagnostics. The review covers ECMs, their strengths and weaknesses, as well as improvements proposed in the literature. Findings show that ECMs are highly accurate and are widely used in online SOC estimation due to simple calculations. However, these models require large amounts of data to train. Often, accelerated aging data is used to train ECMs, but this proves detrimental to model accuracy when real testing data is used. Finally, cell level models such as the ECM tend to generalize the factors influencing the aging process: some degradation at the material level is left unexplained.

The study concludes with an introduction of a novel ECM application with state-space Bayesian parameter estimation. The relationship between SOC and open circuit voltage (OCV) is fitted to a curve, which changes as the battery ages and is therefore useful to estimate for diagnostics. Initial parameter identification and subsequent updating with aging battery data is performed using a combination of Markov Chain Monte Karlo and particle filter methods. The approach is compatible with dynamic battery data and therefore is useful for monitoring the health of a battery in commercial use. Model implementation within a BMS is challenging due to required computational resources, however, calculation acceleration and distributed computing opportunities are discussed.

This research was funded by the Research Council of Lithuania using student research project No. S-ST-24-115 funds.

Keywords: lithium-ion batteries, equivalent circuit models, battery management systems, state-space models, Bayesian methods.

FANO-RESONANT OPTICAL COATINGS FOR INCREASING EFFICIENCY OF HYBRID THERMAL-ELECTRIC SOLAR ENERGY HARVESTING

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ABSTRACT

Photovoltaic (PV) cells suffer from loss of efficiency and longevity due to thermalization of electrons caused by ultraviolet light and heating of the cell caused by below-bandgap infrared photons [1]. Spectrally selective reflectors/absorbers can reduce undesirable light illuminating the photovoltaic cell, contributing to its useful lifespan and efficiency of the PV-coating system [1]. Fano-resonant optical coatings (FROCs) [1] have proven to be highly effective in increasing both of these characteristics by acting as selective reflectors and selective absorbers. A FROC must be composed of four layers, which, from the top, are: a thin (<50 nm) layer of lossy dielectric, an extremely thin (<20 nm) layer of metal, a thick (>50 nm) layer of low-loss dielectric and an extremely thick (>100 nm) layer of metal [1].

Reflectance and absorbance of FROCs was computed using transfer matrix method [2]. Refractive index dispersions of real materials were taken from scientific literature to ensure realistic results of simulations. Iteration of structural parameters and different materials was used to explore the parameter space of FROCs and relate their parameters to optical and thermal performance. Using particle swarm optimization [3], a numerically-estimated physics-based fitness function was minimized to obtain parameters of FROCs which are optimal for hybrid thermal-electric power generation.

FROCs were designed for single and multi-junction PV cells. The FROC worked as a spectrally selective absorber – it absorbed and converted into heat what the PV cell would not absorb. Several optimal FROC designs were obtained through optimization – some were more beneficial in terms of absorbance of thermal radiation while others had better selectivity in reflectance of PV cells. Efficiency of hybrid thermal-electric power generation was numerically estimated using the "AM 1.5 G" solar spectrum [4]. The highest estimated absorption efficiency of FROC was 31.53% while the estimated hybrid thermal-electric power generation efficiency of that PV cell – FROC system was 57.60% (Figure 1).

The authors designed selectively reflecting thin solid optical coatings optimized for solar absorption outside of the photovoltaic range. The designed coatings have been numerically estimated to increase the solar harvesting efficiency of a hybrid thermal-electric power system consisting of a photovoltaic cell and a Fano resonant optical coating.

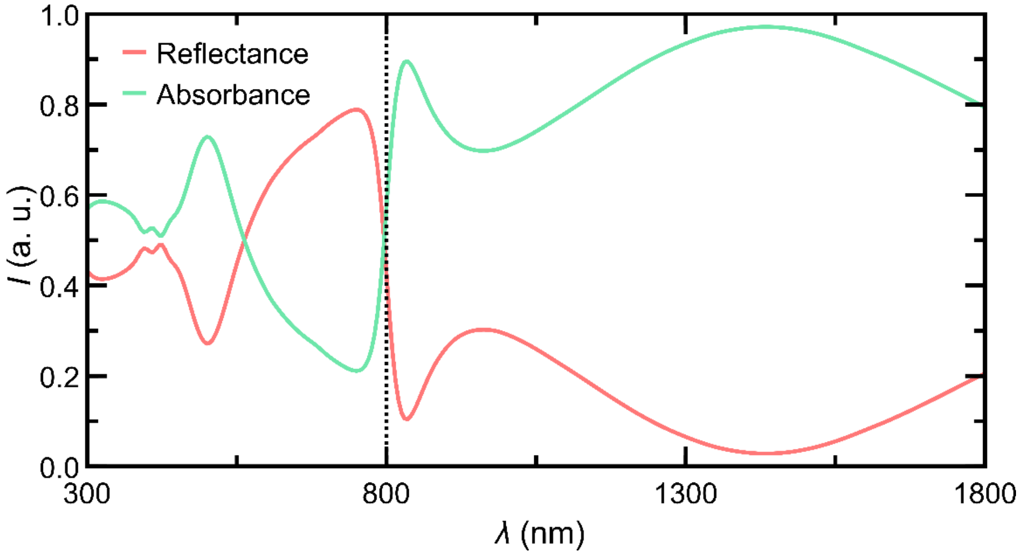

***Figure 1** Reflectance and absorbance spectra of Fano resonant optical coating optimal for solar absorption beyond the photovoltaic range of an amorphous silicon solar cell. The FROC is composed of GaAs (67 nm, top layer), Ni (19 nm), Ta_2O_5 (165 nm), and Ag (100 nm, bottom layer).*

Keywords: photovoltaics, spectrally selective coating, Fano resonant optical coating

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RESILIENCE, RELIABILITY, RISK, AND SECURITY IN DISTRICT HEATING SYSTEMS: EXPLORING PARALLELS AND CONTRASTS

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ABSTRACT

In scientific and engineering disciplines, precise terminology is crucial for accurate communication and interpretation of research findings. However, overlapping definitions and inconsistent use of key concepts can lead to flawed analyses and misguided decision making. This issue is particularly pronounced in the evaluation of critical infrastructure systems such as district heating, where different methodologies may yield varying assessments of system performance and vulnerability. This study aims to clarify the similarities and differences between the commonly used concepts of resilience, reliability, risk, and security, as well as their application in the evaluation of district heating systems (DHS) found in the most recent scientific literature. DHS are increasingly important in urban energy planning, offering benefits such as improved energy efficiency, reduced emissions, and integration with renewable energy sources [1]. The transition to fifth-generation district heating systems (5GDHS) introduces new capabilities, including decentralized energy exchange [2] and the use of lower-temperature heat sources [3]. However, as these systems evolve, so do the challenges associated with increased complexity, reliability, resilience, and security (increased complexity of components and automatization may result in increased mechanical and software failures). DHS face a variety of threats, including extreme weather conditions [4], technical malfunctions, cybersecurity vulnerabilities [5], and geopolitical disruptions [6]. Recent cases, such as cold waves causing heating demand disruptions [7], underscore the importance of assessing DHS resilience. Likewise, cyberattacks on energy grids highlight the growing need for robust security measures. The failure of a DHS can have severe consequences, particularly in colder regions where heating is essential for public health and survival. Thus, a comprehensive evaluation framework is needed to anticipate and mitigate such risks effectively. Understanding the key concepts used in DHS assessment is essential for ensuring system security and sustainability in the face of emerging threats. However, resilience, reliability, risk, and security are often used interchangeably [8], despite their distinct meanings. Reliability refers to a system's ability to function under normal conditions, whereas resilience encompasses its capacity to recover from disruptions [9]. Risk assessment focuses on identifying potential hazards and their likelihood, while a widely accepted definition of security in this context, provided by the International Energy Agency, is "the uninterrupted availability of energy sources at an affordable price" [10]. Misinterpreting such concepts can lead to ineffective policies and resource misallocation [11]. For instance, prioritizing reliability without considering resilience may result in a system that functions well under normal conditions but collapses during crises. Over-reliance on a single metric, such as reliability, may lead to underestimating vulnerabilities that become critical during extreme events. Similarly, misinterpreting security risks can result in inadequate cybersecurity measures, exposing DHS to attacks. A notable example is the failure to anticipate cascading failures in interconnected heating networks, where a localised issue escalates into a widespread outage [12]. Addressing these challenges requires a clear understanding of evaluation methodologies and their appropriate application to prevent overconfidence or neglect in system assessments. The ability to identify failure points and assess potential disruptions is crucial, particularly in colder regions where heating is a necessity rather than a convenience. Ensuring the resilience and security of DHS requires a precise and standardized approach to system evaluation. By clarifying the definitions and appropriate applications of key assessment methodologies, researchers and practitioners can improve decision-making and risk mitigation strategies. Thus, establishing clear definitions and standardized methodologies is vital to ensuring accurate and reliable DHS assessments, ultimately contributing to the development of more resilient, secure, and efficient heating systems.

Keywords: Resilience, Reliability, Risk, Security, District Heating Systems (DHS)

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UPGRADING OF THE WAX-LIKE LIQUID PRODUCT DERIVED FROM THE PYROLYSIS OF WASTE PLASTIC

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ABSTRACT

In recent years, thermal energy storage (TES) systems have emerged as an effective solution to ensure the sustainability of renewable energy sources and meet energy storage demands. These systems enable the heat energy storage through three primary mechanisms: sensible heat storage, latent heat storage (LHS), and thermochemical energy storage. Among these technologies, LHS, which utilizes phase change materials (PCMs), stands out due to its high energy storage capacity during solid–liquid phase transitions. In particular, paraffin waxes are widely used owing to their favorable melting behavior, high chemical stability, and low cost. On the other hand, more than 350 million metric tons of plastic waste are generated globally each year, and this amount is projected to triple by 2060. Common waste plastics, such as low-density polyethylene (LDPE), can be converted to products with properties similar to commercial paraffin waxes through thermal transformation methods like pyrolysis. Consequently, their use as substitutes for commercial PCMs aligns with sustainable waste management principles. In this study, N, N-dimethylacetamide (DMA) was employed to enhance the applicability of the liquid product obtained from the pyrolysis of waste plastics (LDPE) as a PCM. The PCM products were analyzed using GC-MS and DSC techniques and subsequently compared with commercial paraffin wax. The analyses revealed that the properties of the upgraded PCM using DMA closely approximate those of commercial paraffin wax.

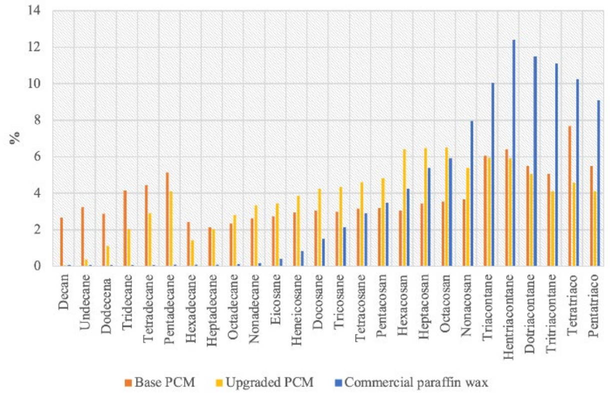
Introduction: TES has become increasingly important in ensuring the sustainability of renewable energy sources and preventing heat from being released into the environment as waste heat. TES methods are classified into sensible heat storage, thermochemical energy storage and, latent heat storage. In a LHS system, substances that store or release energy through phase transition are referred to as PCMs. Among various types of PCMs, paraffin waxes are widely preferred due to their advantageous properties [1]. Composed mainly of straight-chain n-alkanes, paraffin waxes exhibit high LHS capacity and provide high energy storage density relative to their low mass. They also demonstrate favorable melting and solidification behavior with minimal supercooling. Furthermore, paraffins are chemically stable and resistant to reactions with most substances [2], [3]. However, as they originate from fossil-based resources, their carbon footprint and environmental impact remain significant concerns. To mitigate carbon footprint and environmental impacts, wax production from polyolefins via thermochemical conversion (i.e. pyrolysis) techniques offers a sustainable alternative. LDPE, a type of polyolefin plastic, constitutes a significant portion of municipal plastic waste. In this study, the wax-like liquid product obtained from the pyrolysis of waste LDPE was upgraded using DMA and subsequently compared with commercial paraffin wax.

Materials and Methods: The pyrolysis experiments were realized with a stainless steel fixed-bed reactor (240 cm^3) under atmospheric pressure with a continuous nitrogen gas flow. A homogeneously prepared 30 g sample of waste LDPE was subjected to pyrolysis at 450°C, with a controlled heating rate of 10°C/min. Following the experiment, wax-like liquid (the base PCM), which accumulated in the liquid collection containers, was collected using dichloromethane as the solvent. Subsequently, the solvent was removed using a rotary evaporator to obtain the base PCM.

The base PCM derived from waste LDPE was upgraded with DMA. For this, 5 g of the obtained wax was dissolved in 50 mL of DMA and stirred in a water bath at 50 °C for 1 hour. The resulting solution was then filtered to remove insoluble impurities. Characterization studies were carried out by GC-MS and DSC for the base/upgraded PCMs and commercial wax? GC-MS analyses were conducted utilizing an alkane standard with a calibration certificate (Dr. Ehrenstorfer, Alkanes Mix 10, Lot no. 90703TO). DSC measurements were conducted using a SETERAM Labys TG-DTA/DSC instrument.

Results and Discussion: Figure 1 shows the alkane fractions of base PCM, upgraded PCM and commercial paraffin wax.

Alkanes were categorized based on their chain length into short-chain alkanes (C10–C15), medium-chain alkanes (C16–C20), and long-chain alkanes (C21 and above). Commercial paraffin waxes primarily consist of alkanes with carbon numbers ≥17 [4]. The GC-MS analysis revealed that the produced base PCM exhibited high proportions of both short-chain and long-chain alkanes (Figure 1). The extraction process resulted in a 46.9% decrease in short-chain alkanes in the base PCM, with long-chain alkanes constituting 76.39% of the total fraction. Furthermore, all hydrocarbon compounds identified in the liquid products were determined to be heavy hydrocarbons and their derivatives [5]. These findings suggest that the chemical composition of the produced wax closely aligns with that of commercial waxes.



Chain lengths	Base PCM (%)	Upgraded PCM (%)	Commercial paraffin wax (%)
Short-chain alkanes	22.51	10.57	0.45
Medium-chain alkanes	12.24	13.04	0.86
Long-chain alkanes	65.25	76.39	98.68

Figure 1 Alkane fractions of base PCM, upgraded PCM and commercial paraffin wax.

In the DSC graph of the upgraded PCM (Figure 2), a peak was observed at 42.6°C, corresponding to a heat flow of -0.6474 mW/mg. This peak indicates the phase transition (melting temperature) of the sample. The area under this peak, measured as -42.74 J/g, represents the phase transition energy, which corresponds to the energy absorbed by the material during its phase change. Similarly, in the DSC graphs of the base PCM and commercial paraffin wax, peaks were observed at 54.8°C and 62.4°C, respectively, with heat flows of -0.9278 mW/mg and -1.574 mW/mg. The areas under these peaks, measured as -77.17 J/g and -178.5 J/g, respectively.

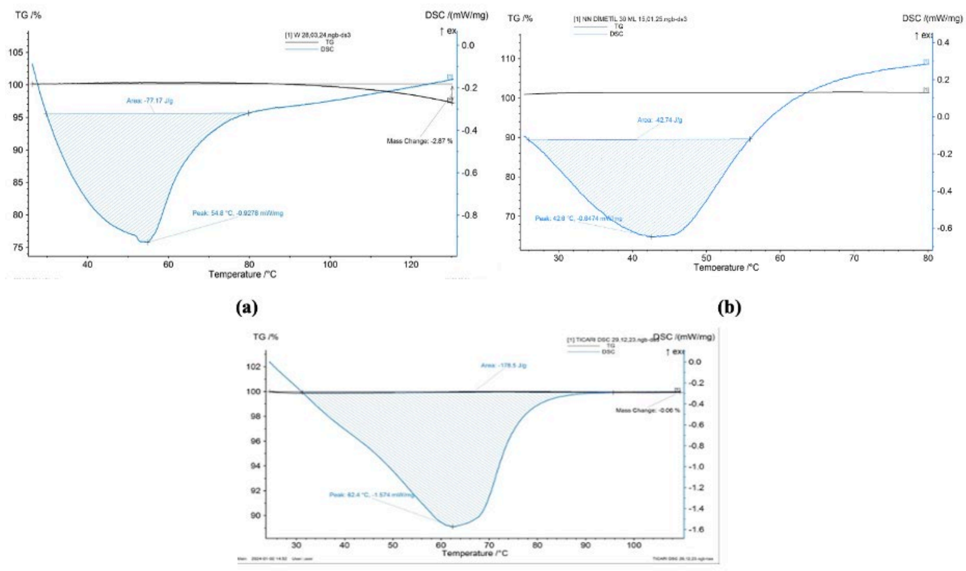


Figure 2 DSC graphs of base PCM (a), upgraded PCM (b) and commercial paraffin wax (c).

Conclusion: In this study, LDPE pyrolysis liquid product was upgraded by using DMA. As a result of this upgrading process, it was determined that the structure of the upgraded PCM was similar to that of commercial paraffin wax. The short-chain alkanes in the base PCM decreased, while long-chain alkanes constituted the majority of the total fraction. DSC analyses indicated that the latent heat capacity and melting temperature of the upgraded PCM were lower. A decrease in the melting temperature to 42.6°C has been observed, suggesting that the obtained upgraded PCM may be suitable for thermal management in lithium-ion batteries, which operate in the 20-40°C range, with performance declining outside of this temperature range.

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Keywords: LDPE, paraffin wax, phase change material, pyrolysis

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DETERMINATION OF SURFACE TEMPERATURES OF SOME AGRICULTURAL PRODUCTS USING ELECTROHYDRODYNAMIC, HOT AIR, AND ELECTROHYDRODYNAMIC-HOT AIR METHODS

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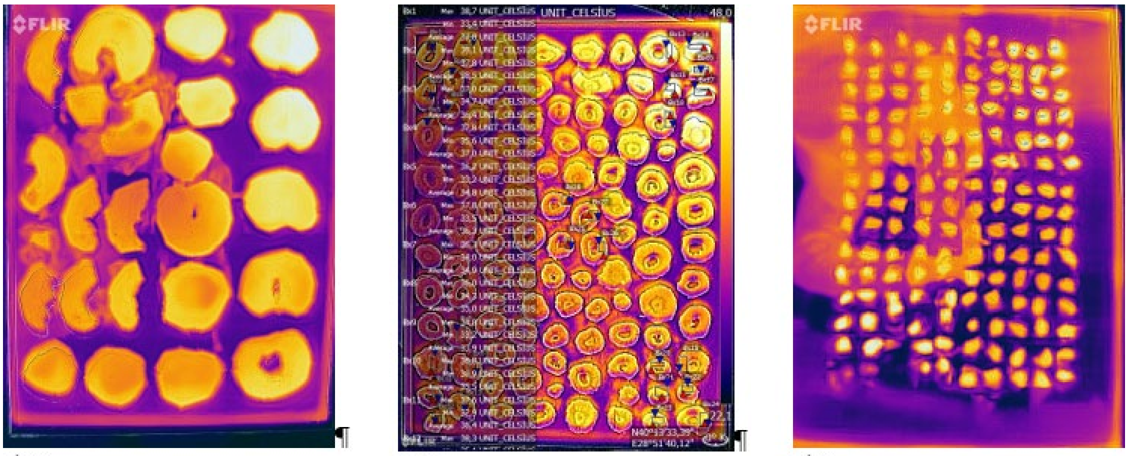
ABSTRACT

Fruits and vegetables play an important role in human health with their nutritional value and essential bioactive components. After harvest, they are subject to rapid deterioration with high respiration, weight loss, and a tendency to microbial contamination. In this respect, products are processed, transformed, and preserved in different forms. One of the most important and oldest of these preservation methods is drying. Hot air drying has come to the fore as a widely used drying method for drying agricultural products for many years. However, since the operation of this method at high temperatures causes damage to the nutritional properties of the product, it is considered to be one of the disadvantages of the method. Different non-thermal drying methods have recently been studied to prevent quality loss, especially in sensitive foods. The Electrohydrodynamic (EHD) drying method stands out as a heat-sensitive method. The method is based on the principle that a secondary flow called corona wind, which is obtained by applying high voltage to a curved electrode such as a needle, wire, or pin, disrupts the boundary layer of the biological material and increases the evaporation rate of moisture. As a result of the previous scientific studies, the disadvantage of the EHD drying method is the drying time's length. It has been reported that it may be helpful to combine the traditional drying method to accelerate the drying process and to help transport moisture to the surface [1]. Following this direction, the new equipment has been developed by utilizing the advantages of the two methods.

In this study, strawberry, peach, and ginger samples were dried using EHD, hot air, and EHD-hot air combined method, and their surface temperatures were measured using a thermal camera. In the study, 20 and 30 kV values for the EHD method, 50 and 55 °C temperatures for the hot air method, and 20 kV-50 °C, 20 kV-55 °C, 30 kV-50 °C, 30 kV-55 °C were applied for EHD-hot air combined method.

The lowest temperature values for all products were found in the products dried using the EHD method. The temperature values of the samples dried by the EHD method (20 and 30 kV) decreased below the product inlet temperature at the end of the first two hours of drying and reached the product inlet temperature value at the 3rd hour of drying. After this hour, the product temperature gradually approached the ambient air temperature. After this time, the product temperature gradually approached the ambient air temperature. In the hot air method, the surface temperatures of the products reached 41.10 °C - 46.13 °C (strawberry), 42.34 -52.29 °C (peach), and 34.16 - 37.05 °C (ginger) for the 50 and 55 °C hot air method, respectively. As expected, the increase in drying temperature increased the product surface temperature. In the EHD-hot air combined method, the surface temperature value of the samples dried at 20 kV-50 °C and the surface temperature value of the samples dried at 30 kV-50 °C at the same temperature decreased as the volt value increased. In addition, as in the hot air drying method, the product temperature increased as the temperature value of the samples dried at the same volt value increased. The final temperature of the products dried with 50 °C was lower than those dried with 20 kV-50 °C and 30 kV-50 °C. The same situation was observed in the products dried at 55 °C. Considering the same drying temperature, the final temperature of the product was higher in the EHD-hot air combined method than in hot air.

As a result, it was determined that the surface temperature of the product dried by the EHD method was lower than the hot air and EHD-hot air combined method At the end of drying in the EHD method, the final temperature of the products reached the ambient temperature. The fact that the electrohydrodynamic (EHD) method does not require heat input makes this method a remarkable alternative for the drying industry, especially in the drying of heat-sensitive foods.



a) b) c)

Figure 1 Thermal images of a) peach, b) strawberry, and c) ginger.

Keywords: Electrohydrodynamic, surface temperature, thermal camera, drying.

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OPTIMIZATION OF WASTE HEAT RECOVERY: EXPERIMENTAL ANALYSIS OF HEAT TRANSFER AND CONDENSATION DYNAMICS

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ABSTRACT

The utilization of waste heat in industrial processes is essential for enhancing production efficiency and aligns with the principles of the circular economy. Recovering and repurposing waste heat improves resource efficiency while mitigating environmental impacts. The European Union actively promotes the adoption of energy-efficient technologies to minimize waste heat generation, thereby reducing energy costs and maintaining industrial competitiveness. Enhancing energy efficiency not only contributes to pollution reduction but also aligns with broader environmental objectives. Lithuania's energy strategy places a strong emphasis on electricity, heating, and energy efficiency, particularly in promoting energy generation from waste sources. Such initiatives support both economic growth and environmental sustainability. EU-funded Horizon 2020 projects, such as Innovative WAter recoverY Solutions (iWAYS), further advance waste heat recovery technologies by integrating heat, material, and water recycling across multiple industrial sectors.

The Nuclear Engineering Laboratory (NEL) at the Lithuanian Energy Institute (LEI) has conducted experimental investigations using a specialized setup designed to analyze heat exchange and condensation processes for the optimization of waste heat recovery. This setup includes a serpentine heat exchanger through which both hot and cold fluids circulate. The hot fluid consists of dry air with controlled steam injection, creating a humid air flow around the serpentine heat exchanger. Meanwhile, municipal water serves as the cold fluid, flowing through the serpentine to facilitate heat exchange.

The experiments aim to assess the influence of key parameters, such as the inlet temperature of humid air (ranging from 80°C to 200°C) and its mass fraction (10% to 20%), under a Reynolds number of 5000 and a flow rate ratio of 3:1 (cold to hot fluid). By systematically varying these parameters, we seek to understand their impact on fluid behavior and condensation efficiency under different operating conditions. Local heat transfer experiments enable precise data collection on heat transfer dynamics and condensation mechanisms.

Findings from these experiments highlight the critical role of humid air inlet temperature and mass fraction in the design of condensing heat exchangers. Under specific operating conditions, these parameters significantly influence heat transfer and condensation efficiency, making them crucial considerations for optimizing heat exchanger performance in various industrial applications.

Keywords: Waste heat recovery, heat exchanger, condensation, condensation efficiency.

ANALYSIS OF ENVIRONMENTAL PROTECTION ASSESSMENT IN INDUSTRIAL HEATING SYSTEMS

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ABSTRACT

Industrial heating systems are a significant contributor to global emissions, requiring a shift towards more sustainable technologies and environmental protection increase. Analyzing the environmental protection increase of industrial heating systems is important to promote sustainable practices in industrial facilities and reduce greenhouse gas emissions. Technologies are constantly being improved, and new methods are being developed. These are all ways to reduce environmental impact. One of the methods is the integration of advanced control units such as proportional integral controllers, variable frequency drives and secondary heat utilization to optimize the energy consumption and heat capacity of pumps, water and steam systems by improving their efficiency in terms of environmental protection [1].

Electrifying industrial processes presents a feasible substitute for traditional thermal energy sources, particularly for heat pumps, water heating, flue gas recovery, and steam systems. These technologies are crucial for minimizing primary energy expenses and recovering secondary heat. They significantly increase the sustainability of industrial operations. The adaptation of renewable energy heat sources, such as solar systems, and their use in hybrid models is a key aspect of industrial modernization. These systems can reduce the usage of traditional fossil fuels and contribute to a more sustainable energy mix. Extracting excess heat from industrial processes is a promising strategy to improve energy efficiency and reduce primary energy demand by integrating additional process equipment. Systems using excess heat are considered resource efficient as they can reduce the production of secondary gases and increase the efficiency of the plant in delivering heat to consumers. [2] Secondary heat recovery technologies have been widely researched and deployed, particularly in the European Union, where they contribute to energy savings and sustainability [3]. Developing environmentally sustainable technologies and obligating businesses to adopt them may not always be the best choice, but in the face of EU standards, industry must evolve and introduce completely new technologies or adapt existing systems with environmentally friendly equipment that not only improves environmental performance but also saves energy resources.

In summary, the environmental assessment of industrial heating systems requires a multifaceted approach that includes advanced technologies, renewable energy sources and waste heat recovery strategies. One of the main reasons for energy savings in heating and heat supply systems – is the application of thermal insulation that meets the specified requirements for pipelines, storage tanks and heat generating equipment. By focusing on these areas, industrial companies can significantly reduce their costs and environmental impact while contributing to a more sustainable future.

Keywords: energy, heat, environmental

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1.5. Energy Economics and Policy

MODELING THE IMPACT OF UNCERTAINTY FACTORS ON THE DEVELOPMENT OF DISTRICT HEATING

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ABSTRACT

The energy sector is currently experiencing a major transformation, with a significant increase in the number of intermittent RES, fluctuations in energy prices, and the emergence of new participants in the DH market. DH might play an important role in the introduction of new technologies such as Power-To-Hydrogen, Power-To-Heat and heat storage solutions for balancing supply and demand in energy systems and creating synergies between electricity and district heating, contribution for decarbonization of other sectors. All innovative heat generation solutions may have a high potential to contribute to the integration of RES, but their impact on the heat supply system is unclear due to a number of uncertainties. These uncertainties include fluctuations in electricity, biofuel and natural gas prices, as well as new investments in heat generation and transformation facilities, such as investments by operators in wastewater heat pumps of different capacities, biofuel water heating boilers, solar collectors with storage systems, the integration of flexibility technologies through investments in electric boilers, investments in Power-to-H2 and Heat solutions, investments in seasonal PTES-type heat storage capacities, Power-to-Heat solutions (air-to-water heat pumps), the emergence of investments by independent heat producers in biofuel boilers. It is therefore essential to have a comprehensive planning methodology that would help to ensure a sustainable least-cost heat supply system. In current energy planning practice, most models are deterministic, ignoring uncertainty and relying on long-term forecasts of important parameters. A more comprehensive and complex approach might be achieved by extending deterministic methods with uncertainty stochastic methods. These approaches enable more reliable and robust energy strategies, potentially achieving carbon neutrality and energy autonomy while accounting for various uncertainties in the planning process. However, in the context of the DH sector, there is a lack of knowledge and adaptability of stochastic approaches that would evaluate a wider perspective of uncertainties - economic, strategic, and technological. Therefore, this research contributes with the main aim to develop and apply a methodology for integrating uncertainty factors into partial economic equilibrium model to find least-cost decarbonization scenarios for district heating. To this purpose, an integrated conceptual framework is developed, including economic modelling of district heating in a selected city (Vilnius) with sensitivity and uncertainty analysis. The novelty and uniqueness is revealed by extension of the model with Monte Carlo sensitivity and uncertainty analysis which leads to the identification of optimal solutions for the reduction of heat costs and CO2 emissions. The obtained results demonstrate that the highest impact on the reduction of heat auction costs has the operator investments in air-water type compression heat pumps and renewable energy generation complex equipment of wind turbines, a PEM-type hydrogen electrolyzer, and an industrial compression heat pump for the recovery of waste heat from electrolyzer into DH network. It is worth to emphasize that the partial equilibrium model combines the electricity, district heating and hydrogen sectors in a single conceptual case, by producing three different products - green electricity from wind farms, hydrogen and waste heat from an electrolyzer. In order to maximize the investor financial profitability, it is assumed that the wind farms would operate independently from H2 and waste heat generation sources, by selling green electricity to the market. Meanwhile, the hydrogen and waste heat production would be organized by using the spot market price of electricity. The volatility of the operator costs would be mitigated and eliminated by the green hydrogen production, which would diversify the risks of competing in the DH sector by selling the waste heat in auction system. Additional financial revenues would be obtained from the green electricity produced by wind turbines. Based on the developed partial equilibrium model, an iterative process was performed which helped to find the least cost and the most profitable new energy units combination in the DH system in the face of uncertainty. The model also demonstrates unique capabilities for comprehensive evaluation of potential financial risks to other existing DH market participants regarding upcoming new possible green generation and transformation solutions.

Keywords: District heating, Power-to-Heat, Power-to-Hydrogen, Energy planning, Sensitivity and Uncertainty analysis

GREEN WORKFORCE DEVELOPMENT: A POLICY AND ECONOMIC APPROACH TO SUSTAINABLE ENERGY TRANSITION

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ABSTRACT

Developing a Green Workforce in Energy Policy and Economics, as governments and corporations strive for long-term profitability while reducing their environmental impact, sustainability has emerged as a key issue in energy policy and economics. Green Workforce Development (GWD), which improves skills in resource optimization, energy efficiency, and renewable energy management, is essential to incorporating sustainability into the energy industry. Green Workforce Development's Contribution to the Energy Transition. In order to support energy efficiency initiatives, carbon reduction plans, and circular economy practices, green workforce training aims to increase employees' technical proficiency and policy awareness. Adoption of renewable energy, smart grid deployment, and sustainable resource management are highlighted in effective training programs, creating a workforce that can spearhead the clean energy transition. By creating a trained workforce capable of overseeing low-carbon technology and green supply chains, investments in GWD support economic expansion and energy security. Green training has several financial advantages, such as reduced operating expenses, increased resource efficiency, and long-term sustainability improvements. Furthermore, improving workforce development in the energy sector boosts a company's brand and draws in investors and legislators who are concerned with environmental, social, and governance (ESG) issues. Obstacles in the Development of Green training programs face many obstacles despite their advantages, including high implementation costs, opposition to changing policies, and a lack of regulatory incentives. Furthermore, in a time of rapid technological advancement, energy companies frequently find it difficult to ensure staff adaptability and align training programs with changing regulatory frameworks. Governments and corporations must include green workforce development into national and corporate energy policy in order to improve sustainability performance and economic competitiveness. Policies should support public-private partnerships, tax breaks, and subsidies to enable widespread worker upskilling in renewable energy technology. Constant funding for green worker training would guarantee a robust energy sector that can meet climate goals and promote long-term economic viability [1-5]. In order to investigate the proposed correlations, descriptive statistics, exploratory factor analysis (EFA), and structural equation modeling (SEM) were used to examine 278 valid replies using SPSS and AMOS. Furthermore, ten senior HR managers participated in qualitative interviews that offered contextual information about implementation difficulties and strategic significance.Green organizational citizenship conduct ($\beta = 0.36$, $p < 0.05$), firm-level environmental performance ($\beta = 0.33$, $p < 0.05$), and employees' pro-environmental behavior ($\beta = 0.41$, $p < 0.01$) are all positively correlated with green training activities. According to the results of the interviews, companies who adopted GTD saw increases in employee engagement, financial savings from energy efficiency, and improved organizational reputation. However, obstacles such a lack of support from upper management, opposition to change, and the high cost of implementation were frequently mentioned.

Keywords: Green Workforce Development (GWD), ESG, Circular economy practices

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RETHINKING REGIONAL CONVERGENCE IN THE CONTEXT OF GREEN TRANSITION: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Introduction. Over the past decade, convergence research has gained increasing attention in the context of economic growth and the reduction of socio-economic disparities among countries and regions. Economic convergence theory (Sala-I-Martin & Barro, 1992) supports the effectiveness of cohesion policy when regional disparities decrease. However, this process is highly context-dependent and influenced by factors such as institutional frameworks, local business development, environment, healthcare and education systems, innovation, etc. [1; 3; 5; 6], which leads to mixed results, especially at regional level. The European Union's strategic goal of achieving climate neutrality by 2050 adds a additional dimension to the convergence process - CO_2 minimization, which makes the process itself more dynamic and challenging. Furthermore, this transition may create a 'winners and losers' dynamic, where some countries gain economic benefits while others become stuck in development traps, ultimately slowing convergence and widening disparities [2]. Such context calls for a deeper understanding and rethinking of convergence within the framework of the green transition. Despite growing scientific interest in convergence, research on economic transitions to a low-carbon model remains fragmented. Different studies focus on various economic levels, apply diverse mathematical methods, and use different indicators, leading to inconsistent findings. The aim of this research is to provide a systemized analysis of existing convergence methodologies, approaches, and indicators, specifically in the context of the green transition.

Methodology. To address this gap, a systematic literature review (SLR) was conducted following the PRISMA methodology (version 15). The analysis spans a 12-year period and draws from two leading indexed journal databases: Scopus and Web of Science. The reviewed literature covers research fields in economics, environmental studies, and the energy sector, with a particular focus on the low-carbon economy. The selection of articles was guided by the PICO framework and predefined inclusion criteria. A specialized keyword taxonomy was employed to refine the selection process, incorporating terms such as convergence, divergence, economic growth, and carbon. Based on these criteria, 321 unique articles were initially identified, of which 99 were deemed relevant for in-depth analysis. The robustness of the selection process was validated using Cohen's Kappa coefficient, which yielded a reliability score of 0.8, indicating strong agreement.

Findings & Implications. The research showed that at the majority of scholars tend to examine this topic at the national or country level (51 percent of the sample), 34 percent of the entire sample analyses convergence process at regional, provincial, or state level. Convergence at the urban level is starting to gain attention. The research identified four main thematic clusters that structure the current discourse on convergence research: energy efficiency-driven convergence; Determinants of decoupling, Methodological frameworks, and Empirical convergence Findings.

We found that, in the context of a low-carbon economy, the focus of convergence has expanded beyond GDP to include CO2 emissions, either assessed separately or in relation to the GDP/CO2 ratio. Additionally, we discovered that the determinants of regional convergence have broadened to encompass a wider range of factors that characterize system complexity. We categorized these factors into ten dimensions: urbanization, economy, institutional regulation and support, energy, infrastructure, technology and innovation, natural environment, pollution, human health and education, and demographic and social factors. The research also showed that conventional methods for convergence, such as β- and σ-convergence models, club convergence analysis, dynamic panel data estimation, and spatial econometric techniques, are applicable to regional convergence in the context of the green transition. Furthermore, the methodology has been expanded to include qualitative approaches, such as case study analyses and comparative policy evaluations, particularly in studies focused on governance.

This research makes both academic and practical contributions. First, it adds to the growing body of convergence literature by systematically analyzing the methodologies, approaches, and indicators employed in convergence studies. Second, it clarifies the economic convergence theory by expanding its scope to include CO_2 emissions and their relationship with economic growth, providing a more comprehensive understanding of convergence in the context of a low-carbon economy. The research offers several policy implications, stressing the need to consider a broad range of factors - such as energy, technology, infrastructure, and governance - when assessing regional convergence in a low-carbon economy. While the review provides valuable insights into the current state of convergence research, it also acknowledges limitations, such as the potential bias from relying solely on indexed journals like Scopus and Web of Science, which may exclude relevant gray literature or non-English publications.

Keywords: regional convergence, economic development, low carbon economy.

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NET ZERO ROADMAPS OF THE BALTIC STATES: CHALLENGES FOR LITHUANIA, LATVIA AND ESTONIA

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ABSTRACT

The latest Intergovernmental Panel on Climate Change (IPCC) Assessment Report urges world countries to reach negative emissions by the middle of the 21st century to increase the chances of limiting global warming to the 1.5°C threshold above the pre-industrial level. Lithuania, Latvia, Estonia and approximately 100 other countries have pledged to reach carbon neutrality by 2050 to mitigate climate change. In addition, all three countries drew concrete plans to reduce greenhouse gas (GHG) emissions by 2030, as reflected in the Nationally Determined Contributions (NDC) pledges submitted to the UNFCCC by the European Union and its member states. This study attempts to analyse the critical points for the Baltic States to achieve carbon neutrality by 2050, discussing the opportunities to become carbon neutral a decade earlier and to reach reduction targets for 2030 under the current measures.

Firstly, the climate policy is assessed, and GHG emission reductions by 2030 are compared between NDC pledges, as reflected in the National Energy and Climate Action Plans (NECP) and First Biennial Transparency Reports (BTR), submitted in December 2024. This enables cross-sectoral comparison of GHG emission levels, assuming existing measures (WEM) and additional measures (WAM) scenarios. Secondly, the potential role of carbon absorption from land use and carbon dioxide capture, utilisation and storage (CCUS) is discussed. The reduction potential of the Land Use, Land-use Change and Forestry (LULUCF), or the offsetting potential, is calculated based on the historic emissions and existing studies. The potential for the CCUS-based reductions is based on the existing legal framework. The GHG tendencies in sectors other than Energy are compared as well. Finally, progress is evaluated and juxtaposed between the three Baltic States, highlighting the challenges in the post-2030 period, including the obstacles to reaching a net zero goal by 2050. The situation of the three countries is briefly compared with that of other EU member states.

The study finds out that even though Lithuania and Estonia will likely surpass their NDC pledges by 2030 even without additional measures, a lack of strategy to further decarbonise themselves after 2030 put the countries at risk of not reaching the pledged carbon neutrality objective by 2050 unless policies are significantly improved and the CCUS technologies are used. In addition, due to the projected net emissions from the LULUCF sector in Latvia, this country will likely fail to reach its pledge on time, even if additional measures are taken. This is despite overreaching the 2030 goal under the WEM scenario if the LULUCF sector is excluded. If Latvia fails to achieve its reduction pledges due to net emissions from the LULUCF sector, it may be among at least four to five EU countries failing to reach their 2030 targets. Paradoxically, Latvia is the only Baltic State and one of very few EU countries whose offsetting potential is larger than the projected emission levels by 2040 or 2050. Even though the most significant GHG emission cuts are expected in Estonia, the study projects the lowest total GHG emissions in Lithuania due to the carbon sinks from the LULUCF by 2040. Since CO_2 storage is prohibited under Estonian, Latvian and Lithuanian law, it is impossible to discuss the role of CCUS in meeting the post-2030 goals. The projection analysis concludes that in addition to the LULUCF sector for Latvia and Estonia, other sectors that could significantly contribute to the net zero goal earlier than anticipated are Agriculture (particularly for Estonia, also for Latvia and Lithuania) and Industrial Processes and Product Use (Latvia and Lithuania). Furthermore, only Latvia proposes effective reductions for Transport under the WAM scenario.

Keywords: Biennial Transparency Report, carbon neutrality, climate policy, decarbonisation, Nationally Determined Contribution, Paris Agreement.

CHARACTERISTICS AND EFFICIENCY OF SINGLE-PIPE HEATING SYSTEMS UNDER VARIOUS IMBALANCE MODELS

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ABSTRACT

Hydraulic imbalance in singlepipe heating systems remains a significant issue in older multi-apartment buildings, causing uneven heat distribution, reduced occupant comfort, and increased energy consumption. This study investigates the impact of various system configurations on heat distribution, energy efficiency, and comfort. Five scenarios are analyzed: an unbalanced system without thermostats or balancing valves, a system with thermostats only, a fully balanced system with thermostats and balancing valves, a system without balancing valves and with bypasses fully closed, and a system with balancing valves, thermostats, and return temperature control.

The research utilizes designing tools such as Sancom designing software and Wilo Select online configuration tool, applied to a real case study in Ukmergė, Lithuania, to evaluate energy consumption and hydraulic parameters under different configurations. The study concerns are renovation scenarios of the heating system in a multi-apartment residential building located at Anykščių g. 1, Ukmergė, Lithuania. The building consists of 30 apartments. Total heated area is 1,758.42 m². Results reveal that fully balanced systems with return temperature control significantly enhance energy efficiency, achieving up to 70% energy savings compared to unbalanced systems, while ensuring consistent temperature distribution and occupant comfort [Figure 1]. Renovating a single-pipe heating system and converting it from a constant to a variable flow regime remains a rare and insufficiently explored solution. This study investigates such a case, integrating return temperature control—an approach that is almost never applied in single-pipe configurations. The results demonstrate that even with additional hydraulic resistance introduced by balancing valves and thermostatic control valves, the system performs more efficiently. It consumes significantly less circulation energy than a constant-flow system without these components. Contrary to the common belief that additional hydraulic resistance reduces efficiency, this research shows that a well-controlled single-pipe system can operate more economically and effectively. Compared to findings by other authors—who report energy savings in the range of 10–30% by introducing thermostatic and balancing control mainly in two-pipe systems—this study provides new evidence that single-pipe systems, if properly modernized, can achieve comparable or even better energy efficiency while maintaining thermal comfort. This contributes a novel perspective to the ongoing discourse on energy optimization in old residential buildings.

This study underscores the necessity of implementing balanced and regulated heating systems, demonstrating their importance in achieving energy efficiency and sustainability goals in building renovation projects.

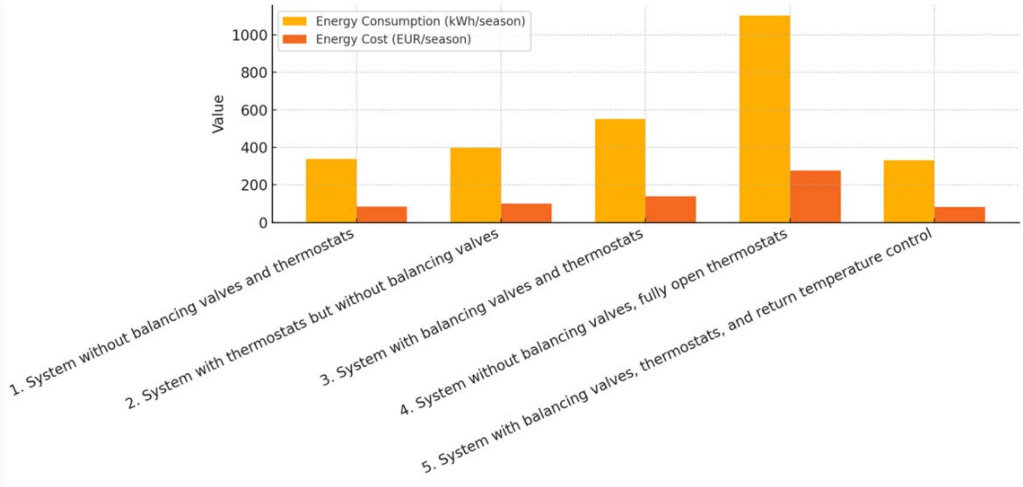

Figure 1 Circulation Energy Use and Cost Across Five Single-Pipe Heating System Configurations.

Keywords: Single-Pipe Heating Systems, Hydraulic Balancing, Return Temperature Control, Thermostatic Valves, Balancing Valves, Circulation Energy, Energy Efficiency, Residential Building Renovation, Thermal Comfort, Multi-Apartment Buildings.

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INTEGRATING CIRCULAR ECONOMY PRACTICES TO ENHANCE SUSTAINABILITY IN THE TEXTILE INDUSTRY

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ABSTRACT

The textile and apparel industry is a key pillar of the global economy, employing over 60 million people. It ranks among the most environmentally intensive sectors, contributing an estimated 8–10 percent of anthropogenic greenhouse gas emissions, which is more than the combined emissions of international aviation and maritime shipping[1]. The environmental impact of the textile industry is largely attributable to a linear "take – make - dispose" model, marked by brief production cycles, considerable resource utilization, and accelerated garment disposal. While circular economy strategies are increasingly considered, research indicates that eco-design is the most effective mechanism for diminishing the sector's environmental footprint. Eco-design entails the systematic integration of durability, disassembly, repairability, recyclability, and low-impact materials during the design process[2]. Life-cycle assessments show that doubling a garment's wear life can cut its climate impact by as much as 44 percent, while reusing just one kilogram of clothing avoids roughly 25 kilograms of CO_2-equivalent emissions[3]. Policy is beginning to align with this evidence: the European Union's proposed *Ecodesign for Sustainable Products Regulation* would make durability and recyclability baseline requirements for all textiles placed on the single market, signalling a global shift toward design-led circularity[4]. While there is growing policy interest, comprehensive analyses of eco-design implementation are still scarce. Most research focuses on individual materials or specific product lines, rarely considering systemic obstacles, supportive policies, or integrated environmental-economic results on a global scale. To fill this void, this study undertakes a systematic review of literature published between 2021 and 2025, using journal articles indexed in Scopus/Web of Science and reputable institutional reports (UNEP, ILO, European Environment Agency, Ellen MacArthur Foundation). The SPAR-4-SLR model provides a structural and methodological guide for this systematic literature review. By using this model, a transparent, rigorous, and replicable approach to identifying, selecting, and analyzing relevant studies is ensured. A thorough search of the Scopus and Web of Science databases identified 1,601 and 1,491 articles, respectively. Following the removal of 1,497 duplicate entries, the remaining studies were screened based on established exclusion criteria. To ensure the inclusion of current and methodologically sound research, the review was restricted to peer-reviewed journal articles published in English between 2021 and 2025. Only studies relevant to circular economy practices within the textile industry were selected. The review is organized around six questions that also inform about future research priorities: (1) What circular economy practices, especially eco-design and recycling strategies, are currently adopted in textile industry? (2) How are closed-loop supply chains and circular business models applied within the sector? (3) What barriers and enablers affect the successful integration of CE practices? (4) What are the sustainability benefits (environmental, economic, social) of applying CE in textile production? (5) What future research directions are needed to scale CE adoption in the textile and fashion industry? (6) How is Life Cycle Assessment (LCA) used to evaluate the environmental impacts and sustainability benefits of circular economy practices in the textile industry?

This review synthesizes recent findings to offer policymakers, business strategists, and researchers practical insights. It highlights the areas where eco-design yields the most significant benefits, identifies systemic mechanisms to promote its adoption, and demonstrates how integrated environmental-economic modeling can inform decision-making. Ultimately, this work emphasizes eco-design's critical function in converting a predominantly linear industry into a robust, low-carbon, and resource-effective global value chain.

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Keywords: Circular Economy, Textile Industry, Eco-design, Circular business, Life Cycle Assessment, Life Cycle Analysis, Closed loop supply chain

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1.6. Bioenergy, Biomass and Biofuels

IMPACT OF DIFFERENT LIGHTING CONDITIONS ON CHLORELLA VULGARIS GROWTH

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ABSTRACT

Chlorella vulgaris is a type of algae that has significant potential to be implemented in a variety of environmental friendly processes like becoming a biofuel alternative instead of non-renewable energy sources. Improving its growth conditions can yield greater amounts of biomass that could help in faster research on this subject. This research attempts to describe how fast the *Chlorella vulgaris* microalgae grows under different lighting conditions. The experiment can be implemented in more efficient growth of *Chlorella* genus algae. Research sample of a tank with 24 hour continuous light was created alongside with control sample, which was under identical conditions, but with 12 hours of light illumination a day. For nutritional supplementation, agricultural fertilizer was used. On top of that, microelement solution was added to the tanks. The two liter bioreactors were aerated and connected to an Aquael Plant lamp(9000K, 10W). Each tank was separated so that the light from one sample wasn't illuminating the other. In the span of three days, compounds such as: total nitrogen, ammonium and ortophosphates were measured. After finishing the measurements, these two samples were analyzed. The 12 hour reactor had faster growth rate compared to the 24 hour one, because the measurements showed more significant drop in compounds concentration(by ~12% more for total nitrogen, ~60% for ortophosphates and ~8% for ammonium). This can be explained by photoperiodic cues interruptions that cause biological processes to be inefficient. It's therefore more beneficial to take example from the natural day cycle for light exposure when working with *Chlorella vulgaris.*

Keywords: ***Chlorella vulgaris,*** **microalgae, biofuels, renewable energy, biomass.**

EMISSIONS OF SO_2 AND H_2S IN STAGED COMBUSTION

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ABSTRACT

In discussions on sustainable development, thermal energetics concentrates on optimizing energy systems to produce economically viable, socially beneficial and environmentally sustainable energy. The EU Directive 2015/2193 requires the use of renewable energy sources and biofuels, leading to a decline in the use of traditional gas and fossil fuel boilers. Developing more efficient and environmentally friendly solid biomass combustion regimes, utilizing forest and agricultural waste, has supported this transition. However, it is also crucial to use all biomass resources, including those previously considered unsuitable due to high emissions. The current challenge is to develop technologies that can reduce harmful gaseous emissions from biomass energy production.

The experiments were conducted using a 25 kW biomass grate-firing scaled down boiler facility [1]. The fuels tested included sunflower husk pellets (S_d=0,09%) and wood pellets (S_d=0,01%). Various staged combustion tests were performed by adjusting the position and stage of the air and recirculated flue gas supply. Additionally, the primary/secondary air ratio and the oxygen concentration in the mixed recirculated flue gas and air were modified by reducing the excess air ratio. The effects of these adjustments on emissions in the flue gas were examined. The secondary air was either decomposed or mixed with the recirculated flue gas. The O_2% in primary and secondary air mix was in range of 13÷21%. Emissions of SO_2 and H_2S were analyzed in flue gas using a gas emission analyzer.

The results indicated that altering the flue gas recirculation (FGR) ratio in primary air does not impact SO_2 emissions, which remained relatively stable at around 30 mg/m³ when sunflower husks were burned, even as O_2 levels were reduced from 21% to 13% in the primary air and FGR mix. However, there was a decrease in H_2S emissions, which fell from 200 mg/m³ to 175 mg/m³. In contrast, the introduction of FGR into secondary air affected sulfur emissions. SO_2 levels increased from 21 mg/m³ to 28 mg/m³, while H_2S levels rose from 162 mg/m³ to 184 mg/m³. A different scenario emerged with lower sulfur fuels, such as wood pellets. When FGR was combined with secondary air, there was only a minor impact on SO_2 and H_2S emissions, fluctuating around 12 mg/m³ and 65 mg/m³, respectively. However, when FGR was mixed with primary air, SO_2 emissions increased from 5 mg/m³ to 11 mg/m³, and H_2S emissions rose from 40 mg/m³ to 60 mg/m³.

The introduced FGR in biomass combustion positively affects NO_x emissions and reduces combustion temperature, but it also increases harmful sulfur emissions such as SO_2 and H_2S. To avoid specific emissions, combustion must be balanced to comply with the established standards while not compromising the boiler operational regimes.

Keywords: Biomass, sulfur dioxide (SO_2), hydrogen sulfide (H_2S), staged combustion, emissions.

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ENHANCING BIOHYDROGEN PRODUCTION FROM TROPICAL BIOMASS WASTE USING BIOCHAR, NANOPARTICLES, MAGNETIC FIELDS, AND IMMOBILIZATION TECHNOLOGY WITH ISOLATED *CLOSTRIDIUM TERTIUM* IGP01

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ABSTRACT

Lignocellulosic biomass waste, including cacao pod husk (CPH) and spent coffee ground (SCG), became a promising substrate as a carbon source for biohydrogen production using a dark fermentation approach. However, the substrate from the lignocellulosic biomass still showed some challenges that caused lower production yield and less cost-efficiency in terms of upscale production. Many researchers focused on exploring pretreatment and enhancement methods, including the application of enzymes to hydrolyze complex compounds. Additive supplementation has also been investigated, such as the addition of various biochar, nanoparticles, metal monomers, metal oxides, and its immobilizations, as well as the introduction of magnetic fields and intermediate substances. Modifying hydrogen-producing bacteria (HPB) has emerged as another approach to enhancing biohydrogen production, which includes exploring new HPB strains and co-culturing techniques. The study aims to investigate the optimum temperature for nanoparticle synthesis (45, 60, and 75°C) was also examined to maximize biohydrogen concentration and production in batch dark fermentation. The supplementation effect of biochar (10 g/L), nanoparticles (100 mg/L), immobilization techniques mixed with biochar and NPs (10% w/v), also magnetic fields on biohydrogen production performance from cacao pod husk (CPH) and spent coffee ground (SCG) hydrolysate were performed in this study using newly isolated *Clostridium tertium* IGP01 as inoculum. Hydrothermal pretreatment of dried CPH and SCG powder was performed by adding 10% w/v to 1% v/v H_2SO_4 and then autoclaving at 130°C for 1 hour. The hydrolysates were diluted to adjust the total sugar content to 10 g/L before fermentation in batch bottles. The Modified Reinforced Clostridium Medium (MRCM), with sucrose as the carbon source, was used for comparison.

The optimum temperature of 60°C resulted in the formation of 53% magnetite and 18% hematite, which enhanced biohydrogen production yield by 20% in sucrose-based media. In the dark fermentation with lignocellulosic biomass hydrolysate as a substrate, the addition of immobilized biochar and nanoparticles showed the highest enhancement in hydrogen concentration and production yield for both CPH and SCG by *C. tertium* IGP01. Yielded biohydrogen achieved 3.61 and 9.27 mmol H_2 per gram substrate, individually. The production yield increased by more than twofold and was 76.4 ± 4.3% higher, respectively, compared to the control. Moreover, the increase in biohydrogen performance was accompanied by a reduction in 5-(hydroxymethyl) furfural, influenced by an increase in carbonyl (C=C), quinone (C=O), and hydroxyl (O-H) bond groups following immobilization. The addition of immobilized biochar also supported biofilm formation by providing a surface for attachment, allowing HPB to maintain stable conditions. As the first study to explore the potential of *C. tertium* IGP01 for biohydrogen production from CPH and SCG hydrolysates, this work highlights the incorporation of immobilization techniques with biochar and nanoparticles as a promising approach to enhance biohydrogen generation, leveraging the efficiency of the newly isolated hydrogen-producing bacteria.

Table 1 Comparison of biohydrogen yield with other feedstocks and Clostridium genera

Bacterial Isolates	Substrate	Source of bacteria	Temp (°C)	Bio-H_2 Yield per gram substrate		Ref.
				mL	mmol	
Clostridium acetobutylicum X_9	Corn stalk	Fermenter liquor	37	75.6	3.40	[1]
Clostridium thermocellum 7072	Corn stalk	DSMZ*	55	37.6	1.69	[2]
Clostridium thermocellum 27405	Distillers Grain	ATCC**	60	23.8	1.07	[3]
Clostridium perfringens 13124	Wheat straw	AD sludge	40	78.5	3.53	[4]
Clostridium sp. FS3	Corn stalk	AD sludge	36	92.9	4.18	[5]
Clostridium lentocellum Cel10	Cassava residue	Panda excrement	37	90.7	4.08	[6]
Clostridium tertium IGP01	CPH	AD sludge	37	80.3	3.61	This study
Clostridium tertium IGP01	SCG	AD sludge	37	206.1	9.27	This study

**Deutsche Sammlung von Mikroorganismen und Zellkulturen, German Collection of Microorganisms and Cell Cultures; **American Type Culture Collection; AD sludge (Anaerobic Digestion sludge)*

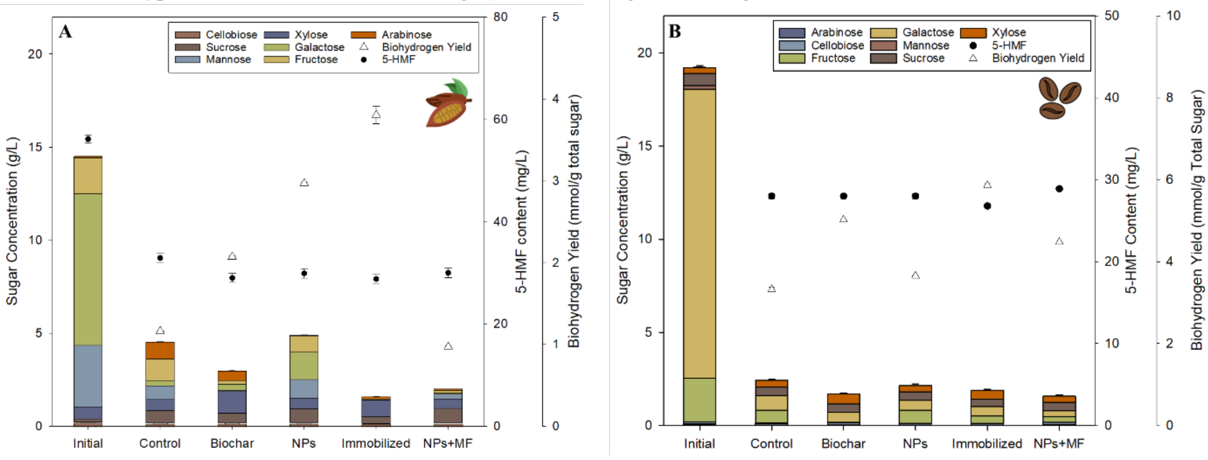

Figure 1 Profile of sugar composition before and after dark fermentation also comparison of biohydrogen yield and 5-HMF with additive supplementation and magnetic field.

Keywords: biochar, biohydrogen, cacao pod husk, immobilization, magnetic fields, nanoparticles, spent coffee ground.

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SUSTAINABLE MANAGEMENT OF PLASTIC WASTE: EVALUATING PYROLYSIS AND GASIFICATION METHODS FOR HIGHER ADDED VALUE PRODUCTS RECOVERY

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ABSTRACT

For the past couple of decades, various plastics, mainly polypropylene (PP), low- or high-density polyethylene (LDPE/HDPE) have become one of the dominant wastes as the population has increased. These plastics have made a massive contribution in almost every human activity, therefore, the distribution and improper utilization of it has become one of the most concerning environmental issues all around the world. Unfortunately, the most common way of treating plastic waste is by landfilling or incinerating them. Although, plastics might be adapted for converting its waste into higher added value energy products. Feedstock recycling through thermal treatment, specifically pyrolysis and gasification, might be a promising alternative for the management of plastic waste. Both processes can generate plastic waste into valuable products, including fuels, chemicals and syngas, making them attractive options for waste-to-energy strategies. Therefore, this study is aimed to observe the fundamental characteristics of plastics via pyrolysis applying thermogravimetry (TGA) and Fourier transform infrared spectroscopy (FTIR) to analyze functional groups of evolved gaseous products and finally analyze their chemical structure by using gas chromatography – mass spectrometry system (GC/MS). Further experiments will also include plasma assisted gasification, as an effective method for converting plastic waste into useful products like syngas, which can be used for energy generation or the production of various chemicals. The products obtained through plasma gasification are heavily influenced by factors such as the type and flow rate of the gasifying agent, the steam-to-carbon ratio, the equivalence ratio, and the configuration of the plasma source and torch. Recent research has shown encouraging results in the conversion of various waste materials including HDPE, PP, and LDPE into syngas when plasma gasification is performed in a CO_2 environment. Some researchers have discovered that water vapor plasma gasification can achieve a higher H_2/CO ratio, as demonstrated by biomass gasification studies. However, there is a gap in knowledge regarding the use of water vapor plasma gasification for plastic treatment, and extensive research is required to determine the optimal parameters and conditions that will produce a sufficient H_2/CO ratio in the syngas. Therefore, plasma assisted gasification of plastics will be used to investigate the possibilities to apply various plastics such as HDPE, LDPE and PP for conversion to syngas using different gasifying agents and determine optimal parameters for achieving the highest H_2/CO ratio. Therefore, the present study aims to investigate the plasma gasification of plastic materials like HDPE, LDPE, and PP using different gasifying agents to identify the optimum parameters for achieving the maximum H_2/CO ratio in the syngas By evaluating the gaseous products, this study aims to determine the energy potential and chemical value of the products derived from plastic waste, providing important insights into how pyrolysis and gasification processes can contribute to sustainable plastic waste management.

Keywords: Plastic, pyrolysis, gasification, waste, bioenergy

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POTENTIAL USAGE OF BIOGAS PLANT WASTE AS NOURISHMENT / FERTILIZER IN CHLORELLA VULGARIS FARM

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ABSTRACT

Scientific research about potential usage of biogas plant waste as fertilizer. Fertilizer could be used as substrate of biochemical reactions that happen during growth of Chlorella Vulgaris algae. In research it was compared how specified concentration of condensate (biogas plant waste) effects on growth of algae and concentration of compounds such as: ammonium nitrogen; orthophosphate; Nitrogen total; nitrates; nitrites. It was also examined how concentration of condensate is affecting concentration of algae in sample. Research took part in 5 bioreactors, saturated, illuminated in which 4 of them was enriched of condensate and 1 of them was sample to compare to. Based on the results it can be concluded that usage of condensate has influence on accumulation of elements and biogenic compounds during breeding. In reactors where condensate was added elements such as amonium, nitrates, nitrites, lasted longer than in the reactor where no condensate was added. This fact influenced positively on lifespan of cologne – concentration of chlorophyl in the sample was bigger in the same reactors where nitrites, nitrates, ortophosphate, amonium was more concentrated during breeding time.

Keywords: Chlorella sp.; Bioplant waste; fertilizer; biogenic elements; algae plant; microalgae; biomass.

NANOPHYTOREMEDIATION: NANOTECHNOLOGY OF ENHANCED SOIL HEAVY METAL ROMOVAL – A LITERATURE REVIEW

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ABSTRACT

By 2050, the world's population is predicted to reach 9.6 billion, which might result in a 70-100% increase in food demand. Therefore, it is essential to address soil pollution problems, preserve natural resources, and develop agricultural practices while minimizing the negative impact on the environment. The main challenge of the 21st century is to develop innovative, cost-effective, and sustainable soil remediation solutions. Traditional remedial treatments such as soil removal, washing, and chemical stabilization are often expensive and have an adverse environmental impact. Phytoremediation is an ecologically sustainable method of biological remediation. However, the toxicity of pollutants, which can hinder plant growth and lower biomass, frequently limits its efficacy. This review aims to investigate how the integration of nanotechnology into phytoremediation can improve the efficiency and sustainability of soil heavy metal removal, while addressing the limitations and knowledge gaps in current practices.

The use of nanotechnology may enhance the efficacy of phytoremediation while reducing its limitations. Nanoparticles promote plant growth and ability to accumulate heavy metals, increasing the efficacy of the phytoremediation process. In moderate concentrations, some nanoparticles can reduce the toxicity of heavy metals. Therefore, in recent years, the application of nanotechnology in bioremediation has been gaining increasing attention. Nanomaterials are excellent at absorbing heavy metals due to their high surface area-to-volume ratio and numerous active metal binding sites. They can also be adapted to target specific metals, making them highly effective. Furthermore, their adjustable surface chemistry improves interaction with heavy metal ions, resulting in increased absorption efficiency.

Typically, physical, chemical, and biological methods – or hybrid combinations of these methods – are used in the creation of nanoparticles. The biological approach is more environmentally friendly than the costly and energy-intensive physical and chemical synthesis methods, especially for green nanoparticle systems created through plant- or microorganism-mediated processes.

Although nanoparticles have been shown to be effective at removing contaminants, there are still some limitations. It is necessary to properly select nanoparticles and ensure their stability, with the minimum amount required to guarantee sustainable nanophytoremediation. Scientific studies indicate that improperly chosen nanoparticle concentrations can be toxic to plants, with any unabsorbed excess potentially entering the environment. When choosing nanomaterials, it is critical to consider the specific plant species. This field lacks sufficient information, underscoring the need for further research to overcome or at least mitigate the challenges encountered during the process.

Keywords: phytoremediation, nanotechnology, nanoparticles, soil pollution, heavy metals.

CONFERENCE PAPERS

2. PHYSICAL SCIENCES

2.1. Thermal Physics, Fluid Mechanics and Metrology

EXPERIMENTAL INVESTIGATION OF THE EFFECT OF AIR PARAMETERS ON AN ETHYLENE GLYCOL DROPLET IN EVAPORATION CYCLE

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ABSTRACT

The rise of modern industry has led to rapid development and widespread use of high-power electronics such as data centres, supercomputers, electric vehicles, airborne avionics and lasers in a wide range of applications. Thus, the problem of cooling such systems is now very relevant [1] - they accumulate a large amount of heat in a small confined space, which increases the operating temperature and adversely affects the lifetime and stability of electronic devices. For this, a cooling process is extensively used by spraying the liquid and turning it into tiny droplets of liquid. Water in dispersed form is the most widely used material. However, various other liquids are being used in spray cooling in the search for ways to remove excess heat as efficiently as possible and without increasing the size of a device. For example, ethylene glycol can be used when the operating environment is below the solidification temperature of water for heat dissipation in the air for modern electronic equipment [2].

This study is based on an experimental investigation showing the effect of bypassing atmospheric air flow parameters on the ethylene glycol droplets' thermal state and phase change process in its evaporation cycle. In a test section of the experimental set-up, a single ethylene glycol droplet is suspended on a thermocouple bead and supplied air flow overflows it. The experiments are carried out in various modes, such as changing air temperature and adding additional humidity to the flow. During the experiments, the temperature of the ethylene glycol droplet is measured every second with the thermocouple on which the droplet is suspended. Droplet size change is measured using a high-speed camera, and recorded video is analysed later.

The experiments demonstrated that additional humidity and temperature of the supplied airflow affect the ethylene glycol droplet thermal state and phase change processes in its phase transformation mode cycle. These factors determined a higher temperature of equilibrium evaporation and a shorter time for the transitional regime. Study shows that the increase in the equilibrium evaporation temperature of the liquid droplet is due to the additional humidity, although this effect decreases at the higher air temperatures. Experimental data showed that ethylene glycol droplet behaves unconventionally under certain airflow conditions - its equilibrium evaporation temperature is higher than the supplied airflow temperature. For example, the experimental droplet was heated with 50.5 °C air flow and humidity of X_{vg} = 0.087, and the equilibrium evaporation temperature reached about 57 °C. This is due to the chemical reaction that takes place at the point of contact between the droplet and the surrounding humid airflow.

Keywords: ethylene glycol droplet, thermal state, phase change, experimental investigation.

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PYROLYTIC CONVERSION OF PLASTICS: THE KINETIC COMPENSATION EFFECT IN ARRHENIUS PARAMETERS ESTIMATION

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ABSTRACT

Estimation of pyrolysis kinetic parameters and decomposition model development is an important step in the research design, which determines the energy barrier required for reaction initiation and process optimisation to maximise the product yield. Furthermore, it is a crucial step in the scale-up of the process and reactor design development. In kinetic analysis, the Arrhenius activation energy (E_a) and the frequency factor A) exhibit a strong positive correlation under identical experimental conditions for the same reaction, a phenomenon known as the compensation effect. In theory, these parameters are supposed to be independent, however this effect is observed in many previously published studies. According to the ICTAC Kinetics Committee, the reasons for this correlation origination include experimental errors, incorrect mathematical model selection, the influence of reversible reactions, temperature gradients within the sample, uneven particle size distribution, and other factors. ICTAC Kinetics Committee also highlight the need for several different heating rates employment and a range of temperatures to minimise the uncertainties and the occurrence of the compensation effect in the kinetic analysis [1].

This research focused on plastic devolatilisation, which is a primary pyrolysis reaction, namely primary cracking or random scission, following a first-order reaction model (1):

$$\frac{d\alpha}{dt} = k \cdot f(\alpha) = A \cdot e^{-\frac{Ea}{RT}} \cdot (\alpha^* - \alpha_t) \quad (1)$$

where k is the reaction rate constant, A – is the pre-exponential factor (1/s), E_a – activation energy (J/mol), R – universal gas constant (8.315 J/mol·K), T is the pyrolysis temperature (K), parameter α^* signifies the maximum volatile matter yield specific to the feedstock material, while α_t represents the volatile yield at the holding time t during the experiment. The kinetic parameters are determined by the least-square fitting of a theoretical model to the experimental results.

A range of temperatures from 500 °C to 1200 °C with holding times of up to 15 seconds was used to analyse the rate of primary cracking of polypropylene (PP), polystyrene (PS) and plastic waste mix and to develop a devolatilization model. The kinetic compensation effect plot, representing the positive correlation between the kinetic parameters estimates including the data points from several previous research is given in Figure 1. The line functions in the graph correspond to the constant reaction rate values obtained at 800 °C for PP, PS and plastic mix feedstocks and the estimates points on the lines – calculated kinetic parameters values. The broad distribution of kinetic parameters values compared with previous studies is observed, following the positive correlation. The k value calculated in this study most closely corresponds to the values determined by fast pyrolysis at the respective temperature. However, a complete match with previous studies was not observed.

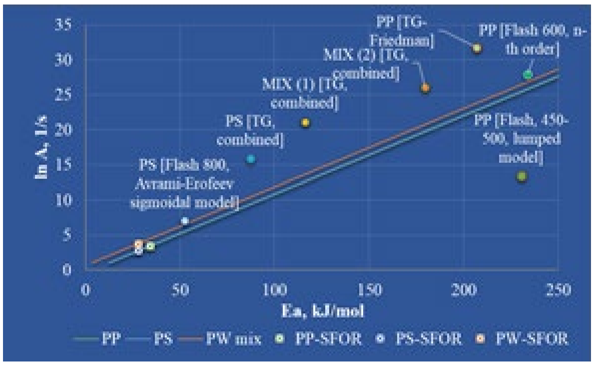

Figure 1 The kinetic compensation effect between the values of activation energy and the logarithm of pre-exponential factor.

Overall, this study revealed the temperature and holding time influence on plastic pyrolytic decomposition rate, the developed reaction model highlighted the product yield changes depending on the process conditions. The reaction rate increased within temperature elevation and the product yield increased exponentially with holding time. The calculated compensation curves plotted with the values of kinetic parameters from previous research were compared and a conclusion was made that k values and corresponding kinetic parameters agreed mostly with the ones reported in studies with complying experimental conditions.

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NUMERICAL SIMULATION OF LARGER SCALE HYDROGEN DEFLAGRATION EXPERIMENT USING DYNAMIC MESH REFINEMENT

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ABSTRACT

1. TOPICALITY

The worst-case scenario in a nuclear power plant involves the generation of hydrogen in an overheated core, leading to a potential hydrogen explosion. Similarly, in hydrogen energy applications, hydrogen explosions present a significant safety risk. To mitigate this risk, robust simulation tools are needed to estimate explosion behavior, offering insight into flame and explosion dynamics.

Several scientific modeling approaches exist, including lumped parameter and computational fluid dynamics (CFD) codes. Lumped parameter models can estimate realistic static overpressures but lack the detailed resolution necessary for flame propagation analysis. CFD codes, on the other hand, provide high-fidelity data but often rely on commercial software, such as Fluent, or are not publicly available. This limitation underscores the need for an open-source alternative that enables comprehensive combustion modeling.

To address this gap, we have developed an open-source combustion library, *flameFoam* [1], within the OpenFOAM [2] framework. Initially, in OpenFOAM 9, *flameFoam* was implemented as a standalone solver, requiring manual implementation of many OpenFOAM functionalities. Despite these constraints, it demonstrated good agreement with experimental results in multiple studies [3][4].

With the restructuring of OpenFOAM in version 11, flameFoam has been rewritten as a combustion library, allowing seamless integration with OpenFOAM solvers. This update provides access to all OpenFOAM functionalities, making it a powerful tool for combustion simulations. Among the most critical features now available are dynamic mesh refinement (DMR) and radiation heat transfer modeling, both of which are crucial for improving the accuracy and efficiency of hydrogen explosion simulations.

2. RESEARCH METHODS

To demonstrate *flameFoam's* capabilities, we performed a simulation of a premixed hydrogen-air-steam explosion experiment HD-22 conducted in the 60 m^3 THAI large-scale experimental facility. During the specific experiment, the vessel was filled with a premixed mixture of 9.9% H_2, 25.3% steam, and 64.8% air, at 365.05 K and 1.49 bar initial temperature and pressure. The gas was ignited at 0.5 m height, and pressure and flame position evolution were recorded.

Unsteady Reynolds-Averaged Navier-Stokes simulations were performed using the Extended Turbulent Flame speed Closure (ETFC) combustion model, Zimont turbulent burning velocity correlation, Malet correlation for laminar burning velocity, and k-ω SST turbulence model. Second-order discretization schemes were used for spatial and temporal discretisation. The base grid cell width was 4 cm, and time step was automatically adjusted by limiting the Courant number to 0.5.

To accurately resolve the flame surface, two levels of dynamic mesh refinement were used at the flame surface. Moreover, to account for radiative heat transfer, P1 radiation model was employed.

3. RESULTS

As shown in Figure 1, the mesh is dynamically refined around the flame surface, as expected (red denotes burnt mixture, and blue – unburnt), thus giving desired simulation detail in desired locations without the need for global refining.

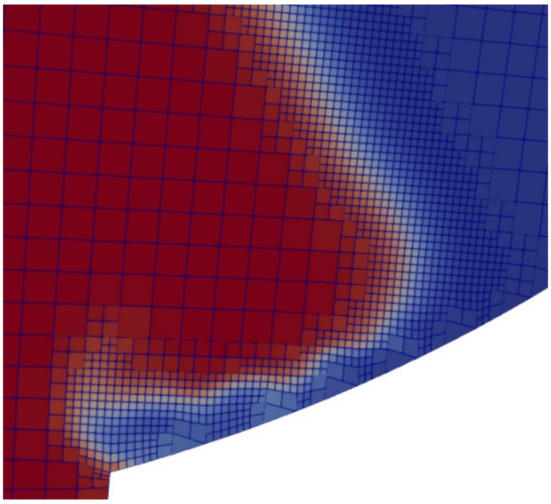

Figure 1 Dynamically refined mesh at flame surface. Red and blue denotes burnt and unburnt mixtures, respectivelly.

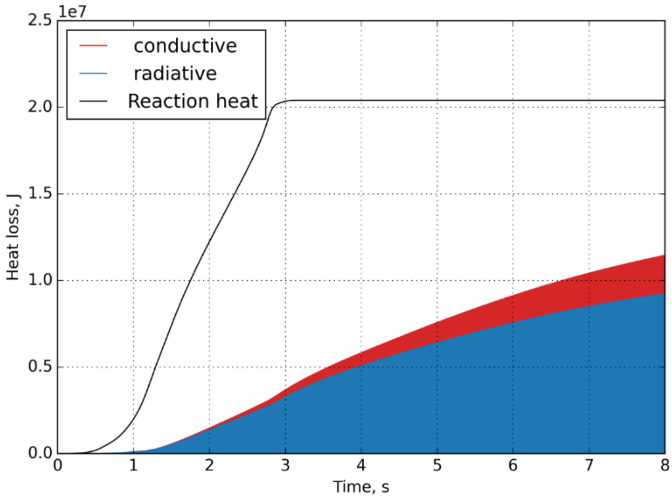

Figure 2 Heat loss due to radiative and conductive heat transfer.

Figure 2 indicates that radiative heat transfer contributes to around 80% of the total heat lost. Clearly, radiative heat transfer plays a crucial role in simulations of slow hydrogen deflagration. Thus, flameFoam is now compatible with yet another important functionality of OpenFOAM and has become a more desirable choice for both scientists investigating flame dynamics and engineers applying these techniques for hydrogen safety and explosion risk assessment.

4. CONCLUSIONS

A recent restructuring of flameFoam combustion solver into a combustion library for OpenFOAM now allows the use of both dynamic mesh refinement and radiative heat transfer models. Dynamic mesh refinement has great potential to reduce simulation computational costs, and radiative heat transfer constitutes the major part of heat loss in slow deflagrations. Therefore, flameFoam has become a very powerful alternative for both researchers and practitioners in the nuclear and hydrogen safety fields.

Keywords: flameFoam, OpenFOAM, Hydrogen safety, Slow hydrogen deflagration, Computational fluid dynamics.

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2.2. Material Sciences and Technologies

ZnO NANOWIRES HYDROPHOBICITY: IMPACT ON VAPOR FILM FORMATION AND FRICTION REDUCTION

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ABSTRACT

Energy production, transportation, and construction materials provide major environmental issues because of their high energy consumption and CO_2 emissions [1]. In order to protect the climate, energy production must use fewer fossil fuels [2]. By lowering drag, hull shape optimization, microwave injection, and nanocoatings help the marine industry save energy [3]. Scientific literature divides drag reduction techniques into active and passive categories [4]. To reduce hydrodynamic resistance, the active technique is creating a layer of gas or vapor surrounding a moving object, such as the Leidenfrost vapor layer [5]. On the other hand, the passive method uses superhydrophobic surfaces, which have better air-trapping and water-repellency properties. These surfaces can be used for anti-icing protection, friction reduction, corrosion resistance, and anti-adhesion [6]. Applying a gas layer over a solid surface in a liquid environment can significantly lower energy consumption and hydrodynamic resistance in marine applications. ZnO surface modifications based on polymers, especially those using polydimethylsiloxane (PDMS), improve hydrophobicity and raise the water contact angle above 150° [7]. This study looks at how hydrophobic nanocoatings affect the durability and development of vapor films. The effect of coatings on cooling dynamics and falling rates is examined by varying the temperatures of the sample and the water. The findings show that on a heated sample at 200 °C, the hydrophobic ZnO+PDMS coating prolonged vapor film production 3,5 times longer than on an untreated sample at 25 °C water temperature. In the allocated water tank, the coated sample also showed an 11% increase in the dropping rate.

Keywords: nano-coating, vapor film, Leidenfrost effect, hydrophobicity, drag-reduction.

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PLASMONIC METASURAFCE FOR ENHANCED GREEN HYDROGEN PRODUCTION BY PHOTOELECTROCHEMICAL WATER SPLITTING

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ABSTRACT

Hydrogen evolution reaction (HER) kinetics under solar light context has been enhanced by heterostructure photocatalysts assembled from plasmonic nanoparticles (NPs) coupled with semiconductors. Plasmonic Heterostructures manifested HER photocatalytic efficiency greater than solitary semiconductors because plasmonic NPs magnify the absorption wavelengths through their localized surface plasmons resonance (LSPR) within the visible–IR sweep. Nevertheless, these regimes exhibit major hinders of poor charge mobility from the Schottky junction, diminishing and limiting their noteworthy employment. On the contrary, the Plasmonic metasurface is a quintessential route for an undeviating metamorphosis of solar light to green hydrogen. It's an exquisite technique to magnify the quantum tunnelling to adjacent RGO shielding barrier via the creation of hot spots and thermionic emission, through and over the feeble metal-metal junction (Ohmic junction). This approach could be considered to attain intensified hydrogen evolution kinetics at the onset potential of $0V_{RHE}$. According to the estimated computational assumptions, an explicit transmittance peak has been observed at 608 nm to produce Plasmonic lattice resonance or coupling by accompanying diffractive modes of a periodic array (SLR) and LSPR of single nanoparticles to enhance near-field coupling. In the visible region, this attribute can be employed to achieve almost 70%-80% HER kinetics compared to the complete solar spectrum, conversely, as solitary, at a specific wavelength corresponds to Plasmonic lattice coupling (608 nm), efficiency could be 20% to 30%[1-3].

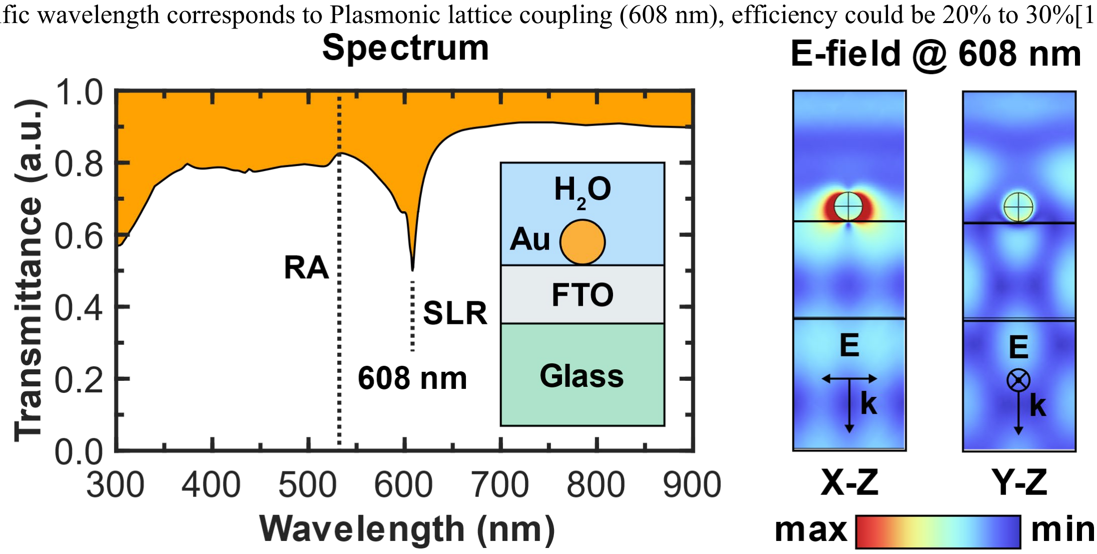

Figure 1 Estimated Computational SLR Response.

Keywords: Thermionic emission, Plasmonic lattice resonance, diffractive modes, HER kinetics.

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FABRICATION OF COTTON TEXTILES WITH ZINC OXIDE NANOCLUSTER STRUCTURES VIA LOW-TEMPERATURE PLASMA SPUTTERING AND ASSESSMENT OF THEIR CYTOTOXICITY AND ANTIMICROBIAL ACTIVITY

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ABSTRACT

Modern textiles modified with nanoparticles are gaining attention for their antimicrobial properties, UV protection, and resistance to heat and flame [1]. These textiles help address the global challenge of microbial infections and antibiotic resistance by preventing microbial growth on surfaces, especially in medical environments [2]. Nanoparticles, including zinc oxide (ZnO), might exhibit antibacterial properties due to their small size, high surface area, and ability to disrupt bacterial membranes, generate reactive oxygen species (ROS), and interfere with DNA and proteins [3]. However, traditional methods for incorporating nanoparticles into textiles face challenges such as poor adhesion and environmental concerns. Low-temperature plasma sputtering offers a more eco-friendly and effective solution, enabling the uniform deposition of nanoparticles without harmful chemical emissions [4]. While the antibacterial properties of nanoparticle-coated textiles were shown to be effective against some bacteria, their cytotoxicity remains underexplored. This research focuses on optimizing ZnO nanoparticle deposition into cotton material to enhance antibacterial efficacy against broad-spectrum of Gram-positive and Gram-negative bacteria, as well as investigate the cytotoxicity of ZnO-coated fabrics. The potential cytotoxicity of the ZnO-coated fabrics against human umbilical vein endothelial (HUVEC) cells was evaluated using the MTT assay [3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide] and morphological analysis under an optical microscope. Comprehensive material characterization using SEM, AFM, and XPS confirmed uniform ZnO nanoparticle distribution and stable adhesion to fabric fibers. Antibacterial tests demonstrated significant microbial reduction. However, cytotoxicity was observed in HUVEC cells, with cell viability decreased to 10%–15% after 24 and 72 hours. This study underscores the potential of using the glow discharge sputtering technique as a zero-waste method to produce antimicrobial ZnO textiles for biomedical engineering applications, such as rehabilitation and medical devices. However, their cytotoxicity limits their use in applications where they interact with human cells. Future work will refine deposition parameters to enhance antimicrobial efficiency while minimizing biological risks.

Keywords: Antimicrobial textiles, Zinc oxide (ZnO), Plasma sputtering, Cytotoxicity, Nanotechnology, Functional coatings.

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FORMATION OF METAL HYDRIDES ON THREE-DIMENSIONAL SPHERICAL SURFACE STRUCTURES

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ABSTRACT

Hydrogen as a renewable fuel has been widely considered one of the best alternative fuels because the exhaust gases in hydrogen-powered vehicles mainly contain water vapor. A key technological challenge to the widespread use of hydrogen as a sustainable energy carrier is to store it in a safe, efficient, and economical manner. After decades of exploration, it is still a big challenge to find practical systems that can provide satisfied thermodynamics, kinetics, and cycling stabilities for hydrogen storage applications.

In this context, metal hydrides, as hydrogen storage materials, are attracting a growing interest, as they have the potential to achieve high volumetric energy densities, reducing costs and safety concerns. Moreover, the wide variations of their thermodynamic properties among the several classes of materials make them highly versatile. 3D spherical metal hydrides offer a promising route due to their unique properties, particularly the high surface area and volume-to-surface ratio they can provide. As mentioned earlier, the features make spherical structures admiringly adequate in terms of hydrogen storage in a compact and reversible form and make them important candidates for applications like fuel cells, portable energy devices, and renewable energy storage.

In our study, we will highlight the advantages, challenges, and applications of using metal hydrides on a spherical surface and address properties like pressure, temperature, kinetics, and activation energy. We will also suggest materials like Zr (zirconium), Ti (titanium) and their coating over Al granules for hydride formation using magnetron sputtering technology and their advantages and possible results in terms of hydrogenation/ dehydrogenation. Zr and Ti were chosen for their excellent hydrogen absorption properties and stability in hydrogen hydride formation. They are known for their high hydrogen absorption efficiency, low dehydration temperature and good durability. They are also corrosion resistant and can form stable metal hydride structures. Alternative materials such as Mg and Fe were considered, but due to their thermodynamic instability and chemical properties, Zr and Ti are more suitable for this application. Magnetron sputtering is used to form coatings because it allows the creation of thin, uniform coatings with better structural properties. This method improves surface activity and can increase hydrogen absorption. During spraying, the microstructure of the coating changes - finer crystals are formed, which helps to adsorb hydrogen faster and more efficiently. The study expects that magnetron sputtering will improve the hydrogen absorption properties. The coating morphology will be analyzed using SEM to evaluate the surface structure, grain size, and porosity. The coating thickness will be measured because it has a direct impact on the hydrogen absorption and desorption efficiency. The more uniform and thinner the coating, the more efficient hydrogen adsorption can occur. Morphology and thickness will also be correlated with hydrogen capacity in order to optimize these parameters for hydrogen storage. Meanwhile, the crystal structure is studied using XRD.

Keywords: Metal Hydrides, Hydrogen Storage.

RECOVERING VALUABLE ELEMENTS FROM BOTTOM ASH: A SUSTAINABLE APPROACH TO RESOURCE UTILIZATION

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ABSTRACT

Bottom ash (BA) is a byproduct of the incineration of non-recyclable municipal solid waste (MSW). BA primarily consists of quartz and mineral impurities and has a higher moisture content and unburned residues than fly ash [1, 2]. Due to its composition, BA presents an opportunity for resource recovery by extracting valuable elements and compounds, contributing to waste reduction and environmental sustainability [3].

This study investigates the potential extraction of calcium carbonate ($CaCO_3$) and alumina (Al_2O_3) from BA generated at the Kaunas cogeneration power plant (CPP). Chemical leaching with 1 M HCl, 1 M Na_2CO_3 and 15% NaOH solutions were employed to extract the target compounds, utilizing ion exchange, precipitation, and oxidation reactions. pH control played a critical role in the recovery of materials. $CaCO_3$ extraction involved stirring BA in HCl, followed by vacuum filtration. The filtrate pH was adjusted to 8–9 with Na_2CO_3 and formed precipitates were dried.

For Al_2O_3 extraction, two methods were applied. Firstly, BA was stirred with NaOH. In the first method, the filtrate was neutralized with HCl to pH 7–8. In the second, the pre-treated material was stirred with HCl, and the leachate pH was adjusted to 5–7 with NaOH. Formed precipitates were dried and calcined at 800 °C and 1000 °C. The recovered materials were analyzed using X-ray diffraction (XRD), thermogravimetric analysis (TGA), and energy-dispersive spectroscopy (SEM-EDS).

EDS analysis of the BA before the $CaCO_3$ extraction identified Ca in the amount of 3.69 %. Post-extraction, the amount of Ca increased fivefold and reached 19.90 %. XRD confirmed the presence of $CaCO_3$ in the extracted materials from BA. $CaCO_3$ is widely used as a pH buffer and stabilizer in concrete, ceramics and glass [4].

In the first Al_2O_3 extraction method, according to the EDS analysis Fe was detected in the amount of 8.11 %. Post-extraction, Fe amount decreased to 7 %, corresponding to 13.5 % iron oxide, but the material was extracted with fewer impurities. The XRD results confirmed presenting chemical elements found during EDS analysis in chemical minerals such as iron oxide (hematite and magnetite), quartz, cristobalite, anorthite and dolomite. The extracted Fe_2O_3, with its high surface area and electrostatic, can be used in the production of construction materials forces to enhance cement hydration, increasing compressive and tensile strength [5]. In the second method, EDS analysis identified 3.31 % Al. Post-extraction Al increased threefold (9.19 %) at pH 7 and fourfold (12.97 %) at pH 9, corresponding to 27.68 % and 55.33 % Al_2O_3, respectively. According to the XRD analysis results, gahnite ($ZnAl_2O_4$) was identified at 800 °C (pH 7) and 1000 °C (pH 9), a spinel-phase compound valued for its hardness, thermal stability and applications in semiconductors, ceramics and catalysis [6, 7].

This study demonstrates that the leaching method is reliable to optimize BA resource recovery, reduce waste sent to landfills and minimize environmental impact.

Keywords: bottom ash, leaching, alumina, calcium, extraction.

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LAYERED ACOUSTIC STRUCTURES MADE OF PLASTIC MICROFIBER PULP WASTE WITH RESONATOR FOR LOW- AND MIDDLE-FREQUENCY SOUND ABSORPTION APPLICATIONS

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ABSTRACT

This study investigates the development and acoustic performance of a layered composite structure composed of plastic microfiber pulp (PMFP) and plastic acoustic resonator, designed for low-frequency sound wave control. Addressing the dual challenge of reducing plastic waste and enhancing low frequency sound absorption, the research explores the use of recycled plastic materials for innovative acoustic applications. The PMFP raw material was obtained from a local plastic recycling company. The material was dried for 24 hours in 70±3 °C without mixing. After the mixture was dried to separate the PMFP, the blender was used. Resonators were manufactured from PET-G plastic filament using 3D printing fused deposition modelling technology. The working principle of resonator is based on the Helmholtz resonator, which is made up of two air chamber cells with variable length and diameter necks. PMFP was tested in various thicknesses, while the resonators were 3D-printed with adjustable neck lengths and diameters to achieve optimal sound absorption characteristics. The acoustic performance of the composite materials was evaluated in an impedance tube according to ISO 10534-2 for their sound absorbing properties. Results showed that, as the thickness of the PMFP sound absorption increased, the peaks shifted to lower frequencies, with the 50 mm thick samples exhibiting a peak absorption coefficient of 0.74 at 500 Hz. When combined with resonator, the structure's effectiveness increased significantly, with the best-performing configuration achieving a highest absorption coefficient of 0.93 at 1250 Hz. Moreover, introducing air gaps behind the composite material further enhanced low-frequency absorption, with a 50 mm air gap shifting the peak sound absorption to 315 Hz, reaching a coefficient of 0.87. The study concludes that the layered composite structure, with recycled plastic waste, provides an effective and environmentally sustainable solution for low-frequency sound absorption. This makes it suitable for use in various industrial and environmental noise control applications, offering an innovative approach to control noise in indoor areas while addressing plastic waste concerns.

Figure 1 Example of structured sound absorbing material made from resonator and PMFP.

Keywords: innovative materials, fibre composites, resonators, sound absorption, building acoustics.

SILICON POWDERS FROM WASTED PHOTOVOLTAICS CELLS FOR HYDROGEN GENERATION STUDIES

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ABSTRACT

The recent trend towards renewable energy is highly growing, and the term 'green energy' represents clean energy with lower CO_2 and greenhouse gas emissions. Due to its high energy density and environmentally friendly nature, hydrogen is now considered a promising clean energy source. However, the main hydrogen production route is based on the steam reforming method, emitting approximately 10 kg of CO_2 per 1 kg of H_2, contributing significantly to global emissions. Another alternative could be electrolysis, where green hydrogen is produced using renewable electricity. However, this method faces challenges related to relatively high electricity costs, the necessity of rare earth metals for electrode production (proton exchange membrane electrolysers), which limits its scalability, and, in some cases, issues related to an uninterrupted supply of green electricity. Therefore, alternative methods should be explored that can efficiently produce clean hydrogen and, in the best scenario, utilize waste materials as feedstock, contributing to both energy sustainability and waste reduction [1, 2].

Meantime, inefficient or end-of-life photovoltaics cells (PVCs) present significant recycling challenges due to their complex material composition and the lack of established recycling infrastructure. Many of these cells are currently discarded in landfills, despite containing valuable materials. Therefore, it is essential to develop alternative methods for recycling or repurposing PVCs to minimize waste and recover valuable materials efficiently [3].

In this work, we tested the ability to produce clean hydrogen from waste PVCs reaction with water. Specifically, silicon plates were removed from the solar cells, and then ball-milled to produce a powder-based fraction of Si. Part of the material was treated in low-temperature hydrogen plasma to increase its reactivity. Both types of powders were tested for hydrogen production via their reaction with water. The structure and morphology of the samples were carried out using SEM, EDS, and XRD. EDS confirmed the presence of additional elements, including aluminum, silver, oxygen, and carbon, which are associated with the metals used in the electrical connections. The SEM images revealed a relatively similar structure for powder without and with plasma treatment. Meantime, the plasma treatment contributed to the improvement of the hydrogen yield compared to non-treated powders.

These findings demonstrate the potential of repurposing waste photovoltaics cells for clean hydrogen production. The enhancement in hydrogen yield through plasma treatment highlights the importance of material modification in optimizing reactivity. Such types of activities contribute to the consumption of waste PVCs, by producing clean hydrogen together with a possibility to utilize the reaction byproduct elsewhere.

Keywords: Hydrogen generation, Hydrolysis, Photovoltaics Cells , Plasma treatment, Waste-to-Energy.

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ELECTROCHEMICAL SENSOR BASED ON MXENES FOR CADMIUM ION DETECTION IN WATER

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ABSTRACT

Heavy metal contamination has become a significant environmental and health concern due to rapid industrialization and urbanization. Among these, cadmium is one of the most concerning heavy metals due to its toxicity. Cadmium is carcinogenic and can cause severe damage to the respiratory system, kidneys, and bone structures. This metal can enter the environment through various natural processes, such as volcanic activity, erosion, and forest fires. However, human activities—such as mining, smelting, phosphate fertilizer production, and electroplating—are considered the primary sources of cadmium and its ions in the environment. As a result, cadmium poses a significant threat to public health and environmental well-being, necessitating continuous monitoring to prevent potential harm. Water is one of the systems that can become contaminated with cadmium. To track cadmium ion concentrations in water, various types of sensors are employed. Among them, electrochemical sensors offer advantages such as rapid and simple procedures, high accuracy, and low manufacturing costs [1]. These sensors can be made from a variety of materials, each with its own benefits and drawbacks. Recently, MXenes have gained significant attention in the field of electrochemical sensors. Their mechanical strength, flexibility, tunable properties via surface termination groups, and high electrical conductivity make them excellent materials for sensor development [2-4]. In this study, we explored an electrochemical sensor for cadmium ion detection in water, based on the interaction between cadmium ions and MXenes.

The sensor was produced by drop-casting a MXenes-Nafion mixture onto the surface of a glassy carbon electrode. Differential pulse voltammetry was used to assess key sensing features, including the limit of detection (LOD), selectivity, and sensitivity. Measurements were conducted in acetic buffer solution (ACB) at various pH values and temperatures (8 – 30°C) to evaluate how these factors influence the sensor's performance. The sensor's stability was tested over a four-week period by preparing electrodes at the same time and conducting experiments on them periodically.

The sensor's performance was found to depend on both pH and temperature. Temperature dependence showed a higher response in warmer solutions, although this increased the risk of MXenes oxidation (Figure 1). At 20°C at pH 4.5, the sensor achieved a sensitivity of 5.36 μA/(μM·cm²) and a LOD of 0.82 μM, within a working range of 1.03 μM to 27.53 μM. The sensor exhibited stable performance for three weeks, with a gradual decline in signal due to MXenes oxidation (Figure 2). It was also able to detect cadmium ions in various real-life water samples with high accuracy.

In conclusion, the developed GCE/MXenes+Nafion sensor is suitable for the accurate and rapid detection of cadmium ions in aquatic environments both warm and cold. Its advantages include the potential for real-time monitoring and simple sample preparation procedures. While the LOD for detecting cadmium in drinking water is too high, this sensor could be valuable in industrial settings, where cadmium concentrations are typically higher.

Keywords: MXenes, Electrochemical sensors, Cadmium sensing.

THEORETICAL INVESTIGATION OF SUBSTRATE AND ADHESION LAYERS ON AU TRIANGLE ARRAY FOR PLASMONIC APPLICATIONS

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ABSTRACT

The thin layer coating of noble metals on conductive or dielectric substrates is very important for plasmonic and photonic applications. However, noble metals such as gold do not adhere well to the carriers due to their low reactivity and cause various problems, such as delamination or peeling in the prepared films.

To improve the adhesion, an adhesion layer of a few nanometers thick, such as Ti and Cr, is applied between the substrate and noble metal films[1]. Due to the unique optical and electrical properties of each substrate and adhesion layer, it is very time-consuming to optimize parameters experimentally. Therefore, in this study, we theoretically investigated the effect of Ti and Cr adhesion layers on Si and SiN substrates using the finite-difference time-domain (FDTD) method to prepare nano triangular arrays. For this, we used different thick adhesion layers and investigated the ultra-thin film effect at different periodicities of layered gold nanotriangles. Optical properties and electric field (EF) distributions of films were examined and analyzed for Au/Ti/Si, Au/Ti/SiN, Au/Cr/Si, and Au/Cr/SiN, along with Au/Si and Au/SiN for reference. In the FDTD studies on the Si substrate, it was determined that the reflectance minimum for Au 30 nm shifted to higher wavelengths when an adhesion layer was added. Additionally, EF changes were shown in Figure 2., and findings were presented for future studies.

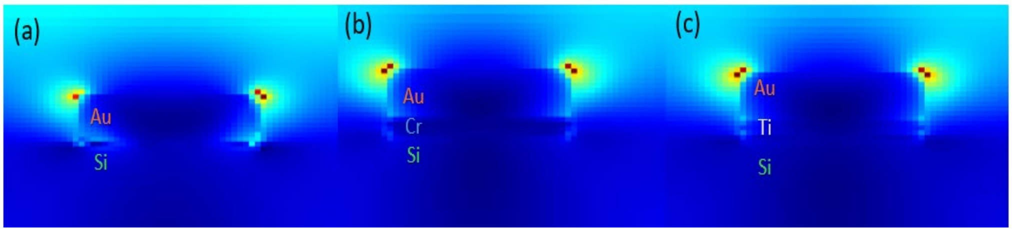

Figure 2 EF distribution graph of (a)Au/Si (b)Au/Cr/Si, and (c) Au/Ti/Si.

Keywords: Plasmonic, photonic, adhesion layer, array, FDTD

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COMPARATIVE ANALYSIS OF NUMERICAL SIMULATION OF FIBER COMPOSITE

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ABSTRACT

Glass fibers are used in a variety of applications, such as concrete reinforcement, aerospace and military sections, automotive and infrastructure, for properties of high strength, lightweightness and aging resistance. Jute is a durable and sustainable natural fiber mostly used in packaging and for geotextiles. While composite materials can be expensive and have difficulties recycling them, mixing natural fibers with synthetic ones can be an alternative method of making composites more sustainable and affordable without impairing their mechanical properties.

The aim of this study is to investigate the differences of finite element modeling techniques and element types on the tensile properties of glass/jute composites and compare the results with experimental findings. The research is based on the article "Tensile strength evaluation of glass/jute fibers reinforced composites: An experimental and numerical approach" by Khalid M.Y. et al. [1] for composites' fabrication of four stacking sequences (GGGGG, GGJGG, GJGJG, GJJJG). The composites were cut and subjected to a tensile test according to ASTM D3039 standards. The numerical simulation was done using ABAQUS software using shell and solid elements, applying properties from the original article. Composite layers were defined using ABAQUS engineering constants, consisting of the modulus of elasticity, Poisson's coefficient and shear modulus. Fibers were oriented in the tensile direction. Meshes for the shell and solid elements were chosen as S4R and C3D8R, respectively.

Experimental results show that the incorporation of a single layer of jute in a composite does not significantly influence the composite's tensile properties – a composite made of only glass fibers showed 87 MPa strength, while a composite containing one layer of jute is only 5% weaker. Simulation results complemented experimental results with some errors that occurred due to natural fibers' (jute) tendency to non-uniformity of the fiber's diameter. The difference between the simulation and experimental results of a glass composite was 3%, while a sample containing one layer of jute reached 67 MPa strength. While results using both shell and solid elements were identical, composite, made of solid elements, takes longer to prepare for simulation due to different thicknesses of laminates, however, all stresses or displacements of layers can be seen simultaneously. Shell elements allow to see top and bottom layer stress or displacement and each layer must be checked separately. In conclusion, for difficult constructions, it is recommended to use shell elements for their simplicity and fast calculation results, and when it is essential to see tensile stresses over all plies, it is suggested to use solid elements.

Keywords: fiber composite, glass fiber, jute fiber, numerical simulation, tensile test.

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EFFECT OF THE DEPOSITION TEMPERATURE ON THE STRUCTURE AND PROPERTIES OF CR/NI-DLC COATINGS

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ABSTRACT

Extensive approaches to improve the diamond-like carbon coatings properties and functions were explored recently, to meet the needs of several applications in broad fields such as biological implants, automotive industry, micro/nano-electromechanical systems (MEMS/NEMS), magnetic storage devices, solid-state batteries and more. Thus, various metal dopants such as Ti, Ag, Ni, Cr, Mo, etc. are used to deposit metal doped diamond-like carbon films. The usage of two metals doping of chrome and nickel was reported in several literature research [1–6]. The chromium doped DLC films demonstrated a superior mechanical and tribological properties, and lower internal stress value. Meanwhile, the addition of nickel into DLC films allows to reduce the residual stress and increase wear resistance of the DLC films. In this research both metals were used simultaneously as co-dopants in the DLC films to improve the properties of the films.

The chromium-nickel doped amorphous diamond-like carbon thin films (Cr/Ni-DLC) were deposited on Si (100) substrates by magnetron sputtering. The graphite and the Cr-Ni cathode currents were fixed at 1.5 A and 0.25 A, respectively. The Cr-Ni target consists of Ni and Cr of 80% and 20%, respectively. The deposition time was kept for 10 min, and the synthesis temperature varied between 180 and 235 ºC. The Cr and the Ni contents in the coatings were regulated by adjusting a slit wide in a shield mounted above the Cr-Ni target. It was obtained that the concentration of Cr and Ni in the DLC films varies from ~1.9 to ~3.2 at.% and from ~4.5 to ~12 at.% for Cr and Ni, respectively. The increase of the Ni/Cr concentration leads to the decrease of the sp3 C-C sites fraction and induced the oxidization in the films. The increase in the deposition temperature promoted the formation of sp2 carbon sites in the films. The nano-hardness and Young's modulus of Ni/Cr-DLC films were improved with addition of a low Cr and Ni concentration compared to the undoped DLC films. The friction coefficient decreased from 0.10 to 0.064 with addition of small amount (about 6.5 at.%) of Cr/Ni dopants compared to undoped DLC films. Further increase in the Cr/Ni concentration results in a re-increase in the friction coefficient of films.

Keywords: Cr/Ni-doped diamond-like carbon, microstructure, friction coefficient, nano-hardness.

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2.3. Combustion and Plasma Processes

INVESTIGATION OF FLAME STABILITY AND HEAT RELEASE IN PLASMA-ASSISTED COMBUSTION OF HYDROGEN-AMMONIA-METHANE MIXTURES

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ABSTRACT

Nowadays, natural gas plays a crucial role in European industries, such as glass and cement production. Around the world, governments and industries are increasingly focusing on cleaner, low – carbon alternatives that can meet energy demands. These industries tries moving away from conventional natural gas toward renewable gases. Hydrogen (H_2) and ammonia (NH_3) are among the most promising alternatives due to their potential for clean energy generation and compatibility with existing natural gas infrastructure [1]. Hydrogen can be obtained via electrolysis from renewables or produced from natural gas with carbon capture, while ammonia—synthesized from nitrogen and hydrogen—serves as both a practical fuel and an energy carrier [2]. However, these low-carbon fuels present combustion challenges such as lower radiant heat transfer, flame stability issues, and increased NOx formation, particularly in burners originally designed for methane (CH_4) [3].

This work investigates the combustion characteristics and thermal radiation of methane, ammonia and hydrogen blends, focusing on the role of non – thermal plasma [4] in stabilizing and enhancing the flame. Experiments were performed on a fully premixed gas burner rated at 1,33kW thermal power. Various gas mixtures were prepared by blending methane, ammonia, and hydrogen in different proportions, ensuring a constant thermal input. The burner was equipped with anode and cathode electrodes, forming a narrow gap through which a gliding arc plasma was generated by 120kHz frequency and 8kV voltage. For the flame and plasma stabilization the permanent neodymium magnets were used.

The experimental stand was equiped with mass flow controllers to regulate fuel and air supply, an ICCD camera (Andor iStar DH734) for time resolved chemiluminescence of flame radicals (OH^*, NH^*_2) [5] and a mid infrared (MIR) spectrometer covering 2000 – 5500 nm to capture the main emission bands of water vapor (H_2O) and carbon dioxide (CO_2). A water cooled SBG01thermopile was used to measure total heat flux at a fixed distance from the flame.

Visual flame observations showed that hydrogen addition significantly enhanced flame brightness and stability, while ammonia addition tended to elongate the flame and shift color from bright blue toward yellow or red, depending on the mixture. In highly ammonia – rich blends, the flame became less stable under lean conditions but was successfully stabilized by the gliding arc plasma. Non-thermal plasma shortened the flame, intensified its color, and promoted a more turbulent and stable V – shape, especially for difficult to burn mixtures.

Heat flux measurements further confirmed the role of plasma in enhancing radiative heat transfer. Although 100% methane yielded the highest baseline heat flux other mixtures still achieved a notable 13 – 15% improvement in flux when plasma was activated, highlighting the potential of non-thermal plasma to boost heat release in low-carbon fuel blends. These improvements are attributed to higher flame temperatures, better intermediate radical generation (OH^*, NH^*_2), and more complete combustion.

The findings reveal that non-thermal plasma assistance can significantly improve flame stability, increase thermal radiation, and enhance combustion efficiency. Overall, plasma – assisted combustion represents a promising pathway to address the technical challenges of introducing ammonia and hydrogen into existing combustion systems.

Keywords: plasma assisted combustion, hydrogen enriched fuels, ammonia methane blends, flame stability, infrared radiation, heat transfer.

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ARTIFICIAL NEURAL NETWORK-BASED PREDICTION OF SYNGAS LAMINAR BURNING VELOCITY FOR CLEAN ENERGY APPLICATIONS

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ABSTRACT

Syngas is a fuel mixture primarily composed of H_2 and CO, with varying amounts of CO_2, and H_2O. Its composition varies significantly, affecting combustion behaviour and making accurate predictions of Laminar Burning Velocity (LBV) crucial for safety and efficiency in gas turbines, engines, and industrial burners.

Traditional LBV prediction methods, including empirical correlations and chemical kinetics simulations, face limitations in accuracy and computational cost. This study explores an Artificial Neural Network (ANN)-based approach to develop a fast and accurate LBV prediction model for syngas. The ANN is trained on an extensive synthetic dataset generated via Cantera chemical kinetics simulations, considering temperature, pressure, and fuel composition (H_2, CO, CO_2, H_2O, and air fractions).

Preliminary results show that the ANN achieves computational efficiency far exceeding Cantera simulations, with initial LBV predictions demonstrating physically consistent trends. Further work will focus on expanding the dataset, optimizing model accuracy, and improving generalization across diverse syngas compositions.

1. Introduction

Syngas, a versatile fuel consisting mainly of H_2 and CO, often contains varying amounts of CO_2 and H_2O, produced via gasification or pyrolysis of carbonaceous materials [1]. Its composition depends on the feedstock and production method, influencing combustion behaviour, efficiency, and safety [2,3].

Predicting laminar burning velocity (LBV) is essential for combustion modelling, system design, and safety in gas turbines, engines, and industrial burners. However, due to complex reaction kinetics, LBV estimation remains challenging [4].

Traditional methods include:

- Empirical correlations, which are fast but lack flexibility and accuracy.
- Chemical kinetics simulations (e.g., Cantera), which are precise but computationally expensive.

To address these limitations, this study explores Artificial Neural Networks (ANN) as a fast and accurate alternative for syngas LBV prediction across diverse conditions.

2. Methodology

Given the high variability of syngas composition, a comprehensive dataset is essential for training a robust ANN model. Instead of relying solely on experimental data, which is often limited, we generate a large synthetic LBV dataset using Cantera chemical kinetics simulations.

For each syngas mixture, LBV values are computed under different conditions, considering key parameters such Temperature, Pressure, H_2, CO, CO_2, H_2O (steam) and air fractions.

This results in a six-input ANN model that integrates our insights from previous studies and emphasizes innovative research by considering variable syngas compositions with steam.

The model is trained using an optimizer switching technique, where different optimizers (Adam, SGD, RMSprop) are applied in sequence to avoid local minima and improve convergence.

3. Preliminary Results

Initial findings indicate that the ANN model significantly outperforms Cantera in computation speed, reducing LBV estimation from several minutes to milliseconds. Generated LBV curves for specific syngas compositions exhibit physically consistent trends, aligning with expected combustion behaviour. While the ANN demonstrates good agreement with Cantera for several syngas cases (see Figure 1), deviations are observed at extreme pressures and steam-rich mixtures, highlighting the need for further dataset expansion and optimization. Moreover, the larger variety of syngas composition data is also needed for the creation of general case model.

Figure 1 ANN predictions agreement with Cantera computations.

4. Conclusion

The proposed ANN-based model demonstrates significant computational efficiency in LBV prediction, reducing estimation time from minutes to milliseconds. Preliminary results suggest physically consistent trends, but further validation is required to enhance accuracy and generalization across diverse syngas compositions. Ongoing work focuses on refining model accuracy, expanding the dataset, and optimizing the ANN architecture to improve generalization across diverse syngas compositions.

Keywords: Syngas, Artificial Neural Networks, Laminar Burning Velocity, Machine Learning, Hydrogen Combustion, CFD, Clean Energy.

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TEMPERATURE DIAGNOSTICS UNDER THE NON-THERMAL PLASMA APPLICATION TO THE COMBUSTION PROCESS

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ABSTRACT

The worldwide population expansion has resulted in higher energy carrier usage and intensification of the pollutions from human-made sources in environmental systems. Recent efforts are concentrated on transforming waste materials into energy due to it's sustainable potential and possible zero net emission state. Plasma technologies, in particular, show significant promise for transforming a wide array of materials into products with high added value, such as fuels, as well as a possibility for deep utilization of byproducts from different spheres of industry, such as off-gas from the landfills, by combustion process support and enhancement. However, the method of plasma influence on the combustion process is still a subject of debate, since the mechanisms of plasma influence are quite complex and stochastic. This study investigates the effects of plasma assistance on vibrational, rotational, electronic, and translational temperatures of an OH* A-X transition. For temperature diagnostics was used the data obtained from the UV-VIS OES graph, which was later employed into the SPECAIR code. The hydroxyl (OH*) molecular band, corresponding to the $A^2\Sigma^+ \rightarrow X^2\Pi$ transition ($v = 0 \rightarrow v' = 0$) within the 306–314 nm range, appears in the emission spectrum as a result of water molecule dissociation in the plasma. Typically, the rotational temperature of the OH radical closely reflects the gas temperature. [1]. This temperature is measured using the OH* (A2 Σ+) band at 306.357 nm [2–4] . Based on these findings, various temperature profiles—electronic, rotational, vibrational, and translational—were calculated. These profiles, depicted in Figure 1, correspond to regimes with and without plasma assistance for gases containing 25% of CH_4 in CO_2 stream, 30% of CH_4 in CO_2 stream and 35% of CH_4in CO_2 stream ($BG_{25/75}$, $BG_{30/70}$, and $BG_{35/65}$), respectively.

Notably, the changes in rotational, vibrational, and translational temperatures during plasma-assisted combustion were relatively modest in absolute terms, whereas the electronic temperature exhibited substantially larger variations. Under plasma-unassisted combustion conditions with a 23% oxygen fraction in air (v/v), the electronic temperatures were measured at 4560 K, 5000 K, and 5300 K for the $BG_{25/75}$, $BG_{30/70}$, and $BG_{35/65}$ regimes, respectively. Upon application of plasma, the electronic temperature increased by 31.5%, 22%, and 12.9% for the BG25/75 regime at oxygen fractions of 23%, 25%, and 29% (v/v), respectively. Similarly, the BG30/70 regime exhibited increases of 42.5%, 26.6%, and 18.9%, while the BG35/65 regime showed increases of 34.5%, 23.6%, and 15.9% for the corresponding oxygen fractions. In contrast, the rotational and vibrational temperatures for $BG_{25/75}$ and $BG_{30/70}$ remained nearly constant between plasma-assisted and plasma-unassisted combustion. The variation in electronic temperature reflects the change in internal energy with respect to entropy under conditions of constant volume and particle number [5]. Consequently, the concurrent increase in electronic temperature, alongside the stable rotational temperature, suggests that the primary effect of the non-equilibrium Gliding Arc plasma employed in this study is an enhancement of the molecular kinetic energy rather than a direct increase in the thermal energy of the gas [5].

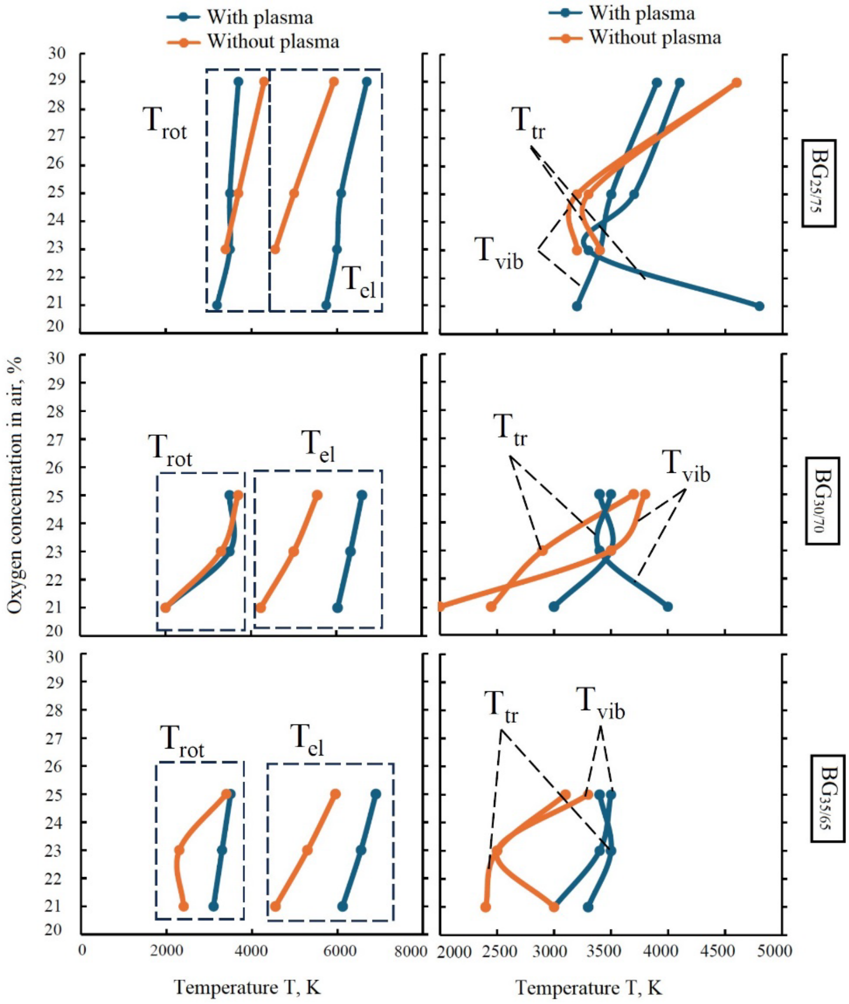

Figure 1 Profiles of different temperature with and without plasma assistance.

Keywords: Non-thermal non-equilibrium plasma, Rotational Gliding Arc, Temperatures, Combustion enhancement.

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INFLUENCE OF SODIUM HYDROXIDE SURFACE TREATMENT AND STEARIC ACID COATING ON FRICTION REDUCTION

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ABSTRACT

In the last few decades, much research has been done to save net power energy by reducing fuel energy consumption and reducing the emission of CO_2; these can only be achieved if the drag friction reduction increases by a respectable percentage. Many techniques have been used to reduce drag friction; for instance, the air lubrication technique has saved 20% of energy on average. Another passive method that can effectively lower friction is coating the surface with a superhydrophobic or hydrophobic surface or low-friction polymer material, such as silicon or polytetrafluoroethylene (PTFE). Texturing the surface by making some grooves to manage the boundary layer flow is also an effective way to reduce the drag coefficient. This study reduces friction by creating a hydrophobic layer on the aluminum surface. NaOH solution at two different concentrations (2.5 and 7.5 g/L) were added to roughen the samples, then the rough samples were immersed in stearic acid (0.01 M) for 24 hours. The velocities of each sample were calculated after measuring the required time for the samples to travel along a fixed distance (1.87 m) using v = d/t. Tables 1 and 2 demonstrate that the velocity of pure aluminum samples, which are uncoated, increases with temperature. This causes the viscosity to drop, which lowers the friction until it reaches 14.11% at 250°C. Then, the velocity decreased due to the formation of microbubbles around the aluminum surface at 300°C. These layers act as a lubricating layer that insulates the surface of aluminum from the water. This layer has a lower viscosity than the water, which reduces shear stress and then the friction reduction. At a high temperature of 400°C, the Leidenfrost effect occurs, reducing the velocity of pure aluminum samples. The same scenario happened in the samples with NaOH. Still, the bubbles were formed and constructed at low temperatures in the samples with stearic acid (NaOH 2.5 g/l) due to the change in the surface morphology and wettability; however, the change of the properties of the surface with temperature also affects the friction reduction.

Table 1. Velocity calculation result for low concentration of NaOH (2.5g/l).

Temperature (° C)	Pure Al (m\s)	Al with NaOH (2.5) (m\s)	Al with NaOH (2.5) + stearic acid(m\s)
Cold samples	0.85	0.83	0.84
200	0.96	0.85	0.95
250	0.97	0.92	0.91
300	0.88	0.89	0.86
400	0.91	0.91	0.90

Table 2. Velocity calculation result for high concentration of NaOH (7.5g/l).

Temperature (° C)	Pure Al (m\s)	Al with NaOH (7.5) (m\s)	Al with NaOH (7.5) + stearic acid(m\s)
Cold samples	0.85	0.86	0.88
200	0.96	0.96	0.92
250	0.97	0.89	0.88
300	0.88	0.85	0.86
400	0.91	0.87	0.87

Keywords: Drag reduction, surface modification, coating techniques.

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3. ENVIRONMENTAL SCIENCES

3.1. Precision Agriculture, Horticulture and Forestry

28-YEARS OF BARK BEETLE AND WIND-DRIVEN CHANGE AND NATURAL DEVELOPMENT OF NORWAY SPRUCE (*PICEA ABIES*) STANDS: A CASE STUDY OF DUBRAVA NATIONAL FOREST RESERVE

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ABSTRACT

As areas of minimal forest management, natural forest reserves provide insight into natural forest ecosystem function and development over time in the face of various threats. The Norway spruce (*Picea abies* (L.) H. Karst) has been severely affected by wind damage and bark beetle outbreaks in most areas of Lithuania. This study aims to assess spruce-dominated forest reserve dynamics following series of severe *Ips typographus* outbreaks and wind damage events in Dubrava forest reserve.

By using data collected from long-term observation plots, we aimed to; i) underline the main tree damage and mortality-causing factors in Dubrava forest reserve; ii) evaluate tree mortality and stand structure dynamics over time; iii) identify stand structural and environmental factors that contributed the most to the processes of regeneration and ingrowth.

This study applied data from 34 cyclically remeasured permanent observation plots established in Dubrava Forest Reserve in 1996. Since their establishment, the plots were also measured in 1998, 2001, 2011, 2016, and 2022, using the Lithuanian National Forest Inventory methodology. This study largely focused on sites containing fertile mineral soils with normal moisture regimes and periodically water-saturated fertile mineral soils. Our analysis identified *Ips typographus* and wind as the main spruce mortality cause agents.

The species significance of spruce in the Dubrava Forest reserve has declined, in addition to the forest stands total basal area and volume. Meanwhile, broadleaf tree species have increased in importance value. Stand structural and environmental variables were found to be significant for regeneration. High soil fertility-dependent interspecific competition was found between spruce natural regeneration and other tree and understory species such as common hazel (*Corylus avellana*), rowan (*Sorbus aucuparia*), Norway maple (*Acer platanoides*), and bird cherry *(Frangula alnus*), in originally spruce-dominated stands.

BIOCHEMICAL ANALYSES OF PERENNIAL VEGETABLE GENUS *ALLIUM*

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ABSTRACT

The perennial vegetable genus *Allium* has been consumed since ancient times, but the growing demand for non-traditional plant products nowadays encourages research into new plant species and cultivars. The leaves of the perennial vegetable genus Allium have a very high biological value and are valued by consumers for this reason. Therefore, it is important to study plant cultivars and determine the time harvesting to obtain quality products. The study material was harvested from the experimental vegetable field of the Institute of Horticulture of Lithuanian Research Centre for Agriculture and Forestry in 2023 and 2024. The biochemical parameters were established in fresh weight (FW) at the Laboratories of Biochemistry and Technology of the Institute of Horticulture [1,2]. The biochemical elements (total sugar, soluble solids, ascorbic acid, nitrates, dry matter) were observed in five species: *A. schoenoprasum, A. angulosum, A. nutans, A. fistulosum, and A. ursinum.* Measurements were performed of harvests, which were done three times: in spring, summer, and autumn. The obtained results showed that differences in the biochemical elements of different cultivars of the perennial vegetable genus *Allium* were influenced by genetic origin and harvesting time. The highest amount of total sugar, soluble solids, and ascorbic acid were more intensive in spring for all cultivars in our investigation years. The accumulation of dry matter and nitrates content varied seasonally between varieties. *A. ursinum* No. 22-01 is distinguished with the highest content of ascorbic acid (96.0 – 98.0 mg %) and lowest content in nitrates (35.7 – 50.5 mg/kg) in both years. *A. shoenoprasum* L. 'Aliai' is distinguished with the highest accumulation of total sugar – 5.27 % in 2024. The highest amount of soluble solids (12.0 %) was measured in *A. schoenoprasum* No. 04-32 in 2024.

Keywords: perennial vegetable genus *Allium*, chemical elements, cultivars.

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RESPONSE OF YOUNG CONIFERS TO THE SIMULATED IMPACT OF URBAN POLLUTANTS

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ABSTRACT

Particulate matter (PM), tropospheric ozone (O_3), and carbon dioxide (CO_2) impact the growth and health of trees in urban environments in various ways, with the extent and severity of damage depending on the species, pollutant combinations, and exposure duration. Tropospheric ozone, in particular, induces oxidative stress in foliage tissues, while PM interacts with trees through foliar deposition. Tree canopies act as highly effective natural filters, capturing and accumulating PM on their surfaces. As noted in the literature, conifers are more sensitive to pollutants than deciduous trees, yet they often grow in urban areas. This study examined how two coniferous species, naturally found in Lithuanian forests, respond to PM exposure under elevated O_3 and CO_2 concentrations. More specifically, we focused on three-year-old Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) H.Karst.) seedlings and evaluated early responses to the treatment. The treatments included *(i)* a combination of PM at elevated levels of O_3 (180 ppb) and CO_2 (650 ppm); *(ii)* no PM at elevated levels of O_3 (180 ppb) and CO_2 (650 ppm); *(iii)* PM at standard levels of O_3 (< 40–45 ppb) and CO_2 (< 400 ppm), and *(iv)* no PM at standard levels of O_3 (< 40–45 ppb) and CO_2 (< 400 ppm)-control. The growth parameters as stem height and diameter, and biochemical parameters as photosynthetic pigments-contents of chlorophyll a (chl a) and b (chl b), carotenoids, total polyphenols (TPC), total flavonoids (TFC), and total soluble sugars (TSS) – were evaluated as the significant ($p<0,05$) response to treatments compared to control.

In the early stages of the simulation experiment, the treatments had no significant impact on coniferous seedling stem height and diameter growth. However, Norway spruce seedlings decreased in diameter under the treatment of a combination of PM at elevated levels of O_3 and CO_2. All treatments reduced the concentrations of chl a and chl b in Norway spruce seedlings. In Scots pine seedlings, the concentrations of chl a and chl b were reduced after exposure to elevated levels of O_3 and CO_2 (with no PM). Additionally, chl b was decreased after a single PM treatment at standard levels of O_3 and CO_2. The carotenoids decreased in Norway spruce seedlings under the combination of PM at elevated O_3 and CO_2, and in Scots pine seedlings under elevated O_3 and CO_2. The TPC in Scots pine seedlings decreased under single PM treatment but increased under the elevated combined O_3 and CO_2. Meanwhile, TPC increased under single PM treatment in Norway spruce seedlings. The TFC decreased in Norway spruce under elevated combined O_3 and CO_2 in both cases-with and without PM treatment. However, TFC did not change for Scots pine seedlings. The TSS decreased under single PM treatment but increased under the elevated O_3 and CO_2 for both Scots pine and Norway spruce seedlings. The PM combination at elevated O_3 and CO_2 caused higher TSS in Norway spruce seedlings.

In conclusion, simulated PM exposure less influenced Scots pine than Norway spruce seedlings. While PM exposure significantly reduced chlorophyll b and TPC in Scots pine, it had a higher effect on Norway spruce, particularly in stem diameter and carotenoid concentrations compared to control. Therefore, Scots pine showed greater resilience to PM exposure in the early growth stages under simulated urban pollution.

Keywords: CO_2, ozone, particulate matter, stem growth, biochemical effect, urban pollution.

COMPARISON OF THREE DIFFERENT OAT CULTIVAR REACTIONS ON FUSARIUM HEAD BLIGHT BASED ON HYPERSPECTRAL ANALYSIS IN GREENHOUSE CONDITIONS

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ABSTRACT

Oats belong to small grain cereals, a group of crops that also includes wheat, rye and barley. Oats are mostly cultivated in Northern Europe and North America and are valued for grain quality characteristics and low requirements for soil and temperature. This crop species is also popular among organic farmers. The spread of different fungal diseases in oats can negatively affect the yield and quality of grains. *Fusarium* head blight (FHB) caused by fungi of the genus *Fusarium*, results in production of mycotoxins in the grain, which in significant quantities are toxic to both humans and farm animals. FHB at specific developmental stages can be detected by spectral analysis using remote sensing technologies. A multispectral or hyperspectral camera can be used to assess FHB before harvest, which would be a useful tool for farmers or plant disease-controlling authorities.

As part of PhD research, greenhouse trials were conducted using three different oat cultivars: 'Husky', 'Ivory' and 'Lelde'. Seeds and plants at the mid-flowering stage (BBCH 65) were inoculated with *Fusarium* spp. spore material (containing *F. culmorum, F. poae, F. oxysporum, F. graminearum* and *F. sporotrichioides*). Disease development on oat grains was assessed visually, using a microbiological test and a hyperspectral camera. Disease severity visual scoring was conducted at the medium to late milk stage (BBCH 75-77). Hyperspectral imaging of inoculated and control plants was conducted from the end flowering stage (BBCH 69) till the early ripe stage (BBCH 83). For hyperspectral data analysis, a special program was developed, that estimates the severity of disease based on head blight index (HBI). The program uses spectral differences in the ranges of 665–675nm and 550–560 nm.

The highest disease severity reached when the plants were inoculated at the mid-flowering development stage, visual estimation results ranged in 33 – 50 % classes. In seed inoculation variant visual estimation of disease severity ranged in 14 – 21 % classes. The disease severity estimation based on hyperspectral data analysis ranged from 22,6 to 45,3 % for plants inoculated at the mid-flowering stage and from 12,8 to 21,2 % for plants when inoculation was conducted on seeds. Microbiological test results confirmed that the most common pathogen was *F. culmorum* (55 %).

Keywords: Precision Agriculture, Remote Sensing, Hyperspectral Analysis, Oats, Fusarium Head Blight

PLANT GROWTH-PROMOTING PROPERTIES OF *RHODIOLA ROSEA* ROOT ENDOPHYTIC BACTERIA

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ABSTRACT

Plants inhabiting environments with suboptimal growth conditions often have a pronounced capacity to attract and sustain microbial communities that improve nutrient absorption and expand abiotic stress tolerance. *Rhodiola rosea* L. is a succulent plant of the *Crassulaceae* family adapted to sandy or rocky soils or dry tundra. The present study aimed to investigate the plant growth-stimulating potential of *R. rosea* endophytic microbiota. Seventy-three endophytic bacteria isolates were obtained from the rhizome of *R. rosea* plants and were assigned into 14 distinct bacterial genera of Firmicutes (26%) or Proteobacteria (74%) phyla. Screening for functional genes related to the nitrogen cycle, phosphorus mineralisation or dissolution, and traits associated with nitrogen fixation (56% of isolates), siderophore production (40%), inorganic phosphorus solubilisation (30%), and production of indole-related compounds (51%) led to the classification of the isolates into 16 distinct clusters. Co-cultivation of 45 selected isolates with germinating Arabidopsis seedlings revealed 18 and 5 isolates that resulted in more than a 20% increase in root or shoot growth, respectively. The study results established the complexity of the succulent *R. rosea* endophytic microbiome and identified isolates for potential plant growth-stimulating applications. This study identified several bacterial isolates with plant growth-promoting properties that present a promising target for consideration in the design of phytostimulant formulations suitable for sustainable and environment-friendly agriculture practices.

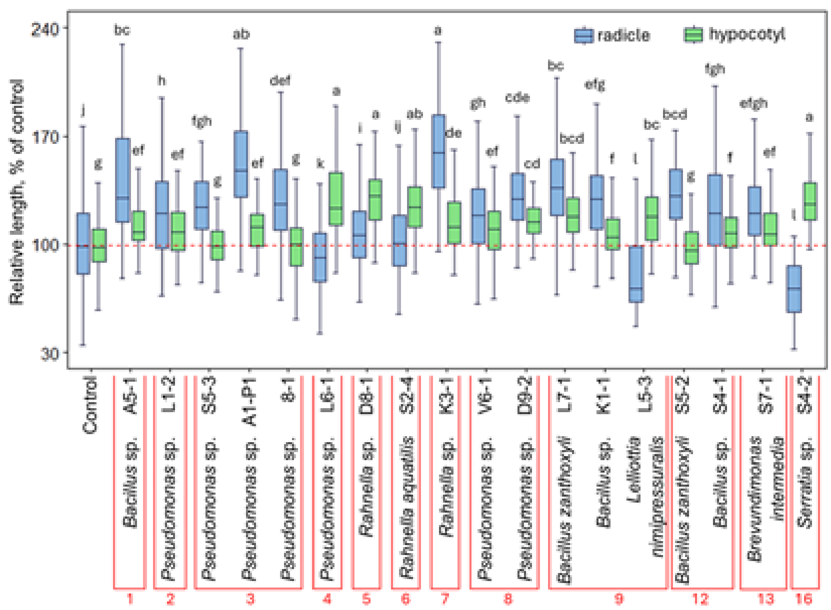

Figure 1 Arabidopsis seedling radicle (blue fill)- and hypocotyl (green fill)-growth-modulating effect of selected endophytic bacterial isolates obtained from R. rosea rhizome.

EFFECT OF SOIL PROPERTIES ON CARBON DIOXIDE EFFLUX UNDER DIFFERENT TILLAGE

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ABSTRACT

The intensity of soil carbon dioxide efflux can vary depending on meteorological conditions, tillage systems, and chemical properties of the soil. The aim of this work is to determine the effect of environmental factors and soil chemical properties on CO_2 efflux under different tillage methods with different textures.

The study was conducted at a long-term field experiment in Central Lithuania. The local soil site is categorized as *Cambisol* (Loamy, drained) according to WRB [1]. Soil texture composition (sandy loam and loam) was determined using pipette method according to FAO. Soil CO_2 effluxes from topsoil depth in different treatments were investigated using a closed chamber method (LI-COR LI-8100A Automated Soil CO_2 Flux System) [2]. The water content in the soil and soil temperature were recorded by portable sensor HH2 WET [2]. The soil carbon dioxide effluxes, soil temperatures and water contents were measured five times per growing season from April to August in 2021. Soil samples for chemical properties of the soil were collected from 0–10 cm soil layer in April 2021.

The carbon dioxide efflux varied from 0.69- 2.48 μmol CO_2 m^{-2} s^{-1} during the growing season. Soil CO_2 efflux was 8.6% lower in conventional tillage than in reduced tillage and no-tillage. The temperature in sandy loam and loam soil varied from 8.4 - 23.5 °C and 10.3-28.7 °C, respectively. The volumetric water contents in the sandy loam and loam soil varied from 5.6%-18.3% and 6.0%-18.0%, respectively. Soil CO_2 efflux (20.1%), soil temperature (18.3%) and volumetric water contents (5.1%) in loam was higher than in sandy loam. Soil organic carbon and total nitrogen, tended to decrease in following orders: no-tillage (11.1 g kg^{-1} and 1.34 g kg^{-1}) > reduced tillage (10.4 g kg^{-1} and 1.21 g kg^{-1}) > conventional tillage (9.4 g kg^{-1} and 1.07 g kg^{-1}), respectively. The moderately acidic and neutral pH values were observed at 0–10 cm soil depth in sandy loam and loam soil, respectively. Soil organic carbon (26.9%), total nitrogen (24.8%), available phosphorus (14.4%), available potassium (15.6%), soil pH (19.1%) was higher in loam soil than in sandy loam soil.

Our research showed that soil temperature ($r = 0.80$) and volumetric water contents ($r = 0.77$) had a direct effect on CO_2 efflux from the soil, and available potassium was a direct effect but was not strongly dependent. But soil organic carbon ($r = 0.83$), total nitrogen ($r = 0.80$), and soil pH ($r = 0.80$) posed indirect effect, although they were a strong relationship with soil CO_2 efflux.

Soil temperature, volumetric water content, soil organic carbon, total nitrogen and soil pH significantly influenced soil environment-atmosphere CO_2 exchange rate. Soil CO_2 efflux was dependent on tillage. It decreased from no-tillage to conventional tillage application. This phenomenon can be explained by more favorable soil conditions for soil biota, root development, and soil aggregates stability representing soil index of soil health environment.

Keywords: soil CO_2 efflux; soil organic carbon; total nitrogen; soil pH; volumetric water content; soil temperature.

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UNLOCKING THE POTENTIAL OF NETTLE FIBER (*URTICA DIOICA* L.): A BIORESOURCE FOR SUSTAINABLE AGRICULTURE

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ABSTRACT

The increasing global population seriously threatens the ability to ensure food security and agricultural productivity, as demand for food production has resulted in an overreliance on chemical inputs, negatively impacting the ecosystem. Therefore, finding simple and sustainable solutions within the agricultural ecosystem is necessary to improve agricultural productivity and provide better resilience to climate change impact. Research on utilizing plant biomass as biostimulants is becoming more attractive since there is a prevailing need to elevate crop yield and soil health while minimizing the detrimental effects of synthetic fertilizers. The use of organic amendments in sustainable agriculture has drawn significant interest due to their potential to enhance soil health and crop productivity. Nettle (*Urtica dioica* L.) has emerged as a promising candidate in sustainable agriculture. Nettle is a perennial plant containing unlignified fibers, which grows readily in the wild throughout Europe and Asia. It has a rich profile of plant nutrients (carbon, calcium, magnesium, potassium, nitrogen, and phosphorus) and bioactive compounds (flavonoids, phenolic acids, carotenoids, sterols, and coumarins) suitable for enhancing crop productivity and soil health. In this context, nettle-based amendments could pave the way for promising results, with positive impacts on growth stimulation and leaf promotion. Due to the abundance of bioactive compounds, nettle extracts can act as biostimulants with demonstrated efficacy in improving seed germination, plant vigor, and resistance to biotic and abiotic stresses. Furthermore, incorporating nettle fiber-based amendments into the soil promotes a balanced ecosystem, playing a crucial role in nutrient cycling, nutrient uptake, and resilience to plant pests and diseases. In this regard, more in-depth research is required on the multifaceted role of nettle fiber in modern agriculture, emphasizing its contributions to soil health, plant growth, and environmental sustainability. This review highlights the agricultural applications of nettle fiber, identifies knowledge gaps, and suggests future research directions to maximize its potential in sustainable farming systems.

Keywords: Nettle, Slurry, Bioactive compounds, Biostimulants, Plant productivity, Soil health.

EFFECT OF PET MICROPLASTICS ON GROWTH AND GAS EXCHANGE PARAMETERS OF CHERRY BELLE RADISH (*RAPHANUS SATIVUS* L.)

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ABSTRACT

Plastic pollution is a growing environmental concern, with microplastics increasingly contaminating soil ecosystems. These tiny plastic particles originate from various sources, including industrial waste, plastic degradation, and agricultural applications, and their persistence in the environment raises concerns about their potential ecological impact. Among microplastics, polyethylene terephthalate (PET) is a widely used polymer found in packaging materials, textiles, and beverage containers. PET microplastics can alter soil properties, affect water retention, disrupt microbial communities, and interfere with plant growth. Despite their widespread presence, limited research has been conducted on their effects on seed germination, early plant development, and physiological processes. Understanding these impacts is crucial for assessing potential risks to agriculture and ecosystem health, as microplastic accumulation in soil could directly affect food security and sustainable farming practices.

This study investigates the effects of PET microplastics on the growth and gas exchange processes of Raphanus *sativus* L. (Cherry Belle radish). Cherry Belle radish was chosen due to its fast germination, short growth cycle, and sensitivity to soil conditions, making it an ideal model for assessing early-stage plant responses to microplastic exposure. Investigating how PET microplastics influence seed germination, plant biomass, and physiological traits can provide valuable insights into the broader implications of plastic contamination in agricultural systems. To assess these effects, PET microplastics of approximately 800–1000 µm in size were incorporated into the soil at concentrations of 1%, 3%, and 5% (w/w). The experiment includes 1 control group and three treatment groups. Each group had three replicates. Plants were grown in ambient 400 ppm CO2 concentration and 21/14 °C of day/night temperature, relative air humidity was 60/70% and 14/10 h light/dark regime. The photosynthetically active radiation at the leaf level was ~300 mol m^{-2} s^{-1}. The growth conditions were maintained and carried out for 90 days. Plants were cultivated under controlled conditions for 40 days, after which morphological and physiological parameters were analysed. The study examined plant growth characteristics such as shoot and root height, fresh and dry biomass, and leaf morphology. In addition, gas exchange parameters were evaluated using the Li-COR device, which measured stomatal conductance, photosynthetic rate, transpiration rate, intercellular CO_2 concentration, and water use efficiency. Statistical analyses, including ANOVA and then Tukey's HSD were performed to determine the significance of observed differences among the treatments.

Results demonstrated that increasing PET microplastic concentrations negatively impacted key physiological traits, particularly at the highest exposure level (5%). Treatment with 5% PET significantly reduced ($p \leq 0.05$) photosynthetic rate, and transpiration rate by 22% and 28% respectively, suggesting that microplastics interfered with gas exchange, likely through soil-mediated stress responses. Marginal reduction was observed in dry root and stomatal conductance. However, intercellular CO_2 concentration ($p = 0.2675$) and water use efficiency ($p = 0.1201$) remained unaffected, indicating that while stomatal function was impaired, plants may have partially compensated through altered physiological mechanisms.

Morphological analysis revealed a significant reduction in fresh and dry shoot weight ($p \leq 0.05$), at the 5% PET concentration, suggesting that plastic exposure hindered biomass accumulation. However, shoot height, root height, leaf width, did not show statistically significant differences across treatments, indicating that some growth parameters remained resilient despite microplastic exposure. The observed reductions in biomass and gas exchange efficiency at 5% PET concentration highlight the potential of PET microplastics to disrupt plant physiology, possibly by altering soil properties, nutrient availability, or water retention capacity.
These findings underscore the need for further investigation into the long-term implications of microplastic pollution in agricultural soils. Given that plastic contamination is an emerging threat to global food production, understanding its effects on plant health is essential for developing mitigation strategies. Future research should explore the underlying mechanisms by which PET microplastics affect plant-soil interactions, including their

influence on soil microbial communities, root architecture, and nutrient dynamics. Addressing these knowledge gaps will be crucial for informing policies on plastic waste management and sustainable agricultural practices.

ENDOPHYTIC BACTERIA OF EUROPEAN ASH: BENEFICIAL ALLY IN THE FIGHT AGAINST ASH DIEBACK

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ABSTRACT

Phytopathogens can pose a significant threat not only to targeted plant species but to the whole ecosystem, too. Emerging fungal diseases may lead to severe declines in tree populations and thus decrease biodiversity. For the past 30 years, European ash (*Fraxinus excelsior* L.) has been facing a mortality-inducing ash dieback disease caused by the fungi *Hymenoscyphus fraxineus.* The pathogen stays on fallen sick ash leaves and produces airborne spores that can travel long distances by wind. These spores land on healthy ash tree leaves in warmer and humid conditions and then germinate on the leaf surface. Colonization begins, the pathogen enters through stomata, necrotic lesions appear, the infection spreads even further into the twigs, and then to the tree's vascular system (xylem). Symptoms lead to wilting, dieback of ash shoots and branches, and bark lesions [1]. Moreover, the weekend trees may be more susceptible to biotic stressors, such as insects or fungi, and abiotic stressors like drought - thus accelerating the decline [2].

In Lithuanian Research Centre for Agriculture and Forestry, Institute of Forestry, laboratory of Forest Plant Biotechnology, research was conducted to find an ecologically safe way to protect European ash from ash dieback. For this purpose, endophytic bacteria from a European ash stand located in Dubrava Forest were extracted, and their antagonistic capabilities were tested under in vitro conditions. In total, 9 easily cultivated endophytic bacteria were identified and tested for their antagonistic potential against ash dieback and different plant growth-promoting traits (PGPT's) for trees. Isolates were tested for the fixation of nitrogen (N), solubilization of potassium (K) and inorganic phosphate, organic phosphate mobilization, and production of siderophores (iron sequestration) by using prepared selective media in Petri dishes [3]. Fresh bacterial colonies were streaked on Petri dishes and then incubated for a week at 28℃. The formation of biofilms and production of phytohormone indole-3-acetic acid (IAA) was checked spectrophotometrically [3]. These multiple tests were carried out in triplicates, statistical analyses were conducted using SPSS (version 28.0.1.1 (IBM Inc.)), employing the Kruskal-Wallis H test ($p<0.05$). The antagonistic activity of isolates was measured in experimental weeks 2, 3, and 4. Results varied: in vitro pathogen–potential antagonist experiment revealed that 5 bacteria (638, 645, 646, 690 and 731) out of 9 tested slowed down or completely stopped the growth of *H. fraxineus* during all 4 weeks of the experiment. Furthermore, three bacteria (645, 646 and 690) showed higher levels of produced IAA (ranging between 20-44 µg/ml), three bacteria formed biofilms stronger than others (633, 645 and 731). Six out of nine bacteria could fix nitrogen, six could produce siderophores, five could solubilize potassium, six could solubilize organic phosphates, and none could solubilize inorganic phosphates. Best-suited bacteria for further investigations will be chosen for field experiments as follows: endophytes 638, 645, 646, 690, 731.

Keywords: endophytes, *Fraxinus excelsior* L., *Hymenoscyphus fraxineus,* antagonists.

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SMART FARMING REDEFINED: PORTABLE AIR-COUPLED ULTRASONIC TECHNOLOGY FOR PRECISION AGRICULTURE

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ABSTRACT

Agriculture is undergoing a transformative era driven by advancements in precision technologies. This research introduces a novel portable air-coupled ultrasonic device designed to elevate precision agriculture practices. Unlike traditional contact-based or invasive agriculture testing mechanisms, this innovative solution leverages non-invasive, air-coupled ultrasonics to deliver real-time insights into crop health, soil properties, and moisture levels.

The device's compact design ensures field portability while maintaining high measurement accuracy, even in variable environmental conditions. Through the use of advanced signal processing and cloud computing, this technology provides reasonable data to farmers, enabling efficient resource management, enhanced crop yields, and reduced environmental impact.

The device utilizes air-coupled ultrasonics to measure leaf thickness, ultrasound velocity, attenuation, and density, parameters essential for estimating relative water content and water potential with high precision. Conventional methods, such as pressure chambers or gravimetric techniques, are time-consuming, invasive, and require skilled labor. In contrast, this system ensures instantaneous data acquisition with higher accuracy and repeatability, even in varying environmental conditions.

By integrating advanced signal processing and cloud-based analytics, the proposed device provides actionable insights for farmers, optimizing irrigation strategies, improving crop yield predictions, and reducing water wastage. This approach represents a significant advancement in non-destructive plant investigation, paving the way for a smarter, more sustainable agricultural future.

Keywords: Ultrasound, signal-to-noise ratio, spread spectrum signals, spectral losses compensation, resonance spectroscopy.

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EXPLORING THE ANTIOXIDANT AND ANTI-INFLAMMATORY POTENTIAL OF UNDERUTILIZED PLANT MATERIALS BY SOLID-STATE KOMBUCHA FERMENTATION

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ABSTRACT

Since radical scavenging species cause oxidation of the macromolecules and DNA, they also contribute to developing diseases like cancer, diabetes, and metabolic disorders. Plants produce protective compounds including phenolics, carotenoids, chlorophyll, and flavonoids that quench radical scavenging species while providing anti-cancer and anti-inflammatory properties. With the devastating effect of the radical scavenging species on human health, it is important to analyze both the antioxidant activity and its anti-inflammatory properties in underutilized plants such as weed plants and easy-to-grow microgreens. Additionally, potential methods to enhance these properties, such as solid-state kombucha fermentation, should also be explored.

This study for the first time describes the comparative analysis of these bioactive compounds in horseradish (*Armoracia rusticana*) leaves, sunflower microgreens *(Helianthus annuus),* and red clover *(Trifolium pratense)* flowers both before and after solid-state fermentation by spectrophotometric methods. Dry samples of these three plants are subjected to both control (non-fermented) and treatment (fermented) conditions, yielding six treatments in total. Solid-state fermentation is conducted over three days at 28°C. For each plant, eight replicates are analyzed for flavonoids and phenolic compounds using spectrophotometric methods with a microplate reader, while three replicates are used to quantify chlorophylls, carotenoids and anti-inflammatory activity. The results will facilitate a comparative analysis of the effects of fermentation on the concentrations of these bioactive compounds while also identifying observable trends and patterns through qualitative data interpretation.

Horseradish exhibited the highest levels of polyphenols (69.34 and 101.26 mg/g rutin equivalents of sample dry weight), flavonoids (60.46 and 93.19 mg/g rutin equivalents of sample dry weight) both pre- and post-fermentation comparing to other plants. *Armoracia rusticana* leaves also reported the highest total chlorophyll content (8.12 mg/g of sample dry weight) before fermentation, and carotenoids (5.69 mg/g of sample dry weight) post-fermentation among all the treatments. Notably, fermentation decreased total polyphenolic compounds in sunflower and red clover by 36.68% and 19.69%, respectively, comparing with the control group. Across all the plants, the anti-inflammatory properties in the fermented group exhibited an increase of 94–100% following the fermentation process.

Keywords: Antioxidants, Bioactive compounds, Underutilized plants, Secondary metabolites, Plant Nutrition, Anti-inflammatory properties

Acknowledgment: This project has received funding from the Research Council of Lithuania (LMTLT), agreement No. S-ST-24-61.

3.2. Pest Management and Food Safety

ANTIOXIDANT AND ANTIMICROBIAL ACTIVITY OF *AEGOPODIUM PODAGRARIA* EXTRACTS AGAINST FOOD SPOILAGE MICROORGANISMS

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ABSTRACT

Over time, there is an increasing number of evidence that some food additives are harmful and could have negative effects on the health of the population. Therefore, the demand for natural substitutes for synthetic food additives is increasing due to consumers' concern on health issues. These additives are added to ensure that the food remains safe to eat and to not allow for it to spoil so fast. Food spoilage remains a global economic problem that is not yet under control. It is estimated that annually about 1.3 billion tonnes of food, amounting to 30% of global food production intended for human consumption is lost or wasted [1]. Multiple factors contribute to food spoilage, one of the most dangerous factor being food spoilage microorganisms – bacteria (*Salmonella typhimurium*., *Bacillus cereus*, *Escherichia coli* or *Micrococcus luteus*), fungi (*Alternaria* spp., *Penicillium* spp., *Fusarium* spp.) or even yeast, such as *Candida albicans* [2,3]. It is known that various phytocompounds, derived from spices and herbs have antimicrobial properties. By such, they could be used as natural antioxidants and antimicrobial agents to eliminate the microbial contamination of food products, therefore ensuring safer food and increasing its shelf life.

Aegopodium podagraria (also known as goutweed) is a perennial herbaceous plant that grows in shaded areas and is widely distributed across the country. The plant is a source of various antibacterial and antifungal compounds, such as coumarins, glycosides, essential oils and various phenolic compounds, including flavonoids. Despite the plant's biologically active compounds, it is somewhat forgotten, even though it is available in our environment and is easy to obtain.

Thus, the aim of this study was to evaluate the antioxidant activity, total phenolic and flavonoid content of native plant *Aegopodium podagraria* and determine the antimicrobial activity of the plants extract on bacteria and fungi, that are known to cause food spoilage. The herb was collected during flowering stage at location 54.8208758, 24.0492927. All botanical parts of the plant (leaves, stems, flowers and roots) were extracted by conventional maceration method using 2 different solvents: water and 75% methanol. Antioxidant activity, total phenolic and flavonoid content was determined by spectrophotometric methods and expressed in rutin equivalents. Antimicrobial activity on various food spoilage microorganisms was determined by diffusion methods. Highest TPC and TFC was determined in the flowers – 100,96 mg/g and 50,04 mg/g respectively. Compared to flowers, TPC in the leaves was found to be 1.5 times lower, while flavonoid content was about 3 times lower. The lowest concentration of phenolic compounds was found in stems and roots of the plant. In all cases, extraction with methanol significantly ($p \leq 0,05$) increased the yield of phenolic compound and antioxidant activity. A positive correlation was found between the concentration of phenolic compounds and antioxidant activity. Antimicrobial activity assessment results revealed that the extracts successfully inhibited the growth of various microorganisms – the highest antimicrobial activity was observed in the methanolic extracts of leaves and flowers, while the most sensitive microorganisms to their effects were *M. luteus* and *S. typhimurium*, as well as *Alternaria* spp. and *Penicillium* spp. fungi. These results provided valuable insights into using the compounds from the native and widely distributed plant *Aegopodium podagraria* as natural food preservatives to minimize the waste of food due to spoilage microorganisms.

Keywords: *Aegopodium podagraria,* extracts, food spoilage, microorganisms, antioxidant, antimicrobial.

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3.3. Climate change, Plant Genetics and Breeding

THE IMPACT OF DIFFERENT ORIGIN AND CONCENTRATION OF MICROPLASTICS ON THE PHYSIOLOGICAL PARAMETERS AND MACRONUTRIENT COMPOSITION OF BUCKWHEAT (*FAGOPYRUM ESCULENTUM* L.)

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ABSTRACT

Microplastic pollution is a well-documented issue in water ecosystems, and its role in agroecosystems is being discussed more and more. Recent studies have shown microplastic influence on plant growth parameters and soil properties, it's indicated as a potential threat to grown production and its quality. According to the literature, buckwheat can serve as a promising model for crop studying as bioindicators seeking to evaluate plant reactions to harmful substances. It is known that buckwheat can grow in poor soil conditions and has a strong response to stressors, such as microplastics. However, there is still a gap in information about buckwheat response to different microplastic composition and concentration.

Laboratory experiment was conducted to examine how different concentrations (0.05%; 0.1%; 0.3%; 0.5%) of polyethylene (PET) and polypropylene (PP) microplastic particles in soil affect the buckwheat growth parameters (length of the plant, length and architecture of roots, number of leaves) and total nitrogen, total carbon in the plant and soil. The research results showed that the concentration of PP (0.1%) influenced the growth of buckwheat, especially the plant height and root length: the highest measurements of the plant height and root length were 20.57±3.18 cm and 3.78±1 cm, respectively. However the same concentration of PET showed a negative effect on plant height, 17.20±2,65 cm, and a lower number of leaves 3.60±0.88; moreover, PET 0.3% affected roots length to grow (1.46±1.14 cm). No significant changes in total carbon and total nitrogen were determined in analyzed groups.

Our results show that buckwheat responded to microplastic stress. However, further in-depth studies are required to elucidate the interactions between microplastic exposure and the defense mechanisms of buckwheat in response to microplastic-induced stress.

Keywords: microplastics, buckwheat, polyethylene (PE), polypropylene (PP).

ASSESSMENT OF THE SUITABILITY OF GLOH2O AND E-OBS DATASETS FOR STATISTICAL DOWNSCALING OF CMIP6 MODELS OVER LITHUANIA

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ABSTRACT

Climate change is one of the greatest challenges of this century, posing a significant threat to the stability of the environmental systems and socio-economic well-being. Effective, scientifically informed climate change mitigation and adaptation strategies require highly accurate and reliable regional-scale climate projections. General circulation models (GCMs) are commonly used to simulate past and future climates under various IPCC climate scenarios. However, several issues arise regarding the use of GCMs in the regional scale studies. The resolution of climate data produced by GCMs is usually too coarse for the regional studies, limiting accuracy and the overall quality of these studies. Statistical downscaling is the common approach to addressing the limits brought by the coarse resolution. In this study, 17 GCMs were used together with Bias Correction Constructed Analogues with Quantile mapping reordering (BCCAQ) to downscale the climate data from approximately 1° to 0.25° grid cell resolution. This approach was applied to the territory of Lithuania, which lies in the southeastern part of the Baltic Sea. The study was based on the two historic climate databases, GloH2O and E-OBS, overall aiming to determine which of these databases is more suitable for statistical downscaling in the selected region. Both databases contain harmonized climatic data, however they differ in the scale of data (E-OBS is Europe-wide, GloH2O is global-wide), methods of data extrapolation, density of meteorological stations and reanalysis approaches. The use of these harmonized databases is common and appropriate, as empirical climate data tends to be inconsistent in spatial and temporal scales, containing multiple data gaps. To compare these databases and evaluate their suitability for conveying studies in the selected region, the air temperature and precipitation outputs from the downscaled GCMs within the IPCC climate reference period (1995–2014) were analysed against real historical observations from the 16 meteorological stations. The results proved that different databases have different advantages and shortcomings when simulating climatic parameters. Overall, statistical downscaling performed on GloH2O showed slightly better results than E-OBS when compared to historical observations for average air temperature and total precipitation across all models. GloH2O-based downscaled GCMs produced simulations that on average differed by only 0.06 °C for the air temperature and by 4 percentage points for the annual precipitation compared to historical observations. However, the E-OBS dataset had a significant advantage in evaluating drizzle precipitation, which is important because GCMs generally tend to overestimate drizzle precipitation and significantly reduce the number of dry days. This tendency was clearly revealed when GCMs simulations were downscaled with GloH2O. Even after applying statistical downscaling, GloH2O-based downscaling underestimated the number of days without precipitation by an average of 92 days, whereas E-OBS-based – overestimated it by only 10 days. The results of this study may further aid selecting the most appropriate dataset for the statistical downscaling based on the target outcome of the future study. The results may be applied in future scientific studies to determine environmental and socio-economic impacts stemming from climate change, such as changes in the natural hydrological regime patterns and associated pressures for water users.

Keywords: climate simulations, GCM, statistical downscaling, BCCAQ, E-OBS, GloH2O.

PROTOZOAN *TETRAHYMENA TERMOPHILA* MODIFICATION VIA SELECTIVE BREEDING IN ORDER TO AQUIRE RESISTANCE TO HEAVY METALS

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ABSTRACT

Tetrahymena thermophila can serve as a biological system to bind heavy metals dissolved in water through the action of metallothioneins, divalent metal transporters, ATP-binding cassette transporters and other proteins, which form coordinate bonds between heavy metals and primarily oxygen atoms [1]. This bio-based approach offers a potential sustainable alternative to conventional heavy metal treatment methods (e.g., precipitation, ultrafiltration) [2]. *T. thermophila* was chosen as the research organism due to its rapid multiplication rate, high genetic variability, extensive documentation in the literature, complex metallothionein pathways, and minimal ethical considerations [3]. Five different heavy metals – zinc, molybdenum, copper, chromium(III), and chromium(VI) – were tested.

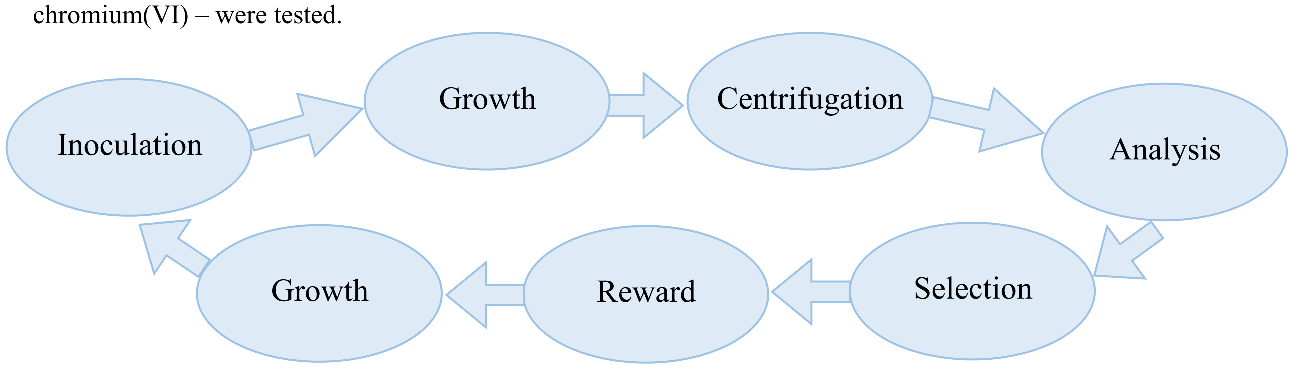

Figure 1 Full experimental design of the selective breeding system.

The selective breeding experimental design consisted of three main distinct phases: inoculation, selection, and reward. The hypothesis being that repeated exposure to heavy metals, followed with transfers to metal-free media for detoxification, would enable the protozoa to develop and enhance resistance over multiple generations. Resistance to heavy metals was possible via one or more of the following mechanisms: an increased production of ion-binding proteins, enhanced efficacy of ion-binding, an overall increase in cell number, or an accelerated rate of ion unbinding. Conversely, potential unwanted effects could also occur, such as: reduced protein synthesis, diminished protein concentration or efficacy, or a general decline in metabolic rate.

Ten different cultures per each heavy metal were made. Each one was inoculated with the same amount of live *Tetrahymena thermophila* cells. A standard 2% peptone medium, supplemented with 19.04 µM $FeCl_3$ and 0.2% D-glucose, with the pH adjusted to 7.0 using a 0.05 M NaH_2PO_4/Na_2HPO_4 buffer system was used for all experiments. Heavy metal ions were introduced as freshly prepared, concentrated stock solutions at concentration, representing similar toxicity levels (40–60 µM), with the addition diluting the final sample volume by precisely 17.0%. Metal ion solutions were needed to be freshly prepared to minimize loss/inaccuracy due to hydrolysis. Growth was carried out over a 24-hour period at 35 °C in a non-shaking, climate-controlled incubator. Each culture was grown in 7.65 mL of medium within sterile, capped 50 mL tubes, ensuring sufficient oxygen supply and minimizing contamination risk.

Following the growth phase, cultures were centrifuged at 3000 rpm for 3 minutes. This precipitated over 99% of grown biomass without causing damage to live cells. The supernatant was then immediately analyzed using a *Perkin Elmer Optima 8000 optical emission spectrometer* to quantify the residual heavy metal content. Additionally, each metal ion solution, used during inoculation, was analyzed as controls. HNO_3 was added to these controls prior to the growth phase to prevent formation of hydroxides on test tube walls. The centrifugated pellet was immediately resuspended and returned to the incubator, as a reduction in temperature would increase toxicity.

For the selection phase, the culture exhibiting the highest biosorption rate (i.e., the lowest concentration of heavy metals in the supernatant) was identified as the optimal candidate. Further analysis was done optically to confirm cell viability and assess their physiological condition. This culture was then rewarded by inoculation into a fresh, sterile nutrient medium devoid of heavy metals. This step not only provided a slightly higher nutrient concentration—owing to the absence of dilution—but also facilitated the propagation of cells with modified genetic material to a new generation of uncontaminated daughter cells, thereby consolidating the resistance phenotype. After 1 day of growth, the rewarded cells would be inoculated into heavy metal containing media, starting the cycle anew.

At the selected heavy metal concentrations, it was observed that samples required metabolic adaptation for survival, which was one of the set criteria for experimental conditions. Heavy metal toxicity was assessed via two methods: first, by inoculating a small number of cells into media containing heavy metals; and second, by introducing heavy metals into media that already contained maximum cell growth. In the first method, approximately 68% (n = 38/56) of samples achieved maximum growth, whereas in the second method, 100% (n = 47/47) maintained maximum growth. Across all samples, the values indicated a binary outcome: either near-maximal growth or no growth at all, with no intermediate states observed. These findings highly suggest the presence of metabolic changes in which population dynamics likely play a major role.

Ultimately, heavy metal resistance could not be achieved using this selective breeding approach. The bonds formed between heavy metals and proteins were found to be too stable to be disrupted by either fresh media or cell division. As a result, heavy metal-bound proteins were transmitted to daughter cells. This was determined by observation of distinct physiological changes – altered movement of cells (Fig 2.). Within 2–4 days, the mortality rate reached 100% in all samples (n = 265), regardless of the detoxification conditions applied. Completely removing heavy metals from solution by centrifuging the biomass proved ineffective as the biomass itself has already bioaccumulated a lethal amount of heavy metals. It remains uncertain whether lower heavy metal concentrations might yield successful modifications. It is highly likely to yield the same results over a longer period of time, due to the protozoan inability to unbind ions. Consequently, alternative approaches, such as DNA insertion, should be considered in place of selective breeding.

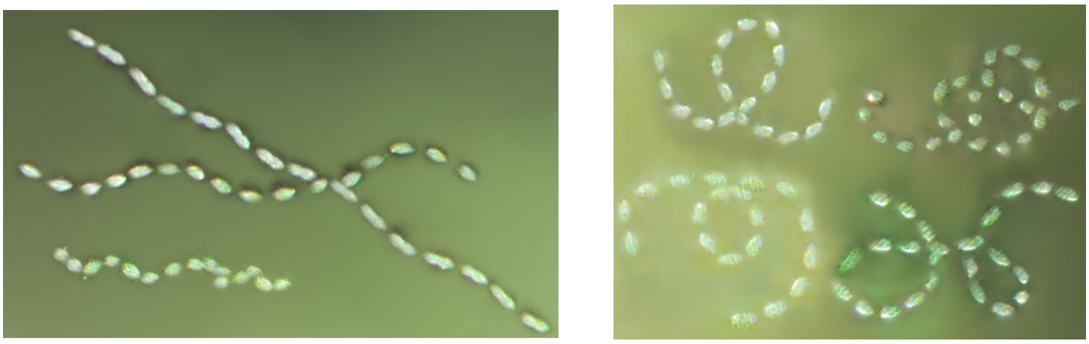

Figure 2 Left – movement of Tetrahymena thermophila during normal conditions. Right – under toxic conditions. After exposure, movement never returned to normal.

Keywords: Tetrahymena thermophila, heavy metals, bioaccumulation, metallothionein.

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BREEDING AND RELEASE OF THE HERMIT BEETLE (*OSMODERMA BARNABITA*) BASED ON THE DEVELOPED METHODOLOGY

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ABSTRACT

The hermit beetle (*Osmoderma barnabita* Motsch.) is a saproxylic species that inhabits old trees, particularly oaks, and relies on decaying wood for its development. Today, old trees are increasingly rare in the modern landscape, yet they provide essential habitats for many species, including the hermit beetle. In the Lithuanian Red Data Book, *O. barnabita* is classified as vulnerable and strictly protected, as it is in many European countries. This research aims to assess the success of breeding *O. barnabita* in captivity using an established rearing and breeding methodology. In this research, adult beetles were captured in Oak Grove Park in Kaunas from 2019 to 2021 during their active period (June–August) using pheromone traps attached to tree trunks. The beetles then were transferred to breeding containers filled with a specially prepared substrate consisting of 50–60% composted oak leaves, which serve as the primary diet for larvae, and 40–50% of oak rot affected by brown wood rot. Eggs laid in the substrate were left undisturbed until hatching. After 60–90 days, larvae were transferred to rearing containers, where they were developed for 2–4 years. Larvae and pupae were released into specially prepared nesting boxes in the wild during May–June, when average temperatures reached 12–16°C. Since the start of the breeding program, significant results have been achieved. In May 2024, 200 larvae and 51 pupae were released in Verkiai Regional Park. Currently, approximately 1043 larvae and pupae remain in the rearing containers, including 154 from previous years and 889 newly bred individuals. During a prior project (2020–2022), 758 larvae and 160 pupae were successfully released into Verkiai Regional Park. These efforts are part of two LIFE initiatives: "Creating an Ecological Network for Organisms Dependent on Mature Trees" (2017–2022) and the ongoing "LIFE Osmo Baltic. The Path of Old Oaks for the Hermit Beetle in Lithuania and Latvia" (2024–2030) projects, which aim to protect and restore suitable habitats for *O. barnabita* and other species dependent on mature trees. In the summer of 2021, the first adult beetles were observed flying in Verkiai Regional Park after more than 16 years of absence, confirming that the re-establishment process was successful. In subsequent years, additional individuals were recorded, further validating the effectiveness of conservation efforts in this historical habitat.

Keywords: *Osmoderma barnabita*; endangered species; breeding; umbrella species; LIFE project; Natura 2000.

THE IMPACT OF STATE REGULATION ON HOUSEHOLD WASTE MANAGEMENT PRICING: THE LITHUANIA CASE

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ABSTRACT

Governmental regulation plays a crucial role in correcting monopolistic inefficiencies and addressing market failures, especially in essential public services. In the waste management sector, state oversight can help ensure fair pricing, cost efficiency, and environmental sustainability.

In Lithuania, starting from 2024, partial state regulation was introduced for waste treatment services (administered by regional waste management centers – RATCs), under the authority of the National Energy Regulatory Council (VERT). This regulation aims to cap waste treatment and disposal tariffs, reduce pricing disparities, and increase affordability for households.

However, other components of the service — such as waste collection, transportation, and administrative costs — remain under municipal control. As a result, significant regional price differences persist, especially in rural areas where unregulated costs are often higher.

Previous studies suggest that while regulation can improve affordability and fairness, partial regulation may also reduce local flexibility and effectiveness. In Lithuania, the introduction of the "ability to pay" principle (limiting household waste fees to 1% of average disposable income) was expected to enhance equity, but its uneven application raises concerns about transparency and regulatory effectiveness.

This study examines whether partial state regulation has improved price transparency, reduced household costs, and incentivized waste sorting, or whether existing gaps in regulation continue to undermine these goals.

Existing research on waste management regulation predominantly focuses on full-scale Governmental intervention or deregulated market models, with little attention is given to the hybrid regulatory frameworks, where only part of the pricing structure is state controlled. Until now, state regulation in Lithuania's waste management sector was largely limited to legislative guidelines without direct intervention in service pricing. The introduction of partial price regulation in 2024 presents a unique case, raising fundamental questions: What are the objectives of such selective regulation? How does it impact final consumers? Does it lead to tangible benefits, or does it merely function as an additional oversight mechanism?

To assess the impact of partial state regulation, a comparative statistical analysis is conducted using data from all Lithuanian municipalities. The analysis focuses on four key areas: regional price disparities, affordability of services, sorting incentives, and pricing model structure. For regional disparities, waste management fees in municipalities with and without VERT regulation are compared, using the latest officially approved tariffs valid as of February 1, 2025. In municipalities under VERT regulation, both pre- and post-regulation tariffs are examined to assess changes.

Affordability is evaluated by calculating household waste management costs as a percentage of average disposable income per municipality, identifying cases where the 1% affordability cap is exceeded. Sorting incentives are analyzed by comparing fees for households that sort vs. do not sort waste.

All data is collected from publicly available municipal and Regional Waste Management Centers (RATC) pricing decisions, VERT regulatory documentation, and local regulations. The collected data is processed using descriptive statistical methods to identify pricing trends, disparities, and regulatory effects on transparency and fairness.

The results demonstrated that sorting incentives are conflicting (contradicting). Specifically, in some VERT-regulated municipalities (e.g., Panevėžys, Utena), the price of sorted waste exceeds that of unsorted waste, discouraging proper sorting. In Panevėžys, separately collected biological waste is nearly double the price of mixed municipal waste. Furthermore, significant regional pricing disparities exist. Particularly, a comparison of weighted regional prices shows variations between municipalities, with the highest observed fee (for municipal waste) at 74.42 EUR per ton (Tauragė Regional Waste Management Center (Tauragė RATC)) and the lowest at 58.59 EUR per ton (Marijampolė County Waste Management Center (Marijampolė AATC)). Limited impact on affordability is found. Despite VERT's intervention, affordability concerns persist. In specific cases (e.g., large households, increased collection frequencies), some municipalities exceed the 1% disposable income cap, raising equity concerns. Next, the hybrid regulation experiences challenges. While VERT oversight has increased transparency, its impact on actual pricing remains uncertain, as administrative and transportation costs remain unregulated, allowing price disparities to persist.

Thus, as state regulation of waste management pricing evolves, future research should focus on the long-term effects of hybrid price regulation on affordability and regional disparities, optimizing pricing structures to ensure sorting incentives align with environmental objectives, regulatory gaps and unintended consequences, including whether unregulated cost components undermine pricing fairness and a comparative analysis of alternative pricing models, such as penalty-based vs. incentive-based waste management pricing.

Keywords: state regulation; waste management pricing; hybrid regulation models; sorting incentives; regional disparities.

CLIMATE CHANGE, THE ECOLOGICAL CRISIS, AND THE IMPERATIVE OF MULTILATERAL REFORM: THE HOLY SEE'S POSITION

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ABSTRACT

Topicality

This paper examines the insights expressed by Pope Francis regarding the ecological crisis and the reform of the multilateral system. The topic is highly relevant due to the increasingly severe consequences of climate change, the weak enforcement of international agreements, and ongoing debates about global governance mechanisms that can ensure the common good. On the international stage, there is a growing focus on the necessity for more effective state-to-state cooperation and the strengthening of civil society's role.

Research Methods

This study employs document (text) analysis, comparative analysis, and content summarization. The principal focus is on a detailed comparative analysis of official papal documents (*Caritas in Veritate, Laudato Si* and the apostolic exhortation *Laudate Deum*), as well as other ecclesiastical and diplomatic sources, to elucidate the Holy See's position on ecology and multilateral political reform.

Results

- **Ecological Crisis**: Pope Francis criticizes international agreements (e.g., those from Rio de Janeiro and the Stockholm Declaration) for their insufficient implementation or weak enforcement, urging the need for meaningful commitments backed by sanction mechanisms.

- **Reform of Multilateralism**: He calls for an overhaul of the old multilateral diplomatic system, proposing the strengthening of global organizations by granting them real authority and effective oversight procedures.

- **Role of Civil Society**: The significance of grassroots social movements is underscored—they exert pressure on political leaders, and Pope Francis advocates for international lawmaking to respond to civil society initiatives.

- **Critical Perspective**: The pope acknowledges that some NGOs and movements may be influenced by business or political elites, necessitating a cautious yet generally supportive stance on their broader inclusion.

Main Conclusions

Pope Francis's vision of reforming multilateralism and enhancing global organizations could have a significant impact on curbing climate change and addressing issues in impoverished nations, as he advocates the emergence of strong global governance mechanisms with real authority. At the same time, he emphasizes that such authority must not be concentrated in the hands of a single individual or elite group. The proposed reform underscores effective enforcement measures, transparent oversight, and broad participation by civil society, thereby fostering institutions robust enough to ensure accountability, protect human rights, and serve the common good without resorting to a centralized superstructure. An active civil society, alongside scientists, NGOs, and other stakeholders, should help pave the way for broader agreements and their enforcement. Nevertheless, it is essential to remain vigilant about potential power manipulations, thus ensuring that this global authority remains genuinely inclusive, democratic, and oriented toward the well-being of all humanity.

Keywords: Climate change, ecological crisis, multilateralism, global governance, Pope Francis, Holy See, civil society, international law, Caritas in Veritate, Laudato Si, Laudate Deum, NGOs, institutional reform.

GENETIC ANALYSIS OF SOSNOWSKY'S HOGWEED (*HERACLEUM SOSNOWSKYI*) POPULATIONS IN LITHUANIA USING MOLECULAR MARKERS

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ABSTRACT

Sosnowsky's hogweed (*Heracleum sosnowskyi* Manden.) is an invasive species from the Caucasus region [1]. The plant has spread widely throughout the Baltic region [2], Belarus [3], Russia [3], and Ukraine [4] primarily due to its use as a silage crop during the Soviet Union. This monocarpic perennial plant of the carrot family (Apiaceae), poses serious health risks as its sap causes severe photosensitivity and burns. It sprouts early, rapidly forms dense vegetation, and outcompetes native species. Climate change is expected to accelerate its spread, particularly in northern latitudes with long daylight and suitable moisture [5]. This expansion could threaten low-biodiversity areas and impact the carbon cycle by altering soil structure [5]. In Lithuania, the species is widespread and has primarily been studied from botanical and ecological perspectives, with limited genetic research conducted to date [6, 7, 8, 9]. Unlike its counterpart *H. mantegazzianum*, which has been extensively studied at the molecular level in Europe, *H. sosnowskyi* has received relatively little attention. Therefore, it is crucial to investigate this species from a molecular perspective to better understand its invasiveness.

The study aims to investigate the genetic structure of seven Lithuanian Heracleum sosnowskyi populations through the Simple Sequence Repeats (SSR) and Inter-Simple Sequence Repeats (ISSR) analysis. The objectives of this research are (1) to assess the level of polymorphism of 5 SSR loci in *H. sosnowskyi*, (2) to evaluate the polymorphism of ISSR loci in the species, and (3) to analyze genetic relationships within and among the studied populations.

The SSR analysis was performed on 56 samples, consisting of 7 populations with 8 individuals each, while the ISSR analysis included the same 7 populations with all collected samples (142 in total). For SSR analysis, PCR was conducted using 10 primers, followed by DNA fragment analysis via capillary electrophoresis. The data were analyzed using Peak Scanner Software (v1.0) (Applied Biosystems), and potential genotyping errors were assessed using Micro-Checker (v2.2.3) [6]. The data were further analyzed using the GeneAlEx Microsoft Excel add-on [7]. For ISSR analysis, PCR was conducted using 6 markers, and DNA fragment analysis was performed through agarose gel electrophoresis. The data from ISSR analysis were analyzed using the GeneAlEx Microsoft Excel add-on [7] and PAST software (v1.14c) [8].

Analysis of molecular variance (AMOVA) for SSR markers revealed that most of the genetic variation (69%) was attributed to within-population differences, while 17% was observed among populations. The remaining genetic differentiation (14%) was found among 4 regions: (1) Central Lithuania, (2) the Northern region, (3) the Eastern region, and (4) the Želva area as the last region. The medium polymorphism level was estimated to be 80 %. For ISSR analysis, AMOVA revealed that 50% of genetic variation was attributed to within-population differences, while 36 % was observed among populations. The remaining 14% was found among similar regions as SSR analysis, with one difference-Želva was attributed to the Eastern region, identifying 3 regions in total. The medium polymorphism level for ISSR markers was estimated to be 54%. Overall, SSR and ISSR analyses demonstrated genetic variation ranging from moderate to low. The SSR results suggest that *H. sosnowskyi* populations in Lithuania are relatively homogeneous, while the ISSR results indicate greater genetic diversity between populations.

Keywords: Sosnowsky's hogweed, alien species, invasive species, plant genetics, population genetics, genetic diversity, environmental threat, health threat.

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SEWAGE SPILL EFFECTS ON DYNAMICS OF BIOGENIC COMPOUNDS IN GIRSTUPIS STREAM

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ABSTRACT

Urbanization of river catchment areas inevitably leads to increased water and sediments pollution. Accidental spill of raw municipal sewages has detrimental consequences on small river ecosystems (1). The aim of this study was to analyse the effects of accidental municipal sewage spill in Kaunas stream Girstupis on pollution with biogenic N and P compounds as well as its dynamics in soil, water and bottom sediments. Sampling of stream water was done above and below the spill in Girstupis parc (Pašilės St., Kaunas) during the incident as well as 2 and 8 weeks after it, in 2023 May and June. Samples of bottom sediments and polluted soil were collected 2 and 8 weeks after the spill. Concentrations of ammonium-N, nitrate-N, phosphate-P, oxidation-reduction potential (ORP) were evaluated in water and water extracts of soil and sediments as described by Hood-Nowotny et al. (3) and ISO 6878:2004 (4).

Significant increase in ammonium-N and phosphate-P downstream concentrations by 4 and 2,5 times, respectively, was detected during the spill event. At the same time, the level of ORP and nitrate-N, which is the most oxidized N compound, decreased by 40% and 90% (Figure 1). Two weeks after the spill, only phosphate-P concentration was higher (50%, $p<0,05$) below the spill as compared to upstream concentration, whereas 8 weeks after the spill, concentration of nitrate-N increased downstream the spill place. An increase in nitrates level is most possibly related to the leakage from soil as well as the nitrification process as was already observed in previous research (5). The importance of nitrification is even more obvious when analysing the shift in composition of inorganic N pool in soil and bottom sediments.

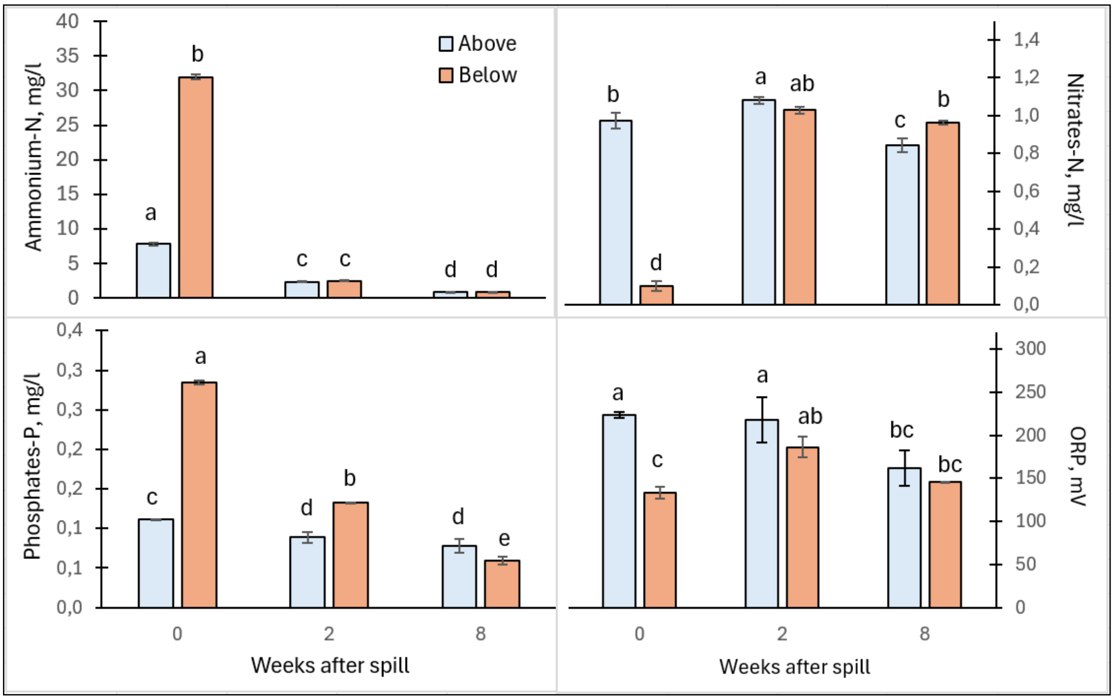

Figure 1 Concentrations of nitrogen and phosphorus compounds and oxidation-reduction potential (ORP) in Girstupis water above and below the sewage spill during the spill event as well as 2 and 8 weeks after it. Whiskers and the same letters indicate SE and statistically significant differences between the means.

Ammonium-N and nitrate-N concentrations in polluted soil significantly changed in a two-month period after an incident. The level of ammonium highly decreased, whereas level of nitrate-N significantly increased by almost 50% and 30%, respectively (Figure 2). The reasons for greater reduction of ammonium compared to nitrate concentrations could be intensive assimilation by plants, and leakage of nitrates to the stream. Concentration of phosphate-P also decreased significantly in polluted soil during the research period.

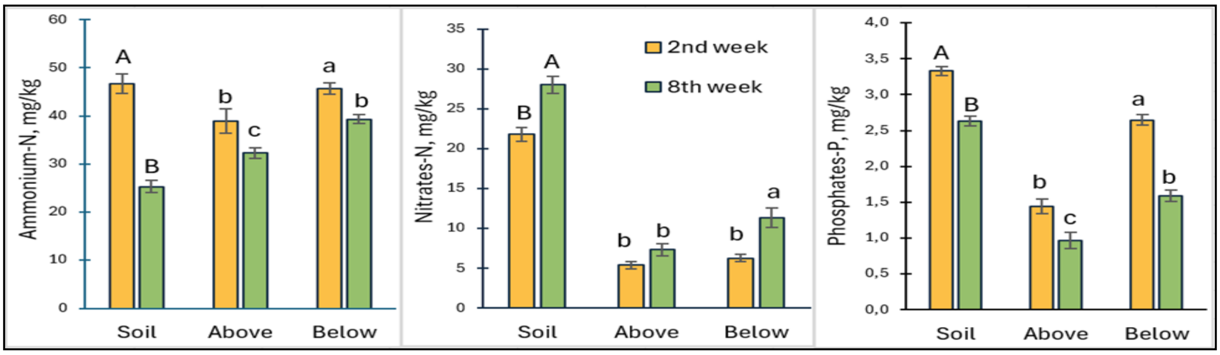

Figure 2 Concentrations of nitrogen and phosphorus compounds in polluted soil and bottom sediments above and below the spill in Girstupis 2 and 8 weeks after it. Other designations as in Figure 1.

The level of N and P compounds in the bottom sediments downstream the spill event remained higher as compared to the upstream concentrations both 2 and 8 weeks after an incident (Figure 2). The highest increase was detected for phosphate-P, i.e. 83% and 64%, 2 and 8 weeks after spill event, respectively. In contrast, an increase in level of nitrogen-N in bottom sediments was negligible 2 weeks after the spill, but its downstream concentration increased over time and 8 weeks after the spill became 56% higher than upstream concentration.

Our study highlights the detrimental effects of accidental municipal sewage spill on ecological status of urban stream Girstupis in Kaunas. During the spill even the ammonium-N water concentration exceeded the limit of bad ecological status class more than 20 times, whereas the stream water corresponded to bad ecological status class according to phosphate-P level (6). Accumulation of N and P compounds in polluted soil and bottom sediments leaded to prolonged effects of sewage spill event. Concentrations of ammonium-N and phosphate-P decreased in polluted soil and bottom sediments over time, however, remained significantly higher in downstream sediments even 8 weeks after the spill. The nitrification process significantly increased nitrate-N level in water, polluted soil and bottom sediments at the end of investigation period.

Keywords: sewage spill, nitrification, riverine nitrogen and phosphorus.

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