CONECT 2025

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RIGA TECHNICAL UNIVERSITY

XVIII International Scientific Conference of Environmental and Climate Technologies

BOOK OF ABSTRACTS

14–16 May 2025 | Riga, Latvia

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XVIII International Scientific Conference of
Environmental and Climate Technologies

BOOK OF ABSTRACTS

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Design: Paula Lore, Vilnis Laizans
Main managing editor: Dace Lauka
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More information: www.conect.rtu.lv

ISBN 978-9934-37-166-0 (pdf)

Scientific Committee

ISSN 2592-9704

CONECT 2025
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CONECT 2025

XVIII International

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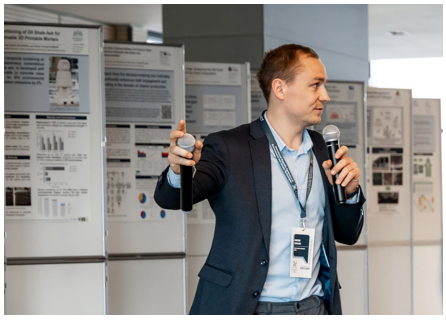

Conference papers are published in the internationally indexed journal Environmental and Climate Technologies (ISSN: 2255-8837), indexed in SCOPUS and Web of Science.

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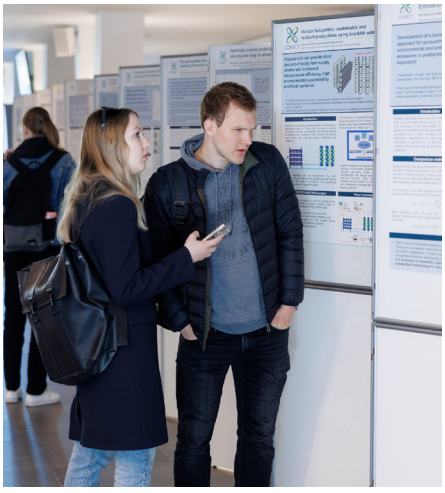

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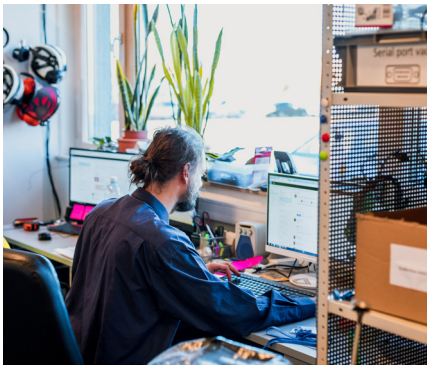

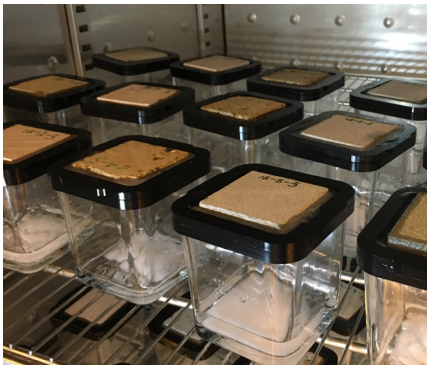


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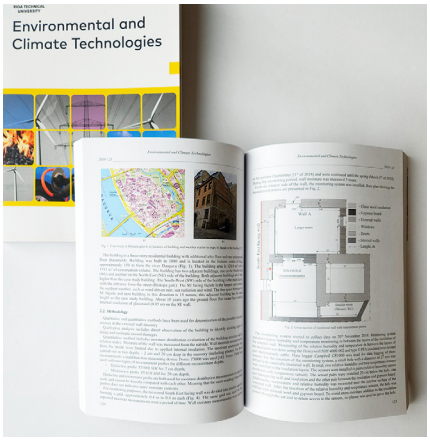

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ENERGY EFFICIENCY, ENERGY SYSTEMS (DISTRICT HEATING)

https://doi.org/10.7250/CONECT.2025.001

OVERHEATING RISK ASSESSMENT IN PASSIVE ENERGY RENOVATIONS IN SPAIN

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Abstract – The regulations of the European Union (EU) demand the improvement of the energy efficiency of buildings. Following this, thermal insulation-based passive energy renovations can reduce the energy demand of buildings. Thus, increasing the thermal insulation of the envelope has shown many improvements by reducing the energy loss in heating energy demand dominant areas. Consequently, national regulations of Member States, like the National Building Code (NBC) of Spain, require high thermal insulation levels for renovation processes. In addition, many high-performance labels demand thermal insulation above mandatory levels, like EnerPhit (the renovation label by Passivhaus). Nonetheless, renovations based on thermal insulation may affect the thermal comfort of buildings, depending on outdoor climatic conditions. The influence of adding thermal insulation on the possible increase in temperatures of residential spaces is still uncertain and requires analysis, given the risk of overheating. Based on this hypothesis, the objective of this study is to assess the influence of thermal insulation-based passive renovation on the overheating risk of residential spaces, focusing on the different climatic conditions of Spain. For this, the study evaluates the thermal conditions under different renovation scenarios on one residential multi-family archetype typical from the 70s and 80s, without any insulation. To this end, the research follows a three-staged methodology. First, the study identifies and defines one archetype, 12 climatic zones of Spain (following NBC) and 12 passive renovation strategies: four types of renovation strategies (façade exterior insulation, roof insulation, window replacement and the combination) in three efficiency levels (basic level, NBC required level and EnerPhit required level). Second, the study performs the Building Performance Simulation (BPS) of the parametric combination of all the climatic conditions and renovation strategies, analyzing the indoor operative temperature. Finally, the study evaluates the overheating hours based on the thermal comfort model by the Chartered Institution of Building Services Engineers (CIBSE). The evaluation shows the increase or decrease of overheating hours under different climatic conditions, renovation types and thermal insulation levels. These results indicate that the climatic zone is a key factor in assessing the overheating risk. Therefore, the study identifies the critical climatic zones of Spain with high overheating risk, which require more in-depth analysis to avoid overheating on energy renovations.

Keywords – BPS (Building Performance Simulation); Climate; Energy renovation; EnerPhit; National Building Code (NBC); Thermal Comfort; Thermal insulation

ACKNOWLEDGEMENT

This research work is part of Markel Arbulu's Doctoral Thesis, funded by the Predoctoral Training Programme for Non-Doctor Research Personnel of the Ministry of Education of the Basque Government (PRE_2023_2_0007). Moreover, this research is also part of Jorge Otaegi's Doctoral Thesis, funded by the University of the Basque Country UPV/EHU under grant number PIF 21/235.

https://doi.org/10.7250/CONECT.2025.002

APPLYING AI TO HVAC SYSTEMS: A CRITICAL ANALYSIS OF DATA-RELATED CHALLENGES

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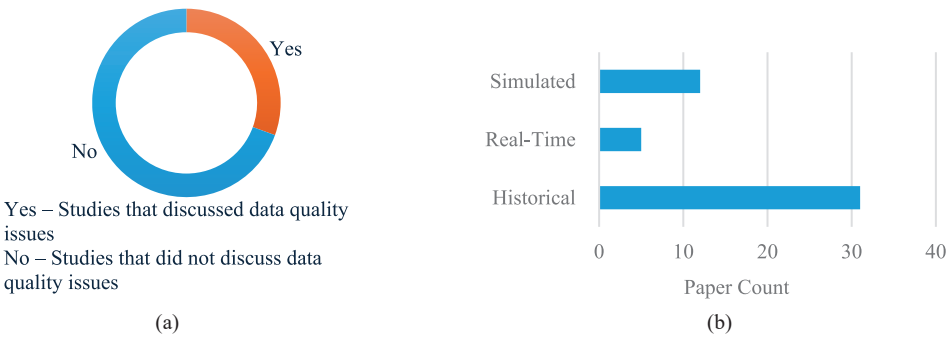
Abstract – Integrating AI in HVAC systems is a promising approach that helps enhance energy efficiency in buildings, which leads to cost savings and provides environmental benefits. However, the effective performance of these AI models, especially in HVAC systems, depends not only on the model design but also on the data's quality, reliability, size, availability, and management. Data plays an important role in determining the accuracy and reliability of the AI model's performance. This paper analyses recent studies that apply AI models to achieve energy efficiency in HVAC systems from a data perspective, examining various aspects of data management in Deep Learning and Hybrid models applied to HVAC in buildings, such as data availability, the different data sources, type, quality issues, and data splitting methods. Through this analysis, the paper aims to provide insights into data-related challenges and recommend ways to overcome and mitigate them to develop AI models that perform more effectively. The paper highlights the importance of developing better data-handling practices to have more accurate, efficient, and reliable AI models in HVAC systems. The findings reveal that combining multiple data types can enhance model performance and generalizability. Moreover, the analysis concludes that the main data type for residential buildings is simulated data rather than real-world data; this could be due to privacy concerns. Meanwhile, commercial buildings have commonly utilized more structured and reliable dataset sources, enabling more precise modelling. The findings also indicate that data quality is overlooked by researchers in many studies, where only 31 % of the analysed papers discussed quality issues, reflecting that it is not yet a standard practice in this field. Additionally, this analysis addresses the scarcity of reliable and audited data. Therefore, and in response to this issue, this paper recommends accessible and reliable data resources that can be employed in AI applications for HVAC systems in buildings.

Keywords – Building management systems; deep learning; energy efficiency; machine learning



(a) Proportion of studies discussing data quality issues; (b) number of studies by data type.

https://doi.org/10.7250/CONECT.2025.003

TRANSFORMING NON-RESIDENTIAL BUILDINGS: THE ROLE OF SUBSIDIES AND SUSTAINABLE ENERGY CONSUMPTION

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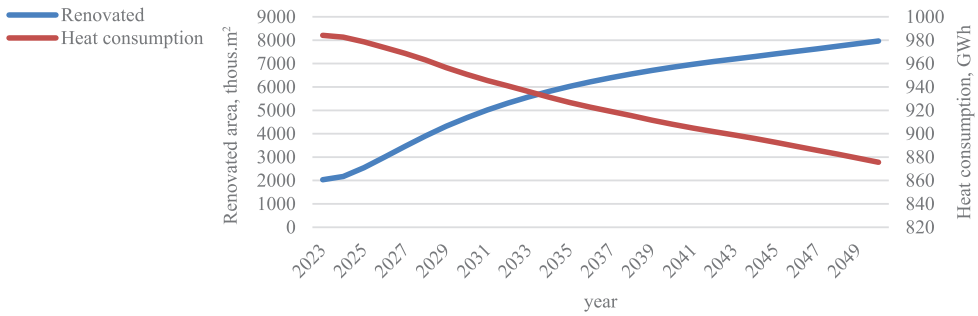
Abstract – The European Union has set ambitious goals to achieve climate neutrality by 2050, and one of the main target areas is heat production. According to the latest statistics, heat production is one of the largest sources of greenhouse gas emissions. Although reduction of the heat consumption of residential buildings is often addressed, the non-residential buildings are no less important. In Riga, non-residential buildings make up 43 % of the total building area, and those connected to the district heat supply are responsible for 25 % of the total heat demand. Thus, it is important to include the renovation of the non-residential buildings as well as the construction of new buildings in energy efficiency measures. The study explored the key factors influencing the renovation of non-residential buildings, also considering the effect provided by the availability of subsidies on the renovation rate. A system dynamics model was developed, and the model includes four main modules: construction of the new area, renovation dynamics, energy supply module, and the impact of subsidies. The purpose of the model was to analyse the potential future trends and determine whether the climate goals set by the European Union will be achieved with the existing renovation rate. Non-residential buildings were divided into three parts: educational buildings, buildings of state and other non-living areas. Years of commissioning and the type of heat supply were considered. The results of the simulation indicate that with the existing policy, it is possible to achieve 89 % renovation level in municipal building sector, 91 % in educational building sector and 62 % renovation level in other non-residential buildings by 2050. Heat energy saving in 2050 from renovation is 14 % in buildings with district heating and 9 % in buildings with alternative heating compared to 2023. The results of this study can provide significant input to policymakers and industry professionals, helping to develop effective strategies for achieving the climate goals and ensuring sustainable development.

Keywords – Building renovation; district heating; energy efficiency; system dynamics modelling



Effect of renovation on heat energy demand in Riga

https://doi.org/10.7250/CONECT.2025.004

HEAT RECOVERY VENTILATION IN SPANISH APARTMENTS: COSTS, BENEFITS, AND FEASIBILITY

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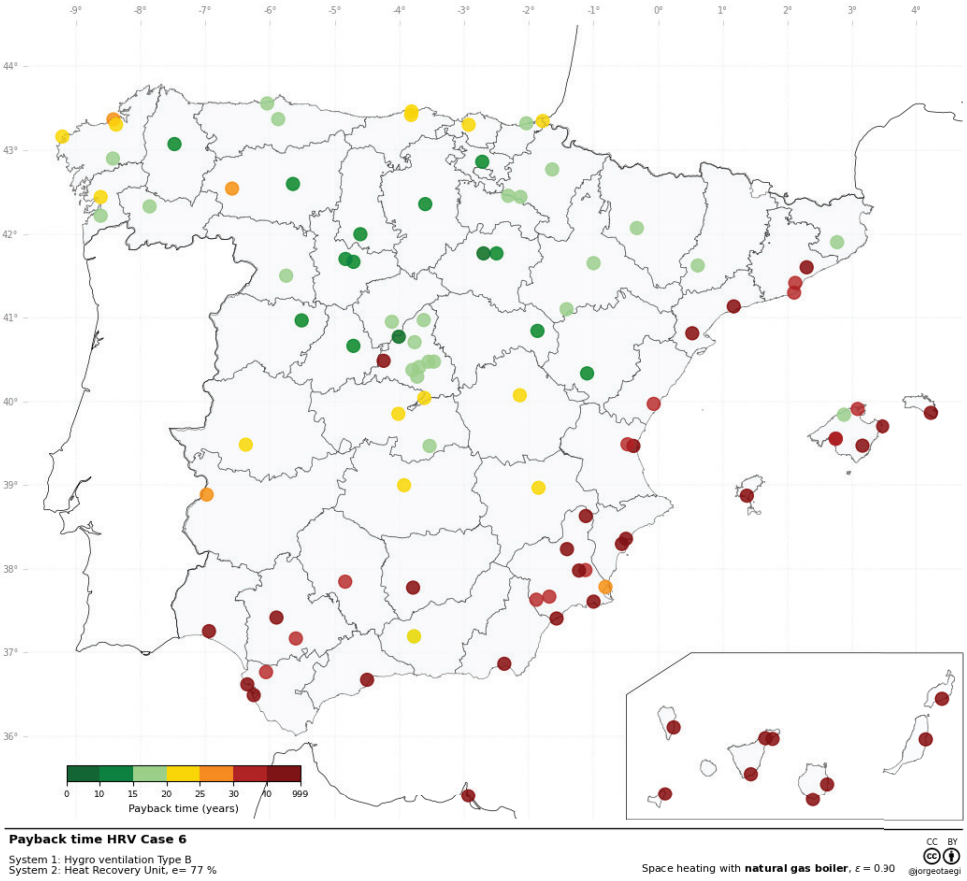
Abstract – Mechanical ventilation systems with heat recovery (HRV) are increasingly promoted as a key measure to improve indoor air quality and reduce energy losses in residential buildings all over Europe. HRV is often mandatory in modern national regulations and green building certification systems or labels. In southern European countries like Spain, HRV systems are often included in new dwellings, required indirectly by building code in the coldest climatic zones. However, the economic viability of HRV systems depends greatly on climate and ventilation rates. This study evaluates the profitability of mechanical heat recovery ventilation in apartment buildings in Spain, considering variations across its diverse climatic zones. The analysis used regional climate data to quantify energy savings attributable to HRV systems and compared them with the alternative cost of heating, using an LCOE approach, which also accounted for initial installation costs, operating expenses, and energy price trends. To do so, a constant flux ventilation rate according to CTE DB-HS 3 was considered, with 5 apartment typologies, in 104 locations in all 50 provinces of Spain. Results reveal that HRV systems demonstrate limited economic viability in most regions of Spain. In colder inland regions, the payback time for HRV systems was adequate, whereas in warmer Mediterranean and southern climates the investments turned out to be not amortizable, underscoring a strong climate-dependency in their economic feasibility. In milder coastal areas like the northern coast of Spain and the Basque Country, results showed payback times over 20 years. These findings are presented graphically, highlighting the geographical differences in payback times under current market conditions in the building typologies. Beyond economic factors, this paper acknowledges the benefits of HRV systems, like improved thermal comfort in winter, filtration of exterior air and the potential reduction of overall building energy demand, but contextualizes them in the broader framework of energy efficiency. Additionally, the potential benefits of demand controlled ventilations are discussed. This paper aims to guide policymakers, architects, engineers, and homeowners in making informed decisions about HRV adoption. Future work could incorporate life-cycle cost analyses and dynamic energy modeling to capture broader implications and refine the assessment of HRV systems in new residential developments and retrofits.

Keywords – Energy efficiency; energy policy; heat recovery ventilation; LCOE (Levelized Cost of Energy); mechanical ventilation; nZEB (Nearly Zero Energy Building); payback period; thermal comfort



Results of payback time of scenario 6 for heat recovery ventilation in peninsular Spain and the Balearic and Canary Islands, using a natural gas boiler for space heating.

ACKNOWLEDGEMENT

This research work is part of the corresponding author's doctoral dissertation, funded by the University of the Basque Country UPV/EHU under grant number PIF21/235.

https://doi.org/10.7250/CONECT.2025.005

ADVANCING TOWARDS POSITIVE ENERGY DISTRICTS (PED) USING A LIFE CYCLE ASSESSMENT APPROACH

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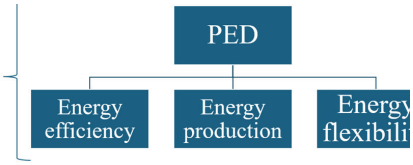
Abstract – Cities and their inhabitants are among the largest consumers of energy and contributors to environmental pollution, accounting for 70 % of global greenhouse gas emissions. One of the European Union's key strategies for addressing this issue is the development of Positive Energy Districts (PEDs). Although some PEDs already exist, the concept remains an emerging field of study that goes beyond achieving neighborhoods with net-zero energy imports – or even net-positive energy production. It also emphasizes sustainability and the reduction of greenhouse gas (GHG) emissions. This article explores solutions for implementing PEDs, focusing on energy flow analysis and Life Cycle Assessment (LCA) to inform decision-making. Developing PEDs is a multifaceted process that involves improving building energy efficiency, assessing existing energy sources, exploring opportunities for on-site energy generation, integrating renewable energy systems, and ensuring efficient storage of generated energy. A significant aspect of LCA is calculating embodied emissions for all PED-related implementations, particularly in existing districts where substantial improvements are needed to meet PED goals. In such cases, LCA plays a crucial role in ensuring not only net-zero energy imports but also meaningful GHG emission reduction. Although LCA is not yet widely applied in the development of PEDs, this article highlights its importance in addressing key aspects of achieving climate neutrality goals when transforming urban areas to PEDs. Existing districts with nearly zero or zero-energy buildings have lower embodied emissions when transformed into PEDs, due to the high energy efficiency of the buildings. However, they achieve smaller overall emission reductions because of their already low baseline impact. This underlines the importance of establishing a clear baseline and defining expected outcomes when creating PEDs, ensuring the achievement of net-zero or net-positive energy imports and supporting progress toward climate neutrality.

Keywords – Buildings; climate neutrality; energy efficiency; energy flexibility; energy production; urban areas; zero emissions



LCA framework for implementing Positive Energy District (PED)

ACKNOWLEDGEMENT

This activity/work has been supported by the EU Recovery and Resilience Facility within the Project No 5.2.1.1.i.0/2/24/I/CFLA/003 "Implementation of consolidation and management changes at Riga Technical University, Liepaja University, Rezekne Academy of Technology, Latvian Maritime Academy and Liepaja Maritime College for the progress towards excellence in higher education, science and innovation" academic career doctoral grant (ID 1002).

https://doi.org/10.7250/CONECT.2025.006

THERMAL BEHAVIOR OF PIGGYBACK LAID DISTRICT HEATING AND DISTRICT COOLING PIPES

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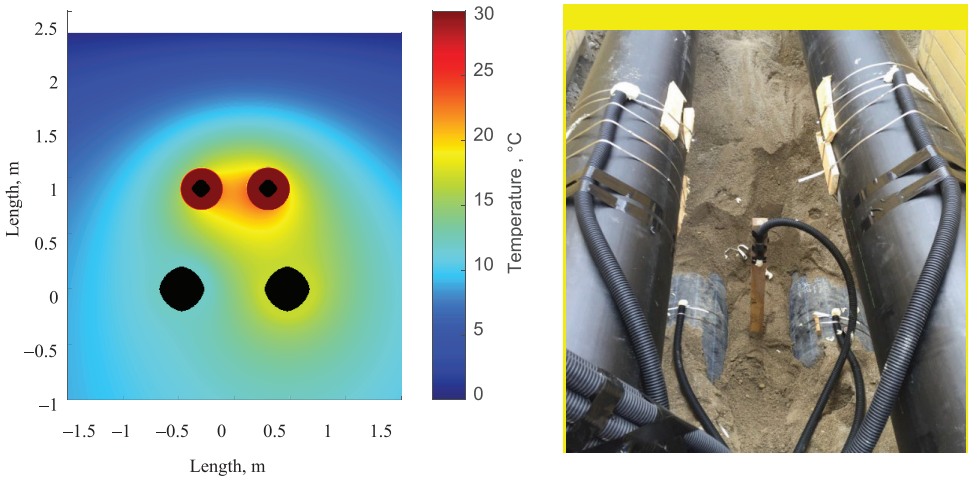
Abstract – The expansion of district heating networks is a key component of Europe's strategy to reduce CO2 emissions and achieve climate targets. Simultaneously, district cooling networks are being developed in major metropolitan areas, with cities like Hamburg, Paris, Vienna, Berlin, and Munich. A key challenge in the implementation of both heating and cooling systems is their economic viability, which is strongly influenced by the design and construction of the distribution infrastructure. Efficient network design requires a high demand density and the adoption of intelligent pipe-laying strategies. In this context, the piggyback installation of district heating and cooling pipes – where both systems are laid above one another in the same trench – has gained attention to optimize space usage and reduce construction efforts. However, this installation method can lead to significant thermal interactions between the two systems, particularly in cases where the temperature differences between the heating and cooling pipes create mutual effects that impact the performance of each system. This paper investigates the thermal behavior of piggyback-laid district heating and cooling pipes through a case study in Munich, where over 400 meters of district heating and cooling pipelines are installed in this configuration. The study provides detailed insights into the execution and experimental measurement setup of the pipeline section and evaluates the thermal interactions using long-term simulations of transient heat transfer. Experimentally obtained Temperature-Data is used to validate the Model and allows a detailed analysis of the actual heat transfer within the cross-section. The results of the simulation highlight the extent to which pipe placement influences the thermal performance of the systems. Furthermore, a parametric study is presented to explore how modifications to the pipe geometry can optimize the arrangement, potentially improving the efficiency, sustainability, and cost effectiveness of both district heating and cooling networks. This research aims to inform the design and operation of urban energy systems, providing valuable guidance for enhancing energy efficiency in metropolitan regions striving to meet stringent climate goals under cramped underground conditions.

Keywords – District heating; district cooling; heat losses; finite element analysis; transient heat transfer; pipeline construction; piggyback



FEM-Simulation and Measurement setup (Copyright SWM)

ACKNOWLEDGEMENT

This work is a result of cooperative discussions at HafenCity University in the research projects UrbanTurn (03EN3029F) and En-Eff:Netzregelung (03EN3076B). These projects are nationally funded under the EnEff: Program by the Federal Ministry for Economic Affairs and Climate Action of Germany. The funding is gratefully acknowledged by the authors.

https://doi.org/10.7250/CONECT.2025.007

MODELLING AND CHARACTERIZATION OF AN ICE STORAGE FOR OPTIMIZED OPERATION

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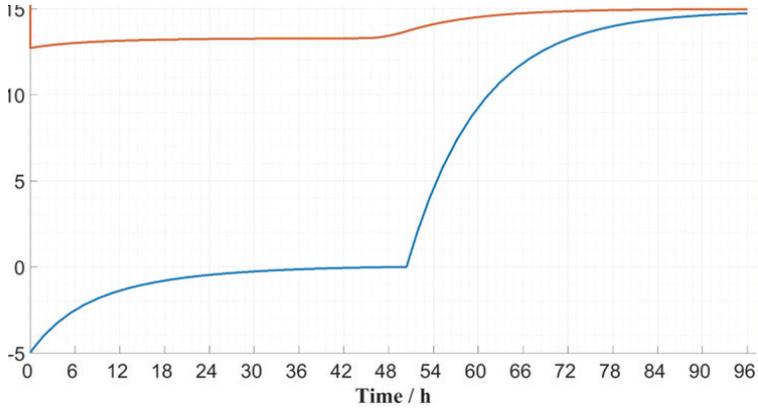
Abstract – Ice storage systems (ISS) present a flexible option for the storage of thermal energy. However, due to the distinctive nature of the phase change, issues arise with ISS that are not present in conventional thermal energy storage systems. This mainly concerns the determination of the state of charge (SOC) of the ice storage during operation, as the SOC of conventional sensible thermal energy storages can be determined by a simple temperature measurement. Nevertheless, this method is not sufficient for ISS due to the constant temperature during phase changes. However, knowledge of the SOC is essential for optimum operation of the whole system. Therefore, this work deals with the modelling and experimental characterization of an ISS. The mathematical modelling is performed using a one-dimensional, discrete, dynamic model. The integration of fluid property models allows a continuous calculation of the thermodynamic properties of the fluid during the simulation. The model calculates the heat transfer coefficients, the heat flow, the transported energy and the current SOC of the ISS. Furthermore, the model has been designed to be as flexible as possible. Therefore, both icing and de-icing processes can be simulated (de-icing process shown in Figure (a)). Additionally, a variety of fluid mixtures, including water with distinct glycol proportions, can be simulated. In order to validate the results obtained in the simulation, an ice storage setup with stainless steel spiral heat exchanger has been equipped with appropriate measurement equipment. This includes temperature sensors at different locations of the ice storage tank as well as the measurement of all necessary fluid properties of the heat transfer fluid. Additionally, a capacitive sensor placed alongside the heat exchanger is employed to measure the current degree of icing in the storage (Figure (b)). Ice and water have different dielectric constants, which is utilized here to determine the ice thickness. Initial comparisons between the simulation and measurement results demonstrate a high degree of agreement. This work uses the local measurement and simulation data to make a global state of charge estimation for ISS.

Keywords – Capacitive measurement; heat transfer; Phase Change Material (PCM); State of Charge (SOC); thermal energy storage



(a) Simulated temperature curve of a de-icing process

(b) SOC determination setup

ACKNOWLEDGEMENT

This work has been supported by the Government of Upper Austria in the project 'COMPESTO – comprehensive energy storage', Research Grant Wi-2022-600132/7-Au and in the project 'ICE4H&C – ICE Heating and Cooling for SFH and MFH' (FET-Future energy technologies call).

https://doi.org/10.7250/CONECT.2025.008

ROLE OF ENERGY MANAGEMENT SYSTEM IN SCHOOLS AND PRIMARY SCHOOLS IN RIGA

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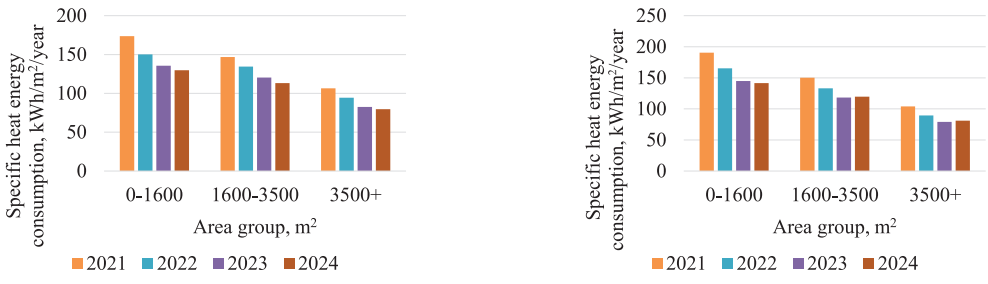
Abstract – Educational buildings, such as schools and primary schools, are significant energy consumers, and improving their energy efficiency is crucial for reducing operational costs and negative impact on the environment. This study addresses the need to evaluate the effectiveness of Energy Management Systems (EMS) in optimizing heat energy consumption, focusing on the specific heat energy use (kWh/m^2) and the role of energy managers in sustaining long-term efficiency. The objective of this study is to assess how the implementation of an EMS impacts heating energy consumption and to identify additional measures needed to sustain improvements. The methodology is based on the analysis of actual heating energy consumption data obtained from utility bills collected from educational institutions. Key approaches include climate normalization of data, the process of normalizing energy consumption data to account for changes in weather conditions, allowing for accurate comparisons across time periods, metric estimation, and statistical analysis to assess trends in energy use. Interviews with employees responsible for building usage provide a better understanding of the actual operational activities that impact energy efficiency. Results show that EMS implementation significantly reduces specific heat energy consumption during the first two years, achieving savings of up to 13%. These reductions are attributed to the establishment of systematic monitoring, real-time energy tracking, and improved operational efficiency driven by energy managers. However, starting from the third year, the effectiveness of EMS alone begins to decline, indicating that monitoring and reporting efforts, while essential, are not sufficient to sustain energy efficiency improvements in the long term. The results highlight that the benefits of EMS decrease over time, showing the need for combined strategies to maintain energy efficiency in schools and primary schools. Future work should prioritize improving monitoring tools, education of responsible employees, and applying affordable upgrades to buildings.

Keywords – Building energy optimization; educational buildings; energy monitoring; energy performance indicators; heating efficiency



Specific heat energy consumption indicators in Riga schools and primary schools after the implementation of the EMS (a) Schools, (b) primary schools

https://doi.org/10.7250/CONECT.2025.009

CONCEPTUAL FRAMEWORK FOR ALGORITHM DEVELOPMENT IN SUSTAINABLE ASSET MANAGEMENT OF DISTRICT HEATING NETWORKS

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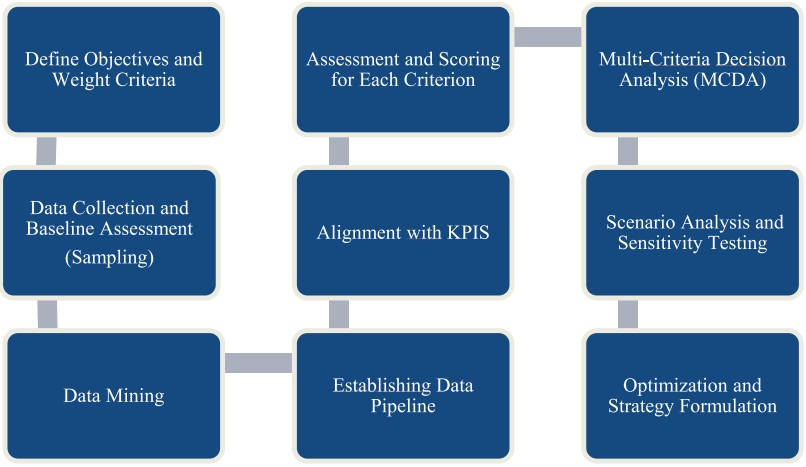
Abstract – The sustainable asset management of district heating networks (DHNs) presents a complex challenge, integrating ecological, economic, and social sustainability dimensions. To address this, we developed a structured methodology for an algorithmic framework that supports sustainability assessments in DHNs. The proposed framework follows nine systematic phases, including defining objectives and weights, data collection and mining, establishing a data pipeline, aligning with key performance indicators (KPIs), conducting multi-criteria decision analysis (MCDA), and performing scenario-based sensitivity analysis. These phases enable the algorithm to assess both operational and strategic aspects of asset management. By incorporating six distinct sustainability scenarios – ranging from stricter environmental regulations and economic constraints to climate resilience and circular economy transitions – the framework evaluates potential outcomes and optimal strategies. Each scenario provides insights into the trade-offs and synergies between different sustainability objectives, guiding decision-makers in balancing efficiency, cost-effectiveness, and environmental impact. The results from scenario analyses inform tailored strategies, such as infrastructure reinvestment plans, predictive maintenance schedules, or adaptive regulatory compliance measures, ensuring resilient and future-proof DHN operations. This research establishes a foundation for data-driven, scenario-based sustainability management in DHNs, offering practical guidance for decision-making based on defined criteria and KPIs. The structured approach enhances flexibility and adaptability in asset management, paving the way for empirical validation and real-world implementation.

Keywords – Asset Management; conceptual framework; District Heating Networks; KPIs; Multi-Criteria Decision Analysis; scenario analysis; sustainability



The nine phases of conceptual algorithm development for sustainable asset management in district heating networks

ACKNOWLEDGEMENT

The authors acknowledge the financial support by the Federal Ministry for Economic Affairs and Climate Action of Germany in the project SAM-FW (project number 03EN3078B).

https://doi.org/10.7250/CONECT.2025.010

GIS-BASED ASSESSMENT OF 5TH GENERATION DISTRICT HEATING AND COOLING (5GDHC) SYSTEMS WITH SEASONAL THERMAL ENERGY STORAGE

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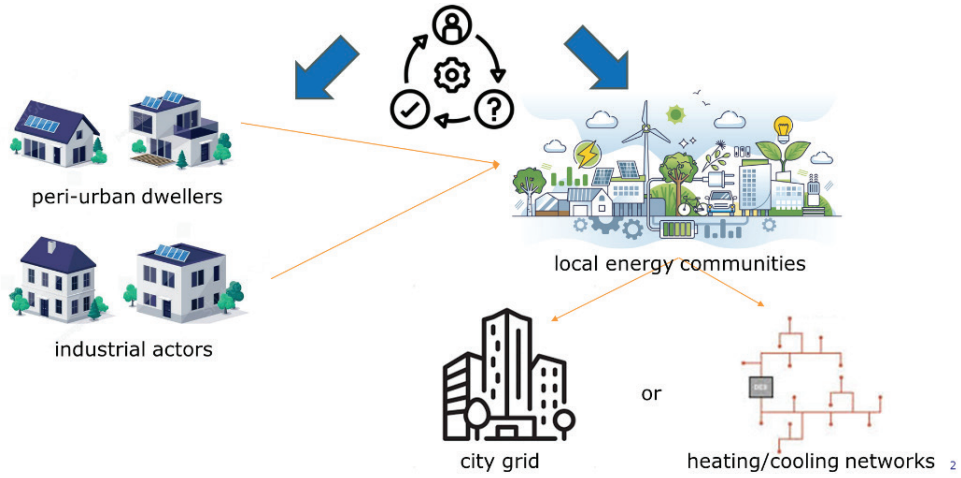
Abstract – The transition to sustainable energy solutions necessitates innovative approaches to district heating and cooling (DHC) systems. Fifth-generation district heating and cooling (5GDHC) systems, integrated with seasonal thermal energy storage (TES), offer a promising pathway to enhancing energy efficiency while reducing environmental impact. This study, conducted within the OPTIMESH project (OPtimized Thermal prosumer Integration in a Multi-Energy System), explores the robust design of 5GDHC systems tailored for business parks in Flanders through Geographic Information System (GIS) assessment. OPTIMESH aims to optimize the integration of thermal prosumers – buildings that act as both consumers and producers of thermal energy – within multi-energy systems. By leveraging GIS-based methodologies, we identify and analyse potential locations, evaluate energy exchange feasibility, and configure network layouts. The study incorporates multiple data sources, including operational data on waste heat availability, building models, and HVAC system data, to ensure accurate and efficient network design. A high linear heat density is essential for 5GDHC system viability, necessitating a rigorous assessment of more than 40 potential locations across Flanders. GIS tools are employed to assign EPC labels, detect waste heat sources, and map underground utilities such as cables, gas, and water pipelines. We systematically compare three standalone heating solutions – natural gas boilers, air-source heat pumps, and ground-source heat pumps – to assess the relative benefits of 5GDHC deployment. To achieve an optimal configuration, our methodology evaluates up to 60 different network configurations per location. The integration of GIS-generated spatial data with graph-theory-driven simulations allows for a comprehensive assessment of potential layouts, ensuring efficiency in both thermal energy distribution and seasonal storage utilization. The results of these simulations are exported, post-processed, and visualized for further analysis. Key methodologies presented in this study include GIS assessment, thermographic imaging, image recognition, exergy analysis, and steady-state simulations. Our findings highlight the critical role of high-resolution data in designing effective 5GDHC networks. The results cover various aspects, including input assumptions, location selection, network configurations, energy exchange dynamics, and feasibility metrics. This research underscores the economic and ecological advantages of 5GDHC systems, particularly in business parks where simultaneous heating and cooling demands can be efficiently met. By systematically integrating diverse data sources and advanced simulation techniques, this study provides a robust framework for the development of next-generation DHC systems, contributing to a more sustainable and resilient energy infrastructure.

Keywords – Energy efficiency; network configuration; sustainability; thermal prosumers; waste heat



Energy Ecosystem: Connecting peri-urban dwellers, industries, and local communities.

https://doi.org/10.7250/CONECT.2025.011

TYPICAL PROBLEMS AND THE SOLUTIONS FOR HEATING SUBSTATIONS

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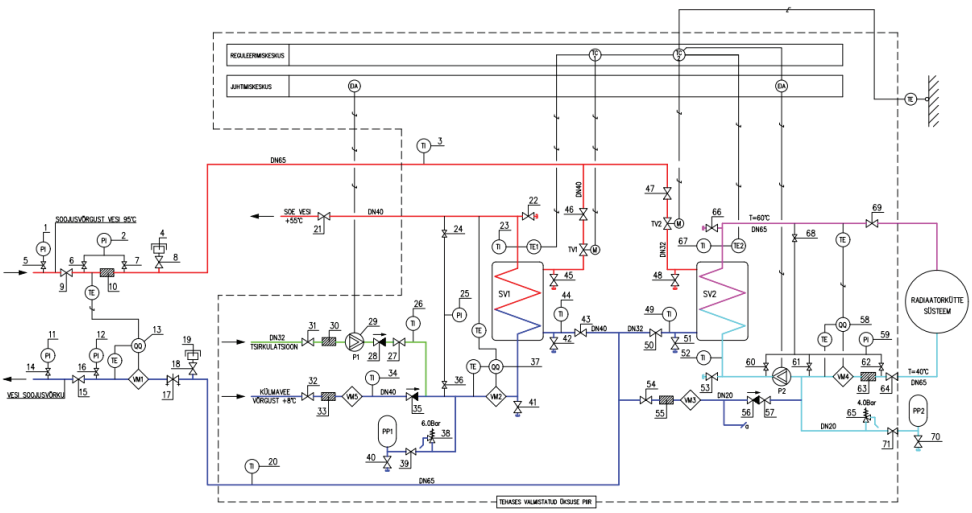
Abstract – District heating (DH) systems are widely used for heat supply in Nordic countries. Early detection and elimination of faults in DH systems ensures the efficiency and longer lifetime of these systems. Heating substations are an essential part of district heating systems. They ensure that the required temperatures for space heating and domestic hot water (DHW) are provided to the buildings. In heating substations, the main faults, such as fluctuations in temperatures, noise, vibrations, cavitation and wear on valves and other moving parts, are caused by wrong dimensioning of the equipment. The study aims to find how the substation's operation is affected by incorrectly selected components and how several types of faults can be solved or avoided. This study mostly focuses on the dimensioning of the following heating substation's components, control valve, heat exchanger, circulation pump, etc., as incorrect dimensioning of this equipment can cause most faults which can be easily avoided. In this study recent research publications that present approaches to the elimination of failures in heating substations are examined with focus on data analysis. In the study examples of substations that have been deployed and the problems met in their operation are presented, proposing solutions for how failures could have been prevented, and which equipment should have been selected. The study will provide useful results for heating substation designers to avoid most common mistakes in dimensioning the substations and therefore avoid increased operational costs, and premature equipment failure.

Keywords – Dimensioning; district heating systems; heating substation; fault detection



An example of heating substation's diagram used in district heating projects

ACKNOWLEDGEMENT

This work was co-funded by the Estonian Research Council via project TEM-TA78.

https://doi.org/10.7250/CONECT.2025.012

FEASIBILITY ANALYSIS OF DISTRICT COOLING TECHOLOGIES IN COLD CLIMATE: A COMPARITIVE STUDY

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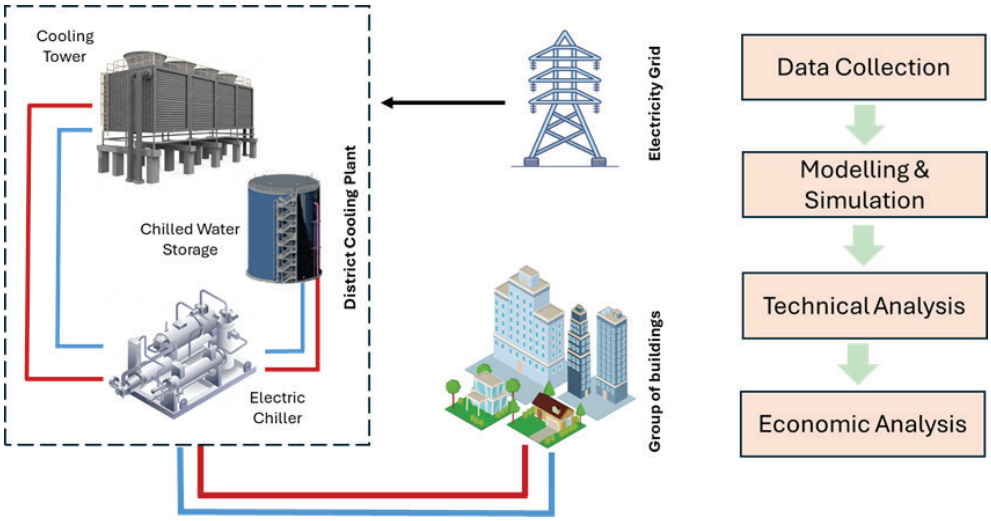
Abstract – Climate change-induced heat waves are becoming increasingly frequent in Europe, thereby affecting people's health, comfort and productivity. Hot summers and population growth have escalated the space cooling demand of urban energy landscapes, even in cold climates. It is in direct correlation with the increased demand for residential air-conditioning units and individual heat pumps. A relatively new technology, District Cooling (DC) is seen as an alternative to individual cooling solutions. Typical DC system consists of a centralized cooling plant that serves the cooling demand of multiple buildings by circulating chilled water through underground pipes. In some European cities, DC systems are competing with individual cooling solutions due to their ability to scale down carbon emissions and promote energy efficiency. However, these DC systems suffer from techno-economic challenges such as high investment costs and electricity cost fluctuation. In this scenario, the integration of energy storage technology with DC systems presents a promising solution through peak shifting, load sharing, energy savings etc. Chilled water energy storage is one of the widely considered technologies in the DC industry. Though some studies are reported in literature, the potential of thermal energy storage for DC applications is not fully explored. The feasibility of space cooling systems is influenced by location dependent factors such as climatic conditions, load profile and economic parameters. The aim of the study is to investigate the feasibility of district cooling technologies in cold climates from customer's perspective. Based on preliminary results, it is observed that the district cooling plant coupled with chilled water storage has the lowest levelized cost of cooling (53.35 EUR/MWh) as compared to typical DC system and on-site electric chillers. This finding is highly influenced by the inputs and assumptions considered by the user. The current study also involves Modelica-based modelling of main components, simulation of developed models to assess the system performance and estimation of economic competitiveness of system configurations. It is expected that these findings shed light on the design and planning of the proposed system, thereby strengthening its widespread application across northern European cities.

Keywords – Cold storage; levelized cost; district energy; energy planning; energy storage; Modelica; system modelling; performance analysis; space cooling; sustainable energy



Pictorial representation of the proposed system and research methodology

ACKNOWLEDGEMENT

This work was supported by the Estonian Research Council grant (MOB3JD1230) within the project "Comprehensive Investigation of Cold Thermal Energy Storage Integrated District Cooling System"

https://doi.org/10.7250/CONECT.2025.013

THERMAL PERFORMANCE ANALYSIS OF PHASE CHANGE MATERIAL THERMAL ENERGY STORAGE PROTOTYPE

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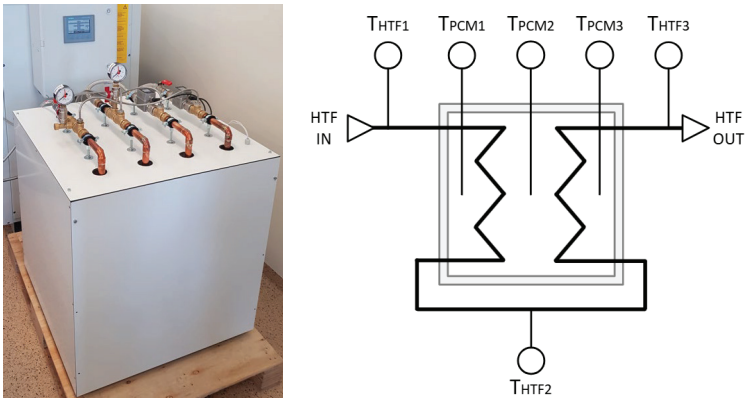
Abstract – Latent heat thermal energy storage (TES) plays an important role in increasing the energy density of the storage systems. Phase change materials (PCMs) are used as a latent heat storage medium; however, because of the low thermal conductivity of most PCMs, it is important to ensure effective heat transfer between heat transfer fluid (HTF) and PCM. The study presents experimental analysis of thermal performance of high energy density PCM-based TES prototype (PCM TES). The PCM TES prototype consists of a thermally insulated storage tank, a compact fin-and-tube type heat exchanger, and an organic PCM RT58 (93 kg). The unit is designed for use in heating and domestic hot water preparation systems in the temperature range of 40–60 °C. The PCM TES charging and discharging experiments were performed using an experimental setup that consists of buffer tanks with an electric heater and cooler for the preparation of hot and cold HTF (water), a mixing valve with actuator and electronic constant temperature controller, flowmeters, circulating pumps, expansion vessels, 6 temperature sensors (Pt100), process control and monitoring system. Several parameters have been analysed, including HTF temperature and mass flow rate, PCM temperature, PCM charging and discharging time, heat transfer rate of the heat exchanger, stored and released thermal energy. The experiment showed that the heat transfer rate during the charging process at a mass flow rate of 0.1 kg/s and an average inlet temperature of hot water of 72 °C decreases from 20.9 kW to 3.4 kW with an average of 9.3 kW. During the discharging process at a mass flow rate of 0.1 kg/s and an average cold water inlet temperature of 16 °C the heat transfer rate decreases from 19.2 kW to 2.2 kW with an average of 10.6 kW. The amount of heat absorbed and released in the PCM temperature range 20–70 °C is 7.48 kWh and the duration of the charging and discharging is 48 min and 44 min, respectively.

Keywords – Heat exchange; latent heat; Phase Change Material (PCM); Thermal Energy Storage (TES)



PCM TES prototype and experimental setup

https://doi.org/10.7250/CONECT.2025.014

TOWARDS INTRODUCTION OF ELECTRIC BUSES: PUBLIC ATTITUDES IN CONTEXT OF TEMPERATURE COMFORT LEVEL

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Abstract – One of the primary challenges in integrating electric buses into public transport systems is their cost. This financial burden is exacerbated in colder climates due to the significant energy required to heat the passenger compartment. To address this issue, the project 'Development of a Sustainable Heating Solution for the Salon of Public Electric Transport' was undertaken. It aimed to enhance the feasibility of electric buses during winter months. The project included an assessment of current heating standards and solicited passenger feedback on bus heating. This article presents the study's findings, which comprised three segments: an evaluation of existing solutions, a survey capturing passenger opinions, and an observational study correlating passenger behaviour with weather conditions and onboard temperatures. The survey results indicated generally favourable public attitudes towards green transportation, albeit as long as they did not have to additionally pay for it. Awareness of heating as a contributing factor to increased expenses was relatively low, with only one-fifth of respondents acknowledging it. When interviewed, most passengers rated the onboard temperature as 'acceptable' or 'too warm'. On the other hand, the onboard observations showed, that when riding a heated bus on a winter day less than 20 % of the passengers removed their winter accessories or loosened their overcoats inside the heated buses, despite the interior temperature being up to 20 °C warmer than outside. One would expect that would lead to health risks due to excessive sweating resulting from overheating. In conclusion, it has been ascertained that to date, minimal research has been conducted on strategies to reduce heating costs in electric buses. Further investigation is essential to explore the array of options, both technical and regulatory, to optimize heating systems in line with the electrification of public bus fleets.

Keywords – Electric bus; heat, ventilation and air conditioning (HVAC) in electric buses; heat accumulators; public transport; thermal comfort

ACKNOWLEDGEMENT

This work has been supported by the European Regional Development Fund within Project "Development of a Sustainable Heating Solution for the Salon of the Public Electric Transport", project identification number 1.1.1.1/18/A/168

https://doi.org/10.7250/CONECT.2025.015

THE IMPLEMENTATION OF THE DISTRICT HEATING ENERGY SECURITY INDEX THROUGH A LEGISLATION FRAMEWORK

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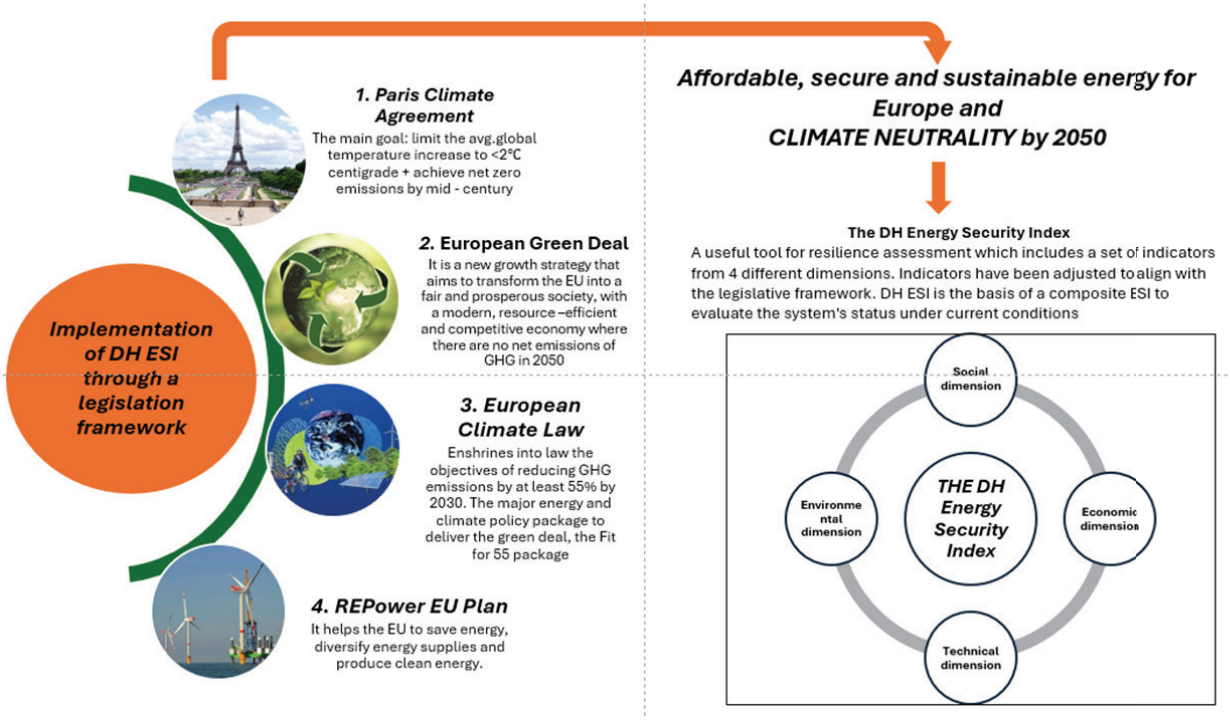
Abstract – The resilience of district heating (DH) is a relevant research topic, as energy systems are frequently affected by natural and human-induced disruptions, such as floods and supply chain issues. A valuable tool for resilience assessment is the Energy Security Index (ESI). In the existing literature, it is mostly used for the evaluation of a country, but not as much for certain energy systems. In this study, a municipal DH system is studied through the lens of energy security. An ESI is used to better evaluate the state of the DH system during unplanned interruptions. It includes a set of indicators – social, economic, environmental, and technical – that form the basis of a composite ESI to evaluate the system's status under current conditions. In this study, the previously developed methodology is applied to a case study from Latvia. Adjustments to the indicators are made, and three main risks – dependency on energy imports, affordability of DH, and diversity of heat sources – are identified to facilitate a more thorough analysis of the specific system. The results have been adjusted to align with the legislative framework in Latvia and the European Union concerning DH development. This adjustment aims to propose realistic scenarios for system improvement, considering its specific characteristics. These results can be used for decision-making at the municipal level, and the developed methodology can be applied to other cases.

Keywords – Composite index; district heating; energy security index; resilience assessment



DH ESI through a legislation framework

ACKNOWLEDGEMENT

The research has been done within the Fundamental and Applied Research Project "Resilience Metrics for District heating Systems: A Comprehensive Framework (DH INERTIA)", project No. Izp – 2023/1-0039, funded by the Latvian Council of Science.

https://doi.org/10.7250/CONECT.2025.016

THE ROAD TO ZERO-EMISSION FLEETS: CHALLENGES, OPPORTUNITIES, AND THE ROLE OF DATA-DRIVEN DECISION-MAKING

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Abstract – The transition from internal combustion engine (ICE) fleets to zero-emission vehicles (ZEVs) is a critical step toward achieving corporate sustainability and regulatory compliance with European Union (EU) decarbonization targets. However, many businesses face significant challenges in fleet electrification, including high upfront costs, uncertain operational feasibility, and inadequate charging infrastructure. Traditional fleet transition approaches often rely on general estimations rather than data-driven strategies tailored to specific fleet usage patterns and business constraints. This paper explores the current state of corporate fleet electrification, highlighting key barriers and the limitations of existing transition models. It emphasizes the critical role of data analytics, predictive modelling, and optimization techniques in facilitating cost-effective and operationally viable fleet transformation. By leveraging real-world fleet operation data from *carmonitor.eu* – such as trip duration, energy consumption, and route characteristics — combined with external factors like vehicle market availability and energy pricing, businesses can develop informed transition strategies that minimize financial risk and maximize sustainability benefits. We propose a framework for a data-driven decision-support system that integrates fleet monitoring, scenario simulations, and tailored recommendations for electrification. This system aims to provide corporate decision-makers with actionable insights that optimize vehicle replacement strategies, charging infrastructure planning, and long-term fleet efficiency. The paper concludes by outlining key research directions and the next steps toward developing a robust, scalable tool for fleet transition optimization. Through this approach, businesses can make informed, strategic decisions that accelerate their path toward zero-emission mobility while ensuring economic and operational feasibility.

Keywords – Electric Vehicles (EV); fleet electrification; data-driven decision-making; corporate sustainability and mobility; logistics and fleet sustainability.

ACKNOWLEDGEMENT

This paper has been published within the research project "Software development for the transition to environmentally friendly, zero-emission vehicles in company transport fleets." carried out within grant program by European Regional Development Fund and Central Finance and Contracting Agency in the research program "Competency Center for Digital Products" Project number: 2.2.1.3.i.0/2/24/A/CFLA/001

https://doi.org/10.7250/CONECT.2025.017

COMPARATIVE STUDY OF THE THERMAL PROPERTIES OF NANOPARTICLE-ENHANCED PHASE CHANGE MATERIALS FOR BUILDING ENVELOPE APPLICATIONS

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Abstract – Phase change materials (PCMs) are gaining attention for their potential to improve the thermal energy performance of building envelopes. However, PCMs generally have low thermal conductivity, which means they absorb and release heat at a slower rate. This can limit their effectiveness in applications where fast heat transfer is essential for maintaining desired temperatures. Additionally, the performance of PCMs depends heavily on their phase transition temperature. If the temperature in the building fluctuates significantly, PCMs may not operate effectively or activate at the right moments. This study investigates the enhancement of paraffin wax, a commonly used PCM, through the incorporation of various nanoparticles to address these limitations. Furthermore, this paper gives insight into the best option for nano-additives in building envelope applications in temperate climate zones. A series of experiments were conducted using a heat-flux apparatus to assess the impact of carbon nanotubes (CNTs) and zinc oxide (ZnO) nanoparticles on the thermal conductivity and phase transition characteristics of paraffin wax. Results indicate that the inclusion of CNTs, both multi-walled (MWCNT) and single-walled (SWCNT), significantly increases the thermal conductivity of paraffin wax, with improvements ranging from 10 to 100 times depending on the concentration and type of CNTs. Additionally, the incorporation of ZnO nanoparticles enhances the response to temperature fluctuations, improving the speed of thermal energy storage and release. ZnO also acts as a nucleating agent, reducing the phase transition time by 10–50 %. This study demonstrates that nanoparticles, particularly CNTs and ZnO, significantly enhance the thermal performance of paraffin-based PCMs, making them more suitable for efficient building envelope applications that require fast heat transfer and stable indoor temperatures.

Keywords – Carbon nanotubes; heat-flux apparatus; nano particles; phase change materials; thermal performance; zinc oxide nanoparticles

https://doi.org/10.7250/CONECT.2025.018

BOOSTING ENERGY TRANSITION OF THE DAIRY VALUE CHAIN: A LIFE PROJECT

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Abstract – The dairy sector faces several challenges, including economic instability, environmental concerns, and climate impacts, while striving to meet the EU's Green Deal and Sustainable Development Goals (SDGs). Nowadays, the sector contributes significantly to greenhouse gas emissions, mainly from dairy cow breeding and energy-intensive processes like milk processing. Yet, it is also vulnerable to climate change effects, including heat stress in livestock, reduced water availability, and declining soil fertility. To address these challenges, the sector must focus on sustainability, resilience, and decarbonization. Key strategies include reducing production costs, improving resource efficiency, mitigating environmental impacts, and adopting energy-efficient technologies. Beyond technological advancements, enhanced transparency and collaboration across the supply chain are critical. Open communication and data sharing among farmers, processors, distributors, retailers, and consumers can facilitate the development and implementation of sustainable practices. Stronger partnerships and collaborative initiatives can foster innovation, drive investment in sustainable solutions, and ensure that the dairy sector not only survives but thrives in a future marked by climate change and increasing societal expectations for environmental responsibility. Only through such a comprehensive and collaborative approach can the dairy sector effectively address its challenges and achieve its sustainability goals. The LIFE-CET-2022-funded BETTED project aims to accelerate the dairy sector's energy transition by fostering the adoption of renewable energy and energy-efficient measures like heat pumps for milk processing and dairy product production. Targeting small and medium enterprises, the project emphasizes capacity-building, investments in sustainable technologies, and reducing fossil fuel dependency, ensuring the sector's economic and environmental viability. This paper aims to present the toolbox developed under the project. Furthermore, this paper reviews existing Life Cycle Assessment and Environmental Product Declaration studies to analyze the environmental impacts of dairy products using a consistent cradle-to-grave system boundary and functional unit for comparability. This analysis establishes benchmarks for key indicators like the Global Warming Potential to assess dairy system sustainability. This research contributes to scientific knowledge by enhancing the accuracy and consistency of environmental impact assessments in the dairy sector, thanks to the standardized toolbox and the comparable benchmarks provided. Furthermore, the developed benchmarks offer practical applications for industry stakeholders, policymakers, and consumers, enabling informed decision-making towards more sustainable dairy production and consumption practices.

Keywords – Dairy industry; decarbonization; energy efficiency; energy transition; life cycle; value chain.

ACKNOWLEDGEMENT

The contents of the paper are a part of the program of the project Boosting Energy Transition of The Dairy value chain (BETTED). BETTED has received funding from the European Union's LIFE Clean Energy Transition 2022 program under grant agreement No. 101120856.

https://doi.org/10.7250/CONECT.2025.019

EXERGY CALCULATIONS IN WASTEWATER SYSTEMS. CASE STUDY

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Abstract – Faced with geopolitical, socio-economic and environmental pressures, in 21st century is a growing global demand for sustainable, renewable energy systems. These demands also apply to engineering systems and civil engineering structures. The method for analysing the energy balance of a wastewater system is exergy analysis. Exergy analysis is a measure of the efficiency of the system and also a measure of the change in the potential of the system. In this study, the amount of resources required for the wastewater system of the city of Ogre (Ogre region, Latvia) is evaluated through exergy analysis. The Ogre wastewater system is characterised by the reuse of wastewater – heat is recovered from the wastewater. The recovered heat is used to provide heating in the Ogre Central Library (the largest passive public building in Latvia). The study compares two exergy calculations. The first is calculated without a heat recovery system (the authors' patent), the second with a proprietary heat recovery system. The study shows that the wastewater system has a higher exergetic potential with a higher value if wastewater heat is recovered or used. In addition to the energy saved, carbon dioxide (CO_2) emissions are reduced proportionally. The calculations in the study were carried out using the Hellström methodology. The aim of the study is to compare the exergy balance of a wastewater system including heat recovery from wastewater. The main objective of the study is to promote the use of renewable resources in water management facilities, to highlight the importance of exergy calculations and to encourage CO_2 footprint reduction activities. Hypothesis: "using renewable resources and exergy method reduces CO_2 footprint".

Keywords – Carbon dioxide; energy; exergy; heat recovery; sustainability; wastewater system

02

ENERGY AND ENVIRONMENTAL MODELLING

https://doi.org/10.7250/CONECT.2025.020

A COMPREHENSIVE DATA MONITORING AND LOGGING SYSTEM FOR LITHIUM-ION BATTERY PACKS IN AGRICULTURAL ROBOTICS

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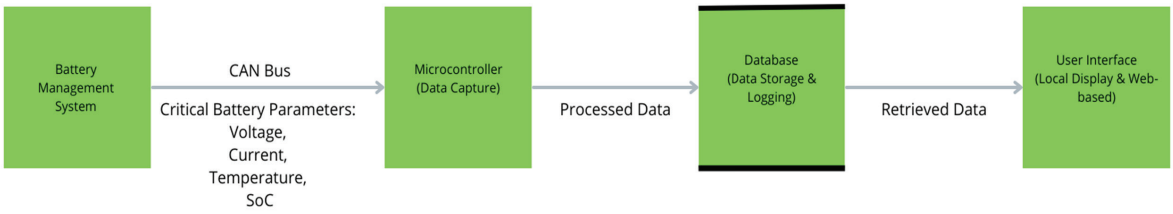
Abstract – This paper presents the development and evaluation of a monitoring and data capture system designed to track critical parameters of a lithium-ion battery pack used in an agricultural robot. Agricultural robots rely heavily on battery performance to operate efficiently and reliably in the field. As a result, ensuring that the battery is well-managed and monitored can significantly improve the robot's operating time, reduce downtime, and extend overall battery life. Given the growing emphasis on energy efficiency in modern agricultural practices, optimizing battery usage and storage plays a crucial role in reducing energy waste and improving sustainability. Our approach integrates both hardware and software elements to collect, store, and present key battery parameters. We utilize a Battery Management System (BMS) that communicates vital data such as voltage, current, temperature, and State of Charge (SoC) through a Controller Area Network (CAN) bus. A dedicated microcontroller reads and processes these signals, and then transfers them into a central database for long-term logging and analysis. This enables precise tracking of battery health and performance, ultimately supporting more energy-efficient robotic operations. To make this information accessible to users, we developed a clear and intuitive interface. Operators can view the data on a built-in display located directly on the robot, as well as remotely through a web-based interface and an API. This dual-access approach supports on-site monitoring during field operations, as well as remote diagnostics and decision-making. Such flexibility aids in timely maintenance, better charging strategies, and overall improved resource management – key factors in maximizing energy efficiency and minimizing unnecessary power consumption. Preliminary tests performed under realistic field conditions indicate that our system reliably captures and records the critical battery parameters. The data collected facilitates early detection of potential issues, preventing unexpected breakdowns and saving valuable time and costs. In future work, we plan to implement advanced analytics and machine learning algorithms to predict battery failures and optimize charging schedules. By providing a robust and accessible tool for battery management, this system contributes to more efficient, sustainable, and productive agricultural robotic operations while reinforcing the importance of energy storage and utilization in modern farming.

Keywords – Cell-level management; condition tracking; Controller Area Network (CAN); diagnostics; energy storage device; Graphical User Interface (GUI)



Data Flow Diagram of the Battery Monitoring and Logging System

ACKNOWLEDGEMENT

This work has been supported by the Estonian Research Council within the project "Autonomous movable power station" EAG304 and Estonian University of Life Sciences within the project "Development of precision fertilization technology of cultivated berries" PM210001TIBT.

https://doi.org/10.7250/CONECT.2025.021

ADVANCING ELECTRICITY STORAGE TECHNOLOGIES WITH A SYSTEM DYNAMICS APPROACH

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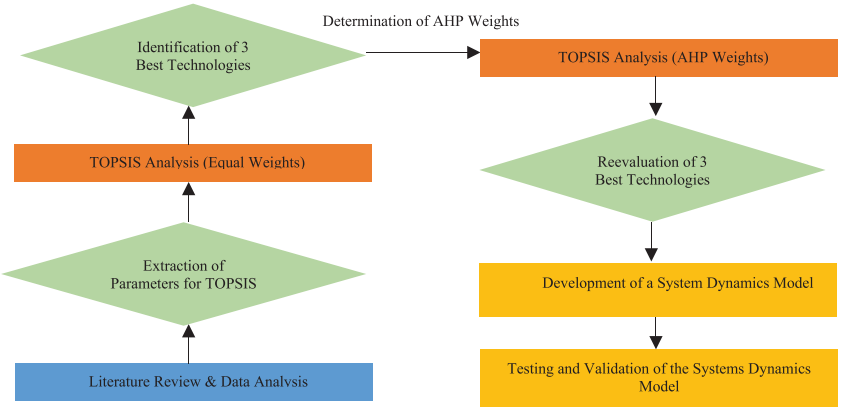
Abstract – Climate neutrality targets and strategies show that the share of renewables in energy generation is set to increase, nevertheless their variability, seasonality and lack of reliability pose significant challenges. With the continued growth in energy consumption, demand for energy storage is becoming more evident. The integration of renewable energy and the reliability of the grid depend on the installed storage capacity. However, the overestimation of the amount of storage needed can result in wasted investment. Therefore, to enable proactive energy policy – making and efficient energy system planning, it is necessary to be able to predict how the installed capacity of specific energy storage applications will develop over time. This study conducts an electricity storage technology assessment to investigate feasibility and technological progress, compare available technologies and conclude the main drivers and barriers affecting the adoption rate. A multi-criteria analysis approach is applied to compare the different types of energy storage technologies available. TOPSIS analysis, a ranking method based on distance from the ideal solution, was used to identify the electricity storage technologies that are closest to the ideal solution, followed by a more in-depth analysis – a systems dynamics approach. The system dynamic model was built in Stella Architect to further assess the viability of these technologies, predict and compare installed capacities. The results reveal various critical factors that influence the rate of deployment of electricity storage technologies: capital and operating costs, storage installation time, market distribution constraints, storage outages, lifetime, etc. This paper concludes which technologies should be given more consideration for deployment and what are the key factors affecting their installed capacity over time. The findings of this study underline that energy storage is one of the key steppingstones towards the energy transition, providing insights into technology prioritization and driving factors identified.

Keywords – Electricity storage technologies; energy storage comparison; energy storage systems (ESS), energy transition; system dynamics



A flowchart of methodology

https://doi.org/10.7250/CONECT.2025.022

SCENARIO MODELLING FOR MUNICIPAL ENERGY TRANSITION IN THE BALTIC SEA REGION

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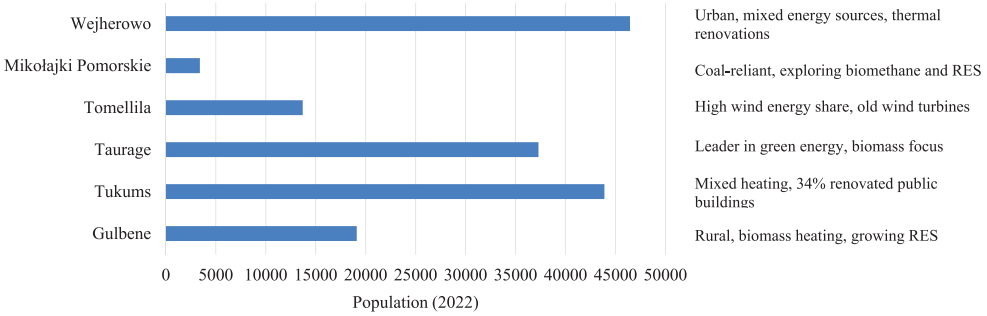
Abstract – In the context of the EU Green Deal and the Paris Agreement, the transition to renewable energy sources and the deployment of energy storage systems are fundamental for a sustainable and low-emission tomorrow. However, given the diversity of municipalities in terms of resources, infrastructure, and socio-economic conditions at local energy transition level, main actors face numerous challenges related to the implementation of new renewable energy generation projects, lack of capacity to initiate, install, and develop new projects, for which the underlying unifying factor is economic and lack of knowledge/specialists. Hence there is a need for a modelling platform that can model scenarios for the deployment of different energy generation/storage technologies in municipalities, thus saving financial resources and assessing risks and potential before the actual deployment. This research paper is a follow-up to previous publications in which the authors characterized Baltic Sea region municipalities through benchmarking and identified their storage potential and engagement in the energy transition. The focus of this case study, however, is the development of a modelling platform using systems dynamics approach to provide local public authorities support in decision-making for energy system planning. The model was validated and piloted in six municipalities – Tukums, Gulbene, Wejherowo, Tomellila, Mikolajki Pomorskie and Taurage. A scenario modelling approach based on existing municipal parameters was used for piloting. The study reveals the outcomes of different simulated scenarios in each of the municipalities and provides insights and resources to address the challenges of energy storage deployment. The study analyses the potential and means of municipalities to move towards an energy transition, but each municipality is different, and one approach does not fit all. The findings mainly address renewable energy production, storage, costs and emissions. The results of the pilots are a useful tool for municipalities to understand possible actions to reduce emissions, become more sustainable to meet EU targets whilst maintaining a stable and reliable energy supply.

Keywords – Energy efficiency; energy policy; energy storage; energy sustainability, energy transition; municipality



Pilot municipalities and their key characteristics

ACKNOWLEDGEMENT

This research is funded by the Interreg Baltic Sea Region's project "Carbon driver energy equilibrium at the municipal scale (Energy Equilibrium)", Project no. #C027.

https://doi.org/10.7250/CONECT.2025.023

ASSESSMENT OF POTENTIAL ENVIRONMENTAL IMPACT: SYNTHETIC AND NATURAL BINDERS

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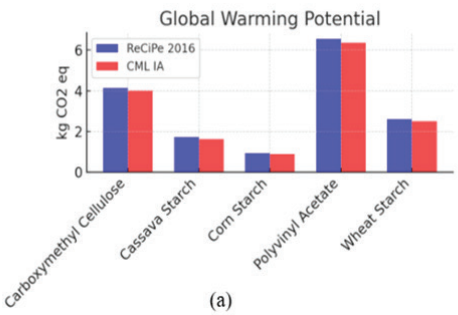
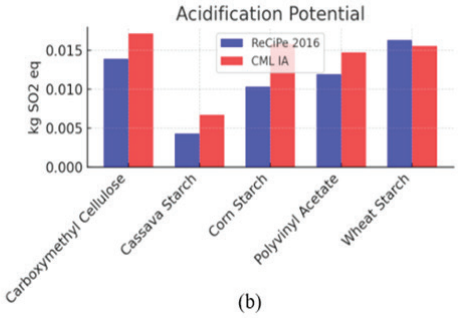
Abstract – Binders play a critical role in the construction industry, especially when combined with plant-based granulates and fibers. The binder is selected based on its physical and chemical characteristics for compatibility with certain construction requirements. New market trends highlight the use of green binders that meet global sustainability targets, demonstrating a move toward greener building and environmental sustainability. This study presents a cradle-to-gate comparative life cycle assessment (LCA) of synthetic binders – namely Polyvinyl Acetate (PVA) and Carboxymethyl Cellulose (CMC) and agriculture starch-based binders made from cassava, wheat, and corn. The Life Cycle Assessment was conducted using SimaPro software based on ISO 14040/14044 standards using the ReCiPe Midpoint and CML IA Baseline. The assessment is cradle-to-gate with a function unit of 1 kg for binder production. Key environmental sustainability metrics such as Global Warming Potential (GWP) and Acidification Potential (AP) are assessed to rank the binder sustainability relative to each other. The results show that synthetic binder PVA has the highest environmental impact in almost all impact categories, especially GWP (6.55 kg CO2 eq in ReCiPe and 6.37 kg CO2 eq in CML) and AP (0.012 kg SO_2 eq in ReCiPe and 0.015 kg SO_2 eq in CML). Among natural binders, Corn Starch shows the lowest environmental impact with GWP values of 0.930 kg CO2 eq (ReCiPe) and 0.896 kg CO2 eq (CML) and AP values of 0.010 kg SO2 eq (ReCiPe) and 0.016 kg SO2 eq (CML). The agricultural binders (Cassava Starch, Wheat Starch, and Corn Starch) are environmentally friendlier than the synthetic binders (PVA and CMC). Although agricultural binders carry environmental costs associated with farming operations, they have lower environmental impacts than synthetic alternatives, demonstrating their sustainability potential in binder applications.

Keywords – Environmental impacts; Life Cycle Assessment (LCA); sustainable binders; synthetic binders; starch-based binders



(a)



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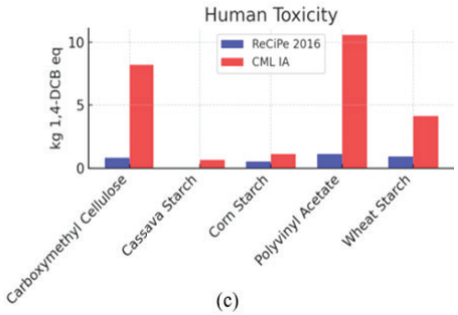

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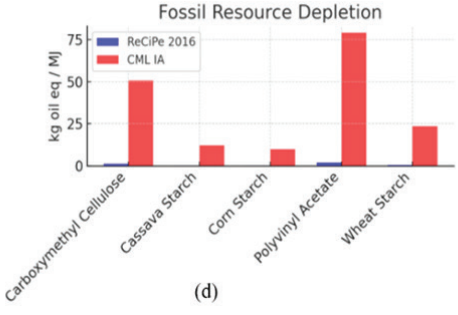

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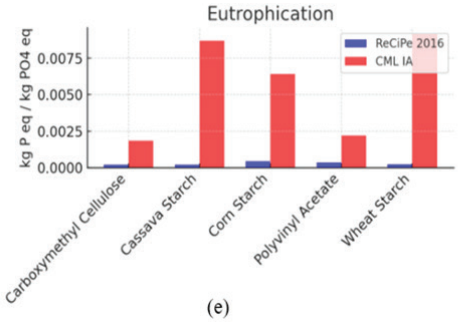

(e)

Comparative evaluation of impact categories ReCiPe vs CML (a) Global Warming Potential (GWP) (b) Acidification Potential (c) Human Toxicity (d) Fossil Resource Depletion (e) Eutrophication

https://doi.org/10.7250/CONECT.2025.024

ENHANCING DIESEL ENGINE PERFORMANCE AND REDUCING TAILPIPE EMISSIONS WITH BIODIESEL MIXTURE ETHANOL AND BUTANOL BLENDS AT VARYING SPEEDS

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Abstract – Using fossil fuel in diesel engines is one of the major causes of high emissions from the engine tailpipe that are hazardous to the ecosystem. The biodiesel mixture (BDM100) produced from 50 % of waste vegetable oil (WVO) and 50 % of soybean oil (SBO) has shown potential. This biodiesel blend was produced by mixing 15 % ethanol and 15 % butanol, resulting in a biodiesel mixture-ethanol blend (BMET15) and biodiesel mixture-butanol blend (BMBT15). One effective solution to such a problem is to add ethanol and butanol to a biodiesel mixture produced. This study aims to thoroughly assess and compare a single-cylinder diesel engine performance and exhaust gas emission characteristics fueled by the standard diesel (D100), BDM100, BMET15, and BMBT15. The experiments were conducted on a single-cylinder, four-stroke diesel engine at different speeds of 1000 rpm, 1500 rpm, 2000 rpm, and 2500 rpm. The results indicated that the brake power (BP) of biodiesel mixture, biodiesel mixture-ethanol blend, and biodiesel mixture-butanol blend decreased compared to standard diesel fuel. The brake-specific fuel consumption (BSFC) of biodiesel mixture, biodiesel mixture-ethanol blend, and biodiesel mixture-butanol blend increased compared to standard diesel fuel. The brake thermal efficiency (BTE) of biodiesel mixture-ethanol blend presents a higher value than standard diesel, biodiesel-mixture, and biodiesel mixture-butanol blend at maximum speed. The hydrocarbon (HC) of biodiesel mixture, biodiesel mixture-ethanol blend, and biodiesel mixture-butanol blend decreased compared to standard diesel fuel. The carbon dioxide (CO_2) of biodiesel mixture, biodiesel mixture-ethanol blend, and biodiesel mixture-butanol blend decreased compared to standard diesel fuel. The Bosch Smoke Number (BSN) of biodiesel mixture, biodiesel mixture-ethanol blend, and biodiesel mixture-butanol blend decreased compared to standard diesel fuel. Using pure biodiesel mixture, biodiesel mixture-ethanol blend and biodiesel mixture-butanol blend in a diesel engine decreases all emission characteristics compared to standard diesel fuel at a maximum speed.

Keywords – Biodiesel; biodiesel mixture; diesel engine; emissions; performance

https://doi.org/10.7250/CONECT.2025.025

HYDRAULIC MODELLING FOR ENVIRONMENTALLY FRIENDLY SMALL HYDROPOWER: INNOVATIONS AND APPLICATIONS

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Abstract – After the outbreak of war in Ukraine, one of the aggressor country's goals was to destroy the energy infrastructure of our country. Therefore, about half of Ukraine's power generation capacities have been lost (with 90 % of wind and one-third of solar generation lost). In this situation, hydropower plants and pumped storage power plants played and continue to play a key role in the resilience of the power system, covering two-thirds of the peak capacities in the daily load curve of the power system. However, Russia has started to attack the hydropower facilities of large hydropower plants. In such a situation, the role of small hydropower plants should be emphasized. On the one hand, Ukraine has a large hydropotential for developing small hydropower engineering which has the same features as the HPP with large capacities (producing scarce peak energy, providing highly maneuverable capacities, improving the quality and reliability of electricity supply by regulating frequency, voltage, and power reserve, etc.), as well as small hydropower plants are an important element of distributed generation by influencing the operation of power grids. On the other hand, current tendencies require minimizing negative influences on the environment. One such negative effect of small hydropower plants is changing the natural hydraulic and hydrological regime of rivers where the hydropower plants are located. To reduce this, it is necessary to model and predict future hydraulic regimes of SHPPs at the designing stage. The objective of this work is to consider and analyze the example of modelling the hydraulic regimes of small hydropower plants using computer software, which allows to study and analysis of different variants of hydropower plant composition and choose the optimal one with minimal impact on the environment. Using the example of an existing small HPP, the hydraulic conditions in the tailrace channel of the hydropower plant during turbine operation and during flood passage were modelled, which can be characterized by the formation of a turbulent flow in the riverbed and can lead to erosion of the riverbed bottom and banks. Based on the obtained results, the conclusions and recommendations for the safe operation of considered small HPP were made.

Keywords – Environmental impact; hydraulic regime; modelling; small hydropower plant

ACKNOWLEDGEMENT

This work has been supported by the program "Strengthening the Capacity of Public Universities in Ukraine in 2025" from the Ministry of Foreign Affairs of the Czech Republic.

https://doi.org/10.7250/CONECT.2025.026

GEOSPATIAL ANALYSIS FOR ENVIRONMENTAL ENGINEERING: A LITERATURE REVIEW

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Abstract – The recently increased availability of open geospatial datasets and the increased availability of publicly available remote sensing imagery provide possibilities to advance their use in environmental engineering analysis. The analysis of remote sensing imagery, especially using machine learning technology, to improve pattern recognition, allows to tackle such problems as land cover change, illegal waste landfills, vegetation analysis. The limitation of this approach is mainly the fact that remote sensing can detect only changes that have already happened, and it is complicated to use it for the detection of causes of environmental problems. This research aims to discover the latest tendencies and gaps for the potential to use open remote sensing data to investigate environmental engineering related issues, for example, renewable energy potential, causes of greenhouse gas emissions and environmental pollution detection. To reach the aim of the study a literature analysis and content analysis methods are applied. The literature analysis focuses on ability and limitations of geospatial analysis to assess environmental engineering related issues by using Earth Observation data and without investing into dedicated data acquisition. In addition to the literature analysis, the existing sources of other geospatial open data at the European Union scale are overviewed to determine their applicability.

Keywords – Environmental engineering; geospatial analysis; literature review; remote sensing

https://doi.org/10.7250/CONECT.2025.027

SELECTION OF CRITERIA FOR LOAD ANALYSIS ON ELECTRICAL GRID IN THE CONTEXT OF TRANSPORT ELECTRIFICATION IN LATVIA

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Abstract – The following research paper addresses the pressing issue of the projected load on the electricity grid in the context of transportation electrification in Latvia. This is examined in relation to potential Electric Vehicle (EV) growth models, the current status, and implementation plans aimed at achieving the goals set by the Latvian Updated National Energy and Climate Plan 2021–2030, the Alternative Fuels Infrastructure Regulation (AFIR), and the Renewable Energy Directive (RED). The analysis considers local legislation, electricity and Renewable Energy Sources (RES) production and consumption profiles, as well as the charging habits of EV owners. The goal of this study is to create a comprehensive model for electricity demand prediction with Distributed Energy Solutions (DES) and Smart Charging capabilities for grid infrastructure development. According to research conducted by Danish scientists, "in a favorable scenario where 25 % of vehicles are electric by 2030, they are expected to contribute approximately 4 % to the peak load on a winter workday between 6 and 8 PM. In the worst-case scenario, they contribute 15 % to the peak load. In 2040, 80 % of the vehicles are expected to be electric and contribute between 15 % and 55 % to the annual peak consumption in Denmark." The tendency behind shift in peak loads stresses the need for proactive grid planning highly relevant to Distribution System Operators (DSOs). The current grid development related to public 'Destination' EV charging primarily responds based on unsystematic requests for electricity connections by Charging Point Operators (CPOs) and an internally developed general simultaneity coefficient methodology. Furthermore, the 'Highway' EV charging infrastructure within Trans-European Transport Network (TEN-T) must be built from scratch in accordance to AFIR regulation, with specific attention given to the core sections as well as the transport flow context to the comprehend sections of it. The author also examines the shift in the EV charging profile, from predominantly "Home" overnight Alternating Current (AC) slow charging to Direct Current (DC) fast charging on-the-go. The modeling of network system scenarios for case of Latvia considers changes in charging patterns relatively to Electric Vehicle Charging Infrastructure (EVCI) availability by System Thinking approach. The causal loop diagram incorporates not only social (users' habits), economic (growing portfolio of new affordable and used EVs, and future price parity with Internal Combustion Engine Vehicles (ICEV)), and governmental (incentives, tax tariffs, and fines for missed CO2 targets) part, but also the technical – flexible transportation electrification options such as Battery Energy Storage Systems (BESS) and Vehicle-to-Grid (V2G). As a result, the paper states that the change of charging habits and, thus, a raising public EV Charging Infrastructure growth and its utilization rate could severely impact the peak load and must be addressed.

Keywords – Battery Energy Storage Systems; DSO; EV Charging; EVCI; Peak load; Smart Charging; Transport electrification

https://doi.org/10.7250/CONECT.2025.028

OPTIMIZING ENERGY BALANCING AND FLEET ELECTRIFICATION THROUGH INTELLIGENT CHARGING SYSTEMS: A DATA-DRIVEN APPROACH FOR SMALL-SCALE ENERGY STORAGE AGGREGATORS

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Abstract – The rapid electrification of transportation necessitates the development of intelligent energy management solutions to ensure the efficient operation of electric vehicle (EV) fleets while maintaining grid stability. Traditional energy balancing methods primarily target large-scale power systems, leaving smallscale energy storage aggregators – such as distributed EV charging hubs – without effective optimization frameworks. This paper presents a data-driven approach to optimizing fleet electrification and energy balancing through an intelligent IT system that integrates distributed energy storage with real-time charging coordination. We propose a mathematical optimization model that dynamically adjusts charging strategies based on energy availability, grid demand, and fleet operational requirements. By integrating ISO 15118 communication standards with advanced energy balancing algorithms, our system enables realtime interaction between EVs and the power grid, allowing vehicles to dynamically adjust their charging rates based on grid conditions and electricity pricing. ISO 15118 facilitates seamless authentication and bidirectional energy transfer, while energy balancing algorithms optimize fleet-wide charging schedules to distribute load efficiently. This synergy reduces peak demand stress by preventing simultaneous high-power charging events and minimizes charging costs by leveraging off-peak tariffs and vehicle-to-grid (V2G) capabilities. The proposed model is validated through simulation-based case studies, demonstrating up to a 20–30 % improvement in energy efficiency and a reduction in grid dependency compared to conventional unmanaged charging strategies. The results highlight the potential of IT-driven energy balancing solutions in enhancing the sustainability and cost-effectiveness of fleet electrification. This research contributes to the broader transition toward decentralized energy management, offering actionable insights for fleet operators, energy providers, and policymakers. Future work will explore real-world deployment and machine learningdriven predictive optimization to further enhance system performance.

Keywords – Demand response in Electric vehicle (EV) charging; grid-aware charging; ISO 15118 and energy balancing; time-of-use pricing optimization; vehicle-to-grid (V2G)

ACKNOWLEDGEMENT

This paper has been published within the research project "Development of a prototype of an environmentally friendly electric car charging ecosystem by integrating renewable energy sources and balancing the power grid" carried out within grant program by European Regional Development Fund and Central Finance and Contracting. Project number: 2.2.1.3.i.0/1/24/A/CFLA/004

https://doi.org/10.7250/CONECT.2025.029

DEFINING THE SOCIAL-ECONOMICAL DIMENSION OF ELECTRIC VEHICLE PEAK CHARGING SHIFTING IN LATVIA

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Abstract – Public charging points (PubCP) are often more powerful than private charging points, such as home chargers. PubCP charging behaviour is embedded in a social context where on one side is the PubCP infrastructure that promises to be accessible and always deliver the promised power while on the other side, there is a growing concern about these charge points adding additional strain to the electrical grid in peak hours. This study investigates the social and economic factors influencing electric vehicle (EV) charging behaviour in Latvia, focusing on shifting peak charging demand to alleviate grid stress. Through a mixedmethods approach, including surveys of more than 200 EV users and interviews with key stakeholders (main charging point operators, municipality representatives, and government officials), this research aims to: 1) identify current EV charging patterns and peak usage times; 2) understand user preferences and constraints; and 3) explore potential demand-side management (DSM) strategies to encourage off-peak charging. Findings reveal significant potential for shifting peak demand through targeted interventions, such as time-of-use pricing, smart charging technologies, and tailored incentive programs. This research provides valuable insights for policymakers and stakeholders in developing effective strategies to integrate EVs into the Latvian electricity grid while ensuring grid stability and promoting sustainable transportation.

Keywords – Automotive industry; battery electric vehicles; behavior change; charging behavior; demand shift; expert interviews; public charging points

https://doi.org/10.7250/CONECT.2025.030

MODELLING AND EVALUATION OF PHOTOVOLTAIC SYSTEMS COMBINED WITH CHARGING STATIONS FOR ELECTRIC VEHICLES

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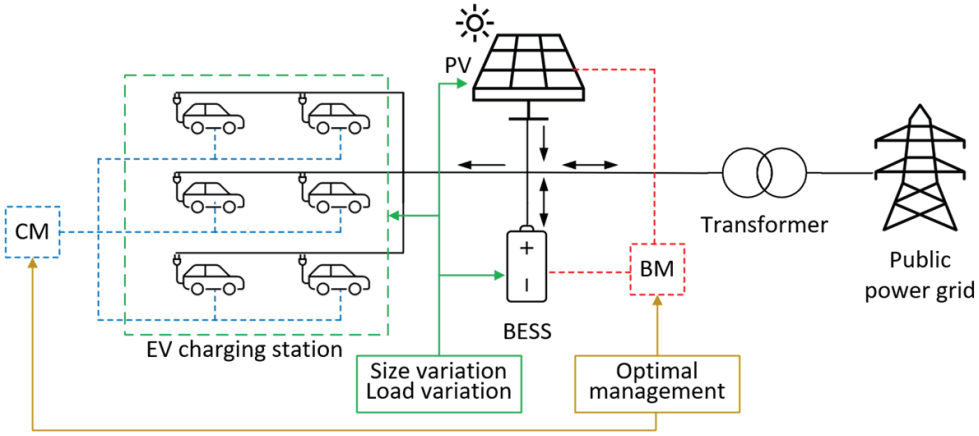
Abstract – The expansion of charging infrastructure for electric vehicles (EV) in Europe is progressing steadily. However, available charging capacities are rapidly approaching their limits, particularly at highly frequented public charging points, such as those along highways. One reason for this limitation is the restriction in electrical grid capacity. A solution to this problem could be the combination of large ground-mounted photovoltaic (PV) systems and public EV charging stations. The onsite usage of the energy provided by the PV system, offers a substantial advantage, as it leads to a significant reduction in the load on the electrical grid. In order to ensure sufficient power, even during periods of darkness or bad weather, the integration of battery energy storage systems (BESS) may be an additional option. This approach not only effectively mitigates the risk of overloading the electrical grid and ensures the reliability of energy supply, it also supports demand-oriented, decentral and flexible renewable integration. The present work therefore analyses the interaction of PV-BESS systems and EV charging stations and their impact on the power grid. The study is conducted using a mathematical model in MATLAB Simulink®. The model includes a ground-mounted PV system, a BESS including battery management (BM), EV charging stations and a transformer connected to the public power grid, see Figure. The EV charging stations are additionally equipped with a variety of controls, for instance, charging management (CM) can be executed in static, dynamic or sequential modes. The function of the CM is based on the economic model predictive controller (eMPC). By varying the individual components, such as the connected load of the ground-mounted PV system, the storage capacity of the external BESS and different charging profiles of EVs, questions regarding the optimum BESS size, BESS operation or optimum CM can be answered. Based on the simulation results, statements concerning the effects on the public power grid can be made. The influence of the PV-system, the BESS and the EV charging station on the quality parameters of the public power grid, including electrical voltage and frequency, can thus be investigated.

Keywords – Battery energy storage system (BESS); Battery Management (BM); Charging Management (CM); parameter study; power grid



Schematic model structure and components considered

ACKNOWLEDGEMENT

This work has been supported by the government of Upper Austria in the projects "COMPESTO – comprehensive energy storage", Research Grant Wi-2022-600132/7-Au and "Restore – Investigation of different energy storage technologies on the resilience of sector-coupled energy systems"

https://doi.org/10.7250/CONECT.2025.031

MACHINE LEARNING APPROACH FOR PREDICTING ENVIRONMENTAL IMPACT: A NEURO-FUZZY MODEL FOR LIFE CYCLE IMPACT ASSESSMENT OF STRAWBERRY PRODUCTION

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Abstract – Artificial Intelligence (AI) is transforming traditional methods reliant on human knowledge by introducing machine learning techniques, which offer effective solutions for complex challenges. An example of such a case is the evaluation of the environmental impacts of products throughout their lifecycle. This study bridges the gap in life cycle assessment (LCA) by leveraging AI to predict environmental impacts in agriculture, specifically using LCA data from one cultivation system to model another. We employed Adaptive Neuro-Fuzzy Inference Systems (ANFIS) to predict CO_2 equivalent emissions for open-field strawberry production, utilizing greenhouse strawberry data. The novelty lies in combining machine learning with LCA to address data scarcity and improve predictive accuracy in agricultural impact assessments. The model was trained with data generated in MATLAB and validated against emissions computed using the Ecoinvent 3.10 database and SimaPro software. Among the three fuzzy inference system (FIS) generation approaches – Fuzzy C-Means (FCM), Subtractive Clustering (SC), and Grid Partitioning (GP) – FCM exhibited the highest accuracy. This methodology showcases AI's potential to transform LCA, enabling more efficient, data-driven sustainability assessments.

Keywords – ANFIS; artificial intelligence; carbon footprint; global warming potential; sustainability

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BIOTECHNOLOGIES, BIORESOURCES

https://doi.org/10.7250/CONECT.2025.032

MYCELIUM THERMAL INSULATION MATERIAL

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Abstract – The study explores the potential of mycelium-based materials as sustainable thermal insulation for construction. Mycelium, the vegetative part of fungi, grows on organic substrates such as agricultural byproducts, forming a lightweight, biodegradable composite with insulating properties. Experiments focus on optimizing thermal conductivity, mechanical strength, and environmental sustainability of the material. Mycelium insulation demonstrates thermal conductivity values comparable to traditional materials like mineral wool and expanded polystyrene (EPS), with a range of 0.039 to 0.05 W/m K. The production process employs renewable resources, is non-toxic, and aligns with circular economy principles by repurposing agricultural waste. Challenges remain in enhancing water resistance and mechanical adaptability. The findings underline mycelium's potential as an eco-friendly alternative in modern sustainable construction, emphasizing its role in reducing carbon footprints and promoting resource efficiency.

Keywords – Agricultural by-product; eco-friendly materials; mycelium; thermal insulation

https://doi.org/10.7250/CONECT.2025.033

REGIONAL LIFE CYCLE INVENTORY OF SOFT WHEAT IN CENTRAL ITALY: A PRIMARY DATA-BASED STUDY

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Abstract – Wheat is one of the most important cereals worldwide as it plays a fundamental role in the diet of all population groups, including low-income ones. It accounts for the largest share of cereal production, representing about 20 % of calories and protein in the human diet. In Italy, 6.5 million tons of bread wheat are produced annually, spread across 540 000 hectares, placing the country among the top 15 global producers. The aim of this study is to present a Life Cycle Inventory (LCI) of the soft wheat supply chain in central Italy, following the guidelines outlined in ISO 14040:2006 and ISO 14044:2006, using primary data provided by three major Umbrian farms (central Italy) that are part of the supply chain of an important Italian bakery products industry (Colussi S.p.A). Among the various stages of soft wheat production analysed, we focused on the protection against fungal diseases and the use of pesticides, as this phase involves particularly critical points due to process variability. The reference unit used in this study was defined as 1 ha, and all the stages from raw materials production to seed harvesting were considered.

The regionalized inventory provided by this study can be used as a starting point for data collection and as a guideline for future studies in comparable areas, allowing for more accurate results through the use of primary data.

Keywords – Environmental impact; soft wheat; LCI; Life Cycle Assessment

ACKNOWLEDGEMENT

We acknowledge financial support under the National Recovery and Resilience Plan (NRRP) published on 14.9.2022 by the Italian Ministry of University and Research (MUR), funded by the European Union – NextGenerationEU.

https://doi.org/10.7250/CONECT.2025.034

HYDROGEN SULFIDE REMOVAL FROM BIOGAS USING POLYURETHANE FOAM AND CELLULAR CONCRETE WASTE BIOFILTERS: EXPERIMENTAL EVALUATION AND COMSOL SIMULATION

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Abstract – This study evaluates the hydrogen sulfide (H_2S) removal efficiency of a laboratory-scale biofilter packed with a combination of polyurethane foam (PUF) and cellular lightweight concrete (CLC) waste under varying operational conditions. The biofilter, consisting of five stages, was operated for six days to assess the effects of inlet loading rates, H_2S concentrations, temperature, and humidity on removal efficiency. Experimental results revealed that the PUF-CLC waste configuration achieved removal efficiencies of up to 85 % in the initial stages and 65–70 % in the later stages. These findings were compared to a biofilter packed solely with CLC waste, which demonstrated a slightly higher efficiency of 90 % in the initial stages and 70 % in the later stages under similar conditions. COMSOL 6.1 simulations were conducted for both configurations to model biogas flow, H_2S concentration, and removal trends. The simulation results aligned closely with the experimental data, showing comparable performance across the two setups. The study highlights the advantages and limitations of PUF-CLC waste biofilters and provides insights into the optimal design and operation of biofiltration systems for biogas purification.

Keywords – Hydrogen sulfide (H_2S) removal; biofilter; polyurethane foam (PUF); cellular lightweight concrete (CLC) waste; biofiltration system; removal efficiency; COMSOL 6.1 simulations

Biofilter packed with PUF and CLC waste to remove H2S from biogas

ACKNOWLEDGEMENT

We acknowledge financial support under the National Recovery and Resilience Plan (NRRP) published on 14.9.2022 by the Italian Ministry of University and Research (MUR), funded by the European Union – NextGenerationEU.

https://doi.org/10.7250/CONECT.2025.035

ENHANCING LIPID EXTRACTION AND TRANSESTERIFICATION EFFICIENCY TO OPTIMISE MICROALGAL BIODIESEL

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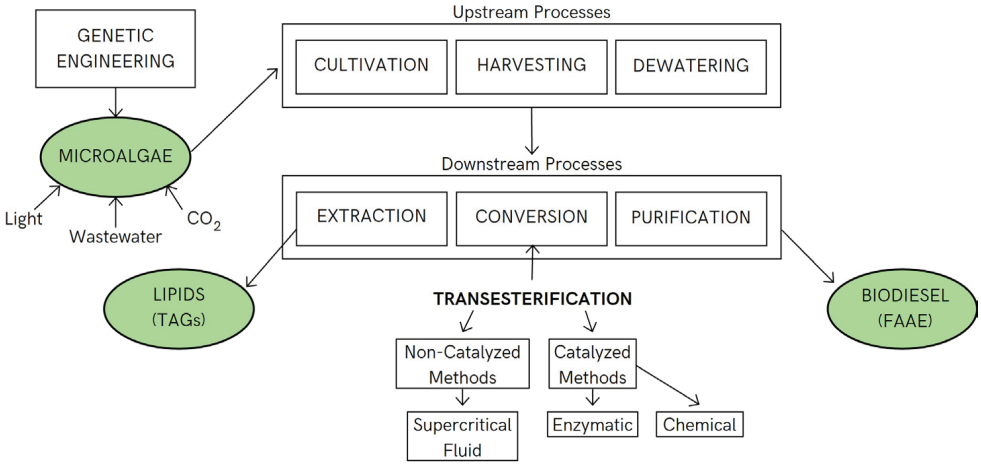
Abstract – The global quest for sustainable energy solutions has intensified as the adverse effects of fossil fuel consumption become increasingly evident. Rising energy demand underscores the need for biofuels derived from biological sources to reduce reliance on fossil fuels. Among various biomass sources, microalgae have emerged as promising biodiesel feedstock due to minimal resource requirements, rapid growth, and superior carbon fixation efficiency compared to terrestrial crops. In this contribution a review on the microalgae-derived biodiesel is presented, with particular attention to the role of lipid extraction and transesterification processes. Advancements in upstream processes – cultivation methods such as phototrophic, heterotrophic, and mixotrophic systems, harvesting, and dewatering – and downstream processes, including lipid extraction, conversion, and purification are critically discussed. A scheme of the key steps is represented in the figure. The review focuses on the role of chemical and enzymatic catalysts in enhancing transesterification efficiency, achieving yields of up to 94 %. Homogeneous catalysts, including base and acid types, are highlighted for the high activity, with base catalysts excelling under mild conditions and acid catalysts proving more effectiveness for high free fatty acid content. Heterogeneous catalysts are emphasized for the reusability, non-corrosiveness, and reduced environmental impact, although challenges like limited mass transfer and catalyst deactivation persist. Enzymatic systems, especially those enhanced with magnetic nanoparticles, are shown to achieve up to 93 % fatty acid ethyl ester yields while mitigating issues such as saponification and high energy demands of traditional methods. Additionally, emerging non-catalytic approaches, such as supercritical fluid technology, are highlighted for the ability to achieve single-step conversion of algal lipids to biodiesel, with yields exceeding 85 %. Finally, this contribution explores the potential of genetic and biochemical engineering to boost lipid productivity and metabolic efficiency, advancing toward fourth-generation biofuels. Indeed, recent results underscore the viability of microalgae as keystone in the global transition to sustainable energy. However, economic and technical barriers, such as high production costs and energy requirements, currently hinder large-scale implementation of microalgae-based biodiesel. Current interdisciplinary research prioritize cost-effective cultivation systems, innovative reactor designs, and strategies for co-product utilization within algal biorefineries to achieve scalable and sustainable biodiesel production.

Keywords – Biofuel; catalyst efficiency; fatty acid ethyl ester; genetic engineering; lipid extraction; microalgae



Key steps in the mechanism of microalgae biodiesel production

https://doi.org/10.7250/CONECT.2025.036

CULTIVATION OF EUGLENA GRACILIS ON RESIDUES FROM A FOOD INDUSTRY

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Abstract *– Euglena gracilis* is a photosynthetic flagellate able to grow in mixotrophic conditions. Its biomass can accumulate high-value molecules. Relevant concentrations of twenty amino acids, nine types of minerals, fourteen varieties of vitamins, fatty acids and chlorophyll can be found in Euglena biomass. Still, maybe the most important stored compound is paramylon, a linear β-glucan acting as immune support and cholesterol reducing agent, exclusive to Euglena species. In 2017, paramylon was approved as a novel food ingredient by the US Food and Drug Administration and the market value for β-glucans is estimated over 0.5 million USD per ton. The cost for Euglena production is very high, and is especially related to the cost of the required carbon source. The present research is being carried out to optimize at lab-scale (4 L photobioreactors, 1.5 L working volume) the cultivation of Euglena using as substrates industrial residues from a firm processing food commodities. Considering the needs of Euglena, the liquid fraction of the anaerobic digestion of residues was used and mixed, at different ratios, with a sugar-rich vinasse. Different working pH were tested. As the aim of Euglena production is to use its biomass in pet feed formulations, it was also important to check contamination, especially by eumycetes, which find favorable growth conditions in the presence of nutrients and sugars and at low pH. As the accumulation of paramylon reaches its maximum in a short time (24–72 hours), different cultivation times were also tested in batch (up to 216 hours) and compared with semicontinuous cultivation process (Hydraulic Retention Time = 10 days). All the results were compared with those from blank tests, carried out in the same conditions but using Cramer Myers synthetic growth medium. The best results were obtained in batch, at pH 5, using the liquid fraction of anaerobic digestate enriched with 2.5 % of vinasse: at 48 h the TSS growth rate was 160 mg/L/day (higher than in the blank test), the removal of total N and PO4-P were 48 % and 31 %, respectively, the algal count was 2.12*105/mL and TSS and VSS concentrations 0.81 and 0.71 g/L, respectively. Paramylon concentration in the biomass was 35 % and no contamination occurred. The experimentation is going on testing and comparing HCl and CO2 to control pH and performing analyses on pigments and fatty acids in the biomass. Based on the obtained results, the production rate of paramylon would be 56 mg/L/d, and this is promising for the use of Euglena biomass for pet food production. Further, the possibility of growing Euglena exclusively on the effluent from anaerobic digestion and on the vinasse from the factory is being confirmed, and this is very interesting from the economic point of view, involving a consistent saving on cultivation costs. In the end, the relevant uptake of nutrients is also important, as in case of disposal the effluent should be treated to meet the required quality for discharge. This kind of cultivation should thus be considered as an important element of circular economy.

Keywords – Algal biomass; food commodities; lab-scale testing; paramylon.

ACKNOWLEDGEMENT

This work has been supported by Sedamyl, Saluzzo (CN), Italy.

https://doi.org/10.7250/CONECT.2025.037

SUSTAINABLE EXTRACTION OF BIOACTIVE COMPOUNDS FROM SPRUCE AND PINE GREENERY: ANTIOXIDANT AND ANTIMICROBIAL POTENTIAL

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Abstract – Timber harvesting of coniferous trees results in significant biomass side streams, including coniferous greenery (needles and branches), a rich source of bioactive compounds with immunostimulatory, antimicrobial, and antioxidant properties. Despite their potential applications, large-scale utilization of these bioresources remains limited due to challenges in efficient and sustainable extraction methods. This study focuses on developing environmentally friendly extraction techniques for obtaining high-value bioactive extracts from spruce (Picea abies L.) and pine (Pinus sylvestris L.) needles. Green solvents, such as glycerol and propylene glycol, were employed in extraction processes, replacing conventional organic solvents that require additional processing steps to acquire the extractives. A comparative analysis of conventional, ultrasonic-assisted, and heat-assisted extraction methods was performed to identify optimal extraction conditions. Process parameters, such as temperature, solvent concentration and extraction duration, were systematically varied to enhance the extraction yield of bioactive compounds. The extracts were analyzed for total polyphenol content and biological activity using DPPH, FRAP, and CUPRAC assays. Additionally, antimicrobial efficacy was evaluated against a range of Gram-positive and Gram-negative bacteria, including Staphylococcus aureus, Listeria monocytogenes, Escherichia coli, Salmonella enterica, and the yeast Candida albicans. The results demonstrated that heat-assisted extraction significantly improved polyphenol recovery and antioxidant potential, making it a promising method for large-scale applications. Propylene glycol extracts exhibited notable antimicrobial effects, particularly against Staphylococcus aureus and Listeria monocytogenes, with potential implications for pharmaceutical and food industry applications. Glycerol extracts, on the other hand, demonstrated superior antioxidant activity, making them suitable for use in cosmetics and nutraceutical formulations. Furthermore, the study highlights the role of green extraction techniques in supporting the principles of circular bioeconomy by sustainably utilizing forestry by-products. These findings underscore the potential of coniferous needle extracts as natural bioactive compounds with diverse industrial applications. Future research should focus on identifying the specific compounds in optimized extracts to define their potential applications better. Integrating green chemistry principles in biomass utilization reduces environmental impact and contributes to developing sustainable, high-value bioproducts.

Keywords – Antimicrobial properties; antioxidant activity; circular bioeconomy; forestry by-products; green solvents; polyphenols; sustainable chemistry

ACKNOWLEDGEMENT

This research was funded by the Rural Support Service Republic of Latvia project "Full-cycle processing of green biomass from skewers to produce high-value feedstocks for the chemical and pharmaceutical industries" (Nr: 23-00-A01612-000007).

https://doi.org/10.7250/CONECT.2025.038

HYDROTHERMAL HUMIFICATION OF SPRUCE GREENERY AS AN ENVIRONMENTALLY FRIENDLY TOOL FOR PRODUCTION OF SYNTHETIC HUMIC SUBSTANCES AND EVALUATION OF REACTION DYNAMICS

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Abstract – Peat is the main raw material for soil enhancers, but it is a slowly renewable fossil resource, and its extraction leads to significant greenhouse gas emissions, primarily in form of CO2 and CH4 with minimal NOx discharge. According to the Latvian State Forest Research Institute 'Silava', 70 % of these emissions come from peat used in agriculture, contributing to a total of 1 709 kt CO2 equivalent. A sustainable alternative is spruce (Picea abies L.) greenery, a forestry by-product left behind after log extraction. This underutilized biomass, which can account for up to 50 % of a spruce tree's dry mass, contains valuable compounds that can be extracted. The remaining material, rich in lignin, cellulose, and hemicellulose, can then be converted into synthetic humic substances through a hydrothermal humification process. This study promotes an end-of-waste approach by applying an innovative hydrothermal humification method to transform low-value forestry residues into synthetic humic substances that replicate the properties of natural peat humic substances for agricultural use. This conversion process generates significantly fewer greenhouse gas emissions than peat extraction and has the advantage of not requiring energy-intensive drying of biomass before synthesis. The findings of this research contribute to the development of high-value bioproducts from forestry residues, supporting circular economy principles within Latvia's bioeconomy. Results demonstrate that spruce greenery biomass can be effectively converted into synthetic humic substances. The study examines the optimal conditions for hydrothermal humification, synthesis duration, and process temperature, to maximize the yield of synthetic humic acids, fulvic acids, and their low-molecular byproducts. The structural formation dynamics of synthetic humic substances were analyzed using advanced analytical techniques such as FTIR, 13C-CPMAS-NMR, and EPR spectroscopy, while the formation of fulvic acids and by-products were assessed using spectrophotometric methods such as total carbohydrates, total polyphenols, and their corresponding biological activities. This research provides essential insights into hydrothermal humification dynamics for the production of synthetic humic substances, their properties and future synthesis designs.

Keywords – Circular bioeconomy; forestry by-products; greenhouse gases; humic acids; hydrothermal humification; peat; sustainable chemistry

ACKNOWLEDGEMENT

Special thanks to Arturs Zarins from University of Latvia Institute of Chemical Physics and Andris Antuzevics from University of Latvia Institute of Solid State Physics for help with EPR spectroscopy.

This research was funded by the Rural Support Service Republic of Latvia project "Full-cycle processing of green biomass from skewers to produce high-value feedstocks for the chemical and pharmaceutical industries" (No: 23-00-A01612-000007).

https://doi.org/10.7250/CONECT.2025.039

EFFECT OF DRYING TEMPERATURE ON THE ANTHOCYANIN PROFILE OF SELECTED BERRY PRESS RESIDUES

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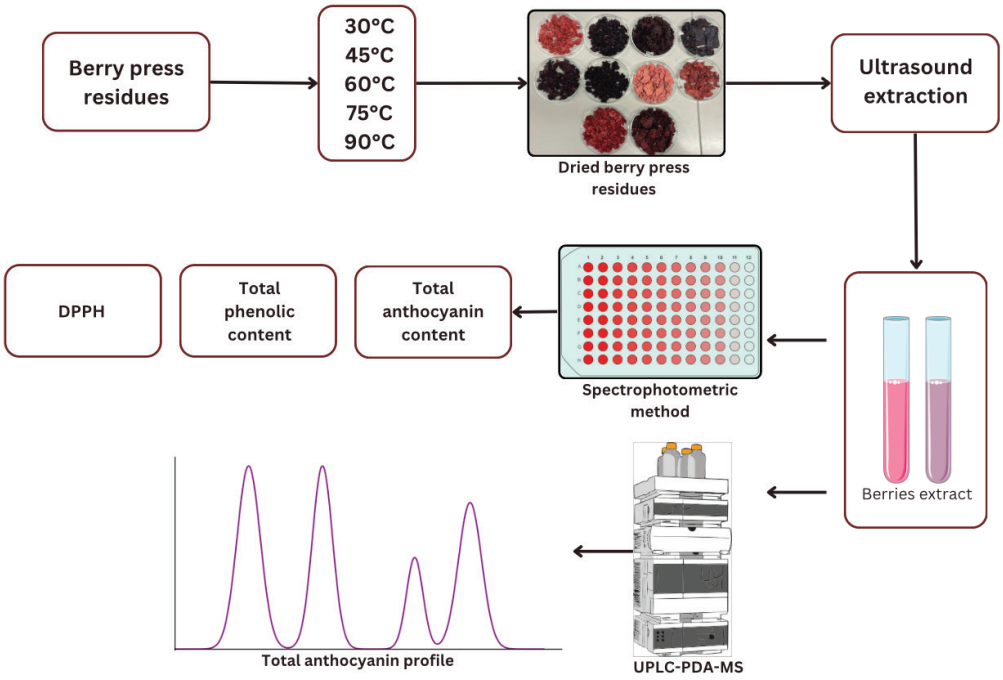
Abstract – Natural pigments as an alternative to synthetic dyes are gaining importance due to the potential health risks associated with synthetic colorants. The research investigates the impact of drying temperature on the total anthocyanin content, total phenolic content, and DPPH activity of various berry press residues. In this study, berry press residue samples were subjected to different drying temperatures (30 °C, 45 °C, 60 °C, 75 °C, and 90 °C) using conventional and vacuum drying methods. The dried samples were subsequently ground and extracted using an acidified ethanol solution. Anthocyanin content was measured via the pH differential method, while total phenolic content and DPPH antioxidant capacity were analysed using spectrophotometric techniques. The total anthocyanin profile of selected berry press residues extracts was measured via UPLC-PDA-UV. The results indicated that drying temperature significantly influenced the stability and retention of anthocyanins in the berry press residues. Lower drying temperatures (30 °C and 45 °C), preserved higher levels of anthocyanins and phenolic compounds, where degradation was more pronounced. The anthocyanin content in bilberries was found to be approximately two times lower at 105 °C compared to 60 °C. The vacuum drying method demonstrated improved pigment retention across all temperature ranges compared to conventional drying. These findings highlight the potential of low-temperature vacuum drying as a preferable method for preserving anthocyanins in berry press residues. The study provides valuable insights for developing stable, natural colorants suitable for various industrial applications. Future research may focus on refining drying parameters and investigating the stability of these natural pigments in finished food products.

Keywords – Anthocyanins; conventional; pomace; stability; total polyphenols; vacuum drying.



Temperature and drying method effects on anthocyanin profile of berry press residues

ACKNOWLEDGEMENT

This research was supported by the Latvian Council of Science project "Biorefinery-derived Functional Ingredients for Enhanced Conjugate Stability of Natural Dyes through Co-pigmentation – ChromaQuest" (project Nr. lzp-2024/1-0066).

https://doi.org/10.7250/CONECT.2025.040

THE ROLE OF ARTIFICIAL INTELLIGENCE TECHNOLOGY IN THE FULFILMENT OF SUSTAINABLE DEVELOPMENT GOALS IN BIOGAS PRODUCTION

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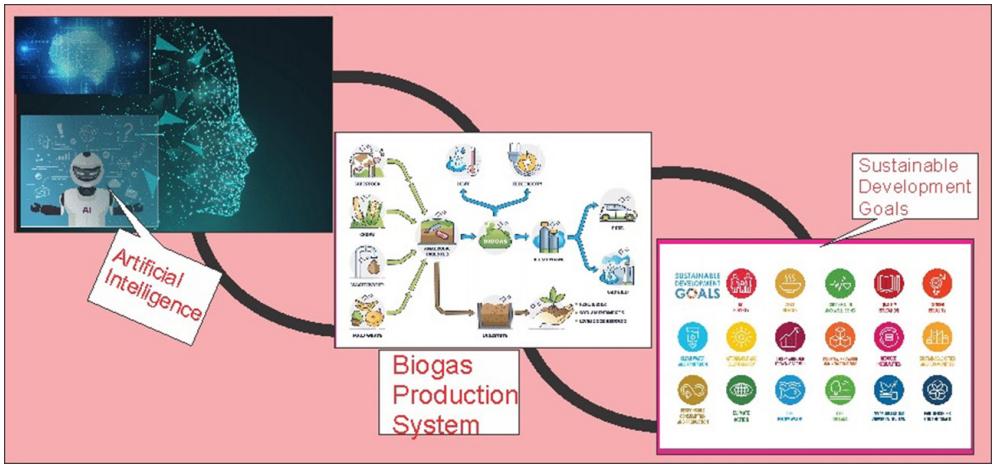
Abstract – Artificial intelligence (AI) can significantly improve the efficiency of the process, as well as optimize resources and the sustainability of the biogas production process. As part of the United Nations' Sustainable Development Goals (SDGs), this comprehensive review investigates the role of artificial intelligence-driven technologies in enhancing biogas yield, process monitoring, and waste management. This study aims to analyse the literature on AI's functions in assessing feedstock availability and quality for achieving Sustainable Development Goals, forecasting biogas yield, and overseeing biogas production processes. This systematic review leverages the Preferred Reporting Items for Systematic Literature Review and Meta-Analysis, PRISMA, to painstakingly review research papers published between 2016 and 2023 using Pubmed, Scopus and Web of Science to understand how AI can assist farmers and biogas plant operators in making informed decisions, identifying anomalies, and forecast biogas yield, ultimately contributing to sustainable development. We analysed the papers to identify research gaps and different artificial intelligence like Artificial Neural Networks (ANN), Genetic Algorithms (GA), Tree-based Pipeline Optimization Tools (TPOT), Random Tree (RT), Random Forest (RF), Adaptive-Network-based Fuzzy Inference System (ANFIS) etc., which have been used in previous research relevant to this study. The result from our study emphasizes recent progress, obstacles, and prospective research avenues for integrating AI into biogas production. It can be concluded that AI-augmented biogas systems, such as machine learning, predictive analytics, and process automation, enhance anaerobic digestion, mitigate greenhouse gas emissions, and facilitate the adoption of renewable energy (SDG 7), facilitate waste-to-energy projects, promoting sustainable consumption and production (SDG 12) while alleviating environmental pollution (SDG 13). Hence, AI can substantially aid in sustainable energy transitions and circular bioeconomy frameworks, bolstering global initiatives to attain various SDGs.

Keywords – AI; Biogas production; optimize resources; sustainable development; PRISMA



Artificial Intelligence in Biogas Production for SDG fulfilments

ACKNOWLEDGEMENT

The authors acknowledge the University of South Africa, South Africa for funding the research work.

https://doi.org/10.7250/CONECT.2025.041

REVIEW OF BIOGAS PRODUCTION AND BIO-METHANE POTENTIAL OF FISH SOLID WASTE AND FISH WASTE

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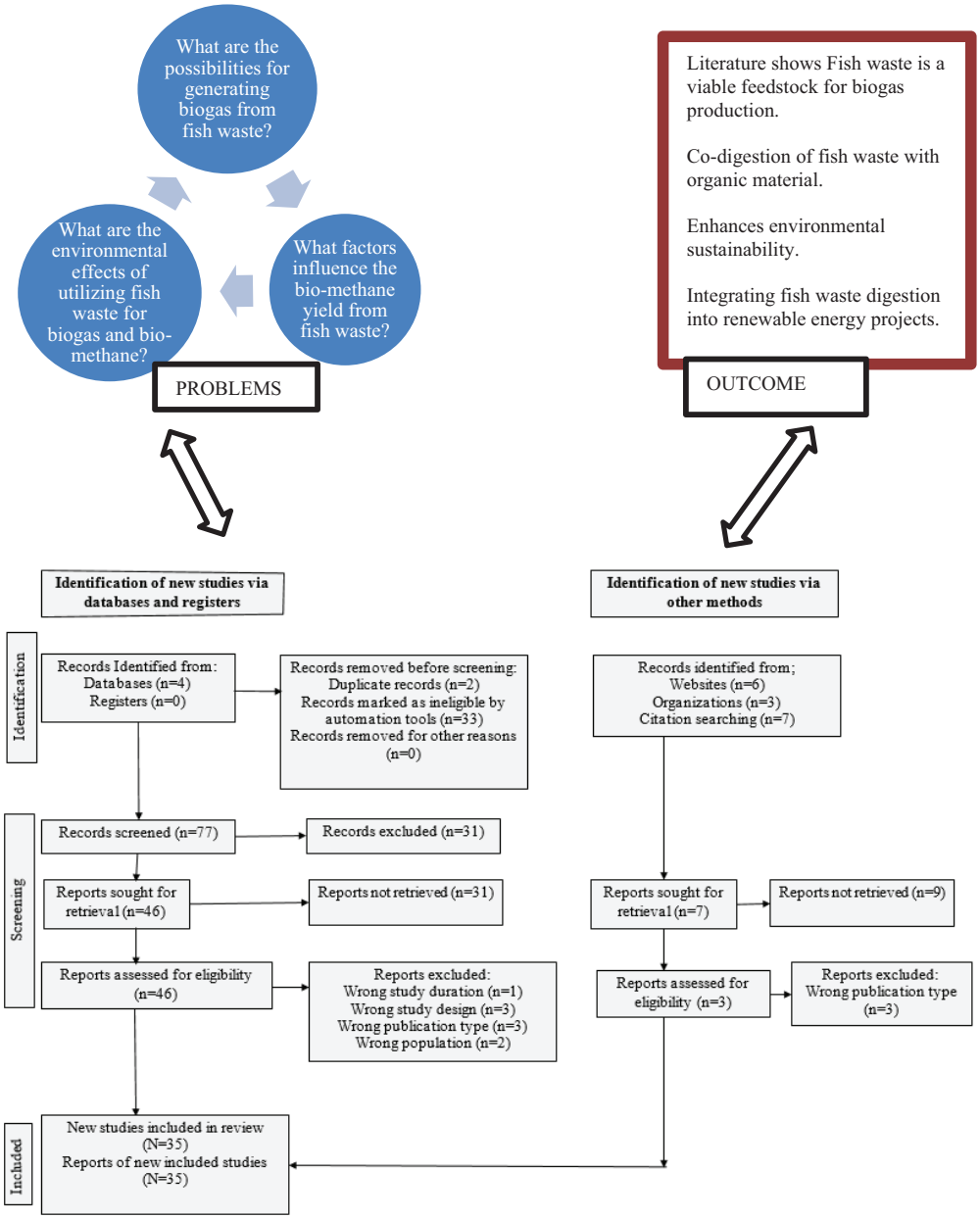
Abstract – The growing amounts of fish waste from South Africa's fishing and aquaculture sectors pose environmental challenges and present opportunities for renewable energy production. South Africa's current energy mix heavily relies on coal, with renewable sources representing only a fraction of the total supply. The country's waste management is also constrained by the large volumes of organic waste sent to landfills, increasing greenhouse gas emissions and pollution. The review synthesizes findings from various studies on the anaerobic digestion of fish waste, assessing its feasibility, efficiency, and ecological advantages as an energy source. Fish waste, high in proteins and lipids, shows promise as an effective feedstock for biogas production, particularly when co-digested with other organic materials to improve microbial activity and methane output. However, the variability in results across studies highlights the need for standardized methodologies and consistent reporting, as differences in study designs and digestion parameters affect outcomes. Key limitations identified include the heterogeneity in research approaches, inconsistent biogas yield reporting, and a lack of thorough sustainability evaluations, which hinder the generalizability of findings. The review recommends further empirical studies to optimize the anaerobic digestion of fish waste tailored to South Africa's specific context. The methodological quality of the reviewed studies supports a JBI Grade B recommendation, indicating moderate promise for fish waste as a renewable energy resource. In conclusion, fish waste represents a valuable yet underutilized resource for renewable energy that aligns with South Africa's energy and waste reduction objectives. Expanding biogas production from fish waste could help decrease reliance on fossil fuels, reduce greenhouse gas emissions, and divert organic waste from landfills. Policymakers and energy practitioners are urged to explore fish waste digestion within the renewable energy framework. At the same time, future research should focus on optimizing co-digestion processes and addressing logistical and regulatory challenges. This review lays the groundwork for future research and policy efforts to harness fish waste for sustainable biogas production.

Keywords – Bioenergy; fish waste digestion; just energy transition; renewable energy; sustainability



PRISMA FLOW DIAGRAM showing the reviewed literature search process

ACKNOWLEDGEMENT

The authors acknowledge the University of South Africa, South Africa for funding the research work.

https://doi.org/10.7250/CONECT.2025.042

SYNGAS BIOMETHANATION: OVERCOMING MICROBIAL, REACTOR, AND PROCESS LIMITATIONS FOR A SUSTAINABLE ENERGY FUTURE

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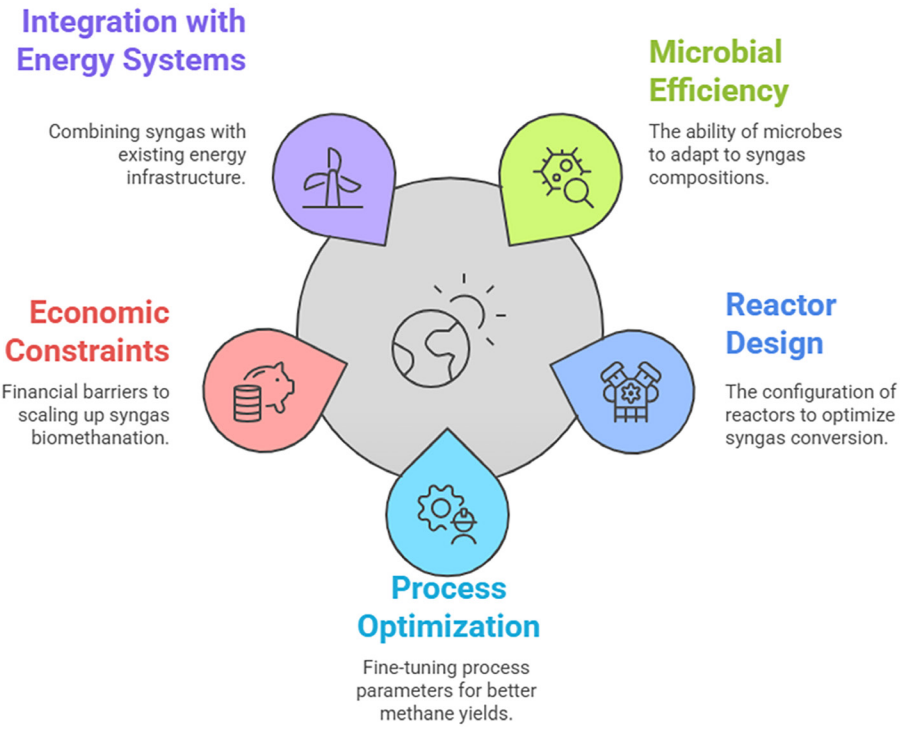
Abstract – Syngas biomethanation has emerged as a promising technology for converting synthesis gas (CO, H_2, and CO_2) into renewable methane, offering a sustainable alternative to fossil-based natural gas. However, despite significant progress at the laboratory scale, the transition to industrial applications remains hindered by multiple challenges spanning microbial efficiency, reactor design, process optimization, and large-scale feasibility. At the fundamental level, mass transfer limitations significantly constrain the biological conversion of syngas, with poor gas-liquid diffusion of CO and H_2 affecting microbial metabolism. Moreover, the adaptation of microbial consortia to varying syngas compositions remains insufficiently understood, particularly regarding the dominant pathways under mesophilic and thermophilic conditions. Reactor design further exacerbates these challenges, with current configurations (continuous stirred-tank reactors, packed bed reactors, and membrane bioreactors) struggling to achieve efficient syngas conversion at high productivity rates. Process parameters such as temperature, H_2/CO ratio, and trace element supplementation also require fine-tuning to enhance methane yields while maintaining process stability. While small-scale experiments have demonstrated promising results, scaling up remains a major hurdle due to economic constraints, reactor operational challenges, and the need for reliable feedstock supply. Additionally, the integration of syngas biomethanation with existing energy infrastructure, including powerto-gas technologies and anaerobic digestion systems, requires further investigation to ensure economic viability and process efficiency. This review systematically explores these multi-scale challenges, from bench-scale research to commercial deployment, highlighting key research gaps and potential strategies to accelerate the transition of syngas biomethanation from laboratory studies to industrial reality.

Keywords – Biomethanation; gas-liquid mass transfer; microbial adaptation; renewable energy; syngas fermentation; sustainable development goals (SDGs); waste-to-energy



Challenges in Syngas Biomethanation

https://doi.org/10.7250/CONECT.2025.043

LIQUID-STATE SURFACE FERMENTATION OF MYCELIUM MATS TO PRODUCE SUSTAINABLE LEATHER-LIKE MATERIALS

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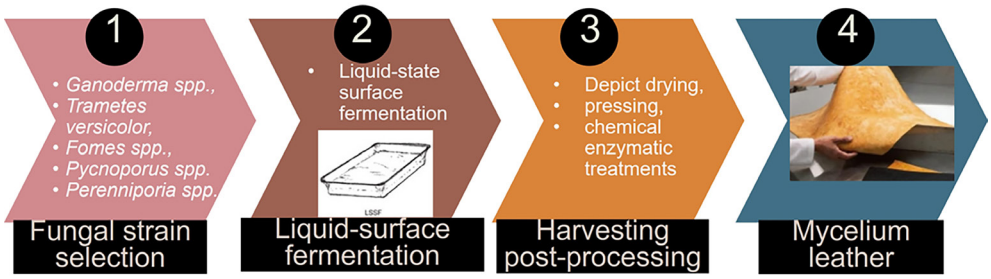
Abstract –The increasing demand for sustainable alternatives to fossil-based materials has driven research towards biofabrication approaches. Textile and fashion industry is one of the most polluting industrial sectors in the world, responsible for high greenhouse gas emissions and global wastewater. For that reason, the fashion industry is facing growing pressure to reduce its environmental impact. Among the major environmental issues associated with this sector are the unsustainable cultivation of fibres, the extensive use of non-renewable and non-biodegradable materials and highly polluting production processes. One of these non-eco-friendly processes is leather tanning, which consumes large amounts of water and energy while potentially releasing heavy metals and toxic compounds into the environment. Conversely, plastic-based leathers, have a lower carbon footprint than animal leather during their production, but they are dependent on fossil resources and have negative environmental effects (microplastic accumulation). In this contribution a review on possible sustainable alternatives to synthetic leather is presented, focusing on innovative mycelium-based materials. Particular attention is given to production methods involving liquid-state surface fermentation, highlighting the potential for reducing environmental impact while maintaining desirable material properties. Filamentous fungi and their potential to create leather-like biomaterials through controlled fermentation processes are critically discussed. Important parameters like fungi species selection, nutrient composition, growth conditions and treatment techniques are analysed. A schematic overview of the process is provided in the figure. Moreover, different types of treatments that could enhance mechanical performance, durability and water resistance are explored. Comparisons with real and synthetic leather are analysed, highlighting the advantages that the mycelium-leather has in respect to biodegradability and energy efficiency. Current challenges such as scalability, production cost and the need for standardization are critically considered, as they still limit widespread industrial adoption. Ultimately, current advancements in mycelium biotechnology, bioengineering strategies and material optimization are explored, highlighting the potential of mycelium-based materials as a sustainable alternative to conventional leather.

Keywords – Biofabrication; biomaterials; fungal-leather; fungal biotechnology; liquid-state surface fermentation; mimco-leather; non-leather materials; sustainability; sustainable fashion



Scheme of the process to create leather-like biomaterials starting from *Filamentous fungi*

https://doi.org/10.7250/CONECT.2025.044

ENHANCING METHANOGENESIS IN ANAEROBIC BIOREACTORS USING *PHRAGMITES AUSTRALIS* AND ADDITIVES – A REVIEW

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Abstract – Anaerobic digestion of lignocellulosic biomass, particularly Phragmites australis (common reed), presents potential for sustainable biogas production. However, its rigid structure and high lignocellulose content hinder microbial accessibility and methanogenesis efficiency. To overcome these limitations, various additives including iron-based nanomaterials, trace metal additives, enzymatic pretreatments, and cosubstrates have been investigated to optimize biogas yield, methane content, and process stability. This review presents a comprehensive analysis of the role of supplements in improving anaerobic digestion of Phragmites australis. It has been demonstrated that iron-based nanomaterials, including iron oxide (FeO_4), micro zero-valent iron (ZVI), iron (II, III) oxide, and zero-valent iron nanoparticles (nZVI), reduce process inhibition and improve redox balance. Additionally, micronutrient supplementation (e.g., nickel, cobalt) promotes microbial enzymatic activity by enhancing methanogenic pathways. Enzymatic pretreatment methods including cellulase and hemicellulase enhance hydrolysis efficiency, resulting in increased volatile fatty acid production and higher methane yield. Co-digestion with nitrogen-rich substrates such as food waste or manure has also been found to optimize the carbon to nitrogen ratio, reducing ammonia inhibition and promoting stable microbial activity. Additionally, by strengthening methanogenic pathways, micronutrient supplementation increases microbial enzymatic activity. Cellulase and hemicellulase are two examples of enzymatic pre-treatment techniques that improve hydrolysis efficiency, resulting in increased volatile fatty acid production and a higher methane output. This review addresses important issues with feedstock recalcitrance, process inhibition, and biogas quality while highlighting the additives' synergistic benefits in maximizing anaerobic digestion performance.

Keywords – Anaerobic digestion; biogas production; iron-based nanomaterials; methanogenesis; Phragmites australis

04

RENEWABLE ENERGY TECHNOLOGIES

https://doi.org/10.7250/CONECT.2025.045

BLOCKCHAIN SOLUTIONS FOR DECARBONIZATION: INSIGHTS FROM A BIBLIOMETRIC ANALYSIS

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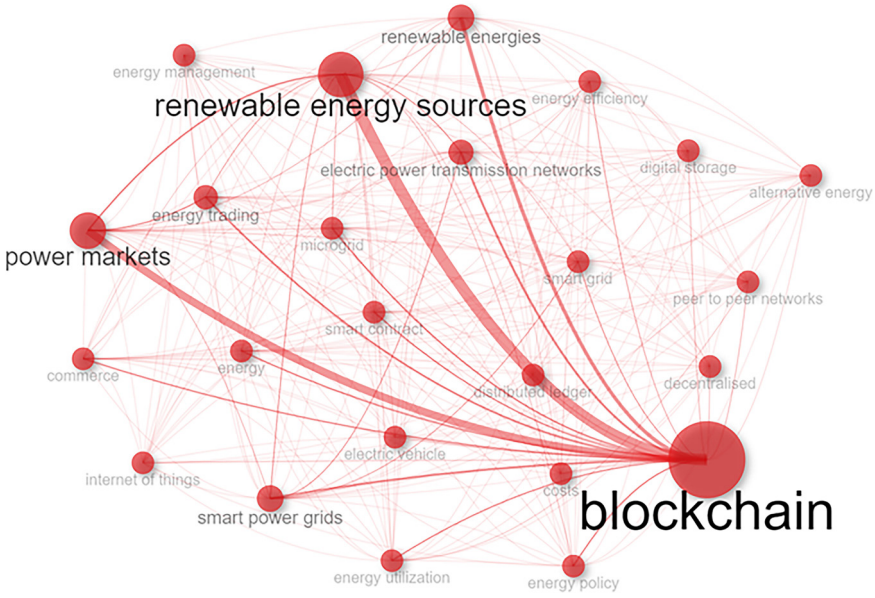
Abstract – The integration of decentralized and digital technologies like blockchain in sectors that aim to fulfil certain decarbonization goals could be a promising solution to facilitate the transition to climate neutrality. With the aim to construct a comprehensive and systematic bibliometric analysis on the inclusion of blockchain technology in renewable energy, transport (electric vehicles) and agri-food industry this paper provides in-depth analysis of existing studies on these topics to identify future research opportunities. Using R-studio, Web of Science and Scopus data were analysed and visualized. The results of this study indicate growth of the publication count throughout the years. This research shows that the most productive countries are China and India, although the average citations per article is higher in United States of America and United Kingdom. Trend topics, thematic evolution and co-occurrence network from this study suggests that the application of blockchain technology in analysed sectors should be combined with other digital solutions like Internet of Things and artificial intelligence to increase security, facilitate systems' management and assist in policy planning. The identified research gaps are connected to blockchain technology and renewable energy storage systems (e.g., hydrogen), materials used in electric vehicles' batteries and circularity (including life cycle and recycling) in agri-food sector and other studied sectors.

Keywords – agri-food; blockchain; decarbonization; electric vehicles; renewable energy



Co-occurrence network for "blockchain" and "renewable energy", Scopus data

https://doi.org/10.7250/CONECT.2025.046

ADVANCED WELDED STRUCTURES FOR ADAPTIVE MOBILE POWER STATIONS: DESIGN AND ANALYSIS

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Abstract – Energy storage and its utilization, regardless of location, enable the provision of critical services and machinery operation in remote and isolated areas, such as rural regions, islands, or in war and crisis scenarios. By employing modern energy production and storage systems, it becomes possible to ensure a reliable energy supply in areas with inadequate or damaged electrical infrastructure. During the design of the mobile energy solution, a critical objective is to minimize the overall weight of the structure. For this purpose, the primary construction material is the lightweight yet durable heat-treated and artificially aged aluminum alloy profiles, which form the structural framework for both the station and the solar panel mounting and moving system. Structural integrity is as strong as the weld and base material connecting the profiles.

Constructing a renewable energy station from superior lightweight materials offers significant energy and sustainability benefits, such as reduced material usage, fuel efficiency, and carbon emissions. The research findings indicate that optimized welding parameters are important for the structural integrity of the aluminium alloy 6082T6 construction. The case study of a mobile power station demonstrates the practical applications of this approach, where carefully selected welding techniques and parameters ensure that joints achieve mechanical performance comparable to that of the base material. This ensures that both strength and durability requirements are met. The study concludes that tailored welding processes are crucial to minimizing the adverse effects of heat input on the material properties of heat-treated aluminum alloys. Lowering the heat energy input for structural manufacturing is energy saved from manufacturing. Considering these effects, manufacturers can leverage the alloys' mechanical advantages in lightweight constructions, thus expanding their applicability in industries focused on weight reduction and structural integrity. These findings provide valuable insights into advancing innovative engineering solutions in sectors such as transportation of renewable energy stations, aerospace, and marine. Overall, selecting a proper manufacturing technology, materials and methods results in energy efficiency and allow for innovative structural solutions for welded structures with a complex configuration.

Keywords – Construction welding; constructional integrity; energy production; mobile renewable power station; solar power

Fig. 1. Mobile renewable energy station front isometric

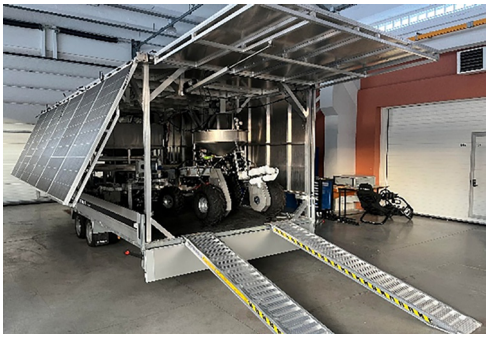

Fig. 2. Mobile renewable energy station rear isometric

ACKNOWLEDGEMENT

Funder: Estonian Research Council Foundation, project: EAG304 “Autonomous transportable energy production station”.

Funder: Estonian University of Life Sciences, project: PM210001TIBT “Development of precision fertilization technology for cultivated berries”.

https://doi.org/10.7250/CONECT.2025.047

POTENTIAL OF WIND-HYDROGEN (POWE2X) ENERGY SYSTEMS IN LATVIA

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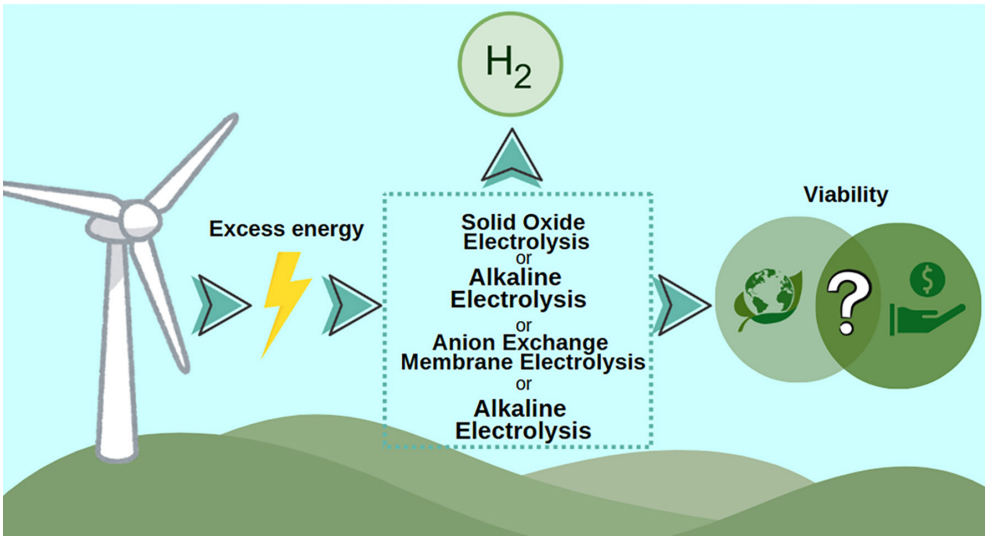
Abstract – Growing concerns about greenhouse gas emissions have made the development and use of carbonneutral technologies a pressing issue in the European Union, particularly for replacing fossil energy sources. Among these, green hydrogen emerges as a promising alternative for replacing fossil fuels. Integrating windhydrogen systems addresses a key challenge in the wind energy industry – energy inconsistency – by aligning supply with demand. This problem is quite significant, because it was stated that most of wind energy is produced during low demand hours creating excess energy; consequently, it is sold during low energy price hours. By this, wind energy production becomes less profitable than it could be, so energy storage and Power2X technologies and its research becomes more relevant. However, the economic viability and climate impacts of Power2X system integration remain significant concerns. Latvia, where the share of wind energy is rapidly increasing, faces rising questions about renewable energy storage possibilities and their rationality. This study evaluates the potential of wind-hydrogen Power2X systems in Latvia by analyzing three methods for converting wind energy into hydrogen for storage and subsequent use, using Python mathematical modelling in system dynamics analysis of wind energy generation and hydrogen production technologies. Finally, the study calculates and compares the profitability and climate impact of the proposed Power2X systems against conventional energy sales during production hours. The results of this study present a comparison of five scenarios for wind energy usage. 1st scenario: direct wind energy selling during its production time. 2nd, 3rd, and 4th scenarios, respectively: wind energy is sold directly during its production time only when electricity prices are high. However, during periods of low electricity prices, this energy is used for hydrogen production via three different technologies – alkaline electrolysis, proton exchange membrane electrolysis, and solid oxide electrolysis. Using input data, the potential of each technology, as well as its economic and environmental viability is calculated and compared to the 1st (base) scenario. This dynamic model provides recommendations for the development of wind-hydrogen systems in Latvia, as well as a practical framework for evaluating the performance of dynamic wind-hydrogen systems in any other country and for any specific situation.

Keywords – Decarbonisation; energy storage; green hydrogen; renewable; wind energy



Green hydrogen production evaluation overview

https://doi.org/10.7250/CONECT.2025.048

DESIGN STRATEGY AND OPTIMIZATION OF A RENEWABLE-BASED ENERGY MIX IN LATVIA REGION

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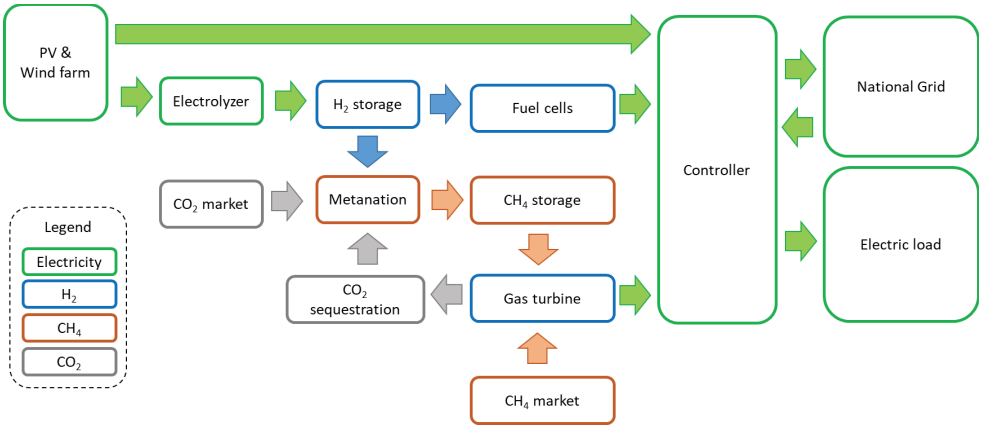
Abstract – The global increase in energy consumption is forcing the energy sector to evaluate the energy transition from fossil-based systems to renewable energy sources. Unfortunately, the impact of non-dispatchable generation affects grid stability and the ability to meet night time loads. In addition, a shift from summer to winter is required to increase the penetration of renewables. The introduction of storage technologies and the energy mix could overcome some of the problems associated with the green revolution. The aim of the work is to assess the best combination of generation systems and storage to meet the electricity needs of a 100 MW peak load city in the Latvian region with an annual energy load of 700 GWh. The energy hub considered, shown in the figure, represents a valuable evolution of a traditional gas-fired power plant coupled with the most cost-effective renewable resource generators: photovoltaic and wind turbines. To exploit the renewable surplus, part of the electricity is converted into hydrogen, which drives a fuel cell and a methanation system linked to the gas turbine. The method used is Trnsys-based numerical modelling coupled with multivariable particle swarm optimization to minimise the levelized cost of electricity under different renewable penetration scenarios. The LCOE is 0.96 EUR/kWh for a 50% RES production and doubles for a fully renewable system. The optimised energy mix includes an electrolyser with a capacity equivalent to 24 % of the renewable capacity. The results of the analysis show the crucial role of the H2 system, which is 20 times larger than the CH4 system.

Keywords – Energy efficiency; energy modelling; energy storage; hydrogen; intermittent power production; renewables; transient simulation



Energy hub layout with power generation and gas flows

https://doi.org/10.7250/CONECT.2025.049

MATERIAL FLOW ANALYSIS OF RESIDUAL BIOMASS FOR COMBUSTION FOR LATVIA WITH SANKEY DIAGRAMS

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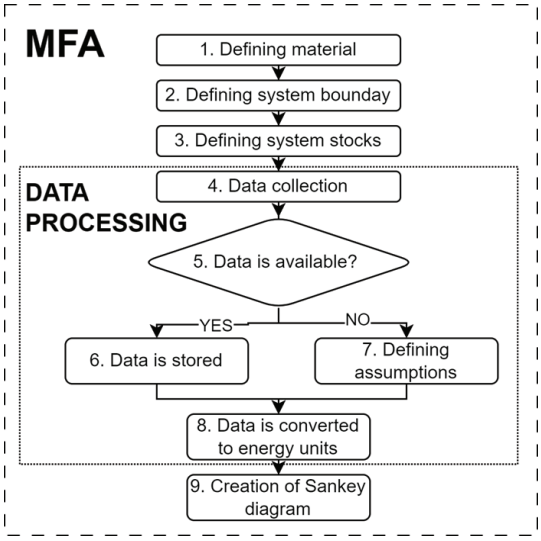
Abstract – To meet climate targets, Europe has increasingly utilized biomass as a renewable alternative to fossil fuels for combustion and heat production. This shift has resulted in the heating sector becoming heavily dependent on primary wood biomass. However, recently implemented regulations have introduced restrictions on the use of primary wood in the energy industry. While low-quality biomass holds significant potential for combustion, there is limited information regarding the availability and quantities of non-wood biomass resources in Latvia. To evaluate what share of non-wood biomass resources can be used to cover roundwood consumption, material flow analysis approach was used. None of the studied biomass resources in this article can individually cover the required energy demand; however, a combination of all the studied resources can cover it. Specially grown energy crops exhibit the highest potential, but other analyzed biomass types have local availability and could be utilized in specifically adapted local boiler houses.

Keywords – Alternative; biomass; energy; leaves; MFA; reeds; wood



Material flow analysis algorithm for the study

ACKNOWLEDGEMENT

This research is funded by the Latvian Council of Science, project Alternative biomass knowledge for transition towards energy independence and climate targets (Bioenergy Observatory), project No. lzp-2022/1-0414.

https://doi.org/10.7250/CONECT.2025.050

APPLICATION OF ASPEN PLUS SOFTWARE FOR RESEARCH INTO SUSTAINABLE BIOMASS UTILIZATION TOPICS: A REVIEW

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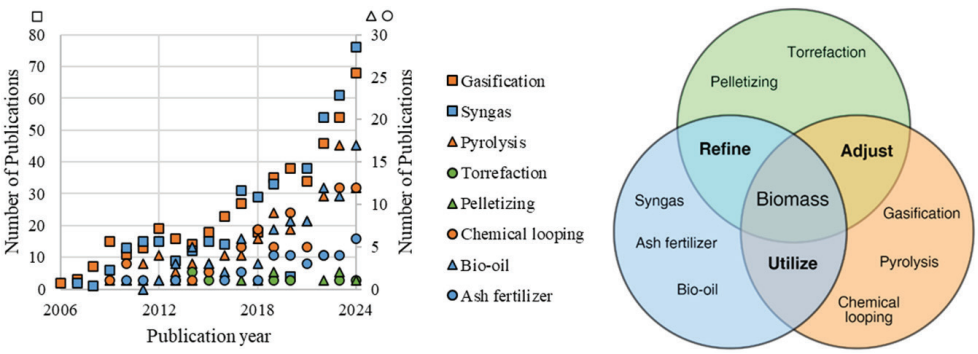
Abstract – Historically, technological developments have been experimented with by testing or demonstrating the viability of an innovative idea. However, using advanced software can increase the added value of the study, which can resume at a much faster and more reliable progression. In the context of biomass disposal, there is a significant tendency to use the Aspen Plus software over the last two decades, as evidenced by available data in the Scopus database. Most of the studies related to the types of processing technologies consist of the gasification process (38.7 %). Pyrolysis (8.0 %) and chemical looping (5.6 %) are less studied. In the case of processed products, the use of syngas is most investigated (35.6 %). A promising direction is the utilization of bio-oil (7.3 %). Studies also explore the potential of using ash as a valuable fertilizer (2.7 %). Few studies use Aspen Plus to improve biomass properties; only 1 % focus on pelletizing, and 0.6 % on torrefaction. However, these processes are interconnected because all of the mentioned processes are utilized in the bioenergy sector, whether as a by-process of combustion or as combustible itself. Aspen Plus software can chemically analyse and optimize these processes to increase efficiency and economic performance. The authors will assess their options for integrating the Aspen Plus software into own future studies based on the information gathered. The availability of published data in identified articles will enable the comparison of results and the partial validation of the model.

Keywords – Aspen Plus; bioenergy; biomass pellets; biomass utilization; combustion process; densification; energy density; modelling; pelletizing



Material flow analysis algorithm for the study

ACKNOWLEDGEMENT

This publication was supported by 2024 Riga Technical University's Doctoral Grant programme.

https://doi.org/10.7250/CONECT.2025.051

FROM WIND TO POWER: UNLOCKING LATVIA'S RENEWABLE ENERGY POTENTIAL FOR CLIMATE NEUTRALITY

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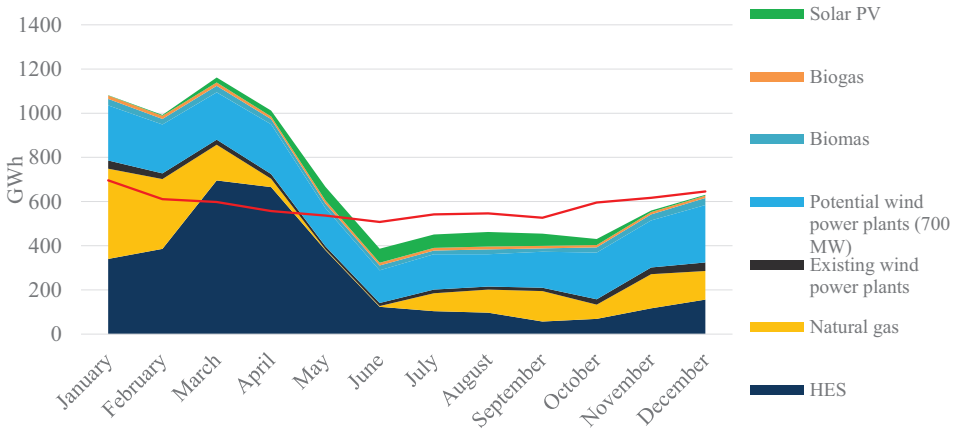
Abstract – The European Union has set an ambitious goal to achieve climate neutrality by 2050. To meet this target, it is essential to significantly increase renewable energy production. However, electricity generation from renewable energy sources is intermittent, meaning energy can only be produced when the respective resources (e.g., sun, wind, favorable hydrological conditions) are available. This often does not align with the electricity consumption demand curve and to meet the demand, electricity must be generated from fossil energy sources. In Latvia, according to 2024 data, the largest share of electricity is generated by hydropower plants (53 %), followed by thermal generation (29 %), with natural gas accounting for most of this share. Meanwhile, only 4 % of total electricity production comes from wind energy, which is a low figure considering Latvia's geographical conditions and wind energy potential. However, several large-scale wind power projects with a combined capacity of 700 MW are currently in the planning stages. The implementation of all planned projects could make a significant contribution to achieving the EU's climate goals. In the energy sector, meteorological data plays a crucial role in calculating and forecasting the availability of renewable energy resources and energy production potential. To assess electricity generation from planned wind farms, calculations were carried out to determine the potential wind energy available. To estimate wind speed at a height of 185 meters, available wind speed data from ground measurement stations were adjusted using the logarithmic function most frequently employed in literature. The calculations provided an estimate of the potential electricity generation from wind farms, with results visually represented by calendar months. The findings indicate that the total electricity output from wind farms could increase by 2383 GWh/year, allowing decreased use of natural gas during spring and consequently reducing GHG emissions. The data shows that during winter and spring months, the available electricity exceeds the electricity demand. Consequently, it is essential to find solutions to balance electricity consumption and production loads, ensuring the efficient use of valuable renewable electricity. Such solutions include energy storage, for example, battery energy storage systems or converting electricity into other energy carriers, such as hydrogen. Results can further be used to identify the most suitable methods for electricity storage.

Keywords – Climate; demand; electricity; intermittent; renewable energy; storage; wind



Electricity produced and consumed in Latvia by source (GWh), 2024.

ACKNOWLEDGEMENT

This publication was supported by 2024 Riga Technical University's Doctoral Grant programme.

https://doi.org/10.7250/CONECT.2025.052

THE POTENTIAL OF ENERGY COMMUNITY DEVELOPMENT IN LATVIA THROUGH DYNAMIC BUILDING AND RENEWABLE TECHNOLOGY MODELING

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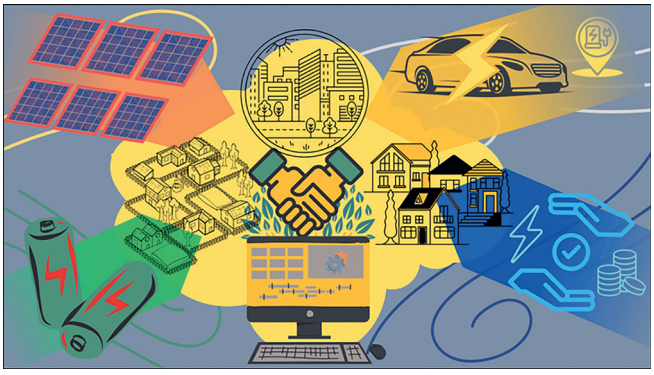
Abstract – As the world faces climate change induced increases of mean average temperature and severe weather events, the transition to renewable energy resources is ever important. The current rate of the transition is shown to be too slow, therefore, a more decentralized approach, for example, energy communities, might accelerate the phase-out of fossil fuels. Thus, the goal of this study is to realize the current state of energy communities, including the technology with the highest potential, and the barriers that are preventing a wider adoption, and to see how renewable technologies and peer-to-peer energy trading models can be practically integrated to develop renewable energy communities in Latvia. This is done by placing an emphasis on renewable technologies that support these communities, such as 5th Generation District Heating and Cooling and Distributed Energy Resources, and how these innovations contribute to energy efficiency and carbon reduction. As part of this study, a dynamic multiple building model is developed, through which the integration of the renewable technologies and peer-to-peer energy trading schemes are analysed. The study finds that the most significant barriers include regulatory gaps and uncertainties, financial constraints, technical and knowledge limitations, and social resistance, which continue to hinder the widespread integration of energy communities, specifically in Latvia. By examining these barriers and the technological advancements that support decentralized energy and analysing them through the dynamic model, this study highlights the potential and creates opportunities for energy communities to drive the European Union's and the Latvian green energy transition and reduce energy poverty, paving the way for a resilient and sustainable future.

Keywords – Distributed energy resources; distributed energy resource management system; energy storage systems; fifth generation district heating and cooling; renewable energy community



Energy community modeling framework

https://doi.org/10.7250/CONECT.2025.053

TECHNO-ECONOMIC OPTIMIZATION OF SOLAR PANEL INSTALLATIONS: BALANCING THERMAL PERFORMANCE AND ECONOMIC VIABILITY

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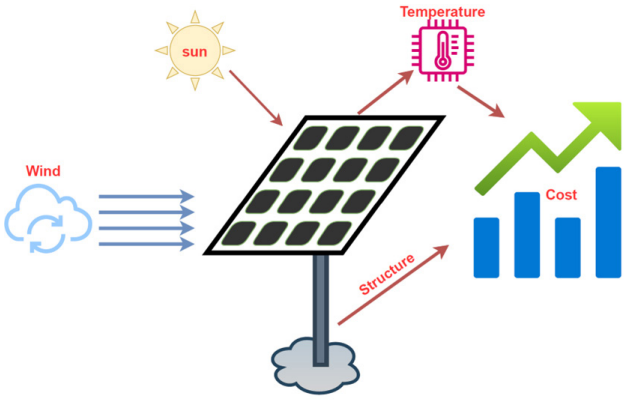
Abstract – As solar energy continues to gain prominence as a sustainable power source, optimizing solar panel configurations for maximum efficiency and economic viability is crucial. This study explores the interplay between installation height and tilt angle in improving thermal performance and power output while managing structural and economic constraints. This study uses computational models to optimize solar panel installation height and tilt for better thermal performance and cost-efficiency. By analysing convective cooling, wind loading, and structural stresses, the study identified configurations that enhance energy output while minimizing structural costs. It was found that increased heights improve air circulation around panels, lowering solar cell temperatures and thereby enhancing efficiency through passive cooling. Higher tilt angles were also shown to improve heat dissipation by inducing air turbulence, though both increased height and tilt raise wind loading, which in turn requires sturdier and costlier support structures. The optimal configuration was identified as a height of 0.165 meters and a tilt angle of 25.022°, balancing efficiency gains with manageable structural demands. This setup achieved a Levelized Cost of Energy (LCoE) of $0.07/kWh, an ROI of 16.3 %, and a payback period of 6.25 years, offering a 42 % lower LCoE than a non-optimized configuration with a height of 7.5 meters and a tilt of 75°. This optimization also resulted in a 60 % improvement in ROI and a 37.5 % reduction in the payback period. The study underscores the importance of tailored height and tilt configurations to enhance efficiency without incurring prohibitive costs, particularly in varying climate conditions. It is recommended that future research explore different installation surface types and climates to further refine the balance between performance and cost.

Keywords – Economic analysis; elevated installations; installation optimization; structural integrity; thermal analysis



Techno-economic analysis of solar installations

https://doi.org/10.7250/CONECT.2025.054

IMPLICATIONS OF CLIMATE CHANGE ON PV GENERATION IN SEMI-ARID ZONES

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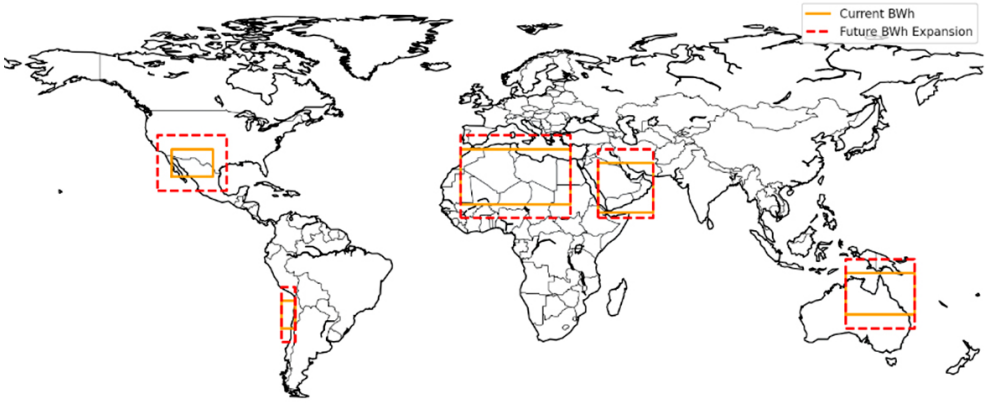
Abstract – Adopting photovoltaic (PV) solar energy in regions with abundant sunshine offers a promising pathway for transitioning towards renewable energy sources. However, deploying PV solar energy faces challenges posed by climate change, which can potentially undermine its effectiveness and reliability. One significant concern is the impact of rising temperatures on the efficiency of PV panels, which can lead to reduced electricity production. This paper investigates the potential effects of climate change on PV production in the Cold Desert (BWk) Climate Zone through comprehensive PV performance simulations. Utilizing PVsyst software, we conducted an in-depth analysis of 1MW PV systems under current climate conditions and projected future scenarios in 2060. Our assessment focused on understanding how rising temperatures may affect PV performance in the BWk Climate Zone, characterized by cold winters and hot summers with low precipitation. Figure shows a world map illustrating the current arid, desert, hot (BWh) climate zones and their projected expansion into adjacent areas, potentially turning cold desert (BWk) zones into hotter, arid regions. Orange regions: represent the current BWh climate zones. Red dashed regions: indicate the hypothetical future expansion areas of BWh zones. The simulation results revealed a slight decrease in global horizontal irradiation (GlobHor) from 2230.4 kWh/m^2 to 2154.8 kWh/m^2 and a corresponding increase in horizontal diffuse irradiation (DiffHor) from 488.51 kWh/m^2 to 553.15 kWh/m^2. The ambient temperature (T_Amb) rose from an annual average of 18.51 °C to 20.07 °C. Despite these climatic changes, the global incident irradiation on the collector plane (GlobInc) and the effective global irradiation corrected for IAM and shadings (GlobEff) showed only minor reductions. Consequently, the energy injected into the grid (E_Grid) experienced a marginal decrease, from 33928.701 kWh to 33856.461 kWh annually. These findings indicate that PV production is expected to decrease, but the reduction is relatively minor, amounting to an insignificant value of 0.021 %. This finding suggests that while climate change may impact PV efficiency due to increased temperatures, the overall effect on PV production in the BWk Climate Zone remains minimal.

Keywords – Climate change; cold desert (BWk) climate zone; energy sustainability; Jordan; Ma'an; PV performance; PVsyst simulation; renewable energy



Projected Arid Desert Hot (BWh) Climate Zones expansion into Cold Desert (BWk) Zones

ACKNOWLEDGEMENT

The author would like to express his sincere gratitude to the German Jordanian University (GJU) for its continuous support in advancing research and innovation in the field of renewable energy. Special appreciation is extended to the Deanship of Scientific Research at GJU for providing the necessary resources and funding that facilitated the successful completion of this study.

https://doi.org/10.7250/CONECT.2025.055

INVESTIGATIONS ON PASSIVE SOLAR LIQUID DESICCANT REGENERATOR UNDER INDOOR SIMULATED CONDITIONS

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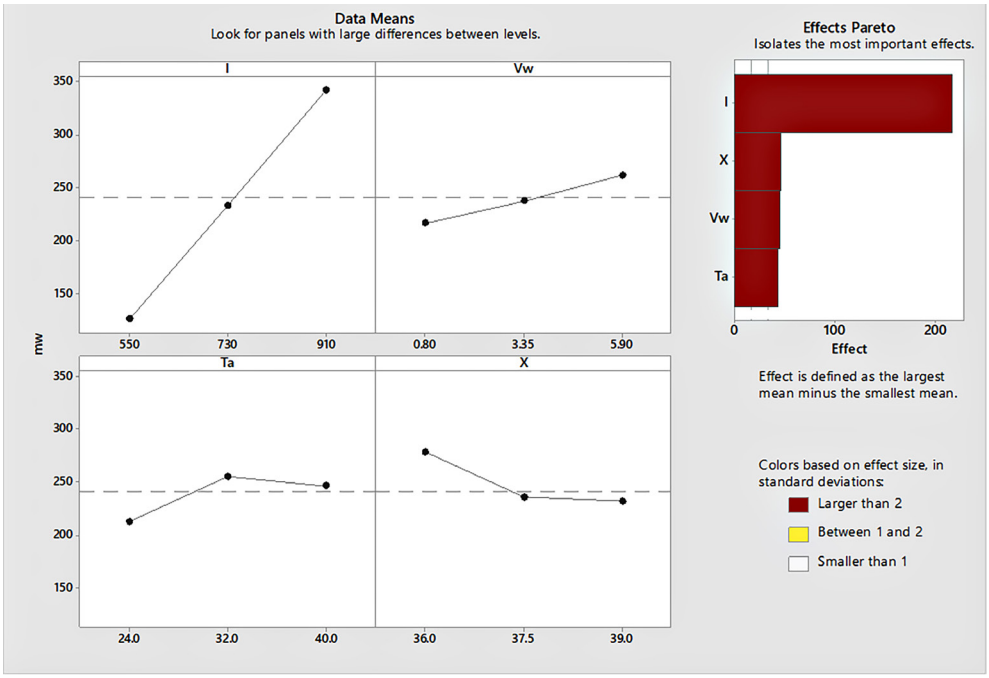
Abstract – Demand for air conditioning is rising exponentially due to improving economic conditions of large population of the world, growth of built-up space, changing lifestyles of people and higher comfort expectations. Most of the air conditioning systems use vapor compression refrigeration technology which needs electrical power to run. This has resulted in issues like higher peak demands for electrical power and higher direct and indirect emissions of greenhouse gases as well as other pollutants. The above issues can be alleviated by developing thermally activated air conditioning technologies, which use heat as the main energy source. Out of various thermally activated air conditioning technologies, liquid desiccant-based air conditioning (LDAC) systems are very attractive due to their adaptability for solar thermal energy. In LDAC systems the dehumidifier provides cooling using concentrated LD solution. This solution gets diluted there by absorbing moisture. The regenerator of LDAC systems utilizes thermal energy to remove water from the dilute LD solution to concentrate it and thus complete the cycle. The performance of the solar regenerators may be evaluated in terms of regeneration rate (moisture removal rate in ml/m2·h) and regeneration efficiency (useful heat/ solar energy input, unitless). Weather parameters like solar insolation, wind velocity, ambient temperature and system parameter like concentration affect the performance of the regenerator. The regenerator used in the current study is 'passive solar', meaning that no fan or pump is used in the device and solar thermal energy is the source of energy. Regression analysis of full factorial study was done using MinitabTM software to understand the effect of various parameters on performance of the passive solar regenerator. It is observed that as independent parameters, solar insolation, ambient temperature and concentration of LD have significant effect on the performance of the solar passive regenerator. The pareto chart shows that solar insolation has the most prominent effect on performance followed by the concentration of LD. Solar insolation has a positive effect on performance while higher concentration affects the performance negatively. The interaction plot for regeneration rate shows that solar insolation, when paired with other parameters, also has a considerable effect on the performance. The two-way interaction of wind velocity and concentration also has significant effect on the performance. Using ANOVATM, it was seen that the full factorial experiment design is linear. The insights developed in current work would help decide viability of using the passive solar regenerator at a given location and deciding the concentration range to be used in LDAC systems.

Keywords – Air conditioning; green technology; sustainable development; renewable energy technologies; solar energy



Main effects screener for regeneration rate

ACKNOWLEDGEMENT

This work has been supported by the University Grants Commission (UGC), Govt. of India, within the project "Development and demonstration of passive solar regenerator for liquid desiccant based air conditioning system".

https://doi.org/10.7250/CONECT.2025.056

ANALYSIS OF PHOTOVOLTAIC RAILWAY NOISE BARRIER CONFIGURATION FOR GREEN ENERGY GENERATION

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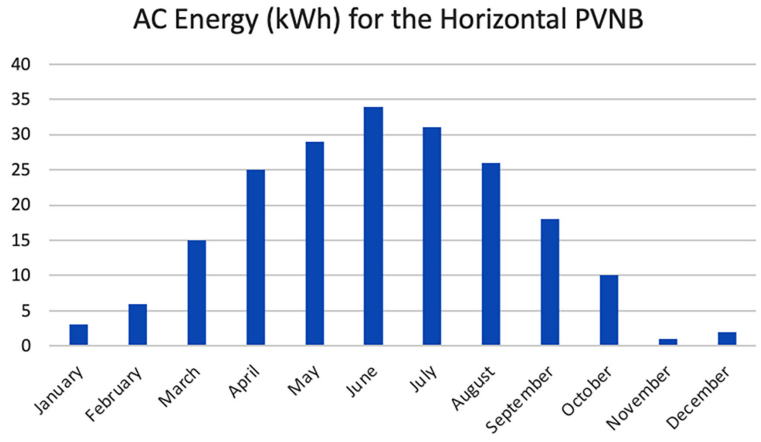
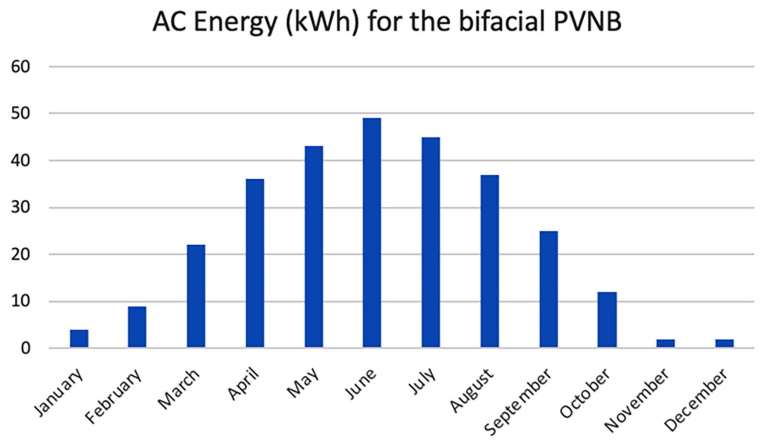
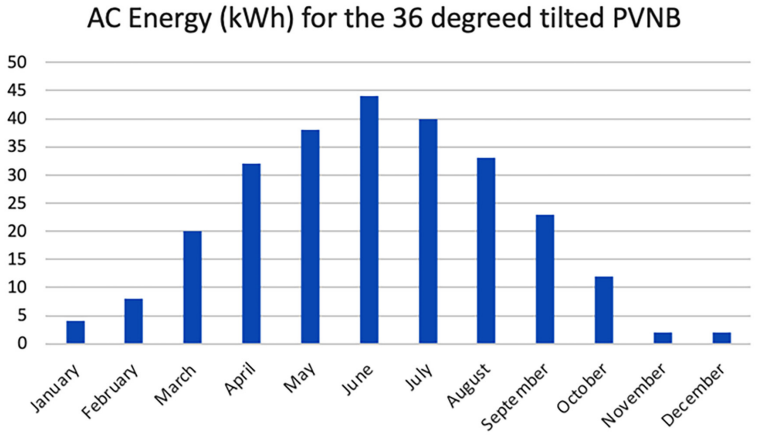
Abstract – Sustainable energy is a crucial aspect of our urban development, with a rising demand for energy resources, having the ability to integrate sustainable energy generation technologies with the existing infrastructure represents a possible solution for the high energy demand in populated regions. The regulations in the European Union state the maximum allowable noise levels to be 55 dB(A) in residential areas during the day and 55 dB(A) during the night, with the rising demand for reliable means of transportation, railways are becoming an essential part of the urban infrastructure. The use of Photovoltaic noise barriers (PVNBs) is expanding globally to meet those needs, and different studies are being conducted to evaluate the performance of this technology in various scenarios and configurations. This study focuses on the performance of the Photovoltaic integrated panels without affecting the overall efficiency of the noise reduction barrier. The primary results for energy generation evaluation show that the best results can be obtained from a bifacial PVNB, meaning that the Photovoltaic segment is in a vertical configuration mounted on top of a railway noise barrier, as shown in the following figure, where three different configurations for the PVNB were studied and based on the results it is clear that bifacial PVNB outperforms the other configurations, with a difference of almost one-third in the AC energy generated. This study was conducted using PVWatt calculator. This tool was developed by the national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Although it is optimal to use the vertical configuration for the PVNB, noise mitigation efficiency is still an aspect to consider.

Keywords – Efficiency; photovoltaic noise barrier; PVWatt calculator; sustainability







Comparative evaluation of green energy generated by three different configurations of the PVNB

05

LOW CARBON DEVELOPMENT AND BIOECONOMY

https://doi.org/10.7250/CONECT.2025.057

CLIMATE DIPLOMACY OF ESTONIA, LATVIA, AND LITHUANIA: WHERE DO THEY COMPARE IN CLIMATE ACTION, BASED ON THEIR INVOLVEMENT IN THE UN CLIMATE CONFERENCES

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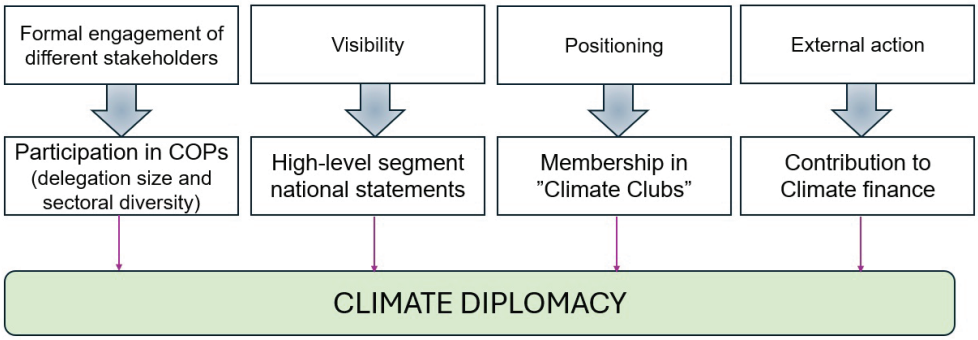
Abstract – The study compares how Lithuania, Latvia, and Estonia address global climate change internationally. Even though the institutions of the European Union play a pivotal role in setting the climate change mitigation goals, and Nationally Determined Contributions (NDC) are submitted collectively, the ambition and involvement vary significantly between different EU member states. Each country has diplomatic tools to negotiate, particularly during the Conference of Parties (COP), the climate conferences held annually in the framework of the United Nations Framework Convention on Climate Change (UNFCCC) since 1995, and through external action. Successful climate diplomacy in this study is understood as proactive participation in the above-mentioned conferences, including delivering high-level segment national statements, delegation size and the involvement of different stakeholders in the process, memberships and propositions in Climate clubs aiming at quicker decarbonisation, and contribution to the international climate finance by assisting developing countries. Climate diplomacy is evaluated by analysing the documents available on the UNFCCC website regarding participation, statements, and pledges to climate finance. The study finds that although no Baltic State stands out as a clear frontrunner in climate action, Estonia has become more outspoken in the international arena, particularly since COP26 in Glasgow. Meanwhile, Latvia and Lithuania can be considered more as bystanders. At COP28, Estonia became the first and, so far, the only Baltic State to have ever built its pavilion to present itself as 'a consistent advocate for environmental stewardship and climate action'. Estonian participation record is also notable for the participation of academicians and researchers, while Latvian participation can be praised for the highest share of the civil society attending the conferences. Estonia and Latvia have involved various stakeholders other than the government representatives in the climate negotiation process. Meanwhile, the size of Parties (government and its agencies) is the biggest in Lithuania; Lithuanian and Latvian delegations tend to be the most diverse at the ministerial level – seven ministries have sent their delegates to the COPs, which may signify the political involvement is not limited to the ministry in charge of energy. However, Estonia remains more carbon-intense than Latvia and Lithuania, and none of the three have joined the most ambitious Climate clubs. This case study helps understand the role and negotiating potential of the EU member states in climate change talks, where each can become frontrunners, passive bystanders or obstacles in implementing the common EU position and contributing to global decarbonisation.

Keywords – Baltic States; climate change policy evaluation; Conference of Parties; COP participation patterns; decarbonisation; high-level segment statement; net zero



Study methodology algorithm

https://doi.org/10.7250/CONECT.2025.058

INVASIVE PLANT BIOMASS AS A RESOURCE OF BIOLOGICALLY ACTIVE SUBSTANCES FOR BIOECONOMY

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Abstract – Invasive plants can be considered a significant environmental problem: a direct threat to biodiversity, but also affecting productivity of agricultural production, forestry, and human and animal health. Considering the intensity of invasive plant spreading, European Union member states and other countries put efforts of invasive plant spreading control and eradication of existing populations. Invasive plant biomass can be a valuable resource for bioeconomy. The aim of the study is to evaluate possibilities to use invasive plant biomass as a source of biologically and pharmacologically active substances (polyphenolics, lipids and fatty acids). Invasive plants, common in North Europe has been used: lupine, Sosnowsky's hogweed and Japanese, Bohemian and Sakhalin knotweeds. For extraction, traditionally used solvents were compared with green (low toxicity, biogenic origin) solvents, and good performance of the environmentally friendly solvents has been demonstrated. Using for extraction sequence of solvents of differing polarity biorefinery concept has been demonstrated to obtain different groups of substances from the same biomass sample. An important group of substances in all invasive plants are polyphenols, thus indicating high stress tolerance of studied plants. Several polyphenols are plant specific (such as emodin, quercitin and others) and thus invasive plants can be a valuable source of phenolics for application in biomedicine, food industry and other areas. The data show that the fatty acid composition of different knotweed species is very similar. Bohemian knotweed exhibits higher proportions of certain fatty acids, such as linoleic acid and eicosanic acid, in comparison to other species. Japanese knotweed, on the other hand, generally displays intermediate levels for most fatty acids but stands out with distinct peaks in components such as linolenic acid. In contrast, Sakhalin knotweed dominates in several fatty acids, including palmitic acid, which highlights its unique biochemical profile. Thus, invasive plants can serve as valuable resource of biologically active compounds for differing applications and their biomass biorefinery can serve as resource thus supporting invasive plant eradication efforts.

Keywords – Extraction; fatty acids; green chemistry; invasive plants; lipids; polyphenolics

ACKNOWLEDGEMENT

This work has been supported by the Latvian Council of Science project No.lzp-2022/1-0103 "Chemical ecology of invasive plants ss in NATURE, elaborate their control and develop new generation of herbicides (InnoHerb)"

https://doi.org/10.7250/CONECT.2025.059

RECULTIVATION STRATEGIES FOR PEAT EXTRACTION FIELDS: A CASE STUDY IN LATVIA

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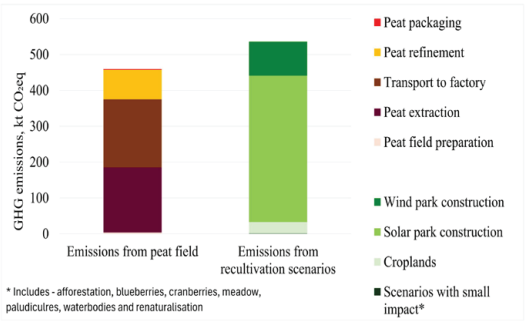
Abstract – Peat bogs are serving as habitats for diverse species and essential components of the natural environment. Currently, peat extraction is actively carried out in various regions to meet the demands of industries such as horticulture and in some cases even energy production. To mitigate land degradation caused by peat mining, the European Commission, through the Nature Restoration Law (Regulation (EU) 2024/1991), has established a goal to restore habitats. This includes repurposing peat mining fields into areas designated for various restoration measures. When defining a repurposing strategy for a specific peat extraction field, an important aspect is to assess the environmental impact of the different scenarios. This study is made in cooperation with the Latvian peat extraction company with the goal of achieving climate neutrality by the year 2050. The company is a significant producer of peat substrate with a capacity of 115 thousand tonnes per year. Ten recultivation scenarios were identified for the company's peat extraction field: afforestation, blueberry cultivation, cranberry cultivation, paludiculture, waterbodies, croplands, grasslands, renaturalisation, solar parks and wind parks. These scenarios were compared with the baseline scenario, i.e. the situation if peat extraction were to continue in this field. The required data for the recultivation scenarios were collected and normalized to the functional unit of 1 ha. The obtained life cycle assessment results for each recultivation scenario were assigned to the respective planned area for each scenario foreseen by the company's climate neutrality plan. All scenario emissions have been attributed to 50 years of land use, starting from implementation of the scenarios in 2025. Three main emission reference points were identified for the 50-year greenhouse gas emissions assessment: short-term 2030 (when peat extraction for energy in Latvia must cease), medium-term 2050 when climate neutrality must be achieved and long-term - emissions after 50 years (2075), when the vegetative life of berry plants has reached its end and when forest stands have reached the optimum age for tree harvesting. The results show that the highest emissions per 1 ha over 50year period are from the installation and reconstruction of solar panels. For each scenario, the emissions per respective planned area were calculated. It was determined that each scenario individually results in lower emissions compared to the baseline. However, when the emissions from all scenarios are added together, the sum is greater than the baseline. Therefore, it is necessary to investigate the recultivation scenarios further and optimise the land areas to optimise the recultivation scenario area and impact from them.

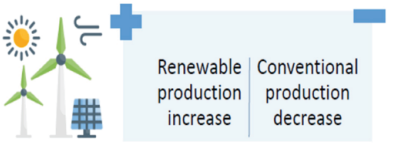
Keywords – Environmental LCA; GHG emissons; nature restoration law; peatlands; recultivation

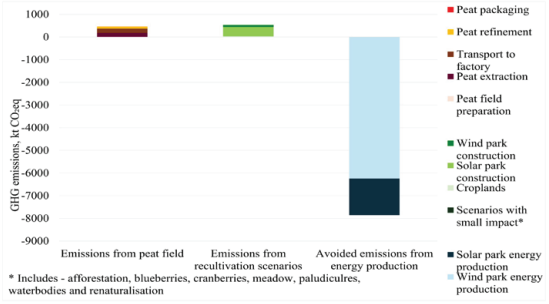
Peat extraction fields

Recultivation scenario implementation in peat extraction area



Emission data comperison between peat extraction and recultivation scenarios





Emission data comperison between peat extraction, recultivation scenarios and avoided emissions from energy production

A comparative analysis of greenhouse gas amissions from peat extraction and recultivation

ACKNOWLEDGEMENT

The work has been developed as part of the Fundamental and Applied Research Project "Sustainable Strategies for the Restoration of Peat Mining Sites (Peat4Res)", project no. lzp-2022/1-0405, within the framework financed by the Latvian Science Council.

FLPP FUNDAMENTĀLIE UN LIETIŠĶIE PĒTĪJUMU PROJEKTI

Peat4Res

https://doi.org/10.7250/CONECT.2025.060

CARBON FARMING: CALCULATION OF EMITTED AND SEQUESTERED CARBON FOR AN AGRICULTURAL ENTERPRISE. FIELD FARMING

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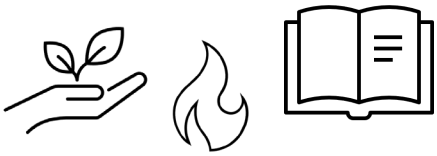
Abstract – Achieving climate neutrality and reducing atmospheric emissions are more critical than ever. Since the agricultural sector is one of the largest contributors to global carbon emissions, the concept of carbon farming is being explored – reducing carbon emissions and sequestering carbon in plants, soil and water. This study combines information from existing research about carbon sequestration with perennial crops and operational data from an agricultural enterprise with a laboratory experiment to assess the carbon dioxide sequestration potential of sea buckthorn plants at different stages of growth. Data obtained from the experiment combined with information about field size, crop yields and resource consumption from an agricultural enterprise, are used to calculate field carbon dioxide balance over the last two harvest seasons. The findings identify key factors influencing sustainable outcomes and propose practical recommendations to enhance sustainability in agricultural systems.

Keywords – Carbon-connected agriculture; carbon dioxide (CO_2) sequestration; carbon farming; perennials; sea buckthorn.



ACKNOWLEDGMENT

The research has been done within Fundamental and Applied Research Project "Carbon farming Certification system: The transition towards result-based agriculture sector (CarbFarmS)", project No. lzp-2023/1-0055, funded by the Latvian Council of Science.

https://doi.org/10.7250/CONECT.2025.061

TRANSFORMING ENERGY USE IN AGRICULTURE: PATHWAYS TO SUSTAINABILITY AND CLIMATE NEUTRALITY IN LATVIA

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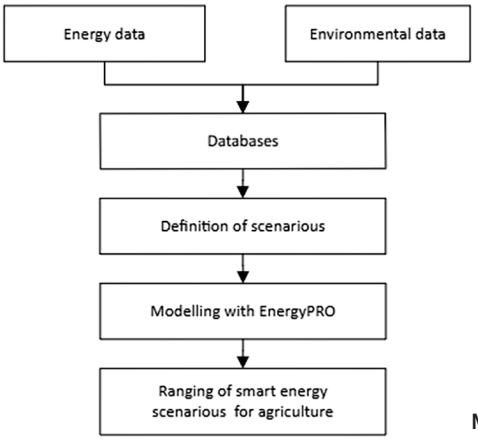
Abstract – The agricultural sector plays an essential role in shifting to a low-carbon economy and climate neutrality. The modernization of the agriculture sector is closely linked to improvements in efficiency and productivity while maintaining sustainability. As one of the main sectors contributing to climate change due to greenhouse gas emissions, the agriculture sector is a crucial player in striving towards more sustainable agricultural systems. A critical challenge in agriculture is the sector's entrenched reliance on fossil fuels, which hinders its progress and prolongs the timeline for achieving climate neutrality. Sustainable agriculture should be implemented in common agricultural policies and payment schemes. The aim of this research is to analyze the potential of transforming energy use in Latvia's agricultural sector towards climate neutrality and energy sustainability. EnergyPRO modelling for the assessment of the energy sector and the possibilities of implementing an energy-sustainable approach were applied, and twenty-five scenarios were analyzed to assess the emissions generated and resources consumed to produce 10 MWh of heat and electricity in both individual and cogeneration systems. The results indicated that hydrogen from wind energy is the most energy-efficient resource for thermal or combined heat and power production; hydrogen from wind or solar energy has emerged as the most efficient for electricity production.

Keywords – Climate neutrality; EnergyPRO; GHG emissions; modelling; renewable energy



Methodological framework

ACKNOWLEDGEMENT

The research was developed within the framework of the Fundamental and Applied Research Project "Carbon farming Certification system: The transition towards result based agriculture sector (CarbFarmS)", project No. lzp-2023/1-0055, funded by the Latvian Council of Science.

https://doi.org/10.7250/CONECT.2025.062

EVALUATING CARBON FARMING PRACTICES: A SYSTEM DYNAMICS MODEL FOR SOIL ORGANIC CARBON MANAGEMENT IN AGRICULTURE

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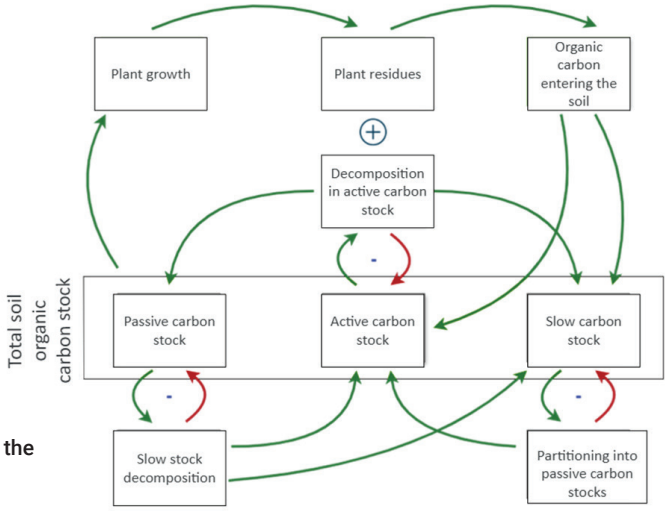
Abstract – Agriculture generates a significant number of emissions. Most of the emissions from agriculture are emissions from soil management. Carbon farming practices are being proposed in the industry to promote sustainability and mitigate climate change. The aim of the research was to create a system dynamics model capable of predicting and representing changes in the amount of organic carbon in soils under the influence of various agricultural practices and, using the created system dynamics model, to find out the influence of various agricultural practices on changes in organic carbon stocks. The tasks included literature analysis, creating and simulating a system dynamics model, and obtaining results on the effectiveness of selected agricultural practices. A system dynamics model was created based on the data obtained from the literature analysis and the IPCC guidelines on emission inventories. It was obtained from the model that using direct seeding in combination with the inclusion of cover crops in crop rotation planning over 10 years increases the total amount of soil organic carbon the most – by 7.5 tons/ha or 12. It was concluded that reducing the intensity of tillage and increasing the amount of plant residues contributes to the greatest increase in the total carbon stock. The greatest losses or emissions occur when the intensity of tillage and the amount of plant residues increase.

Keywords – Agriculture practices; carbon farming; carbon sequestration; emissions; modelling



The main causal relationships of the system dynamics model

ACKNOWLEDGEMENT

The research was developed within the framework of the Fundamental and Applied Research Project "Carbon farming Certification system: The transition towards result based agriculture sector (CarbFarmS)", project No. lzp-2023/1-0055, funded by the Latvian Council of Science

https://doi.org/10.7250/CONECT.2025.063

TANGLED THREADS OF OPPORTUNITY: A CO_2 VALORISATION ROADMAP FOR REGIONAL DECARBONISATION

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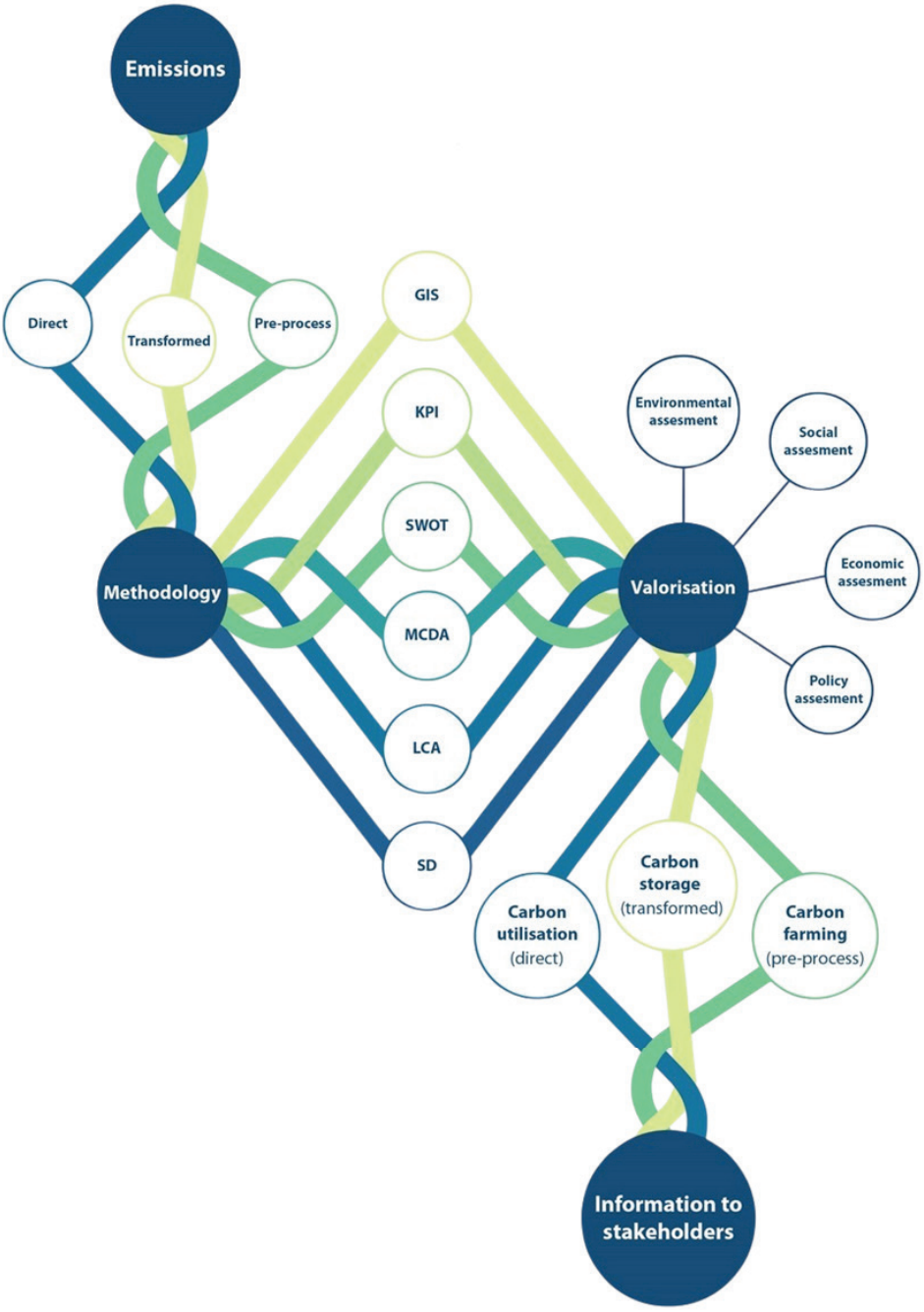
Abstract – The study aims to develop a roadmap for effective carbon dioxide (CO_2) valorisation in Latvia. The study adopts an innovative "tangle of threads" methodology, integrating multiple approaches to evaluate CO_2 valorisation pathways. The work considered the entire route of CO_2 valorisation and offered a roadmap for decision-makers for effective CO_2 valorisation in the regions of Latvia and is based on a consecutive multi-modelling approach, combining literature review, Geographic Information Systems, Key Performance Indicator analysis method, SWOT analysis, multi-criteria decision analysis, life cycle assessment, economic analysis, system dynamic modelling and social life cycle assessment. Five key valorisation scenarios were analysed during the research, including algae ponds, food and beverage production, methanol, ethanol, and cement production. Algal biomass production and food and beverage sectors demonstrated the highest sustainability and minimal environmental impact. The research concluded that CO_2 valorisation is viable for achieving Latvia's regional decarbonisation goals.

Keywords – Carbon capture and utilisation; decarbonisation; regional development; sustainability



The tangle of threads methodology of the study

https://doi.org/10.7250/CONECT.2025.064

INNOVATIVE STRATEGIES FOR CO_2 STORAGE IN MARINE ENVIRONMENTS: ASSESSING FEASIBILITY AND ENVIRONMENTAL IMPACT

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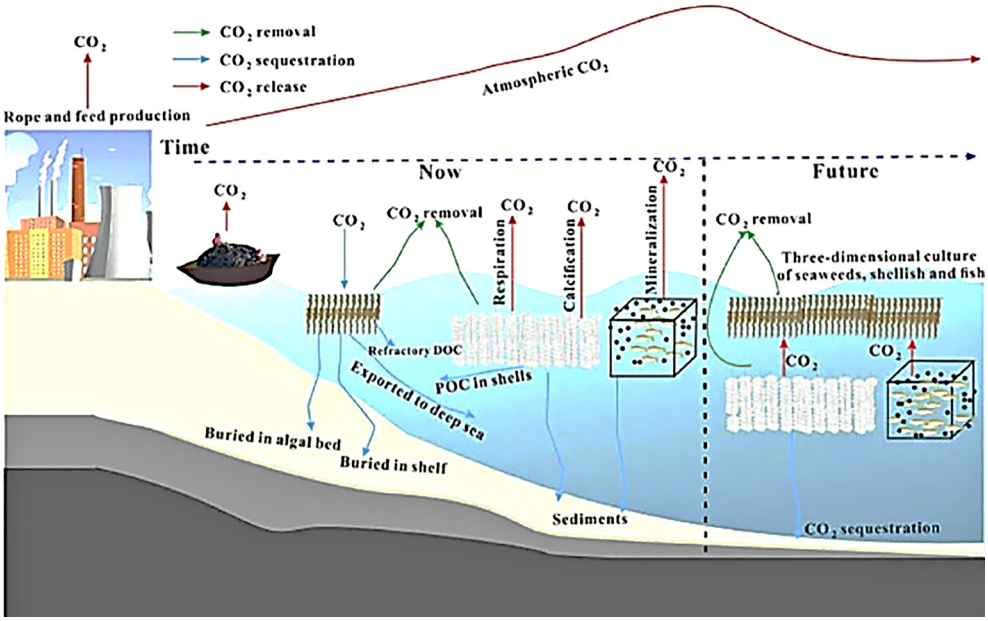
Abstract – The rapid increase in atmospheric carbon dioxide (CO_2) due to human activities is a pressing concern that demands innovative solutions. The study examines the feasibility and impact of storing CO_2 in marine environments as a method to combat climate change. To explore various techniques for oceanic CO_2 sequestration, we investigate direct injection into deep-sea formations, mineral carbonation and the enhancement of natural processes like phytoplankton growth, which play a crucial role in carbon capture. The approach integrates oceanographic data, chemical modelling and ecological impact assessments to provide comprehensive analysis. The focus is on the stability of stored CO_2, the risks of leakage, and the potential effects on marine ecosystems. Some findings suggest that certain deep-sea geological formations offer secure long-term storage with minimal harm to marine life. Furthermore, the research emphasises the importance of addressing the regulatory and ethical challenges of oceanic CO_2 storage, highlighting the need for robust international guidelines and cooperation. In addition to the scientific and technical aspects, we consider the socio-economic implications of implementing these technologies. This publication presents a comprehensive overview of current research, identifies promising future directions and explores the socio-economic implications of marine CO_2 storage technologies. The objective is to foster collaboration among scientists, policymakers and stakeholders in developing sustainable carbon management solutions. By advancing our understanding of marine CO_2 storage, we aim to contribute to global efforts in mitigating climate change and promoting environmental sustainability.

Keywords – Carbon management; carbon sequestration; climate change mitigation; ecological impact; environmental impact; leakage risks; oceanographic data; phytoplankton growth.



Carbon removal, sequestration and release by mariculture in an important aquaculture area, China. Science of The Total Environment. (Source: Li W., Li X., Song C., Gao G. (2024).

https://doi.org/10.7250/CONECT.2025.065

CLIMATE CHANGE EFFECTS ON AQUACULTURE: A CASE STUDY OF LATVIA

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Abstract – Aquaculture is one of the fastest-growing food production sectors, but the imminent impact of climate change puts aquaculture at risk. In the production of aquaculture products on ponds, the production process is significantly affected by climatic conditions, in particular climate change resulting in changes in average air and water temperatures, rainfall, changes in the hydrological regime and groundwater levels. At the same time, ponds are an essential element of environmental services, also contributing to the conservation of biodiversity and habitats. in 2024, 31 ponds in an area of 3.9 thousand ha (75 % of the total pond area) ensured the production of aquaculture production using environmentally friendly methods with increased standards for the maintenance of water bodies and fish farming, thus contributing to the preservation and improvement of the environment and biodiversity, but due to the fulfilment of environmentally friendly requirements through the production of reduced production. Without exploiting the potential for maximum water productivity and losing some of the potential income, the competitiveness of businesses suffers. Protected and non-game birds and animals also cause significant damage to pond farms. One of the priorities of the Latvian Aquaculture Development Plan 2021–2027 is the prevention of the adverse effects of climate change, where financing event for aquaculture, which provides environmental services, for aquaculture enterprises affected by the environment and climate change, is foreseen within the framework of the Programme for the Development of Fisheries 2021–2027. The aim of the study is to determine the potential impact of climate change on aquaculture production in Latvia. A partially structured Questionnaire was used to collect data. Bottom descriptive and Indicative methods were used for statistical analysis of the collected data. Collected data was analysed using frequency distributions, mean ranks and Mann-Whitney U test. The results showed that in order to balance the public interest in environmentally sustainable and biodiversity-preserving aquaculture production with ensuring the competitiveness of producers, it is necessary to continue to provide public support to cover revenue foregone or additional costs incurred by enterprises. Climate change has a significant impact on air and water temperatures, not only in open fish farming systems, but also in closed systems, which incur higher production costs in order to maintain and ensure optimal breeding conditions for fish species.

Keywords – Aquaculture farms; biodiversity conservation; climatic environments; sustainability

ACKNOWLEDGEMENT

This study was prepared by the Latvia University of Life Sciences and Technologies research project "Sustainable solutions for Development of the aquaculture sector in Latvia", research grant No. DG6, contract No 3.2-10/202.

https://doi.org/10.7250/CONECT.2025.066

SYSTEMATIC LITERATURE REVIEW: COMPARISON BETWEEN DIFFERENT FOREST BIOMASS ESTIMATION METHODS

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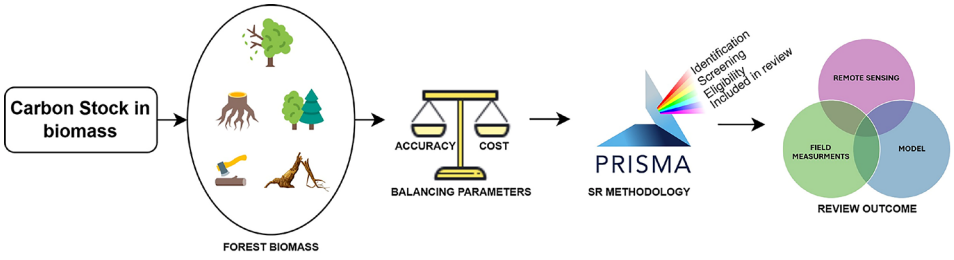
Abstract – Land use, land use change and forestry sector (LULUCF) is important in terms of carbon sequestration; it plays a crucial role in achieving Green Deal goal by making the EU climate neutral by 2050. This goal can be achieved by increasing carbon sequestration in LULUCF. Living biomass during its growth sequestrates CO2, therefore, if knowing the amount of biomass in forest, it is possible to calculate total carbon stock and annual carbon sink. Therefore, it is important to accurately estimate forest biomass. This systematic literature review (SR) follows PRISMA methodology (Preferred Reporting Items for Systematic reviews and Meta-Analyses method), which provides an overview of different methods used to estimate biomass from the forest. Several approaches to estimate biomass exist, like traditional methods, where measurements and information collections are done in field and allometric equations are applied; this method can be precise but needs large amount of labor and can be spatial limited, other method includes advanced technology, where remote and optical sensing data are used to determine variables, this method spatial efficient, but requires calibration with field data. Comparative analysis indicates advantages, limitations and accuracy of each method, showing the importance of compromise between scalability and accuracy. It is concluded that LiDAR can provide accurate information on higher cost, where SAR or ORS use can be cost effective but can be limited by complex data processing or cloud cover, field – based methods can have high biomass estimation accuracy, but can be time consuming. Future research should be aimed at hybrid methods, to achieve more precise biomass estimation, with lower costs.

Keywords – Allometric equations; carbon sequestration; GHG emissions; modelling; land use, land use change and forestry; remote sensing



Forest biomass estimation alternative methods

ACKNOWLEDGEMENT

This research is funded by the Latvian Council of Science, project "Climate Neutrality Decision Models in Action", project No. VPP-KEM-Klimatneitralitāte-2023/1-0002.

https://doi.org/10.7250/CONECT.2025.067

THE COMPARISON OF SUSTAINABLE AVIATION FUELS THROUGH HYDROPROCESSED ESTERS AND FATTY ACIDS (HEFA) AND ALCOHOL-TO-JET (ATJ)

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Abstract – Approximately 21.2 billion of carbon has to be reduced for achieving Fly Net Zero. The International Air Transport Association has targeted the production of sustainable aviation fuel (SAF) to be 449 billion liters by the year of 2050. The feedstock supply by then is going to be problematic. This study compares the SAFs produced through two different route: Hydroprocessed Esters and Fatty Acids (HEFA), derived from triglyceride-based oil and Alcohol-to-Jet (ATJ) derived from alcohol. The HEFA SAF is produced from palm oil feedstock, and ATJ SAF is produced from ethanol and butanol (named ATJ-e and ATJ-b). Firstly, the properties of the two produced fuel products are measured and both compared with conventional jet fuel based on ASTM specifications, including density and viscosity with various temperatures, auto-ignition temperature, smoke point, flash point, cetane number, heating value, and distillation temperature. Secondly, the combustion behaviors of HEFA and ATJ SAFs, including the spray characteristics and ignition behaviors, are also examined and compared. In addition, the combustion behaviors of five different blendings (0 %, 25 %, 50 %, 75 %, 100 %) with HEFA and ATJ SAFs are tested.

Keywords – Alcohol-to-Jet; butanol; combustion behavior; ethanol; Fly Net Zero; Hydroprocessed Esters and Fatty Acids; sustainable aviation fuel

ACKNOWLEDGEMENT

This project was supported by the National Science and Technology Council, Taiwan, through grant 113- 2221-E-006-210

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https://doi.org/10.7250/CONECT.2025.068

CARBON FOOTPRINT MITIGATION IN THE MANUFACTURE OF BIODIESEL FROM RECYCLED FRYING OIL USING ETHANOL AS AN ALTERNATIVE

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Abstract – Increasing climate change is driving the search for more sustainable strategies to mitigate the environmental impacts associated with the production of biodiesel derived from frying oil. Although the transesterification of frying oil (FA) allows obtaining biodiesel, the inputs used in this process can have a high environmental cost, particularly in terms of Carbon Footprint (CF). The use of ethanol as a reagent in the transesterification of FA appears as a promising alternative, with the potential to significantly influence the Life Cycle Assessment (LCA) of biodiesel and reduce its carbon footprint. In this study, the HC was evaluated for the LCA of the production of 1 kg of biodiesel under two experimental conditions: a 1:6 molar ratio of methanol-AF and a 1:9 ratio of ethanol-AF, using potassium hydroxide (KOH) at 0.35 % as catalyst and the subcritical temperatures of both alcohols to obtain biodiesel in a short time. The methodology included the definition of the LCA according to ISO 14067:2018, the elaboration of a greenhouse gas (GHG) emissions inventory for each stage of the production process and the calculation of the HC using CCalC$_2$ software. Five key stages in the production of biodiesel from FA were identified. The results showed that the CH of biodiesel produced with methanol is 5.79 kg CO_{2eq} per functional unit (FU), while biodiesel obtained with ethanol plus 5 has a CH of 5.35 kg CO_{2eq}/UF. This represents an environmental improvement of 7.60 % in favour of ethanol. Thus, it is concluded that the use of ethanol offers superior environmental performance in the LCA of biodiesel made from frying oil.

Keywords – Biodiesel; carbon footprint; Life Cycle Assessment; transesterification.

ACKNOWLEDGEMENT

Special thanks to Dr Erminia Sanaguano of the State University of Bolivar for her special contribution to this research work.

https://doi.org/10.7250/CONECT.2025.069

MULTI-CRITERIA ASSESSMENT OF CARBON FARMING: EVALUATING KEY PERFORMANCE INDICATORS

Edite MEIKULANE[1], Lelde VISTARTE[2], Lauma BALODE[3], Veronika LIBEROVA[4], Tereza BEZRUCKO[5], Valerija KOSTEVICA[6], Jelena PUBULE[7]*

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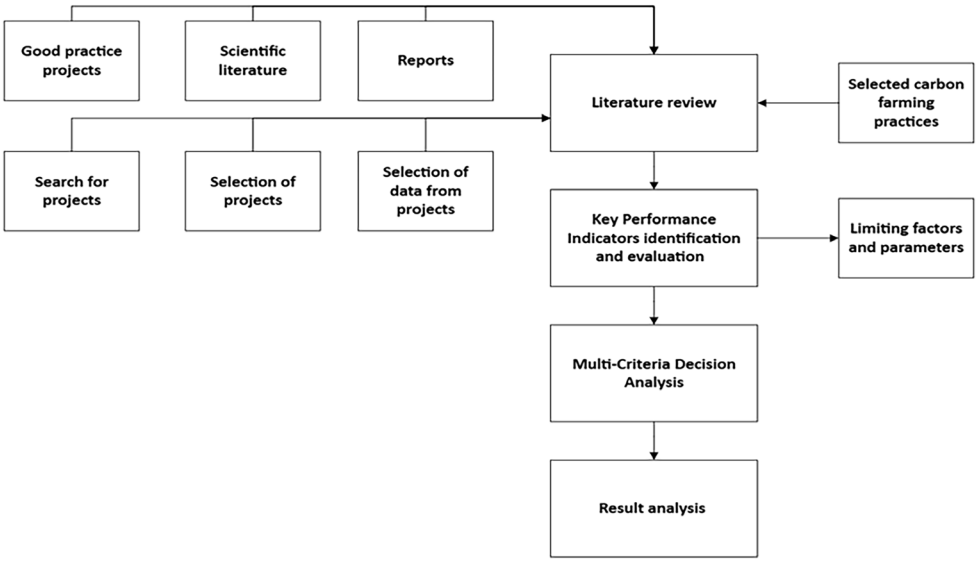
Abstract – Carbon farming represents a critical approach for mitigating greenhouse gas emissions within the agricultural sector, contributing to climate neutrality goals set by the European Green Deal. This study develops a systematic framework for multi-criteria decision analysis for the assessment of result-based carbon farming mechanisms. A structured set of key performance indicators has been analysed and adopted for Latvian conditions, incorporating CO_2-equivalent reduction metrics, sustainability indicators, and cobenefit evaluations to quantify the environmental and socio-economic impacts of carbon sequestration practices. The identified KPIs encompass agronomic, economic, environmental, and social dimensions, including crop yield, land availability, water use efficiency, energy efficiency, cost per ton of CO_2 sequestered, return on investment, economic value of carbon sequestration, labour productivity, N_2O and CH_4 emissions intensity, land use efficiency, infrastructure availability, adoption rates of methods, and total greenhouse gas emission sequestration potential. The study evaluates a range of carbon farming practices, including zero tillage, minimal tillage, cover crops, intercrops, biogas production, biomethane, soil carbon capture, perennial plants, agroforestry, organic fertilization, crop diversity, crop rotation, biochar application, grazing management, organic permaculture, and bio-tillage. The results contribute to a comprehensive decision-making framework for policymakers, land managers, and agricultural stakeholders.

Keywords – Carbon farming; indicators; key performance indicators, modelling; multicriteria assessment.



The methodological framework

ACKNOWLEDGEMENT

The research was developed within the framework of the Fundamental and Applied Research Project "Carbon farming Certification system: The transition towards result based agriculture sector (CarbFarmS)", project No. lzp-2023/1-0055, funded by the Latvian Council of Science.

https://doi.org/10.7250/CONECT.2025.070

THERMAL PERFORMANCE, ENERGY AND ENVIRONMENTAL ASSESSMENT OF BAMBOOBASED PANELS FROM INDUSTRIAL WASTES FOR LOW CARBON BUILDINGS

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Abstract – Insulation is one of the most effective methods for reducing energy consumption in both the heating and cooling of buildings. Selecting the right materials is crucial as, in addition to reducing emissions from the operation phase thanks to high energy efficiency, it is important that innovative materials also have a low impact during the production process. A growing interest focuses on the replacement of synthetic insulations with recycled materials. Among these are by-products from industrial transformation and manufacturing, residues from agro-industrial processes, and farming wastes. Natural materials have substantially less embodied energy than processed materials, so their use in new buildings and refurbishments can make a worthwhile contribution to sustainability. In this scenario, bamboo is an abundant and promising source. Its ability to capture CO_2 from the atmosphere, enhanced by its rapid growth, makes it an ally in mitigating climate change and GHG emissions. To sustain its CO_2 absorption capacity, bamboo requires regular harvesting. A valuable application of bamboo prunings is in the production of furniture and textiles. Furthermore, due to its exceptional strength-to-weight ratio and resistance to moisture and insects, bamboo is well-suited for manufacturing durable structural components and building materials, particularly in humid climates. This, however, results in a considerable amount of waste generated at various stages of the bamboo life cycle. This work aims to reduce construction environmental impacts using vegetal waste collected from the different phases of bamboo processing to produce monosheet thermo-insulating panels. Bamboo was characterized, milled to the particle size of 1.397 mm and incorporated into the adhesive. As low-impact alternatives to synthetic glues, two vegetal glues were used, specifically cellulose-based, selected based on polymer hydrophobicity and water solubility when dry, influencing the samples' permeability. Preparation and drying procedure was developed and preliminary tests identified the optimal mixtures which balance mechanical strength and minimum adhesive. 9 circular samples (φ=100 mm) 40 mm thick were prepared mixing bamboo grains with 3 types of glue (vinyl glue, methyl cellulose, 4 % CMC), each used in 3 different concentration levels (50 %, 75 %, 85 %). Thermal conductivity of the panels was experimentally evaluated by C-Therm TCi thermal analyser according to ASTM D7984. Energy saving potential of the best solution was compared to that of commercial synthetic panels through dynamic simulations on a case study building in central Italy. The environmental impact of the new component was assessed through a 'Cradle to Gate' LCA. The optimal vegetal glue

combination is the 85 %-one. It was observed that for higher densities, the thermal properties worsen. Considering the production phase, the innovative panel's embodied energy is over 20 % lower than that of traditional insulation material.

Keywords – Bamboo; building insulating systems; dynamic simulation; energy performance; grinded fibers; Life Cycle Assessment; natural glues; recycled sustainable materials; thermal characterization

ACKNOWLEDGEMENT

This work has been supported by Project of relevant national interest PRIN2020, funded by the Ministry of University and Research (MUR). Project name: URBEM - Urban Reference Buildings for Energy Modelling - PRIN2020

https://doi.org/10.7250/CONECT.2025.071

HYDROTHERMAL CARBONIZATION OF SLUDGE DIGESTATE – OPTIMIZATION FOR ENERGY APPLICATION

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Abstract – Anaerobic sludge digestate (SD), a by-product of anaerobic digestion, can be used as fuel. However, the high moisture content and poor dewatering properties makes SD unfit for direct energy applications such as combustion and thermal gasification. Hydrothermal carbonisation (HTC) process, which uses water as a reaction medium, is a suitable pretreatment method to enhance the dewatering and fuel properties of SD. Hydrochar (HC) obtained after HTC of SD can be used to substitute some fraction of coal for various energy applications. In the present study, HTC of SD was performed using design of experiment (DoE) approach and the reaction conditions were varied from 158–242 °C and ~10–138 min, respectively. Dewatering assessment of the treated slurry showed that a minimum reaction temperature of 190°C for 34 min was required to substantially improve digestate's dewaterability. Thermogravimetric analysis revealed enhanced fuel properties of HC compared to initial feedstock.

Keywords – Design of experiment; hydrothermal carbonization; sewage sludge; sludge digestate; waste to energy

https://doi.org/10.7250/CONECT.2025.072

CARBON FARMING IN THE EU: A POLICY TOOL OR A BUSINESS OPPORTUNITY?

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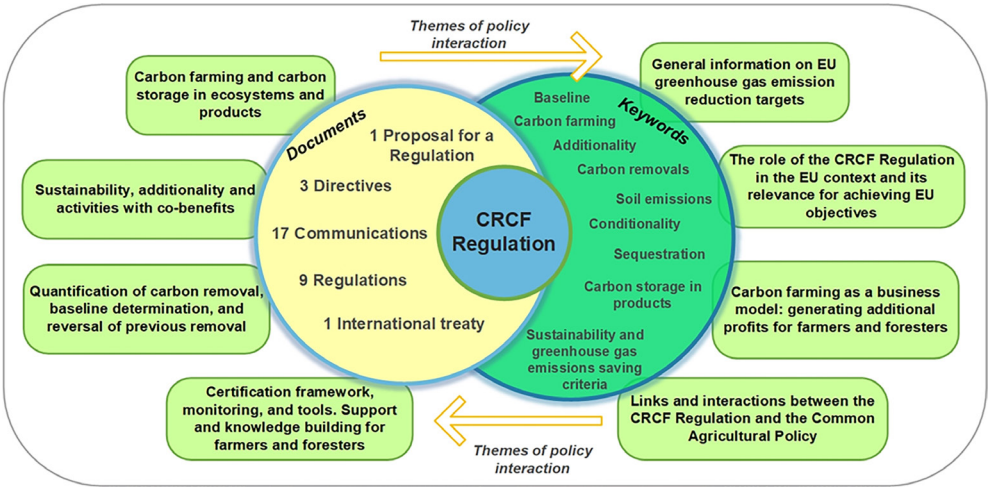
Abstract – The European Green Deal has set ambitious targets to reduce greenhouse gas emissions and achieve climate neutrality by 2050. To achieve these, carbon sequestration and long-term storage must be increased not only through technological carbon capture and storage solutions, but also through nature-based carbon pools. Bioeconomy sectors have an important role to play as they include sustainable practices in agriculture, forestry and marine ecosystems that contribute to carbon sequestration. The new Common Agricultural Policy programming period (2023–2027) sets more ambitious environmental and climate targets than previous periods, including carbon farming practices to reduce greenhouse gas emissions and sequester carbon. This approach prepares and motivates farmers to switch to sustainable practices at an early stage. This is important because once the voluntary EU Certification Framework of the CRCF Regulation (EU) 2024/3012 is fully operational, interested farmers and foresters will be able to actively participate in a new business model by trading carbon credits alongside conventional products. In order to better understand the role of the CRCF Regulation in the context of the EU's climate neutrality objectives and its interaction with other EU policy planning documents and legal acts, a content analysis was carried out, which led to the identification of key drivers and opportunities of the new CRCF Regulation. The results show that the CRCF Regulation plays an important role in the EU decarbonisation processes and in increasing carbon sequestration, in particular in the agriculture and forestry sectors. Certified activities will contribute to carbon removals and sequestration in both ecosystems and industry, while preserving biodiversity and ecosystem integrity. In addition, carbon sequestration and storage in construction products can contribute to a carbon neutral construction sector. Carbon farming offers a new business model where land managers are rewarded for sustainable management practices that increase carbon sequestration in biomass and soils.

Keywords – Carbon credits; carbon farming; carbon removal; certification framework; EU climate policy; EU policy planning; sustainable agriculture



Regulatory context, key concepts and policy interaction themes of the CRCF Regulation

ACKNOWLEDGEMENT

This work has been supported by the Latvia's state budget Fundamental and Applied Research Project "A Policy Planning Roadmap for Carbon Farming Certification Schemes" No. lzp-2023/1-0417.

06

CIRCULAR ECONOMY SYSTEM. SUSTAINABILITY

https://doi.org/10.7250/CONECT.2025.073

BUILDING CAPACITY FOR CIRCULAR ECONOMY: CROSS-REGIONAL INSIGHTS ON WASTE MANAGEMENT, RESOURCE EFFICIENCY, AND ECODESIGN FROM THE BALTIC SEA AND KAZAKHSTAN

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Abstract – This paper explores innovative approaches to waste management capacity building aimed at advancing the principles of circular economy, resource efficiency, and eco-design. The study presents insights derived from collaborative research conducted across six institutions: three research institutes situated along the Baltic Sea and three counterparts based in Kazakhstan. By leveraging case studies and comparative analyses, the research examines the dynamics of knowledge exchange and cross-sectoral integration within the context of energy management and modelling. A key objective of the study is to identify and disseminate best practices in waste valorisation and resource optimization. The research highlights how diverse regional contexts – characterized by differing socio-economic, regulatory, and environmental challenges – can serve as complementary learning environments for fostering innovation. Using a multidisciplinary approach, the participating institutes developed and tested models for sustainable waste management systems that prioritize lifecycle thinking, material reuse, and reduced environmental footprints. Central to the study is the integration of energy management techniques into waste management practices, addressing the complex interdependencies between material flows and energy systems. Modelling tools were employed to simulate scenarios that optimize resource recovery and energy efficiency, demonstrating their applicability in both Baltic and Central Asian contexts. These scenarios reveal opportunities for reducing greenhouse gas emissions, lowering operational costs, and enhancing system resilience. The findings emphasize the importance of cross-border and cross-sectoral collaboration in building adaptive capacities for a circular economy. Knowledge transfer between regions enabled the co-creation of tailored strategies that consider local policy frameworks, technological readiness, and stakeholder engagement. Additionally, the study underscores the role of eco-design in bridging gaps between waste generation and resource recovery, encouraging systemic changes that align with sustainable development goals. This research contributes to the growing body of literature on circular economy practices by providing actionable insights into the implementation of integrated waste and energy management systems. It also offers a framework for replicating similar capacity-building initiatives in other regions facing comparable challenges. The paper concludes by outlining policy recommendations and avenues for future research, with a focus on scaling successful interventions and fostering long-term partnerships. By synthesizing lessons from both European and Central Asian contexts, this study advocates for a globalized yet locally adaptable approach to sustainable waste management and resource efficiency.

Keywords – Circular economy; eco-design; energy management; knowledge exchange; resource efficiency; waste management

https://doi.org/10.7250/CONECT.2025.074

MIXED TEXTILE RECYCLING: OPPORTUNITIES FOR SUSTAINABLE PRODUCT DEVELOPMENT

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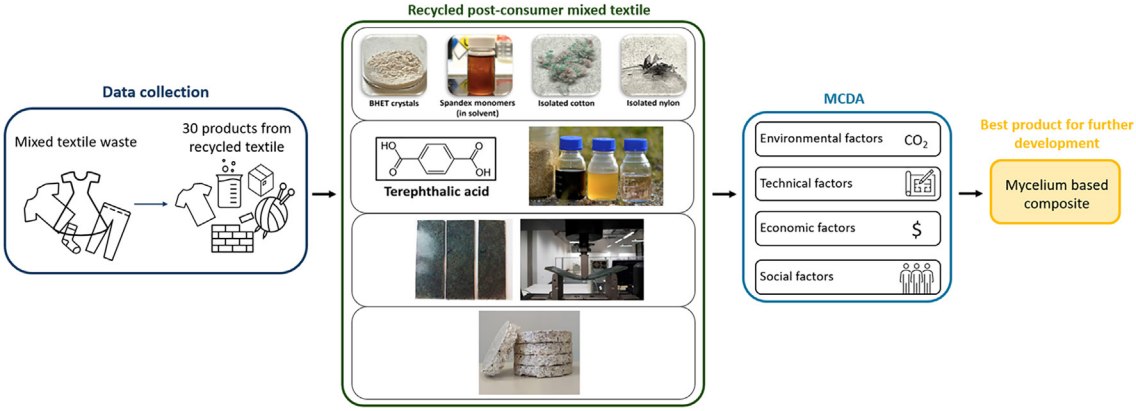
Abstract – The Waste Framework Directive mandates that, starting from January 1, 2025, separate collection of textiles must be introduced in all Member States of the European Union. The aim of separate collection is to promote the circular economy in the textile system by creating favorable conditions for recycling and re-use. However, in order to promote recycling, there are still challenges in terms of textile variety and mixtures. Currently, there are no commercially viable technologies to recycle mixed textiles back into textiles or high value-added products. Therefore, the aim of this study was to determine if there are any products in the research process that could be obtained from post-consumer mixed textile waste and, if so, to assess which is the most suitable for further development. Two methods were applied: data collection and multi-criteria decision analysis. A total of 30 research articles were identified, but only four were selected for further analysis based on their relevance to the research objective. The products obtained in the selected studies were (1) bio-oil and terephthalic acid, (2) textile-reinforced composite for building applications, (3) mycelium-based composite for thermal insulation and (4) textile fibers (cotton and nylon), spandex monomers and bis(2-hydroxyethyl) terephthalate. The products were evaluated using nine criteria covering economic, environmental, social and technical factors. The multi-criteria decision analysis showed that at this time, mycelium-based composite for thermal insulation has the highest potential for further development. The results show that it is possible to recycle mixed textiles into high value-added products. Future research should focus on scaling up the production of mycelium-based material and conducting a more detailed assessment of the economic, social and environmental impacts.

Keywords – Circular economy; Multi-Criteria Decision Analysis (MCDA); postconsumer textiles; value-added products



Methodological framework for assessing mixed textile recycling

https://doi.org/10.7250/CONECT.2025.075

DEVELOPING LOW-CO_2, 3D-PRINTABLE CONCRETE WITH WASTE ASH AND RECYCLED AGGREGATES

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Abstract – The construction sector is responsible for over 35 % of the EU's total waste and greenhouse gas (GHG) emissions, as stated in the Circular Economy Action Plan. The European Green Deal highlights the need for energy-intensive industries, such as construction, to reduce emissions and become more sustainable. 3D concrete printing (3DCP) is an emerging technology that can lower material use and waste by optimizing models before printing. However, it currently relies on significant amounts of cement, which is a major source of CO_2 emissions. To address this issue, this study developed a low-CO_2, 3D-printable concrete by replacing cement with industrial waste ash as a binder and incorporating recycled waste aggregate (RWA). The ash used was high-calcium fly ash, whose binding properties were enhanced by combining with pozzolanic waste materials. The used RWA was sourced from construction and demolition waste (CDW) landfill and compared to conventional crushed aggregates (CCA) to evaluate performance differences. Granulometric analysis showed similar particle size distributions (PSD) between both aggregate types, ensuring comparable workability and water demand in both concrete mixtures. The RWA-based and CCAbased mixtures achieved 28-day compressive strength of 18.6 MPa and 20.6 MPa, respectively. Although the RWA-based concrete exhibited slightly lower strength, the difference was minimal, demonstrating its viability for use in 3DCP for sustainable, low-rise construction applications where a mechanical strength of around 10 MPa is sufficient. The main focus of this study was to assess the environmental potential of this new material. Results showed that the low-CO_2 mix reduces emissions by approximately 80–90 % compared to conventional 3D-printable concrete, with the majority of the reduction coming from the cement replacement. The use of recycled aggregates contributed to a smaller reduction.

Keywords – Additive manufacturing; construction and demolition waste; low-CO_2 concrete; low-strength concrete; recycled waste aggregate; waste ash

ACKNOWLEDGMENT

This research is Supported by postdoctoral grant No RTU-ZG-2024/1-0008 under the EU RRF project No 5.2.1.1.i.0/2/24/I/CFLA/003.

https://doi.org/10.7250/CONECT.2025.076

SOCIAL LIFE CYCLE ASSESSMENT FOR WILD HARVESTING AND CULTIVATION OF *F. LUMBRICALIS* RED MACROALGAE

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Abstract – The sustainable development of macroalgae production in Europe, particularly in the Baltic Sea Region, presents significant socio-economic opportunities and challenges. While global seaweed production is dominated by Asian countries, European efforts are growing, with increasing interest in both wild harvesting and offshore cultivation. This study conducts an Explorative Social Life Cycle Assessment (SLCA) of *Furcellaria lumbricalis*, comparing wild harvesting (WH) and offshore cultivation (OC) scenarios to evaluate their social impacts. Using the Social Hotspot Database (SHDB) and following UNEP/SETAC 2020 guidelines, we assess key social risk indicators, including labor rights, community impacts, and governance structures. Results indicate that WH carries lower social risks than OC, with total impact scores of 432.85 Pt for WH and 719.51 Pt for OC. The WH scenario identifies seaweed harvesting as the most socially impactful stage, with high-risk indicators such as injuries & fatalities, forced labor, and discrimination. While WH supports traditional economic activities and fosters community engagement, occupational safety and fair labor practices remain areas for improvement. Furthermore, the SHDB hotspot analysis reveals that many social impacts of WH extend beyond Estonia, particularly in supply chain regions such as Ivory Coast and China. Conversely, the OC scenario demonstrates higher social risks, primarily due to extended maintenance activities required during the three-month cultivation period. Boat maintenance emerges as the most socially impactful stage, contributing significantly to labor rights risks, occupational hazards, and governance-related issues. Although OC presents scalability potential, the associated social burdens highlight the need for enhanced worker protections and improved governance frameworks before large-scale adoption. To refine these findings, Monte Carlo simulations (5 000 iterations) were conducted, confirming that WH consistently outperforms OC in social sustainability. The absence of overlap between the impact ranges reinforces the conclusion that wild harvesting is the more socially sustainable option under current conditions. However, the long-term viability of WH requires improvements in labor conditions and sustainability policies to ensure equitable benefits for coastal communities. This study underscores the need for a balanced approach in macroalgae production, integrating environmental, economic, and social considerations. Future research should incorporate localized, stakeholder-driven data to improve the granularity of S-LCA applications. Additionally, refining OC technologies and governance structures could mitigate social risks, potentially making it a more sustainable alternative in the future. These findings contribute to ongoing discussions on social sustainability in the blue bioeconomy, supporting informed policymaking for European macroalgae industries.

Keywords – Blue bioeconomy; Life Cycle Thinking; macroalgae production; Social Hotspot Database; Social Life Cycle Assessment

ACKNOWLEDGMENT

This research is funded by the Blue Bio ERA-NET Co-Fund project "Total Value Chain Optimization of seaweeds Furcellaria lumbricalis, a bioeconomical ALGAE demonstration (TACO ALGAE)", project ID No. 36.

https://doi.org/10.7250/CONECT.2025.077

CHALLENGES, BEST PRACTICES AND SOLUTIONS FOR SUSTAINABLE LOCAL FOOD SUPPLY CHAINS IN LATVIA, LITHUANIA AND SWEDEN

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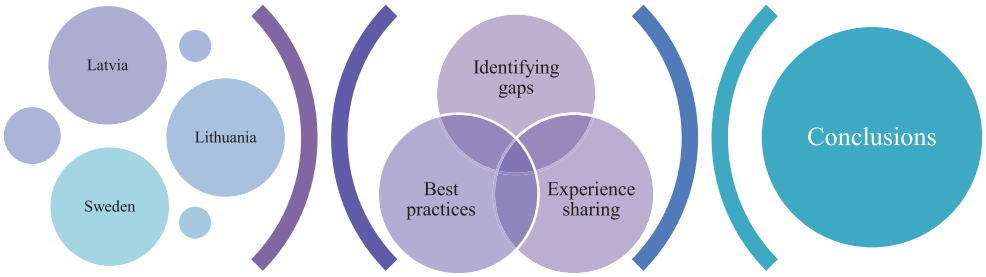
Abstract – Food security requires more than just increased availability, as supply chains face challenges such as climate change, inequality and waste. A sustainable food system provides numerous benefits, aligning with the European Green Deal's Farm to Fork Strategy, which aims to promote sustainable production, ensure food safety, reduce waste, and combat climate change. Additionally, it supports regional economies, preserves cultural identity, enhances food tourism, and helps prevent food fraud. Aim of the research is to analyse challenges, best practices and solutions for sustainable local food supply chains based on stakeholders face to face onsite workshops organized in Latvia, Lithuania and Sweden. Stakeholders interviewed were farmers, local food producers and distributors, local government representatives, as well as researchers from the food, regional development and environmental engineering fields who shared with their experiences and useful information about their experiences of dealing with obstacles. The initial results indicate the following group of obstacles like all the countries analysed. (1) There is no clear definition of the local food supply chain, creating uncertainty and inconsistencies in its interpretation. (2) Local food supply chain stakeholders are eager to collaborate to sell their products wholesale, ensuring the necessary production volumes. While meeting these demands can be challenging for individual producers, cooperation would make it achievable, enabling a more efficient and sustainable supply chain. (3) Local food supply chain stakeholders lack support from local governments, because currently the minimum requirements required by local governments are met, but this affects the ability of local producers to grow. (4) Lack of effective public education on the benefits of local food and its integration into daily life. Improving awareness and understanding would increase demand, support the growth and development of local food producers, and bring economic and social benefits to the community.

Keywords – Farm to Fork strategy; food safety; local food production; supply chain gaps



Research framework for assessing gaps in local food supply chain.

ACKNOWLEDGEMENT

This research is funded by Swedish Institute, project "Sustainable Local Food Supply Systems in the Baltic Sea Region" (SLFSS), project No. 00193/2023.

https://doi.org/10.7250/CONECT.2025.078

HARDENING AND RESISTANCE OF MAGNESIA BINDERS OF VARIOUS COMPOSITIONS

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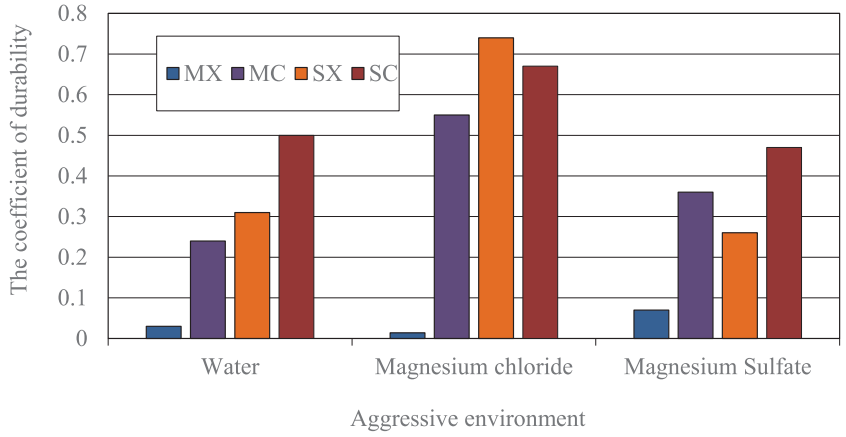
Abstract – An analysis of the scientific and technical literature of recent decades indicates an increasing interest in magnesia materials. There are convincing facts about the advantages of caustic magnesite and materials based on it. Magnesia materials are characterized by low energy consumption, intense hardening, high strength and adhesion to various surfaces. There is a known positive experience of using magnesia binders to produce concrete of dense and porous structure. Currently, the unique properties of magnesia materials are not fully exploited for the following reasons: limited amounts of natural magnesite deposits, low water resistance of hardened magnesia stone. The purpose of the work is to study the effect of mineral additives and salt sealants on the hardening and resistance of binders in aggressive aqueous environments. The experiments used raw materials: caustic magnesite, metallurgical slag, ash from thermal power plants, and iron-containing man-made waste. Solutions of magnesium chloride, magnesium sulfate, iron sulfate and their combinations were used to seal magnesia binders. The composition of magnesia materials was investigated using diffractometric analysis. The properties of the materials are determined by methods of physico-mechanical tests. The results of strength tests of magnesia binders located in various media: air, water and salt solutions are presented. The strength indicators are complemented by photographs of the appearance of the samples exposed to corrosive influences. The reasons for the change in the resistance of binders in aggressive liquids are substantiated. Preferred compositions of magnesia binders that exhibit increased resistance to corrosion processes are proposed. The research results are aimed at developing resource-saving technologies and increasing the durability of efficient building materials.

Keywords – Caustic magnesite; combined binders; corrosion; strength.



The coefficient of resistance of binders after 21 days of testing in aggressive environments

https://doi.org/10.7250/CONECT.2025.079

SCREENING LIFE CYCLE ASSESSMENT OF BIOBASED VITRIMER COMPONENT SYNTHESIS

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Abstract – The development of polymers from renewable raw materials while ensuring that the material is recyclable after the end of its life cycle is essential for Europe to achieve the goals set by the Green Deal and to approach climate neutrality in 2050. The goal of the TReResin project is to develop a new type of thermosetting resin with almost 100 % renewable raw material content, which can be recycled by changing the chemical conformation of the polymer due to the thermally reversible reactions of βamino polyesters. Within the project, Aza-Michael components, donor and acceptor, will be synthesized from used cooking oil (UCO). UCO is a waste without nutritional value generated in food processing industries, restaurants, and households. UCO is a combination of triglycerides and free fatty acids that have undergone physicochemical changes during food preparation (high temperature, moisture). Life cycle assessment (LCA) can be helpful early in the development phase, particularly for chemical processes, in identifying hotspots, comparing alternatives, assessing possible environmental implications, selecting production routes, and improving the processes themselves. The aim of the study was to evaluate the environmental impact of UCO-based AzaMichael donors and acceptors developed at the Latvian State Institute of Wood Chemistry suitable for the development of bio-based vitrimer resins. The synthesis technology currently is at TRL 2. The chosen system boundary was cradle-to-(laboratory) gate, and the functional unit was 10 g UCO-based Aza-Michael donor or acceptor. The production system for Aza-Michael components included feedstock production, required energy, and other chemicals needed for the synthesis process. The LCA model was built according to the ISO 14040/44:2006 series. LCA analysis was performed using SimaPro 9.6 software by Pré Consultants. Potential environmental impacts were assessed according to ReCiPe's (2016) v1.1 midpoint method, and global warming potential (GWP) was assessed using the Intergovernmental Panel on Climate Change (IPCC), 2021 GWP 100a' method. For the first time, the environmental impact of a lab-scale bio-based vitrimer component synthesis is investigated, hot spots are identified, and routes for improvement are explored. Primary data for the life cycle inventory were gathered from the experiments in the laboratory which is an advantage and best-case scenario. However, the LCA also highlighted the challenges of performing LCA on new types of chemical synthesis pathways, as background data availability and quality are limiting.

Keywords – Circular economy; environmental assessment; life cycle assessment; used cooking oil; vitrimers.

ACKNOWLEDGEMENT

This research was funded by the Latvian Council of Science, project "Bio-based, Highly Crosslinked β-Amino Polymer Resins as Thermally Recyclable Building Blocks (TReResin)", project No. lzp-2024/1-0333.

https://doi.org/10.7250/CONECT.2025.080

FIRST INSIGHTS INTO THE EFFICIENCY OF LATVIA'S BEVERAGE PACKAGING DEPOSIT REFUND SYSTEM

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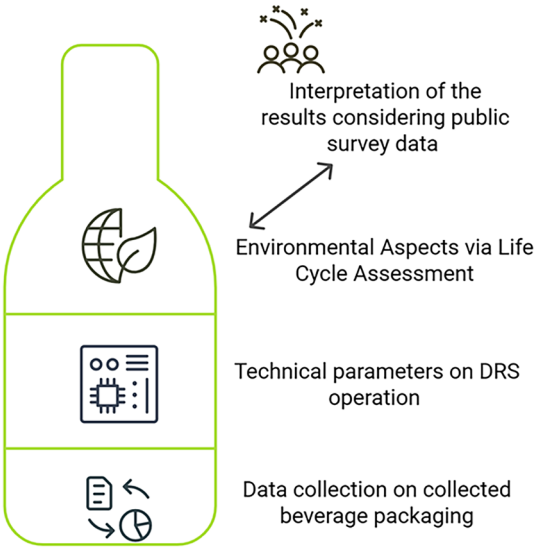
Abstract – From 1 February 2022, a container deposit refund system (DRS) started operating in Latvia with a transitional implementation period of 6 months. It is designed to contribute to the circular economy objectives in Latvia, i.e., to return packaging materials to the economy as recycled resources. Currently, the DRS can accept glass, PET and tin bottles for non-alcoholic beverages, beer and spirits up to 15 %. According to the Latvian DRS operator data, the return rate has increased from 62 % in 2022 to 83 % in 2024. The current research analyses two years of experience with the DRS in Latvia, highlighting its technical and environmental aspects. The study's methodology involves data analysis of collected beverage packaging alongside key operational parameters, including collection system maintenance, transportation distances, and recycling processes. Based on this analysis, a life cycle assessment (LCA) is performed to measure the environmental impact of the system's operation compared to the benefits gained from recovered materials. Considering the significant social impact on the efficiency of the DRS, the study is supplemented with survey data collected in Latvia in 2024, analysing public participation in the system. The survey by Ulla Milbreta *et al*., conducted among 985 respondents, equally distributed by gender, reveals the following insights significant for the further development of the DRS:

- Financial motivation dominates across all age groups, though its influence diminishes substantially with age, declining from 81.2 % in the 18–25 age group to just 21.2 % among the 65 years old and older. Environmental motivation, cited by 58 % of respondents, exhibits notable variations. It is particularly prevalent among men aged 56–64 (79 %). For men, rates range from 40 % (18–25 group) to 50 % (65+ years). For women, it ranges from 63 % (18–55 years) to 44 % in the 65+ age group.
- Lower participation among older respondents: 19 % (27 % women, 11 % men) of those aged 65+ report not participating in the DRS due to a lack of packaging to return, compared to 0.9 % of women and 7.7 % of men aged 18–25. On average, 9.3 % of the respondents reported not using the DRS system.
- The usage of DRS refunds decreases with age: 57 % of respondents in the 18–45 age groups redeem their deposit money, declining to 42 % in the 46–64 age group and 31 % among 65+. Donations of refunds remain consistent at around 11 % across all age demographics.

Keywords – Beverage bottles; LCA; public participation; recycling; waste



Integrated analysis of Latvia's DRS

https://doi.org/10.7250/CONECT.2025.081

INTERVENTIONS FOR ENGAGING HOUSEHOLDS IN THE CIRCULAR ECONOMY

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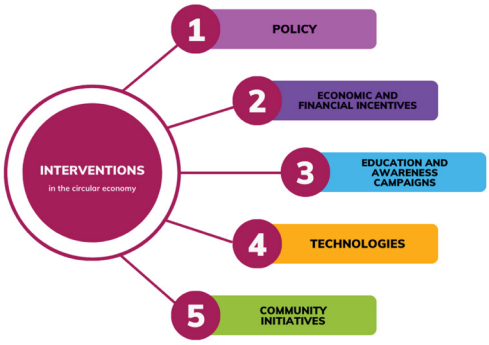
Abstract – Increasing resource consumption and global climate change are creating an urgent need to change the economic system and promote a shift from a linear to a circular economy. This is an important step towards sustainable development and contributes to achieving the United Nations (UN) Sustainable Development Goals to achieve climate neutrality by 2050. To achieve this goal, all stakeholders, including the household sector, need to be involved. This paper analyses the mental models of different groups – Easy-to-reach, Hard-to-reach and experts – to see how different interventions affect each group's ability and readiness to move towards a circular economy. The cognitive maps are used as an analysis tool and are processed using the Mental Modeler tool, which allows different scenarios to be visualized and modelled in different groups. The results show that each group responds differently to interventions, especially the Hard-to-reach group, so each group needs different strategies to change their behaviour. The Easy-to-reach are more open to sustainable solutions and can be reached through educational campaigns, while the Hard-to-reach are not ready to accept change and are most often reached through economic interventions. Furthermore, the results show that behaviour change is most effective when different interventions are linked and tailored to each group. The study concludes that there is a need to develop multi-level policy interventions that work simultaneously across all groups, creating a systematic approach to the transition to a circular economy. Therefore, to promote the transition to a circular economy, it is necessary to develop strategies and policy interventions that involve not only the Easy-to-reach groups but especially the Hard-to-reach groups whose participation is essential for the transition to sustainability. By addressing the different behaviours of these groups and through target interventions, greater societal participation in the circular economy can be ensured.

Keywords – Behaviour change; circulation model; cognitive mapping; consumer behaviour; mental model; sustainable consumption



Integrated analysis of Latvia's DRS

07

ENVIRONMENTAL AND ENERGY POLICIES AND FRAMEWORKS

https://doi.org/10.7250/CONECT.2025.082

FACILITATING REGIONAL INNOVATION THROUGH SUSTAINABLE AND MULTIMODAL TRANSPORT SOLUTIONS: THE CASE OF LITHUANIAN COUNTRYWIDE COLLECTIVE APPROACH

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Abstract – New EU Industrial Policy based on circular economy principles and the European Green Deal as the New EU Growth Strategy serve as key roadmaps. Environmental responsibility and digital efficiency – Europe's twin to a green and digital economy – paves the way for Small and Medium-Sized Ports (SMSPs) to improve innovation capacity, upgrade demanded future skills and competencies, accelerate EU policies compliant with operational, environmental, legal, digital, social and market performance for regional innovation and thus regional development. By building upon use case scenarios of strategic and collective approaches for Lithuanian sea and inland waterways ports, the paper showcases how SMSPs can enable sustainable transportation through transferable sustainable electrification and multimodal connectivity and sectoral integrity solutions. Indeed, collective and collaborative approaches among national SMSPs improves regional and national innovation development. Based on the role model – Baltic Sea Region – Lithuania's increase in logistical performance was ranked second among all littoral states. Illustrated use case scenarios of affected Lithuanian SMSPs reveal how ports are capable to kick-start sustainable transportation contributing to regional innovation with quantified and qualified solutions on Onshore Power Supply (OPS), electrification and digitalisation of port operations through Internet of Things (IoT) and Blockchain solutions used for transport and monitoring operations.

Keywords – Inland ports; Lithuanian waterways; small and medium-sized ports; seaports; regional development; regional innovation

https://doi.org/10.7250/CONECT.2025.083

LOCAL-LEVEL CHALLENGES IN SUSTAINABLE MOBILITY: SURVEY RESULTS FROM THE BALTIC SEA REGION

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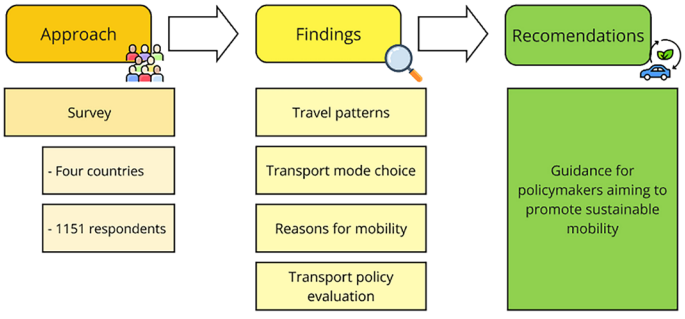
Abstract – Transportation is a substantial source of greenhouse gas emissions; therefore, achieving climate neutrality requires focusing on sustainable transportation. An assessment of the literature indicated that municipalities can successfully implement sustainable transportation legislation and encourage behavioural shifts toward lower-emission mobility options by tailoring solutions to their community's specific needs. This study examines travel patterns, reasons for mobility, and transportation mode choices in four European countries – Latvia, Estonia, Poland, and Sweden – using survey data from 1 151 respondents in selected municipalities. Using survey data, this study seeks to evaluate public opinion on existing transportation policy measures, identify preferred policies, and highlight regional differences. Notably, Estonia and Latvia strongly preferred cycling, while private car use remained dominant in all regions, contributing to environmental concerns. The survey also investigated the elements that influence travel mode choices, and the most important ones were distance, journey time, comfort, convenience, and public transit availability. While support for sustainable transportation policies varies by country, the findings show a widespread desire for improved public transportation, pedestrian-friendly urban planning, and remote work options to reduce commuting. Municipalities must address issues such as housing and job disparities, as well as a lack of efficient public transportation in rural areas. These findings provide guidance for policymakers aiming to promote sustainable mobility and reduce transportation-related emissions, with an emphasis on measures that are tailored to regional contexts.

Keywords – Emission reduction; EU member states sustainable mobility; public opinion; transportation policy; travel patterns



Study framework

ACKNOWLEDGEMENT

This work has been supported by the Interreg Baltic Sea Region Programme project CommitClimate [grant number #C026].

https://doi.org/10.7250/CONECT.2025.084

THE ROLE OF HOUSEHOLD INCOME IN IDENTIFYING ENERGY POVERTY

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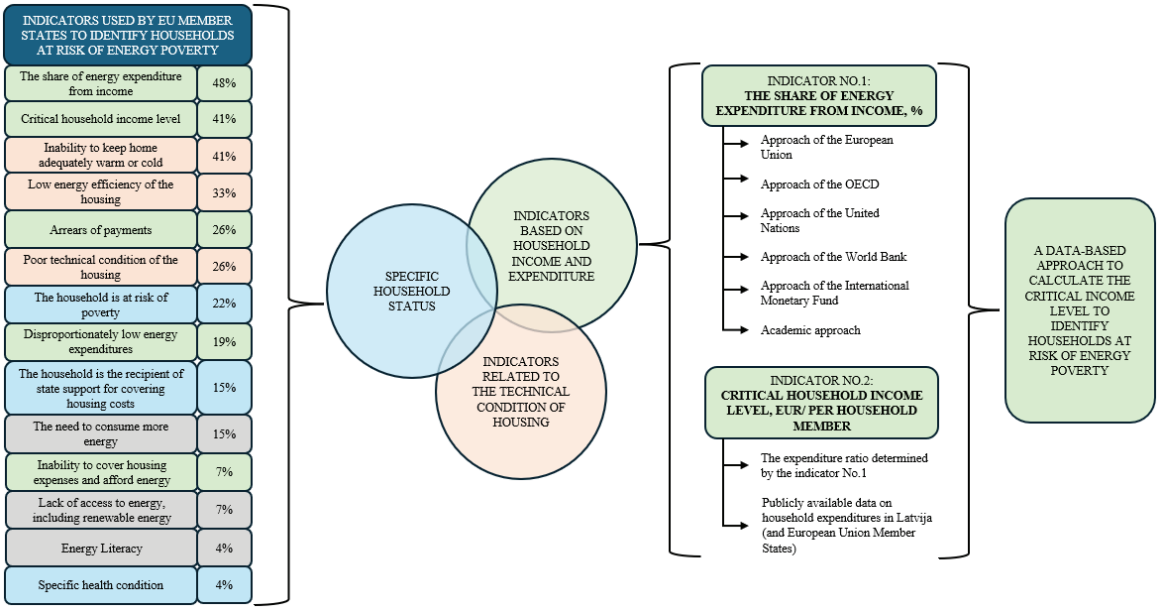
Abstract – Energy poverty and the identification of households at risk of it have become increasingly important topics for research and national policy implementation. This issue has gained significance due to rising energy resource costs, geopolitical events, income inequality among households, and rapidly occurring climate change. It affects indicators that characterize households' quality of life, such as health status, life expectancy, and education level (or access to education), while also significantly impacting climate change and efforts to reduce greenhouse gas emissions. Reducing the proportion of households at risk of energy poverty is particularly relevant in countries with extreme temperatures, where ensuring a suitable indoor climate is crucial, such as in Latvia, where the concept of energy poverty and its identification has not been sufficiently developed. To develop a data-driven concept for identifying energy poverty that is suitable for Latvia and could be applied by other European Union member states in the long term, this paper analyzes information from the integrated energy and climate plans of EU member states regarding their current approaches and indicators for identifying energy poverty. Using a decomposition method, it was concluded that the most frequently used indicators are the share of household energy expenditure in total household income (%), and the household's critical income level (EUR). Additionally, it was found that member states use different approaches for determining these indicator values, including data from EU databases, national household surveys, and national registers regarding individuals' status. Based on the information mentioned above, the paper analyzes the concept of affordable housing as defined by international organizations and academics, concluding what share of household expenditure in household income should be considered affordable, while also identifying mandatory housing-related expenditures. As the result of study, a datadriven method and formula for calculating the critical income level of a household (EUR/month per household member) is developed, and an insight is provided into what the critical income level of a household at risk of energy poverty might be in Latvia using the developed calculation method and calculation formula.

Keywords – Affordable housing; data-based approach; energy poverty; EU approach; housing costs; household expenses; household income



Decomposition method for introducing a data-based approach to calculate the critical income level for identifying households at risk of energy poverty

https://doi.org/10.7250/CONECT.2025.085

SUSTAINABLE DEVELOPMENT OF PORTS: ANALYSIS OF CLIMATE NEUTRALITY STRATEGIES FOR CASE OF LATVIA

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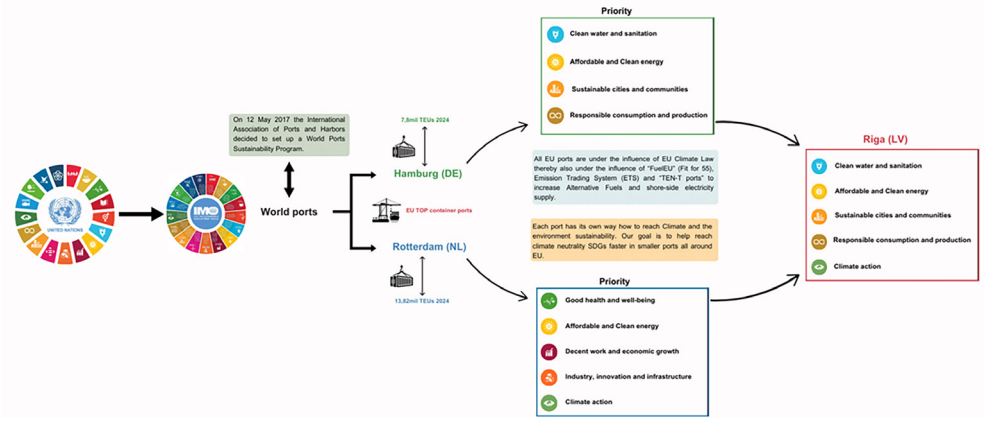
Abstract – In an increasingly complex and uncertain world, port resilience is essential; ensuring port sustainable development is the key to maintaining a competitive national economy. Ports are key nodes in global supply chains, which must transition to low-carbon systems, while aligning with the rest of Sustainable Development Goals (SDGs) to ensure economic viability, environmental sustainability, and social responsibility. The main research question of the study is how to achieve climate neutrality in ports in a sustainable way in the case of Latvia. Achieving such transformation requires a holistic approach that integrates decarbonization strategies that allow the alignment of the decarbonisation of the port with multiple SDGs. By investigating existing sustainable development strategies implemented in the Port of Hamburg and Port of Rotterdam, focusing on their contributions to specific SDGs, this study identifies key measures that contribute to climate neutrality in ports and evaluates their applicability in the Latvian context. Various energy transition pathways are assessed, comparing fossil fuel-based maritime operations with alternative fuels and best-fit scenarios for the case of Latvia are proposed from a systems thinking perspective. The results of the analysis provide insights into how different strategies will impact port infrastructure adaptation and contribution to SDGs. In such way, this study contributes to a deeper understanding of the challenges and opportunities for Latvian ports in achieving climate neutrality while enhancing resilience and sustainability.

Keywords – Decarbonisation; low-carbon ports; marine transport; renewable fuels; SDG



Sustainability priorities of EU ports in alignment with UN SDGs

https://doi.org/10.7250/CONECT.2025.086

A MULTICRITERIA DECISION-MAKING-BASED APPROACH FOR PRIORITIZING SUSTAINABLE BUILDING CONSTRUCTION BARRIERS IN A DEVELOPING ECONOMY

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Abstract – Implementation of sustainable practices in building sector has always been a great concern but often neglected. The situation becomes more serious for under-developed or developing countries where more focus remains on the economic aspects of construction. Neglecting such vital aspects usually results in unsuitable practices with negative impact on social and economic growth in the long run. Many factors are attributed to such practices. However, managing such an important challenge requires a thorough identification of barriers along with investigating the level of impact on sustainable building development, thus enabling policy makers to formulate the targeted strategies. The current work aims to develop a hierarchal framework to investigate the social, economic, environmental and governance barriers undermining sustainable construction practices in a developing country. A comprehensive literature review guided to shortlist 54 critical factors. A semi-structured questionnaire tool, based upon the Delphi technique, was developed to assist data collection. Multicriteria decision analysis technique, Analytical Hierarchical Approach (AHP), ranked the identified alternatives using pairwise comparison criteria. Fuzzy comprehensive matrix (FCEM) was developed to assess the overall evaluation of individual factors. With a centesimal value of 62.034, the social aspects were observed to the highest contributing factors in such barriers, with governance making the least. This indicated that social factors would require a comprehensive strategy to be managed properly to support sustainable endeavors for future developments.

Keywords – Fuzzy Logic Approach (FCA); hierarchical framework; multicriteria decision; sustainable development

https://doi.org/10.7250/CONECT.2025.087

ADVANCING LOCAL CLIMATE ACTION: INSIGHTS FROM THE PIEDMONT REGION, ITALY

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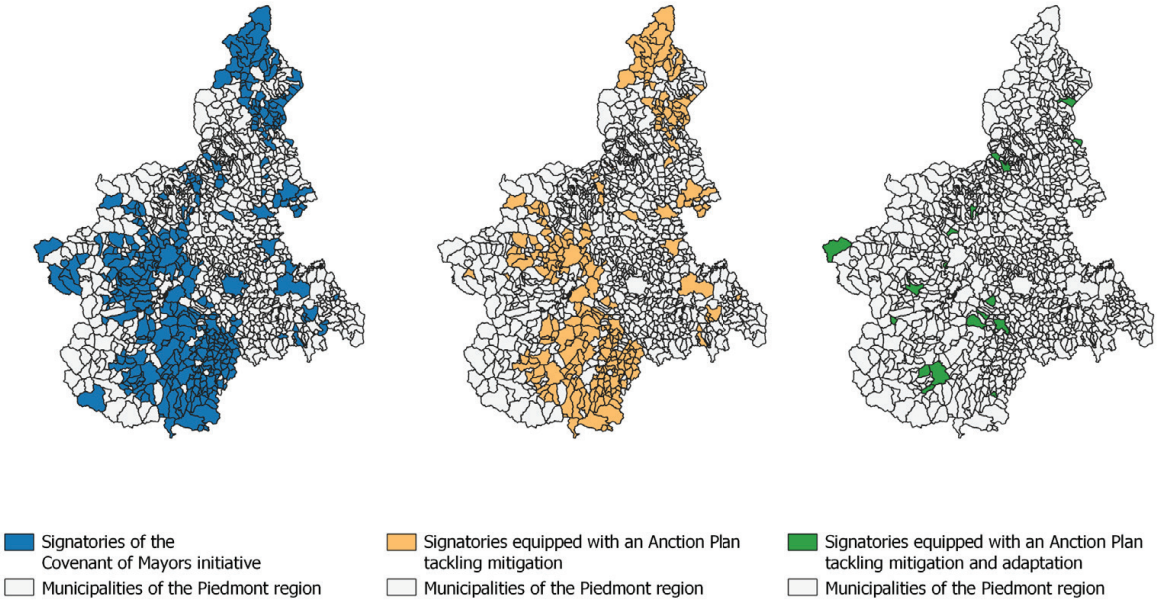
Abstract – While the impacts of climate change are increasingly apparent and expected to worsen in the near future, effective mitigation and adaptation strategies, plan and actions are becoming compelling. Despite the need for an integrated approach among governance levels, local authorities lie at the forefront of climate action, due to their proximity to the affected communities. However, the potential of this local climate governance is under discussion, as its efficacy is still unclear. This study focuses on the municipalities in the Piedmont region (Italy). It investigates how these municipalities tackle climate change within the consolidated framework of the Covenant of Mayors, the global-level initiative sponsored by the European Commission that since 2008 promotes and supports climate action at the local level. The assessment is based on a quali-quantitative analysis, owing to official documents and expert surveys. The results show that mitigation is rather consolidated, but it often relies on the willingness of private actors to act, hence pushing the achievement of climate targets beyond the direct control of the municipal authority. Furthermore, the study reveals a significant underdevelopment in terms of adaptation; though a certain attention for ecosystem services and wellbeing emerges, the ability to effectively act appears limited. Overall, the results hint at the inherent complexity of governing local climate-related planning, especially for municipalities, that suffer from limited funds and resources, as well as internal political instability. Although difficulties will persist, being structured in the socio-political context, we argue that local partnerships connecting different levels of governance and incorporating private actors and communities in the planning and implementation system can strengthen local resilience against global climate challenges, enhancing climate action and fostering the sustainability of local communities.

Keywords – Adaptation; climate action; Covenant of Mayors; local governance; mitigation; Piedmont

Mitigation; Piedmont



Distribution of climate action among the municipalities of the Piedmont region (Italy)

https://doi.org/10.7250/CONECT.2025.088

POLICY ANALYSIS ON MICROBIAL BIOMASS VALUE CHAINS

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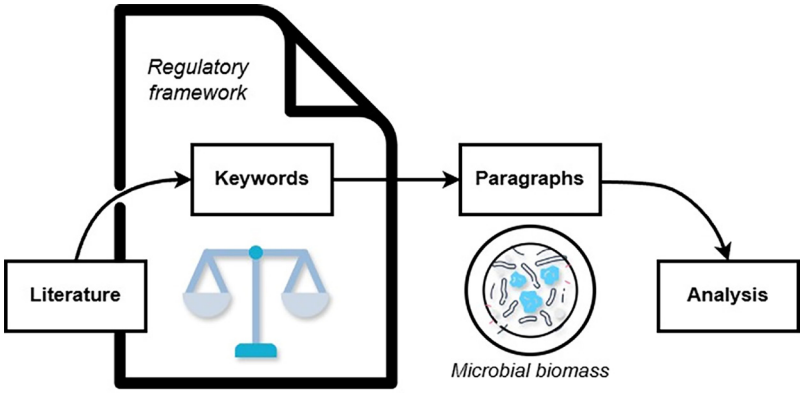
Abstract – Alternative protein sources as a means for fighting food insecurity have become more prevalent in various initiatives. Nevertheless, there are only a few cases with actual microbial food and feed production on an industrial scale. The overall landscape is developing, but as there are very few functional plants, it is not clear whether the regulatory framework is robust enough to ensure product safety and whether the regulatory framework does not include any unnecessary hurdles for alternative food and feed to reach the market. In this paper, a content analysis was performed of various European Level documents referred to microbial biomass value chains, including the potential substrates of agro-industrial sources. The literature sources were gathered using a snow-balling approach and further analysis was done on a keyword basis screening the documents for corresponding paragraphs. Quantitative sorting was done by assessing the keyword count, document types, and timeline. As a result, regulatory gaps and hurdles for microbial biomass production from agro-industrial side streams were elucidated.

Keywords – Alternative protein source; biomass value chains; microbial biomass; policy review, regulatory framework.



Framework for policy analysis on microbial biomass value chains

ACKNOWLEDGEMENT

The work has been developed by the Fundamental and Applied Research Project "Herbicides as tool for selection of edible protein-rich mutants", project No. lzp-2022/1-0126, funded by the Latvian Council of Science.

08

ENVIRONMENT, HEALTH, POLLUTION PREVENTION

https://doi.org/10.7250/CONECT.2025.089

EVALUATION OF LONG-TERM NITROGEN AND PHOSPHORUS CONCENTRATIONS IN DRAINAGE FIELD RESEARCH SCALE MONITORING SITES IN LATVIA

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Abstract – The primary objective of the Water Framework Directive is to establish guidelines for preventing the deterioration of the status of EU water bodies and achieving good ecological and chemical status for Europe's rivers, lakes, and groundwater. To achieve this objective, it is essential to evaluate the influence of various factors on water quality. Long-term assessment of water quality necessitates regular and systematic monitoring of water status. Furthermore, analyzing water quality across different spatial scales is crucial for identifying factors influencing water quality and determining potential pollution sources. In this study, the spatial scale at the drainage field research level was investigated in greater detail. The drainage field research level encompasses the catchment area of a single drainage system, covering an area smaller than 0.8 km^2. Six research sites, in which water samples were collected as part of the Agricultural Runoff Monitoring Programme, were examined: B-2, M-2, Vienziemite-2, AP-3, AP-5, and Zemg, with catchment areas ranging from 0.04 to 1.69 km^2, with agricultural land accounting for 86–100 % of the total area. The study focused on analyzing long-term average concentrations of total nitrogen (TN), ammonium-nitrogen (NH_4-N), nitratenitrogen (NO_3-N), total phosphorus (TP), and phosphate phosphorus (PO_4-P) (mg L^{-1}) as well as identifying long-term trends using the Mann-Kendall test. The findings indicated that lowest average TN concentration (1.3 mg L^{-1}) was recorded at the Vienziemite-2 site, dominated by perennial grasslands, while the highest average concentration (10.1 mg L^{-1}) was observed at the B-2 site, characterized by intensive agricultural practices. The Mann-Kendall trend analysis revealed that 67 % of monitoring sites showed a decreasing trend in TN and NO_3-N concentrations, while 83 % of sites exhibited an increasing trend in NH_4N concentrations. Additionally, 67–83 % of sites demonstrated a decreasing trend in TP and PO_4-P concentrations. This study highlights the importance of spatially explicit long-term monitoring to understand the impact of agricultural activities on water quality and to support effective water management strategies.

Keywords – Agricultural water quality; Mann-Kendall test; trend analysis; water quality

ACKNOWLEDGEMENT

The data collection for this research was funded by the project 'Assessment of the impact of natural and anthropogenic factors on the losses of nitrogen and phosphorus compounds from agricultural lands', of the Ministry of Agriculture of the Republic of Latvia. The preparation of this paper has been financially supported by the Base Research Funding provided by the Ministry of Education and Science of the Republic of Latvia.

https://doi.org/10.7250/CONECT.2025.090

NUMERICAL ESTIMATION OF WALL HEIGHT FOR PROTECTING HUMANS FROM ACCIDENTAL HYDROGEN EXPLOSION CONSEQUENCES

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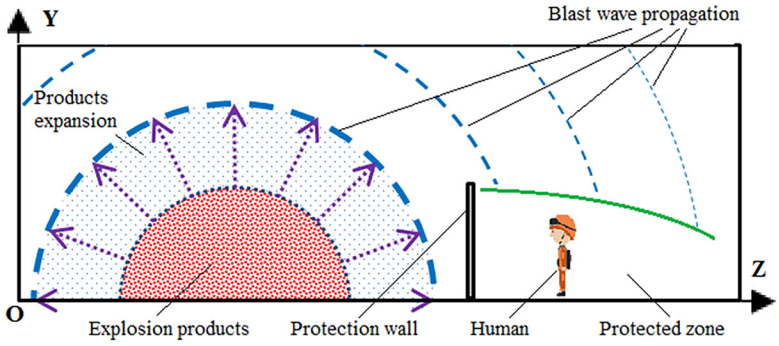
Abstract – The purpose of the study is to numerically determine the height of a wall designed to protect people from the negative effects of a blast wave, ensuring a specified level of safety. An accidental explosion of a hemispherical hydrogen-air stoichiometric cloud is considered. Near the epicenter of the accident, a person is subjected to shock-impulse loading as the blast wave front passes. A protective wall is installed between the accident epicentre and the person's location to mitigate the explosion's impact on human health. The wall's transverse size (width) is sufficiently large to ensure that it does not affect the safety of a person whose location remains unchanged. The required height of the protective wall can be determined by solving an inverse problem in gas dynamics, focusing on the movement of a multicomponent mixture of hydrogen combustion products through the surface layer of the atmosphere at the accident site. The gas flow disturbed by the explosion collides with the wall barrier, partially reflects off the wall, and moves around it in a vertical longitudinal plane, exerting a baric effect on a person. Solving the combined gas-dynamic and safety problem of human damage by a blast wave helps determine whether the current height of the protective wall is sufficient to ensure a safe level of conditional probability of human damage. A series of computational experiments were conducted for different heights of the protective structure using the mathematical model of a gas explosion and probit analysis. As a result, the relationship between the conditional probability of human injury and the vertical size of the wall was established in the form of a plot. Using this plot, a safety expert can determine the required wall height to ensure a sufficient level of human safety in the event of a hydrogen explosion accident.

Keywords – Blast wave front; environmental consequences; gas dynamics direct problem; hydrogen explosion; overpressure; probit analysis; shock-impulse load



Model diagram of the hydrogen accidental explosion process.

https://doi.org/10.7250/CONECT.2025.091

PARAMETERS REGULATING MICROORGANISM PROPERTIES AND INFLUENCING SOIL REMEDIATION POTENTIAL

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Abstract – Scientists state that in recent years, the level of soil contamination worldwide has significantly increased, mainly due to atmospheric deposits, floods, agricultural and industrial activities, and mining. Soil contamination is a widespread issue that negatively impacts the functions and processes of soil microorganisms. This pollution is associated with disrupting the physiological functions of microorganisms and disrupting processes related to the decomposition and transformation of organic matter. Heavy metals are significant factors of soil pollution, posing a threat to ecosystem functions due to their toxicity, persistence, and ability to bioaccumulate. The soil hosts diverse communities of microorganisms with specific metabolic capacities. Some microorganisms contribute to the decomposition of organic matter by interacting with toxic metals, while others participate in the formation of natural nanoparticles, thereby reducing the toxicity of heavy metals. Microorganisms can be used to immobilize heavy metals, but their effectiveness depends on various parameters such as soil type, chemical composition, pH, temperature, and moisture. The study identified suitable conditions that can stimulate the growth and activity of microorganisms. Optimal temperature is essential for the metabolic processes of microorganisms, such as enzyme activity, pollutant degradation, and biomass growth. Too low pH can inhibit the growth and enzyme activity of microorganisms, while too high pH slows down their activity. The article discusses that although microorganisms can be used in bioremediation, their activity is influenced by soil parameters. Understanding microorganisms` properties and operational parameters is essential for their successful application in soil bioremediation processes. However, this requires delving into not only the complexity of ecosystems, the impact of pollutants, and environmental parameters. The targeted application of microorganisms in bioremediation could become one of the main solutions for combating soil contamination and achieving environmental sustainability.

Keywords – Bioremediation; heavy metal; microorganisms; soil pollution.

https://doi.org/10.7250/CONECT.2025.092

SUSTAINABILITY ASSESSMENT OF FIRE-RETARDANT CHEMICALS: THE CRITICAL ROLE OF FUNCTIONAL UNIT SELECTION IN AN LCA-BASED STUDY

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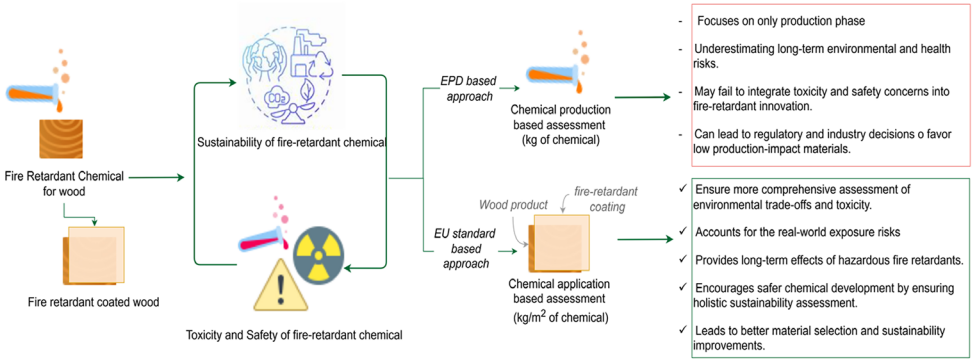
Abstract – The sustainability assessment of fire-retardant chemicals for wood requires careful consideration of their environmental impact, toxicity, and safety. However, the selection of an appropriate functional unit in Life Cycle Assessment (LCA) remains a critical yet often overlooked factor that can significantly influence decision-making. Current methodologies primarily rely on Environmental Product Declarations (EPDs), which assess impacts per kilogram of fire-retardant chemical produced. While useful for material-level comparisons, this approach may mislead the assessment of the environmental burden of fire-retardant applications, as it fails to consider the actual treated surface area and fire performance requirements. Alternatively, a functional unit aligned with European fire performance standards, such as EN 16755, which assesses fire-retardant-treated wood in real-world conditions, provides a more application-oriented perspective by considering the impact per square meter of treated wood. This study conducts a comparative LCA of business-as-usual (BAU) fire retardants using both functional units to demonstrate how the choice of functional unit can significantly impact environmental sustainability results and conclusions. The results highlight that an EPD-based approach can overlook the full environmental and health impacts of fire retardants, especially when they contain hazardous substances. In contrast, a functional unit aligned with technical applications and performances ensures a more consistent representation of environmental trade-offs and human health considerations. The misalignment of functional units can lead to regulatory and industry decisions that favour materials with lower production-phase impacts but higher long-term environmental and health risks. Given these challenges, a unified approach to functional unit selection is urgently needed in the sustainability assessment of fire retardants, especially for toxic chemicals now addressed within the Safe and Sustainable by Design (SSbD) principles, offering a framework for developing both safer and environmentally sound alternatives. In this direction, this study underscores the necessity of the application of a more robust, standardized approach for new chemical products in order to straighten material innovation towards safer, more sustainable products like the case of novel fire-retardants.

Keywords – Chemical alternatives; environmental impact; fire safety; functional unit; toxicity; wood products.



Comparative LCA of BAU fire retardants

ACKNOWLEDGEMENT

This work is supported by the ERDF, Interreg Estonia – Latvia program, project " Development of wood flame retardants with low environmental impact (FireStop) project No. EE-LV00014.

Interreg Estonia – Latvia Co-funded by the European Union

FIRESTOP

https://doi.org/10.7250/CONECT.2025.093

ASSESSMENT OF BIOFUEL ASH IMPACT ON SOIL QUALITY CHANGES

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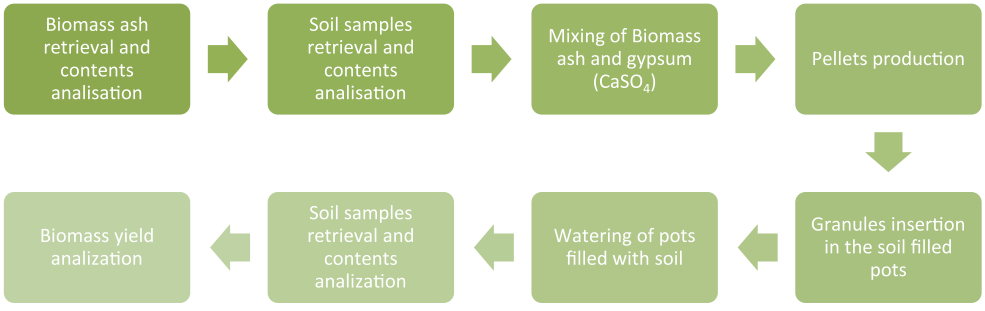
Abstract – The degradation of urban soils quality is an emerging issue caused by rapid urbanization, poor land management practices and pollution. These factors lead to reduced soil fertility and diminished vegetation in certain areas. Biomass ash, a byproduct of the biomass combustion process, proved to be an effective soil amendment due to the high levels of major soil nutrients, most notably calcium, potassium, and phosphorus. However, managing the fine particle size of biomass ash is problematic, because wind could disperse particles into the air and migrate them to unwanted places, possibly causing wastewater pollution or even respiratory health hazards. To address these challenges and produce effective urban soil fertilization technique this study explores pelletization of biomass ash with gypsum as a stabilization technique and its application on degraded soil using various application rates ranging from 1.00 t/ha to 7.00 t/ha. A series of controlled experiments were conducted to determine the ash pellets impacts on soil pH, nutrient availability, and plant biomass growth. The findings show that pellets of biomass ash to gypsum of ratio 5:1 with 12 % of water addition were the most optimal to minimize binder usage and produce pellets durable enough for transportation and field distribution. Biomass ash considerably improves soil quality by increasing nutrient content in soil with potassium increasement in soil from initial 1.2450±0.00225 % concentration up to 1.4889±0.0268 % and calcium increasement from initial 1.8016±0.0213 % concentration up to 2.3438±0.0230 % depending on the fertilization rate. Research has revealed that soil fertilization using ash pellets with rate of 1t/ha showed no significant increase in biomass yield, however higher fertilization rates can increase ryegrass biomass yield by 9–38 % with the highest increase in biomass yield with biomass ash addition of 7 t/ha. The study underlines the potential of biomass ash pellets as an environmentally sound and sustainable solution to urban soil remediation as well as reduction of waste.

Keywords – Ash pelletization; biomass ash waste; soil quality improvement



Biomass ash impact on soil quality and vegetation framework

09

WASTE. WASTE TO PRODUCT, VALUE ADDED PRODUCTS

https://doi.org/10.7250/CONECT.2025.094

THE CALORIC VALUE OF MUNICIPAL SOLID WASTE GENERATED IN GEORGIA FOR ENERGY RECOVERY

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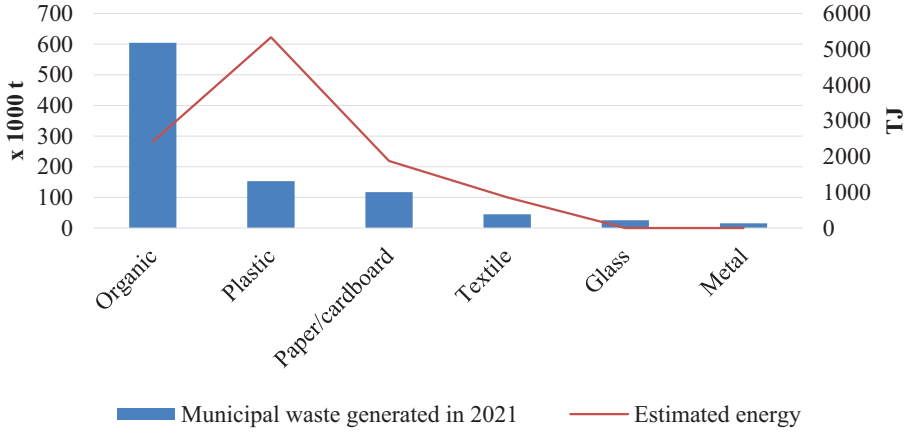
Abstract – Waste management approaches such as prevention, reuse, recycling, and recovery are key objectives, which stand in a Waste hierarchy of priority. The same Waste Hierarchy is a basic principle of the waste management policy of Georgia. Waste recovery is a priority approach over landfilling. In this case, it should be noted that more than 90 % of waste generated in Georgia is landfilled, which has negative social, economic, and environmental impacts. Thus, along with reusing and recycling, Waste-to-Energy (WtE) should be a solution for sustainable WM systems. Municipal waste generation in Georgia is characterized by increasing dynamics. For example, in 2015–2023, waste generation per capita increased from 207.8 kg to 302.2 kg. Accordingly, the amount of municipal waste disposed of in landfills has significantly increased. According to data from the National Statistics Office of Georgia, in 2015, 774.4 thousand tons were placed in landfills, and in 2023 – 1116.6 thousand tons, which is more than 90 % of the municipal waste generated annually. On the other hand, the calorific value of municipal waste generated in Georgia is of interest in terms of energy recovery, taking into account the experience of many developed countries, in particular Sweden and Denmark. As is known, for the effective use of municipal waste for energy recovery, it is necessary that the average lower calorific value of waste should be at least 7 MJ/kg and must never fall below 6 MJ/kg. Plastic waste is characterized by the highest calorific value, paper and textiles are also acceptable for energy recovery. Organic waste has a rather low calorific value (4MJ/kg), which is not recommended for Waste-to-Energy technologies. Plastics such as Polypropylene PP, Polyethylene HDPE, and Polyethylene Terephthalate PET have a high calorific value. In this regard, it should be noted that municipal waste generated in Georgia consists of about 13–14 % plastic, 10–11 % of paper and cardboard, and more than 4 % of textiles. Organic waste constitutes the largest portion of municipal waste generated in Georgia (over 54 %), however, this type of waste is not of interest in terms of energy recovery, as the calorific value of organic waste is very low (4 MJ/kg).

Keywords – Caloric value; energy recovery; organic waste; plastic; paper; textile; waste hierarchy; Waste-to-Energy (WtE).



Estimated energy recovery from MSW, Georgia, 2021

https://doi.org/10.7250/CONECT.2025.095

STRUCTURAL EQUATION MODELING (SEM) APPROACH FOR CAUSAL INVESTIGATION OF CAUSES AND CHALLENGES FOR DEMOLITION WASTE SUSTAINABLE MANAGEMENT

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Abstract – Demolition waste from road networks remains a significant global issue with profound environmental and economic implications. The situation becomes more of a concern when the quantum of such infrastructure facilities is also taken into account. However, a great number of impacts can be managed if the relationship between the causes and their challenges can be established at the planning stage, an early life cycle phase. The current work proposes a comprehensive framework for sustainable Demolition Waste Management (DWM). By identifying critical causes and impacts, a Delphi-based data tool explored the interrelationships among variables influencing DWM in such construction endeavours. Additionally, Life Cycle Assessment (LCA) methods assess the environmental impact of demolition waste management. Using Partial Least Squares Structural Equation Modeling (PLS-SEM), the study analysed connections between causes, challenges, and solutions in DWM for road projects. It reveals significant relationships, showing that demolition waste causes strongly influence both challenges (path coefficient = 0.727) and solutions (path coefficient = 0.175), underscoring their dual impact. Moreover, challenges exhibit a robust link with solutions (path coefficient = 0.760), emphasizing their role in shaping effective strategies. Addressing root causes and challenges is crucial for efficiently and sustainably mitigating demolition waste impacts sustainably. The developed framework offers systematic approaches for tackling demolition waste, providing pathways for capacity building, implementation, and evaluation. It empowers industry stakeholders with actionable insights to enhance DWM practices and offers guidance for policymakers in managing road construction waste sustainably. This research underscores the importance of addressing underlying causes and challenges to manage the complexities of demolition waste effectively while promoting environmental stewardship and economic efficiency.

Keywords – Demolition Waste Management; environmental management framework; multicriteria decision modeling; statistical modeling

https://doi.org/10.7250/CONECT.2025.096

FROM WASTE TO POLYURETHANES: ENVIRONMENTAL ASSESSMENT OF BIO-POLYOLS BASED ON USED COOKING OIL

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Abstract – Used cooking oil (UCO) is a valuable resource that can be utilized in different ways, from animal feed and biodiesel production to bio-based feedstock for polymeric materials. UCO is a cheap, renewable resource that can be utilized as an input to produce polymer precursors like polyols, the starting material for polyurethane. Due to the fact that the European Union has recognized the bio-based industrial sector as a priority area for sustainability, it is crucial to evaluate the environmental performance of bio-based products. UCO was successfully employed to synthesize bio-polyols that will be used to produce a two-component polyurethane system. Experimental results at the laboratory showed that UCO, a biogenic waste stream, can be successfully used as a renewable feedstock for polyurethane production. The aim of the study was to evaluate the environmental impact of UCO-based bio-polyols developed at the Latvian State Institute of Wood Chemistry suitable for development of flexible polyurethane foams. The chosen system boundary was cradle-to-(laboratory) gate and the functional unit was 1 kg UCO-based bio-polyol. The production system for bio-polyols included feedstock production, required energy, and other chemicals needed for the synthesis process. The LCA model was built according to the ISO 14040/44:2006 series. LCA analysis was performed using SimaPro 9.6 software by Pré Consultants. Potential environmental impacts were assessed according to ReCiPe's (2016) v1.1 midpoint method and global warming potential (GWP) was assessed using the Intergovernmental Panel on Climate Change (IPCC), 2021 GWP 100a' method. Results show that GWP for UCO-based bio-polyols was more than 40 % lower than petrochemical polyols. ReCiPe results indicate that chemicals besides the UCO used in bio-polyol synthesis contribute around 70 % to the environmental impact, electricity consumption 20 % and 10 % contributes waste generated. LCA results can provide guidance on the improvement options of the UCO-based bio-polyol synthesis process. The results show the importance of life cycle assessment integration in the early-stage development of new bio-based precursors and polymers.

Keywords – Bio-polyols; circular economy; environmental assessment; life cycle assessment; polyurethanes

ACKNOWLEDGEMENT

This research was funded by the European Partnership Innovative SMEs project BIODESIGN4INSULATION.

https://doi.org/10.7250/CONECT.2025.097

ADVANCING SUSTAINABLE CONSTRUCTION IN THE BALTIC REGION BY INDUSTRIAL BY-PRODUCTS AND WASTE VALORIZATION: A REVIEW

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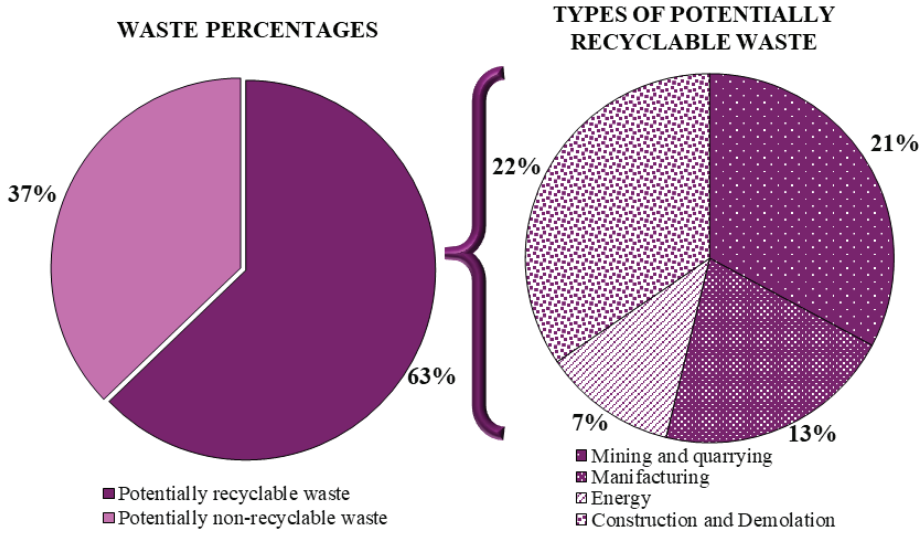
Abstract – The Baltic region faces increasing challenges in managing industrial by-products and wastes due to growing industrial activity and stringent environmental regulations. At the same time, the construction industry is under significant pressure to adopt sustainable practices and reduce its carbon footprint. It is therefore essential to identify and summarize opportunities for the use of industrial by-products and waste in the Baltic Sea region in order to develop sustainable building materials that are in line with circular economy principles and carbon neutrality objectives. In the Baltic Sea region, 63 % waste is coming from mining and quarrying, manufacturing, energy production, and construction and demolition. These wastes can contain compounds containing Si, Ca or Al, which are essential for the production of building materials, thus giving these wastes a chance to be recycled again. In additional, the Baltic Sea region has a wide range of industrial residues and by-products, such as glass-based, clay-based and cement-based residues and by-products. By carefully identifying the current situation and studying the characteristics of waste and by-products, it is possible to identify innovation opportunities, including the development of region-specific formulations and the optimization of processing methods, to improve the economic and environmental benefits of waste valorization. It is possible to significantly reduce industrial waste, thereby saving resources and providing cost-effective alternatives to traditional raw materials. Summarizing the current research and practical achievements, a roadmap for the development of sustainable construction practices in the Baltic region has been developed. Also, future directions for research, policy initiatives and industrial cooperation to unlock the full potential of industrial by-products for sustainable construction has been proposed.

Keywords – Baltic Sea Region; industrial by-products; recycling; sustainable building materials; wastes



Waste distribution in the Baltic Sea Region
according to potential use in the production of construction materials

ACKNOWLEDGEMENT

This work has been supported by the Research Council of Lithuania (LMTLT), agreement No S-PD-24-125.

https://doi.org/10.7250/CONECT.2025.098

POLICY ANALYSIS OF LATVIA'S WASTE SECTOR: A SYSTEM DYNAMICS APPROACH

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Abstract – Latvia's waste management sector generates annually increasing waste volume, more than doubling to 2.71 Mt in 2023 from 1.26 Mt in 2004. The current national policy aims to address this challenge to reduce waste generation and landfilling by promoting circular economy principles. The long-term strategy is focused on achieving climate neutrality in 2050 with a 58 % reduction in greenhouse gas emissions compared to 2017 levels. This study performed a comprehensive analysis of European Directives, National Policy Plans, Regulations, and IPCC reports for the waste management sector. Relevant data has been systematically extracted from these documents and analysed. In this study, a System Dynamics approach has been used to capture complex interactions within the waste management sector. The System Dynamics model has been developed to assess and evaluate the current state of Latvia's waste management sector and incorporate various policies. The model has been validated on historically available data and structural analysis. Policies regarding ways to minimize waste generation, greenhouse gas emissions and their associated effects on socioeconomics have been analysed using the model. An interactive decision-making interface has been developed on top of the model to be used by stakeholders for various scenario analyses. The interface allows users to analyse Business-as-Usual (BAU), optimistic, worst-case scenario, and custom scenarios by providing own inputs and policy mix. Two stakeholder workshops have been performed where waste management experts and policymakers performed scenario assessments using the developed interface. Discussions with the stakeholders during the workshops have shown trust and support for the model, and they report that it is beneficial to incorporate the model into the national policy analysis and planning.

Keywords – Circular economy; climate change mitigation; decision making; environmental impact; eco-design; greenhouse gas emissions; sustainability

ACKNOWLEDGEMENT

This work has been funded by the Latvian Council of Science within the research project "Climate Neutrality Decision Models in Action" No. VPP-KEM-Klimatneitralitāte-2023/1-0002

https://doi.org/10.7250/CONECT.2025.099

MUNICIPAL WASTEWATER BY-PRODUCTS UTILIZATION

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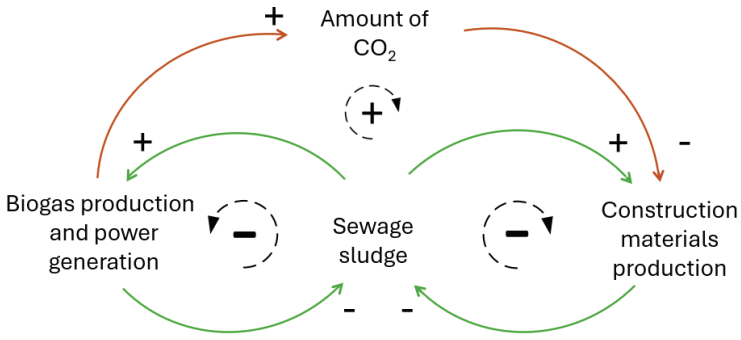
Abstract – The challenges of mitigating climate change today require innovative and sustainable solutions to reduce carbon dioxide (CO_2) emissions. Wastewater sludge, a byproduct of the wastewater treatment process, presents a valuable resource for contributing to emission reduction and the circular economy. This study analyzes the utilization of wastewater sludge with a dual-focus approach: biogas production as a short-term solution and the manufacturing of construction materials as a long-term strategy. Biogas generation provides an immediate method for energy recovery, reducing dependence on fossil fuels, while the use of sludge in cement and concrete production offers a sustainable alternative to energy-intensive traditional materials. The study evaluates the environmental and economic impacts of these methods, emphasizing their role in reducing CO_2 emissions and addressing issues such as waste accumulation and soil degradation. A system model is developed using *Stella Architect* to assess the feasibility and scalability of these approaches. The findings suggest that large-scale implementation of wastewater sludge utilization can play a crucial role in climate change mitigation and resource efficiency. However, further research is necessary to enhance technological advancements, optimize costs, and support broader global adoption.

Keywords – Bioeconomy; climate technologies; environmental solutions; sustainable municipalities; wastewater sludge



Causal loop diagram for sewage sludge management

https://doi.org/10.7250/CONECT.2025.100

COMPARATIVE ANALYSIS OF THE THERMAL DECOMPOSITION PROCESS OF ASBESTOS WASTES FROM DIFFERENT REGIONS

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Abstract – Asbestos minerals were one of the most popular and cheapest raw materials used in the construction industry in the past. They were used primarily in the form of cement-asbestos composite material. Nowadays, we know that asbestos possesses carcinogenic properties. Due to this fact, asbestos was banned in many countries, especially in EU countries. All asbestos-containing materials are considered dangerous wastes and stored in special landfills, which causes significant environmental pollution. One of the proposed methods to solve this problem, may be thermal treatment during which the dangerous asbestos structure can be destroyed. Several asbestos-containing wastes from different countries were examined and compared. These asbestos-containing materials were characterised by chemical analysis (XRF) connected with mineralogical phase analysis by X-ray diffraction (XRD). The thermal decomposition of samples was studied by differential thermal analysis (DTA) and thermogravimetric measurements (TG/DTG). The material's behaviour at high temperatures was also studied using a high-temperature microscope. Moreover, computer simulations connected with the formation of the liquid phase were also carried out by specialised engineering software. In this stage, based on data presented in available literature related to chemical composition, the behaviour of asbestos waste from different countries was also analysed and compared. The studies have shown a significant difference in the behaviour of the tested cement-asbestos materials from different countries under high-temperature conditions. This may affect the prospects for reusing neutralised asbestos waste, especially in the context of the main mineral composition of thermally treated cementasbestos wastes. This fact implies possible directions for the economic management of such waste.

Keywords –Asbestos waste; cement-asbestos materials; FactSage calculation; mineralogical composition; thermal treatment

ACKNOWLEDGEMENT

This research was funded in whole by the National Science Centre, Poland under "Sonata 17" grant number UMO-2021/43/D/ST5/00356

https://doi.org/10.7250/CONECT.2025.101

ANAEROBIC DIGESTION OF SOLID LUBRICANT WASTE FROM STEEL WIRE DRAWING

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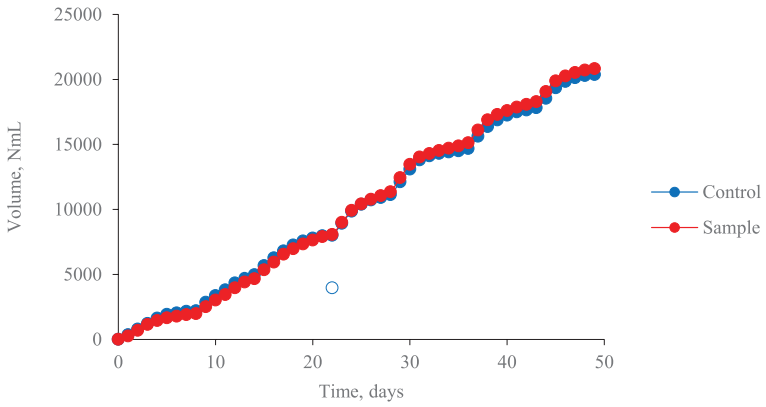
Abstract – In the framework of the STAR (Stearato dai processi di Trafilatura del filo di Acciaio come Risorsa) project, funded by the Italian Ministry of the Environment, the valorisation of stearate based solid lubricant waste from wire drawing process as an energy source is investigated. As for anaerobic digestion, preliminary tests determined a biomethane production in the range 500–900 L/kgVS, much higher than the production from animal waste (around 400 L/kgVS). On this basis, co-digestion of the waste with primary sludge from wastewater treatment was tested. The experiments used 2-litre reactors with a 1.5litre working volume, equipped with valves, gas bags, and connected to an Automatic Methane Potential Test System for real-time biomethane monitoring. Reactors, mixed every 30 minutes, were filled with anaerobic inoculum and sewage sludge, flushed with nitrogen, and maintained at 35 °C. Following a stabilization period, the reactors were operated in semi-continuous mode, with a hydraulic retention time of 3 weeks. Weekly, a digestate sample of 0.5 L was replaced by an equivalent amount of fresh substrate: primary sludge with 10%VS stearate waste in the sample reactor and primary sludge in the control reactor. Before the feeding, the substrate was concentrated to 30 g/L of total solid. This solid concentration was maintained to ensure an Organic Loading Rate of around 1 $g \cdot L \cdot d^{-1}$ and to enhance operational stability. Cumulative biomethane production as a function of time (Figure) reached up to more than 20 NL in seven weeks and did not show significant differences between sample and control, thus supporting the hypothesis that anaerobic digestion is a suitable treatment for this type of waste.

Keywords – Biomethane; primary sludge; semi-continuous reactor; stearate waste



Cumulative biomethane production

ACKNOWLEDGEMENT

This work has been supported by the Italian Ministry of the Environment (CUP H43C23000780001).

https://doi.org/10.7250/CONECT.2025.102

UNDERSTANDING HARD-TO-REACH: MENTAL MODELS BEHIND HOUSEHOLD WASTE PRACTICES

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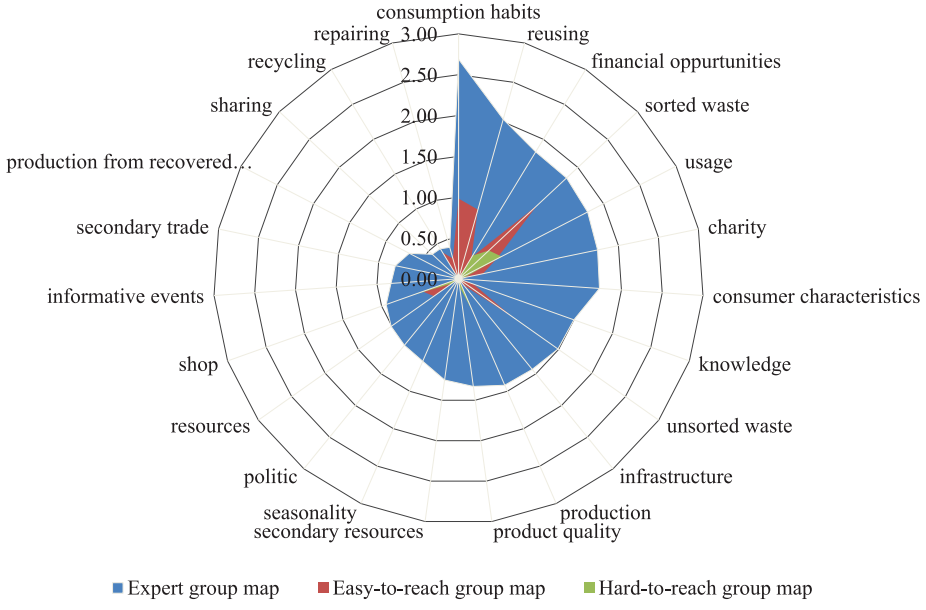
Abstract – An effective transition to a circular economy, including sustainable waste management practices, requires the active participation of all stakeholders, including households. However, a part of the population is often left out of public participation campaigns. This study investigates the mental models of such uninvolved or hard-to-reach groups, comparing them with those of easy-to-engage and expert groups, and analysing what determines their attitudes and actions. The study uses cognitive maps as an analysis tool to reveal the logic of group beliefs and behaviour that influence waste management choices. Using the Mental Modeler tool, the study simulates behaviour under different policy scenarios, highlighting differences in group behaviour. The results reveal a particularly low level of responsiveness of hard-to-reach groups to current waste management strategies. The study offers strategic guidelines for policymaking and adapting behaviour change measures based on understanding differences in group mental models. The conclusions emphasize the need for deeper engagement strategies tailored to each group. This study makes an essential contribution to the field of environmental communication and policymaking, especially with regard to the sustainable transition to a circular economy at the household level.

Keywords – Circular economy; cognitive mapping; consumer behaviour analysis; scenario analysis; waste management; waste reduction.



Comparison of concept centrality indicators in group maps.

https://doi.org/10.7250/CONECT.2025.103

SUSTAINABLE FIRE RETARDANTS FOR WOOD: BRIDGING THE GAP BETWEEN SAFETY AND SUSTAINABILITY

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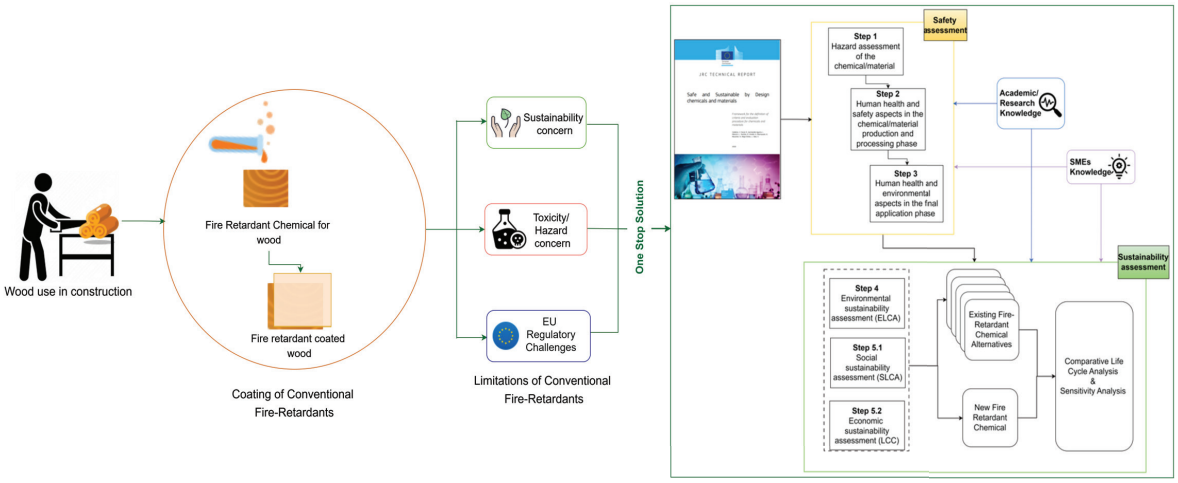
Abstract **–** Wood-based products contribute significantly to Latvia's and Estonia's GDPs, playing a crucial role in their economies. Wood is increasingly being promoted as a sustainable alternative in the construction sector as a renewable, easily processable, and high-strength material. However, its inherent flammability presents a major safety concern, necessitating the use of fire-retardant treatments. While effective in enhancing fire resistance, traditional fire-retardant development often poses environmental and human health risks due to their toxic components, less environmental friendliness, potential indoor air quality hazards, and economic infeasibility. With the increasing regulatory restrictions under European Union framework, there is a pressing need to meet the regulatory and market demands for environmentally friendly, efficient, and economically viable fire retardant. This review follows the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analysis) methodology to ensure a systematic and transparent selection of studies related to fire retardant chemicals for wood products. Through PRISMA screening and analysis, this paper provides a comprehensive evaluation of fire-retardant chemicals for wood, assessing their safety, fire performance, and environmental impact through the lens of the Safe and Sustainable by Design (SSbD) framework. The paper critically examines the limitations of conventional fire-retardants, including their toxicological concerns, persistence in the environment, and compliance challenges with EU regulations. The implementation of SSbD principles in fire-retardant design offers a viable pathway towards safer, high-performance, and sustainable solutions. By integrating regulatory compliance with sustainability-driven innovations, this review outlines key considerations for developing new fire-retardants that meet technical, safety and environmental standards. Research gaps, policy challenges, and industrial opportunities are highlighted to facilitate the wider adoption of sustainable fire-retardant solutions for wood applications. Ultimately, this review underscores the critical need for an industry-wide shift toward holistic, sustainable fire-safety strategies, ensuring that wood remains a viable and eco-friendly construction material without compromising fire protection standards.

Keywords **– Construction products; European regulations; Fire protection chemicals; Non-toxic flame-retardant coatings; PRISMA methodology; Safe and Sustainable by Design (SSbD)**



Safe and Sustainable by Design (SSbD) Framework for new Fire-retardant Chemical

Challenges, Regulatory Constraints, and Sustainable Frameworks for Developing Fire-Retardants in Wood Products.

ACKNOWLEDGEMENT

This work is supported by the ERDF, Interreg Estonia – Latvia program, project "Development of wood flame retardants with low environmental impact (FireStop)" project No. EE-LV00014.

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Co-funded by the European Union
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