BOOK OF ABSTRACTS

of the 1st International Conference on Green Innovation and Circular Economy Advancing Green Technologies and Circular Economy through Innovation

Editor: Prof. Konstantinos Aravossis

Athens, Greece
20-23 October 2024

GRICE

International Conference on Green Innovation and Circular Economy

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Editor's Preface

The 1st International Conference on Green Innovation and Circular Economy (GR-I-CE) 2024 is a unique, hybrid, International Conference that combines high quality academic presentations with the development of collaborative networks. The main goal of the Conference is to encourage discussion amongst stakeholders involved in green innovation and circular economy, such as research centers, businesses, public institutions, universities, SMEs, NGOs, startups, decision makers and innovators.

During the conference, academics, researchers, start-ups and business representatives will exchange knowledge and develop synergies in the fields of environmental remediation, waste management and sustainable development, presenting circularity and innovation solutions. In fact, the participants can schedule meeting sessions with other participants (i.e. Academics, Researchers, Startups and Companies Representatives) using a dedicated platform with scouting and searching features, dedicated for carrying out B2B, B2A and A2A meetings, offering a unique opportunity for all participants to meet each other, exchange ideas and discuss cooperation opportunities.

GR-I-CE 2024 offers the opportunities for researchers to present their research and publish their work after the Conference in Special Issues of prestigious international scientific journals, while entrepreneurs and innovators can engage with academics and explore avenues for transforming visions into sustainable businesses.

The scientific scope of GR-I-CE 2024 covers all sustainability themes, focusing on green innovation and circular economy research and applications. Green innovation focuses on developing environmentally

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friendly technologies, reducing resource consumption, and mitigating climate change. On the other hand, a circular economy emphasizes the reuse, recycling, and repurposing of products, minimizing waste and conserving resources. The combination of these concepts forms innovative circular solutions, contributing to economic growth and long-term planet viability. The main research topics include:

Circular Economy

- Improved Waste Management
- Circular Water Management
- Circular Design
- Circular Business Models
- Circularity Evaluation
- Circular Supply Chains
- Productivity and Innovation Measurement
- Strategy and Innovation Management
- Circularity and Innovation Standards

Green Innovation

- Innovation Policies and Instruments
- Innovation and Creativity
- Open Innovation
- Knowledge Transfer
- Digital Transformation
- Green Technologies
- Optimization Theory and Applications
- Sustainable Materials and Technologies
- Sustainability-Oriented Innovation Management
- Green Entrepreneurship

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Environment and Sustainability

- Climate Change
- Natural Resources Management
- Environmental Planning and Engineering
- Environmental Economics
- Sustainable Business Models
- Sustainable production and consumption
- AI and Sustainability

Decision Policies and Strategic Planning

- Economy Transformation Perspectives
- New Education Approaches
- Inclusive Green Transition
- Foresight
- Energy Policy and Management
- Energy Transition
- Decision Support System
- Supply Chain Management and Logistics

Finally, the editor would like to thank:

- The authors of the papers, for their scientific and insightful contributions;
- The reviewers of the papers, for their assistance in ensuring high scientific standards;
- The Supporters of GR-I-CE 2024, for their invaluable support;
- The cooperating International Scientific Journals, for their contribution in disseminating the research presented during the Conference;
- The Community Partners of GR-I-CE 2024, for their contribution in promoting the Conference and its impact;

- All involved participants, for their involvement in the exchange of knowledge and insightful research;
- Grafima Publications for their collaboration as well as their contribution to the editing of the Conference's Book of Abstracts.

The Editor
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Environment and Sustainability

Decision Policies and Strategic Planning

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Circular Economy

A conceptual sustainability performance measurement framework for circular supply chains

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Abstract

Sustainability concerns in supply chains have become increasingly pronounced due to the environmental, social, and economic impacts of global production and distribution networks. These challenges encompass issues such as the significant carbon footprint of transportation and logistics, the proliferation of waste from excessive packaging and disposable products, and the depletion of natural resources through extraction and consumption. To address these challenges, Circular Supply Chains (CSC) have emerged as a paradigm shift in supply chain management. Circular supply chain management is the integration of circular economy (CE) paradigm principles into supply chain management. Unlike traditional linear supply chains, which follow a 'take-make-dispose' model, circular supply chains aim to close the material and energy loop through the restorative and regenerative cycles with a vision of zero waste. Sustainability is operationalized inside a circular supply chain through strategies of the Circular Economy (CE). The circular strategies include the 3R, 4R, 6R or 9R frameworks. The circular strategies may not necessarily lead to more sustainability. To this effect, any decision regarding the implementation of circular practices inside a supply chain to obtain more sustainability depends upon the performance measurement of circular supply chains. So, a performance measurement system for circular supply chains is needed. The current literature lacks a holistic performance measurement system that addresses the complex relationships between circular strategies and the sustainability performance of circular supply chains. To address this gap, the

objective of this study is to propose a holistic conceptual performance measurement system (PMS) for circular supply chain management (CSCM). To do this, initially a literature review has been carried out with the following research question: "How can the impacts of CE strategies on the sustainability performance of circular supply chains be assessed holistically?"

Based on the results of the literature review, a holistic PMS for CSCM should: Address all circular supply chain stages i.e., Plan, Source, Make, Deliver, Use, Return, and Enable, Address the full lifecycle of products and materials within the CSC, ensuring a more comprehensive assessment of circularity efforts across all stages; Encompass all the three dimensions of sustainability performance i.e., environmental, economic & social to assess sustainability holistically; Integrate multiple CE strategies to reveal synergies and trade-offs between strategies, guiding more effective implementation of circular practices. To satisfy these requirements for a holistic PMS for CSCM, a conceptual multi-dimensional, multi-criteria performance measurement framework is proposed.

The proposed framework has three dimensions, triple bottom line (TBL), circular economy strategies and circular supply chain processes.

Triple Bottom Line: The TBL dimension comprises environmental, economic, and social sub-dimensions. This dimension helps in capturing the sustainability performance holistically.

CE Strategies: The second dimension of the framework has the categories of CE strategies. There is no exhaustive R framework that includes all the strategies through which sustainability can be operationalized inside CSCM. However, the various CE strategies can be categorized as prevention strategies, resource optimization strategies and resource recovery strategies. These three categories are the sub-dimensions of the CE strategies dimension. By categorizing performance measures according to the CE strategy they align with, the framework enables the identification of how specific circular economy practices contribute to overall sustainability goals.

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Circular Supply Chain Processes: The third dimension is the circular supply chain processes. It has the CSC process based on the SCOR framework. Aligning performance measures with specific CSC processes provides clarity on where in the supply chain circular and sustainability efforts have the most impact, facilitating targeted improvements and optimization.

Keywords: *circular economy, sustainability, supply chain management, performance measurement, conceptual framework*

Unlocking the Potential of Olive Pomace and Wastewater: A Fractionation Approach to Sustainable Valorization

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Abstract

Olive oil production generates significant amounts of olive mill wastewater (OMW) and olive pomace as by-products, posing major environmental challenges due to their high organic load and potential for contamination (e.g., groundwater and soil contamination, odor pollution). OMW contains high concentrations of organic compounds, phenolic substances, and mineral salts, making it difficult to treat using conventional methods.

Several techniques have been investigated for OMW and olive pomace treatment, including physical methods for phenolic compound extraction and chemical and biological methods for organic load reduction. Natural treatment systems, such as constructed wetlands (CWs) and stabilization ponds, have also been studied as alternative solutions but are suitable for small-scale treatment.

Olive pomace, once considered a waste, has recently attracted the attention of researchers in an attempt to apply new fractionation techniques to attain the valorization of its constituent components, such as cellulose, hemicellulose, lignin, phenolic compounds, and more distinct fractions of stones, pulp, and water. The fractions can potentially be utilized for biofuel production, value-added chemicals, bioplastics, and composites, while the nutrient-rich fractions could be used as organic fertilizers, soil amendments, and animal feed additives. However, to date, those methods have not

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reached the desirable efficacy due to the poor biodegradability of olive pomace caused by its characteristic constituents. These methods remain expensive and not scalable for industrial usage.

PhenOlives has pioneered a cost-effective industrial solution for the valorization of OMW and olive pomace, addressing environmental concerns while simultaneously creating economic opportunities through the production of value-added products from this abundant by-product.

PhenOlives' solution holds significant importance for the olive oil industry, as it encompasses a comprehensive, readily applicable innovative approach. The key aspects of PhenOlives' patented process are:

1. **Recovery of Valuable Fractions**: The patented method enables the recovery and separation of multiple high-value fractions from olive pomace, including:
   - **Nutrient-Rich Pulp Fraction**: PhenOlives' method yields a pulp fraction abundant in polyphenols and other beneficial compounds, ideally suited for incorporation into functional foods, nutraceuticals, and dietary supplements.
   - **High-Quality Stone Fraction**: The olive stones, once considered waste, or exploited as an energy resource, are recovered as a valuable fraction. These stones serve as a sustainable and renewable alternative to fossil-based materials, finding applications in the production of bioplastics, composites, and other eco-friendly products.
   - **Clean Water Recovery**: Remarkably, PhenOlives' process enables the recovery of clean water, which is seamlessly reintegrated into the production cycle, promoting water conservation and minimizing environmental impact.
2. **Comprehensive Valorization**: By fractionating and recovering multiple components from olive pomace, PhenOlives' patented technology maximizes the valorization of this by-product, transforming what was once considered waste into valuable resources.

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3. **Circular Bioeconomy**: PhenOlives' approach aligns with the principles of a circular bioeconomy, where waste is minimized and resources are efficiently utilized, contributing to sustainability and environmental conservation.
4. **Innovative Process**: The patented process involves a unique and proprietary method for transforming olive pomace into high-value products, demonstrating PhenOlives' technological innovation and expertise in this field.

Through this innovative fractionation approach, PhenOlives not only addresses the challenges posed by olive pomace but also unlocks new avenues for sustainable and value-added products. By transforming what was once considered waste into valuable resources, PhenOlives exemplifies the principles of a circular bioeconomy, paving the way for a more sustainable and resource-efficient future.

Keywords: *olive pomace and wastewater valorization, circular bioeconomy, fractionation approach*

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Progress in Eco-Industrial and Circular Business Parks: Updated framework and cases from the Netherlands

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Abstract

To transition to a circular economy, eco-industrial parks (EIPs) and Circular Business Parks (CBP) are needed. However, developing EIPs and CBPs is complicated. Nevertheless, some EIPs that are successful with industrial symbiosis and utility sharing activities happening. For instance, there are only few case on EIPs and CBPs in the Netherlands reported. Therefore, the progress on EIP and emergence of CBP in the Netherlands is addressed in this paper asking: "How to facilitate the implementation of industrial symbiosis and utility sharing activities in EIPs in the Netherlands? To answer this question, the factors for the success of industrial symbiosis and utility sharing in EIPs were identified through the literature review to update the framework of Eilering & Vermeulen (2004). Three new factors were added, leading to ten factors important to implement industrial symbiosis and utility sharing when developing an EIP or CBP. The factors are: (1) vision and ambition, (2) location-specific physical features, (3) location-social specific features, (4) business-specific features, (5) proposed measures, (6) organisation of decision-making, (7) policy instruments, (8) economic features, (9) external context, and (10) serendipity.

The refined framework was applied to three successful parks in terms of industrial symbiosis and utility sharing: Inno Fase in Duiven, Industrial Park Kleefse Waard in Arnhem, and Biopark Terneuzen in Zealand. Data collection took place via semi-structured interviews with respondents for each case study. Findings show that industrial symbiosis and utility sharing activities could be identified at all three parks. Inno Fase is engaged in many industrial symbiosis activities by exchanging different types of flows such as biomass, biogas, water, electricity and heat, while othersynergies are under development. At IPKW mainly utility sharing activities were found, including a gas-fired power plant fed by the on-site wastewater treatment plant. Other smaller flow exchange activities include plastic, biomass, and wood reuse by some of the companies. The case of Biopark Terneuzen revealed that the exchange of flows ass typically used in the literature is not accurate because some intended exchanges never materialized. A cross-case analysis was conducted to identify what sub-factors or barriers were present in every case. In total, 63 sub-factors could be identified that influenced the success of the park. It appears that social innovation is key to implementing industrialsymbiosis and utility sharing.

Keywords: *circular economy, eco-industrial parks, industrial symbiosis, circular business parks, social innovation*

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Advancing Circular Design in Architecture: A Framework for Decision-Making Mechanisms

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Abstract

With the rapid urbanization, the depletion risk of resources and the increasingly felt environmental impacts of the climate crisis, the necessity to reconsider prevailing understandings in design and construction activities has emerged. This entails a shift from the current linear economic model towards a circular economy model, involving the reduction of raw material and energy consumption, and the reevaluation of these resources through adaptable parameters such as reuse, reduction, remanufacturing, and repair. Circular design embodies a systemic comprehension of design-production practices, centered around the circular economy model. It involves envisaging the life cycle and usage scenarios of structures and their components from the outset of the design phase. To effectively implement this comprehensive approach of circular design, management of architectural data within architectural design-production processes is essential, enabling informed design-construction decisions.

Existing studies have explored architectural software, their program extensions and theoretical flow diagrams for analyzing the circularity of architectural structures. However, there are limited studies on decision-making mechanisms throughout the design-to-construction processes. Increasing academic research on the theoretical framework of decision-making mechanisms is expected to enhance the consistency and accuracy of decisions made. Although the evaluation criteria for circular design remain ambiguous, increasing academic research in this field will lead to both the

refinement of conceptual frameworks and the emergence of realistic and feasible projects.

Questions such as the extent to which decisions made during architectural design influence the circularity of structures and whether circular design criteria can be established as decision-making mechanisms based on architectural sub-components form the basic motivation of this study. The aim is to develop a decision-making mechanism capable of verifying compliance with circular design criteria during the architectural design phase. It is envisaged that this decision-making mechanism will operate based on software and be integrated into a machine learning model, thus proposing a system that can be integrated into design-production-logistics-construction processes. Within this study, the facade cladding component was selected from the Brand' shearing layers diagram as a reference, and a decision-making mechanism assessing the compliance of its subsystems with circular design criteria was developed. This will enable the measurement of circularity at the building component-material level from the early stages of design.

This study aims to put forward a theoretical framework for the development of decision-making mechanisms for structures designed and repurposed within the realm of circular design. By incorporating inputs from researchers across various disciplines, it is envisioned that the conceptual content can be further elaborated and refined. The integration of the decision-making mechanism into a machine learning model was achieved through the preparation of a flow diagram, and an artificial decision-making mechanism was created using synthetic data through a decision tree and random forest algorithms in a Jupiter notebook.

It is believed that further contributions from diverse disciplines such as economics and engineering, in addition to architecture, are expected to broaden the array of decision mechanisms, allowing for the definition of more complex relationships and their evaluation within the context of circular design.

Keywords: *circular desing, circular decision-tree, circular machine learning flowchart*

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Energy Intensive industries decarbonization circularity path: Steel, Glass and Cement industry success cases

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Abstract

Europe is striving to become the world's first climate-neutral continent by 2050 and reach a decarbonization rate of 80-95% (compared to 1990) by 2040. Energy-intensive industries (EIIs) are considered a notoriously 'hard to abate' sector and a critical asset for climate transition, therefore a clear long-term vision and strategy are required to remain competitive while contributing to the decarbonization targets of the EU.

The EIIs ecosystem includes a wide range of high-energy intensity sectors correspond to 24% of EU energy consumption and 16,5% of greenhouse gas (GHG) emissions produced mainly from fuel combustion, electricity production, and process emissions. In this regard, innovative solutions are necessary to transform the way those sectors operate. Efficient industrial processes, integration of renewables and renewable hydrogen, electrification of industrial processes, digitalization and industrial symbiosis are among them. Furthermore, re-usage of obtained materials and alternative raw materials are crucial. All EIIs are highly resource-dependent, and nearly all energy-intensive industries already rely heavily on materials recyclability. For most basic materials therefore, enhanced circularity will become even more critical over the next decades, as a strategy to reduce emissions, reduce energy use, maintain supply security, and enhance production and growth while reducing costs.

We are highlighting steel, glass and cement industrial cases as they stand out among EIIs in promoting circular economy concepts. Cement manufacturing process is energy intensive, corresponding to 50-60% of the total production cost, and is highly targeting in usage of alternative raw materials in order to maintain its sustainability. Steel industry is also an essential factor in the development and deployment of innovative, CO2-mitigation technologies, improving resource efficiency and fostering sustainable development in Europe while steel is 100% recyclable therefore a fundamental part on the circular economy pathway. Glass manufacturing industry is energy intensives due to the need for heating the raw materials at a very high temperature, in order to melt, coat and annealing glass containers, fibers or flat glass slides. However, glass industry innovates in effective adaptation of reuse and recycling strategies.

In this review, are demonstrated the projects implementation under various forms of renewable energy sources and circular pathways strategies, in the productive processes of cement industry, glass industry and steel industry towards sustainable industrial decarbonization. More specifically, Milaki Cement Plant of HERACLES-Holcim, Ebroacero S.A. steel industry, Arcelor Mittal Ghent steel plant, Verallia S.A. Spain glass industry and Heidelberg Materials Cement Plant are presented as good practice examples towards sustainability.

Keywords: *energy intensive industries, circularity, decarbonization*

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The economics and policy of decarbonisation carriers: how, when and where to abate

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Abstract

Energy supply is responsible of more than 80% of anthropogenic CO2 emissions whose rapid accumulation in the atmosphere is in turn responsible of unsustainable global warming(overshoot of 1.5 °C) to avoid which carbon neutrality should be achieved in a few decades."Accelerating" the(supposed) decarbonization of energy supply in sectors different of power generation is commonly considered a necessary step to reach such a goal. Nevertheless, this article points out that (at least in principle) this kind of "acceleration" (e.g. through indiscriminate targets and stringent policy provisions, including over-subsidies for RES producers) might not be desirable. In fact, the allocation of renewables (among different uses, different abatement carriers and over time) is by no means a trivial choice. To explain why, looking at the different end uses (including "hard to abate" ones), we analyse the main energy carriers of abatement (electrification, biomethane, hydrogen and e-fuels), looking for intertemporal and interspatial optimization of renewables allocation, by estimating the LSCOA (levelized social cost of abatement), and by accounting for uncertainty about energy prices and renewables costs. The principal conclusion is that, before electricity supply is fully decarbonised, only greenfield biomethane should be allocated to thermal and transport uses, in the meantime "accelerating" the allocation of electric renewables to power generation. Only when this latter is almost completely decarbonised, policies should promote deep penetration of

electric renewables in the other uses. Otherwise, the risk is to significantly slowdown the entire process of energy supply decarbonization, and even to undermine the achievement of the progressive climate targets.

Keywords: *energy supply, decarbonisation, renewable energies, social-cost benefit analysis*

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Optimizing Water and Energy Use in Industry: A Decision Support Framework for Industrial Wastewater Treatment and Reuse

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Abstract

Water demands for the industry are increasing, with the manufacturing sector accounting for approximately 40% of total water extractions in Europe (Capa et al 2022) and representing over 70% of total industrial water use in many European countries (Eurostat, 2022). This surge in demand is causing the depletion of underground water resources, reducing the flow of rivers and lakes, escalating water pollution, and endangering the sustainability of aquatic ecosystems.

A sustainable solution to address water scarcity and rising water demand involves the treatment and reuse of industrial wastewater (Lazarova et al., 2001). This approach provides dual benefits: it alleviates pressure on drinking water sources and reduces the environmental impact of industrial wastewater discharges. By treating and reusing their wastewater, industries can reduce their reliance on external freshwater supplies and promote sustainable practices. Wastewater Treatment Plants (WWTPs) play a vital role in implementing such practices by improving wastewater quality to enable reuse, thereby reducing a plant's freshwater consumption. However, WWTPs require significant amounts of energy to operate, with energy needs comprising 25-40% of the operating costs of a conventional WWTP.

The assessment of the energy consumption of a WWTP as well as the selection of water reuse applications are complex issues that must be considered holistically as they are influenced by various factors (e.g. WWTP

capacity, type of industry, national legislation, available area) (Arampatzis et al., 2019) and there is not a single available solution. Consequently, analyzing the water-energy nexus in the impact assessment of wastewater reuse applications is a high-priority issue for sustainable energy consumption and the development of new sustainable paradigms for the water cycle.

This study aims to develop a decision support framework (DSF) for manufacturing industries to select reuse applications for their treated wastewater, based on the nexus of water (WF) and carbon (CF) footprint. The DSF is comprised of the following steps:

Step 1: Evaluation of the existing energy consumption in the WWTP of an industrial plant

Step 2: Selection of the appropriate water reuse application

Step 3: Selection of the appropriate wastewater treatment process

Step 4: Process design

Step 5: Environmental assessment though WF and CF analysis and evaluation of the total water recovery system

The study also examines the implementation of the Decision Support Framework (DSF) in a brewery. Breweries use large amounts of water for beer production and for cleaning equipment and facilities. Applying the methodology to the brewery demonstrates that the reuse of treated wastewater can reduce freshwater consumption and enhance the sustainability of industrial operations. The results indicate that reusing treated wastewater in the brewery can meet much of the non-potable water needs, such as cooling and cleaning equipment, thus reducing the pressure on natural water resources. Furthermore, water reuse decreases the total WF of the plant without significantly increasing the CF, as the processes selected (Step 3) and designed (Step 4) for wastewater treatment require low energy.

Keywords: *water footprint, wastewater reclamation and reuse, energy consumption, manufacturing industry*

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Impact assessment of photovoltaic panels with life cycle analysis techniques

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Abstract

Photovoltaic (PV) technologies are developing rapidly as a result of their ability to reduce energy consumption from conventional sources as well as the growth of global energy expenditures. Nevertheless, several impact categories during the PV panel life cycle occur and some principal sectors are affected. These impact categories are assessed by applying life cycle analysis (LCA) techniques through various software programs, databases and methods. Such analyses of energy technologies are crucial, as they can reveal the occurrence of hazardous emissions at distinct life cycle stages. In the present paper, a PV panel impact assessment through life cycle analysis is carried out.

Photovoltaic (PV) systems hold a crucial role in the much-anticipated shift from the conventional model of electrical energy generation based on fossil fuels to a more sustainable one based on renewable sources. PV panels are the fundamental building block of PV systems, converting solar energy into electrical energy with a certain degree of efficiency. The utilization of as much of the available solar energy as possible has been a long-established goal of renewable energy researchers. It has also gained the interest of governments, electric utilities, as well as individual residential and commercial consumers seeking to achieve energy self-sufficiency and reduce

harmful emissions associated with environmental degradation. However, it has also been established that, contrary to popular belief, PV panel technologies can, in fact, be associated with harmful emissions. A thorough evaluation of the true environmental effect of photovoltaic panels requires looking at every stage of their life cycle, from the procurement of raw materials to their eventual disposal. Research on potential mitigation strategies and more efficient use of solar energy can be aided by the assessment of the life cycle effects of PV panels.

PV technologies can be distinguished into several categories depending on their production process, cost and efficiency. They consist of PV panels exploiting solar energy and contributing to the global pursuit of a more sustainable future. LCA methodology can contribute to this cause by assessing PV panel impacts during their life cycle. These factors have an influence on ecosystem quality, ecosystem health, and human health.

More precisely, a combination of PV technologies –-–monocrystalline, multicrystalline, copper indium gallium selenide (CIGS), amorphous, and ribbon–-– is studied, by means of a system configuration retrieved from the Global LCA Data Access (GLAD) network. The impact categories of ozone depletion, human toxicity, particulate matter, ionizing radiation, photochemical ozone formation, acidification, eutrophication, and ecotoxicity, as well as the sectors of human health, ecosystem quality, and environment, are assessed using the openLCA software, the ecoinvent database, the eco-indicator 99, IMPACT 2002+, ReCiPe, and TRACI methods.

Keywords: *photovoltaic technologies, photovoltaic panels, life cycle analysis, life cycle impact assessment*

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Influence of Social Inclusion on Recycling Cycles of Circular Economy: Cases of Waste Picker Organizations in the Global South

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Abstract

A circular economy implies more than efficient flows of materials and waste reuse. Circular economy implementation must consider stakeholder involvement, social cohesion, and educational programs, specifically in the global South. In these places, the social dimension indicates some barriers and challenges of resistance to multiscale changes. However, the social implications of the circular economy have been limitedly explored. Waste pickers organizations and informal workers represent an opportunity to reincorporate waste in recycling cycles. Also, waste picker inclusion in circular economy recycling cycles is a potential source of social benefits, offering better work and socio-economic conditions. However, associations and organizations of waste pickers' impact on circular supply chains and networks are underestimated and controversial. This study aims to understand how waste pickers' role impacts the circular value network of recycling. For that, we collected qualitative data from deep interviews of multiple cases of waste picker organizations and enterprises that use recycling as a circular strategy in Colombia and Brazil. We propose a novel framework to understand what factors drive waste pickers' inclusion and how waste pickers' role influences

the environment in circular economy transformation. We used a causal-loop perspective to analyze the relationships of waste pickers organizations' inclusion with other actors of recycling networks. With this framework, we verified that the role of waste pickers depends on the improvement of their skills, conditions, and infrastructure for recycling, government, and private incentives, politics of local and national governments, and participation of waste pickers intermediaries as well as universities and consulting firms. These variables positively influence the waste recovery flows and closing loops of materials. In this inclusion process, enterprises, intermediaries, and local governments are focused on facilitating skill development in business and waste management, offering incentives, and reinforcing transparency and trust between circular network actors. Some actors, such as multinational companies, exert a positive force on the accelerating waste pickers' inclusion process in the reverse cycle of materials with some recycling and collection technology development, which is a fundamental factor in waste pickers' inclusion. However, this factor does not guarantee the inclusion and improvement of waste pickers' conditions. Also, creating financial models of profit and consumer sensitization impacts solid waste collection, accelerating the waste picker inclusion process. Other aspects, such as political waste instruments and sustainability trends, potentialize circular implementation conditions through public incentives and interests alignment of different actors for recycling. The critical theoretical insight is that waste picker organization inclusion recognizes waste pickers as suppliers, which fosters social impact and contributes to circular economy transformation. These advances illustrate how including waste picker organizations can significantly influence the reverse flow of materials and create diverse benefits across environmental, economic, social, and institutional areas. This theoretical contribution to the circular economy and system dynamic streams could support policy development applications, enhance circular economy safety conditions, and empower waste pickers organizations. Finally, this framework

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demonstrates that social inclusion helps raise awareness of the roles and services of waste pickers, dignifies their work, separates it from poverty, and emphasizes the importance of circular economy in promoting circular economy transformation and more sustainable practices, highlighting the potential for positive change.

Keywords: *social inclusion, circular ecosystem, social responsibility, clausal-loops, social dimension*

Sustainable Homes: Comprehensive Energy Audit of a Residential Building

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Abstract

Globally, the energy efficiency of a residential building greatly influences the health of individuals. According to the Environmental Protection Agency (2024) we spend 90% of our time indoors hence it is important that the air indoor and the building efficiency is safe providing comfort, cost-effectiveness, and minimizes operational emissions of greenhouse gases and other pollutants within our immediate environments.

Energy audits of residential buildings are one of the key diagnostic tools that provides pathways to be explored. All houses have non-ideal openings that permit the inflow and outflow of air which results in energy loss within the thermal envelope. Determining the areas of leakiness and locating and taking steps to mitigate these problem results in the building been made suitable for use and ensures safety among home occupants. Any penetrations in the thermal envelope of the building can be a source of air leaks majorly observed as gaps around doors and windows.

This energy audit is done to determine the leakiness or tightness of a residential two-bedroom building in New Mexico, United States to determines major sources of the building energy consumption. Using different instruments such as IR cameras to determine energy losses within the thermal envelope, blower door test for leakage, sol metric sun eye for the optimization of solar panel systems such as photovoltaic systems and hot

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water systems, and analysis of the gas and electricity bills over an extended period using the kill-a-watt instruments to determine the current energy consumption of the building.

This building we tested was found to have high energy leakiness as compared to the average building. The leakage shows about 13.9air changes/air as compared to the average house in the United States of 3.5air changes/hr, energy consumption from electricity reached higher levels within the summer and winter months with heaters or cooler resulting in higher consumption of energy. These measurement and modeling tools help identify major energy losses and provide suggestions for improvements in the building, improving efficiency and lessening environmental footprint and reducing the energy consumption within the home

Keywords: *energy audit, air quality, energy efficiency, greenhouse gases*

Waste to chemical: an innovative approach to achieve zero CO_2 emission target

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Abstract

The waste to chemical technology is perfectly in line with the aim of GHG emissions reduction. The simple scheme of converting the carbon and hydrogen contained in waste through partial oxidation allows to reduce GHG emissions because part of the carbon remain in the molecule of methanol. In this article we are going to show how to reduce almost to zero CO_2 emission when we convert waste into methanol.

The waste to methanol technology is composed of different sections:

- Gasification - the core of the process where solid waste is converted into syngas;
- Cleaning and purification - main pollutants contained in waste are removed from syngas;
- Conditioning - required to achieve the proper syngas composition for methanol synthesis;
- Methanol synthesis and distillation – adjusted syngas reacts into conventional synthesis loop and final purified methanol is produce.

Conditioning is actually required since the syngas coming directly from gasifier reflects the composition of waste – about 50%w of carbon and 8 %w of hydrogen – and it presents a low methanol ratio ($\frac{H_2-CO}{CO+CO_2}$). Indeed, methanol reaction stoichiometry required a defined methanol ratio, equal at

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least to 2. To enhance methanol ratio a fraction of syngas is sent to water gas shift reaction, increasing H_2 but producing CO_2, then CO_2 is separated and recovered by PSA or amine unit. In this way, the proper syngas composition is achieved. But CO_2 is fatally produced. Coming from a separation unit this CO_2 stream is highly pure and can be directly stored or used for several applications, such as carbon fertilization or food & beverage sector.

Nevertheless, conditioning can be done differently: pure hydrogen stream can be directly mixed to syngas in order to reach the proper methanol ratio. With this solution all the carbon contained in waste is converted into methanol. To have a real benefit in terms of environmental impact of the technology, H_2 should be green, i.e. it has to be produced through electrolysis powered by renewable energy. Electrolytic H_2 integration enhances the strength of waste to methanol technology: the yield of the process is doubled, meanwhile zero CO_2 is fatally produced by the process.

In conclusion, when renewable energy will be widely available, the integrated waste to methanol process will become, at once, a threefold beneficial technology for:

- waste conversion ensuring material recovery;
- zero emissions methanol production;
- long term energy storage.

Keywords: *waste-to-methanol technology, greenhouse gas (GHG) emissions reduction, syngas conditioning, green hydrogen integration*

Reusability Metrics of Electronic and Mechanical Components for Second-Life Battery Systems

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Abstract

In the near future, the number of electric vehicle (EV) batteries, no longer appropriate for automotive use, will dramatically increase. At the end of their warranties the expected EV batteries nominal capacity will vary between 70 – 80 %. This is also the First-Life End-Of-Life threshold adopted by most within the automotive industry. Whereas these EV batteries will not be appropriate for automotive applications, they could be repurposed for stationary energy storage systems as Second-Life batteries.

The new Battery Regulation of the European Union is enforced as of July 2023 and ensures that batteries within the EU have a low carbon footprint due to the reduction of resources required, the reduction of raw materials (from non-EU countries) and an increase of reuse and recycling in Europe. The result of this act is the shift to a circular economy growth model, the increase in security of supply for raw materials and energy overall and the enhancement of the EU's strategic autonomy.

Working towards the direction of the circular economy growth model, we present the first steps a battery industry must take for the repurposing of 1st life traction batteries (industrial EV's) for an industrial stationary energy storage system.

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More specifically, we address the issue of the reusability of first life electrical and mechanical components (except for the lithium-ion cells), and we introduce quantitative and decision-making tools for an automatic and safer choice of these components for the Second-Life applications.

The methodology of the reusability analysis of a Second-Life battery, includes the evaluation of the Bill of Materials (BOM) list of the battery system, the grouping and sorting of the different materials, their evaluation from engineers and blue-collar workers and the final assessment with a decision matrix. The criteria introduced in the decision matrix include the price, the volume, the warranty, the environmental impact, the availability (in the market) and the recyclability of the electrical and mechanical components. The results of this assessment show a trend on how many of the electrical and mechanical components are suggested to be recycled or repurposed for Second-Life applications based on each one of the main criteria we introduced in the decision matrix.

Whereas the reusability analysis tool, we introduce in this research, is built on the BOM list of a battery system, it can be adopted by other industries (automotive, electronics, etc.) as well. We must note that, although it gives a good estimation of the battery components that we should repurpose or recycle, the first question that should put on the table regarding the reusability of any electrical or mechanical component, is if this reused component is safe for the consumer.

The transition from a linear to a circular economy growth model demands the transition from the theory to practice, breaking out of old models and introducing novel methodological approaches. The lessons of the circular economy approaches are accumulating – as they show that the gains from making the transition outweigh the effort and the economic risk.

Keywords: *green innovation, circularity, second-life batteries, reusability, lithium-ion batteries*

Removal of Heavy Metals from Industrial Wastewater Using Natural And Organically Modified Minerals

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Abstract
The reuse of industrial or municipal wastewater for irrigation is increasingly common due to its availability and the pressing need for effective disposal methods. However, this practice elevates heavy metal concentrations in water and soil. This study investigates the removal of heavy metals from industrial wastewater from the petroleum industry through an adsorption process using natural and organically modified minerals.

Petroleum wastewater samples were charged with Cr(III), Cr(VI), Cu(II), Mn(II), Ni(II), Cd(II), Pb(II), and Zn(II) ions at 10 mg/L concentration levels. The efficiency of adsorption by natural and modified zeolite and vermiculite was evaluated using adsorbent concentrations of 10 g/L with a pH of 4. Overall, the experimental results showed that vermiculite was more effective in removing pollutants from the wastewater. Lead and chromium removals using vermiculite were shown to be greater than 99% according to Atomic Absorption Spectrometry (AAS) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

Statistical evaluations have shown that the efficiency at which vermiculite removes pollutants is influenced by the mineral content, adsorption capacity, and percentage of removal. Similarly, zeolite's effectiveness depends on its adsorption capacity and rate of removal. The results indicate

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that both natural and organically modified minerals are effective in purifying industrial wastewater containing heavy metals, achieving removal rates that meet environmental standards.

Thus, this study highlights the potential of using vermiculite and zeolite as cost-effective and efficient solutions for treating heavy metal-laden industrial wastewater, offering a promising approach to mitigating the environmental and public health risks associated with heavy metal contamination.

Keywords: *absorption, wastewater, zeolite, vermiculite, heavy metal removal*

Application of Benders Decomposition for the Solution of Non-Linear Wastewater Treatment Network Design Problem

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Abstract

The growing global climate crisis has intensified the need for sustainable resource management, particularly in areas facing increasingly frequent droughts. Water scarcity is becoming a critical issue for many nations, and as a result, stakeholders are turning towards innovative solutions like the circular economy of water to address this challenge. In this context, Wastewater Treatment (WWT) is a crucial policy that can play a significant role in tackling the water shortages, while protecting the environment. In this paper, the problem of the Wastewater Treatment Network Design (WWTND) is addressed, by taking into consideration various factors, such as the distance between the residential areas and the treatment plants and the estimation for the evolution of the towns' population in the future. These population growth projections are made in order to estimate the

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volume of wastewater generated in the future in every town and incorporate this parameter into the design.

Moreover, the costs of expanding existing network or building a new one is considered, in which different components are included such as the pipeline cost and the treatment plant cost. These components are inherently non-linear functions, as they depend on the volume of wastewater produced and treated within the network. More specifically, the cost functions are concave, meaning thatthe cost growth rate is smaller in large volumes of wastewater than the cost growth rate in small volumes of wastewater. The research presented in this paper builds on previously published work that focused on the application of piecewise linearization on the non-linear WWTND model and the straightforward solution ofthe derived linearized model. However, in the herein work,to be able to solve large scale instances, the classical Benders Decomposition method is implemented. The method is applied within two different approaches: a) "First Linearize, Then Decompose" (FLTD) and b) "First Decompose, ThenLinearize" (FDTL). In FLTD the Non-Linear Original Problem (NLOP) is transformed through piecewise linearization into a linearized model, which is solved by the classical Benders Decomposition. In FDTL, the NLOP is decomposed into a linear primal subproblem and a non-linear master problem, which is then linearized with piecewise linearization. Moreover, in order to further accelerate the solution procedure, Valid Inequalities (VIs) are proposed. These extra constraints are added into the master problem of Benders Decomposition in order to warm start it and offer better initial bounds, that will eventually need less iterations and computational time to reach convergence.

The developed methodology has been implemented on a real-world scenario in an area in Luxemburg. The study area includes 20 residential-industrial clusters located in the provinces of Mersch, Redange, and Capellen in Luxembourg. These clusters are currentlyconnected to 24

mechanical and biological wastewater treatment plants (WWTPs). The design time horizon for this model spans 50 years. The mathematical model determines the optimal state of the wastewater network at the end ofthe time horizon. The computational results show that FDTL outperforms FLTD, which could not solve the instance even after a significant amount of time. Furthermore, the use of VIs makes the FDTL even more efficient leading to the optimal solution in reduced computational time. Finally, regarding the resulted network configuration, it must be noted that the expansion of biological treatment plants is proposed against the mechanical ones, since the former have a lower cost per amount of wastewater treated.

Keywords: *benders decomposition, wastewater treatment, network design, non-linear programming*

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Optimal Network Design of Bio-Waste Recycling Bins in Cyprus

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Abstract

The Circular Economy (CE) has emerged as a pivotal concept in recent years, offering a sustainable alternative to the traditional linear economic model. As environmental concerns intensify, particularly around resource depletion and waste generation, the CE model presents a pathway to more sustainable growth. Its core idea is to promotereducing, reusing andrecycling of goods in a closed-loop system in which waste is minimized. One of the most critical areas where CE can make a significant impact is waste management, as this sector plays a vital role in transforming discarded materials into valuable resources.

While significant progress has been made in recycling materials like paper, plastic, and glass, there remains a substantial gap in the recycling of biological waste, particularly in European Union (EU) member states. Biological waste, or biowaste, includes organic materials such as food waste, garden waste, and other biodegradable materials. Despite the high potential

for converting biowaste into compost or energy, many EU countries have yet to develop widespread, efficient systems for biowaste recycling. This paper seeks to address that gap by studying the optimal placement of a network of biowaste recycling bins. This Facility Location Problem (FLP) is formulated as a Mixed-Integer Linear Problem (MILP) that incorporates social, economic, spatial and environmental parameters.

The model is implemented on Cyprusas a case study, where the whole country is divided into its postal sectors. Each sector is treated as a discrete area for the purposes of the model. One of the key challenges in implementing a biowaste recycling system is estimating the amount of biowaste generated in each sector. To address this challenge, a sophisticated technique is proposed for biowaste estimation, which takes into account demographic factors from the Statistical Service of Cyprusand values of the CE indicators determined by the European Commission. Geographic Information System (GIS) data is processed using theopen-source software“QGIS”. This detailed spatial analysis allows the model to make more accurate predictions about where recycling bins are needed most.

Also, two types of public bins are considered with a capacity of 240 and 1100 liters and different purchase and installation costs. Once the biowaste generation estimates are integrated into the mathematical model, the optimization process begins. The model calculates how many biowaste recycling bins should be installed in every postal sector based on various constraints, such as budget limitations. A sensitivity analysis is also conducted to explore how changes in the available budget affect the optimal placement of the bins. This analysis provides valuable insights into how different levels of investment can influence the effectiveness of the recycling network. The results of the optimization process are visualized using heatmaps in QGIS, which provide a clear and intuitive representation of where biowaste recycling infrastructure should be installed.

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The methodology developed in this study is a powerful tool for decision-makers and stakeholders by providing a rigorous, data-driven approach that can help guide investment and policy decisions. The integration of spatial, economic, and environmental data ensures that the proposed solutions are both practical and sustainable. Moreover, the sensitivity analysis offers flexibility, allowing stakeholders to make informed decisions based on available resources and future projections.

Keywords: *circular economy, biowaste bins, network design, facility location*

Green Innovation

Implementing Circular Economy Models via Open Innovation: A literature Review

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Abstract

To overcome the modern environmental challenges, the European Green Deal has set a clear vision for transition towards Circular Economy (CE), aiming to transform the European Union (EU) into a resource-efficient and competitive economy. To achieve this transition, the EU has recognized the importance of innovation in accelerating circularity in all levels by building, through the innovation process, new and suitable to each case CE models. Lately, a particular innovation model has been recognized by the literature and the practitioners as a strong answer in building and implementing CE models, named Open Innovation (OI). OI contributes mainly by promoting collaborations and by the intensification of knowledge, solutions and know-how sharing between the collaborators, while traditional closed innovation, limits the innovation process into a closed environment.

CE in all levels and sectors has been significantly researched throughout the last decades, qualitatively and quantitatively. On the other hand, regarding OI, the research may not be as thorough as in the case of CE themes but has also been researched significantly.Focusing on CE models implementation through OI, it is a recent phenomenon, and little is known about the integration of the two themes.

The subject of this paper is to review the existing literature on implementing CE models via OI, providing the reader with substantial

insights on current practices, barriers, and prospects of the selected approach. Towards that end, a systematic literature review is being carried out, focusing specifically on the meeting point of CE and OI, as a newly introduced subject in research and practice. The vast scope of CE is categorized using the prevalent three implementation levels approach: macro, meso and micro level, to organize both the research work and the conclusions. Keys aspects on OI include the organizations' OI capacity, referring especially to culture, organizational structure, and practices.

This review aims to collect and highlight insightful information on both research and practice, supporting the work of policy makers, decision makers and executives or innovation managers in public or private organizations, that are engaged with the transition towards a circular economy, as well as the research community surrounding both CE and OI. Research gaps will also be pointed out, as well as new directions for future research on both subjects.

Keywords: *open innovation, circular economy, circularity, openness*

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Employing Additive Manufacturing to Promote Sustainability in Shipbuilding – A Paradigm of a 3D Printed Sensing Device

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Abstract

Additive manufacturing, also referred to as three-dimensional (3D) printing, is based on the melting, deposition, and solidification of an appropriate building material that leads to the production of a component with high-dimensional accuracy and a smooth surface finish, the degree of which is determined by the type of application. Until now, additive manufacturing has mostly been used for health and medical purposes; however, it progressively expands to many other manufacturing disciplines, significantly altering their production lines. The main reasons for this are the continuously evolving range of building materials with different application-specific properties and the ability to manufacture objects with complicated geometries on demand. Furthermore, the combination of 3D scanning and 3D modelling techniques enables fast manufacturing of defective replacement parts, prolonging the service life of obsolete equipment. Considering the above, it is safe to conclude that additive manufacturing can play a definitive role in the circular economy by reducing emissions and waste and minimizing transport and production

costs, thereby providing a significant boost to the economic system while promoting sustainability.

Although there have been some reports where additive manufacturing has been utilized in certain marine applications, for purposes such as the fabrication of specialized tools and structural segments of engines, its adoption has been limited because the marine industry does not necessarily benefit significantly from the same “drives” as other industries (e.g., creation of lighter components or patient-specific instruments). Thus, it is important that new, relevant "drives" should be explored in order to promote its widespread adoption. Potential “drives” could include the development of superior performing components, part consolidation, and digitalized spare parts.

Sensing devices are essential in ship operation and performance monitoring; the measured parameters are used to optimize the operation of specific subsystems in order to ensure acceptable performance, as well as for safety reasons. To maintain an on-board adequate quantity of spares for all sensing devices though is something vastly expensive; thus, only sensors required as “critical” spares (Section 10.3 ISM Code)are kept. Consequently, in most cases, items such as metal parts and internal combustion engine hardware (bearings, liners, and cylinder covers) are typically included in the inventory. Therefore, in the case of a sensor failure, the ship-owner or the management company has to face its production cost combined with the cost for its handling/packaging, while on many occasions, there is an extended waiting period. Additionally, when a ship is not new (e.g., over 15 years old), a significant percentage of the installed sensors are already outdated, and many are out of stock.

The innovative approach of this research is focused on the design, manufacturing, and characterization of a new, state-of-the-art fully 3D printed sensor for strain measurement in the shipbuilding industry. The manufacturing process is simple and requires only a single 3D printer. The

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employed building materials (filaments) are commercially available, while the sensing elements can be directly connected to the macroworld, overcoming the necessity of wire bonding. These factors significantly contribute to low fabrication cost, high availability (on-demand remote printing), ease of replacement, simplicity, and reliability. Overall, the successful fabrication of this specific paradigm paves the way for an innovative and more sustainable fabrication method for sensing devices, suggesting numerous potential applications in the shipbuilding industry and other industrial sectors.

Keywords: *additive manufacturing, FDM technology, sensors, maritime engineering, strain gauge*

Enhancing sustainability in manufacturing: the role of ontologies in planning & scheduling activities within manufacturing systems

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Abstract

Today's manufacturing is going through changes due to digitalization and the Industry 4.0 paradigm. In that sense, manufacturing systems are facing a transition from traditional systems to the ones more compatible with Industry 4.0. Digitalization is expanding itself all over the world and is consequently followed by a huge amount and variety of generated data that need to be formalized. Therefore, manufacturing systems need tools and approaches that enable them to extract and form knowledge efficiently from the vast amount of data collected throughout the systems.

Moreover, digitalization and smart manufacturing strive for sustainable development and a more sustainable-oriented performance at the industry level, as well as enhanced efficiency in manufacturing operations. In manufacturing, production planning and scheduling are critical for optimizing resources and productivity. Scheduling is a short-term task for execute the planned activities, that are more detailed than the ones of "planning", in order to ensure efficient production. By the other way, planning is the process of defining the main objectives and how to reach them; it's a strategic process. Together, planning and scheduling form the backbone of manufacturing operations, maximizing productivity and efficiency.

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Integrating sustainability into these processes is crucial for minimizing waste, reducing energy consumption, and mitigating environmental impacts. By aligning scheduling and planning with sustainability goals, manufacturing can foster a more environmentally conscious and sustainable ecosystem. Integrating sustainability into these processes is essential for minimizing environmental impact (reduce energy consumption, reduce costs…) while maintaining efficiency.

To that point, the objective of the paper is to explore the tools, such as ontologies, taxonomies or knowledge graphs, that would help towards a standardize representation of data in order to facilitate planning and scheduling activities within manufacturing contexts. Indeed, ontologies, taxonomies, and knowledge graphs serve as structured frameworks for organizing and representing information. These frameworks facilitate the management of data related to the improvement of systems, solutions to problems, enhance sustainability or improve collaboration among the supply chain parts. Moreover, by integrating sustainability criteria into these frameworks, organizations can optimize scheduling and planning activities to align with economic and environmental objectives and societal needs.

In order to achieve the above-mentioned objective, a representative analysis of the current literature was performed. 48 papers, including ontologies, knowledge graphs and taxonomies, related to the research question "How do ontologies/knowledge graphs/taxonomies contribute to scheduling and planning of manufacturing activities?", were identified. An analysis was conducted through mapping and categorization of the 48 selected papers with respect to several criteria: first of all, according to the strategic (long-term objectives), tactical (mid-term objectives) or operational goals (short-term objectives) in scheduling or planning to which the identified ontologies, knowledge graphs and taxonomies contribute. Then, it is expected to scrutinize sustainability-related objectives and knowledge representation within these ontologies, knowledge graphs, and

taxonomies. Based on the literature results, solutions will be explored to integrate sustainability concerns in studied ontologies/knowledge graphs/taxonomies in the context of scheduling and planning in manufacturing activities.

Keywords: *sustainability, ontology, planning, scheduling, manufacturing*

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Mapping Sustainable Development Goals of Circular Economy-Based Start-ups: An Exploratory Study from India

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Abstract

The concept of Circular Economy (CE) has garnered increasing attention as a sustainable alternative to the traditional linear economic model. CE aims to minimize waste and maximize resource efficiency by promoting the reuse, refurbishment, remanufacturing, and recycling of products and materials. This paper explores the alignment between Circular Economy principles, Sustainable Development Goals (SDGs), and intellectual property (IP) considerations, using a sample of Indian start-ups in this domain.

The methodology employed is based on a multifaceted approach and a mix of quantitative and qualitative research methods. Firstly, leveraging social media platforms such as Instagram, our research utilized an account dedicated to raising awareness and disseminating knowledge about Circular Economy practices. Through engaging content, we aimed to catalyze discussions and foster a community committed to sustainable practices. Secondly, surveys and quizzes were conducted via Instagram to gather insights into public perceptions, attitudes, and behaviour regarding Circular Economy initiatives. These interactive tools facilitated the collection of valuable data which were complemented with survey responses for our analysis of aspects which couldnot be captured on the social media.These findings from holistic exercise, brought insights into awareness level on CE

being still in infancy in India. Further, studying the business models of the CE start-ups, we could also get insights into their focus on sustainability.By mapping the principles of CE onto the SDGs framework for the studied sample, we identify areas of convergence and divergence, highlighting opportunities for enhanced collaboration and strategic alignment.

Next, we focused on the academic and practitioners' trends regarding circular economy in India which portend, it has attracted investments totalling $1.8 billion over the past five years between 2016-2021, as reported by early-stage venture capital firm, Kalaari Capital. "India's leadership in technology and innovation creates an opportunity to accelerate its transition towards the Circular Economy, especially in light of greater cultural acceptance towards circular practices." As per the report, India has the capability to leverage circular economy principles and innovation across key sectors such as cutting down waste generated from the fashion industry, efficiency in agriculture and cutting down food wastage, adoption of electric vehicles and use of multimodal transportation in mobility, reducing carbon emission in construction and finding replacements for rare earth minerals. So, we analyze a sample of 10 leading Indian start-ups working in the domain of circular economy, from a multi-perspective approach. Intellectual property rights are one such perspective, given their nature for incentivizing innovation especially for small businesses as the start-ups. This in turn enables fostering the transition towards a circular economic paradigm. In conclusion, this research contributes to the growing discourse on Circular Economy by elucidating its interconnectedness with SDGs and intellectual property considerations. By fostering interdisciplinary dialogue, the paper generates insights to catalyze action in the small business sector, for a more sustainable and resilient global economy.

Keywords: *circular economy, green innovation, intellectual property, sustainable development goals, start-ups*

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A decision-making strategy for the selection of Additive Manufacturing thermoplastic materials based on material attributes

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Abstract
Additive Manufacturing (AM) comprises a family of technologies that produce solid objects through a layer-by-layer deposition method resulting in functional parts with minimum material wastage in contrast to subtractive manufacturing. Fused Deposition Modeling (FDM) is a material extrusion AM technique that deposits the polymer filament on a platform through a heated nozzle which follows a well-defined tool path for each layer according to a specified 3D digital model. By adopting AM design strategies such as topology optimization, the amount of the material in the design domain can be reduced without affecting the structural integrity of the final product. FDM is considered a sustainable production process that enables the manufacturing of highly complex parts with minimal material usage, while integrates the on-demand and on-site production providing shorter supply chain networks and resulting to energy conservation.

Polymers are versatile, lightweight, and easy processing materials with a broad application range that covers most of society's needs. However, the non-biodegradable nature of fossil-based polymers constitutes a serious environmental issue. An efficient transition to sustainability requires reconsidering the conventional manufacturing of plastic products, either by developing bioplastics which are biodegradable and/or derived from

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renewable resources, or by recycling and reusing the common synthetic plastics contributing to circular economy. A wide range of novel thermoplastic polymers originating from fossil-based resources can be manufactured via the FDM technique and are utilized as consumer or industrial products. Recycled polymers from waste items can also be used as FDM printing filaments, reducing the need for fossil resources and contributing to a more sustainable manufacturing process.

In the present work, a decision-making method is applied for the selection of the most suitable FDM material considering multiple criteria such as tensile strength, light weightness, UV-ageing resistance, chemical resistance, maximum operating temperature, dimensional accuracy, visual quality, material cost and printability. The examined FDM list of materials includes commercially available polymers used in common FDM machines, i.e. standard polymers for general use, such as HIPS, PETG, ABS, engineering polymers, such as PLA, PC, PA, POM-H, PMMA, and high-performance polymers, such as PVDF, PPS, PSSU, PSU, PEEK and PEI. To build the decision matrix, the values of the criteria were obtained from technical data sheets, experimental results reported in literature and expert opinion from practitioners. The multi-criteria decision-making method, Promethee II, is applied to three scenarios that represent different FDM-printed product requirements. The corresponding weights of each criterion with respect to each scenario were assigned by experts in the industrial sector.

This work also attempts to examine the possibility of recycling and reusing the above-mentioned materials as FDM feedstock, according to relevant published research studies in literature. This prospect could serve as an additional sustainability-oriented criterion for the material selection decision-making process. Fossil-based polymers that can be recycled and reused offer appealing options to decision-makers and designers, since they ensure high quality and performance of the new FDM-printed product,

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considering they offset the environmental impact of their original use and promote a circular economy.

The derived results confirm that the proposed multi-criteria decision-making strategy provides an effective tool and a systematic method to address the FDM materials selection problem including most of the common thermoplastic polymers currently used in FDM, while useful conclusions are derived for the suitable selection of 3D printing material according to the requirements of its application.

Keywords: *additive manufacturing, fused deposition modeling, sustainability, thermoplastic materials, multi-criteria decision-making*

Complementary Green Innovations for Sustainable Future

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Abstract

1st National School on Green Innovation and Sustainable Development of the Human Environment in linkage with UNESCO MAB Program was in Poland in the region of the oldest in Europe border park in the Pieniny Mts. in 1968 and the 1st International School in this field focused on Environmental Health, Biodiversity and Circular Bioeconomy was in 1973, followed by 50 years of problem-solving lifelong learning.

This education was oriented on transdisciplinary cooperation among experts and common action with knowledge-based society including exchange of good practice from different countries for integration early detection of environmental risk factors for

human and animal health and biodiversity, supplemented by dissemination innovative technologies (including laser biotechnology) for better prevention and reduction of the environmental contamination and sustainable management of the natural resources, adopted to climate change - in particular water Management; including model area introduced by of the Krakow Water PLC.

These activities are aimed at compliance with Directive 2020/2184 of the European Parliament and of the Council, ensuring compliance with its provisions by introducing modern and innovative technologies for its treatment. At the same time, ensuring a sustainable future for supplying the

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residents of the city and region of Krakow with healthy drinking water. At the same time, measures are being taken to apply renewable energy sources and the principle of circular economy. Artificial intelligence solutions are also used in these activities, especially in the field of energy savings. AI solutions may also be augmented with advanced numerical simulations backed by High Performance Computing resources available scientists via the national and international HPC centers. The same methods may be used by commercial entities utilizing public cloud providers.

The paper will present solutions in the above area.

Keywords: *learning on green innovations, circular economy, sustainable water management, environmental biotechnology, health, AI, simulations, HPC, clouds*

A Reward Scheme for Used Cooking Oil Collection using a Smart Digital Platform - The Case of Western Macedonia

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Abstract

Used cooking oil (UCO) is edible oil of vegetable or animal origin that has been used to cook food to a point where it is no longer fit for that purpose. UCO from households is nowadays mostly disposed of together with municipal waste or simply poured into drainage. These actions pose severe environmental risks. When UCO is poured down the drain, it hardens and infiltrates into local sewer, water and waste management facilities, which are not equipped to process fats, oils and grease. While the recycling of UCO has been a requirement for food industry companies in most of Europe, such effective collection and recycling on a household level is still not gaining traction even if it counts more than 50% of the total production. According to EU estimations, the potential UCO to be collected per year from households could be as much as 2.000.000 tons, significantly more than the current collected amount. This indicates that domestic UCO is a relatively untapped market and efficient collection strategies should be explored.

Collecting UCO from households presents inherent difficulties (mainly due to the logistics involved in collecting small amounts of UCO from a very large number of individual households), and the economic viability of

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collection systems requires securing enough UCO, and therefore the participation of as large a proportion of citizens as possible. The success of UCO collection initiatives strongly depends on the participation of individuals and probably the most important issue is to motivate citizens to recycle their used oil instead of simply disposing it with other Municipal Solid Waste or pouring it to the kitchens' sinks. On the other hand, the major technical challenge of recycling household UCO is its collection, mainly due to the high logistics costs of such a process.

Reward schemes have been implemented in European cities to increase citizen participation and adopt better waste management practices. In this respect, SYMBIOLABS has partnered with DIADYMA S.A. (the official body of waste management for the Region of Waste Macedonia) to introduce a reward scheme designed specifically for facilitating the collection of UCO from households in the region of Western Macedonia. The system includes the use of innovative collection machines (called UCO's ATM's) and its operation is supervised through a digital platform developed by SYMBIOlABS. with a two-fold aim: improve the monitoring of recycling rates in specific municipalities and reward citizens who participate in proportion to their contribution of UCO. DIADYMA deployed the reward scheme using the digital platform, with the goal of reaching 10.000 households in the region.

Through the operation this reward system, the quantities of UCO that are discarded without being recycled are reduced, while at the same time the collected UCO from households is being reused to create new products of high added value while offering a new revenue stream to DIADYMA. Finally, the implementation of such a point rendering mechanism can be transferred to other types of waste in Western Macedonia as well and become the base for the transition to a circular economy era.

Keywords: *used cooking oils, recycling, green innovation*

Growing Sustainability: Mycelium-based acoustic panels

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Abstract

Mycelium is a part of fungi that grows underground and on different substrates as a network from thread-like structures called hyphae. While growing, it decomposes dead plant matter and grows, resulting in the creation of a moldable and stable composite material [1]. Mycelium-based materials fit well within circular economy principles, as they can be locally grown, they are biodegradable and can be cold-composted at the end of their lifecycle, thus avoiding landfill accumulation and further carbon emissions associated with waste management [1],[2]. Additionally, mycelium-based composites are non-toxic and have fire resistance properties [3], and therefore their application in architecture and industrial design are actively explored globally as a sustainable material solution [4]. Recent research has found that cardboard-based mycelium composites exhibit strong acoustic performance in terms of sound absorption [5]. In this work, we propose a sustainable approach to aesthetically customized sound absorption and sound diffusion panels made by mycelium composites.

Our method focuses on two stages, finding the suitable material composition for the creation of an acoustic panel and creating a design process that can form the specific material into a customized panel. Through our experimentation, we used a standard open-source biotechnological

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protocol for mycelium-based fabrication [6], and followed the steps of selecting the fungus and the growth substrate, the inoculation of the substrate with the mycelium, the molding of the inoculated substrate, the incubation of the composite, and the unmolding and drying of the composite [7]. Starting with the mycelium substrate cultivation, we experimented with ready-to-use mycelium substrates containing the strains *Ganoderma lucidum* and *Pleurotus Ostreatus*. In our pursuit to enhance the environmental and economic sustainability aspects of the project, we proceeded with the investigation of different readily available organic waste materials to create our own substrates such as sawdust, cardboard, and straw.

Increasing global population growth results in higher yearly production of agricultural goods, leading to an increase in agricultural byproducts. Many of these byproducts are considered pure agricultural waste and are often discarded or burned, contributing to the release of carbon dioxide, atmospheric particulate matter, and other greenhouse gasses [8]. Straw is one of the most commonly used organic waste materials used in the creation of mycelium-based substrates [9]. These organic materials offer a promising option for product design and manufacturing, emphasizing sustainable production processes and a circular lifecycle [10].

The custom substrates were used to create a series of test samples that stood as a basis that informed our design process, tailored for this specific materiality. Regarding the design process, we employ a Material Driven Design [11] approach that requires a deep understanding of the material properties, acoustic analysis, and digital design and fabrication methods. More specifically, we developed a parametric design model through which we can customize the dimensions and aesthetics of the panel, while adapting the desirable sound-absorbing and sound-diffusing properties. In conjunction, we developed a fabrication workflow that can be followed within the framework of a maker space. The above process was initially tested and documented through educational workshops where a series of mycelium-based prototypes of the generated panel geometries were produced.

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The scalability of this approach and the relevant timescales are issues for further investigation, as an outlook of our research is to progress towards large-scale cultivation of mycelium panels within local contexts, aiming for a sustainable transition to ecological acoustic panels, and for an affordable solution that would be spread to a broader audience, by following an open-source ethos.

Keywords: *mycelium-based composites, green innovation, acoustic panels, aesthetic customization, sustainable development*

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Circular Economy, Innovation, Entrepreneurship and their Relationship with Economic Growth by using Econometric Analysis

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Abstract

Circular economy, innovation, research and development methods affects economic growth a lot. To be more specific, human development generates opportunities to entrepreneurial activity on economic growth. It is a well known fact, economic policies promote opportunities which contribute to international entrepreneurial activities. Thus, it is important to identify the relationship between innovation and economic growth with econometric models such as Granger causality test in order to answer with empirical methods, proving which variable have an impact on what. Rudra P. Pradhan, Mak B. Arvin (2020), estimated causality relationships among entrepreneurship, development, innovation and economic growth for European Union countries for 201-2016 using VAR models to calculate long-term or short-term relationship.

According to bibliography, european zone is ineffective due to economic crisis and global competition. This is the reason that European Union launched the Europe 2020 Strategy to improve innovation, entrepreneurship leading to economic growth. Rudra P. Pradhan et al (2016), used auto-regressive model to estimate interactions between innovation, financial development and economic growth for 18 Eurozone countries between 1961-2013, assert that development of financial sector contributes to long-

term economic growth. Having studied the bibliography, we are convinced that the majority of authors maintain the same ideas.

Technology start-ups are crucial factors for economic growth. It is vital to examine the factors which lead to the success of start-ups, innovation and entepreuneship. Wong, P. K. et al (2005), used data for 37 countries which participate in GEM 2002, to measure which type of entrepreneurship has the most dynamic impact on economic growth. In our estimation models we will use macroeconomic indicators such as logarithm of GDP, investments and indicators combined with innovation and circular economy.

It is essential to rely on empirical models in order to observe the outcome of innovation methods for a new start up business and the impact of GDP. Therefore, it is necessary to measure the impact of human capital in combination with entrepreneurship, innovation and economic growth.

Additionally, it is crucial to exclude empirical conclusions if entrepreneurship contributes to economic growth. For this reason, specific indicators will be used such as education level and level of taxes to design tax structure in such a way so that economic growth is further achieved. It is advisable that we should use panel data for 22- EU counties and VAR models for 4 EU countries which are high in innovation methods according to World Economic Forum classification.

Keywords: *circular economy, innovation, entrepreneurship, economic growth, OLS, VAR*

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The Role of Entrepreneurship Support Initiatives on the Development of Innovative Startups

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Abstract

Innovative startup firms are a key factor in upgrading the technological identity of a country, supporting a more sustainable growth. In particular, the fact that they are organizations based on strong competencies (qualitative founders, knowledge, specialisation) makes them very effective in the innovation process.

The purpose of this research is to investigate and understand the various factors that affect the development of innovative startups. It is essential that certain variables such as GDP, unemployment, consumer price index are further processed so that empirical analysis is achieved to result in reliable conclusions. These forms are well-known for their rapid and dynamic growth, which can be affected by a variety of factors, however, their development and success is a complex process that depends on many and different factors that are connected to both their internal and external environment.

The empirical analysis based on a extensive sample of innovative startups that have joined different entrepreneurship support initiatives (such as incubators, accelerators, innovation programmes, competitions). To archive this economic goal, regression analysis will be used to study the relationship between dependent and independent variables. In particular, the study investigates what variables contribute to the success of these innovative

startups, such as their innovative business models, the quality of the products and services they provide, their access to sources of funding, their ability to attract and retain talent, and their ability to form partnerships and collaborations. Furthermore, the research attempts to investigate how the institutional context in which startups developed influences their ability to grow and succeed.

To attain this goal, an in-depth examination of a significant number of startup businesses was carried out using statistical tools, bringing out useful findings at a national level. Anonymous data was gathered from business accelerators, innovation and entrepreneurship hubs and other initiatives covering a 10 year period. These programmes were designed with the vision to support the development of a new generation of entrepreneurship, through the creation of new & sustainable startups. By utilizing statistical tools and selected quantitative methodologies, this study carried out a detailed investigation of the relationships, links and patterns between diverse factors. This approach shed light on the complex dynamics and contingencies that affect startup success in many contexts. Finally, the outcome of this study was to provide useful information and insights about the key-factors that affect the growth and success of innovative startups by stimulating the development of various entrepreneurial ecosystems and educating new startups to comprehend and seek more tailored acceleration factors and programmes that contribute to success.

Keywords: *innovation, entrepreneurship, start-up firms, estimation models*

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Enhancing Societal Resilience in Eastern Attica by Coupling Sewer Mining Solutions with Digital Twin Systems

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Abstract

Sewer Mining (SM) units, functioning as circular, autonomous and distributed water reuse systems have proven to be effective solutions for densely populated, space-constrained and drought-prone environments installed directly where water demand exists. SM technology involves mobile wastewater treatment systems housed in containers, capable of extracting wastewater from local sewers, treating it on-site, and reusing it at the point of demand. This process produces high quality reclaimed water suitable for irrigation of green areas, recharging aquifers, and other urban applications. To enhance distributed urban water management, renewable energy solutions have been integrated to minimize reliance on the grid, making these systems a promising prospect for creating circular energy-efficient systems.

In parallel, Digital Twin (DT) platforms are sophisticated software systems that create and manage digital replicas of physical configurations or processes. These platforms integrate data from various sources to simulate, analyze, and optimize the performance of their real-world counterparts. This research investigates the coupling of innovative solutions with tangible real-time visualization platforms in real-world conditions. SM units serve as

an excellent demonstration case, where monitoring and controlling subsystems through visual representations – such as tables, graphs, and images – can enhance the understanding of processes, and increase the maturity and reliability of the configuration.

The objectives are multifaceted. First, the operators remotely monitor and control the system to ensure that the produced irrigation water meetscurrent legislation criteria, to fine tune the operations and to prevent any unexpected event. Additionally, online visualization of the system's operation engages and motivates stakeholders, encouraging the extension and adaptation of successful solutions to other areas tailored to specific local needs. Policymakers can also monitor these technologies, and based on their stability and efficiency, work towards maturing the regulatory and polity frameworks. This would facilitate the integration of such solutions into the national and regional strategic plans for funding and implementation. Finally, this study aims to demonstrate that local co-creation and living lab activities at demonstration sites, combined with digital twins, can activate local communities, enhance social initiatives and acceptance of innovative solutions, and promote climate change adaptation efforts, contributing to the increase of the overall resilience of society.

Keywords: *circular solutions, digital twins, local community engagement, societal resilience*

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Does Digitalisation Affect the Material Footprint of Nations? Evidence From Panel Data Analysis

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Abstract

The challenge of achieving sustainable development is increasingly gaining prominence. The urgency of this process is underscored by the growing global and local effects of climate change, biodiversity loss, and pollution, which have urged societies to seek a transition from traditional, fossil fuel-dependent economies to economies that are carbon-neutral, equitable, and resilient to climate impacts. This shift is not merely a theoretical aspiration; it has become a practical necessity as countries face the challenge of escalating environmental crises that threaten both natural ecosystems and human well-being. The concept of sustainable development, which seeks to balance economic growth with environmental protection and social equity, has become a central focus for policymakers worldwide. In this context, one of the critical areas of exploration is the possibility of effectively decoupling economic growth from environmental degradation---a complex challenge that requires innovative solutions and a rethinking of traditional economic models.

At the same time, the world has witnessed a significant transformation driven by the digital revolution, which has fundamentally altered both production and consumption patterns. Digital technologies have been recognized as powerful drivers of change, capable of reshaping industries, markets, and even societal norms. However, despite the widespread

acknowledgment of the disruptive potential of digital technologies, there remains considerable debate about their impact on sustainable development. This debate centers on whether digitalisation can genuinely contribute to the creation of sustainable value or whether it might, in some cases, amplify existing environmental challenges.

The role of digitalisation in achieving sustainable development is a complex issue. On one hand, digital technologies offer numerous opportunities for enhancing efficiency, reducing resource consumption, and promoting more sustainable practices across various sectors. For instance, innovations such as smart grids, precision agriculture, and digital supply chains have the potential to reduce waste and lower carbon emissions. On the other hand, the widespread adoption of digital technologies also raises concerns about their environmental footprint, particularly in terms of energy consumption, electronic waste, and the potential for increasing consumption patterns. The question of whether digitalisation can be considered a significant enabler of sustainable development, therefore, remains unsolved.

In this study, we seek to contribute to this ongoing debate by analyzing the impact of digitalisation on sustainable development through the lens of the Environmental Kuznets Curve (EKC). The EKC hypothesizes that as an economy grows, environmental degradation initially increases but eventually decreases after a certain level of economic development is reached. By examining the relationship between the material footprint—a consumption-based indicator of resource use—and digitalisation, good governance institutions, and economic processes, we aim to provide new insights into how digitalisation might influence the trajectory of sustainable development.

Using panel data analysis for 116 countries over the period from 2002 to 2016, our study finds a negative relationship between digitalisation and material footprint. This suggests that higher levels of digitalisation are

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associated with lower levels of resource consumption. However, our analysis also reveals that factors such as GDP, consumer-price inflation, and certain aspects of governance contribute to an increase in material footprint, highlighting the complexity of the relationship between economic processes and environmental outcomes. Additionally, we find that higher levels of education, as measured by mean years of schooling, are associated with a reduced material footprint, underscoring the importance of education in promoting sustainable development.

These findings suggest that while digitalisation holds promise as a tool for advancing sustainable development, its effects are mediated by a range of economic, technological, and institutional factors. Therefore, achieving sustainable development in the digital age could require not only technological innovation but also supportive policies and governance frameworks that can harness the potential of digital technologies while mitigating their negative impacts.

Keywords: *environmental Kuznets curve, material footprint, Internet, digital technologies, sustainability*

The Generation of Greentech Innovation Ideas through External Open Innovation Programs: The Case of GAEA Challenge

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Abstract

The world currently faces demanding environmental challenges that need to be addressed as soon as possible. Innovation seems to be the key for sustainable solutionssuch as new green technologies, methods and tools and has been recognized as a way through, in both research and policy level. At the same time,Open Innovation (OI)in particular, has emerged as a promising model for environmental solutionsgeneration by intensifying the information flows between innovators and relevant stakeholders.The GAEA Challenge as an external Open Innovation Program (OIP)is one emblematic example of an OI paradigm and represents a pivotal initiative aimed at addressing Europe's pressing energy and environmental challenges, intensified by the Ukraine-Russia conflict. Utilizing an OI model, GAEA aims to stimulate the generation of innovative ideas specifically in the fields of energy and raw materials. This model was chosen for its ability to foster cross-sector collaboration, enhance information exchange, and accelerate solution development through the participation of a wide range of stakeholders.

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The program followed a structured process, documented through quantitative and qualitative data, engaging stakeholders from the Quadruple Helix model: academia, industry, government, and civil society. More than 700 innovators from across Europe participated in the innovation process, selected for their expertise and potential to impact the European green innovation ecosystem. Their involvement was facilitated through hybrid communication channels and training procedures, ensuring a diverse and inclusive exchange of knowledge and perspectives.

The proposed research will dive into theOI processes of GAEA Challenge to identify all critical factors and procedures connected to the generation of green ideas and its successful 1st phase, while explaining the selection of the utilized innovation model and design. The results from the 1st phase of the GAEA Challenge offer valuable insights into the effectiveness of OI in environmental problem-solving. This paper will present these findings, assess the success of the program in each participating country, and provide conclusions regarding the anticipated long-term impact of the initiative.

Keywords: *open innovation, innovation processes, green innovation, greentech startups, open innovation design, open innovation programs, cleantech*

Environment
and
Sustainability

Techno-Economic Study of a Small-Scale Biogas Plant Utilizing Biowaste of a Canning Factory in Central Macedonia

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Abstract

As a renewable source, biomass can play an important role in reducing the environmental footprint of energy systems. The food industries, which constitute a central element of the Greek and European economy, produce waste including mostly biodegradable organic matter, a potential substrate of energy production by anaerobic digestion. In the current project, a techno-economic analysis is carried out of the installation of a small-scale anaerobic digestion system, including composting of the digestate, for the treatment of biowaste of a cannery in Central Macedonia. The results show that the economic efficiency of the investment is promising (ROI 20.9%, SPP 4.28 yr, V 869 €, NPV 18,579 €, IRR 23.8%, DPP 4.70 yr), and it can be improved (ROI 23.5%, SPP 3.93 yr , V 1,356 €, NPV 26,143 €, IRR 26.2%, DPP 4.29 yr) by the seasonal co-treatment of the biowaste of the plant examined with biowaste of a peach processing and canning unit, added in ratios between 1.5: 1 and 4: 1. As a result, decentralized units of waste treatment, even of a small capacity, are potentially attractive investments which improve the economic performance of food industries and their environmental profile.

Therefore, it is shown that the adoption of integrated small-scale systems for biowaste treatment is not necessarily inefficient from an economic point

of view, which argues in favor of the necessity to consider scenarios of decentralized treatment. The benefits of this decentralized management for the company, as well as for any other with similar characteristics that will adopt such a system, include the following:

1. The decrease of operating costs derived from:
   - **a.** The partial substitution of the thermal energy derived from the combustion of natural gas with a corresponding energy derived from the use of biogas.
   - **b.** The partial substitution of a quantity of fertilizer resulting from the use of compost, which has resulted from the aerobic treatment of the digestate.
   - **c.** The elimination of the expenditure related to the collection and management of the unit's bio-waste.
2. Highlighting the company's environmental ("green") profile, which increases its economic competitiveness in the food industry sector.
3. Environmental benefits, as biomass is used efficiently as a renewable resource, resulting in the reduction of carbon dioxide emissions and other atmospheric pollutants, while, at the same time, natural resources are used more efficiently and effectively.
4. The installation of the system provides to industry the opportunity to develop another parallel business activity, since the potential for the utilization of additional quantities of bio-waste is large and, therefore, the economic profit from converting the unit into a small bio-waste management pole may be even more valuable than what was determined in the current feasibility study.

Keywords: *circular economy, biowaste, renewable energy sources, techno-economic analysis, food industries*

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An Environmentally Sustainable Healthcare Unit in Greece

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Abstract

For sustainable development, society needs sustainable health and medical care systems, which themselves must meet sustainability criteria in their operation. However, our health systems face urgent problems that call into question the sustainability of their services. On the one hand, the health care industry has a significant share of carbon dioxide emissions - depending on the source between 5 and 6 percent, produces large amounts of waste (sometimes hazardous) and has a very high-water consumption.

In many cases, healthcare units have not yet begun to deal systematically with sustainability in its three dimensions, environmental, social and financial. In addition, management support for transformation and taking the necessary measures for sustainability in healthcare units is important.

For the implementation of a sustainable development, the following procedures are required identification of relevant areas with significant potential for improvement in terms of sustainable management in the healthcare unit, identifying the best examples for exploiting the potential improvement, development or selection of intelligent means for effective, efficient and sustainable implementation/implementation of the application examples and development of an application-oriented design and implementation significant opportunities for improvement in the healthcare units.

Creating an environmentally sustainable healthcare unit in Greece, involves tailoring strategies to the specific environmental challenges and opportunities present in the Greek principles. Parameters that should be examined to achieve this challenge are energy efficiency, green building design, waste management, water conservation, sustainable transportation, community engagement procurement practices and health promotion.

Healthcare units can install solar panels to generate electricity, reducing reliance on non-renewable energy sources. Additionally, optimizing HVAC systems and implementing energy-efficient lighting can further reduce energy consumption. Incorporating green building principles into hospital design and renovation projects, can enhance sustainability. This includes eco-friendly building materials, maximizing neutral ventilation and daylighting, and integrating green spaces such as gardens or green roofs.

Effective waste management is crucial for environmental sustainability. Healthcare units can implement recycling programs for paper, plastic, glass, and other recyclable materials. Proper segregation and disposal of medical waste are also essential to prevent pollution and protect public health. About water conservation, healthcare units can implement water-saving measures such as installing low-flow fixtures, capturing rainwater for irrigation, and implementing greywater recycling systems. These practices help conserve water resources and reduce strain on local water supplies.

Encouraging sustainable transportation options, can help reduce carbon emissions and alleviate traffic congestion. Healthcare units can provide electric vehicles, promote the use of shared transport among staff, and offer incentives for using public transportation.

Engaging with the local community is essential for promoting sustainability. Healthcare units can organize educational workshops, participate in community clean-up events, and collaborate with local environmental organizations to raise awareness and foster environmental

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stewards. Emphasizing preventive care and wellness can contribute to both environmental and public health. Healthcare units can promote healthy lifestyles, encourage plant-based diets with lower environmental footprints, and provide green spaces for physical activity and relaxation.

Keywords: *environmental sustainability, healthcare units*

A Strategic Plan for Renewable Energy Transition in a Coal-Dependent Province in Indonesia: Employing Participatory Backcasting Approach in South Kalimantan

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Abstract

Participatory backcasting addresses a growing critique of clean energy scenario studies that rely solely on quantitative analytical tools and researchers' expertise. Consequently, an increasing number of studies are now utilizing the participatory backcasting approach for clean energy analysis in the Global South. This paper develops and refines a participatory backcasting methodology and applies it to the coal-dependent province of South Kalimantanin Indonesia. While backcasting studies often generate new visions rather than taking into account existing visions, our study compares four existing renewable energy visions indiscussion with key stakeholders and subsequently strengthens the most favoured vision for further assessment and elaboration.

We applied this approach in the South Kalimantan Province of Indonesia, where the gross regional domestic product strongly depends on

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coal mining. Based on input gathered during interviews, consultations, and a focus group discussion, we formulated the necessary changes, identified driving factors and challenges, and developed a road map and follow-up agenda for the vision preferred by stakeholders. The road map and follow-up agenda were categorized into economic, technological, as well as cultural and behavioural structural changes. The participatory backcasting approach we proposed was well-received by the South Kalimantan Provincial Government, and other local key stakeholders, committed to increasing the use of renewable energy in the upcoming revision of the Regional Energy General Plan. Our study also contributes to the literature on backcasting analysis, which often lacks an examination of clean energy transition visions in regions whose economies relyon income from fossil fuels.

Keywords: *backcasting, stakeholders, regional energy transition, Global South, Indonesia*

Geochemical Perspective for the Implementation of the CO_2-based Electrothermal Energy and Geological Storage System (CEEGS) Concept

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Abstract

Policy instruments such as the Paris Agreement and the Green Deal of the European Union highlighted the mandatory reduction of greenhouse gas emissions by using alternative energy sources limited to carbon load. CO_2 capture and storage technologies constitute a field of global research, however, their wide scale adoption is still limited due to economic challenges, specially related to its long-term storage.

The "CO_2-based Electrothermal Energy and Geological Storage System-CEEGS" concept based on the daily or seasonal energy storage by integrating electrothermal energy storage in which CO_2 is utilized as the working fluid in transcritical cycles combined with the CO_2 storage in geological formations. During periods of surplus renewable energy, the CO_2 is received from a stable source, e.g. an industry with high CO_2 emissions, goes through a heat pump system to increase the pressure, releases heat to a

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hot-water storage and is finally injected into a geological reservoir. This process is known as the charge cycle. In periods of electricity demand, the CO_2 is retrieved from the reservoir, recovers heat from a hot-water reservoir subsequently moving a turbine to generate electricity. The low-pressure CO_2 passes through a condenser, cooled and pumped again in the geological reservoir through another injection well.

CEEGS is still in low technical readiness level (TRL 2) with the main challenge in understanding surface, wellbore and underground components integration and specification of feasible conditions for each one. Porous media are potential geological environments capable of storing CO_2. The geochemical interactions between them and the injected CO_2 were investigated under the framework of CEEGS project to analyse the precipitation of new mineralogical phases at equilibrium state that could cause changes in the physicochemical parameters of the reservoir, e.g. clogging. For the investigation, aqueous geochemical calculations were performed by PHREEQC software.

Two case studies are examined. The first one represents a depleted hydrocarbon field (DHF)and the interactions between reservoir rock-remaining hydrocarbons-remaining water-CO_2 were investigated. The second one focused in a DSA for the investigation of reservoir rock-brine-CO_2interactions. Both tested scenarios had siliciclastic host rocks while the DHF considered in addition carbonates.

After the injection in DSA, CO_2 reacting with the brine forming carbonic acid which is partially dissociates, giving carbonic (CO_3^{2-}), bicarbonate (HCO_3^-), and hydrogen (H^+) ions. This process decreases the pH, and the initial present phyllosilicate and clay minerals dissolve. Hematite, goethite and K-jarosite are precipitating. Also in the case of DHF, carbonic acid was formed, causing a dissolution of carbonate minerals, chlorite, and K-feldspar, leading to the precipitation of siderite and clay minerals such as kaolinite, Ca-montmorillonite and illite. Hematite and goethite are also

precipitating in this case, however an amount of them is dissolved due to carbonate minerals dissolution. This process gives an initial increase of reservoir's permeability; however, the potential decrease of pressure results in the precipitation of the dissolute carbonate minerals, K-mica, as well as the secondary clay minerals Ca-montmorillonite, illite, and kaolinite that migrate to pore throats, decreasing the permeability after long-time. This phenomenon is more extend when swelling minerals are precipitating in the system, e.g. Ca-montmorillonite. Siderite precipitation can also lead to clogging or corrosion due to the small minor colloidal nature of siderite particles.

In summary, taking into consideration the new mineralogical phases in both the tested environments, the CO_2 storage in DSA is safer than in DHF due to the lack of swelling clay minerals and siderite.

Keywords: *CO_2 emissions, underground energy storage, renewable energy sources, geochemistry, circularity*

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Correlation Analysis of Population, Energy Consumption and Overshoot Day Global Trends

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Abstract

For much of human history, the extensive exploitation of natural resources occurred without a full understanding of its long-term impacts. It wasn't until the mid-20th century that scientists began highlighting the dangers of overconsumption of natural resources due to human activity. Despite their efforts, data limitations hindered effective advocacy for resource conservation. The Global Footprint Network, established in 2003, introduced Earth Overshoot Day three years later, providing a crucial metric for assessing humanity's ecological impact. Earth Overshoot Day marks the annual point when humanity's consumption of ecological resources exceeds Earth's capacity to regenerate them within that year. Over the years, Earth Overshoot Day has progressively moved earlier, reflecting increasing rates of resource consumption. In 2024, Earth Overshoot Day is projected to fall on August 1st, underscoring the critical need for sustainable resource management. This study presents a comprehensive analysis of the correlation between global population trends, energy consumption, and

Earth Overshoot Day. Advanced data analysis tools such as R Studio and Python were utilized to develop a mathematical regression model, enabling precise recording, processing, and validation of results. Through their analysis, significant trends and correlations were identified, providing a comprehensive understanding of the interaction between population growth, energy consumption dynamics, and the progression of Earth Overshoot Day. Data for this study was sourced from reliable databases, including global population data from the United Nations, Earth Overshoot Day trends from the Global Footprint Network, and global energy consumption data from the U.S. Energy Information Administration. Population data were measured in increments of 10 million, while energy consumption was measured in exajoules and petawatt hours to ensure accuracy and comparability across trends. The findings highlight the critical role of energy consumption, particularly from fossil fuels, in advancing Earth Overshoot Day. However, sustainable long-term solutions are necessary for meaningful progress. International cooperation and adherence to agreements like the Paris Agreement and the Sustainable Development Goals are essential for promoting sustainable practices and reducing global overshoot.

Keywords: *earth overshoot day, world population, energy consumption, sustainable living*

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Development of a Hybrid Renewable Energy System Methodology for Meeting Water and Electricity Needs in Samothrace

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Abstract

The escalating impacts of global warming are becoming increasingly evident, and one significant consequence is the soaring cost of electricity. This issue poses a substantial challenge that highlights the need to pivot to cost effective renewable energy solutions. The small island of Samothrace, located in northeastern Greece, faces similar difficulties but also holds a unique competitive advantage in addressing these challenges. The island possesses one of Greece's strongest wind potentials and is connected to the mainland electricity grid, presenting an opportunity for innovative solutions to meet its energy needs sustainably.

Within this research, a Hybrid Renewable Energy System (HRES) is designed for Samothrace. The system is comprised of 10 Wind Turbines (WTs) with a total nominal power of 23.5 MW and a desalination system using Reverse Osmosis (RO) with a capacity of 2400 m^3/day. The HRES is integrated with two different energy storage scenarios: the first scenario proposes a green hydrogen system; while the second, a Lithium-Ion Battery (LIB) system.

The HRES proposed provides Samothrace with reliable, clean energy, directly from the WTs when available, and from the energy storage systems when not. The energy storage systems optimize energy use by storing excess energy and releasing it when there is a deficit.

To enhance system efficiency, part of the energy generated by the WTs will power the desalination plant to produce potable water. Due to the 20 MW capacity limitation of the electrical interconnection to the mainland, incorporating a desalination plant within the HRES reduces energy waste, benefiting locals who may receive water and energy at minimal to no cost.

To achieve these goals a tailormade model was formulated. Initial estimates of energy and drinking water demand were made, along with the wind data for the region, as provided by the Hellenic National Meteorological Service (2023) The operating scheme for the four scenarios was then formulated, and a simulation was conducted for a 10-year period (2011-2020). An economic model was developed to calculate the economic performance of each scenario, emphasizing on the Net Present Value (NPV) and Internal Rate of Return (IRR). Based on these results and reliability data, the systems were dimensioned accordingly.

In all scenarios, the reliability of electricity and drinking water for the residents of Samothrace exceeded 99%, solely through the use of their respective HRES. Additionally, water and electricity are provided at no charge to residents, locally and independently of the mainland, to ensure social acceptance for the project. This approach achieves compelling economic performance indexes for the proposed 25-year lifespan of the project in all scenarios.

In conclusion, this paper underscores the significant potential of Samothrace to produce clean and reliable energy that is economically competitive. By leveraging its underutilized interconnection with the mainland, Samothrace can harness its exceptional wind potential, thereby generating substantial benefits for both local residents, and the broader

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global community. Additionally, this study evaluates the strengths and weaknesses of contemporary energy storage systems, providing valuable insights into their effectiveness and areas for improvement.

The implications of this research extend beyond Samothrace, suggesting a scalable model for other regions with similar renewable energy potentials. Future work may explore further optimization of the HRES systems mentioned and their applicability to different geographical contexts.

Keywords: *hydrogen, LIBs, WTs, desalination, HRES*

Skyros Project: Building Community Resilience and Climate Change Literacy

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Abstract

As the impacts of climate change become increasingly apparent, the need for resilient communities and climate-literate citizens has never been more urgent. The Skyros Project, now in its tenth year, offers a robust model for achieving these goals through innovative educational and environmental initiatives on the island of Skyros, Greece. This paper explores how the Skyros Project has successfully engaged local communities, fostered environmental stewardship, and promoted sustainability practices. The project employs a multi-faceted approach that includes hands-on activities, educational programs, and strategic collaborations with organizations. Key initiatives like the innovative Trash Art project, which transformed waste materials into community art installations, illustrate how practical actions can raise environmental awareness and drive behavioral change. Additionally, the Skyros Project's partnerships with local authorities have been pivotal in integrating sustainability into community planning and daily life. These collaborations have not only enhanced local infrastructure but also built a foundation of trust and cooperation essential for community resilience. The Skyros Project stands as a testament to the power of

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community-driven initiatives in combating climate change. It demonstrates that through education, collaboration, and creativity, it is possible to cultivate a resilient society equipped to face the challenges of our changing world.

Keywords: *climate change, sustainability, multi-faceted approach*

Sewage Sludge Pyrolysis and Gasification for Biochar Production in Circular Economy

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Abstract

For the past few decades, following the principles of circular economy, materials previously considered as waste are being examined as potential resources. This study seeks to depict the research that has been accomplished not only in the area of sewage sludge valorization through energy-producing technologies, but also the utilization of the derived by-products, such as biochar. A comprehensive bibliometric and visual analysis was conducted in order to examine research trends in the field of sewage sludge pyrolysis and gasification for energy and biochar production. Utilizing VOS viewer software, results from two advanced searches in the Scopus database were analyzed. The first search included the terms "sewage sludge," "pyrolysis," and "biochar," while the second search employed "sewage sludge," "gasification," and "biochar."

A general statistical analysis of the search results was performed and graphs on various key parameters were generated. This statistical overview provided a foundational understanding of the research landscape and identified key trends and contributors in the field. The temporal distribution of publications indicates an increased interest in sewage sludge pyrolysis, gasification and their produced biochar over the past decade. Specifically, the number of publications has been steadily increasing, highlighting the

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expanding recognition of these technologies' potential in waste management and sustainable energy production. Analysis of publication distribution by country revealed that China is the predominant contributor in both research areas, underscoring its leading role in advancing technologies for sewage sludge treatment and valorization. The visual analysis using VOS viewer further elucidated the research trends and networks. Co-occurrence and co-authorship maps were generated to visualize key terms, concepts, and collaborations within the datasets. These maps revealed the central themes and influential research groups driving advancements in sewage sludge pyrolysis, gasification and their produced biochar.

A significant finding from this analysis is that the number of results from each search reveals that many researchers have studied pyrolysis and the produced biochar of sewage sludge, while gasification remains a relatively nascent process. The relatively fewer publications and lower citation rates suggest that gasification technologies for sewage sludge and the potential uses of its biochar are still in the early stages of development. However, the increasing trend in publications indicates growing interest and investment in this area, suggesting its potential for future growth.

Keywords: *sewage sludge, pyrolysis, gasification, circular economy, bibliometric analysis*

An Intelligent Method for Separating Metal Tin Cans

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Abstract

The global production of solid waste, continues to rise, posing significant environmental and economic challenges. Recycling offers a sustainable solution, but the effective management of metal waste remains a complex task. Metal tin cans, have become a major contributor to environmental pollution. Their widespread use in packaging, and consumer goods has led to a surge in metal waste. Despite efforts to reduce metal tin can consumption, the industry continues to grow, driven by demand for lightweight, durable, and affordable materials. The environmental impact of metal waste is substantial. Metal tin cans are slow to degrade, persisting in the environment for centuries. They contribute to pollution in landfills, waterways, and oceans. The production of metal tin cans also consumes significant amounts of raw materials, exacerbating resource depletion and climate change.

Recycling offers a potential solution to the metal waste crisis. However, effective recycling requires proper sorting and processing. Challenges in identifying and classifying different types of metal tin cans hinder recycling efforts. Moreover, the economics of recycling can be influenced by factors such as market demand for recycled materials and the cost of collection and processing. To address the growing metal waste problem, it is essential to promote recycling, improve sorting technologies,

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and develop innovative solutions for metal waste management. By adopting a circular economy approach, we can reduce our reliance on virgin metal tin cans, conserve resources, and mitigate the environmental impacts of metal pollution.

In this study, metal sorting techniques are investigated. We focus on our self-developed, artificial intelligence-based tin can separator. The system has been built with features that can operate under harsh industrial conditions in mind.This system consists of conveyor belts and equipment such as machinery, advanced cameras, air jets, pedals, embedded video processing platforms, electronics control components,collection hoppers,an air compressor including an air tank and an outer casing to protect the system. We use state-of-the-art deep learning techniques in our system.In order to perform basic deep learning-based image processing and automation operations, in addition to our own solutions, open source frameworks such as Open CV are also utilised in the system.In coordination with the software development process, training and test datasets to be used in deep neural networks were produced using the interfaces we developed. These databases were then integrated into the tin can separator software. We also take into account different camera usage scenarios that were also taken into consideration to make the system work under different conditions. The efficiency of the software and components in the module was tested with different camera types -multispectral, depth, RGB-D, laser cameras, etc.- and optimisation studies were carried out by debugging and solving possible problems, and the software and the system were made fast, efficient and high performance. The performance of the tin can detector was tested using both train and test datasets in a simulation environment. Moreover, the overall system, including the separator hardware, was tested in a fully constructed conveyor belt with real-world waste. The resulting system is robust and fast to deal with the real-world scenarios.

Keywords: *artificial intelligence, environment, circular economy, recycling, metal waste*

Institutional challenges to just and sustainable climate strategies

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Abstract

While crises in the international system may encourage engagements, crisis discourses risk overlooking the intersectional nature of crisis, meaning that all individuals are neither equally affected, accountable nor have equal resources to react to crises. This is also the case when it comes to climate change, which was originally framed as a natural science problem, without much consideration given to social dimensions. In this study we discuss the role of European climate institutions in developing sustainable and inclusive climate strategies and explore certain institutional obstacles, which limit the room for innovative thinking and inclusion of justice approaches. We argue that climate institutions are especially important when it comes to sustainable and just transition measures since they have authoritative knowledge and organize climate politics through their problem definition, which affects both inclusion of knowledge and representation of different social groups in climate politics. The study concludes with the notion that narratives highlighting justice aspects of climate change are slowly but surely gaining prominence within climate institutions at different levels. Established institutional practices and norms however still slow down this work, often resulting in parallel processes, with little coordination between policies.

Keywords: *climate change, climate strategies, institutional challenges*

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An Agent-Based Model for the Urban and Spatial Planning in the center of Athens: The case of 15-min city

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Abstract

Nowadays, more and more people worldwide tend to live in cities.This increased urbanization has resulted in significant challenges for city planners, who must ensure that urban areas can expand in a sustainable, organized, and efficient manner. The increased demand for space and services requires detailed spatial planning to maintain a high quality of life for city residents. In response to these challenges, this paper introduces an Agent-Based Model (ABM) designed to assist in the urban planning process, specifically for the city center of Athens in Greece.

Urban planning is essential to accommodate population growth and evolving infrastructure needs. The ABM presented in this paper is built on a well-defined literature protocol, which provides a structured framework for the model's development. The model is created in a step-by-step process, beginning with an overview of its objectives, followed by an in-depth explanation of its design

concepts, and concluding with detailed descriptions of its mechanisms and functionalities. The ABM focuses on simulating population movement in the context of the "15-minute city" concept, a growing trend in urban planning that aims to ensure that residents can access essential services and facilities within a 15-minute walk or bike ride from their homes.

The concept of the 15-minute city has gained attention in recent years as cities around the world look for ways to reduce urban sprawl, decrease traffic congestion, and promote more sustainable living environments. The goal is to create neighborhoods where citizens can meet most of their daily needs — such as healthcare, shopping, education, and recreation — without the need to travel long distances. This approach not only improves the quality of life for residents by saving time and reducing stress but also contributes to environmental sustainability by decreasing the reliance on cars, thereby reducing emissions.

In the case of Athens, the ABM explores whether the current infrastructure meets the needs of its citizens within the framework of the 15-minute city. The model takes into account various characteristics and requirements of the population, including healthcare access, transportation options, and proximity to essential services. By simulating the movement of residents within the city, the model assesses whether Athens' current infrastructure allows its citizens to access crucial services within a reasonable distance from their homes, and it identifies gaps in the existing urban layout.The model operates by dividing the city into multiple layers, each representing a different type of service or infrastructure that citizens need. These layers include healthcare facilities, schools, public transportation networks, and recreational spaces, among others. Each layer is examined to determine how well it meets the needs of the population in specific neighborhoods. The model's goal is to pinpoint which areas of the city lack sufficient infrastructure and where targeted expansion is required to meet the 15-minute city criteria.

A key focus of the study is healthcare access, particularly the availability of public hospitals and medical centers. The model simulates residents' ability to access healthcare facilities for scheduled medical examinations, revealing that some neighborhoods are underserved and lack proximity to public hospitals. Based on this analysis, the ABM proposes specific locations where new healthcare centers

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should be constructed to ensure that all residents have convenient access to medical services. This targeted approach allows city planners to prioritize infrastructure development in the areas where it will have the most impact.Overall, the ABM introduced in this paper is a valuable tool for urban planners and stakeholders. By providing a detailed, data-driven analysis of population movement and infrastructure needs, the model offers calculated and optimized solutions for urban expansion.

Keywords: *urban planning, agent-based modelling, 15-min city*

Decision Policies
and
Strategic Planning

Assessing Local Food Production Self-sufficiency Through The Prisma of Material Flows, Geographical Information Systems and Life Cycle Assessment

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Abstract

The increasing global population, extreme weather events, and strained local, regional, and global supply chains are only some of the more prominent challenges that the current industry sectors need to cope with. One such sector is also the food sector, specifically food production and consumption. The United Nations also recognised the importance of sustainable and circular food production and flows within the Sustainable Development Goals (SDG), especially within SDG 1 No poverty and SDG 2 Zero Hunger. Food is also a key sector within the European Union's (EU) Green Deal (GD) strategies and policies. One such approach is the Farm to Fork Strategy, which proposes establishing local production and increasing the local or regional interaction between stakeholders in the food supply chain.

The main issue in resolving the challenges of today's society is understanding the needs, wishes and incentives of all stakeholders within the food sector. While the expanding global supply chain made it possible to trade goods, among other food, on a global scale, thus improving the economic benefits of companies, producers and subsequent consumers, this same global trade also introduced negative impacts. With current economic market

instabilities, rising food production costs and unexpected weather events (drought, floods, diseases), many stakeholders within the global food supply chains have higher incentives towards increasing their economic benefits while putting the social and environmental aspects at the side. Such orientation may often result in a reverse situation from SDGs and GD promotions.

While there are approaches of local food producers to establish with other stakeholders short-distance food supply chains, such endeavours face several challenges. Challenges are related to economic viability, establishing local supply chains, and changing society's lifestyle behaviour. While these challenges are visible, they often must be more appropriately approached. Changing such a broad sector can only be done by undertaking a systematic approach by first understanding the fundamental basics and functioning of local supply chains. Thus, there is a need to establish the current "state-of-the-art" of food supply chains to identify how these are constructed.

The study will first analyse the current food flows at the regional level by employing material flow analysis (MFA). Through MFA, food production, consumption and waste flows will be measured, to understand the local population food needs. After establishing the flows, we will integrate them through the geographical information system (GIS) to follow their current pathways, specifically the outgoing and inflowing flows. By understanding the pathways of food flows and the needs of the local population, we will be able to optimise the localised flows, thus lowering the need for potential imports. Lastly, by employing the Life Cycle Assessment (LCA), we will be able to calculate how potential changes to the current "state-of-the-art" would improve environmental impact and to what extent. By employing such a systematic approach, we will be able to provide potential optimisations, which both stakeholders within the food supply chain and policymakers will be able to implement, thus accelerating a sustainable and circular approach in line with current policies and strategies.

Keywords: *material flow analysis, Geographical Information System, Life Cycle Assessment, supply chain, food production and consumption*

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Simultaneous Biohydrogen and Biomethane Production by Foodwaste, CSTR in series

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Abstract

Two of the biggest challenges facing the global scientific community are climate change and the adaptability to the new situation, as well as energy poverty. A common fact is the fossil fuels and how energy production could be independent of them. At first, bio-methane but also bio-hydrogen could provide alternative solutions. The factor that makes the two fuels more beneficial, is the method used to be produced. Aiming for environmentally friendly fuels that help reduce the use of energy and fossil raw materials, the dark fermentation and anaerobic digestion processes, are highly attractive solutions mainly at the research level. In fact, when the raw material (substrate) to be used is the food waste, then the goal can be achieved two fold. On the one hand, the production of biofuels with a method that requires the use of lower energy and fewer chemical components, on the other hand, food-waste is utilized, reducing the global problem of food dumping and strengthening the principles of circularity and the circular economy in a wider range.

Studies have focused on different substrates and have shown interesting and highly promising results. The present work will focus on the

investigation of the simultaneous production of bio-hydrogen and bio-methane from foodwaste, using dark fermentation and anaerobic digestion methods, respectively. The substrate, consisting of leftovers from fruits and vegetables, will be inserted into a continuous stirred-tank reactor (CSTR) where the dark fermentation process will take place. The effluent of the first CSTR will feed the second CSTR and the methanogenesis will be conducted. Both reactors will be operated in thermophilic conditions. At the same time, all the operation parameters (Temperature, pH, Organic rate, etc.) will be monitored and significant factors, such as VFAs, Ammonium, TOC, COD, and Alkalinity will be determined. In this way, it will be possible to monitor the operation of the process, to quickly and promptly diagnose and deal with any problems, but also to obtain important information (feedback) about the parameters that can affect the process and its efficiency. Much more attention will be paid to monitoring and estimating the production of the two bio-products, measuring the produced amounts of bio-methane and bio-hydrogen and analyzing the yield and productivity by means of microGC analyzer, as well as whether and to what extent this is due to the substrate, to the process and the functional characteristics.

Keywords: *CSTR, foodwaste, bio-hydrogen, bio-methane, circular economy*

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Driving Voluntary Reduction of Single-Use Plastic Consumption: Capability, Opportunity and Motivation

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Abstract

The excessive use of single-use plastics (SUPs), particularly SUP tableware, has led to a global plastic waste crisis with devastating environmental consequences. To mitigate this crisis, it is crucial to understand the factors influencing consumers' voluntary behaviour to reduce SUP tableware (such as straws, stirrers, forks, knives, spoons, cups and their lids, bowls, plates, food containers and covers) consumption. Existing studies, often relying on simplistic models, inadequately capture the intricate and complex nature of human behaviours involved in the engagement of SUP reduction. Grounded in the COM-B model and the Theoretical Domains Framework (TDF), this study aims to understand the factors influencing consumers' behaviour to reduce SUP tableware. The theoretical model views complex SUP consumption behaviour as a system of interacting factors, including capability, opportunity, motivation, and outcome behaviour. Our model assesses the interplay of individuals' psychological and physical (capability), levels of social and environmental support (opportunity), and how people

think and feel (motivation) influence them to curb SUP tableware consumption. An online survey was administered to a total of 998 participants to empirically examine how capability, opportunity, and motivation explain or predict behaviour change in the context of SUP tableware reduction. Results of this study show that capability and opportunity are associated with SUP tableware reduction behaviour, fully mediated by motivation. The model explains approximately 70% of motivation to reduce SUP tableware consumption. Motivation predicts almost 30% of actual SUP tableware reduction behaviour. Capability, opportunity, and motivation are higher-order constructs measured by lower-order constructs. Capability is predicted by action control, action planning, action skills, decision-making, and habits, indicating that specific tactics that enhance behavioural regulations and skills are required to improve individuals' ability to reduce SUP consumption. Behavioural Opportunity is associated with social norms, social support, and environment. While social influence and norms are essential social opportunity factors, it is crucial to recognise that the environmental context and available resources (i.e. physical opportunity) also play a decisive role in facilitating actions to reduce SUP consumption. Motivation is affected by identity, reinforcement, goals, and self-efficacy. This study contributes to the literature by advancing knowledge on using a comprehensive yet parsimonious model to understand single-use plastic reduction and providing a validated COM-B model for future research on intervention approaches to promote sustainable consumption behaviours. Practically, this study paves the way for field research seeking to identify change levers in the context of SUP tableware reduction, ultimately inspiring more consumers to protect our environment.

Keywords: *single-use plastics consumption, SUP tableware reduction, voluntary behaviour change, sustainable behaviour, COM-B, social marketing*

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Charting Sustainability in Cities: Comprehensive Sustainable Index Incorporating Mitigation and Adaptation

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Abstract

Despite numerous planned initiatives, many sustainable actions in cities, particularly adaptation measures, remain unrealized due to a disconnect between available resources and project execution. A significant reason for this issue is the separate planning and valuation of mitigation and adaptation strategies, leading to a lack of comprehensive sustainable decision-making approach. Combining mitigation and adaptation, and considering local goals and preferences in decision-making, can lead to more effective and sustainable urban development. Synergies between these strategies can enhance resilience, reduce greenhouse gas emissions, and promote economic and social benefits.

This article introduces an innovative, comprehensive sustainable index which aims to rationalize decision-making in cities, aligning actions more closely with the goals of cities and key stakeholders. The main innovation of this index lies in its comprehensive approach, considering criteria for both adaptation and mitigation actions. It encompasses all aspects of urban sustainability, including economic, social, institutional and technological factors, rather than focusing solely on climate-related issues.

The sustainable index is part of the novel value-based Multi-Criteria Decision Analysis (MCDA) methodology called SYNERGISE+, developed

under the European Horizon 2020 PROSPECT+ project (www.h2020 prospect.eu). This approach included the creation of original criteria, i.e. the sustainable index, value-based weight elicitation, comprehensive list of mitigation and adaptation actions, and a comprehensive methodology to prioritize actions. Its main novelty, apart from the original sustainable index, is that it recognizes and flags potential synergies from SECAP actions. This article, however, examines solely the sustainable index and explores what it can reveal about the sustainability and values of European cities.

It is a 5-dimensional, 12-subcriteria resulting from thorough research covering over 30 existing sustainable indices to arrive at an all-encompassing new index approach tailored to needs of urban sustainable development. The index includes the following 5 dimensions and their subcriteria: 1) Environmental Impact: Assesses actions based on their potential to reduce emissions and conserve biodiversity; 2) Economic Viability: Evaluates actions based on economic returns, such as job creation and energy security; 3) Social Equity: Assesses actions for their impact on social inclusion and quality of life; 4) Technical Feasibility & Competitiveness: Evaluates technological readiness and scalability, and; 5) Institutional Framework: Focuses on the alignment of actions with political goals and legal frameworks.

While the index has global applicability at the local level, this article specifically examines its application to 45 European cities included in the UN Sustainable Development Goals Index(European Cities SDG Index available at https://euro-cities.sdgindex.org/#/). By mapping all the SDG goals against our sustainable index, we uncovered the specific values and objectives driving these cities' strategies. Furthermore, three value scenarios were developed—status quo, traditional, and sustainable approaches. An assessment was conducted to determine which cities align with each scenario, offering insights into the priorities of these cities not only in their

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sustainability efforts but also mapping their primary focus areas in urban development overall.

The study highlights how cities are aligning their actions with broader sustainable development goals, offering valuable insights into their commitment to fighting climate change. This comprehensive mapping showcases the diverse approaches cities are taking to achieve low-carbon and climate-resilient futures, offering a crucial tool for comparing global urban development and policy-making.

Keywords: *innovative sustainable index, local decision-making, mitigation and adaptation, urban development and governance, synergies*

Supporting Phytoremediation-to-Biofuel Value Chains Design using Multiple Sustainability Criteria

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Abstract

This paper presents a decision support system that has been developed within the frames of the H2020 CERESiS project to support designing biofuel value chains when the biomass originates from phytoremediation activities on land contaminated with inorganic contaminants. The ultimate goal is to identify and assess win-win scenarios of decontamination and phytomanagement of contaminated land while at the same time producing low-iLUC biofuels.

The assessment of the various alternatives is performed in a multi-criteria perspective, adopting criteria from all sustainability dimensions: Economic, Environmental and Social. The presented Decision Support System (DSS) combines various additional features, such as GIS geographical data input, machine learning for biomass suitability assessment and supply chain optimization. The need for such a tool originates from the fact that decisions

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on designing biofuel value chains are intrinsically complicated, due to the large number of stakeholders involved (e.g. farmers/feedstock suppliers, biofuel producers, intermediaries, 3PL, refineries), high seasonality in feedstock availability, high logistics costs & efficiency. The aim is to assist various types of stakeholders, such as problem owners, farmers, farmer associations, biofuel producers, local authorities and policymakers, to understand the feasibility of establishing a phytoremediation-to-biofuel value chains in order to decontaminate geographically explicit contaminated land parcels and produce clean biofuels. Ultimately, the tool can assist the decision makers in selecting the most appropriate scenario for each case.

The CERESiS DSS tool has several key characteristics that diversify it from other biomass value chain assessment tools:

1. It can support whole value-chain assessment
2. It considers all three sustainability dimensions in the assessment (environmental, social, economic)
3. It adopts novel Machine Learning methods for predicting the performance of biomass species on contaminated land
4. It is a practical tool for use by several stakeholders involved in the value chains for pre-feasibility assessment
5. It has generic applicability in the whole of Europe
6. It incorporates the findings from the upstream decontamination and conversion technology development of the CERESiS project
8. It is a modular and expandable platform
9. It incorporates the concept of mobile Fast Pyrolysis plants

The tool has several novel features, such as its ability to allow end-to-end value-chain assessment, the adoption of novel machine learning methods for predicting biomass species performance on contaminated land and allowing consideration of mobile Fast Pyrolysis conversion units together with fixed conversion units.

The DSS tool will be presented through demonstrating its application in a case study. It will analyse multiple alternative value chain scenarios against a range of KPIs. For each scenario, the value chain structure will be defined and optimized, and a muticriteria assessment will be performed and ultimately, a ranking of the scenarios will be obtained.

Keywords: *phytoremediation, decision support, biofuels, value chains, multi-criteria*

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Magnetic Declination as an Important Factor in Climate Impact and Weather Forecast

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Abstract

Numerous studies and various explanations have been published for the possible contribution of space weather to earth's climate. The Sun is the major contributor of space weather with its brightness or irradiance as the most important impact on Earth. It produces energy through light in a variety of wavelengths. The visible wavelengths are responsible for most of Sun's energy with minor changes during the 11-year solar cycle while UV wavelengths show larger changes during the solar cycle and with significant impact on the ozone layer and in the stratosphere. At shorter wavelengths like EUV there are major changes but in very short timescales and only affecting the upper atmosphere, while at IR wavelengths there are minor changes over the solar cycle. The Total Solar Irradiance (TSI) has a range of 1365.5 Watts/m^2 to 1366.5 Watts/m^2 (from solar minimum to solar maximum) with the difference of 1.3 Watts/m^2 resultingin measurable changes in the temperature of the atmosphere.

Other types of space weather can impact the atmosphere as well. Energetic particles interact with the atmosphere and the magnetic field of earth with changes in chemical composition. Studies have proved the contribution of the earth's magnetic field to earth's climate, mostly focused on the ionospheric layer and the possible mid- or long-term effects on earth's climate. Interesting results have been produced on how space weather affects the upper and middle atmosphere, with the main result

being the indirect ozone loss which leads to atmospheric changes like lower stratosphere cooling and upper stratosphere warming, polar vortex enhancement and positive NAM/NAO on the ground.

But what about the short-term effects on earth's climate due to different types of particle precipitation, solar extreme ultraviolet (EUV) and X-ray radiation and what's the contribution of space weather and magnetic declination to earth's weather? Is it possible, the changes in particle precipitation to play an important role in the local climate and local weather?

Here, we propose a weather model based on the changes of the magnetic field and space weather, with objectives being the explanation of the mechanism behind this correlation, the effects on climate and weather and the introduction of a new parameter in weather forecast. The slow changes in the magnetic field are correlated with mid- and long-term climate conditions, while the quick changes in space weather are correlated with short-term weather conditions. In combination, they introduce a new perspective on climate and weather.

The method is based on the calculation of electronic precipitation on isogonic lines (positive or negative declination sets), the schematic imprint of the calculated values of each single isogonic line (resulting in the new term of declination cell) and the interaction of declination cells with major patterns of weather during summer and winter under the contribution of zonal winds and solar activity. It will focus on the interaction of electron precipitation onto the declination cell and what is happening on the main ridge and the edges of the declination cell.

Finally, we'll try to predict major characteristics of climate and weather for the following years with high focus on droughts and extreme precipitation.

Keywords: *climate change, weather forecast, magnetic declination, particle precipitation, space weather*

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Circular Cities in the Framework of Proximity Economy

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Abstract

Cities are on the front line combatting major challenges, notably climate change, pandemics, decarbonisation, air pollution, food security, energy poverty, waste/water management and putting in place circular economy. Cities are hubs of sustainable economic activity, community engagement, innovation. The policy choices local governments make today will determine the successful transition to greener, cleaner, smarter way of living and will offer new economic opportunities. Cities can act as enablers of the transition. Major urban challenges are driven by circularity. New human-centric urban trends and technologies shape circular urban planning, collaborative governance and technology-powered solutions that cities can deploy to speed-up their transition to a green, smart, circular economy.

Cities can lead the circular transition by fostering the use of short supply chains and local production and consumption, towards the benefit of citizens, municipalities and businesses. Circular economy in local level can address market disruptions, increase local resilience and self-sufficiency and involve people in the labour market with job creation. Short value chains can strengthen the resilience of local communities while contributing to environmental sustainability; for example, by encouraging waste reduction and product reuse by keeping them locally produced. The "Proximity Economy", a growing community-oriented concept in Europe, is an human-

centric ecosystem which consists of the production, distribution and consumption of goods and services within short value chains, enabled by and based on local social interactions within a geographical area of perceived closeness. This paper explores the relationships between the circular economy and important concepts such as the sharing economy, the collaborative economy and the social economy and the inclusion of all in the broader concept of the proximity economy. Many good practices and case studies are presented.

At the same time, a spatial planning friendly to circularity and proximity is examined and the importance of urban and regional planning frameworks is presented with a priority on the promotion of local economic development and land use. Citizens and businesses can benefit from the circular economy at city level thanks to the role played by technological and digital proximity solutions, in an innovative way. Circularity in the built environment (reuse of buildings and recycling of outdoor spaces) is supported through policy mapping and examples of practical application. Urban planning can prioritize shared spaces such as parks and pedestrian zones to facilitate social cohesion, accessible public spaces to promote connections and a diverse local economy. In recent years more attention has been paid to urban development with a renewed focus on 'proximity'. Ideas such as the '15-minute city' have highlighted the damage the mobility economy and urban sprawl have caused and demonstrate the need to refocus economic organization to improve quality of life, protect the environment and address other socio-economic issues. Embedding digital technology and encouraging the reuse of old buildings through policy frameworks can strengthen the circular economy, making it more resilient and dynamic (both for the creation of business facilities and shared public spaces). This may include tax incentives, reduced VAT rates for renovation projects or simplified planning permissions for re-use initiatives. Good practices of mixed-use urban design (Spain) and building material cycle are

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presented in the context of the circular strategy of the municipality of Leuven (Belgium).

Geographical proximity plays an important role in circularity because it can facilitate cooperation between companies and the exchange of used materials and waste (industrial symbiosis). A circular ecosystem derived from a context of geographic proximity can in turn facilitate the development of social proximity, "facilitating the exchange of by-products and waste recovery solutions". This is the case, for example, of the Circular Valley, an initiative taking place in the Rhine-Ruhr region of Germany, which involves various local stakeholders to work together to find innovative solutions to promote the transition to a circular economy.

Keywords: *circular cities, proximity economy, innovation, urban planning, industrial symbiosis*

Application of SSM in Structuring Decision Support for Evaluation of "Green" Development Programs

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Abstract

This study presents the decision-making design based on the well-established epistemological principles of the systemic decision-making approach (SSM) regarding the effectiveness of "green" development programs, i.e. programs related to environmental and energy investments. More specifically, this study seeks the formation of a system, which will be an essential evaluation tool for the European Commission and the parties related to financing. The model developed describes the proposed process of evaluating "green" development programs, taking into account multiple perspectives and objectives, as expressed by all stakeholders in a specific organizational context. It is argued that in this way the management of funding will be evaluated in a consistent manner and in accordance with the needs and culture of the competent organizations, which are called upon to fulfill their objectives. The application of SSM and its results, which have a social, economic, environmental and administrative footprint, demonstrate that it can be used as a tool for assessment in complex organizational environments. The methodology provides valuable insights into the intentions and responsibilities of interested parties, which interact with each other and can shape the desired outcome of system implementation.

Keywords: *systemic decision-making approach (SSM), "green" development programs*

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Integrating Circular Economy Principles in Ship Recycling: A review of decision-making approaches

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Abstract

Ship recycling is the complex and systematic technical process of dismantling maritime vessels with the primary objective of extracting and recovering valuable materials. The process provides a significant amount of scrap material to the iron and steel sector, reducing the need for virgin metals to meet the demands of today's global shipping industry. However, it also involves the simultaneous consideration of human rights, environmental protection and social responsibility, creating a balanced approach to ensure sustainable and ethical ship recycling practices. Ship recycling has become increasingly important in recent years as environmental awareness increases and more ways are found to reduce, reuse and recycle materials.

At the same time, there is a growing global focus on the circular economy (CE) to move beyond the current production and consumption model based on continuous growth and increased resource through put. In a circular economy, products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacture, recycling, and composting, to achieve a better balance and harmony between the economy, environment, and society. According to CE principles, recycling is the least favorable option for end-of-life products. Operations such as re-use and remanufacturing can be used to extend the life of marine equipment and

delay the inevitable recycling stage, thereby contributing to significant savings in material resources and value in the form of labor and energy.

The concept of green ship recycling represents a shift towards sustainable and environmentally friendly practices. Green ship recycling embraces principles such as the reduction of hazardous substances, proper handling and disposal of waste materials, and promotion of recycling and reuse of ship components, formulating the circular economy implementation within the maritime industry. The goal of this research is to investigate this field and demonstrate the current state of the literature on the integration of circular economy principles in ship recycling.

Stakeholders in the maritime industry must deal with complex decision factors regarding vessel recycling. These factors play a crucial role in the decision process and the implementation of circular practices towards sustainability. In general, decision-making methodologies provide solutions to the problems involving conflicting and multiple objectives. Several methods based on weighted averages, priority setting, outranking, fuzzy principles and their combination scan be employed.

Furthermore, this review study documents the applicability of decision support methodologies in the ship recycling process. The review process is divided to two sections. The 1st section examines studies that include circular practices in ship recycling, whereas the 2nd section analyses the use of assessment methodologies in ship recycling. The collected studies are clustered according to their field of study, providing useful insights and conclusions about recent trends. This synthesis of existing knowledge and identification of emerging research needs and opportunities will serve as a foundational resource for impactful future research and informed policymaking, particularly in alignment with global environmental and sustainability goals.

Keywords: *ship recycling, circular economy, sustainable supply chain, decision-making*

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Low Carbon Economy in the Fields of Energy and Environment: A Thematic Review

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Abstract

In recent decades the economic growth and the improvement of urbanization rate exert evident impact on the increase of carbon emission nationally and globally, while the energy intensity exerts varying effect on carbon emission. In this context they have been published studies that further propose countermeasures and suggestions in order to realize the development of low carbon economy. This low carbon economy is further pushing industrial structural transformation, strengthening energy conservation, for steering emission reduction in technological innovation and reducing the cost of emission reduction.

In our better understanding of the contentious issue of the transformation of urban distribution industry the self-distribution mode was introduced in the form of low carbon urban distribution mode. This mode determined the main research types of goods, being a methodological proposal to the specific enterprises. Focusing on the climate change, the target of energy conservation and emission reduction, the proposed method of urban distribution mode can

reduce carbon emission intensity, identify core influencing factors of urban distribution mode, and promotes noticeable reduction on carbon emission intensity showing that there are literature conducted methods that can effectively guide enterprises to develop low carbon urban distribution mode and reduce carbon emission intensity of urban distribution. Similarly to urban distribution is the issue of smart grid construction, being an important carrier technology to effectively promote the development of low-carbon economy. Considering the demand response (DR) is commonly regarded as an important core technology in smart grid field, flexible and interactive features of the core business in smart electricity can be demonstrated. Aiming to achieve the interoperability between the grid side and the user side, there have been conducted business in smart grid user interface standards that support further the demand side management. The ultimate goals are the highest benefits of energy conservation and emissions reduction resulting from renewable power generation through optimizing the annual operation of the power system. Subsequently, model's validation and verification of the simulation results in practical regional power systems and corresponding solving algorithms.

From an environmental perspective, but more noticeable in recent decades, greenhouse gases (GHGs) are responsible for global damage, global warming and climate change. The concurring problems in various sectors of the world economy make an imperative need the reduction of the negative impact on the environment and the optimum management of GHGs emissions in the regional economy. Therefore, the best management methodologies should be envisaged towards reducing total costs for economic entities in the interests of the entire region. The implementation of the methodologies are tools of stimulating economic entities, the use of which will realistically bring them and the nearby society closer to a low carbon economy.

On the other hand there are gaps at local, national and regional levels concerning policy making and project formulation, related to climate

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change, sustainable development and human security. It is noteworthy that whenever an increased level of regional growth is prospected, then, this region needs to tread down a path towards a low carbon economy in order to face up to the challenges of climate change. Contrarily, inadequate regional cooperation, energy insecurity and weak governance are identified as key constraints to achieve a low carbon economy in national level of analysis. The most noticeable human actions and priorities on confronting climate change are the adoption of specific climate change policies, the meeting of forums for regional cooperation, as well as private sector initiatives which are able to promote sustainable practices. The tranformation and scaling up from policy planning to action needs to be undertaken, while the main barriers of such a transformation are the political instability, the lack of economic integration as well as limited natural resources that need to be acknowledged and surmounted prior to achievement of sustainable development in regional scale of analysis. A plethora of literature review studies disclosed numerous examples and mechanisms that may encourage coordinated and integrated policies and mechanisms towards low carbon economy, underscoring the effective response to climate change the challenges in regional-topical interest.

Among the numerous examples and mechanisms of encouraging coordinated and integrated policies the authors of this study developed a research method to collect and to include timely published studies on jointly recognizing literature-emerging sectors and low carbon economy in local, regional, national, or continental interest. Therefore, the applied methodology contained the collection of studies retrieved from literature search at the middle of year 2024, covering the documents on "low carbon economy" in their titles. This literature search enabled the organization of search results under the following literature-defined areas:

Regarding the country/territory of documents retrieved the most studies' productive country was China, having 154 documents, following by United Kingdom (22 documents), United States (19 documents, Germany (16

documents) and Spain (13 documents). Besides, regarding the affiliations reported it was shown that the top-10 affiliations were all Chinese Universities with the number of results-publications per university in the field of "low carbon economy" ranging from 4 to 7 documents, each one higher institution. Moreover, regarding the number of results per source type it was a number of 202 documents published in journal, followed by 51 documents in conference proceedings, 13 documents as book or book chapters and 8 documents in book series.

Based on the retrieved documents it was pointed out that the rapid growth of social and economic development has also brought great challenges to the development of regional resources and environment. The deepening and broadening of the sustainable development concept implies the coordinated development of regional resources, environment and economic growth. Indeed, the coordinated development of resources, environment and economic growth is not considered only as the core of industrial growth, but also the promotional accelerator of industrial transfer and the optimal allocation of resources are unavoidably fostering and nurturing factors of social development. However, the necessity of steady upgrading of the industrial structure has subtly emerged severe problems, such as environmental pollution, unbalanced economic development, resource shortage all affecting on various important development areas. The reported findings of this study are consistent with the broadely agreed statement that the development of low-carbon economy has strong feasibility to promote the coordinated development of regional resources, environment and economic growth.

Keywords: *low carbon economy, climate change, environmental pollution, greenhouse gases, carbon emissions, models and simulations, economic growth, regional growth, allocation of resources, sustainable development, review*

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Connecting Classrooms to Communities: A USA-Greece Sustainability Educational Initiative

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Abstract

This groundbreaking initiative is a collaborative academic program designed to bridge the gap between theoretical knowledge and practical application in sustainability. The program is designed as an international course in Crete, Greece, bringing together students and a multidisciplinary and binational team of experts, including educators, local authorities, and stakeholders from the United States and Greece, to engage in hands-on learning experiences that address real-world sustainability challenges. This project is a dynamic platform for exploring sustainable infrastructure, tourism impacts, environmental management, and community engagement. The program emphasizes the importance of cross-cultural and inter disciplinary collaboration, aiming to enhance students' understanding of sustainability by directly impacting the local communities.

This presentation highlights the significance of such international educational initiatives in preparing students for careers in sustainability. By demonstrating how the program's hands-on approach fosters a deep understanding of sustainability complexities and develops essential skills in interdisciplinary collaboration and problem-solving, this poster presentation aims to provide a model for similar programs globally. The initiative enriches academic learning and contributes meaningfully to local and global

sustainability efforts. The conference attendees will gain insights into the practical implementation of sustainability education, the benefits of international and cross-disciplinary partnerships, and the potential for replicating this model in other contexts. The presentation seeks to inspire dialogue and encourage institutions to adopt innovative approaches that bridge academic learning with real-world applications, ultimately advancing the field of sustainability education and addressing pressing global challenges.

Keywords: *sustainability education, cross-cultural collaboration, hands-on learning, interdisciplinary partnerships*

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Optimal Network Design of Public Chargers for Electric Vehicles in Cyprus

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Abstract

The European Union (EU) has set an ambitious goal to reduce net greenhouse gas emissions by at least 55% by the year 2030, a target encapsulated in the initiative known as "Fit for 55". This framework aims to address the urgent need for environmental sustainability by targeting various sectors, among which transportation emissions are a significant concern. The transportation sector is responsible for a substantial portion of greenhouse gas emissions, making it imperative for the EU to implement effective strategies to mitigate these impacts. One of the critical approaches to achieving these reductions involves the widespread integration of Electric Vehicles (EVs). As the use of EVs increases, so too does the necessity for a robust infrastructure to support them, particularly through the expansion of public charging networks across all EU member states.

In this context, this paper introduces a mathematical model designed to optimize the installation of public EV chargers. This Facility Location Problem (FLP) is formulated as a Mixed-Integer Linear Problem (MILP)

that incorporates various critical factors, including social, economic, spatial, and environmental parameters. By taking these diverse elements into account, the model aims to provide a comprehensive solution that balances the needs of the population with the overarching goal of reducing transportation emissions.

The model is implemented on Cyprusas a case study, where the entire country is discretized into its postal sectors. This segmentation allows for a more localized analysis of energy demand, which is essential for determining where EV chargers should be placed. To estimate the energy demand in each sector, the paper proposes a sophisticated technique that leverages both demographic data and the assessment of the number of EVs that may be registered in the future. Using QGIS software, Geographic Information System (GIS) data is processed to gain insights into factors such as population density, existing infrastructure, and potential demand for EV chargers. This GIS-based analysis not only enriches the model but also provides a visual representation of the data, making it easier to identify optimal locations for charger installation.

The model considers various types of chargers with different power in kilowatts, each with its associated purchasing and installation costs. This multifaceted approach allows takes into consideration the financial implications of expanding the public charging network.

Once the energy demand estimates are integrated into the MILP framework, the model seeks to identify the optimal possible locations for public EV chargers while considering various constraints, such as budget limitations. Additionally, a sensitivity analysis is conducted to explore how variations in available budget impact the optimal placement of the chargers. This analysis helps to identify which locations remain viable under different financial scenarios, providing valuable insights for decision-makers.

The results of the optimization and sensitivity analysis are visualized through heatmaps generated in QGIS. These heatmaps provide stakeholders

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with an intuitive representation of the proposed locations for EV chargers, highlighting areas of high demand and potential impact. By translating complex data into accessible visuals, the methodology becomes a useful tool for stakeholders, including government agencies, urban planners, and private investors, allowing them to make informed decisions about infrastructure investments.

Keywords: *electric vehicles, public chargers, network design, facility location*

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