WIRE

Waste biorefinery technologies for accelerating sustainable energy processes

Book of abstracts

WIRE's Final MC Meeting & Working Groups Workshop

Agrocampus

Mont-de-Marsan – France

16-16th September 2025

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WIRE

Waste biorefinery technologies for accelerating sustainable energy processes

Book of abstracts - WIRE's Final MC Meeting & Working Groups Workshop

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EDITORS

Roberta Panizio, Catarina Nobre, Diogo Santos and Paulo Brito

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Foreword

Welcome to the abstract book of WIRE's Final MC Meeting & Working Groups Workshop – "Reflecting on Achievements and Shaping Future Collaborations", held in Mont-de-Marsan, France. This event brought together participants from diverse backgrounds, who gave oral and poster presentations.

As global environmental challenges such as climate change and waste accumulation intensify, the need for sustainable and innovative solutions remains urgent. The extensive use of fossil fuels has significantly increased carbon emissions, accelerating global warming. At the same time, population growth has contributed to waste generation pressures. Sustainable approaches focusing on carbon-neutral energy sources and renewable fuel production are essential. Biorefineries, which convert biomass and organic waste into valuable products, offer a promising way to minimise carbon footprints compared to fossil fuels. They are key to Europe's path to carbon neutrality by 2050.

The recent WIRE COST Action workshop in Mont-de-Marsan not only strengthened the exchange of knowledge and collaboration between academia and industry, but also served to reflect on the progress made during the COST Action, providing an assessment of achievements and discussion of the future of WIRE beyond the funding period.

It provided an opportunity to expand the network of contacts, sustaining and expanding the collaborations that took place during the four years of WIRE COST Action.

These joint efforts are essential for the development of sustainable solutions with positive impacts on the environment, the economy and society.

Thank you to all the collaborators and participants who have been with WIRE COST Action during the four years of funding. Together, we are moving towards a greener and more sustainable future.

The editors:

Roberta Panizio, Catarina Nobre, Diogo Santos and Paulo Brito

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Introduction

By 2030, the bio-based economy is expected to have grown significantly in Europe. One of the pillars of this bioeconomy is the concept of BIOREFINERY, the sustainable processing of several kinds of waste and biomass into a spectrum of marketable products and energy. While in the past many research efforts have been conducted toward understanding, modeling, and designing conversion processes that can sustain a true circular economy, this KNOWLEDGE IS QUITE FRAGMENTED and UNEVENLY DISTRIBUTED across Europe. Several countries lack proper policies and public engagement to address the challenges ahead. HARMONIZATION must start with ROBUST KNOWLEDGE and the ability to cover the WHOLE VALUE-CHAIN, from source materials up to the marketable products… and that is WIRE's mission.

The WIRE COST Action broadly organizes into 4 KEY WORKING GROUPS (WG) that bring together experts from ACADEMIA, INDUSTRY and TECHNOLOGY TRANSFER organizations:

- WG 1: Raw Materials
- WG 2: Biorefinery Conversion Technologies
- WG 3: Biorefinery Applications
- WG 4: Communication and Dissemination

WIRE's Final MC Meeting & Working Groups Workshop was held in Mont-de-Marsan (France) at the Agrocampus from 15 to 16 September 2025.

The main objective of this workshop was to increase the participation of WIRE members through sessions and industry tours, poster presentations by participants, as well as two lectures and WG meetings.

This event contributed to advancing the goals and deliverables of each WGs and promoting interaction between WG´s participants and stakeholders.

WIRE's Final MC Meeting & Working Groups Workshop had 34 papers presented as oral and poster communications, divided among the different WGs.

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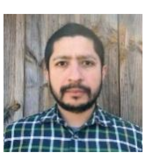

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Event metrics

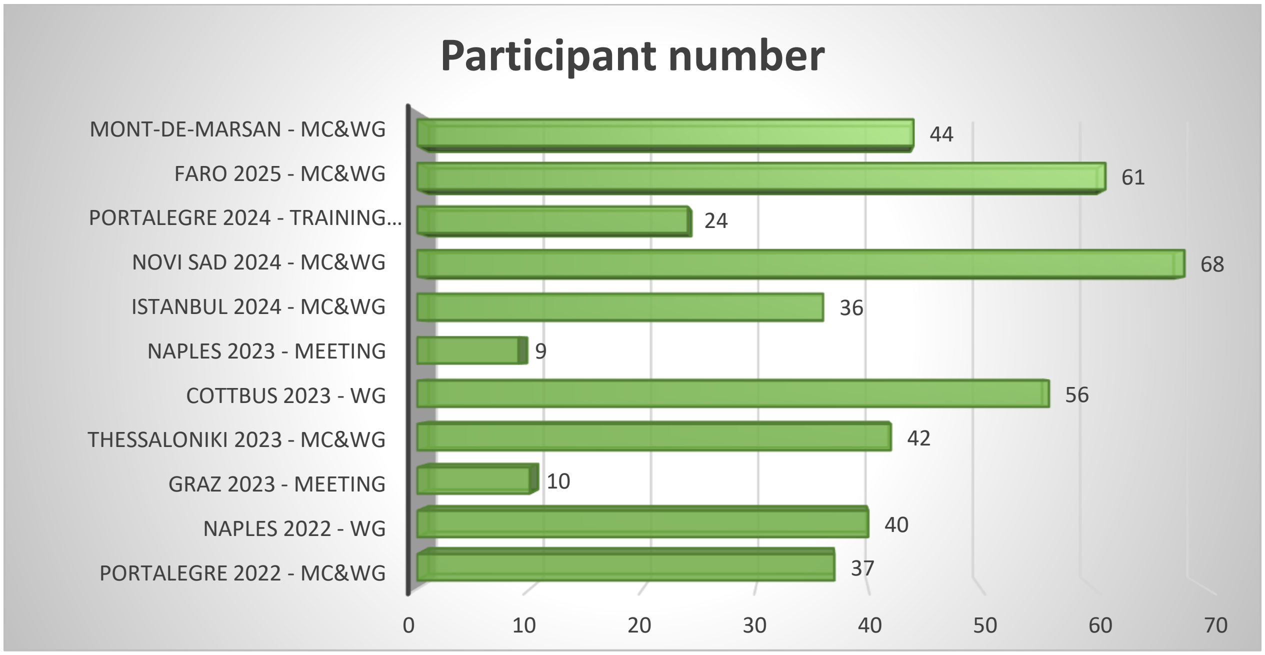

Figure 1: Number of participants in events held during the WIRE COST Action.

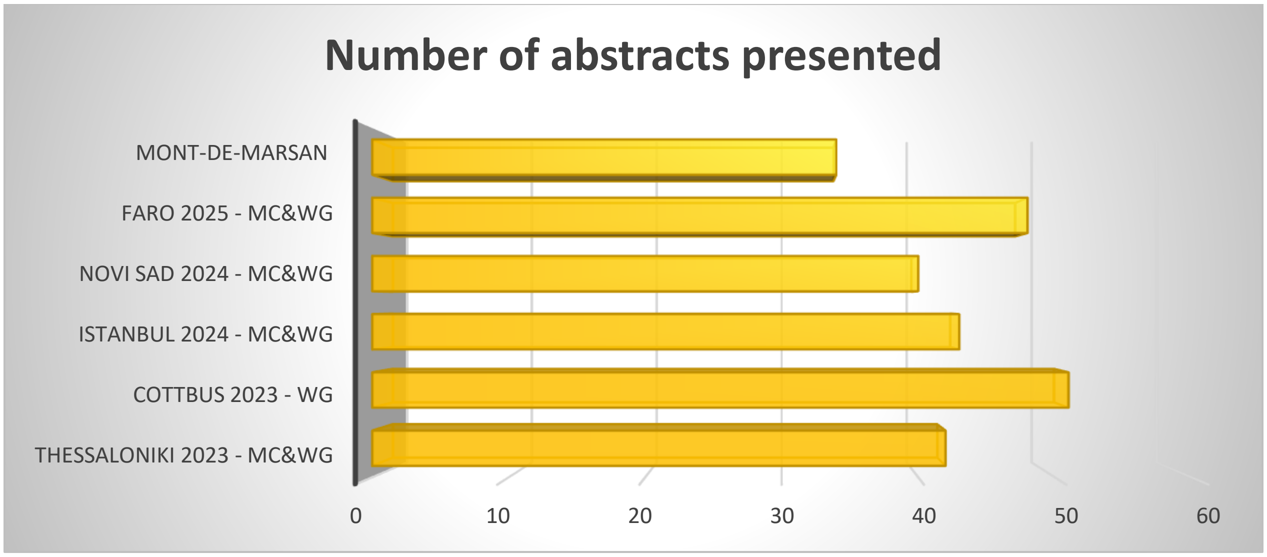

Figure 2: Number of abstracts presented in the abstract books for the events

PHOTOS

WORKING GROUP 1 - Raw Materials for waste biorefineries

Biomass wastes feedstocks for biorefineries cover a wide range of underused and undervalued residual streams depending on the source, including forestry wastes, agro-industrial wastes and effluents, or municipal solid wastes (MSW). Therefore, identifying and surveying the availability and distribution of these feedstocks is key for further biorefinery implementation. As such, WG1 has as main objectives:

(i) The assessment and promotion of sustainable waste biomass supply chains;
(ii) The comparison of different methodologies for pretreatment, harvesting or collection;
(iii) The general logistics and cost-efficiency regarding waste biomass supply chains.

From proposal to beamtime: a practical guide to open-access synchrotron facilities for bio-based materials research

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Abstract: Open-access research infrastructures provide unique opportunities to explore advanced techniques that are not available in many university laboratories. Synchrotron light sources are the most advanced large-scale research infrastructures providing tools that enable a wide range of experiments in fields like chemistry, physics, materials science, biology, and environmental research. Despite their potential, many scientists are still unfamiliar with the application procedures and often may see this process as too competitive or complicated.

This contribution presents a practical step-by-step guide to navigating synchrotron access from an idea to a granted beamtime. Based on first-hand experience with the SOLARIS (Krakow, Poland) and ELETTRA (Trieste, Italy) synchrotrons, it outlines the pathway from idea generation to successful beamtime allocation. As an example, the research on *3D imaging of biofilm–substrate interfaces* performed at the POLYX beamline (SOLARIS) will be presented. The guidance covers key steps, including identifying the appropriate beamline, preparing a competitive proposal, addressing feasibility requirements, performing experiments and handling data afterwards.

This contribution aims to encourage more researchers, especially those working in interdisciplinary fields, and at early stages of their careers, to make use of open-access research infrastructures. By outlining the pathway from proposal to granted beamtime, it supports knowledge exchange and fosters new opportunities for collaboration across disciplines.

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Short biography: Wojciech Pajerski is a postdoctoral researcher at InnoRenew CoE (University of Primorska, Slovenia), specializing in microbiology, materials science, and nanotechnology. His research focuses on bioinspired materials and interfaces between microorganisms and surfaces. He contributes to major European projects on Engineered Living Materials (ELMs), including the ERC-funded ARCHI-SKIN and the EIC Pathfinder REMEDY for eco-friendly architectural solutions. He also leads research supported by a Marie Sklodowska-Curie Seal of Excellence fellowship funded by the Slovenian Research Agency. With patents in bio-based technologies, his research integrates green approaches to reduce environmental impact. His international collaborations and interdisciplinary expertise position him to advance sustainability and green technologies.

High biogas production in anaerobic co-digestion of garden waste

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Abstract: Lignocellulosic biomasses such as Garden Waste (GW) are regarded as major contributors to organic solid waste in urban-industrial areas; however, due to its high lignocellulose content, low biogas yield is observed. Anaerobic co- digestion (AcoD) is a feasible approach for increasing biodegradability and biogas production. This study evaluates AcoD of pre-treated GW with sugarcane bagasse (SB). First, different grinding times (30, 60, and 90 s) were investigated to select optimum particle sizes of substrates. The grinding time of 60 s showed more homogenous size distribution and the highest reduction in the size; for this reason it was used for further experiments. The biogas potential study was carried out with GW:SB at different mass/mass ratios: 1:0 (T1); 0:1 (T2); 0.66:0.33 (T3); 0.5:0.5 (T4) and 0.33:0.66 (T5). As expected, co-digestion (T3, T4 and T5) showed improved biogas production in comparison to T1 and T2. T1 showed the lowest biogas production and T2 showed a high biogas production. T4 (0.5:0.5 GW:SB ratio) showed the highest biogas production, around 8.4 mL biogas* g VSS^{-1}* mg $sCOD^{-1}$, highest biodegradability, 0.74 and sludge activity, 0.41 g COD biogas* g VS^{-1}. Pre-treatment energy requirement is 4 scale of magnitude lower than the energy produced in the reactors and, the co-digestion improved biogas production by two fold, making co- digestion of pre-treated GW and SB a feasible option.

Acknowledgments: This publication is based upon work from COST Action WIRE, CA20127, supported by COST (European Cooperation in Science and Technology).

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Name: **Beni Lew**
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Short biography: Prof. Beni Lew's field of research is in 'processes and systems for agricultural wastes treatment', being granted with several international prizes for his research and teaching skills. Prof. Lew published more than 50 international papers and books at high Impact Factor journals, participated in several international conferences and; has been invited to lecture at different countries (Brazil, Greece, USA, Poland and India). Prof. Lew had PhD students and Post-Doc come from different parts of the world (Germany, Italy, India, Brazil and USA) in his lab and part of these students are nowadays professors in their own countries.

Wood waste valorization by steam explosion

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Abstract: Wood wastes are among the most important biomass available resources in Europe. They are made of lignocellulose, which is a complex matrix of polysaccharides (cellulose and hemicelluloses) and lignin. They represent a promising alternative to fossil resources to produce biomolecules, biomaterials, and energy through biorefinery processes. However, the network formed by the lignocellulose constituents makes it recalcitrant to simple conversions, that is why some pretreatments are often applied to make biological process reactions easier and faster.
Here we present the results of some projects where the steam explosion pretreatment was applied to different wood wastes by varying severity conditions, leading to the creation of large sets of samples. A wide multimodal approach was performed to assess their biochemical composition, spectral properties and physical architecture after pretreatment. This information was expertly gathered and related to the potential of the samples to produce fermentescible monosaccharides, in order to define the most optimal pretreatment conditions for different potential applications.

Acknowledgments: This publication is based upon work from COST Action WIRE, CA20127, supported by COST (European Cooperation in Science and Technology).

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Short biography (should not exceed 100 words): Gabriel Paës is an INRAE research director heading the Fractionation of AgroResources and Environment laboratory. With a transdisciplinary educational background in biochemistry and physical-chemistry of biopolymers, metabolic and enzyme engineering, with positions in academia and industry for more than 20 years, he has become an expert in lignocellulosic biomass characterization and valorisation in the bioeconomy context. In particular, he investigates biomass recalcitrance of various biomass species as raw and pretreated materials, by developing and applying multimodal approaches, in particular microscopy fluorescence-based techniques. His objective is to highlight universal features of biomass recalcitrance that could be easily measurable and turned into markers for sensors to be used in biorefinery processes.

Valorization of Corn Stover from Morlaàs for Biochar Production and Bio-Silica Recovery: Preliminary Insights for Sustainable Energy

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Abstract: According to **IEA (2024)** data, renewable energy accounted for only **14%** and **2%** of the heat and transport sectors, respectively, in 2023, while it reached **30%** in electricity generation, expected to rise to **46%** by 2030, dominated by **solar, wind, and hydropower** (94% of renewable electricity). For heat and transport, renewables are expected to reach **19%** and **6%** by 2030, highlighting the remaining challenges in these **difficult-to-electrify sectors**. In this context, **bioenergy** can play a key role, utilizing **biofuels, solid energy carriers, and gaseous products**. **Pyrolysis**, producing **biochar, bio-oil, and bio-syngas**, can therefore contribute significantly to **sustainable energy strategies**, especially within a **biorefinery approach**.

Corn stover, one of the most important agricultural residues worldwide, is particularly relevant in France, where maize is a major crop, especially in the **Nouvelle-Aquitaine region (Morlaàs)**. This study evaluates three fractions of corn stover for their potential conversion into **biochar, bio-oil, and bio-syngas** via **pyrolysis**, as well as the recovery of **bio-silica** through a mild acid pretreatment (0.1 M HCl, 3 h at 90 °C).

Preliminary analyses indicate that the **silica content** in these fractions is below **1%**, considerably lower than the 5–6% reported for other corn stover varieties in the literature, and much lower than in **rice husks (≈12%)**. The factors contributing to this low content may include **genetic variety, agronomic practices, or local environmental conditions**. **Pyrolysis at 500 °C** with a **heating rate of 10 °C/min** under **inert atmosphere** produced **biochar yields of approximately 19–24%** of the initial biomass. Due to limitations in the current experimental setup, **bio-oil data** are not yet available as their reproducibility is not good enough. Improvements into the experimental set-up will allow for a better collection of this fraction.

These results highlight the potential of local **corn residues** as feedstock for **pyrolysis**, producing **biochar, bio-oil, and bio-syngas** for **energy applications**, while enabling the recovery of valuable sub-products such as **bio-silica**. This study provides some results obtained in this context.

Acknowledgments: This publication is based upon work from COST Action WIRE, CA20127, supported by COST (European Cooperation in Science and Technology).

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Unravelling ethanol metabolic pathways under different feeding regimes in anaerobic digestion ecosystems

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Abstract: Anaerobic digestion offers a dual advantage of decomposing organic matter while producing biogas. Within anaerobic digestion, ethanol acts as a crucial intermediate linking acidogenesis and acetogenesis. Diverse metabolic pathways govern anaerobic ethanol degradation, yielding a range of products such as acetate, propionate, and hydrogen. Understanding the potential ethanol metabolic pathways is essential for optimizing resource recovery. The regulation of ethanol metabolic pathways can be achieved by specific microbial communities. Microbial acclimation can be regulated by different operational modes of sequencing batch reactor (SBR) and continuous-flow reactor (CFR). This study provides a comprehensive analysis of systems performance, microbial community, and ethanol metabolic pathways shaped by different operational modes in anaerobic digestion ecosystems.

Four 5 L reactors were operated with two operational modes, SBR and CFR. In SBR, the anaerobic operation included a 23 h mixing phase with an initial 10-min filling period, while CFR included a 23 h continuous filling and mixing phase. In all reactors, 50 min settlement and 10 min withdrawal were conducted after the mixing phase. The chemical oxygen demand (COD) of ethanol in the synthetic wastewater was 5000 mg/L.

During long-term operation, complete COD removal was achieved in CFR. In contrast, the accumulation of 2250.0 ± 130.0 mg COD/L of acetate, 931.0 ± 184.0 mg COD/L of butyrate were observed in SBR, probably due to the limited activity of acetoclastic methanogens under the low pH condition. Methane production in SBR was less than one-third of that in CFR. Notably, the accumulation of acetate and the reduced pH in SBR facilitated ethanol metabolism towards butyrate production. At the genus level, *Clostridium* and *Sporomusa* were predominant in SBR, while *Desulfolutivibrio* and *Desulfomicrobium* were prevalent in CFR. *Clostridium*, a typical bacterium capable of carbon chain elongation using ethanol and acetate, accounted for 6.5% of the microbial community in SBR. The total relative abundance of methanogens was higher in CFR (24.9%) than in SBR (16.6%). *Methanobacterium* had a higher relative abundance in SBR (13.4%) compared to CFR (1.7%). Conversely, the relative abundance of *Methanospirillum* was notably higher in CFR (16.3%) than in SBR (0.1%). Additionally, *Geobacter* was enriched in CFR.

In conclusions: CFR exhibited advantages over SBR in terms of ethanol degradation and methanogenesis. SBR facilitated a shift in ethanol metabolism toward butyrate production. SBR achieved a notable relative abundance of *Clostridium* and *Methanobacterium*, while CFR showed a remarkable relative abundance of *Desulfolutivibrio* and *Methanospirillum*. The electroactive bacteria of *Geobacter* could be enriched in CFR.

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Short biography: My name is Huanhuan Chang, currently a third-year PhD student at the University of Galway, specializing in Civil Engineering. My primary research focus is on the anaerobic digestion process for wastewater treatment. As a graduate student specializing in environmental science, I am deeply committed to advancing sustainable water/waste treatment technologies. During my undergraduate studies, I developed a strong foundation in environmental science, water/waste treatment processes, and sustainability principles. I was particularly fascinated by the efficient and eco-friendly method for wastewater/waste treatment.

Valorization of Hazelnut Husk Biowaste in Particleboards with Reduced Formaldehyde Emissions

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Abstract: The increasing demand for sustainable and environmentally friendly materials in the wood-based panel industry has encouraged the utilization of agricultural residues as alternative raw materials. This study investigates the valorization of hazelnut husk biowaste in the production of three-layer particleboards, with a particular focus on mechanical performance and formaldehyde emission reduction. Ground hazelnut husks were incorporated into the particleboard structure at substitution levels of 0%, 5%, 10%, and 20% by weight of wood chips. The particleboards were evaluated in terms of modulus of rupture (MOR), modulus of elasticity (MOE), and free formaldehyde content. The inclusion of hazelnut husks led to a considerable reduction in formaldehyde emissions, decreasing from 13.08 mg/100 g in control boards (0% husks) to 7.63 mg/100 g at 20% substitution. This demonstrates the potential of hazelnut husks to contribute to healthier indoor environments by lowering harmful emissions. In addition, mechanical performance improved with moderate substitution levels. The highest MOR (12.52 N/mm²) and MOE (1627.17 N/mm²) values were observed at the 10% replacement level, exceeding those of the control boards (MOR: 9.21 N/mm²; MOE: 1392.17 N/mm²). However, the mechanical strength of particleboard was decreased when the substitution ratio reached 20%, indicating that excessive replacement may compromise structural integrity. Overall, hazelnut husk biowaste can be effectively valorized in particleboard production, offering dual benefits of improved environmental performance and enhanced mechanical properties at optimal substitution levels. This approach not only reduces reliance on virgin wood resources but also promotes the sustainable management of agricultural residues. Consequently, hazelnut husk–based particleboards represent a promising eco-friendly alternative to conventional products, aligning with the growing global demand for low-emission, high-performance, and resource-efficient materials.

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Advanced Surface Functionalization for Enhanced Efficiency and Durability in Waste Biorefineries

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Abstract: The development of efficient and robust waste biorefinery systems requires not only innovative conversion pathways but also advanced material solutions to ensure long-term stability and process performance. This study explores the application of the solvent-free initiated chemical vapor deposition (iCVD) process for the surface functionalization of equipment and components used in biorefinery operations. Polymer-based hydrophobic and chemically resistant nanocoating produced by iCVD is explored as a strategy to minimize corrosion, fouling, and degradation in harsh processing environments. Unlike conventional wet-chemical methods, iCVD enables precise polymerization of functional monomers in the vapor phase without the need for toxic solvents, high temperatures, or complex purification steps. This significantly reduces waste, lowers energy demand, and ensures compatibility with sensitive substrates such as polymers and biomaterials.

Beyond technical performance, the solvent-free and energy-efficient nature of iCVD aligns well with the principles of green manufacturing and the sustainability goals of waste biorefineries. Its scalability further makes it an attractive platform for industrial implementation, offering a realistic pathway to integrate material innovations into waste valorisation processes. By bridging materials science with process engineering, iCVD enables more resilient, environmentally friendly, and economically viable biorefinery infrastructures that support Europe's transition towards a circular and bio-based economy.

In parallel, WG4 of the WIRE COST Action ensures that such advancements are effectively communicated and widely disseminated to maximize their impact. Through coordinated communication strategies, visual identity development, digital platforms, and engagement with industry stakeholders, policymakers, and academic audiences, the scientific progress such as iCVD nanocoatings is transformed into broadly accessible knowledge. This approach strengthens industrial adoption, informs policy, and ensures that the Action's outcomes continue to generate value well beyond its completion.

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Unlocking the Potential of Oxidized Lignin: Nanoparticles for High-Performance UV Protection

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Abstract: Lignin, the second most abundant biopolymer after cellulose and the only aromatic polymer present in significant amounts in nature, constitutes a major structural component of plant cell walls and biomass. In the kraft pulping process, large quantities of lignin are released, the majority of which is incinerated to generate energy. Industrial processes such as LignoBoost and LignoForce make it possible to recover kraft lignin as a solid product, yet its inherent structural heterogeneity, limited solubility, and variable reactivity significantly constrain its use in higher-value applications. Beyond conventional kraft lignin, the kraft process also produces an oxidized fraction during oxygen delignification. This oxidized lignin (OxL) has remained largely unexplored despite its distinct chemical features and potential for more versatile applications. Its higher content of carboxylic groups, lower phenolic hydroxyl content, and superior solubility in both aqueous and organic solvents differentiate it markedly from traditional kraft lignin [1], suggesting strong promise as a cost-effective and sustainable alternative to other technical lignins, such as lignosulfonates. Understanding and exploiting these characteristics could open new opportunities for OxL in fields ranging from construction and agriculture to bioplastics and cosmetics.

In this study, we report the systematic evaluation of the OxL as a functional ingredient in sunscreen formulations. Both bulk OxL and its nanoparticles (OxLNPs), prepared via solvent exchange, were investigated as UV-blocking components. Particle size and surface charge were determined using dynamic light scattering. Creams containing varying concentrations of OxL and OxLNPs were developed and tested for UV absorption, SPF performance, and visual appearance. While UV absorption increased with higher lignin content in all cases, the nanoparticle formulations proved substantially more efficient: the same level of UV protection achieved with 12.5% OxL could be obtained with only 0.1% OxLNPs. Smaller nanoparticles (d=190 nm) demonstrated superior performance, showing 75% higher absorption at 305 nm compared to larger ones (d=460 nm) at identical loading. Furthermore, OxLNPs improved the cosmetic quality of the formulations, reducing yellowing and producing a brighter appearance. The best-performing sample, containing 0.3 mg/g of small OxLNPs, achieved an SPF of 22 with minimal visible difference compared to the base cream.

These results highlight oxidized kraft lignin nanoparticles as a highly efficient, eco-friendly alternative to conventional UV filters, while demonstrating a novel value-added pathway for upgrading industrial lignin into high-performance cosmetic ingredients.

1. J. Sjöström, L. Brandt, G. Henriksson, O. Sevastyanova Oxlignin: A Novel Type of Technical Lignin from Kraft Pulp Mills ACS Omega 2025, 10, 18784−18792 DOI: 10.1021/acsomega.5c00434.

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Exploring the potential of biochar for liquid pig slurry treatment

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Abstract: Biochar has gained growing attention due to its diverse environmental applications, ranging from water purification to carbon sequestration and soil amendment. This study assessed its potential in treating pig slurry collected from a black pig farm in Évora, Portugal. The biochar, produced mainly from residual biomass and weeds, was subjected to chemical and structural characterisation, including analyses of porosity and surface chemistry. Simultaneously, the slurry was characterised in terms of pH, conductivity, chemical and biochemical oxygen demand, total organic carbon, nitrogen, phosphorus, potassium, and suspended solids.
Two experimental approaches were employed using commercial biochar supplied by Ibero Massa Florestal, S.A. In batch mode, different slurry-to-biochar ratios were tested: E1 (1 L : 2 g), E2 (1 L : 10 g), and E3 (1 L : 20 g), over a period of up to 672 hours (four weeks). In dynamic mode, a continuous flow rate of approximately 0.25 L/min was maintained with a fixed biochar mass of 100 g.
The findings revealed that, under batch conditions, nitrate concentrations decreased markedly, with approximately 66% removal within the first 48 hours. Phosphate reduction was also substantial in E2 and E3, reaching nearly 70% after one week. In dynamic mode, although some fluctuations were observed, most parameters showed a consistent downward trend throughout the four test periods.
Overall, biochar clearly demonstrated its effectiveness in reducing pollutant loads from livestock effluents, contributing to improved environmental management and water quality. These results align with the objectives of SDG 6 (Clean Water and Sanitation), by reducing risks of water contamination, SDG 12 (Responsible Consumption and Production), through valorisation of residual biomass, and SDG 13 (Climate Action), by promoting sustainable waste treatment strategies.

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Short biography: P.A.M. Mourão is a Researcher (permanent position) from University of Évora, Portugal. He has a Physics and Chemistry graduation, a master in Physics, and a PhD in Chemistry, in the Materials and Surface area. In the last years, he has consolidated his research in the fields of preparation, characterization, development and application of porous materials, with the focus on the recovery and valorization of different raw materials and waste, from natural and/or synthetic sources, by its transformation into adsorbents with potential application in the liquid (e.g. dyes, pesticides, pharmaceuticals, metals) and gas phases (e.g. CO_2), guided by a circular economy perspective.

He is currently an Integrated Member at the MED and CHANGE research centres, a Collaborator Researcher at the VALORIZA and LAQV-REQUIMTE research centres, and Co-Chair of the Research Chair in Materials Science at the University of Namibia.

Waste-based Biorefineries for Sustainable Production of Biochemicals

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Abstract: Chemical and allied industries remain heavily dependent on crude oil, a finite and non-sustainable resource. For decades, microorganisms have been harnessed to produce value-added products from renewable carbon sources. Microbial cell factories capable of overproducing metabolites through fermentative processes present a promising alternative to fossil-based chemical production. Chemical building blocks can be synthesized via microbial pathways using both edible and non-edible feedstocks. Furthermore, the recovery and recycling of renewable carbon and essential nutrients from waste resources for the manufacture of bio-based products offer several advantages, including biodegradability, reusability, sustainability, and a significant reduction in waste generation, contributing toward a carbon-neutral society. This talk will focus on utilizing waste as a potential feedstock for biorefineries, aligning with a circular economy approach. The seminar will highlight case studies from my own research, demonstrating the use of food (bread) waste, sugarcane bagasse, and brewers' spent grains as feedstocks for producing chemical building blocks such as lactic acid, itaconic acid, xylitol, succinic acid, and 2,3-butanediol.

Keywords: Platform chemicals; Cell factories; Biowastes; Metabolic engineering; Bioprocess engineering

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WORKING GROUP 2 - Biorefinery Technologies

Waste streams have major potential to be converted into addedvalue products, namely energy, fuels, and chemicals due to their energy content and high concentration of hydrocarbon compounds. Taking into account the wide variety of waste streams in terms of composition and properties, as well as the list of final products to which they can be transformed, several technologies are equally available to be implemented in an integrated biorefinery. These technologies include combustion with energy recovery, gasification, pyrolysis, torrefaction, hydrothermal carbonization, anaerobic digestion, electrochemical techniques, fermentation, hydrothermal liquefaction, and many others, which may be coupled to other subsequent processes to generate energy (e.g. via gas turbines or combustion engines), gaseous or liquid fuels (e.g. via watergas shift, methanation or Fischer-Tropsch), and other chemical products (e.g. via catalytic reactors for methanol or ammonia production).

The main objective of WG2 is to collect knowledge for the establishment of a collaborative framework (fundamentals, trends, practices, databases) focused on biorefinery technologies for waste valorisation to added-value products. This will enable the selection of the best solutions to process material feedstocks defined by WG1 and to assess their potential implementation in a determined geographical region.

Exergoeconomic Assessment of Waste Heat Recovery Using a S-CO_2 Cycle

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Abstract: This study focuses on the exergoeconomic evaluation of a re-compression supercritical carbon dioxide (sCO_2) cycle, which is modeled by adapting a gas turbine (GT) system to an existing power plant. Specifically, the analysis was conducted for the Bayburt Municipal Solid Waste (MSW) Power Plant, where a hot exhaust gas stream with an outlet temperature of 431 °C was employed as the primary energy source for additional power generation. Real-time operational data obtained from the facility were incorporated into all stages of the analysis to ensure the accuracy and reliability of the results. In maintaining carbon dioxide in its supercritical phase, the thermodynamic boundaries of the cycle were defined by a minimum pressure of 74 MPa and a maximum pressure of 200 MPa. Among the individual components of the cycle, the gas turbine and recuperator exhibited the highest exergy efficiencies, whereas the precooler demonstrated the lowest efficiency, highlighting a critical point for potential system optimization. By utilizing the actual exhaust gas temperature as the input parameter, the overall power output, along with the corresponding energy and exergy efficiencies of the gas turbine cycle, was rigorously determined. Furthermore, an exergoeconomic assessment is carried out using the Specific Exergy Costing (SPECO) methodology, a widely applied thermoeconomic approach in literature. This analysis enables the calculation of both the total capital cost rate and the overall cost rate associated with the gas turbine cycle, thereby integrating economic considerations and thermodynamic performance.

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Sustainable bioethanol production from agro-industrial residues, by-products and wastes

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Abstract: Due to the intense depletion of resources and adverse environmental effects, over the last several decades, global efforts have increasingly focused on improving the efficiency and sustainability of energy use, as well as on developing and applying new and clean energy sources. Among them, bioethanol obtained by fermentation of biomass stands out as a modern form of renewable energy and a significant substitute for fossil fuels. Traditional bioethanol production is based on corn, cereals, and sugar-based raw materials; however, to address the issue of competition with food sources, increasing efforts are directed toward developing production from industrial by-products and waste lignocellulosic or starch-containing raw materials, such as the agricultural field and process residues, industrial residues and by-products. This research aimed to provide an overview of the sustainable production of bioethanol from agro-industrial residues, by-products, and wastes, with special reference to the factors affecting the bioprocess, optimization methods, and the application of kinetic models and simulations. The bioprocess of bioethanol production is affected by various factors, including temperature, sugar concentration, pH value, fermentation time, and agitation rate, and to ensure the maximum product yield, it is essential to optimize the entire bioprocess. For bioprocess optimization, the response surface methodology (RSM), a statistical technique based on the planning of experiments, the definition of empirical models, and the evaluation of the influence of independent variables on the system response, is often applied. This method is widely used in the design of experiments, development and formulation of new products, as well as in the improvement and optimization of existing products and processes. By performing a bioprocess under optimal conditions, it is possible to precisely define its kinetics, whereby the definition of kinetic models plays a key role in the development of biotechnological processes. Their application contributes to better process control, cost reduction, and quality improvement of the final product, bioethanol. By integrating these models into software tools for bioprocess simulation, it is easier to recognize potential improvements, challenges, and different scenarios during plant operation, and in the design and scale-up phase, they can replace experiments, thus providing a broader and more reliable basis for decision-making.

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Biomethane potential of a mixture of *Lemna minor* and chicken manure in a combined Anaerobic Digestion and Microbial Electrolysis Cell system

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Abstract: Duckweed (Lemna minor, DW) is a common aquatic plant that can grow by using the nutrients such carbon, nitrogen and phosphate in water/wastewater bodies. It has potential to treat the wastewater in the secondary clarifier tanks of the wastewater treatment plants (WWTP), even though it is not grown on demand. Due to its organic content, it can also be used for biogas production in anaerobic digestion plants, where available in the WWTPs. Because it grows by itself on the surface of the clarifier tanks, it has the potential for cost-effective renewable energy. DW has a high lignocellulosic and protein content; therefore, it is favorable to use it as a co-digestion substrate in AD. When co-digested with chicken manure (CM), it can improve the C/N ratio and methane production.

In this study, the mono-digestion of DW and CM, and a 1/1 mixture of both substrates in weight, was evaluated in terms of biomethane potential (BMP) in AD and in a combined anaerobic digestion and microbial electrolysis cell (ADMEC) reactor configuration at different voltage applications. ADMEC reactors supported with voltages of 0.3, 0.7, and 1.2 V, and a reactor without voltage application ($ADMEC_{biofilm}$) were fed with the DW and CM mixture, which had a content of 1/1 in weight. Before the process, DW was pre-treated physically by blending it into a homogeneous mixture to break down its outer hard shell. The volatile solid to total solid ratios (VS/TS) of the DW and CM were around 82±2% and 69±3%, respectively, which indicate the organic material content that can contribute to the biomethane potential. The BMP tests conducted by mono-digestion of DW and CM, and a mixture of DW+CM had a fixed VS concentration of 20 g VS/L in each reactor. The batch-wise anaerobic reactors were operated for three cycles for at least 30 days at a temperature of 35°C. The cumulative biogas production and methane content of the biogas were 2.48±0.21 L (72±5 % CH_4) for the mono-digestion of DW, 4.71±0.33 L (67±4 % CH_4) for the mixture of DW+CM, and 6.9±0.42 L(65±4% CH_4) for the mono-digestion of CM. The biogas productions obtained from ADMEC reactors were 7.96±0.49 L (68±3%CH_4), 8.46±0.57 L (71±5%CH_4), 8.45±0.59 L(69±4 %CH_4) and 7.89±0.55 L(70±4 % CH_4), for the reactors applied with the voltages of 0.3, 0.7, and 1.2 V, and for the biofilm reactor, respectively. The VS removal efficiencies changed between 34 and 55 % for AD reactors and 68 and 73 % for ADMEC reactors. The lower VS removal rate (% 35) in the mono-digestion of DW indicates that the physical pretreatment was not sufficient to break down the content of the DW to make readily available for utilization. On the other hand ADMEC reactors produced more biogas due to more VS utilization in the reactors owing to the biofilm on the electrodes and voltage

application. Higher voltage applications ended up with higher biogas production thanks to more current available in the reactors.

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Production of Bioethanol from Sugar Beet Molasses for Graphene Synthesis in a Biorefinery Approach

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Abstract: Agricultural by-products such as sugar beet molasses represent an abundant carbon-rich resource for waste valorisation within the biorefinery framework. In this study, sugar beet molasses and yeast obtained from a local sugar factory were used in a fermentation process to produce bioethanol. Following purification by fractional distillation, bioethanol with a concentration higher than 90 vol.% was obtained. Instead of being considered only as a fuel or chemical feedstock, this waste-derived ethanol was employed as a sustainable carbon precursor in chemical vapor deposition (CVD). CVD is one of the most reliable and versatile techniques for producing uniform thin films with controlled thickness and morphology. In the context of graphene synthesis, CVD enables the scalable growth of high-quality and continuous layers, which cannot be achieved with many other methods. The use of CVD provides the additional advantage of precise control over deposition parameters, allowing the carbon atoms derived from ethanol to be efficiently decomposed and assembled into ordered graphene structures on copper catalyst substrates. This approach not only demonstrates the adaptability of CVD for renewable precursors but also supports the transition towards greener nanomanufacturing routes. After growth, the graphene layers were transferred onto glass surfaces to investigate their functional properties. Characterization through Raman spectroscopy, SEM, profilometry, and four-point probe analysis confirmed the formation of uniform graphene coatings. The graphene-coated glass maintained high optical transparency while achieving electrical conductivity values above 10^3 S/cm. These results highlight that waste-derived bioethanol can serve as a sustainable precursor for graphene production, supporting greener nanomanufacturing pathways and enabling applications in transparent conductive coatings

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Life Cycle Assessment of Biorefinery Conversion Technologies for Waste-to-Energy Integration

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Abstract: Life cycle assessment (LCA) is widely applied to evaluate biorefinery conversion technologies for waste-to-energy integration. Recent studies show that algae hydrothermal liquefaction (HTL), combined algae processing (CAP), and palm fatty acid distillation (PFAD) differ in their environmental performance. HTL shows negative net emissions, CAP shows very low emissions, while PFAD shows the highest emissions among the compared pathways. Biochemical biorefinery systems based on dark photosynthesis coupled with photo-fermentation of microalgae and apple pomace have been shown to deliver multiple products, including hydrogen, lutein, β-carotene, and protein for animal feed, while maintaining favourable environmental profiles. Comparisons of first-generation (and second-generation ethanol production systems indicate up to an 80 % reduction in greenhouse gas emissions relative to gasoline combustion. Waste-to-energy incineration facilities reduce waste volumes by 95-96 %. Reported standalone electrical efficiency ranges between 14 and 28 %, while cogeneration systems can reach overall efficiencies above 80 %. Global warming potential values for biomass-based energy systems span from 130 to 420 g CO_2-eq/kWh, with a median of 230 g CO_2-eq/kWh, highlighting both opportunities and challenges for waste valorisation technologies. Also, integration of HTL with carbon capture and storage has been shown to reduce greenhouse gas emissions by 102-113 % compared to fossil fuel baselines, while simultaneously lowering the minimum fuel selling price by up to 15 % in optimal scenarios.
These results show that LCA provides a resilient framework to compare conversion technologies and identify paths that enable reductions in greenhouse gas emissions. Biorefinery systems based on waste feedstocks, particularly when combined with carbon capture strategies, show the potential to achieve negative emissions while producing multiple energy carriers and value-added products. In these studies, different digital LCA tools and databases have been employed to model environmental impacts. OpenLCA, SimaPro, and GaBi are among the most frequently used platforms for process-level assessments, often coupled with background data from Ecoinvent and Agrifootprint databases. These tools allow the quantification of midpoint and endpoint categories such as global warming potential, eutrophication, and resource depletion. For biorefinery technologies, hybrid LCA models combining process simulation software (such as Aspen Plus) with LCA tools have also been applied with detailed integration of mass and energy balances into environmental impact modeling.

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Controlling H_2/CO Ratio in Syngas via Combined Solid and Liquid Biomass Gasification

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Abstract: This work presents an experimental result for controlling the hydrogen-to-carbon monoxide (H_2/CO) ratio in synthetic gas through the simultaneous gasification of solid and liquid biomass and/or waste. The approach integrates two thermochemical pathways: gasification of solid biomass (SB) in an oxygen environment, and gasification of liquid biomass (LB) using thermal water vapor plasma. By combining these processes and selecting feedstocks with different H/C ratios, the method enables simultaneous thermal decomposition of multiple biomass fractions, producing syngas with varying H_2/CO ratios.
In the plasma reactor, liquid biomass gasification generates syngas with $H_2/CO > 2$, while solid biomass gasification produces syngas with $H_2/CO < 1$. By adjusting the SB/LB ratio and introducing the low-ratio stream into the plasma- chemical reactor, the overall H_2/CO ratio can be flexibly tuned. The results allow targeted production of syngas compositions optimized for downstream conversion to biomaterials such as biomethane, biomethanol, and other bio-based hydrocarbons.
The proposed method demonstrates a versatile route to valorise diverse biomass and waste feedstocks while achieving precise control over syngas quality, opening new opportunities for sustainable biofuel and biochemical production.

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Short biography: In 2009, the author defended his PhD thesis in the field of gasification of liquid waste to produce hydrogen rich gases. He has continued his career by deepening his knowledge in the conventional and plasma-assisted biomass and waste gasification, pyrolysis and combustion, thermochemical conversion and synthesis of the resulting products by implementing various national or international projects, internships or supervising PhD students. In period 2011-2025, he has been leading a research group in this field.

Hydrothermal Carbonization of Digested Sludge from Wastewater Treatment Plants: Processes, Potential and Key Challenges

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Abstract: The presentation reviews hydrothermal carbonization of digested sludge as a complementary technology for sludge management at wastewater treatment plants. The motivation for expanding the knowledge of hydrothermal carbonization is the challenges of wastewater treatment plants: the increasing volume of sludge, high moisture content, the presence of organic and inorganic contaminants, rising disposal costs, and legislative amendments. Hydrothermal carbonization makes it possible to convert wet sludge under conditions (160 - 250°C ,10 - 30 bar) into hydrophobic hydrochars, but also liquids and gases, eliminating the need for drying. The process also offers heat recovery and integration into existing wastewater treatment plant infrastructure. A key aspect of implementing hydrothermal carbonization is understanding the impact of individual process parameters and their interactions on chemical reaction pathways, and optimizing operating conditions for specific applications. The presentation discusses two pathways for hydrochar utilization: as soil additives or as fuels in thermal processes, assessing their environmental and legal potential. Process liquids were evaluated as a source of valuable resources that can be recovered or used in situ. Despite the compatibility of hydrothermal carbonization with Green Deal policies, challenges related to energy efficiency, legislative compliance, public acceptance, and high investment costs for integrated thermal technologies still need to be addressed. Overcoming these barriers will enable the implementation of hydrothermal carbonization as a sustainable technology in a circular economy.

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Witold has successfully supervised 16 PhD students. Currently (2025) he supervises 5 PhD students as main supervisor and 2 as co-supervisor. In Ireland he has participated in four EU projects and five national, publically-funded projects. He is author of over ninety papers in ISI journals (h-index = 43, Scopus), and more than 100 communications in international conferences.

WORKING GROUP 3 - Biorefinery Applications

The sustainable processing of biomass into a broad spectrum of marketable products is inherent to the concept of biorefinery. Therefore, identifying market applications will play a key role in this WIRE COST Action. Bio-based industries must facilitate and contribute to the production of advanced materials and products (solid, gas, liquid) that form the basis for innovation in the industry. These industrial value chains include end-user products such as biofuels, energy storage materials, electricity, bio-based chemicals, fertilisers, polymers, pharmaceuticals, composites, membranes, electronics, building materials, and others. From the number of different application areas, research on biorefineries is, however, quite fragmented.

The main objective of this WG is thus to enhance the interaction between groups working on different types of advanced processes and materials to accelerate innovation and deployment of novel market solutions.

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Solar-driven Thermochemical Routes for Renewable Fuel Synthesis

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Abstract: The transition towards low-carbon energy systems has intensified research into biofuels production using abundant solar energy. Thermochemical conversion methods, such as pyrolysis, gasification, and hydrothermal liquefaction (HTL), provide versatile pathways for transforming biomass, water, and CO_2 into fuels and energy carriers, including syngas, hydrogen, and liquid hydrocarbons [1,2,3]. These processes require significant high-temperature input, conventionally sourcing from fossil fuels. Concentrated Solar Technologies (CST) offer a sustainable alternative, delivering high-grade thermal energy through optical concentration, with configurations ranging from parabolic troughs and linear Fresnel reflectors to parabolic dish and solar tower systems [2,3]. Parabolic troughs, Linear Fresnel reflectors, parabolic dish concentrators and solar tower systems are the four types of CST, reaching different ranges of temperature, for dedicated applications.
Hydrothermal Liquefaction operates at a temperature range of 250–550 °C and pressures up to 300 bar and converts wet organic biomass into biocrude, a promising liquid intermediate product that can be upgraded into biofuel [4]. The temperature range of both parabolic troughs and linear Fresnel reflectors aligns well with HTL and similar biomass conversion processes. Parabolic dish systems can meet the higher thermal requirements of gasification (700–1200 °C), while solar towers are capable of achieving extreme temperatures and are considered suitable for high-temperature thermochemical cycles, such as H_2O/CO_2 splitting and Zn/ZnO redox processes, where experimental studies have confirmed high efficiencies [1,2].
CERTH is equipped with a variety of CST infrastructure, including a lab-scale solar simulator, a solar furnace, and a mobile platform with dual parabolic troughs which supports the experimental validation of solar-assisted thermochemical methods. Extensive HTL experiments using various residual biomass types have resulted in biocrude yields of up to 80% [4]. Current research efforts focus on optimizing process integration, matching thermal requirements to CST capabilities, and exploring new solar-driven applications in renewable fuel production [1,3].

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Modelling of carbon dioxide emissions chain of biorefinery processes and advanced biofuels application in internal combustion engines

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Abstract: The European Union targets for wider use of biomass for energy production in order to meet net-zero carbon dioxide emissions production by the year 2050, while transportation is responsible for almost one third of carbon dioxide emissions. Transportation is expected to rely for long on liquid fuels combustion in heavy duty and marine vessels internal combustion engines (ICEs), thus it is imperative to timely optimize and apply advanced biofuels in ICEs. The first objective of the present research work is to demonstrate the processes involved in biorefineries including biomass pretreatment and thermochemical pathways for advanced biofuels and sustainable aviation fuels production utilizing woody biomass. The second objective is the provide an integrated methodology for the estimation of carbon dioxide emissions chain involved in the biorefinery processes and the emissions produced by the combustion of various fuels in ICEs. The final objective is to employ the integrated methodology for a biorefinery case study and an ICE with available performance and fuel data, in order to assess the emissions level and the impact from utilization of advanced biofuels. The methodology firstly included mass and energy balance equations for the biorefinery processes energy requirement assessment, which provide the normalized mass of fossil fuel required for biorefinery electricity usage per mass of advanced biodiesel produced. Secondly, the stoichiometric combustion equation for a typical pure hydrocarbon was employed for the assessment of carbon dioxide emissions produced from the operation of ICE. The case study included operational data from a local biorefinery unit receiving and processing woody biomass, while a large slow speed two-stroke marine ICE operating with three different test fuels, namely marine diesel oil, natural gas and advanced biodiesel was investigated. The background of advanced biofuels production from woody biomass and the application of biofuels in internal combustion engines was discussed, while results from the examination of the three test fuels in the ICE revealed that replacement of conventional fossil fuels with biodiesel can result in more than 50% reduction in carbon dioxide emissions. It is envisaged that when biorefinery processes will use renewable electricity, then transportation using advanced biofuels will reach net-zero carbon dioxide emissions, since no emissions will be associated with the use of conventional fossil fuels.

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Enhancing the Biogas Production through Co-digestion of Industrial Sludges

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Abstract: The solids generated during the treatment of industrial wastewater is defined as industrial sludge, which still remains a challenge due to inefficient waste management strategies. This is because most industrial sludges consist of high levels of potentially toxic elements and inorganic contaminants, in addition to high amounts of organic solids. In the last decades, the simultaneous treatment of two or more sludge sources has been proposed to ensure a more feasible and stable operation. In this context, industrial sludge treatment through co-digestion, which aims not only at energy recovery with a certain amount of biomethane production but also at resource recovery, is gaining attraction. Because, imbalanced nutrients, existence of heavy metals, toxic materials, or recalcitrant compounds found in a single industrial sludge, may lead to unsteady digestion and deficient biogas production yield. Thus, co-digestion has been used extensively for converting organic compounds to energy for a sustainable industrial sludge management rather than only ultimate disposal of the generated sludge. In this study, co-digestion of two sludge sources (i.e., from textile and food industries producing woven fabric and edible oil, respectively), was investigated at equal mixing proportions compared to mono-digestion of only food sludge. In this scope, sludge samples from the wastewater treatment plants of the selected industries, was anaerobically digested at mesophilic (35±2 °C) condition until daily biogas production ceased in the headspaces of the batch reactors. Results indicated substantial biogas potential of mixed sludge with a cumulative biogas yield of more than 425 mL/g-VSS_{fed}; about 6-fold higher than that of food sludge digested alone. Besides, chemical oxygen demand (COD) removal reached to ~90% during co-digestion. The pH and alkalinity, on the other hand, maintained good balance and buffering capacity throughout incubation. Therefore, by the combination of food and textile sludges of different characteristics; better digestion performance and enhanced biogas yield could be achieved. Thus, co-digestion is considered to be a promising resource and energy recovery implementation for different industrial sludges with specific compositions, provided that the impacts of potential toxic elements in the digestate are taken into account before their final disposal.

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WASTE BIOREFINERY TECHNOLOGY: TRANSFORMING FIG FRUIT WASTE INTO MULTI-VALUE ADDED BIOPRODUCTS

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Abstract: Agricultural wastes are reservoirs of untapped sustainable energy solutions obtainable via waste biorefinery technologies. This study explored an integrated biorefinery approach of converting waste fig fruit, a common Mediterranean fruit widely cultivated in Türkiye, into useful multi-bioenergy products via a simultaneous hydrogen- Acetone Butanol Ethanol (ABE) fermentation. Metals are excellent cofactors of enzymes in fermentation studies, influencing product yield, fermentation time reduction and metabolic imbalances inhibition. Thus, a Plackett-Burman experimental design is necessary to study the effect of metals (Co^{2+}, Cu^{2+}, Mn^{+}, Fe^{2+}, Na^{+}, Mg^{2+}, Zn^{2+}, Ca^{2+}, K^{+}, Mo^{3+}, B^{3+}) on the integrated biorefinery of waste fig fruits. Targeted bioproducts and metals influencing their production include: acetone (Fe^{2+}, Na^{+}, Mg^{2+}, Ca^{2+}, K^{+} and Mo^{3+}), butanol (Na^{+}, $Zn^{2+}$and Mo^{3+}), ethanol (Na^{+}, $Mg^{2+}$and Mo^{3+}) and biohydrogen (Fe^{2+}, Na^{+}, Zn^{2+}, K^{+} and Mo^{3+}). Mo^{3+} and Na^{+} appeared as critical cations influencing productivity of bioproducts in the ABE fermentation. Notably, molybdenum (Mo^{3+}), a previously unreported metal appeared as a key player in integrated biorefinery of ABE fermentation. Concentrations of the bioproducts obtained in this study were: acetone (6.3 g L^{-1}), butanol (5.03 g L^{-1}), ethanol (1.6 g L^{-1}) and hydrogen production rate (51.5 ml H_2 L^{-1} h^{-1}). This research reveals the possibility of multi-bioenergy products generation from a single biomass, addressing energy poverty and waste management in most developing nations. This study demonstrated the effectiveness of statistical optimization as an integral tool in biorefinery technologies to enhance productivity, yield recovery and excellent waste transformation into useful ventures

Keywords: Waste biorefinery, agricultural waste valorization, sustainable energy, multi-product fermentation, circular economy, renewable biofuels

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Fate of Additives & Contaminants in Chemical Recycling of Plastic

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Abstract: This contribution assembles recent peer-reviewed and industry evidence into a polymer-resolved overview of additive and contaminant fate across chemical recycling routes, with a focus on packaging vs. industrial/WEEE streams and on downstream integration either via refinery units (hydrotreating/FCC) or directly into petrochemical/monomer pathways. Rather than prescribing solutions, we report observed trends and knowledge gaps, noting that many mitigation approaches remain at laboratory or pilot scale and require case-by-case validation.

Across thermal routes, halogens originating from PVC or brominated flame retardants predominantly partition as acid gases (HCl/HBr/HF) when sufficient temperature staging and gas handling are applied; nonetheless, organohalogen carryover into liquids is variably reported, depending on feed composition, reactor design, vapor residence time, and use of scavengers. In WEEE-related polymers (ABS/HIPS-Br, PC/ABS), formation of PBDD/F under thermal stress has been documented; dissolution-based front-end removal of BFRs is therefore discussed as a risk-reduction option, while acknowledging practical trade-offs (solvent loops, residues). Nitrogen- and oxygen-bearing species—stemming from polyamides, PC/ABS, inks/adhesives, and EVOH—can concentrate in oils as basic N-aromatics and oxygenates that impair stability and catalyst lifetimes; analytical work (e.g., FTICR-MS, GC×GC-MS) provides structural insight but site-specific thresholds and upgrading severities remain under active development. Inorganics (TiO_2, $CaCO_3$, talc, carbon black; Sb from PET) mostly report to solids/char, although fines carryover is non-negligible and typically managed with deep filtration and particle counting.

A polymer-by-polymer reading suggests: (i) PE/PP packaging streams are compatible with staged pyrolysis and subsequent polishing toward naphtha-like cuts, contingent on PVC/BFR control and oxygen/nitrogen reduction; (ii) PS is well-suited to monomer recovery (styrene) with downstream purification; (iii) PET depolymerization (e.g., methanolysis/glycolysis/hydrolysis or acetolysis) affords high-purity monomers while segregating colorants/additives and Sb; (iv) PVC demands robust chlorine management (pre-dechlorination or gas-phase HCl capture plus oil polishing) to meet low-ppm specs. (v) for fluoropolymers and PFAS-bearing residues, specialized handling remains prudent. To support harmonization, we share indicative “fit-for-unit” targets (low-ppm halogens; very low N/O; sub-ppm metals; particle-free; stability checks) strictly as literature-based starting points to be refined with host-site specifications.

We conclude with open questions for WG3: round-robin protocols for halogens and N/O speciation; comparability of “total vs. organic” halogen methods; scaling behavior of PAH formation vs. vapor residence; and how dissolution/monomer routes can be combined with thermal conversion of residues while meeting refinery/cracker acceptance criteria.

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Simulation and optimization of bio-oil, biochar, and syngas obtained from the co-pyrolysis of date seeds and tire plastic waste

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Abstract: In this study date seeds and tire plastic waste were used to model and simulate a co-pyrolysis process in Aspen Plus™ in order to analyse the performance of different feedstock blends in bio-oil, biochar, and syngas production. The highest bio-oil yield (286 kg/hr) was obtained at a reaction temperature of 300°C, pressure of 5 bar, and a plastic-to-date seeds blending ratio of 100%, while the lowest bio-oil production (67 kg/hr) was achieved at a reaction temperature of 500°C, pressure of 5 bar, and a plastic-to-date seeds blending ratio of 0%. The highest biochar yield (592 hr/kg) was obtained at a reaction temperature of 500°C, pressure of 1 bar, and a plastic-to-date seeds blending ratio of 100%, while the lowest biochar production (246 kg/hr) was achieved at a reaction temperature of 500°C, pressure of 1 bar, and a plastic-to-date seeds blending ratio of 100%. The highest syngas yield (486 kg/hr) was obtained at a reaction temperature of 500°C, pressure of 1 bar, and a plastic-to-date seeds blending ratio of 100%, while the lowest syngas production (284 kg/hr) was achieved at a reaction temperature of 300°C, pressure of 3 bar, and a plastic-to-date seeds blending ratio of 50%. Overall, biochar and syngas yields were higher than bio-oil yields. A statistically significant correlation was found between the bio-oil yields and the plastic-to-date seeds blending ratio and between biochar yields and the plastic-to-date seeds blending ratio. These results show the suitability of co-pyrolysis of date seeds and tire plastic waste for bio-oil, biochar, and syngas production, that can be used simultaneously as a waste management strategy, but also as an alternative biofuel for the transportation, heating, cooling, and electricity sectors.

Keywords: Bioenergy, biomass, bioresource recovery, circular economy, zero-waste.

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Treatment of poultry manure to produce adsorbent for ammonia and odor hazards - a circular economy-based approach to reduce the environmental pollution of the poultry industry

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Abstract: Poultry manure is a major source of ammonia and volatile organic compounds (VOCs), contributing to environmental pollution and health risks for both poultry and humans. In this work, we developed a reactive biochar a carbon-rich solid produced by thermal decomposition of manure-based biomass engineered to function as an efficient adsorbent for ammonia fixation and VOC capture. Unlike conventional activated carbon, the biochar was further modified post-pyrolysis to enhance its surface reactivity. Among the treatments, biochar exposed to Fe^{3+} solution (Char-Fe) exhibited the highest adsorption capacity, reaching >60 mg N/g, which is ~16-fold higher than untreated biochar (~4 mg N/g) and 4-fold higher than commercial activated carbon (~16 mg N/g). Adsorption performance was validated in both batch experiments and dynamic plug-flow reactor tests, consistently confirming the superior reactivity of Char-Fe due to the introduction of oxidized Fe sites. Moreover, large-scale in situ trials with fresh poultry manure demonstrated a significant reduction in NH_3 emissions with the addition of 15 wt% Char-Fe, maintaining effectiveness even after 24 days. These results highlight the potential of manure-derived, Fe-modified biochar as a circular economy-based solution for mitigating gaseous pollutants while enabling nitrogen recovery for fertilizer applications.

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Advancing Hydrothermal Liquefaction with Concentrated Solar Technologies: From Lab to Semi-Pilot Demonstration

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Abstract: Hydrothermal liquefaction (HTL) is a versatile thermochemical process capable of converting a wide range of highly moist biomass into an energy-dense liquid product (biocrude oil) along with a number of valuable byproducts: a nutrient-rich aqueous phase (mainly containing phosphates and nitrates), a solid fraction in the form of biochar, and a gaseous stream composed primarily of CH_4, CO, and CO_2. Unlike most thermochemical routes, HTL avoids the costly drying step, making it particularly well-suited for wet biomass streams such as agri-food residues, municipal bio-waste, and industrial byproducts. Although the process was first introduced in the aftermath of the 1973 Oil Crisis, it is only in the last decade that HTL has re-emerged as a focal research area. This resurgence is primarily attributed to the accelerating depletion of fossil resources, the abundance of biomass requiring sustainable management, and the mounting pressures of the climate crisis [1].

The inherent advantages of HTL arise from the unique properties of water under subcritical and supercritical conditions (near 374°C and 221 bar). At these states, water acts not only as solvent but also as reactant and catalyst, owing to pronounced changes in its dielectric constant and ionization properties [2]. This translates into higher overall process efficiency and enables a wide operating window of 250–550°C and 5–25 MPa. These operating conditions are particularly favorable for integration with concentrated solar technologies (CST), which can deliver the required heat input in a sustainable and renewable manner.

The current work presents the pathway pursued at CERTH for coupling HTL with CST. Starting from conventional electrically heated lab-scale systems, the research effort has progressively expanded to intermediate testing in an in-house solar simulator (artificial sunlight replicates real solar flux) and finally to semi-pilot, on-field demonstrations using parabolic trough collectors capable of achieving ~350°C [3,4].

Results from essential oils extraction byproducts, are presented to illustrate the impact of CST integration. Comparative tests between conventional and CST heating consistently demonstrate an improvement in biocrude yield and quality, largely attributed to the faster heating and cooling rates offered by concentrated solar input. In several cases, biocrude yields exceeded 50%, with higher heating values approaching those of conventional fossil-derived fuels. In parallel, the solid biochar fraction was characterized, indicating promising applications as a soil amendment, precursor for activated carbon, or alternative solid fuel, while the aqueous phase offers potential for nutrient recovery.

Overall, the findings highlight the technical feasibility and environmental benefits of integrating CST into HTL systems. This hybrid approach not only advances the production of renewable

liquid fuels and valuable co-products but also establishes a pathway toward scaling HTL under real-world, sustainable operating conditions. The synergy between HTL and CST represents a promising breakthrough in the transition toward low-carbon energy systems and a circular bioeconomy.

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Circular Carbon Solutions: Scaling Pyrolysis-Biochar Systems Through Technology Synergies

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Abstract: The global push towards sustainable waste management and a circular economy has driven significant interest in converting waste materials into valuable products. Biochar, a carbon-rich material derived from the thermal decomposition of organic waste, emerges as a promising solution in this context. This study examines the production of biochar from various waste sources, including agricultural residues, municipal solid waste, and industrial by-products, and explores its broad applications in environmental remediation, soil enhancement, and carbon sequestration.

Our research focuses on understanding how different production conditions influence the properties of the resulting biochar. By adjusting key parameters during the thermal conversion process, we aim to tailor the characteristics of biochar to meet specific application needs. The study highlights the importance of optimizing these conditions to maximize the functional benefits of biochar.

We also assess the potential of waste-derived biochar in several practical applications. In agriculture, biochar is shown to improve soil quality, enhance water retention, and boost crop productivity, while also contributing to the reduction of greenhouse gas emissions. In the field of environmental remediation, biochar demonstrates its effectiveness as an adsorbent for pollutants, making it a valuable tool for cleaning up contaminated environments. Moreover, the role of biochar in carbon sequestration is discussed, emphasizing its capacity to lock carbon in a stable form, thereby contributing to climate change mitigation.

This research highlights the versatility and environmental benefits of using waste-derived biochar, promoting its role in sustainable waste management practices. The findings offer valuable insights for researchers, policymakers, and industry stakeholders interested in advancing the circular economy and fostering environmental sustainability.

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Bio-based flame retardants from bio-waste in the frame of circular economy

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Abstract: This study is concerned with the pressing necessity for sustainable alternatives to conventional halogenated flame retardants (FRs), and it does so by developing biodegradable, halogen-free coatings for textiles. The approach combines phosphorus (P) and nitrogen (N) compounds recovered from agricultural and dairy-processing residues with bio-based polymers such as chitosan. The recovery of nutrients was accomplished through the implementation of hydrothermal carbonization (HTC), acid leaching, and phosphate precipitation methodologies. Struvite of approximately 71% purity was obtained from whey-derived residues, while the HTC of sludge digestate and cow manure at 240 °C for 4 h yielded 70–74% solids and >80% P recovery. Two complementary synthesis strategies were explored. Firstly, the Kabachnik–Fields (KF) reaction was optimised through the reaction of chitosan with aldehydes (e.g., furfural) and diethyl phosphite at a pH of 10 and 80 °C. This approach resulted in a solids yield of 93%, accompanied by substantial phosphorus incorporation, as substantiated by ^{31}P NMR analysis. Secondly, a layer-by-layer (LBL) deposition method was employed, whereby alternating coatings of chitosan, phytic acid, and biochar were applied to cotton. The flammability testing demonstrated that the KF-modified chitosan achieved a limiting oxygen index (LOI) of approximately 35%, thereby enhancing its thermal stability. LBL systems with biochar produced non-ignitable samples and achieved a synergy index of 138.2%, indicating optimal char formation. Thermogravimetric analysis (TGA) was conducted to assess the effects of the modified samples on the char residue and decomposition rates. The results obtained from the TGA analysis revealed that the modified samples exhibited enhanced char residue and reduced decomposition rates when compared to the unmodified samples.

Concurrently, the valorisation of chitosan was achieved through the application of KF chemistry, utilising 5-hydroxymethylfurfural (HMF), a pivotal molecule in biorefinery, in conjunction with diethyl phosphite (DEP). Reactions conducted at varying temperatures (298.15 K, 300.00 K, 305.00 K, 310.00 K) exhibited a pronounced correlation between the incorporation of phosphorus and the prevailing thermal conditions. The 80 °C product exhibited optimal properties, characterised by elevated phosphorus content, intumescent behaviour, low-temperature activation, and enhanced resistance to thermal degradation.

The study demonstrates that the recovery of nutrients from waste streams, in conjunction with bio-based polymers and KF chemistry, can yield efficient flame-retardant systems. The present study proposes a novel approach to address the environmental concerns associated with the use of fire retardants (FRs) by combining high FR performance with the circular use of agricultural residues and biorefinery intermediates. This approach offers a scalable, eco-friendly alternative to halogenated FRs and contributes significantly to advancing circular bioeconomy solutions for fire safety.

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WORKING GROUP 4 - Communication and Dissemination

Communication and dissemination are essential to ensure success and achieve the desired impact of the WIRE COST Action. Both internally, and externally, a proper strategy will determine whether or not researchers and stakeholders get engaged and committed to the purposes of the Action. For this, a dedicated WG is created. The main objective of this WG is to ensure that:

(i) The activities and events are adequately promoted and publicitized in advance;
(ii) The findings and developments of this Action are properly communicated to the interested parties (e.g. biorefinery and bioenergy companies; policymakers; NGOs; biomass industry associations; universities) throughout the Action;
(iii) The dissemination effort endures and remains even after its completion.

Strategies for Creating Engaging One-Minute Videos for WIRE's YouTube Channel

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Abstract: As WIRE COST Action continues to expand its digital outreach, the effectiveness of its YouTube channel hinges on the ability to produce concise, visually compelling, and scientifically accurate content. This phase of the project focuses on developing strategic guidelines for crafting impactful one–minute videos that resonate with diverse audiences while maintaining scientific integrity. The goal is to enhance viewer engagement, increase visibility of WIRE's research, and foster a stronger connection between science and society.
Key strategies include:

- Narrative Clarity: Each video should center around a single, well-defined message. A clear storyline – beginning with a hook, followed by a brief explanation, and ending with a takeaway – ensures that viewers grasp the core idea quickly.
- Visual Storytelling: Use dynamic visuals such as animations, infographics, and real lab footage to illustrate complex concepts. Visuals should complement the narration and be designed to maintain viewer attention throughout the video.
- Audience-Centric Language: Avoid jargon and use accessible language tailored to non-specialist audiences. Where technical terms are necessary, brief explanations or analogies should be provided.
- Authentic Voices: Featuring WIRE researchers in short interviews or voiceovers adds credibility and personal connection. Diversity in presenters helps reflect the collaborative and inclusive nature of the COST Action.
- Optimized Format: Videos should ideally be formatted for mobile viewing, with subtitles, clear audio, and high contrast visuals. This ensures accessibility and enhances shareability across platforms.
- Call to Action: End each video with a prompt – such as a question, a link to further resources, or an invitation to engage – encouraging viewers to explore WIRE's work more deeply.

By implementing these strategies, the WIRE YouTube channel will not only disseminate research more effectively but also foster a vibrant online community centered on sustainable approaches and innovation. This methodology ensures that each video serves as a powerful micro-communication tool, bridging the gap between scientific research and public understanding.

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WIRE COST Action Instagram Account Performance

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Abstract:
The official Instagram account of the WIRE COST Action was launched in November 2022 as a complementary communication channel to enhance visibility, foster community engagement, and disseminate scientific activities to a broader audience. Since its creation, the account has published 50 posts, shared 237 stories, and prepared 9 highlights to organize and preserve relevant content. As of August 2025, the profile has 148 followers, follows 136 accounts, and continues to expand its reach within and beyond the WIRE COST Action network.
The post with the highest recorded engagement was published on 10 July 2025, achieving 39 likes and 12 shares, indicating the resonance of specific content formats and themes. The data indicate that Instagram is an effective tool for reaching both internal and external audiences, with non-follower engagement representing a substantial portion of the reach. Stories emerge as the most consumed format, while high-engagement posts are typically linked to milestone events and collective experiences. These patterns suggest that a content strategy prioritizing event coverage, behind-the-scenes perspectives, and community highlights can maximize both visibility and interaction.

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AI-driven Comprehensive WIRE Thematic Dictionary and Relevant Cooperative Patent Classification (CPC) Code Mapping for Waste Biorefinery Technologies

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Abstract: The WIRE COST Action (CA20127: Waste biorefinery technologies for accelerating sustainable energy processes) has generated a diverse body of research spanning resources, conversion technologies, energy carriers, applications, and materials. Capturing and structuring this thematic diversity is crucial for knowledge transfer, interdisciplinary collaboration, and alignment with innovation pathways. In this study, we applied an AI-driven text-mining and keyword clustering approach to the previously published WIRE Books of Abstracts (2023–2024), resulting in a Comprehensive WIRE Thematic Dictionary comprising approximately one hundred high-frequency single and compound keywords. These were systematically organized into five core clusters: (i) Resources, (ii) Conversion Technologies, (iii) Energy Carriers, (iv) Applications & Sustainability, and (v) Materials & By-products.

Each keyword was subsequently mapped to relevant Cooperative Patent Classification (CPC) codes, which are internationally recognized patent classification symbols used to categorize technologies within the global intellectual property system. Linking research themes to CPC codes is valuable not only for specialists in patent analytics but also for scientists and policymakers, as it enables tracking innovation trends, identifying patenting activity, and bridging research outputs with commercialization pathways.

The results highlight dominant technical domains such as waste and biomass feedstocks (C10L, Y02W), conversion technologies including pyrolysis and anaerobic digestion (C10B, C12M, Y02E), emerging energy carriers such as biogas, bioethanol, hydrogen, and biochar (C01B, C10J, Y02E), and high-value materials including lignin derivatives, nanocellulose, and enzymes (C08, C12N, B82Y). The integration of CPC mapping demonstrates how WIRE research outputs align with patent-relevant innovation trends in waste valorization and sustainable energy.

By combining AI-driven thematic analysis with CPC-based patent classification, this work provides a novel reference tool for researchers, innovators, and policymakers. The resulting dictionary and classification matrix serve both as a knowledge management resource within the WIRE community and as a strategic bridge between research and innovation ecosystems, accelerating pathways for waste biorefinery technologies toward commercialization and sustainable impact.

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Bridging Knowledge and Action: AI in the Future of Biorefineries

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Abstract: By 2030, Europe's bio-based economy is expected to expand significantly, with the biorefinery concept - sustainable conversion of diverse biomass and waste streams into a spectrum of marketable products and energy - as one of its main pillars. While research will continue to advance the understanding, modelling, and design of conversion processes to support a truly circular economy, without strategic action, this knowledge may remain fragmented and unevenly distributed across Europe. Some regions will still lack coherent policies and adequate public engagement, which could delay the widespread adoption of biorefinery solutions.
Harmonization will require a comprehensive and integrated knowledge base that covers the entire value chain, from raw materials to final products. This will be the mission of WIRE COST Action. Artificial Intelligence (AI) will be crucial in achieving this mission. AI will process vast amounts of multidisciplinary data, identify emerging patterns, and transform complex technical findings into tailored, accessible content for diverse audiences, including policymakers, industry leaders, and the public.
Intelligent summarization will condense research outputs, automated translation will remove language barriers, and predictive analytics will guide targeted outreach campaigns. AI-driven platforms will enable real-time visualization and interaction with biorefinery-related data, fostering cross-border collaboration and accelerating decision-making. WIRE aims to bridge the gap between technical expertise and societal understanding by integrating AI into its communication and dissemination strategy. This integration will ensure faster policy uptake, greater industry engagement, and a stronger connection between the public and the bioeconomy. Ultimately, AI will act as a catalyst, transforming fragmented knowledge into a cohesive, innovation-driven, and sustainable European bioeconomy.

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From Knowledge to Application: Joint Industry–Academia Efforts for Sustainable Construction

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Abstract: The successful transition of the cement and construction sectors towards low-carbon solutions depends on the ability to align industrial priorities with academic expertise. This project demonstrates how collaborative leadership can bring together companies, research centres, and universities under the umbrella of the c5Lab. By addressing industrial needs such as cost efficiency, regulatory compliance, and market competitiveness, while simultaneously advancing scientific knowledge, it creates a shared framework where both sides recognise the value of working together.

The initiative promotes a joint team approach, where c5Lab researchers collaborate with specialists from partner entities to co-design and validate innovative solutions. This dual perspective ensures that the project generates results that are not only scientifically rigorous but also industrially scalable and impactful. In doing so, it provides a replicable model for how collaborative research and innovation can effectively bridge the gap between industry and academia, paving the way for sustainable transformation.

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From Concept to Commitment: How Facilitation Turns Academic Research into Industrial Projects

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Abstract: Turning ambitious scientific ideas into projects that secure industrial commitment requires more than technical excellence: it requires facilitation. In the C5LAB team, each collaborator works as a bridge between researchers, whose proposals are driven by academic curiosity and scientific advancement, and company boards, whose priorities lie in competitiveness, regulatory compliance, and return on investment. This process involves translating complex research into clear industrial value, while ensuring that academic partners see their work recognised, validated, and expanded.
The experience of c5Lab shows that facilitation is a decisive element in collaborative innovation. By fostering trust, aligning expectations, and structuring multidisciplinary teams across companies and universities, facilitation ensures that projects are not only scientifically rigorous but also strategically relevant and industrially actionable. This dual commitment enables research to reach decision-makers with compelling arguments and provides companies with credible pathways to implement innovation. It is through this role of facilitator that collaborative laboratories can truly drive sustainable transformation.

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Margarida Mateus is the Executive Director of C5Lab – Collaborative Laboratory for Sustainable Construction. With a PhD in Physical Chemistry and an Executive MBA from INDEG-ISCTE, she has over 15 years of experience in R&D bridging academia and the cement industry. She led the design and implementation of the decarbonization strategy and revamping of the Secil cement plant in Outão, and coordinated the first pilot biorefinery for bio-oil production via direct liquefaction integrated in a cement plant. She is the author of over 50 scientific publications and co-inventor on 9 international patents. Her ongoing work focuses on carbon capture, energy efficiency, and the development of low-carbon cementitious materials.

Analysis of the performance of the WIRE COST Action LinkedIn social network

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Abstract:
The LinkedIn profile of the WIRE COST Action, established three years ago, has consistently served as a strategic platform for disseminating scientific knowledge, promoting project milestones, and strengthening professional networks. Over this period, the account has attracted a total of 684 followers, reflecting a steadily growing audience within the target community. Since its inception, 113 publications have been issued, providing regular updates on events, workshops, and outcomes relevant to stakeholders.
The inaugural post, published at the outset of the project's online presence, received 5 reactions, marking the first recorded engagement and serving as a baseline for measuring audience interaction. Excluding a single repost (an external share from WIRE COST Action), the dataset comprises 112 original publications and reposts, which collectively generated 3010 reactions and 335 shares. This level of interaction indicates both interest in the content and the community's willingness to amplify the project's messages.
A closer examination of engagement patterns reveals three distinct peaks:

- 84 reactions – Announcement of the launch of the 1st Training School (Portalegre), representing the highest single-post engagement recorded to date.
- 74 reaction - Closing publication of the 7th Working Group Workshop
- 66 reactions – A subsequent update related to the same Training School, confirming sustained interest in the event.

From a communication strategy perspective, these data points suggest a direct correlation between event-driven content and higher audience engagement. Specifically, in-person events, particularly those with strong visual documentation and timely updates, appear to resonate most with the LinkedIn audience. This trend underscores the importance of integrating well-planned communication strategies with real-time coverage to maximize reach and foster meaningful interaction.
Overall, the LinkedIn activity of the project demonstrates a clear trajectory of growth in both visibility and engagement. The findings underscore the platform's role not only as a channel for information dissemination but also as a catalyst for strengthening the project's professional network and community impact. Figure 1 summarises the impact and engagement for the social media presence of WIRE COST Action on LinkedIn.

Figure 1: Important metrics for social media

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