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ICEER 2024

11TH The 11th International Conference on Energy and Environment Research

July 24-26, 2024 Coimbra, Portugal

The 11th International Conference on Energy and Environment Research

“Renewable Energy Towards Decarbonization”

July 24 – 26, 2024 | Coimbra, Portugal

ICEER 2024

The 11th International Conference on Energy and Environment Research

“Renewable Energy Towards Decarbonization”

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Carlos Felgueiras

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WELCOME MESSAGE

Dear participants of ICEER 2024,

Under the theme “Renewable Energy Towards Decarbonization”, the 11th International Conference on Energy and Environment Research, **ICEER 2024**, is being held in Coimbra, Portugal, an ancient and beautiful city in Portugal.

The growing population in the World, is causing increasing needs of water, food, goods and, above all, of energy. Energy is used in the production of fertilizers, in agricultural activities, all sort of industrial activities, home conditioning, lighting, communications, water and wastewater treatment, waste management, and transportation, among other. The energy requirements are huge and coal, oil and natural gas have been the most important sources, causing the release of greenhouse gases to the environment. These emissions are known to be the main cause of climate changes, with extreme weather events such as floods and droughts.

Policymakers, the common citizen and researchers are urged to plan strategies, change their practices and find alternative sources of energy that are less stressful to the environment, readily available, affordable and above all, that have a lower carbon footprint. Renewable energy can, at least partially, contribute to achieve such goals. However, there are still many challenges to address before renewable energy can be used in hard to decarbonize sectors, such as e.g. maritime transportation and aviation. Energy security relies on a complex energy mix, efficient distribution and storage, with critical materials reaching also risk of shortage. Thus, a thorough analysis of different scenarios considering the whole life cycle within a circular economy perspective is fundamental to allow taking informed decisions to adopt technologies and processes that do not reveal in the future to cause more negative impacts than the present options. In addition, the contribution of energy decarbonization to Sustainable Development relies on better and global education of the current and future generations towards a more efficient and rational use of energy, reducing energy poverty.

After ten editions, ICEER series has been serving as a platform able to promote the active collaboration and discussion among professionals and experts in the field of Energy and Environment Research. Innovative solutions able to address the challenges of our always changing World will be presented and discussed at **ICEER 2024**, in a friendly, multicultural and casual environment, which we anticipate will stimulate further developments and discoveries by the participants.

The recognition of the relevance of these works is their publication in the conference Proceedings, a a volume of the Springer book series “Environmental Science and Engineering”, contributing to the broather dissemination of knowledge and research results.

We hope **ICEER 2024** is up to your expectations and may serve as a representative flag of research in the field of energy and environment.

Welcome to

ICEER2024 – Renewable Energy Towards Decarbonization @ Coimbra

The Conference Committee

CONFERENCE PROGRAM

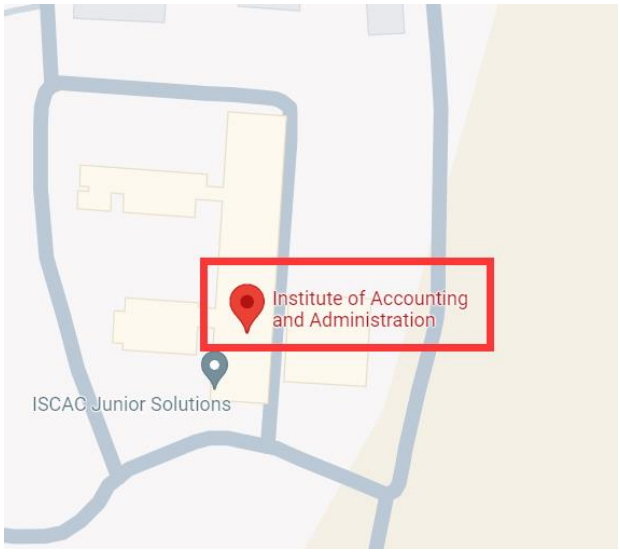
Wednesday, 24th July, 2024 (GMT+1)	
COIMBRA BUSINESS SCHOOL @ Maia Gomes Amphitheater	
17:00-18:00	Registration & Conference Kits Collection
Thursday, 25th July, 2024(GMT+1)	
COIMBRA BUSINESS SCHOOL @ ROOM 3.1	
09:20-12:15	***HOST:* Carlos Felgueiras, CIETI/ISEP**
9:20-9:30	**Opening Remarks** Prof. Nídia Caetano, LEPABE/FEUP & CIETI/ISEP
9:30-10:00	**Keynote Speech**
10:00-11:00	**Session 1A** *Energy Policy, Economics, Planning & Regulation* **E011 E021 E025 E012**
11:00-11:30	*Group Photo & Coffee Break & Poster Session*
11:30-12:15	**Session 2A** *Life Cycle Assessment* **E008 E032 E033**
12:15-14:00	*Lunch*
14:00-15:00	**Session 3A** *Renewable Energy* **E027 E041 E031 E043**
15:00-15:45	**Session 1B** *Energy Policy, Economics, Planning & Regulation* **E049 E003 E023**
15:45-16:15	*Coffee Break & Poster Session*
16:15-17:00	**Session 2B** *Life Cycle Assessment* **E009 E036 E035**
17:00-17:45	**Session 3B** *Renewable Energy* **E034 E030 E047**
19:30-22:30	*Conference Dinner (& Awards)*
Friday, 26th July, 2024 (GMT+1)	
Technical Tour at Universidade de Coimbra (Pending)	

LOCAL INFORMATION

Conference Venue

Coimbra Business Scool | ISCAC

Address: Quinta Agrícola, Bencanta, 3045-601 Coimbra, Portugal



How to get:
Lisbon Airport:
Bus: take Daytrip Shuttle→By the squara Largo da Portagem then go to Beira Rio take 21 R to Bencanta (apeadeiro) and walk 800m
Car:196km

Porto Airport:
Bus: take AirportShuttle.pt - Aeroporto do Porto -> Coimbra to Coimbra then go to Portagem to take No. 14 to São Martinho and walk 500m.
Car:134km

Banks and Foreign Exchange

The Currency is EURO here, you can exchange foreign currency 24 hours at the airport, or exchange at the bank, Money exchanger.

Weather

The Weather Situation of Coimbra in July

Average daily minimum temperature	Average daily highest temperature
16℃	30℃

Emergency

Emergency phone: 112

Power

230V

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Oral Presentations

- **Timing:** a maximum of 15 minutes total, including speaking time and discussion. Please make sure your presentation is well timed. Please keep in mind that the program is full and that the speaker after you would like their allocated time available to them.
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Poster Presentations

- Each poster is for 3 minutes, highlighting the key results presented in the poster. Flash could be presented by poster or slides.
- Language: English. Color printing.
- Poster Size: A0 page (84.1 cm x 118.9 cm) or US Arch E page (36 in x 48 in) in PORTRAIT orientation. The poster should include: Paper ID, Conference Name's Acronym, Significance of the research, the methods used, the main results obtained, and conclusions drawn.
- The number of slides should be restricted to 3 content slides (excluding the title slide and acknowledgment slide).
- Posters are required to be condensed and attractive.
- Please take your poster to the conference by yourself. The conference organizer will not send/keep any posters after the conference.

Dress code

Please wearing formal clothes or national characteristics of clothing

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PROF. NÍDIA DE SÁ CAETANO

Coordinator Professor at the School of Engineering (ISEP) of the Polytechnic Institute of Porto (P.Porto); Associate Editor for Biomass section of *Renewable Energy* (Elsevier); Editorial Advisory Board of Algal Research (Elsevier); Review Editor in Sustainable Energy Systems and Policies (Frontiers); Editorial Board of Green Technology, Resilience, and Sustainability (Springer); Guest Editor of Special Issues in *Frontiers*, *Energies*, *Waste and Biomass Valorization*, *Sustainability* and *ChemEngineering* journals. Editor of Conference Proceedings in *Energy Reports* and *Energy Procedia*.

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- Nídia de Sá Caetano is Coordinator Professor at the School of Engineering (ISEP) of the Polytechnic of Porto, senior researcher with LEPABE/FEUP, collaborator researcher with CIETI/ISEP. Sub-Director of the Master in Sustainable Energies of ISEP (MSE) from 2018; Director of the MSE from 2013-2018.
- Holding a PhD in Chemical Engineering, her scientific track record is: (1) 125 papers in WoS, (2) 6395 citations (in 5789 citing articles) in WoS, (3) H-index 28 in WoS, (4) PI of 4 projects funded by competitive calls (1 as coordinator of LEPABE), (5) researcher of 10 projects, supervision of (6) 5 doctoral and (7) >100 master theses concluded.
- Major research interests are: Biofuels from Waste; Bioethanol; Biodiesel; Waste-to-Energy; Microalgae for wastewater treatment; Microalgae for CO2 mitigation; Biorefineries; LCA; Sustainable buildings.
- Subject Editor for Biomass of Renewable Energy from March 2020. Member of the Editorial Board, of Green Technology, Resilience, and Sustainability. Lead Guest Editor of 12 Special Issues in indexed journals (Energy Reports; Energies; Sustainability; Energy Procedia, Waste and Biomass Valorization, Processes) and Guest Editor of many other Special Issues (Frontiers; Climate; ChemEngineering). Conference and Program Chair of several International Conferences (ICEER series); Member of the STC of International Conferences (WASTES, CCESG, TEEM, REEE, ENASB, JTIR, etc.). Keynote and Invited Speaker for International and National Conferences. Treasurer of APESB (Portuguese Association of Environmental and Sanitary Engineering) from March 2021 (Vice-President from March 2020 to March 2021). Project evaluator for the EC (H2020 MSCA-ITN) from 2019, USDOA and ANI/AdI from 2006, Israeli Science Foundation, among other international and national agencies.

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PROF. CARLOS FELGUEIRAS

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Research Interests: energy quality; energy and buildings; energy and environmental Indicators; renewable energy systems; sustainable energy systems; engineering education

Manuel Carlos Felgueiras received the B.S. and Ph.D. degrees in electrical and computer engineering from the Faculty of Engineering, University of Porto, Porto, Portugal, in 1987 and 2008, respectively. He started is professional career in 1987 as electronic designer for automation systems. Later was invited to supervise a test laboratory for verifying the accomplishment of European Standards in thermoelectric household appliances. He started the teaching activity in 1994 as Assistant Professor and later on as Adjunct Professor and researcher with the Department of Electrical Engineering, School of Engineering, Polytechnic Institute of Porto (P.Porto), Portugal. His research interests include design for debug and test of mixed-signals, remote experimentation in e-learning, renewable energy sources and smart buildings.

Prof. Felgueiras is member of the Portuguese Engineers Association and the Global Online Laboratory Consortium (GOLC). He has published around 90 papers and includes the scientific committee of several conferences.

LIST OF PRESENTATIONS

Special Session 1A: Energy Policy, Economics, Planning & Regulation

Applying the Building Blocks Framework for Circular Economy Progress in Heavy-Duty Vehicle Manufacturing

Joris Nguyen[1,2], G. Bouillass[1], M. Saidani[1,3], B. Yannou[1], P. Graff[2], H. Ouisse[2]
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ABSTRACT
Heavy-Duty and Off-Road (HDOR) machines have a significant circularity potential. However, the implementation of Circular Economy (CE) in this sector, particularly regarding the End-of-Life (EoL) treatment, is still in its infancy. The present paper proposes a methodology to help a good-producing company initiate its CE transition. It encompasses two main steps: (1) an interview consultation strategy and (2) a classification of the resulting information into the CE building blocks framework, adapted from the Ellen MacArthur Foundation (EMF). The latter aims to identify situations to be improved and CE improvement avenues to be adopted. This methodology, applied to an HDOR manufacturer case study, proves to be highly effective in terms of the scope and complementarity of the CE improvement avenues while being easy to use. In this paper, two recommendations are formulated for improving the heavy machinery sector: proper dismantling and identifying in-use and EoL machines. The authors identify challenges for each of these areas of interest to address to shift towards CE in the heavy machinery sector.

Keywords: Circularity, Heavy machine, End-of-life, Industrial diagnosis

1. INTRODUCTION
CE is an economic system that, at each stage of the product life cycle, tends to improve the efficiency of resource usage and lower the environmental impacts [1]. It aims to slow resource loops through design for long-life and product-life extension or to close them through recycling [2].
Contrary to other sectors, such as the automotive one, the CE in the HDOR sector is still in its infancy. The HDOR sector encompasses on-road vehicles weighing more than 3,5 tons and off-road mobile machinery, including trucks, buses, tractors, construction and mining machinery [3]. Around 20 million of them are in use in Europe [4], [5], and approximately one million reach their EoL each year [5]. This represents an EoL tonnage comparable to the automotive sector [3]. However, contrary to light vehicles, this potential is not fully exploited yet [3]. HDOR machines are currently not subject to specific EoL regulations [3]. The EoL treatment activity needs to be better organized [3], and the literature on CE in the HDOR sector is still recent and needs to be expanded. HDOR companies are keen to develop their CE strategy further but still need help finding ways to improve it. Among the different methods and tools companies use to picture the current situation, internal diagnosis is recognized as an effective one [6]. Hence, they can support companies in identifying where and how they can improve the circularity of their activities [7]. In this regard, we propose to address the following research question:
How can a good-producing company, still in its infancy concerning CE, effectively use an internal diagnosis to categorize potential ways of improving its circularity performance?
The study includes a use case from a French HDOR manufacturer that assembles and sells machines worldwide. This company is already involved in some CE-related activities on a modest scale in relation to the scale of waste. This approach includes the second-hand and reconditioned equipment business and the remanufacturing of spare parts.

2. MATERIALS AND METHODS
The main objective of this work is to provide a method for a good-producing company, still in its infancy CE transition, to establish a comprehensive and pertinent roadmap of CE improvement avenues. To do so, this paper proposes a two-step methodology to prepare the assessment, sizing and implementation of actions afterward. It comprises (1) a series of interviews to collect data and (2) a classification of this information into the CE building blocks framework [8] following a proposed decision tree.

Additionally, two literature reviews are performed. One concerning the circular economy in the HDOR sector focused (1) on the lack of information on the use and EoL of HDOR machines and (2) on the EoL regulations and dismantling. The second one reviews frameworks that can be used to classify actions to move towards CE from an internal diagnosis.

3. RESULTS AND DISCUSSION

Around 200 potential CE improvement avenues, corresponding to 70 various situations, are identified, as derived from the interviews. The four CE building blocks [8] are fairly represented, with 56 CE improvement avenues for the production-design block, 50 for the business model one, 45 for the reverse cycle block, and 46 for the cross-cycle and cross-sector one. Examples of situations to be improved and CE improvement avenues are given. The framework is then compared to other frameworks [2,9], highlighting its ease of use and its broad consideration for significant areas on which to act to implement CE strategies successfully. However, these qualities come at the cost of a loss in detail and structure compared to other CE frameworks [2,9].

The interviews, combined with a literature review, also highlighted two main areas of interest to support CE transition in the HDOR sector: (1) HDOR EoL treatment and (2) addressing the lack of information on the in-use and EoL HDOR machines. Several research questions have been identified for each of these areas of interest: (1) What are the economic and circular performances of HDOR dismantling? Which machines and market criteria drive these performances, and how? What are the levers to improve the circularity and profitability of HDOR dismantling? (2) What information should be collected to manage the EoL of the HDOR machines properly? How to collect or estimate this information? What do the HDOR machines become after selling?

4. CONCLUSION

This article proposes a cost-effective approach to identify CE improvement avenues within a large company that has not yet reached CE maturity. We opted for a structured method, including an internal consultation of CE-related players and a classification of the information via the CE building blocks [8]. Results are a broad scope of situations to be improved and CE improvement avenues brought by the internal players themselves. The proposed methodology offers broad coverage of the company's activities, contributing to industrialists' adoption of CE strategies while being comprehensive, relatively fast to apply, and easy to use. Other large companies could use this model at the beginning of their CE transition to mobilize internal intelligence and quickly find broad and sector-specific CE improvement avenues.

To help the HDOR industry progress significantly in CE, we also identify and discuss challenges of particular importance for the sector. These challenges concern two areas of interest: the lack of data on the use and EoL of HDOR machines and the lack of regulation and understanding concerning the EoL treatment. We propose research questions for both areas of interest to address the need to move significantly toward CE in the HDOR sector.

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E021 **10:15-10:30**

Glass Cullet Valorization: Benefits and Limitations for Alternative Applications

Daniel Silva[1], João Mateus[2], Marisa Almeida[3], and Helena Monteiro[1]
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ABSTRACT
Recognized for its infinite recyclability, glass has become a crucial secondary resource in numerous industries. As global glass production continues to grow, there's an increasing urgency to explore and optimize the use of glass cullet. This review dives into incorporating glass cullet within an open-loop recycling system, particularly focusing on its potential in the construction and ceramics sectors. It emphasizes benefits such as waste valorization, resource conservation, and improved mechanical properties. However, challenges like alkali-silica reactions and reduced concrete strength are also discussed. The review highlights the vital role of glass cullet in advancing environmental and economic sustainability and provides valuable insights for further research in sustainable material utilization.

Keywords: Circular economy, glass cullet, incorporation, waste valorization.

1. INTRODUCTION
The glass industry is vital for various sectors from construction to packaging due to its versatility and longevity. Glass cullet, known for its recyclability and potential for indefinite reuse, offers environmental and economic advantages within and beyond the industry. By incorporating cullet, energy consumption and CO_2 emissions are reduced, extending furnace lifespan and conserving raw materials [1]. Internal cullet, sourced from production rejects, and external cullet, from post-consumer recycling, play vital roles, although the latter often faces quality challenges. As European glass production rises, managing the increasing waste volumes through recycling initiatives has become essential for sustainable development [2]. Both closed-loop and open-loop recycling methods are utilized, with cullet finding diverse applications beyond the glass industry, such as in concrete and ceramic applications [3]. This study reviews relevant research on cullet incorporation outside the glass industry, examining different applications and their contributions to circularity, aiming to delineate advantages and disadvantages.

2. MATERIALS AND METHODS
The methodology for collecting and analyzing empirical studies on the use of glass cullet outside the glass industry involved an extensive search focused on relevance, types of glass cullet, applications, and promising results. Various search terms such as “glass cullet”, “glass powder”, “cullet recycling”, “cullet upcycling”, and “glass incorporation” were used. Nineteen relevant studies were selected and documented. Key information was extracted, including product type, process description, waste origin, pre-treatment requirements, incorporation percentage, advantages, and primary limitations or challenges.

3. RESULTS AND DISCUSSION
The studies analyzed demonstrate that glass cullet significantly enhances ceramic production, benefiting applications such as tile manufacturing, stoneware, and vitreous ceramics. Its incorporation into ceramic formulations leads to marked improvements in mechanical properties such as cold crushing strength, flexural strength, and impact resistance, resulting in products with enhanced durability and structural integrity [4-6]. Glass cullet also optimizes thermal properties, allowing for lower firing temperatures and reduced manufacturing times, saving energy and cutting production costs [7]. Moreover, the use of glass cullet in ceramics can lower water absorption rates, improving resistance to moisture-related damage and extending the lifespan of ceramic products [8]. However, challenges such as shrinkage, thermal expansion disparities, reduced green strength, and the presence of stress-inducing compounds like cristobalite must be addressed [4,7-9].
In construction materials, glass cullet offers significant sustainability benefits. By partially replacing aggregates and cement in concrete, it reduces raw material consumption and promotes waste valorization

[10]. Concrete with glass cullet exhibits enhanced workability, microstructure, and reduced water absorption, making it suitable for various construction applications [11]. Additionally, glass cullet shows promise in 3D printing of concrete and in cement pavement applications, where it acts as a pozzolanic binder, improving resistance to cracking and enhancing road aesthetics [10,12].Despite these advantages, challenges like alkali-silica reactions, reduced strength, and issues with workability and bonding require further investigation and improvement [10,11,13].
Glass cullet also finds utility in asphalt mixtures, sub-base material, filtration media, glass fibers, epoxy composites, glazes, elastomeric roof coatings, and more, contributing to waste reduction, resource efficiency, and environmental sustainability [3,14].

4. CONCLUSION

This review examines studies on integrating glass cullet into various applications, focusing on the construction and ceramics industries, as well as pavement materials and filtration media. It highlights the enduring value of glass cullet as a recyclable secondary raw material, offering benefits such as waste valorization, resource conservation, enhanced mechanical properties, and sustainability through cost savings, reduced energy consumption, and lower emissions. However, challenges like alkali-silica reactions, reduced concrete strength, and technical complexities in ceramics must be addressed. Continued research and innovation are essential to addressing technical limitations and optimizing glass cullet use, ultimately enhancing resource efficiency and promoting environmental stewardship.

ACKNOWLEDGEMENTS/FUNDING

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E025 **10:30-10:45**

Hydroagriculture Project - A Portuguese Case Study

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ABSTRACT
Water plays an essential role in the social fabric and comfort of society, as it plays an important role in our survival and subsistence, in its accessibility, in economic activities, and in the particular case of this study, in the manufacture of agricultural products and activities. In a developing society, and with the number of the human population increasing, consumerism takes place, resulting in an increasing need to use space, resources and food. Agriculture is an ancient activity that serves as the basis for ensuring the subsistence and resilience of the population, producing crops and different types of food, from vegetables, fruits, legumes, seeds, etc... and they all have one thing in common: The existence of water. If there are fields suitable for agriculture, but there is no water, they become unusable. Water improvement and supply projects can drasti-cally change this situation, thus stimulating agricultural production. The analysis of this case study, the largest hydroagriculture project in Europe nowadays, aims to highlight the importance of carrying out hydro-agriculture projects and the impact they can have on society.

Keywords: Project design, Sustainability, Water scarcity, Climate change, resources

1. INTRODUCTION
Growing population changed consumption patterns in the global demand for food and agricultural raw materials. This resulted in an expansion of harvest areas and intensification of land use, emerging techniques between land use and rest, and the need to modify land irrigation for agriculture. The Baixo Mondego Hydroagricultural Development benefits a total area of around 15,000 ha, is located in the Baixo Mondego valley and runs along the Mondego River, in Portugal, for a length of approximately 40 km, including the banks of the main tributaries of the Mondego. The Baixo Mondego Hydroagricultural Development benefits a total area of around 15,000 ha, so compared to the production that occurred in year 2018, there is a benefit of around 2.5 times more of the area dedicated to current rice production. This work brings an original analysis contribution, which makes an allusion to the Sustainable Development Goals (SDGs), which are considered to have a positive effect on the following SDGs:

- SDG 2 – Zero Hunger – Increase the quantity and quality of crop production, diversifying the products available for consumption and making them available to society. It should be noted that this point can positively or negatively influence market prices, governed by the law of demand[1];
- SDG 3 – Good health and well-being – Entities such as UNESCO argue that every child has the right to health, food and adequate nutrition[2]. There is a direct relationship between food and health, so it is a fact: We are what we eat[3];
- SDG 8 – Decent Work and Economic Growth – Consulting statistics, Portugal in 1989 had around 1,560,990 people working in agriculture. In 2019, there were 648,252 people working in this area, which represents 2.4 times fewer workers. Although this factor can be justified by the modernization of infrastructures and technologies, Portugal is going through a period of lack of labor. It is urgent to stimulate and recruit labor and conditions so that the agriculture sector has the conditions to grow and be sustainable[4].
- SDG 9 – Industry, innovation, and infrastructure – Portugal covers an area of 89 089 km² of which 81% is rural. Also in these statistics, it is possible to verify that 47% is agricultural land while forests cover 39 %. Another curiosity lays on that 33 % of the total populations lives in rural areas [5]. In the Portuguese context, the modernization and competitiveness of farms will be done through support, investment support will continue to encourage young people to set up new modern and competitive farm enterprises;
- SDG 11 – Sustainable cities and communities – The Portuguese Common Agricultural Plan (PCA) strategy requires Portuguese agriculture and its methodologies to become more sustainable. In this sense, large funds are allocated to farmers for actions that reduce the carbon footprint, organic fertilization,

organic farming and integrated production. In order to contribute to European goals, 19% of the agricultural surface will be cultivated organically by 2030. With regard to climate change, actions will be carried out such as improving the quality of pastures and protecting against fires. Water management, in terms of quantity and quality, plays an important role. The support granted focuses on the renewal of old infrastructure and equipment used in collective irrigation systems and on agricultural farms, which will increase the agricultural area that receives support to improve the efficiency of water use to 4.5%. encourage the implementation of renewable energy, projects with this aspect will receive priority [6] .

- SDG 12 – Responsible consumption and production – The UN (2020) defines sustainable consumption and production as:" the use of services and related products, which respond to basic needs and bring to a better quality of life while minimizing the use of natural resources and toxic materials as well as the emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of future generation". Crop production must respond to demand and demand, in order to avoid food waste, non-utilization of crops, or in the opposite sense, the lack of products on the market which, consequently, reflects the increase in prices and financial difficulties in the monthly budget of families.
- SGD 17 – Partnership for the goals – Creating partnerships between stakeholders results in the stimulation of obtaining results, design, fabrication, deployment of new products and technologies in order to comply with indicators outlined by the European Union.

2. RESULTS AND DISCUSSION

The size and impact of this project is clear: It benefits around 53% of the total existing area in the Portuguese context dedicated to rice production, re-sulting in a production of 840,000 tons of rice annually. For the purpose of measuring global impact, and for mere academic reasoning, in 2005, UN agency distributed 1,000 tons of rice to 50,000 people in five provinces of Cambodia, struggling to cope with food shortages caused by a searing drought. In the same proportion, the production of the Baixo Mondego Hydroagricultural develop-ment would be sufficient for 42 million individuals.

3. CONCLUSION

Water plays an essential role in the social fabric of society, being a factor that influenced the rise of civilizations, as well as their fall. Technologies play a fundamental role in the use of water, from providing the population with water to drink it to irrigating fields for agricultural purposes to respond to a growing population with needs.

Regarding the case study project, although the entire Baixo Mondego could be con-sidered an irrigated area, before the works were carried out, irrigation took place in very poor and difficult conditions throughout the entire valley. This work, still in the construction phase, aims to regularize rivers, defend against floods, controlled drainage and irrigation in appropriate conditions. Parcelling has also been imple-mented in some areas of Baixo Mondego.

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The data is part of the project's descriptive report provided in the tender phase, with the promoter being the Association of Beneficiaries of the Baixo Mondego Hydro-Agricultural Development Work

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E012 **10:45-11:00**

Citizen Science for Action: A Platform to Empower Public Participation in Radon Detection and Mitigation

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ABSTRACT
Despite all related studies and research efforts, radon gas emissions and their impact on human health remain relatively unknown to the general public. The World Health Organization (WHO) estimates that radon is at the origin of 3 to 14% of all lung cancers and, although WHO recommendations to tackle indoor radon exposure are progressively paving the way, most implemented measures have not been effective, so we need new approaches to in-crease public awareness and reduce harmful effects of radon. Awareness will be leveled by prioritizing a citizen science-based approach, which in-volves advocating for a participatory process that encourages the active involvement of citizens in scientific data collection. In the context of this re-search, we are developing a citizen science-based web platform that collects relevant data related to indoor radon concentration. On the web platform, all citizens are encouraged to participate in a pre-diagnosis procedure to assess the radon potential existing in the buildings they live or work in. An automated classification model assesses the potential for indoor radon gas and outputs a pre-diagnosis result in three categories: low, medium, or high risk. Thus, while raising awareness of radon risk, we can provide newly qualified data for indoor radon exposure research.

Keywords: Citizen Science; Indoor Radon Potential; Indoor Radon Risk Communication; Radon Potential Prediction.

1. INTRODUCTION
The accumulation of radon gas inside buildings represents a known public health problem, widely reported by the World Health Organization (WHO). In regions prone to high indoor radon emission, the lack of ventilation leads to high indoor radon concentrations [1]. The risk of exposure is directly correlated with the occupants´ time of exposure, so the radon potential of a specific room building is directly related to the schedule of occupancy [2]. It is required to implement a set of time-consuming procedures to assess Indoor Radon Concentration (IRC) that comprises short and long-term radon measurements in several building rooms, data collection and analysis, technical reports, etc. Silva et *al.* [3] proposed an Indoor Radon Potential (IRP) assessment methodology based on the analysis of data features, designed to provide a first estimate of the indoor radon potential of a selected room in a given building. The proposed platform serves as a first step, involving citizens in the issue and encouraging them to act..

2. MATERIALS AND METHODS
The assessment of radon concentration inside a building requires technical expertise to execute a non-trivial set of tasks. The radon citizen science-based web platform provides radon information and the interface to access the IRP classification model as a starting step for the citizen science interaction process [4]. First, the platform should motivate citizens to obtain an estimate of IRP providing clear, objective, and scientific-based information on indoor radon. The citizen will be able to get an IRP pre-diagnosis classification and, later, provide the radon measurements. These measurements will generate new data that will be used to build a more robust classification model and to get a better understanding about the IRC distribution. To keep citizens engaged, the web platform will provide new features to give citizens access to their data and the scientific results or recommendations, to support interaction among them, and

to get feedback from researchers. The first web platform running version is already online and implements the required features for the IRP pre-diagnosis process and IRC measurement feedback. The web platform is not yet open to general public.

3. RESULTS AND DISCUSSION

The performance of IRP model, albeit some limitations, is not highly critical for the platform's success. The IRP pre-diagnosis component works as an engagement tool. The communication will highlight the probabilistic nature of the estimation and the need to do IRC measurements in situ to get sure about the radon risk. Still, it is crucial to enhance the model accuracy to keep citizen's confidence in all information conveyed by the platform. The platform already implements most high priority platform features, and researchers are using them to validate the platform and insert a new set of samples according to the IRP pre-diagnosis process [5]. Researchers have access to a dashboard that monitors the performance of the IRP pre-diagnosis model and provides data on the IRP as-sessments carried out and the respective IRC measurements loaded by citizens. Data quality is another critical challenge that needs to be continuously managed to avoid quality issues in the gathered IRP pre-diagnosis input data and following IRC measurements. Citizens need to follow the protocol for data collection that includes fundamental instructions for measuring the IRC, such as the position of the radon measuring device. In the IRC measurement submission, citizens must identify the radon device used in the measurements. Besides, every IRC measurement submission will be automatically tested. When the platform detects an outlier, it will trigger an alert to researchers.

4. CONCLUSION

Grounded on the radon potential model implementation, the radon citizen science-based web platform will allow citizens to obtain estimates from the IRP classification model and provide new data for research. The developed web platform is already online but restricted to the research team. After the testing and validation, we will open the web platform to citizens and initiate dissemination initiatives. The iterative development approach will deliver new platform features and versions of the IRP pre-diagnosis to enhance the classification model accuracy and keep a high level of citizen engagement.

It is expected that the gathered data and the knowledge that will result from the interactions between citizens and researchers will be a source of recommendations to mitigate high IRC in existing buildings and to avoid high IRC in the construction of new buildings.

ACKNOWLEDGEMENTS

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Special Session 2A: Life Cycle Assessment

Natural gas supply in Italy in 2030: a Life Cycle Assessment

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ABSTRACT
The recent geopolitical upheavals have changed the supply path of natural gas towards Europe and Italy. In this study the effects of these changes have been assessed. Based on the last available data and on scenarios defined by the Italian transmission operators of electricity and gas (SNAM and Terna) the effect of these changes in the 2030 scenarios are presented. The main change is due to the absence of natural gas from Russia in the medium term and to an increase in LNG. The overall result is a reduction in the climate change of the natural gas mix in Italy in 2030.

Keywords: Life cycle assessment; Natural gas supply; Scenario at 2030.

1. INTRODUCTION
The traditional natural gas supply channels in Italy have undergone significant changes in recent years due to various factors:

- In 2020, with the opening of the Trans-Adriatic Pipeline (TAP) (which reached full operation in 2021), a direct supply channel from Azerbaijan (specifically from the Shah Deniz field in the Caspian Sea) to Italy was opened.
- The Russian invasion of Ukraine and the consequent sanctions proposed by the European Commission greatly reduced the supply from Russia, which repre-sented about 40% of Italy's supplies in 2021.
- In this scenario, the role of Liquefied Natural Gas (LNG) has increased. Starting with the entry of the United States among exporting countries, it has been a rap-id and flexible tool to fill the gaps left by Russian gas. In Italy, the number of regasification terminals increased from three to four in 2023, with the opening of the Piombino terminal.

Gas supply plays a relevant role in the energy sector: In Ecoinvent 3.8 [1], gas supply accounts for 24% of the CO_2 equivalent for the production of 1 kWh of electricity produced by natural gas combined cycle power plants. Its impact is strictly related to the country of origin; it is thus of utmost importance to anticipate the effect of future supply scenarios.

2. MATERIALS AND METHODS
Goal and scope
The aim of this LCA is to assess the natural gas supply in Italy in 2030, because of the role played by this mix in the energy system.
The functional unit is 1 Nm^3 of natural gas supply mix imported in Italy in 2030. The method of the analysis is the Environmental Footprint 3.1 [2]; the impact categories with robustness level I and II have been considered.
Inventory
The cornerstone of the import mix structuring was the scenario defined by SNAM and Terna [3]. It was the only scenario developed after February 2022, and therefore able to take into account the latest geopolitical events and their consequences on supplies.
However, this scenario does not detail the exporting country but only the national production, the forecast of GNL import and the supply channel (north pipeline or southern pipeline).
The latest available data on the origin of the imported gas in Italy refers to 2022 [4] while data about the entry point are available also for 2023 [5]. These data provide a picture of a situation still evolving: the sanctions approved in the year had not yet fully shown their effects, and Russia still appeared among the main suppliers for that year. Predicting the future supply trend was therefore not a simple exercise, as historical data were not available, and future scenarios were still highly variable.
It was chosen to use the historical data from SNAM, which provide information on the gas injected into the network by entry point in 2023 and obtain information on the country of origin from there. The percentage

of countries exporting gas towards Italy from the north pipeline and the percentage of country exporting via southern pipeline have been applied to the scenario defined by SNAM and Terna.
Not all the importing datasets are available in Ecoinvent, thus some datasets have been created ad hoc

3. RESULTS AND DISCUSSION

The 2030 mix results in a visible reduction in impact categories such as climate change, ozone depletion, acidification, and fossil resource consumption. Most of these differences are attributable to the disappearance of Russian gas from the mix (Fig. 1), whose import to Italy had significant impacts especially in these categories. Russian gas imported into Italy has very high impacts, 62% of which are due to transportation, and a highly impacting Russian electricity mix used in the extraction, compression, and transportation phases.

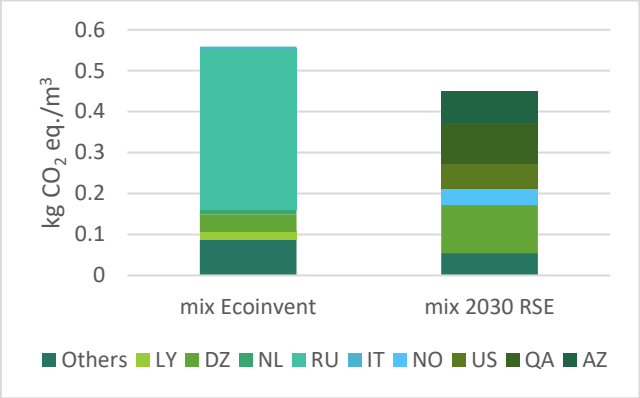

Fig. 1. - Climate change of the Ecoinvent mix and the RSE mix at 2030. Contribution breakdown per importing countries.

4. CONCLUSION

Natural gas plays a fundamental role in the current and medium-term Italian elec-tricity mix (in 2030 according to the latest version of the PNIEC it will constitute 25% of electricity generation [6]), whose impacts reverberate throughout the coun-try's productive sectors.
The upstream role is relevant in terms of environmental impacts, as supply ac-counts for 24% of the impacts of electricity production from natural gas combined cycle plants. The new geopolitical configuration has changed this mix, and it is important to understand its role in the medium term.
The effects of the disappearance of Russian gas from the import mix result in a reduction in impacts on climate change due to specific high impacts caused by high impact in the transportation phase.

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E032 **11:45-12:00**

Life Cycle Environmental Impacts of a Seamless Leggings

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ABSTRACT

This study aims to conduct a Life Cycle Assessment (LCA) of seamless leggings manufactured by a Portuguese textile company, employing a "cradle-to-gate" approach covering all stages from raw material production to packaging at the company gate. Primary data for foreground processes were derived from the company's industrial operations, supplemented with background data obtained in the ecoinvent V3.5 database and the literature. Environmental impacts were assessed using the ReCiPe 2016 Midpoint (E) V1.02 methodology using SimaPro V8.5.2 software in the calculations. Findings highlight that fiber production and spinning exert the greatest environmental impacts due to intensive energy use. Dyeing operations are relevant in the water consumption and freshwater ecotoxicity environmental impact categories. Therefore, initial efforts to mitigate environmental impacts should prioritize these stages. Changing electricity sourcing from the national grid to photovoltaic energy significantly reduces several impact categories, including a 30% decrease in the carbon footprint.

Keywords: Life Cycle Assessment (LCA); Seamless leggings; Portuguese textile company.

1. INTRODUCTION

Textiles, especially clothing, are essential in human societies for protection, warmth, comfort, and cultural identity. However, their production, from raw material cultivation to manufacturing and disposal, consumes siginicant resources, in particular water and energy, and generates significant amounts of waste and pollution. The textile sector accounts for 2-8% of global greenhouse gas emissions, 9% of microplastic pollution, and is a major water consumer [1]. To reduce these impacts, life cycle assessment (LCA) methodologies, as per ISO 14040 [2] and 14044 [3] standards, are employed to identify opportunities for improvement and support decision making. In this study an LCA for a seamless leggings made of polyamide and elastane by a Portuguese company is done, utilizing primary data from the company suplemented with data from inventory databases and the literature. Previous LCAs have mostly focused on other garments or fibers, highlighting issues like high water use in cotton cultivation. This study aims to provide anenvironmental impact assessment for seamless garments, which has not been extensively covered in literature.

2. MATERIALS AND METHODS

Study Goal: The study aims to perform a “cradle-to-gate” life cycle analysis of seamless leggings production by a Portuguese textile company.

Functional Unit (FU): The FU is one pair of seamless leggings in medium (M) size.

System Definition and Study Assumptions: The process system covers operations from raw material acquisition through to final packaging for shipment. Knitting takes place at one facility, while dyeing occurs at another site 10 km away, followed by return to the knitting facility for cutting and packaging. Notably, stages such as distribution, utilization, and disposal are excluded due to data limitations. This attributive assessment focuses on direct environmental impacts of the functional unit, considering Portuguese and European conditions, and employing normal regional transportation methods.

Inventory Analysis and Data Sources: Primary data from industrial processes was primarily used for the foreground processes, complemented by the ecoinvent V3.5 inventory database complemented with the literature whenever necessary for background data. The Portuguese distribution grid mix was used for electricity supply. Transportation was modeled using a 3.5-7.5 ton EURO 5 compliant lorry. Energy consumption for machinery was calculated by multiplying equipment power by average processing time. The fibers used consisted of 90% polyamide and 10% elastane.
Environmental Impact Assessment: The environmental impact assessment employed SimaPro V8.5.2 software integrated with the ecoinvent V3.5 inventory database. The ReCiPe 2016 Midpoint (E) V1.02 method was used to evaluate the environmental impacts associated with manufacturing seamless leggings. The chosen egalitarian (E) perspective ensures a thorough and precautionary assessment of long-term and cumulative environmental impacts across 18 distinct categories. Key impact categories such as water consumption (WC), influenced significantly by the dyeing process, and global warming (GW), driven by energy consumption and carbon emissions from fossil fuels, underscore critical areas like resource use and greenhouse gas emissions.

3. RESULTS AND DISCUSSION

The principal environmental impacts of seamless leggings production stem from raw material production (polyamide and elastane fibers), dyeing, and knitting, with transportation also significant but less than 10% of the total impact. The importance of each stage varies across environmental categories; dyeing stands out in water consumption due to its substantial water usage. Sustainable dyeing techniques, like microbial natural dye production, and water recycling systems can mitigate these impacts.
Fiber production and spinning contribute significantly to climate change, fossil fuel depletion, and eutrophication due to high energy consumption. Transitioning to renewable energy sources can help alleviate these impacts. In toxicity-related categories, dyeing, knitting, and fiber production are the main stages due to hazardous chemical use. Adopting low-impact fibers and dyeing methods, like bio-based dyes, is crucial to reduce these impacts.
Implementing environmentally friendly changes in knitting and dyeing processes requires substantial investment and time. An immediate alternative is switching from the Portuguese grid to fully renewable photovoltaic (PV) electricity, which can be implemented onsite for immediate environmental benefits.
Comparing the base scenario with PV electricity, reductions are evident in most environmental impact categories, notably a 30% decrease in the carbon footprint due to lower carbon emissions from energy-intensive processes. However, some categories show increases, particularly in toxicity and non-renewable resource depletion, due to PV panel production, that involves energy-intensive silicon manufacturing and metal usage like copper for connections.

4. CONCLUSION

This study presents an LCA study of seamless leggings produced by a Portuguese textile company, using as much as possible inventory data sourced from its operational processes. Key stages, such as polyamide and elastane production, knitting, and dyeing; are identified as the primary drivers of the leggings' environmental footprint, each impacting different environmental categories to varying extents. Transitioning to renewable electricity sources emerges as a viable approach, promising a substantial 30% reduction in carbon footprint.

ACKNOWLEDGEMENTS/FUNDING

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E033 **12:00-12:15**

Carbon Footprint of Tinplate Aerosol Cans

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ABSTRACT
This study presents a cradle-to-gate life cycle assessment (LCA) of a three-piece metal tinplate aerosol can, focusing on its carbon footprint. Primary data from industrial practices form the basis of the life cycle inventory for the foreground processes, supplemented by ecoinvent v3.9 inventory database and literature for the background processes. Tinplate emerges as the largest contributor, comprising about 60% of the carbon footprint, followed by wooden pallets (24%) and aluminum foil used in offset printing (10%). Energy consumption during cutting, shaping, and assembly minimally impacts emissions, with natural gas contributing around 1% and electricity about 2% to the total carbon footprint. Overall, the study underscores tinplate production as the key driver of carbon emissions in aerosol can manufacturing.

Keywords: Carbon footprint; Climate change; Life cycle assessment (LCA); Tinplate aerosol can.

1. INTRODUCTION
The packaging industry is crucial to ensure safe product delivery, with a growing emphasis on sustainable solutions to meet market and regulatory demands. Metal aerosol packaging, particularly steel cans, remains significant despite advances in lighter materials like aluminum and plastics. Recent innovations by ArcelorMittal and Trivium Packaging have led to lighter steel cans coated with tinplate, enhancing corrosion resistance and sustainability. Collaborations with companies like Henkel further drive sustainability efforts, reducing material and water use in production [1].
To support sustainability and innovation efforts in packaging, the application of LCA methodologies are essential. LCA evaluates environmental impacts throughout a product's life cycle, aiding in identifying improvement opportunities and informing decisions. Despite limited LCA studies on tinplate aerosol cans, recent industry reports show significant reductions in carbon footprint, reflecting advancements in production and recycling practices [2]. This study aims to fill existing gaps by conducting a cradle-to-gate LCA of a three-piece metal tinplate aerosol can, focusing on carbon footprint assessment and using primary data from Portuguese industrial practices.

2. MATERIALS AND METHODS
Study Goal: This study aims to evaluate the carbon footprint of a three-piece metal tinplate aerosol can produced by a Portuguese company using the Life Cycle Assessment (LCA) methodology [3], in a "cradle-to-gate" approach.
Functional Unit: The functional unit (FU) for this study is 1000 units of empty tinplate aerosol cans, packaged and ready for shipment. Each aerosol can is 65 mm in diameter, 240 mm in height, and weighs approximately 103 grams.
System Definition and Study Assumptions: This attributive LCA study focuses on the production of tinplate aerosol cans, starting with the reception of tinplate coils and includes cutting and forming processes for cupule, bottom, and body components. It includes stages such as crimping, quality testing, palletizing, and preparation for transport within its system boundary. Processes related to filling and distributing aerosol cans are excluded from assessment. The study considerd Portuguese and/or European conditions for foreground processes, with a particular emphasis on energy consumption during production, accurately representing the regional production context.
Inventory Analysis and Data Sources: The foreground inventory data for tinplate aerosol can production were directly sourced from a Portuguese packaging company's operational practices, detailing tinplate consumption, total energy usage, material inputs, waste generation, and emissions for the reference year

2022. Background data for materials and energy production came from the inventory ecoinvent v3.9 LCA database complemented with the literature. This encompassed the life cycle stages from raw material extraction and transportation to energy production and distribution, Hence, the study is a comprehensive "cradle-to-gate" approach to evaluate all associated material and energy-related emissions, thereby assessing the greenhouse gas emissions and carbon footprint of tinplate aerosol cans.
Environmental Impact Assessment: The carbon footprint is evaluated using the ReCiPe 2016 Midpoint (Equalitarian) method and SimaPro v9.5 software to perform the calculations. This method was chosen for its balanced and detailed assessment of environmental impacts, supporting effective communication, regulatory compliance, and continuous improvement.

3. RESULTS AND DISCUSSION

The results identify tinplate, wooden pallets, and thermal offset plates as the main contributors to the carbon footprint, amounting to 217, 89, and 37 kg CO_2-eq respectively over the lifecycle. These findings highlight a critical opportunity for environmental improvement by focusing on these materials. Strategies could include adopting recyclable materials with lower carbon footprints, or exploring alternative materials to mitigate environmental impacts effectively while ensuring the same levels of performance.
In terms of energy consumption during packaging production by the Portuguese company, electricity and natural gas collectively contribute 8 and 2 kg CO_2-eq/FU respectively to the overall carbon footprint. This emphasizes that the bulk of the carbon footprint is embedded in the tinplate material itself, a metallic material that requires significant amounts of energy to be produced.
Breaking down these results into a percentage distribution, tinplate constitutes 60% of the total GWP, followed by wood pallets (24%), thermal offset plates (10%), varnishes, paints, primers, and enamels (2%), electricity (2%), natural gas (1%), and paper/cardboard usage (1%).

4. CONCLUSION

This study evaluated the carbon footprint of manufacturing a tinplate aerosol can by a Portuguese company using real industrial data. Tinplate sheets accounted for 60% of the process's carbon emissions, followed by wooden pallets (24%) and thermal offset plates (10%). Electricity and natural gas each contributed 2% and 1%, respectively, to the overall carbon footprint. To mitigate these impacts, the study recommends improving energy efficiency, adopting renewable energy sources, and enhancing recycling processes in tinplate production. It emphasizes the importance of suppliers adopting environmentally responsible practices, such as reducing emissions and using recycled materials, especially recycled tinplate, and wooden pallets certified by organizations like FSC. Exploring alternatives like recycled plastics for pallets and optimizing metal offset plates to minimize waste are also other possible options. Ultimately, integrating sustainable practices enhances corporate reputation, appeals to consumers, while strengthening market competitiveness.

ACKNOWLEDGEMENTS/FUNDING

The work was financially supported by base Funding of the following projects: LA/P/0045/2020 (ALiCE), UIDB/00511/2020 (LEPABE) and UIDB/50022/2020 (LAETA), funded by national funds through FCT/MCTES (PIDDAC). António Martins gratefully acknowledges the Portuguese national funding agency for sci-ence, research and technology (FCT) for the financial support through program DL 57/2016 – Norma transitória. Teresa Mata gratefully acknowledges the fund-ing of Project NORTE-06-3559-FSE-000107, cofinanced by Programa Opera-cional Regional do Norte (NORTE2020), through Fundo Social Europeu (FSE).

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Special Session 3A: Renewable Energy

E027 **14:00-14:15**

Characteristics of bio-oil from pyrolysis of Eucalyptus wastes in an auger reactor

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ABSTRACT

This work studies the bio-oil production by pyrolysis of residual biomass from eucalyptus in a prototype auger reactor at 550 ºC. The resulting bio-oil was separated into heavy (HF) and light (LF) fractions. The HF constituted 22 to 34 %wt. of the bio-oil and presented a darker color, higher viscosity and lower water content (22 to 30 %wt.) compared to the LF, which constituted 66 to 78 %wt. of the bio-oil. The higher heating value (HHV) of HF ranged from 21.22 to 23.73 MJ/kg_{HF}, while LF varied significantly from 2.48 to 8.48 MJ/kg_{LF}. Elemental analysis of HF from eucalyptus branches and leaves pyrolysis of showed similar carbon content between 0.51 and 0.52 kg_C/kg_{HF}, hydrogen of 0.09 kg_H/kg_{HF}, and nitrogen of 0.01 kg_N/kg_{HF}. Oxygen content, including that in water, ranged from 0.38 to 0.39 kg_O/kg_{HF}. HF shows potential as a fuel precursor but requires further investigation due to its high oxygen content and low calorific value compared to conventional fuels.

Keywords: Bio-oil; Pyrolysis; Residual biomass from eucalyptus.

1. INTRODUCTION

Sustainable forest management is essential for protecting ecosystems, communities, and biodiversity from wildfires while maintaining forest productivity. In Europe, where about 45 % of the territory is forested area [1], the paper and pulp industry heavily rely on forests to obtain its feedstocks, particularly the *Eucalyptus globulus* in southern Europe [2]. The waste generated, such as branches, leaves, and sawdust, is often used in low efficiency energy applications but has the potential to be converted into high-value-added products, like biofuels and biochemicals [3]. In this context, pyrolysis of residual biomass to produce bio-oil has been widely recognized as a key technology for the energy transition and circular economy, reducing dependence on fossil fuels and mitigating greenhouse gas emissions [4,5]. In the pyrolysis process, biomass is subjected to temperatures between 400-600 °C in the absence of oxygen, producing of vapors (permanent gas and bio-oil) and biochar [6].

Despite existing studies on pyrolysis of residual biomass in screw reactors for bio-oil production [7–8], the specific use of eucalyptus forest residues is not well-documented, to the best of authors' knowledge. Filling this knowledge gap is important due to the unique properties of this biomass, which can significantly impact the yields and quality of bio-oil. This study explores the residual biomass from eucalyptus (RBE) pyrolysis to produce bio-oil in a prototype auger reactor, focusing on its production and characterization, such as moisture content, elemental composition, pH, and calorific value. The findings will contribute to developing more effective strategies for producing and applying bio-oil derived from RBE.

2. MATERIALS AND METHODS

In this work, different types of RBE were used as feedstock, included, eucalyptus branches from maintenance and logging activities, as well as eucalyptus leaves and sawdust, which are by-products of the pulp industry. The pyrolysis experiments were conducted at 550 ºC in a prototype auger reactor. The bio-oil collected in the pyrolysis vapor condensation system naturally separated into two distinct fractions after condensation, which were subsequently separated by decantation and labeled as the heavy fraction (HF) and light fraction (LF). All bio-oil fractions underwent further characterized for their water content (Karl Fischer), pH and higher heating value (HHV, using oxygen bomb calorimeter). Additionally, the HF fractions underwent specific characterization for chemical composition (C, H, N - ASTM D 5291), with oxygen content was then calculated by difference.

3. RESULTS AND DISCUSSION

The yield of pyrolysis bio-oil from RBE varied between 0.47 and 0.59 $kg_{bio\text{-}oil}/kg_{biomass,db}$. As previously mentioned, the bio-oil collected from pyrolysis separated into two distinct fractions through decantation. Quantitatively, the HF constituted a smaller portion of the total bio-oil, ranging from 22 to 34 %wt., while the LF comprised between 66 and 78 %wt. The water content in the HF varied from 22 to 30 %wt., with lower values observed in samples derived from the pyrolysis of eucalyptus sawdust. In contrast, the LF exhibited a water concentration of 63 to 84 %wt., with the lower values also observed during experiments with eucalyptus sawdust. Elemental analysis of the HF from pyrolysis of eucalyptus branches and leaves revealed consistent values in both samples: carbon content between 0.51 and 0.52 kg_C/kg_{HF}, hydrogen at 0.09 kg_H/kg_{HF}, nitrogen at 0.01 kgN/kgHF, and oxygen content ranging from 0.38 to 0.39 kg_O/kg_{HF}, including contributions from water-associated hydrogen and oxygen. The higher heating value (HHV) of the HF ranged from 21.22 MJ/kg_{HF} to 23.73 MJ/kg_{HF}, with the highest value observed in eucalyptus branches, closely followed by eucalyptus leaves. In contrast, the HHV of LF was significantly lower than that of the HF due to the high-water content, varying between 2.48 MJ/kg_{LF} to 8.48 MJ/kg_{LF} across samples, with the highest value found in LF derived from eucalyptus sawdust, which also had lower water content compared to the other samples. Regarding pH, both oil fractions showed acid pH, with HF showing slightly higher pH values ranging from 3.36 and 4.96.

4. CONCLUSION

This study investigated the production of bio-oil from residual biomass from eucalyp-tus (RBE) using a prototype auger reactor operating at 550°C, focusing on its production and characterization. The bio-oil obtained by fractional condensation system exhibited comprised two fractions: HF and LF. The HF, despite constituting a smaller volume fraction, showed lower moisture content, higher calorific values, and slightly higher pH. These characteristics indicate its potential as a fuel; however, challenges remain due to its high acidity, oxygen and water contents, which exceed those found in conventional liquid petrochemical fuels. Addressing these challenges requires: (i) optimization of the pyrolysis process to improve these parameters, (ii) further investigation into HF pretreatment methos, and/or (iii) adaptation of oil fuel burners for handling with this type of fuel. Conversely, the LF demonstrated high high-water content and low calorific value, suggesting that direct combustion for thermal energy may be challenging and a suboptimal application, and alternative applications should be explored further.

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E041 **14:15-14:30**

Study on the effects of using different blends of Biodiesel and HVO with conventional diesel in Heavy-duty vehicles

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ABSTRACT

The carbon dioxide emissions into the atmosphere by the transport sector demands an urgent reduction, this implies the necessity to use alternative fuels such as biodiesel (FAME - Fatty Acid Methyl Ester) and HVO (Hy-drotreated Vegetable Oil) in Diesel engines. One of the advantages of both these fuels is the compatibility with current and future vehicle fleets. To investigate the possible effects of using these alternative fuels in Heavy-Duty engines, a methodology was defined, and an experimental set-up was prepared to identify the blending influence on the operation of an engine. In the present study, 6 different blends were considered containing different ratios of HVO, commercial diesel and FAME. A heavy-duty vehicle (HDV) was used in a chassis dynamometer considering performance tests and fuel consumption in 11 stabilized points that were usually common in regular vehicle use. The engine performance and fuel consumption results revealed the potential and weaknesses of using these fuels compared to traditional fuel, revealing the possibility of reducing CO_2 emissions due to the renewability origin, with the highlight that the use of HVO and reduced FAME blends showed no loss of engine performance, but when using HVOxBx and BxHVOxD a slight reduction in torque was detected.

Keywords: Alternative fuels; biodiesel; engines; HVO; renewable energy; sustainable mobility.

1. INTRODUCTION

One of the main worldwide concerns is climate change, most of which is brought on by human emissions of greenhouse gases (GHG) from fossil fuels. Effective political, social, and technical solutions must be implemented as soon as possible in the short, medium, and long terms.

In this critical environmental scenario, the transportation industry has a significant influence. First due to the impact of Transport sector in Europe were responsible for almost 25% of greenhouse gas emissions [1] primarily due to the continued use of internal combustion engines (ICEs) that run on fossil fuels [2]. Secondly, by the resili-ence revealed by this transport sector in reducing CO_2 emissions, what presents an inverse trend when compared to other sectors. With greenhouse gas emissions growing 33.5% between 1990 and 2019, the transportation industry is the only one to have experienced a rise in the last thirty years. The rate of emission reductions has de-creased, making it difficult to reduce CO_2 emissions from transportation significant-ly. Only 22% of transport-related emissions are expected to be reduced by 2050, significantly below of required objectives [3].

For now, the two biofuels that are commonly combined with fossil fuels are etha-nol and biodiesel. The production of biofuels is also gaining traction with another technology called hydro-processing. Thanks to its enhanced physiochemical qualities, hydrotreated vegetable oil (HVO) made with this method has the potential to be a drop-in fuel. The use of renewable fuels can be crucial to reaching future targets for CO2 reduc-tion and energy sustainability. One of the most promising substitutes for diesel fuels derived from petroleum is hydrotreated vegetable oil (HVO) [4].

The present study aims to evaluate the influence on the performance (power and torque) and fuel consumption of a Diesel engine fueled with different fuel blends compared to the use of commercial diesel (B7). Exhaust emissions and other engine operating parameters were also monitored to assess the influence of using those blends on the engine operation and control, during the tests.

2. MATERIALS AND METHODS

Tests were conducted on a chassis dynamometer to measure fuel consumption, emissions, and performance with each fuel blend under analysis:

- Engine power tests (continuous and discrete), where engine performance and its respective specific fuel consumption were evaluated. Three tests were conducted for each fuel blend, ensuring a result derived from the average of values obtained in the tests deemed representative of the en-gine's behavior with that fuel.
- Stabilized test cycle consisting of a set of 11 engine operating points corresponding to real-world driving conditions. These tests allowed for the de-termination of specific fuel consumption values at these operating points.

The set of tests conducted with each of the blends followed the sequence represented in Fig. 1, assuring that any possible influence of engine deterioration could affect the results and any possible trend on the amount of any biofuel could be misunderstood with a tendency of the obtained data:

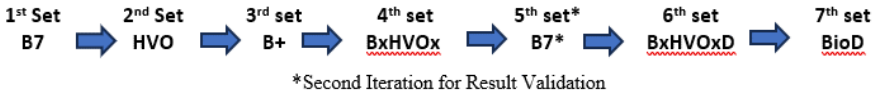

Fig. 1. Sequence of tests with the different fuel blends.

3. RESULTS AND DISCUSSION

The results reveal that the vehicles are generic prepared to use different options, and considering that B100, HVO are already available in Portugal, it should be considered by the freight and transport companies the possibility of considering these options to decarbonize their fleets and contribute to a more sustainable vehicles use. In fact, even considering the small increase in the purchase of the fuels, the initial investment is significatively lower, since this does not require any fleet replacement, just adjustments in the maintenance, and the reduction in CO_2 emissions is obvious and immediate.

Pollutant emissions were also analyzed, but due to the efficiency of exhaust treat-ment systems, the variations of the measured emissions are bellow that the uncertainty of the measurement equipment and the conclusion is that the effect of the use of these fuels does not affect the pollutant tailpipe emissions of the vehicle.

4. CONCLUSION

It is possible conclude that the use of the considered fuels has little or no impact on fuel consumption and vehicle performance, however, due to their higher costs, government incentives may be necessary to encourage transportation companies to accept those fuels more widely. This is justified by the significant reduction in CO_2 emissions that these renewable energy sources offer. If consumption remains unchanged, the discrepancies in the life cycle analysis guarantee at least 80% decrease in CO_2 emissions if any fossil fuel are used, even when the worst fuel consumption scenario is considered.

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E031 **14:30-14:45**

Gasification of residual forest biomass in the context of waste-to-energy

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ABSTRACT
This work presents a critical assessment of the main principles, technologies, and constraints of the gasification process. Finding adequate solutions to address the major limitations of the process could boost the application of gasification as a means to fulfil the waste-to-energy agenda. This work focused mainly on the gasification of lignocellulosic residues, namely residual forest biomass. Major limitations regarding the application of this process were pointed out, related to the presence of contaminants in the producer gas, such as tar and particulate matter, alongside its low calorific value, and reduced hydrogen concentration and H_2:CO molar ratio. These limitations hinder the application of producer gas for advanced processes, including biofuel production or chemical synthesis. Therefore, increasing research efforts are directed towards unlocking this energy carrier's full potential.

Keywords: Gasification; Hydrogen; Residual Forest biomass

1. INTRODUCTION
Despite increasing efforts, 21st-century society remains heavily dependent on fossil fuel energy. Biomass appears as a sustainable option, having enormous advantages over fossil fuels, being its use one of the most valuable measures to mitigate GHG emissions and replace fossil fuels, thus helping the transition of the world to a cleaner energy grid. Moreover, if residues/waste become the main source of biomass used for energy conversion, the utilisation of this resource promotes not only energy independence but also encourages waste recovery, in the framework of Waste-to-Energy policies [1]. Considering the problems related to the use of solid fuels, biomass can be converted into gaseous biofuels through gasification. This process offers high flexibility in terms of feedstock materials and generates a fuel gas mixture that could be used for heat and power generation or be a raw material for biofuels and chemicals synthesis [2]. The remainder of this work presents the main principles and constraints of residual forest biomass gasification as a means of adding value to lignocellulosic residues in the framework of waste-to-energy priorities. Moreover, this work also shows the main research activities and projects developed in the recent past by the IEA bioenergy task 33 “Gasification of Biomass and Waste” participating countries.

2. GASIFICATION PRINCIPLES
The biomass gasification process is characterised by the thermochemical conversion of biomass into fuel gas, at high temperatures, using a known amount of gasification agent, which is most often air but can also be pure oxygen, steam, carbon dioxide or a mixture of these. The oxidant is introduced in sub-stoichiometric amounts, and the process can be divided into several overlapped stages: drying, pyrolysis, reduction, and oxidation, with reactions occurring simultaneously [3]. The producer gas can be applied in heat and power systems (direct combustion, gas engine, gas turbine, combined cycle, Organic Rankine Cycle). Furthermore, if refined to syngas (H_2 +CO), the fuel gas from biomass gasification might be used in the gas grid after conversion to bio-methane, or converted into bio-hydrogen through steam-reforming for fuel cell utilisation [4]. In addition, syngas can be used for biofuels and chemical synthesis [5].

3. CONSTRAINTS
Biomass gasification has major advantages in terms of environmental benefits and energy supply since it can partially replace fossil fuels and fulfil the energy demands of several regions by using their endogenous resources and residues. However, some drawbacks can be identified, hindering the full implementation of the process at the industrial level [6]. The presence of contaminants, namely tar, particulate matter (including dust, ash, alkali compounds and bed material), nitrogen, sulphur, and halide compounds, can lead to damage in the gasifier and downstream equipment, jeopardizing the feasibility of producer gas/syngas applications [2]. Apart from the presence of contaminants, the producer gas from direct (air)

biomass gasification also has a low calorific value (4 – 7 MJ/Nm^3), which poses itself as a main constraint for all energetic applications. Moreover, the producer gas from air bio-mass gasification has a low H_2 concentration (~8 %$vol._{dry\ gas}$) and low H_2:CO molar ratio (~0.6 mol_{H_2}/mol_{CO}) [7]. These characteristics strongly limit the use of producer gas for advanced applications.

4. RESIDUAL FOREST BIOMASS GASIFICATION IN EUROPE

In 1978, the International Energy Agency (IEA) developed a technology collaboration programme - IEA Bioenergy, to promote and improve communication and cooperation between countries with national programmes in bioenergy research [8]. Within this framework, several tasks were created to segment the different aspects and processes linked to bioenergy, with the gasification process integrated into task 33 “Gasification of Biomass and Waste”. With the increasing research regarding biomass gasification, several plants using biomass and waste were built, with more than 120 plants currently operating. From those, 15 plants exclusively used forestry residues located in various European countries: Denmark, France, Finland, Germany, Italy, the Netherlands, Sweden, Switzerland and the United Kingdom [9]. Most of the plants were designed for Heat and Power production, with only 1 for liquid fuels production through FT synthesis, probably due to the gas refining needs for biofuels production.

5. CONCLUSION

This work assessed the main principles and limitations of the gasification process, aiming at its application in residual forest biomass valorisation. The well-recognized potential of this type of waste makes it a suitable candidate for waste-to-energy practices. This process is characterized by the conversion of residual forest biomass into a fuel gas through several heterogeneous and homogeneous reactions at high temperatures in the presence of an oxidant species. This work identified some critical limitations of the gasification process which still hinder its full-scale implementation. The road towards full-scale implementation of residual forest biomass gasification is still full of technical hurdles. In this framework, the recent past has witnessed an increase in research focused on solutions to improve producer gas quality. This trend is expected to continue in the future, which may at last set the conditions for the full utilisation of this technology in the context of the waste-to-energy agenda.

ACKNOWLEDGEMENTS/FUNDING

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E043 **14:45-15:00**

Development of a novel off-grid power module for forest machines based on *Rankine* technology

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ABSTRACT
As a carbon-neutral resource, biomass presents as an alternative, particularly effective in mitigating CO_2 emissions and exploiting renewable energy opportunities in forest regions. This study presents the starting point for developing a new off-grid power module designed explicitly for forest management and maintenance applications, with the primary objective of using the forest residues directly in the forest to power the forestry machines. In this way, a technological analysis was made of three different configurations of *Rankine* cycles. The most suitable configuration for this specific application was identified by developing and exploring their physical models.

Keywords: Biomass; Electricity generation; Forest management; Off-grid power module; *Rankine*.

1. INTRODUCTION
Transport plays a central role in the biomass supply chain. However, it contributes to environmental issues and accounts for a significant fraction of the total costs [1, 2]. These costs, linked to residual forest biomass's geographical dispersion and seasonality [3], make its local utilization and valorization an attractive option. In the logging industry, where large amounts of forest residues are generated, the costs associated with fuel consumption in the equipment involved are significantly high [4]. Traditionally, forestry exploration and management have heavily relied on diesel-powered equipment, resulting in considerable environmental impacts. To reduce the use of these fuels, the electrification of forestry machines has increasingly been adopted in this sector [5]. Therefore, by using residual forest biomass on-site, it will be possible to generate an energy vector capable of directly powering the batteries of forestry equipment. Thus, the use and valorization of forest residues is carried out within the forest itself, without transporting them outside. To achieve this, a semi-mobile and energetically autonomous system, which allows the production of electrical energy through the thermochemical conversion of forest residues, will be necessary. Implementing this system will also reduce the risk of fires and minimize pollutant emissions from transporting the forest residues or, possibly, its open pile burning [6].
Developing this system is one of the objectives of Work Package 2 of the Agenda Transform - Digital Transformation of the Forestry Sector for a Resilient and Low-Carbon Economy [7]. The project aims to evaluate and select technologies capable of using residual forest biomass on-site to generate electrical energy for powering machines used in forestry management and exploration. In this way, this paper presents a technological analysis of different *Rankine* cycle configurations to identify the most suitable configuration for this specific application.

2. MATERIALS AND METHODS
Given the diverse technical solutions provided by *Rankine* cycles, including cycle configurations, operating conditions, working fluids, and components [8], three distinct configurations were selected and studied in this work, namely a water/steam *Rankine* cycle (WRC), an organic *Rankine* cycle with an intermediate circuit (ORC_{ic}), and an Organic *Rankine* cycle with direct vaporization (ORC_{dv}).
The physical models of the *Rankine* cycles and the cooling and heating systems were developed using Matlab®, and the REFPROP thermodynamic database was used to calculate the properties of the thermal and working fluids [9]. In this analysis, the systems are assumed to operate under steady-state conditions, with pressure drops and heat losses in pipes and other system components considered negligible. For the sake of simplicity, as a starting point, it was assumed that the thermal power released in the combustion of forestry residues was equal to 100 kW_{th} and the boiler efficiency was 90%. The main input parameters for the cycle physical models are detailed as follows [10]: in the WRC model the working fluid used was steam, while in ORC_{dv} and ORC_{ic} it was R245fa. The evaporator efficiency was considered 90% for WRC and ORC_{dv}, and 98% for ORC_{ic}. For all models, the regenerator and condenser efficiencies were assumed

to be 98%, and the expander isentropic efficiency was 75%. The *Rankine* cycle pump isentropic efficiency was 50% for the three models, while the cooling circuit pump efficiency was 80%. Already, the thermal fluid pump efficiency was specified at 75%. The maximum cycle pressure for all models was set at 2800 kPa, whereas the minimum cycle pressure was 100 kPa for WRC and 344 kPa for ORC_{dv} and ORC_{ic}. The maximum working fluids temperature has been limited to 150 °C for the ORC_{dv} and ORC_{ic} models. It was also considered that the working fluids had a superheating degree of 20 °C for WRC and 10 °C for the other models, with a consistent supercooling degree of 10 °C for all models. The maximum thermal fluid temperature in the ORC_{ic} model was denoted as the maximum working fluid temperature plus 10 °C, and finally, all models consistently set the inlet and outlet water temperatures at 30 and 50 °C, respectively.

3. RESULTS AND DISCUSSION

An overall analysis of the three configurations showed that the off-grid power module with WRC has a higher overall efficiency (≈18.35%), resulting in a higher energy surplus (≈16.5 kW) and, that way, more energy to power forestry equipment. This value results from increased energy production in the turbine. The working fluids' mass flow rates exhibited significant variations related to water and organic fluids' specific volume and saturation temperatures of water and organic fluids. This way, the ORC pumps have significantly higher energy consumption than pumps for cooling and heating circuits.

Furthermore, the WRC also presents a greater potential for optimization due to the range of operating pressures. This range, opposite to the organic cycles, can still be increased. However, other working fluids and operation conditions must also be tested for the organic cycles.

4. CONCLUSION

From the preliminary results obtained, the water/steam Rankine cycle is the technology that presents the best performance for this application. Future work should optimize these systems further to enhance their efficiency and adaptability. This could involve refining the operating conditions, exploring alternative working fluids, and integrating advanced control strategies to maximize the off-grid power module's operational performance.

From an energy point of view, these results suggest that WRC is the most sustainable technology for integrating the off-grid power module. However, these results should be integrated into a more detailed analysis that evaluates, at least, the system’s mobility and cost in order to reach a final decision.

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Special Session 1B: Energy Policy, Economics, Planning & Regulation

E049 **15:00-15:15**

Risk assessment of reusing treated water from the Viseu Sul WWTP for irrigation and similar uses

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ABSTRACT

Due to the growing water scarcity, the reuse of treated wastewater arises as a possibility for sustainable water management. However, it is necessary to evaluate the possible risks associated with its activity. This study aims to develop a risk assessment of water for reuse, in terms of public health and water resources, for production and internal use by the Viseu Sul Wastewater Treatment Plant (WWTP) and external use in irrigation of green spaces in Viseu. The methodology used was a semi-quantitative risk assessment. The results demonstrated the viability of the production and use of Reused Water by the Viseu Sul WWTP, with an overall risk to public health of 0.68, and for use in irrigating green spaces in Viseu, with an overall risk of 0.75. The overall risk to water resources was 2.33 for nitrogen and phosphorus and 0.78 for *E. coli*. All risks were considered insignificant, considering the criteria defined by the method. Based on the information presented, it can be inferred that the use of treated wastewater to meet Viseu's water needs is a viable option.

Keywords: Risk assessment; Wastewater; Water for Reuse.

1. INTRODUCTION

Currently, water scarcity is a major concern. With increasing economic, population, industrial and agricultural development, the need for water has also increased. Climate change, which disrupts precipitation patterns and the entire water cycle worldwide, also contributes to this water scarcity [1]. Which searches for sustainable use alternatives is essential.

Water for Reuse (WfR) for irrigation is a very relevant alternative for regions with water scarcity. This is the case of the municipality of Viseu, in the interior of Portugal, a region where there is a deficit in water resources during the summer months (June to September). In 2022, local authorities implemented exceptional measures to reuse treated water from the Viseu Sul Wastewater Treatment Plant (WWTP) for irrigation of green spaces [2]. To produce and use WfR in Portugal it is mandatory to follow the standards established by legislation, Decree-Law no. 119/2019, of August 21, republished by Decree-Law no. Law No. 11/2023, of February 10. These legal requests, in addition to prescribing quality criteria for their use, also establish the need to carry out a risk assessment in terms of public health and water resources for the reuse of water.

In this context, this study aims to develop an assessment of risks related to public health and water resources arising from the production of WfR by the Viseu Sul WWTP, for internal use and external use in irrigating green spaces in the city of Viseu.

2. MATERIALS AND METHODS

The methodology used comprises a semi-quantitative risk assessment model in the context of public health and water resources, supported by the scale proposed by Saaty [3] for levels of importance, which ranges from 1 to 9, with 1 being low importance and 9 higher importance. The entire methodology proposed was based on the APA's "Guide for water reuse – Non-potable uses" [1]. The importance tables and some calculations necessary for risk assessment can be found in supplementary material.

3. RESULTS AND DISCUSSION

For public health risks, it is possible to classify treated effluent, with an *E. coli* concentration of 6.5 ucf/100 mL, as having an importance factor (fi) of 1, considered very low. For the production and internal use of WfR, 3 groups of receptors were determined (Table 1). For the irrigation of Viseu's green spaces, 4 groups of receptors were determined (Table 2). A total of 47 exposure scenarios were identified for these receptors, divided between ingestion, inhalation and dermal adsorption. Five barriers were implemented for the production and internal use of WfR by the WWTP, achieving an overall damage of 0.89. For the use of WfR in the irrigation of green spaces, 3 barriers were implemented, arising an overall damage of 0.93. Table 1 and 2 presents the results of global risks to public health.

Table 1. Receptor risk and global risk, in terms of public health, of WFR application in the WWTP.

Production and internal use of RfW by ETAR				
Receiver	Haz.	Vuln.	Dam.	Risk
Worker – Supply	1	0.68	0.89	0.60
Worker – Washing	1	0.87	0.89	0.77
Worker – General	1	0.75	0.89	0.67
Global Risk	0.68		DESPICABLE	

Table 2. Receptor risk and global risk, in terms of public health, of WFR application for irrigation.

Use in irrigation of green spaces in Viseu				
Receiver	Haz.	Vuln.	Dam.	Risk
Worker – Transport	1	0.68	0.93	0.63
Worker – Irrigation	1	0.89	0.93	0.82
Community – Adult	1	0.80	0.93	0.74
Community – Child	1	0.86	0.93	0.79
Community – Elderly	1	0.81	0.93	0.75
Global Risk	0.75		DESPICABLE	

For water resources, the hazard indicators identified were the concentration of nitrogen and phosphorus in treated wastewater and the microbiological risk (*E. coli*). The treated wastewater from the WWTP showed average concentrations of nitrogen and phosphorus, both considered to have an importance factor of 3 for these pollutants. The importance factor for *E. coli* was 1. Despite the possibility of implementing barriers, it was decided, together with the proponents of the reuse project, that no barriers would be implemented. Thus, the damage assumed a maximum value of 1. The receptors found were classified according to the hydrogeological characteristics of the region: Surface waters – average runoff; Groundwater – Absence of aquifers with hydrological continuity in the area and low infiltration. Table 3 presents the global risks to water resources.

Table 3. Global risks to water resources

Indicator	Hazard	Vulnerability	Damage	Global risk	
Nitrogen	3	7	1	2.33	DESPICABLE
Phosphor	3	7	1	2.33	DESPICABLE
Microbiological	1	7	1	0.78	DESPICABLE

4. CONCLUSION

The risk assessment for the reuse of treated water reveals the feasibility of reusing water, both for production and use, whether internal or externally to the WWTP. With a public health risk of 0.68 for the production and internal use of WfR by WWTP, 0.75 for external use in irrigating green spaces in Viseu, and a water resources risk of 2.33 for nitrogen and phosphorus, and 0.78 for microbiological risk. Therefore, water reuse can be a feasible way to mitigate water scarcity in the city of Viseu.

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E003 **15:15-15:30**

Are Biofuels More Environmentally Friendly? The GHG Emissions Impacts of Increased Biofuel Production

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ABSTRACT
During the last decade, the negative consequences of climate change have become more intense and severe. The substitution of gasoline with biofuels can potentially reduce global emissions and help mitigate these negative impacts. However, most studies concentrate on CO_2 emissions and non-CO_2 emissions, which have significantly larger global warming po-tential than CO_2 emissions alone, have largely been overlooked. Non-CO_2 emissions ac-count for more than 19 percent of total greenhouse gas (GHG) emissions in the United States. In this paper, we link the Global Trade Analysis Project Biofuels (GTAP-BIO) model and the Global Trade Analysis Project model with Agro-Ecological Zones (AEZ) and Greenhouse Gas emissions (GTAP-AEZ-GHG) model with the updated database incorporat-ing non-CO_2 emissions to analyze the impact of increased biofuel production on the global economy and emissions. This enables a more comprehensive and holistic analysis of the economic and environmental impacts of substitution of gasoline with biofuels in various countries. We find that global GHG emissions decrease with increased biofuels production. However, emissions reduction is higher in developed counties than in developing countries. We also find that increased biofuel production increases the world Gross Domestic Product (GDP).

Keywords: CGE Model, Biofuels, Non-CO_2 emissions

1. INTRODUCTION
With the increasing negative impacts of climate change and expected scarcity of fossil fuels, the demand for renewable energy has been growing more intensively during the last decade. Among renewable energy sources, biofuels became particularly popular because of their low GHG emissions, especially in the transport sector [1, 2]. Biofuels could play a significant role in mitigating climate change and global energy security. Biofuels have a large positive impact on GDP growth, household income and welfare gain. Even though there are concerns about biofuel uses regarding sustainability issues, such as environmental outcomes, distribution of income, allocation of resources etc. [3].
Most studies show the positive impact of biofuels on the reduction of CO_2 emissions. However, the changes in non-CO_2 have been mostly overlooked. In many countries, non-CO_2 emissions account for the larger share of total GHG emissions representing 40-92% of total GHG emissions [4, 5]. In 2015, non-CO_2 emissions accounted for 25% of total GHG emission worldwide and more than 19% in the U.S. With growing agricultural production, non-CO_2 emissions are expected to grow further. The EPA projected that non-CO_2 emissions will increase by 17% within the 2015-2030 period. Agriculture, energy, and industrial processes waste are the main sectors responsible for non-CO_2 emissions. Among them the agriculture sector generates nearly half (48%) and the energy sector generates nearly one-third (29%) of all non-CO_2 emissions. Major non-CO_2 GHG gases are Methane (CH_4), Nitrous Oxide (N_2O) and F-GHGs [6, 7]. It is obvious that models, which exclude non-CO_2 emissions, are most likely to under-perform. In other words, models that do not account for both CO_2 and non-CO_2 emission may produce misleading results. In this paper, we link the GTAP-BIO and GTAP-AEZ-GHG models with the updated database that includes nonCO_2 emissions to analyze the impact of increased biofuel production on GHG emissions and the global economy. We use a computable general equilibrium (CGE) approach to assess direct and indirect impacts of biofuel policies on specific regions [8, 9]. There are many studies that use CGE models to assess the CO_2 impacts of biofuel production, but they do not provide any implications about changes in non-CO_2 emissions.
Previous studies show that replacing fossil fuels with biofuels reduces GHG emissions, which is confirmed in our study too. However, also considering the non-CO_2 emissions during the production of biofuels [10], results in larger total GHG emissions from biofuels than previously reported. We use our novel approach

to evaluate the impact of increased non-CO_2 emissions on the economy (i.e., GDP, sectoral impacts, regional impacts, etc.).

2. MATERIALS AND METHODS

In this paper we combine the GTAP-BIO and GTAP-AEZ-GHG CGE models with updated non-CO_2 emissions database to assess the total GHG emissions impact of increased biofuels production globally. The GTAP database includes bilateral trade linkage between regions and sectors. In this research, we aggregate the database to 19 regions and 29 sectors to facilitate our analysis and results. This study simulates different future biofuel production scenarios to show the total economic impacts of increased biofuel production as well as changes in total non-CO_2 and CO_2 GHG emissions.

3. RESULTS AND DISCUSSION

The overall level of CO_2 emissions declines due to significant reduction of CO_2 emissions in the transport sectors and from household energy consumption. Nitrous oxide emissions increase in the sugar crop sector but fall in the non-ruminant sector. We also observe a slight increase of methane emissions in the sugar crop sector. Methane emissions decrease in the paddy rice, dairy farms, ruminants and non-ruminants, coal, non-trade-able services sectors resulting in total reduction of methane emissions. Our findings show that land and labor are shifted towards the production of sugar crops, affecting the production levels of other agricultural commodities. In all scenarios, the world GDP increases as we increase production of biofuels.

4. CONCLUSION

We combine changes in non-CO_2 and CO_2 emissions driven by increased biofuels production to provide a more comprehensive analysis of aggregate GHG emission changes in the world. As we increase biofuel production in the U.S., CO_2 emission decreases and non-CO_2 emission increases in the country. The existing literature concentrates mostly on CO_2 emissions. We also find that global CO_2 and non-CO_2 emissions decrease with increased production of biofuels. This can be very helpful for policy makers interested in the reduction of all GHG emissions. Increased biofuel production generates lower emissions in the U.S. compared to Brazil. The transfer of technology can be one way to help reduce biofuel-related emissions in Brazil. We find a positive correlation between the GDP and biofuel production.

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E023 **15:30-15:45**

Experimental tests of an OBD based diesel particulate filter malfunction avoidance system

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ABSTRACT
This follow-up study builds upon a prior publication investigating automotive exhaust aftertreatment systems, focusing on advancements made in response to avoiding early Diesel Particulate Filter (DPF) failure. This article is named “A driver-assist system for efficient DPF regeneration”. Through hardware updates and firmware modifications, the framework presented in the previous study has been refined to adapt to evolving vehicle data acquired from On-Board Diagnostics (OBD). In cases where specific DPF information remains inaccessible due to manufacturer constraints, the system integrates a further improved Fuzzy Logic algorithm to process alternative data sources. The updated system offers enhanced communication capabilities, delivering real-time insights into ongoing regenerations, DPF health status, and predictive analysis of regeneration cycles, informing the driver through an integrated Thin-Film-Transistor (TFT) display. Additional road tests were per-formed to validate the system performance, demonstrate significant improvements in preventing DPF obstructions and optimizing overall system efficiency. This follow-up research presents advancements in detecting ongoing regenerations more accurately, showcasing the successful integration of hardware and software updates to achieve the primary objective of prolonging DPF lifespan. The experimental tests conducted in real environment and presented enabled the validation of the system in terms of its operability and applicability.

Keywords: Controller Area Network, Diesel Particulate Filter, Engine Control Unit, Fuzzy Logic, Regeneration and On-Board Diagnostics.

1. INTRODUCTION
The disruption of DPF regeneration cycles in diesel lightweight vehicles poses substantial environmental concerns. Repeated interruptions to an ongoing regeneration cycle will gradually result in the buildup of unburnt particulate matter within the DPF, engendering more frequent regenerations. Consequently, an increase in pollutants, including CO, NOx, and PM, ensues, contributing to atmospheric pollution [1]. Counteracting these unnecessary regenerations, simply allowing a regeneration to complete, can potentially extend DPF longevity by significant distances. Such measures are especially pertinent for diesel vehicles engaged in short distance travel.
From the tool presented in the previous study [2], this development brings a more adaptable firmware as well as some Graphical User Interface improvements. From the standpoint of information availability, the tool can detect earlier and faster which kind of information the vehicle can provide in a much more reliable way. It is also not bound to the availability of information from the Exhaust Gas Recirculation (EGR) valve, as it is capable of detecting regenerations from alternative sources without redundancy from the Fuzzy Logic algorithm.

2. MATERIALS AND METHODS
As illustrated in Fig. 1, the developed system comprises a microcontroller designed for the acquisition and processing of vehicular data. It incorporates the ELM327 which is an OBD/ Controller Area Network (CAN) to Bluetooth interface, facilitating the transmission of vehicle data wirelessly to the ESP32 micro-controller. A Real Time Clock is employed to synchronize the acquired data with the current timestamp, and a micro-Secure Digital card is utilized both to log the acquired data and to store a configuration file. Additionally, a 2,4inch TFT display is integrated to convey information to the driver.

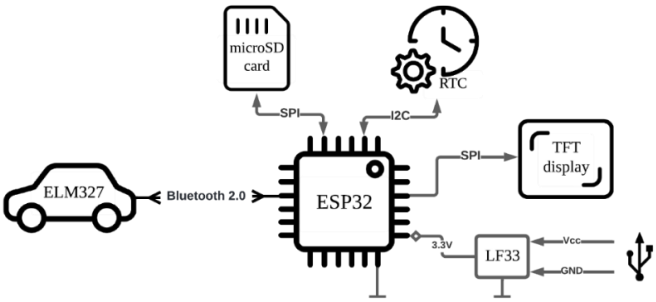

Fig. 1. Diagram of the system and communication protocols used among peripherals

3. RESULTS AND DISCUSSION

The road test presented in Fig. 2 illustrates one of the successful development of this tool that is self-validated, in which the Delta-P sensor was used to trigger the on-screen regeneration information and upon reviewing the data from the Fuzzy Logic system, this was in accordance with the behaviour of the sensor.

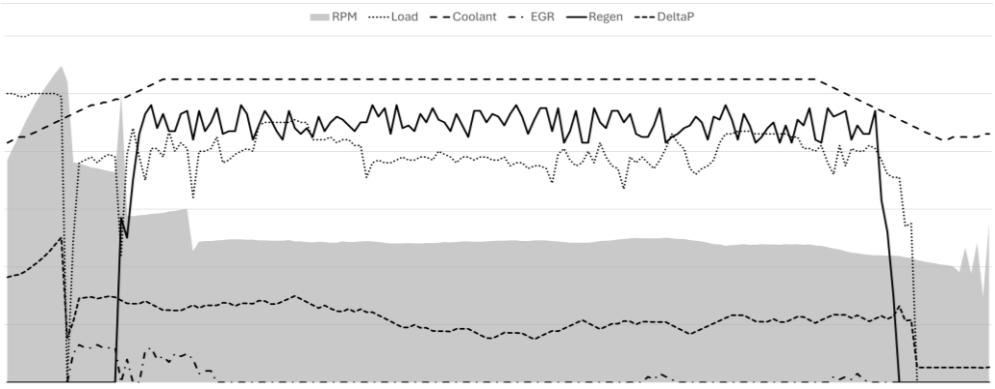

Fig. 2. Enlarged view of the regeneration on the Peugeot 3008.

As evident, apart from the slight fluctuation in the Delta-P parameter during regeneration, it is notable the difference between before the start of regeneration and after the end where the pressure reduced a further after the regeneration ended. This abrupt decline after the regeneration ended can be attributed to the rapid cooling of the DPF as well as less exhaust gas flow speed caused by the alteration of injection strategy [3].

4. CONCLUSION

The developed system enhances understanding of Engine After Treatment System (EATS) and the DPF system, addressing OBD data collection challenges during DPF regeneration. It uses DPF pressure drop, lambda value decrease, and lower EGR usage to detect regenerations accurately. Road tests validated the algorithm. The firmware can query and process any Parameter Identification (PID), enabling real-time EATS diagnosis for various vehicles. With optimization potential and Wi-Fi capabilities, it could support complex projects like live data processing. The tool extends DPF lifespan, saving costs and reducing environmental impact by minimizing DPF waste and the need for new DPFs.

ACKNOWLEDGEMENTS/FUNDING

This work was financially supported by Project SMARTool: Sistema Modular Multi-Protocolar para a Manutenção Preventiva e Preditiva de Máquinas, Equipamentos e Ferramentas Industriais e Outras, (SI I&DT – Empresas em Copromoção, CENTRO-01-0247-FEDER-047116) in the scope of Portugal 2020, co-funded by FEDER (Fundo Europeu de Desenvolvimento Regional) under the framework of PO CENTRO (Programa Operacional da Região Centro).

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Special Session 2B: Life Cycle Assessment

E009 **16:15-16:30**

Life cycle assessment of the production phase of Li-ion batteries for micromobility: a comparison between the use of primary and secondary data

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ABSTRACT
Micromobility stands as a revolutionary paradigm in mobility, revolutionizing both the transportation of goods and personal mobility. Numerous studies are available in the literature that evaluate the impacts along the entire life cycle of these vehicles, frequently relying on secondary data sources. It becomes evident from these studies that the batteries integrated into these vehicles wield substantial influence, underscoring the imperative need for a meticulous analysis to ascertain their true impacts. This study fills this gap by presenting a comprehensive Life Cycle Assessment (LCA) of micromobility vehicle batteries, encompassing both cargo-bikes and electric Bikes (eBikes), utilizing primary data sources. The construction of the Bill of Materials (BoM) for these batteries involved a process of disassembling the devices, weighing, and cataloging all constituent components. The findings of this study unveil the superiority of primary data over secondary data typically found in LCA databases. Using primary data, the climate change impact category increases by 7.6% for Greencell batteries (cargo-bike) and by 14.9% for Bosch batteries (eBike) compared to using sec-ondary data. By employing primary data, this study evades the pitfall of either overestimating or underestimating potential impacts, thus providing a more accurate assessment of the environmental footprint of micromobility batteries.

Keywords: LCA, Li-ion batteries, micromobility.

1. INTRODUCTION
In recent years, micromobility, characterized by the use of light electric vehicles like cargo-bikes and eBikes for goods transportation and personal mobility, has surged in popularity, especially in urban areas. This shift represents a move towards potentially more sustainable transportation compared to traditional internal combustion engine vehicles. Studies indicate that these electric vehicles generally have a lower environmental impact, although the significant effects of battery production and disposal cannot be ignored [1-3]. Most assessments rely on secondary data from existing databases, which may not accurately reflect the true impacts of these batteries. Primary data, obtained from disassembling and cataloging components, provides more precise insights but is harder to obtain. A Life Cycle Assessment (LCA) of batteries for micromobility vehicles revealed that primary data gives a more accurate environmental impact profile than secondary data, underscoring the need for comprehensive and precise modeling to truly gauge their sustainability benefits.

2. MATERIALS AND METHODS
This study aims to assess the environmental impacts during the production phase of batteries used in micromobility vehicles like cargo-bikes and eBikes, using three different data scenarios: Battery BIB, Battery BIB24, and the EcoInvent Battery. The functional unit for comparison is the mass of each battery, with the cargo-bike battery weighing 3.260 kg and the eBike battery 2.985 kg. Primary data for the first two scenarios were gathered by disassembling the batteries to create Bills of Materials, with Battery BIB relying partially on literature data for certain components, while Battery BIB24 uses updated EcoInvent 3.9.1 data. The system boundaries cover raw material extraction, processing, and battery production. No allocation systems were needed for primary data, but the 'cut-off' system was applied to background data from EcoInvent. Environmental impacts were assessed across eight impact categories using the Environmental Footprint Impact Assessment Method. In the EcoInvent Battery scenario, batteries were modeled using the EcoInvent 3.9.1 dataset, adjusted for the mass and capacity of the batteries analyzed. Both the Greencell (cargo-bike) and Bosch (eBike) batteries were disassembled to detail their components, ensuring safe handling by discharging and opening cells in an Argon atmosphere to avoid hazardous material release.

3. RESULTS AND DISCUSSION

In evaluating the environmental impacts of the Greencell and Bosch batteries under three scenarios, distinct differences emerged across eight impact categories. For the Greencell battery, the BIB24 scenario had the highest climate change impact (69.0 kg CO_2 eq), 7.6% higher than the EcoInvent scenario. It also showed the highest impacts for human toxicity categories, while the BIB scenario had the greatest impacts for photochemical ozone formation, acidification, and fossil resource use. Conversely, the EcoInvent scenario exhibited the highest impacts in particulate matter and mineral and metal resource use, though it overestimated these impacts by up to 24.4% compared to primary data scenarios. Similarly, for the Bosch battery, the BIB24 scenario showed the highest climate change impact (67.0 kg CO_2 eq), 14.9% higher than the EcoInvent scenario. It also led in human toxicity and mineral resource use impacts, while the BIB scenario had the highest impacts for ozone formation, acidification, and fossil resource use. The EcoInvent scenario was only highest in particulate matter impacts. Notably, the Bosch BIB scenario underestimated mineral resource use by 14.4% compared to the BIB24 scenario. Overall, no single scenario was consistently superior across all categories, underscoring the variability in environmental impacts depending on the data source and impact category considered.

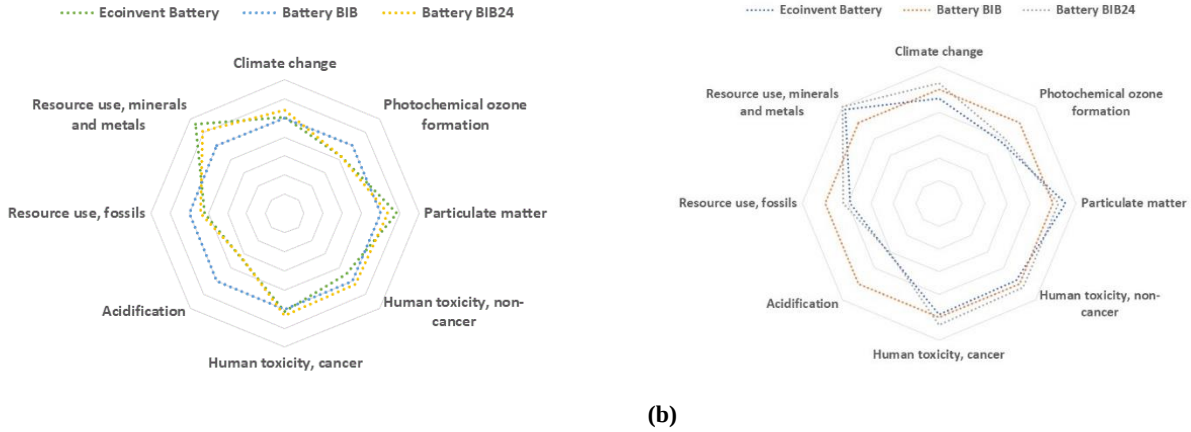

Fig. 1. Graphical representation of the results obtained for the modeling of: (a) Greencell battery installed on the cargo-bike and (b) Bosch battery installed on the eBike.

4. CONCLUSION

This study evaluated the environmental impacts associated with the production of batteries for micromobility vehicles (cargo-bikes and eBikes) under three scenarios: Greencell/Bosch Battery BIB and BIB24 (using primary data from battery disassembly) and the EcoInvent Battery scenario (using secondary data). Across eight impact categories, no scenario consistently outperformed the others. However, primary data, offering a more precise representation of battery production, showed varied impacts: a 7.6% increase in climate change impacts for Greencell batteries and a 14.9% increase for Bosch compared to secondary data, but an 8.0% decrease in mineral and metal resource use for Greencell and a 2.6% increase for Bosch. These findings highlight the importance of primary data for accurately assessing impacts, especially crucial when batteries are replaced multiple times during a vehicle's lifespan.

ACKNOWLEDGEMENTS/FUNDING

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E036 **16:30-16:45**

Life cycle assessment of electricity production system for the scenarios considered in Portuguese Roadmap for Carbon Neutrality 2050

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ABSTRACT
Energy is a crucial issue to every sector. Economic growth and well-being of people are two important factors related to energy. But electricity production has environmental impacts which affects sustainability. The most known impact is climate change caused by the emissions of greenhouse gases but there other impacts and this work addresses them by using life cycle assessment and CML method. The main conclusion is that there other significant impacts such as ecotoxicity, human toxicity and material resources: metals/minerals. The evolution for Portugal, considerating a time span from 2020 to 2050, is clearly positive for some indicators auch as climate change but others present a negative trend (increase).

Keywords: Energy, LCA, Sustainability, Sustainable Development goals.

1. INTRODUCTION
Electricity production systems have been at the top of the priority list of countries in the world and especially in the European Union. Many factors affect this challenge from variability of prices, scarcity of resources and environmental problems such as climate change. Economic [1,2], environmental [3,4] and social perspectives [5] have been addressed in this field. Many measures have been implemented, some related to energy efficiency, others related to energy consumption reduction and with the shift to renewable energy sources (RES). Electricity production has environmental impacts and fossil fuels are a source of concern due the economic and environmental risks. There has been an effort to use the most suitable RES for each country, reducing fossil fuel consumption and energy dependency. However, climate change is not the only negative impact of electricity production, there are others such as Ecotoxicity to freshwater or to marine systems, etc. In this work all Portuguese electricity production is considered and all these environmental problems were addressed using life cycle assessment at different scenarios (2020, 2030,2040 and 2050) [6].

2. MATERIALS AND METHODS
Life cycle assessment was used to determine the environmental impacts associated to the electricity production for each year. Secondary data was retrieved from the Ecoin-vent database v3.10. The method used was CML v4.8 2016, that considers the following impact categories: acidification, climate change, ecotoxicity: freshwater, ecotoxicity: marine, ecotoxicity: terrestrial, energy resources: non-renewable, eutrophication, human toxicity, material resources: metals/minerals, ozone depletion and photochemical oxidant for-mation.

3. RESULTS AND DISCUSSION
In some categories of impact there is a trend to the reduction of impacts, namely climate change, ozone depletion and energy resources. Technologies such as wind and photovoltaics can required higher amounts of materials and increase the values of the categories of impact which they are related to. The carbon intensity of electricity will decrease along the years which is positive.

4. CONCLUSION
Electricity production causes environmental impacts. Concerns about climate change have been growing and that led to the use of renewable energy sources to replace fossil fuels. This work analyzed the environmental impacts of the adopted options for Portugal, by using life cycle assessment methodology

and several impact categories. The impact categories that have a clear reduction are climate change and energy resources, due to the reduction of the use of fossil fuels. The carbon intensity of electricity will decrease along the years which is positive, however, the electricity consumption will not decrese according to estimates. That can only be achieved by the reduction of energy intensity of products and processes, and through important changes in the energy consumption habits.

FUNDING

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E035 **11:30-11:45**

LIFE CYCLE ASSESSMENT OF CONSTRUCTION MATERIALS: A CONTRIBUTION TO BUILDING CERTIFICATION

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ABSTRACT
Growing concerns about environmental issues worldwide have led to the development of methodologies for assessing the environmental impacts of products and systems. As the construction sector is responsible for a large part of such impacts, there is a clear need to apply measures that aim to mitigate or, at least, to reduce to acceptable values such aggressions to the environment. This led to the application of the LCA methodology in the construction sector. This work focuses mainly on the environmental aspects of the LCA, that is, on the embodied energy (EE), embodied carbon (EC) and global warming potential (GWP), to compare different types of buildings.

Keywords: Embodied carbon; embodied energy; global warming potential; LCA; sustainable construction

1. INTRODUCTION
The construction industry is one of the largest and most active sectors in the world. It consumes more raw materials than any other economic activity, as well as energy, and produces construction and demolition waste, which accounts for the vast majority of waste produced throughout Europe, much of which has the advantage of being recycled. Thus, the building sector plays a fundamental role in achieving the global goals of sustainable development.
The challenges for the construction sector are diverse, however, the most important consist of reducing and optimizing the consumption of materials and energy, reducing the waste generated, preserving the natural environment and improving the quality of the built environment. In addition, the construction and management of the built environment must be seen within the perspective of the life cycle, making it important to assess the environmental impacts throughout the whole life cycle of the building.

2. MATERIALS AND METHODS
A spreadsheet tool, *LCA4Building*, was developed using MS Excel. It was adopted 1 m^2 of built area as the functional unit. Depending on the type of construction, the built area corresponds to different quantities of materials; however, the literature is consensual on the adoption of this functional unit.
The tool allows one to calculate the values of the impact categories of a certain project, once the building materials are introduced in the *LCA4Building* tool. The tool only considered the construction phase, leaving the operation/use and deconstruction/demolition phases of the building outside the scope of this study. Therefore, the tool considers the extraction of raw materials, the transportation of raw materials and the production of materials.
The tool includes a list of materials to be used for specific structural/functional purposes, and that must be updated and complemented as new materials are made available in the market. These materials can even have similar composition but be provided by different producers, therefore having different environment product declarations.
Thus, knowing the list of materials it is possible to calculate the values of the chosen indicators, to compare the performance of a project for the various building typologies or using the conventional or alternative materials. embodied energy (EE) and embodied carbon (EC), as well as global warming potential (GWP) values, were extracted from the *ICE – Inventory of Carbon and Energy* database from the University of Bath [1].

The case study consists of the remodelling project of a house with a total area of about 583.00 m^2, located in a property measuring 800.00 m^2 and consisting of 4 floors, i.e. a built area of 1,749.00 m^2.

3. RESULTS AND DISCUSSION

Using the bill of quantities of the project, it was prepared the list of materials from the architectural and structural stability specialties, which represent more than 80% of the project material. The *LCA4Building* was used to calculate the values of the EE and EC, and the GWP per functional unit. The results are shown in Table 1.

Table 1 – The embodied energy, embodied carbon and global warming potential of a remodelling project of a house with a total area of about 583.00 m^2.

	Embodied energy	Embodied Carbon	GWP
Total	4,492,150.95 MJ	305,156.69 $kgCO_2$	326,742.24 $kgCO_2eq$
Total per m^2 of Built Area	2,568.41 MJ/m^2	174.47 $kgCO_2eq/m^2$	186.82 $kgCO_2eq/m^2$

In what concerns the embodied energy, the specialty that contributes most in this case are materials associated with Architecture, but in what concerns the embodied carbon or global warming potential, Stability is the biggest contributor. The construction elements with the biggest influence on EE are the ground floors (15%), the superstructure (14%), waterproofing (14%), walls (14%) and floors (18%), which makes the materials that contribute most to embodied energy are concrete (12%), steel (27%), waterproofing materials (19%) and stone and ceramic finishes (19%). The same happens for EC and GWP; the construction elements with the biggest impact are the ground floors (20%), the superstructure (22%), walls (11%) and floors (14%) but the foundations (8%) are also relevant. Consequently, the materials with the greatest impact on EC and GWP are concrete (26%), steel (31%) and stone and ceramic finishes (19%). In other words, reinforced concrete elements are those that contribute most to both embodied energy and embodied carbon and global warming potential.

4. CONCLUSION

The *LCA4Building* tool allowed to analyze five buildings of different typologies. The Warehouse presented a very poor performance in relation to the GWP level of $kgCO_{2eq}/m^2$ and the Single Family Housing presented an excellent performance of $kgCO_2eq/m^2$. The tool also allowed to evaluate the effect of replacing some materials with others with similar structural/functional performance on the impact categories analyzed. Such tool allows engineers and project developers to project buildings with a better environmental performance, thus contributing to more sustainable buildings.

It was concluded that the construction elements that have the highest contribution to EE and GWP are reinforced concrete elements, insulation and waterproofing elements. Reinforced concrete elements have an high EE and GWP value due to having cement and steel in their composition, as they use a lot of energy in their production (they have a high energy intensity). Similar conclusion was taken for insulating and waterproofing materials, due to using fossil derived feedstock. The tendency is for an increase in the importance of the value of EE and EC, since the values for operational energy and carbon are decreasing with the increase in the energy efficiency of the various equipment. Therefore, it becomes extremely important to know and control the values of embodied energy and carbon. The LCA of a building was shown to be fundamental for its energy certification, as it allows one to know the exact amount of energy that was consumed and the amount of carbon that was emitted during its construction.

FUNDING

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Special Session 3B: Renewable Energy

E034 **17:00-17:15**

Solar Thermal Hybrid Façade - Water-only Mode Performance Assessment

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ABSTRACT
Climate change and sustainable development are some of the main 21st century challenges, most probably one of the greatest challenges ever faced. Technology has reached such a level that it is quite affordable for anyone in developed countries to produce the energy they use. Production and use of renewable energies applied in a producer-consumer paradigm can become a synonym for sustainability (supply-to-demand matching), energy efficiency (closer production and consumption means less energy transport losses) and security of supply (the produced energy is endogenous). Complementary, the cost of renewable energy is becoming increasingly lower since the technology is well known, and devices are more affordable and energetically more efficient. This work intends to demonstrate the potential of renewable energies namely the role of a hybrid solar thermal façade capable of heating air and water, cooling and ventilation. This device achieved an amount of 386.7 kWh energy produced during only a single day which demonstrates the enormous potential of these devices. Furthermore, this technology (solar thermal) has already demonstrated its high reliability over long years of worldwide operation. Further to its residential utilization the façade can be used in alternative contexts such as industrial processes with low enthalpy requirements, commercial buildings, hospitals, and hotels.

Keywords: Building Energy Efficiency, Renewable Energy, Solar Thermal, Sustainability.

1. INTRODUCTION
Within the EU buildings account for 43% of the final energy consumption. The average energy consumption was of about 1.3 toe/dwelling in 2018. Household energy consumption is mainly for water and space heating, about 82% by the year 2000. This value though presents a small decrease to 78.4% by 2022 [1] is still the main share of final energy consumed by households. In fact, household energy efficiency has improved by 29% at EU level between 2000 and 2019 (or 1.8%/year) as shown by the energy efficiency index [2]. The buildings energy consumption scenario is therefore predominantly of a thermal nature.
On the 30th of March 2023, the EU council and EU parliament approved a directive that aims to raise the EU's renewable energy usage target for 2030 to a minimum of 42.5%, up from the current 32% target and almost doubling the existing share of renewable energy in the EU. It was also agreed that the EU would aim to reach 45% of renewables by 2030. The agreement also includes targets and measures to support the uptake of renewables across various sectors of the economy. The revised Directive strengthens annual renewables targets for the heating and cooling sector, and it introduces a specific renewable energy benchmark of 49% for energy consumption in buildings by 2030 to complement EU buildings legislation [3].
Renewable energy capture through a hybrid solar façade will certainly contribute to the EU directive's goal achievement. It is known that the closer the consumption is to production, lower are the losses in the distribution circuit and higher efficiency will be attained. The technology described in this text is a tentative answer to the European Union and Portuguese legislation demands since it promotes energy efficiency and renewable energy implementation in buildings. Furthermore, this technology will also certainly contribute to improve energy classification of buildings.

2. MATERIALS AND METHODS
To acquire and manage data a Yokogawa GP20 with a GX90XA module and two data acquisition boards (GX90XA-04-H0 and GX90XA-10-U2) was employed. In addition, 3 Pt100 temperature probes were deployed along the façade height, namely at the top, middle and bottom of the façade to measure the

water temperature. A delta ohm pyranometer (pyra03) was also used to measure the solar radiation incident to the plane of the façade. Finally, a MIM-12 20H G6 C3T 0 Kobold flowmeter was installed at the façade inlet to measure the water flow.
The main objective of this work is to gather a significant amount of data regarding the device performance which will then be analyzed to assess the device efficiency and power/energy production capacity. After that, neural networks will be produced giving the ability to simulate the system behavior at any worldwide location. This on-site simulation provides important information regarding the payback time of the system, the (estimated) amount of energy produced (monthly, yearly), the quantity of CO_2 emissions that were not emitted (if using this device) and the expected energy costs savings.
This analysis will also lead to a better knowledge of the system and eventually it may result in a series of improvements to the product.

3. RESULTS AND DISCUSSION

The data analysis allows us to understand the high performance and capability of this device to convert solar energy into thermal energy, even on cloudy days. Furthermore, despite the days being colder and shorter in winter it was possible to produce 386.7 kWh of energy in a single day of January. Due to the inclination angle of the façade towards the energy resource (sun) the amount of converted energy is higher than the 365.0 kWh recorded in August under the same circumstances (clear sky day). The energy produced by this device has a very low carbon footprint that can easily reach the zero emissions level if the electricity used to operate the additional equipment comes from renewable energies.
Hence, we are facing a device that operates using technology that is not very complex and is widely known and tested, showing excellent results and enormous potential to reduce the ecological footprint and improve the energy classification of buildings where they need it: space heating and water heating.

4. CONCLUSION

At a time that it is recognized that thermal discomfort is a rule in Portuguese houses [4], it is important to broaden the study of alternatives to this problem. Moreover, the EU Council and Parliament goal of strengthening the renewable energies presence within the buildings sector by introducing a specific renewable energy benchmark of 49% for energy consumption by 2030 to complement EU buildings legislation [3].
Thus, it is clear the importance of devices like this one with well-known technology and high performance, built with materials that are rather easy to recycle and rather innocuous to the environment (unlike, for example, photovoltaic panels).
Besides, though renewable energies are always associated with storage problems, this does not happen with thermal energy as hot water can be easily stored and rather inexpensively for later use.
Installations such as the one herewith documented demonstrate to be a promising alternative to traditional systems for heating and cooling purposes, having as advantage an almost null carbon emissions alongside with the produced energy. The global energy produced for a single day (386.7 kWh) demonstrates the enormous potential of these devices. Furthermore, this technology (solar thermal) has already demonstrated its high reliability over long years of worldwide operation.
Until now, there were no studies about façades with such dimensions and their per-formances. In fact, more studies are needed to assess the performance and efficiency of the other three operating modes: air heating, hybrid mode and ventilation.

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E030 **17:15-17:30**

Clean electricity from direct carbon fuel cell with improved cathode materials

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ABSTRACT
Direct carbon fuel cells (DCFC) generate electricity through the conversion of chemical energy of carbonaceous fuels. Efficient performance of the cell highly depends on properties of materials used in the cell assembly. Some of the important properties of the materials used for the electrodes are their electrical conductivity, catalytic properties for the corresponding reactions that take place on these electrodes, and their mechanical stabilities for a long-term cell operation. In this paper, modified electrodes with enhanced electrochemical properties were tested within a fuel cell with acid treated carbon black as the fuel and a quaternary electrolyte made of 40.3 % Li_2CO_3 / 29.0 % Na_2CO_3 / 23.6 % K_2CO_3 / 7.1 % Cs_2CO_3. The results are compared in terms of open circuit voltage, power, and current. The experimental studies showed that the use of oxidized nickel foam and its chrome and iron alloys have a major effect on overall cell performance.

Keywords: Clean Energy, Electrochemical Conversion, Fuel Cell, Renewable Fuel.

1. INTRODUCTION
Direct carbon fuel cells (DCFCs) convert a fuel's chemical energy into electricity. In DCFCs, the fuel is carbon which is directly converted into electricity without any intermediate reactions. High conversion efficiency is a major advantage of DCFCs compared to conventional fuel cells and heat engines [1,2]. Another significant advantage of the DCFC is the use of a wide range of solid carbon from different sources. Depending on the purity of the carbon source, the only product from this conversion can be clean CO_2 ready for sequestration [3]. Despite many advantages over the other fuel cell technologies, the DCFC technology has not yet been commercialized. Significant challenges are related to the selection of materials that can sustain their integrities in highly corrosive molten carbonate electrolytes at high operating temperatures. A eutectic mixture of metal carbonates Na_2CO_3, K_2CO_3, Li_2CO_3, and some additives often serves as the electrolyte in DCFCs. For this reason, they are often referred to as a molten carbonate DCFC (MC-DCFC).
From the published MC-DCFC performance results, it is clear that the electrode material's mechanical stability in the molten carbonates as well as its influence on the electrode reactions needs improvement [4-6].
In the present work we examined Ni/Cr/Fe as a cathode material for the MC-DCFC and investigated the catalytic activity of NiO on the cathode reactions. The experimental results show that the Ni/Cr/Fe can maintain its mechanical integrity in the high temperature corrosive environment and increase the performance of the cell.

2. MATERIALS AND METHODS
The high purity carbonates from Sigma Aldrich (Canada) were used for preparing the electrolyte. Zirconia felt was purchased from Zircar Zirconia Inc. (USA) and used as a matrix between the electrodes. Anode and Cathode 1 were prepared from Ni foam, Cathode 2 was NiO foam, and Cathode 3 was oxidized Ni/Cr/Fe foam. Carbon black supplied by Cancarb (Canada) was acid treated [7] and used as a fuel.
The samples were analyzed on a Hitachi scanning electron microscopy (SEM)/energy-dispersive X-ray (EDX). Impedance analyses were performed with a Solartron Analytical Cell Test System (1470E) coupled with the Solartron Analytical 1400 Frequency Response Analyzer. Thermogravimetric data was obtained with a Netzsch Jupiter simultaneous thermal analyzer (STA 449 F1).
To investigate kinetics of the electrode reactions and overall cell performance, single planar batch cells were assembled. Each cell was installed into the oven and connected to the cathode and anode gas supply lines. The oven was heated to 550°C and held for 1 h allowing the electrolyte to completely melt, impregnate, and saturate the zirconia separator. Following this, the temperature was increased to 650 °C to let preloaded carbon oxidized and to build the steady open circuit voltage (OCV).

3. RESULTS AND DISCUSSION

The time required for each cell to reach the target voltage of ~1 V upon introducing the CO_2/O_2 mixture to the cathode is used as the first measure of the overall kinetics. At about 5 h, Cell 1 (with Ni- cathode) was slowest to reach the target of ~1 V, followed by Cell 3 (Ni/Cr/Fe cathode) which took about 3.5 h, and the fastest cell was Cell 2 (NiO cathode) at about 1 h. These data show that the cathode materials play an important role on the kinetics of the cathode reactions and cell's overall performances. Cell 3 had highest performance with 368 mW at 866 mA, followed by the Cell 2 with 343 mW and 682 mA, and the Cell 1 with 172 mW at 362 mA. The corresponding impedance data also confirms the lowest ohmic resistances of Cell 3 followed by Cell 2 and Cell 1.

To investigate their oxidation behaviour, Ni and Ni-Cr-Fe foams were exposed to air in the STA at either 700 °C or 830 °C. After 14 h of exposure the Ni foam weight increased by 10.06 % for 700 °C exposure, and 21.58 % at 830 °C exposure. In contrast, the Ni/Cr/Fe foam weight increased by only 2.62 % for 700 °C and 6.46 % for 830 °C exposure, which suggests that oxidation of nickel dominates in this temperature range. These results explain the differences in the kinetics of the cathode reactions. However, the power production performance of Cell 3 was highest. Analysis by SEM/EDX provided some insight into the surface properties. The NiO foam struts were seen to have distinctive breaks and the material was quite brittle. In addition, electrical conductivity would be suppressed as oxidized layers delaminated and as struts in the foam structure severed. The Ni/Cr/Fe foam appeared intact, and the surface was largely dominated by a coarse chromium oxide. Cathode 3 had much less nickel oxides at the surface and its catalytic properties would be controlled by the chromium and iron oxides. The struts remained intact, which was confirmed by general observations of the material's maintained mechanical strength following both TGA and fuel cell testing.

4. CONCLUSION

Cathode materials, including foams of Ni, NiO, and a new Ni/Cr/Fe alloy, were investigated for performance within an MC-DCFC. The experiments showed that the kinetics of the cathode reactions highly depend on the cathode's NiO content which is affected by the oxidation conditions. At higher temperatures the oxidation of the nickel foam is more rapid than at lower temperatures, but the surface integrity of the foam is negatively affected by the high temperature which ultimately lowers the cell performance when assembled with this cathode. The new Ni/Cr/Fe material shows high mechanical stability and good electrical conductivity, and consequently the cell assembled with this cathode (in Cell 3) showed greater power generation than the NiO case (Cell 2) by 7 % and the non-oxidized Ni case (Cell 1) by 53 %. Future work will be focused on the long-term performance of these electrodes.

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E047 **11:30-11:45**

An Energy Storage System for the Alto Douro Wind Power Plant: A technical Study

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ABSTRACT

Renewable energies are key to meeting the world's demand for environmentally friendly energy at a time when fossil fuels are being reduced. In recent years, Portugal has invested in renewable energies as an alternative to energy imports and dependence on fossil fuels. Although the number of hours of sunshine per day is high, the production of wind and hydroelectric energy is unstable due essentially to climate variability, which translates into fluctuations in the energy supplied to the grid. Minimising this problem involves using energy storage systems that guarantee a stable supply of renewable energy at times of low production. This work analyses the feasibility of storing renewable energy in order to maximise the wind farm located in the north of Portugal, in the Alto Douro region. A demand analysis is presented, as well as performance simulations taking into account energy utilisation and profitability, considering the efficiency function and power, and the storage system and type of discharge are defined taking into account the defined assumptions.

Keywords: Battery, Curtailment, Price arbitrage, Renewable Energy, Wholesale electricity market

1. INTRODUCTION

The search for alternative energy sources is a pressing issue in world energy policies, leading to investment in renewable energies as an alternative to fossil fuels. Portuguese investment in renewable energies represents 56.3% per cent of total energy production in 2022, as stated in [1]. Renewable energy sources are key to decarbonisation, to minimising climate change, to the diversity of energy sources and to a more resilient grid [2],[3]. On the other hand, the variability of renewable energy production causes instability and intermittency in the supply to the electricity grid [4]. This variability makes it impossible to forecast supply to the grid, so measures must be taken to eliminate these fluctuations [2],[3]. The study presented in this research was developed for [5] to assess the energy storage capacity of a wind farm and its hybridisation to ensure the balance of energy supplied to the grid [4]. In this way, the energy produced is selected, taking into account the market offers and the different producers. To achieve this goal, the integration of an energy storage system is essential because it makes it possible to minimise energy variability and integrate these renewable energy sources, improving the overall efficiency of production systems [2]-[4] and maximising profits.

2. MATERIALS AND METHODS

Increasing the capacity of the wind turbines installed at the Alto Douro wind farm meant installing offline photovoltaic modules that complemented the wind farm's production, reducing the variability of production during periods of low winds. So, the surplus energy (curtailment) must be stored to avoid wasting energy. To this end, the economic viability of a battery energy storage system was analysed. The study was

supported by the analysis of various data that made it possible to quantify the energy used and simulate the energy stored, thus identifying the technical characteristics of the batteries. To this end, the total energy that would exceed the export limit was quantified on the basis of production figures and the growth of wind energy and hybridisation. Fig. 1 illustrates total annual production.

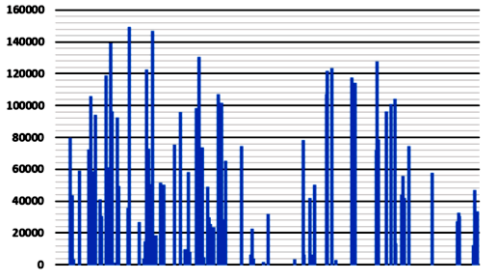

Fig. 1. Curtailment of the park's power station during the last year.

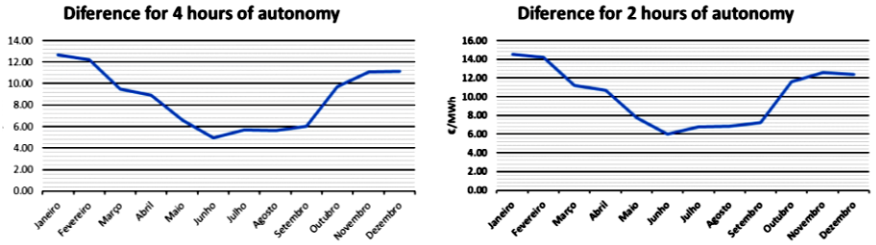

Fig. 2. Price arbitration battery for 4 and 2 hours.

3. RESULTS AND DISCUSSION

Price arbitrage consists of buying and selling electricity according to market fluctuations. However, it is the reduction of excess energy that we are working on, i.e., energy storage at zero cost. So, based on the cost of the batteries, the profits from price arbitrage for 2 and 4 hours and the energy reduction the following evaluation was carried out (Fig. 2) 0.

The comparison of the profits obtained with 4-hour and 2-hour batteries, for an overall efficiency of 90% and a maximum capacity of 10 MWh, resulted in 23422 € and 33913 € for the curtailment profit, and 24897 € and 34566 € for the price arbitrage profit, respectively. The profits from curtailment and price arbitrage will be 44994 € and 61731 € for 4 and 2 hours of storage.

4. CONCLUSION

Eight databases were used in this work, which led to some important conclusions: (i) the best technology for storing surplus energy is currently lithium-ion batteries; (ii) as the export limit is only exceeded a few times a year, the average reduction rate is 2% of the total energy produced;.(iii) among batteries with the same storage capacity, greater profits are obtained with batteries with higher power capacity and shorter operating times; and (iv) the efficiency of the battery selected is of the utmost importance. This is not only because the viability of price arbitrage is affected by this factor, but also because the profit made depends heavily on the efficiency of the battery.

FUNDING

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Posters

E002-A

Optimization of distribution coefficients in energy communities

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ABSTRACT
The expansion of collective self-consumption is a fundamental pillar for the development of energy communities. In Spain the regulation establishes a scheme for the allocation of self-consumed and surplus energy based on distribution coefficients. This implies that the members of the self-consumption community must decide the distribution coefficients assigned to each of the consumers for the management of the energy generated by the self-consumption system, as well as for the allocation of the surplus. In this work, the behavior of several algorithms based on heuristic techniques has been analyzed, with the aim of achieving an adequate economic optimization focused on obtaining the distribution coefficients that maximize the net present value of the collective installation. The modeling of the problem is carried out under totally realistic conditions considering hourly consumption data, electricity prices for domestic consumers, as well as irradiation and photovoltaic production. The results obtained show a clear improvement in the economic performance of the installation by optimizing the distribution coefficients compared to the standard approach corresponding to the default coefficients established in the regulatory framework.

Keywords: Collective self-consumption, distribution coefficients, energy community, energy transition, residential buildings

1. INTRODUCTION
Currently, there's a notable surge in collective self-consumption. Over the past decade, the affordability ratios of photovoltaic generation technologies have become increasingly competitive. This, coupled with recent favorable policies supporting self-consumption, has resulted in attractive profitability for household photovoltaic self-consumption. Nevertheless, the distribution of energy generated for collective self-consumption isn't always optimal in many cases, leading to a loss in economic efficiency of the setup.This study delves into the examination of energy distribution within the regulatory framework of collective self-consumption in Spain, as outlined in RD 244/2018 [1]. The primary objective is to scrutinize the behavior of collective self-consumption employing various techniques to achieve economic optimization, focusing on enhancing the performance of the shared installation. This optimization will be centered on the coefficients of self-consumed and individualized surplus energy. The research will explore several algorithms, ranging from analytical to heuristic techniques, alongside other valid methodologies. These methods will demonstrate the maximum monetary advantage attainable within the confines of the existing regulatory framework.

2. MATERIALS AND METHODS
The study focused on a collective self-consumption setup situated in a residential building within Seville (coordinates: 37º21'57 "N 5º58'59 "W). The building comprises 20 apartments, each with contracted power ranging from 7.0 kW to 2.6 kW and installed power between 9.2 kW and 5.75 kW. To simulate consumption patterns, the LoadProfileGenerator software [2] has been used to derive hourly consumption profiles for each apartment. Consequently, synthetic load profile data has been employed for each consumer.
The economic evaluation proposed focuses on considering the savings achieved in the electricity bill following the installation of the self-consumption system. To quantify these benefits, we suggest utilizing the net present value (NPV) as an economic indicator:

$$NPV(x,y) = -I_{inv} + \sum_{t=1}^{LS} \frac{CF(x,y)_t}{(1+k)^t} \quad (1)$$

The optimization problem proposed in this work can be formulated as the maximization of the NPV subject subject to the sum of the distribution coefficients for the allocation of self-consumed and surplus energy

adding up in both cases to unity. The optimization algorithms implemented and tested are the genetic algorithm and the paternsearch, which have been compared with the results corresponding to the default distribution criteria established in the Spanish regulation. The calculation of the electricity bill has been carried out in accordance with existing Spanish regulations, considering both the terms corresponding to the billing of energy (both imported and exported) and the contracting of power.

3. RESULTS AND DISCUSSION

The base case has considered a power of the collective PV plant of 25 kW. For this case, the NPV corresponding to the default approach was initially determined (i.e., the distribution coefficients obtained through the regulation) and then through the optimized approach by means of the two implemented algorithms: genetic algorithm and pattern search. The results obtained are shown in Table 1, it can be seen how the two optimization approaches improve appreciably the profitability obtained from the default approach, being the genetic algorithm the one that provides better results.

Table 1. Comparison of results obtained by the optimization approaches proposed and the default criterion established in Spanish regulation.

Approach	NPV (€)
Default	50340.9168
GA	52499.3485
PatternSearch	52438.8217

Fig. 1 shows the results obtained after performing a sensitivity analysis by varying the power of the PV installation from 10 to 50 kW. As can be seen, in all cases the optimized approach is an improvement over the default allocation criterion.

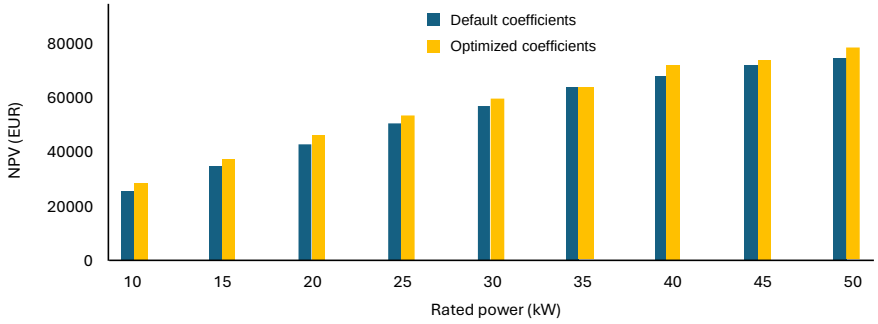

Fig. 1. Sensitivity analysis to PV system rated power

4. CONCLUSION

This work has presented and analyzed several approaches to optimize the allocation coefficients for the allocation of self-consumed energy and energy surpluses, according to the regulations currently in force in Spain. The main objective of the work has been to compare the performance of different optimization algorithms in order to obtain the distribution coefficients that optimize the economic performance of the project. The results obtained from the comparison between two optimization strategies show that the genetic algorithm optimization method allows obtaining the best solution, which improves the economic performance obtained by means of the default coefficients established in the regulation.

ACKNOWLEDGEMENTS/FUNDING

This work was funded by the Spanish Ministry of Science and Innovation under grant PID2021-127550OA-I00.

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E004-A

Development of Transition Metal Compound based Bifunctional Electrocatalysts for Scalable Alkaline Hydrogen Production

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ABSTRACT
The depletion of fossil fuels and their associated environmental impact necessitate a shift towards sustainable energy sources. Hydrogen, produced through clean processes, holds immense potential as a future fuel source. Electrochemical water splitting offers a promising approach for green hydrogen production, but current methods rely on expensive platinum-based catalysts. However, this work explores the development of affordable and efficient electrocatalysts through suitable intercalation of readily available transition metals into NbS2. The paper presents a simple and efficient synthesis method for these transition metals based electrocatalysts. These bifunctional catalysts can drive both hydrogen evolution and oxygen evolution reactions, crucial for complete water splitting in an alkaline medium. Remarkably, when tested in a two-electrode assembly, the electrocatalyst exhibited a low cell voltage of 2.40 V at a current density of ~1.9 A/cm^2. By combining the results of several experimental methods and theoretical calculations, we develop insights into the mechanisms of charge transport, catalytic activity and their interaction in this compound. This research contributes to the development of cost-effective alternatives for hydrogen production, paving the way for a more sustainable future.

Keywords: Electrocatalysis; Hydrogen production; Transition metals; Water splitting

1. INTRODUCTION
Hydrogen, being a promising candidate for alternative energy source, offers a clean, sustainable and cost-effective route to produce the fuel [1], particularly when accomplished through electrochemical H_2O splitting [2]. Although platinum, iridium based noble metals exhibit high catalytic performance, their cost and reserves are not practical for obtaining hydrogen on an industrial scale. Here, we designed a polymetallic sulfide framework with a hexagonal form, which has the general formula T_xMCh_2 (T, M representing transition metals, Ch implicating the chalcogen atom and x<1) [3]. The weak interlayer interaction between the van der Waals layers allows additional transition metal atoms (T) to be intercalated into the original lamellar structure. However, controlled inclusion further increases the tunability available for physical and chemical properties of the nanomaterial, and subsequently, expands the vast nature of potential functionalities. Our research employed a controlled intercalation strategy, introducing transition metals like V, Cr, Mn, Fe and Co into NbS_2, resulting in the formation of $T_{1/3}NbS_2$ structures.

2. MATERIALS AND METHODS
Polycrystalline $TM_{1/3}NbS_2$ samples were synthesized by combining stoichiometric quantities of Nb, Co, and S powders in a quartz ampoule, which was then heated at 900 °C for 5 days.
In order to assess the potential for hydrogen and oxygen evolution reactions, a comprehensive characterization of the samples was undertaken. X-ray diffraction (XRD), Raman spectroscopy, and scanning electron microscopy (SEM) analyses were employed to elucidate the crystal structure, phase purity, and morphology of the materials. Subsequently, the electrochemical performance of the samples for both the hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) was investigated. A three-electrode system was utilized at room temperature on a PGSTAT204 electrochemical workstation (Utrecht, The Netherlands) controlled by NOVA Version 2.1.5 software.

3. RESULTS AND DISCUSSION
SEM revealed the successful formation of well-defined, hexagonal-shaped $TM_{1/3}NbS_2$ samples. Fig. 1 further supports this by showcasing the energy-dispersive X-ray spectroscopy (EDS) data of the $Fe_{1/3}NbS_2$ sample, confirming the presence of the expected elemental composition with accurate atomic ratios. The

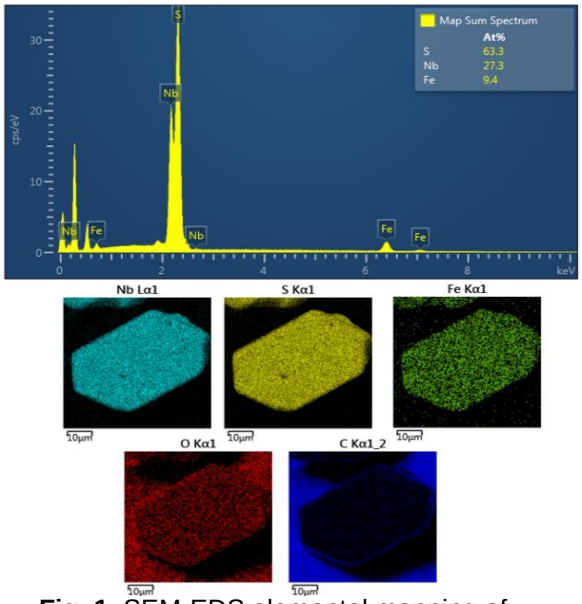

Fig. 1. SEM-EDS elemental mapping of $Fe_{1/3}NbS_2$

electrochemical effectiveness of $TM_{1/3}NbS_2$ systems in catalyzing the HER and OER was evaluated using linear sweep voltammetry (LSV), as shown in Fig. 2(a, b). The LSV plot indicates that the $Fe_{1/3}NbS_2$ sample demonstrated excellent bifunctional electrocatalytic activity, with low HER and OER overpotential of -102 mV and 260 mV at current density of 10 mA/cm^2 compared to other nanostructures.

To assess the compatibility of $Fe_{1/3}NbS_2$ electrodes with fluctuating renewable energy sources, a multi-step chronoamperometric test was implemented (Fig. 2c). This test evaluated the ability of the electrodes to maintain stable current delivery under dynamic power fluctuations. The results were promising, demonstrating a highly stable current density across the entire test range (0.5 to 2 A cm^{-2}). The current density remained highly stable, increasing to a maximum voltage of 2.4V, highlighting the remarkable stability of the $Fe_{1/3}NbS_2$ catalysts at higher current densities. It is expected that this novel material achieves its exceptional performance through a synergistic interplay between the intercalated transition metals and the host NbS_2 lattice. The localized 3d electrons residing on the transition metals interact with the delocalized conduction electrons within NbS_2, fostering the formation of virtual, broadened 3d states [4]. These intermediate energy levels function as efficient stepping stones for electrons, facilitating their transfer between the electrode and adsorbed reactant molecules during electrochemical reactions. This phenomenon optimizes binding energies and significantly reduces the activation energy required for the reaction. These results suggest the selective nature of $Fe_{1/3}NbS_2$ catalyst for alkaline water splititing.

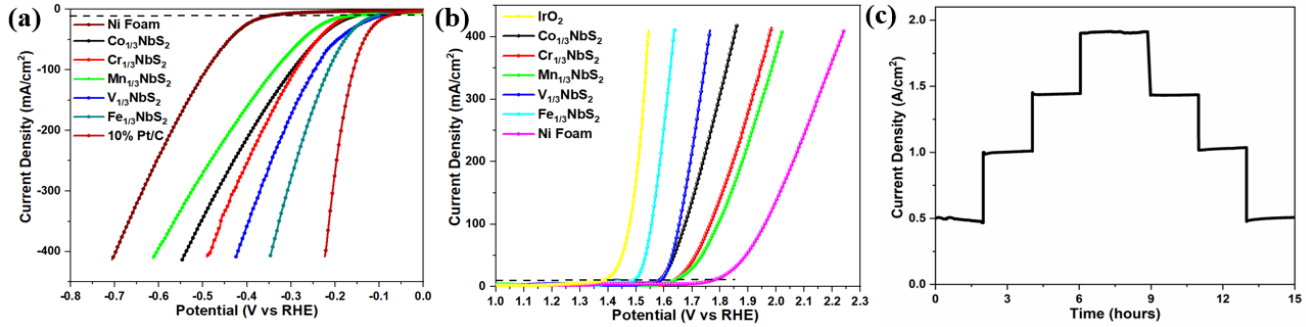

Fig. 2. Electrochemical (a) hydrogen and (b) oxygen evolution characteristics of as-synthesized nanocatalysts in 1M KOH at a scan rate of 5 mV/s, (c) multi-step chronoamperometric test for $Fe_{1/3}NbS_2$.

4. CONCLUSION

The results suggest the successful formation of transition metas doped hexagonal NbS_2 nanostructures. Consequently, the material exhibits enhanced electrocatalytic performance. This integrated approach holds significant promise for improving key performance metrics in water splitting, potentially paving the way for the development of next generation electrocatalysts.

ACKNOWLEDGEMENTS/FUNDING

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E006-A

Addressing Constraints in Solar Hydrogen Production

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ABSTRACT (max 200 words)

Solar hydrogen production could be a viable near to mid-term solution for decarbonization, particularly in countries with high photovoltaic (PV) potential like Portugal. However, if hydrogen supply is to be continuous, costs and environmental impacts can be higher than expected.

We evaluated an electrolyser capacity of 100 MW and applied an evolutionary algorithm to determine the cost-optimal dedicated capacity of solar energy as well as the hydrogen storage capacity for hydrogen supplies ranging from 91 to 636 kg H_2/hr. Our results show, that considering that a 100 MW electrolyser can produce 1.8 tonnes H_2/hr at nominal capacity, it cannot supply more than 0.6 tonnes/hr (35% of nominal capacity) continuously without requiring hydrogen storage capacities in the order of hundreds of tonnes. In such conditions, costs would be 10.3 €/kg H_2 and the estimated impact of Global Warming Potential, including all life cycle stages from raw material extraction to the gate of the electrolyser plant, is 9.3 kg CO2eq/kg H_2. Therefore, our study suggests that solar hydrogen plant design should be done exclusively for production rates below 35% of the nominal production capacity of the electrolyser.

Keywords: Electrolysis; LCA; Optimization; TEA

1. INTRODUCTION

Hydrogen is viewed as an energy carrier and a vector of decarbonization in multiple industries and the transportation sector, owing to its very high Lower Heating Value (LHV) of 120 MJ/kg, no direct GHG emissions upon combustion, and versatility in its utilization [1]. Still, of the 47 Mt/year of hydrogen production capacity announced for 2030, only 2 % is covered by a binding purchase agreement, mostly in the fertilizer, chemicals and oil refining industries (36%) [2]. Notably, many of the use cases in these offtakers will implicate continuous hydrogen supply for economical but also technical reasons. The latter are more relevant particularly for hydrogenation technologies (such as methanation and Fischer-Tropsch) which are not as responsive to fluctuations of flowrates of inputs and outputs as electrolysers are to the fluctuation of renewable electricity [3,4].

In this work, we intend to show the effect that these continuous supply requirements have in the costs and environmental impacts of solar-powered green hydrogen production in Portugal. To do this, we perform optimization of the auxiliary components of the electrolyser plant (dedicated renewable power plants and hydrogen storage capacities) to minimize the levelized cost of hydrogen (LCOH) for different continuous hydrogen production capacities. As an indicator of environmental sustainability, we use the Global Warming Potential indicator (measured in kg CO_2 eq / kg H_2).

2. MATERIALS AND METHODS

Our optimization model determines the installed capacity of solar power and hydrogen storage that guarantees a continuous supply of hydrogen at the lowest cost for a pre-defined electrolyzer capacity of 100 MW. It is run considering the capacity factor profiles for solar power in Portugal between 2015 and 2021, with data at 15-minute intervals [5]. In each interval, hydrogen produced in surplus of the demand is stored. Conversely, when production is lower than demand, hydrogen stored is withdrawn from storage. The model is restricted so that the mass of hydrogen in storage in any time period is always above 0 during the modelled time period, to avoid the failure in the hydrogen supply to a downstream plant. The optimisation was implemented in Microsoft Office Excel using the built-in Evolutionary algorithm included in the Solver extension. The following capital costs were assumed as parameters for optimization: 1597

€/kW (Electrolyser), 1336 €/kW (Solar Plant), 491 €/kg (Hydrogen Storage) and 1200 €/kW (Compressor). Annual OPEX were assumed as percentages of the capital investment: 7% (Electrolyser), 1.7% (Solar Plant), 1% (Hydrogen Storage) and 4% (Compressor) [6] [7,8]. A lifetime of 25 years was assumed for amoritizing capital costs. No interest rates were assumed.

3. RESULTS AND DISCUSSION

Our results show that a continuous provision of 636 kg H_2/hr, obliges a huge hydrogen storage capacities (244 tonnes) in a way that the total storage capacity would equate to more than 380 times the hourly demand. This occurs because solar power is unavailable during night periods, and because in autumn and winter it operates at lower capacity factors. Therefore, the renewable plant size has to be oversized to enable the electrolyser to operate at full load for longer periods of time during the day. When operating at full load, a surplus is produced which is stored to be used during the night or low power generation periods. This oversizing inevitably leads to larger costs and environmental impacts compared to a situation where continuous supply is not a restriction.

Demand (kg/hr)	LCOH (€/kg)	GWP (kg CO_2 eq / kg H_2)	Solar Plant Size (MW)	Hydrogen storage capacity (tonnes)
91	28.5	7.42	38	26
273	12.3	6.26	114	75
455	9.4	6.51	188	174
636	10.3	9.34	442	244

Even though this need for energy storage could be partially mitigated with batteries, this option has been shown in related work [8] to be orders of magnitude more expensive (on a € / kg H_2 basis) than the costs of hydrogen storage. Therefore, their use would not benefit the business case significantly.

4. CONCLUSION

Though solar-powered hydrogen production may be beneficial in other use cases, continuous hydrogen production should not be done solely on the basis of solar power as it is expensive, compromises environmental sustainability and is able at best to produce only 35% of the nominal production capacity when provided with oversized hydrogen storage capacities.

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E010-A

Assessing the Life Cycle of Up-and-Coming Hybrid Storage Systems in the Maritime Industry: State of the Art

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ABSTRACT
The electrification of transportation emerges as a crucial strategy for decarbonizing the sector by substituting fossil fuels with renewable energy. While battery energy storage systems (BESSs) dominate electric transport, their limitations in heavy-duty maritime use prompt exploration of hybrid storage systems (HSSs) in the EU-funded V-ACCESS project. Integrating BESS with supercapacitors or superconductive magnetic energy storage systems (SMES), this initiative aims to elevate HSS readiness and implementation in electric vessels. In this early technology stage, a Life Cycle Assessment (LCA) is crucial to balance technical needs and environmental sustainability.
The present study consists of a literature review on the LCA studies on batteries, supercapacitors, and SMES in marine applications.
From the literature analysis only one study is available which evaluates the global warming associated with an innovative power system consisting of the combination of supercapacitors and batteries in marine applications. The lack in literature on this subject underscore the critical need for further research.

Keywords: Literature review, LCA, SMES, SuperCaps, Batteries, Energy Storage Systems, Marine

1. INTRODUCTION
While maritime transport plays a vital role in the EU economy, it concurrently poses a significant challenge as a substantial and expanding source of greenhouse gas emissions. In 2018, global shipping emissions accounted for 1,076 million tonnes of CO_2, contributing to approximately 2.9% of global emissions resulting from human activities [1]. Projections indicate a potential surge of up to 130% in these emissions by 2050 compared to 2008 levels [2]. On the European front, maritime transport constitutes 3 to 4% of the EU's total CO_2 emissions, surpassing 124 million tonnes of CO_2 in 2021 [3]. Addressing these emissions becomes imperative for aligning with climate goals and ensuring the sustainability of maritime activities within the EU.
The ongoing paradigm shift towards the electrification of transportation represents a key strategy in the concerted efforts to achieve decarbonization within the realm of transportation.
Battery energy storage systems (BESSs) have emerged as the predominant storage technology for electric transport. Despite their dominance, the extensive duty-cycles and rapid dynamic response inherent in maritime transport pose challenges, necessitating oversized BESS. Recognizing this limitation, the EU-funded V-ACCESS (https://v-access.eu/) project investigates into the exploration of hybrid storage systems (HSSs) as a solution. These HSSs integrate BESS with supercapacitors (SuperCaps), superconductive magnetic energy storage systems (SMEs), or a combination of both. The primary objective is to elevate the readiness level of HSSs and facilitate their widespread adoption in electrically propelled vessels.

2. MATERIALS AND METHODS
In order to identify and select the studies to be analysed, a specific literature research scheme was adopted through the selection of international search databases, designated keywords, as well as general and specific eligibility criteria. The literature review was accomplished by using keywords like: “LCA”, “Life cycle assessment”, “lifecycle”, and “ship”, “vessel”, “boat”, and “electric”, “propulsion”, “powered”. In addition, the general eligibility criterion to include only documents in English language was selected.

3. RESULTS AND DISCUSSION
With the defined research method, 148 documents were identified. The number of documents were further refined through a comprehensive abstract analysis and specific eligibility criteria to include only papers

related to marine application case studies in which the environmental impacts were estimated through the LCA approach. According to this analysis, eighteen documents were suitable for the current literature review: seventeen regarding LCAs of battery powered ship and one reporting an LCA of an electric marine vessel equipped with a supercapacitor. For SMES there were no available studies in marine application field. For BESS only LCA in marine application were selected, excluding papers that analyse batteries in other contexts (e.g., automotive use). LCA of SMES and SuperCaps were considered when dealing with other applications.
According to these criteria, seventeen documents related to BESS, one related to SuperCaps and one related to SMES were suitable for the current literature review. However, in addition to the papers selected based on the eligibility criteria, 3 additional papers on SuperCaps and one on SMES have been added. Even if these papers do not apply the LCA methodology, they have been included in the analysis since they carry out an environmental assessment of these ESSs which could provide useful information for the application of the LCA to the case studies selected within the V-ACCESS project.
This study was drawn up based on different LCA studies of electric propelled ship based on battery powered technology. The LCA procedure has been examined in detail and the general rules and procedural steps have been specific for the case study of the innovative combined ESS, to provide methodological indications that allow a correct application of the methodology.
The assessment was performed in order to identify how the main methodological aspects of the LCA were addressed in the available studies, going through the different steps:

- Goal and scope definition
    - Investigated system: type of ship and power systems
    - Goal, function, and functional unit (FU)
    - System boundaries
    - Approach to solve multifunctionality
    - Cut-off rules
    - Impact Categories and Methods
- Life cycle inventory
- Life cycle impact assessment
- Sensitivity and uncertainty analysis

4. CONCLUSION

This stydy reports the state of the art of LCA studies applied to the ESS technologies investigated within the V-ACCESS project. The analysis shows that only one study is available which evaluates the global warming associated with an innovative power system consisting of the combination of supercapacitors and lead-acid batteries in marine applications. However, this study does not apply the LCA methodology. Seventeen documents report on LCA applied to traditional electric vessel based on battery. These studies will provide a useful support in quantifying the potential environmental benefits associated with the innovative combined ESS (battery technology plus supercapacitors or SMES) in the electrical vessel with respect to the traditional solution based only on batteries. The lack of existing literature on this subject highlights the urgent need for further exploration and study.

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E014 -A

Demonstration and Study of MLPE Application for Overcoming Partial Shading Caused by 765kV Transmission Towers

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ABSTRACT
This paper presents the development and experimental validation of a Module Level Power Electronics (MLPE) system designed using GaN-MosFET technology. Aimed at addressing the efficiency losses in solar power installations due to shading, our research involved constructing four distinct 3 kW testbeds to evaluate the system's performance. The results demonstrated a significant recovery, with a 56% reduction in losses attributable to shading. Subsequently, a full-scale demonstration was carried out by implementing the MLPE system in a solar power plant affected by 765 kV line-induced shading. This study confirms the potential of MLPE systems to enhance the efficiency and reliability of solar energy production, particularly in environments susceptible to partial shading.

Keywords: MLPE(Module Level Power Electornics); GaN-MosFET; Mismatch; MPPT;

1. INTRODUCTION
Photovoltaic (PV) systems often suffer from a reduction in overall efficiency due to the inherent series connection of solar modules. When partial shading occurs on any module within a string, it adversely affects the performance of the entire array, as the weakest link dictates the output of connected modules [1]. To overcome this limitation, Module Level Power Electronics (MLPE) have been widely adopted. These devices are attached to individual solar modules to perform Maximum Power Point Tracking (MPPT) independently, thus optimizing the output of each module regardless of the performance of others in the string [2].
To demonstrate the effectiveness of this technology, we developed an MLPE system utilizing GaNMosFET technology. We conducted experiments on a testbed designed to simulate partial shading scenarios, assessing the potential increase in power output. Further, to substantiate the practical benefits of MLPE, we implemented this system in an operational solar power plant affected by shading due to the presence of 765kV transmission towers. This installation aims to validate the system's capability to mitigate energy losses in real-world conditions, providing a robust solution to the challenges posed by shading in solar installations.

2. MATERIALS AND METHODS
To evaluate the effectiveness of the Module Level Power Electronics (MLPE) system, we constructed four separate 3 kW solar power testbeds. Each testbed consists of seven 400W solar modules, totaling a combined generation capacity of 3 kW per installation. These installations were equipped with individual 3 kW string inverters, which operated under various conditions to simulate real-world scenarios. We systematically tested the performance under four distinct scenarios: normal operation without shading, operation under shading, normal operation with MLPE attached, and operation under shading with MLPE attached.
Following the controlled test-bed experiments, the next phase involved field validation. For this purpose, we installed the MLPE system in a commercial solar power plant that experiences partial shading due to nearby 765kV transmission towers. This real-world implementation aimed to verify the MLPE's capacity to mitigate power output losses caused by shading, thereby demonstrating its practical application and benefits in operational settings.

3. RESULT
The experiments conducted on our testbeds provided compelling evidence of the MLPE system's efficacy. In scenarios where shading occurred, the MLPE-equipped installations demonstrated an impressive ability

to recover 56% of the power output lost due to shading. This substantial recovery highlights the critical role of MLPE systems in mitigating the adverse effects of partial shading on solar power production. The result underscores the necessity of implementing MLPE technology in solar power plants prone to shading, proving that it is essential for maintaining high levels of efficiency and operational stability in affected installations.

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E015-A

Does income inequality affect water pollution levels in the United States? Empirical evidence from the United States

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ABSTRACT
This study examines the relationship between urbanization, economic growth, and water quality using time series data for the United States. The autoregressive distributed lag (ARDL) method is used to analyze the short- and long-term impacts of urbanization and economic growth on water quality in the United States. The ARDL bound test results point to a long run cointegration among the variables. The findings reveal a negative long-run relationship between water pollution and urbanization, pointing to the positive effects of urbanization on environmental quality in the United States. Our findings indicate that water pollution decreases by 0.11% for every unit increase in urbanization. Both in the short and long run, the relationship between economic growth and water quality is found statistically insignificant. Additionally, error correction coefficient indicates a stable process of adjustment to the long run equilibrium in about 1.5 years.

Keywords: ARDL Model, Economic Growth, Urbanization, Water Pollution

1. INTRODUCTION
As the world faces record levels of urbanization, industrialization, and globalization, environmental concerns have emerged as a crucial issue. One of these problems that has drawn a lot of attention is water pollution, which has detrimental effects on ecosystems, public health, and the state of the economy.
.Our study aims to address this issue by using country specific time series data to analyze the income-water quality nexus in the United States for the years between 1974 and 2020. For this purpose, we employed an autoregressive distributed lag (ARDL) approach by by Pesaran et al. [1]. Our empirical focus is on assessment of the short- and long-run effects of changes in economic growth and urbanization on changes in water pollution indicator (Fecal coliform) in the U.S.

2. MATERIALS AND METHODS
This study utilizes the Autoregressive Distributed Lag (ARDL) Bound Test to examine the impact of economic growth and urbanization on water quality in the United States from 1974 to 2020. The data span has been chosen based on the availability of the data for all series. The ARDL model is advantageous at capturing both short-term volatility and long-term relationships between the variables, particularly in situations where the available datasets are restricted or include a mix of integrated orders.
The term "urban population," which refers to the number of people living in urban areas, is used as a proxy for urbanization, while the type of bacteria known as "fecal coliform" is used as a proxy for water pollution. Fecal coliform, urban population and economic growth data are obtained from Global Environmental Monitory Systems (GEMS), United Nations Population Division (World Urbanization Prospects: 2018 Revision), World Bank national accounts data, and OECD National Accounts data files, respectively.
Before the form of the ARDL Model, the stationarity of the series is determined. To determine the stationarity, Augmented Dickey Fuller (ADF), Philips Perron (PP) and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) unit root tests are applied. The unit root tests show that all the variables are stationary at level I(0) .
Prior to analyzing the short-term and long-term effects, the prerequisites of the model are examined. The Breusch-Godfrey LM and Heteroskedasticity tests both reveal the lack of serial correlation and heteroscedasticity issues. For the stability of the model Ramsey RESET, CUSUM and CUSUM of squares tests are applied to the data.

3. RESULTS AND DISCUSSION
To investigate the long-run relationship, the Bound Test is applied to the dataset. The F-statistic value derived from the bound test is 6.383161. The null hypothesis, which states that there is no long-term relationship, is rejected since the estimated test statistic is greater than the upper critical value of 5.207 at

the 5% significance level. Therefore, our study shows that there is a long-term cointegration relationship among the variables. The long run coefficients are given in the Table 1.

Table 1. The long run coefficients

Dependent Variable	Fecal Coliform	
Variable	Coefficient	Prob
URBAN	-0.115970	0.0439
GROWTH	0.021941	0.8018

Error Correction Regression in ARDL model is employed to determine the short-term relationship between the variables. The results of the Error Correction Model are shown in Table 2.

Table 2. Error Correction Model

Variable	Coefficient	Prob
C	10.27612	0.0001
CointEq(-1)*	-0.629425	0.0001

The findings suggest the presence of a short-term co-integration between the variables, as seen by the negative and significant error correction coefficient (CointEq(-1)). The results are corroborated by the fact that the t-statistic value above the upper threshold. The findings indicate that after a short-term shock, it reaches equilibrium approximately after 1.5 (1/0.629425) years in the long run.

4. CONCLUSION

The results show that water pollution and urbanization have a negative relationship in the long run, suggesting that urbanization, which serves as a key indicator of economic development and growth, has a beneficial effect on environmental quality in the U.S. The research reveals that a one unit increase in urbanization results in a 0.11% decrease in water pollution. The relationship between economic growth and water quality is found negative statistically insignificant in the long run. There may be possible explanations for that insignificant result such as technological advancements, strict environmental rules and regulations and public awareness and activism in the U.S.

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[1] For the urbanization data, despite the PP test indicating stationarity at the 2nd difference, we consider it to be I(0) due to the majority of tests showing stationarity at the original level.

E017

Effect of mass flow rate and temperature on the gasification of animal fat

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ABSTRACT
In this work, steam reforming of animal fat was studied using a downflow fixed bed reactor. Tests were performed with an emulsion of 40 % fat and 60 % water. Mass flow rate and temperature effects were evaluated in the range of 1.2 g/min to 2.9 g/min and 750 to 950 °C, respectively. Gas chromatography was used to analyze the gas sample from the gasifier to determine the contents of H_2, CO, CH_4, CO_2, C_2H_4, and C_2H_6. Carbon and hydrogen conversion efficiencies, dry gas yield, cold gas efficiency, and higher heating value of producer gas were determined. The results showed that mass flow rate and temperature are operating conditions that determine the composition of the gas obtained and the performance of the gasification process. The gasification parameters increased with the temperature rise, since the best results were obtained at the highest tested temperature. The increase in the operating mass flow contributes to a decrease in the overall performance of the gasification process.

Keywords: Animal Fat; Gasification; Steam Reforming; Fixed Bed

1. INTRODUCTION
The leather sector is one of the prominent industries with a global trade value of USD 242.85 billion in 2022, and it is anticipated to expand from 2023 to 2030 at a 6.6 % compound annual growth rate (CAGR). In Portugal, a total of 3096 enterprises manufactured leather in 2020. At the same time, the leather sector is currently under scrutiny for the negative impacts of its unchecked pollution burden [1]. Tannery produces a vast amount of environmental pollutants in solid and liquid forms, posing a threat to the environment if not disposed of properly. One of the solid residues produced is hide flashings, which can contain about 40 % (*d.b.*) of low-value fat. According to data from the Leather Industry Technological Center, more than 2,000 tons of fat waste were generated in 2019 in Portugal. Currently available disposal techniques for solid leather waste are the landfill and incineration [2].
Due to the negative impact on the environment and the possibility of groundwater and soil contamination, landfill does not present itself as an ideal technical option. On the other hand, there are still many legal constraints on fat incineration.
The gasification of animal fat can be an option for valuing this waste, for which, currently, there are no sustainable options. The gasification process uses biomass under non-oxidation conditions, resulting in significantly lower pollutant emissions, and is, therefore, considered an environmentally friendly process [3]. The performance of a gasifier depends on the properties of the raw material used, the gasification agent employed, and of the operating conditions. The feeding flow rate and temperature influence mightily the quantity and quality of the gas produced [4].

2. MATERIALS AND METHODS
The animal fat was obtained from a Technological Center for the Portuguese leather Industry (CTIC – Centro Tecnológico das Indústrias do Couro). This fat has a high content of saturated fatty acids and is solid at room temperature and it was characterized in terms of its ultimate analysis and higher heating value.
The gasification of animal fat was investigated in a downflow fixed bed reactor composed of alumina particles (6 mm in diameter). An emulsion of 40 % (w/w) of fat and 60 % (w/w) of water was studied at temperatures ranging from 750 to 950 °C, and mass flow rate from 1.2 to 2.9 g/min. Several trials were carried out for each feeding flow rate and temperature tested.

3. RESULTS AND DISCUSSION

With the decrease in mass flow rate, a decrease in the C_2H_4 concentration and a slight reduction in the CH_4 concentration were observed, accompanied by an increase in the CO concentration and a slight increase in H_2 concentration. These results seem to indicate that the decrease in flow rate could favor hydrocarbon reforming reactions. Along the temperatures tested, H_2 concentration increased while CH_4, C_2H_4, and C_2H_6 concentrations decreased. Concerning CO concentration, it was observed an increase of the values with the rise of temperature. Regarding CO_2 concentration, a decrease in values was observed with increasing temperature.

The results obtained indicate that there may be a change in the reaction mechanism between 850 ºC and 950 ºC. The water-gas shift plays a well-known important role in the process up to 850 °C. From this temperature on, methane steam reforming, methane dry reforming, and hydrocarbon reforming reactions become increasingly significant.

To use producer gas as a fuel, its heating value is crucial. The producer gas's higher heating value depends on the gas composition. The higher energy content was obtained at the lowest tested temperature of 750 °C. The reduction in the higher heating value observed when the flow rate decreases is scarce and is mainly related to the reduction of the C_2H_4 concentration in the producer gas.

The gasification process performance was carried out by comparing the calculated gasification parameters. Increasing the flow rate from 1.2 to 2.9 g/min can represent a reduction between 18 % and 7 % for the carbon conversion efficiency, between 14 % and 12 % for the hydrogen conversion efficiency, and between 14 % and 6 % for cold gas efficiency, depending on the working temperature. The carbon conversion efficiency increases from a range of 52-57% to a range of 80-98%, and the hydrogen conversion efficiency increases from a range of 73-84% to a range of 149-174%. Additionally, the cold gas efficiency increases from a range of 61-66% to a range of 98-115%. The results also shows that dry gas yield increased with increasing temperature from a range of 0.75-0.92 m^3/kg to a range of 2.16-2.75 m^3/kg as the temperature rose from 750 to 950 °C.

4. CONCLUSION

The temperature was found to have a strong influence on the gas composition. The temperature rise promotes a reduction of hydrocarbons concentration and a significant increase in H_2 concentration. The change in the gas composition directly impacts the value of the higher heating value of the producer gas, decreasing with the increase in gasification temperature. Concerning the other gasification parameters, an increase in its values was observed with the rise of temperature.

The decrease in mass flow rate allowed an increase in the degree of degradation of organic matter, resulting in a decrease in the concentration of hydrocarbons in the producer gas and an increase in concentration of H_2 and CO. Regarding the gasification parameters, the results obtained showed that the rise of mass flow rate resulted in a decrease in the performance of the gasification process using the experimental installation with the reactor under study.

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E019-A

Accumulation of Metal-Oxide Nanoparticles Decreases the Energy Reserves and Alters the Responses of Biomarkers in Freshwater Mussels (*Unio tigridis*)

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ABSTRACT
Mussels are used as an effective bioindicator animal for environmental pollution. In this study, the responses of biomarkers in the digestive gland and muscle of freshwater mussels (*Unio tigridis*) were investigated following exposure to Al_2O_3, CuO and TiO_2 nanoparticles (NPs). Metal concentrations in tissues were determined by ICP-MS, while NP presence was demonstrated by Transmission Electron Microscope (TEM). Data showed that there were fluctuations in glutathione metabolisms in the digestive gland of mussels. There were significant increases in total glutathione levels, reduced glutathione and oxidised glutathione. Likewise, malondialdehyde levels in the digestive gland increased after NP exposures. Oppositely, there were significant decreases in acetylcholinesterase activity in the foot muscles. The total energy reserves of the digestive gland and foot muscle significantly decreased, but only at the highest NP exposure concentrations. TEM images demonstrated the presence of NPs in the tissues. TEM images suggested that NPs were taken into the cells via pinocytosis. Highest mean concentrations (ppm d.w.) of aluminium (76.5), copper (112) and titanium (114) were measured in the gills and followed by the digestive glands and muscles. This study demonstrated that the biomarkers belonging to different metabolic systems responded to NP exposures, suggesting their usage in the monitoring studies.

Keywords: Accumulation, Biomarker, Energy, Metal, Mussel, Nanoparticle

1. INTRODUCTION
Metal-oxide nanoparticles (NPs) have entered human life in recent years in demand of nanotechnology. The size of these materials ranges between 1-100 nm and contain metal ions. NPs are characterised by their high surface-to-volume ratios, reactivity, surface structure and crystal characteristics. Studies have shown that the toxic effects of a metal in an ionic form or NP form may change, suggesting to investigate the nanotoxicological effects of metals which are used in nanotechnology [1,2]. This suggestion was made due to the use of NPs in many nanotechnological products including medicals, suntan creams, textiles, toothpaste, moisturizers, electronics and toys. Additionally, some NPs such as titanium NPs are used as food additives, indicating the potential toxic effects of these products [3,4].
Energy sources of animals are carbohydrates, lipids and proteins, respectively. The energy expenditures of animals under stressful conditions generally increase to overcome stress caused by internal or external factors. Therefore, the determination of energy reserves of animals exposed to NPs may be important to evaluate their effects, as animal cells use great amounts of ATP under stress [5]. ATPases spend most of the energy produced by the cells. They are a group of enzymes that play an important role in the functional regulation of the cell, and they control metabolic events that require high energy (ATP), such as osmotic pressure, ion movements, and membrane permeability in tissues. For example, in many animal cells, 20% of the total ATP consumed in the cell is used by ATPases, while this situation increases up to 66% in neurons [6,7].

2. MATERIALS AND METHODS
Freshwater mussel *Unio tigridis* were used for test animals. Mussels were allocated in glass (10 L capacity, 10 mussels) aquariums. The chemical and physical qualities of water during the experiments were; 21±1,0°C, oxygen level: 5.7±0.87 mg O_2/L, total hardness: 315.8±19.9 mg $CaCO_3$/L, pH: 7.99±0.16, conductivity: 569±10.1 µS/cm. The experiments were carried out 12 light/12 h dark regime.
Mussels were fed on unicellular algae (*Chlorella vulgaris*) cultured in our laboratory for 5 hours at dark. The length and weight of mussels: 61±0,9 mm and 33±1,5 g ($P>0.05$). Mussels were exposed to different concentrations (0, 1, 3, 9 mg/L) of Al_2O_3, CuO and TiO_2 NPs for 14 days. After exposure, mussels were

taken out from the aquariums and their digestive gland and mussels were dissected out. The analyses of biomarkers were done as explained in Baykose et al. [8].

3. RESULTS AND DISCUSSION

There was no mussel mortality after 14-day NP exposures. There were significant ($P<0.05$) accumulations of aluminium, copper and titanium in the digestive gland and gill of mussels after NP exposures. The TEM images of tissues also demonstrated the occurrence of NPs in the tissues, suggesting their accumulation via pinocytosis. NP exposures caused significant increases ($p<0.05$) in the levels of total glutathione (GSH), reduced-glutathione (rGSH), oxidized-glutathione (GSSG) and malondialdehyde (MDA) in the digestive gland. Oppositely, there were significant ($p<0.05$) decreases in acetylcholinesterase activity in the foot muscles. Total energy reserves of the digestive gland and foot muscle significantly ($p<0.05$) decreased, but only at the highest NP exposures. Nevertheless, NP exposures did not alter ($p>0.05$) the algae filtering capacity of mussels. This study demonstrated that the biomarkers belonging to different metabolic systems responded to NP exposures, suggesting their usage in the monitoring studies for freshwater systems.

4. CONCLUSION

In the present study, the levels of enzymatic and non-enzymatic biomarkers in the tissues significantly changed due to NP exposures. Likewise, the energy reserves of tissues significantly declined after NP exposure, emphasizing that NPs were not innocent compounds and their effects should be investigated further to estimate better the consequences of NP exposures in different groups of animals.

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E022

Co-pyrolysis of brown macroalgae and pinecones in a fixed bed reactor

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ABSTRACT
This study presents results on the slow co-pyrolysis of *Laminaria digitata* (LD) and pine-cones (PC), at an average temperature of 560 °C, for mass ratios LD/PC of 100/0, 50/50, 30/70, 10/90 and 0/100. The biochar yields obtained varied from 35.3 to 31.2 %, for bio-oils the yields were in the range of 23.3 to 39.9 %, and for the gas phase, between 41.4 and 28.9 %, as the amount of PC increased in the feeding mixture. The biochars were characterized in terms of proximate analysis and higher heating value (HHV). The properties of bio-oils that were determined included pH, density, HHV and identification of compounds by infrared analysis. CO_2, CO, CH_4 and H_2 were identified in the gas phase of all the experiments by gas-chromatography, but the most produced gas was CO_2, followed by CO.

Keywords: Copyrolysis, *Laminaria digitata*, Pinecones

1. INTRODUCTION
Due to increasing energy demands, the search for alternative energy sources has increased considerably. Biomass, among other alternatives, has been chosen as a solution, because it can be converted into gas, liquid, and solid phases through several processes, including pyrolysis. This is a thermochemical process where biomass is heated in an inert atmosphere, at temperatures higher than 300 °C, producing a gas phase (composed mainly of CO_2, CO, CH_4 and H_2), a solid phase (biochar) and a liquid phase (bio-oil) [1]. Co-pypolysis, where two or more or residues are fed into a pyrolysis reactor, can improve the yields and properties of the resulting products [2].
In this study, co-pyrolysis experiments using *Laminaria Digitata* (LD) and pine cones (PC) were carried out for different mass ratios of LD/PC in the feed, specifically 100/0, 50/50, 30/70, 10/90 and 0/100.

2. MATERIALS AND METHODS
Pinecones collected from stone pines and maritime pines in the area of Viana de Castelo, Portugal, and macroalgae *Laminaria Digitata* from a beach in the same area, were separated from debris, ground and sieved. Both biomasses were characterized in terms of proximate and ultimate analysis. The higher heating value (HHV) of the two residues was also determined in a Parr calorimeter. Only pre-dryed biomass with particle sizes ranging from 1 to 4 mm were used in the pyrolysis/co-pyrolysis experiments. These were carried out in the same experimental set-up and using the operating mode described by Nascimento et al., using a heating rate of 20 °C·min^{-1} and a set temperature (T_{set}) of 650 °C [3]. After T_{set} was reached, the run continued for another 40 min. Under these conditions, the average final temperature inside the reactor T_{in} = 560 °C.
At the end of each experiment, the yields of biochar and bio-oil were determined using, respectively, the equations (1) and (2):

$$\eta_{biochar} = m_{biochar}/m_{biomass} \quad (1)$$

$$\eta_{bio-oil} = m_{bio-oil}/m_{bio-oil} \quad (2)$$

For the non-condensable gas, the yield is given by equation (3):

$$\eta_{gas} = 1 - m_{biochar} - m_{bio-oil} \quad (3)$$

In these equations $m_{biochar}$, $m_{bio-oil}$ and $m_{biomass}$ represent the mass of the biochar, the bio-oil and the biomass, respectively. For the co-pyrolysis experiments the predicted yields, which can reflect the synergetic effect between the two residues, can be calculated as in equation (4):

$$\eta_{pred} = x_{LD}\,\eta_{LD} + x_{PC}\,\eta_{PC} \quad (4)$$

in which x_{PC} and x_{LD} are the mass fractions of PC and LD in the mixture, and η_{PC} and η_{LD} are the product yields of PC and LD obtained experimentally under the same conditions [4]. The proximate analysis and HHV of biochars were also determined, as well as pH, density and HHV of bio-oils. Samples of bio-oils were analysed with Fourier Transform Infrared Spectroscopy–Attenuated Total Reflectance (FTIR-ATR). The gas phase was analysed by gas chromatography.

3. RESULTS AND DISCUSSION

Comparing the proximate analysis of LD against PC, algae presented lower volatile content then pinecones (67.33 % and 74.64 %) and higher percentage of ashes (15.33 % and 0.71 %). In terms of ultimate analysis, LD presents a lower carbon content (39.16 %) and higher nitrogen percentage (3.07 %) than PC (C - 50.00 % and N - 0.24 %). HHV for LD was 13.24 MJ.kg^{-1} and 19.88 MJ.kg^{-1} for PC.

Fig. 1 shows the comparative analysis of the predicted product yields and the experimental values obtained. The biochar yields varied from 35.3 to 31.2 %, bio-oils yields were in the range of 23.3 to 39.9 %, and for the gas phase, from 41.4 to 28.9 %, as the amount of PC increased in the feeding mixture. For bio-oil, the experimental yields are lower than the predicted ones, while for the gas phase the opposite trend was observed. For biochar, the predicted and experimental yields were very similar.

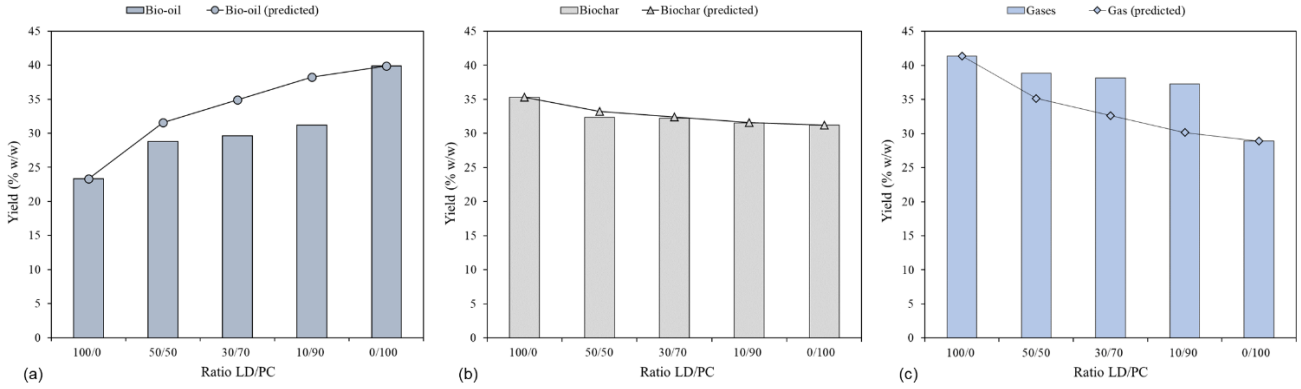

Fig. 1. Experimental and predicted product yields of (a) bio-oil, (b) biochar, and (c) non-condensable gases.

The proximate analysis of biochars showed that, as the amount of PC increased in the feeding mixture, the ash content decreased (31.4 to 2.2 %), and the fixed carbon increased (58 to 89.7 %). HHV of biochars varied between 18.6 to 31.6 MJ·kg^{-1}. The pH of the bio-oils dropped from 8.69 to 3.23, and the HHV rose (2.42 to 15.15 MJ·kg^{-1}), as the percentage of PC increased. CO_2, CO, CH_4 and H_2 were identified in the gas phase of all the experiments, but the most produced gas was CO_2, followed by CO.

4. CONCLUSION

This work presents results on the co-pyrolysis of LD and PC at an average temperature of 560 °C. As the percentage of PC rose in the feed, bio-oil yields increased and biochar and gas yields decreased. Also, by incrementing the amount of PC in the feed material, the HHV of biochars and bio-oils obtained also increased. The gas phase was composed of CO_2, CO, CH_4 and H_2.

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E028-A

How Sustainable is the Ceramics Industry in Portugal? An Exploratory Study

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ABSTRACT
The Portuguese ceramics industry, in 2021, was composed by 1,120 companies, representing 1.3% and 2.1% of the turnover and gross value added of the national manufacturing industry, respectively. In value, it generated more than 1,233 million euros, highlighting the subsectors of flooring and coverings and utilitarian and decorative ceramics. The addition of the ancient tradition associated with the high level of quality and prestige boosted the increase in external demand for the national product. Hence, it is essential that this industry is sustainable, growing responsibly and in balance with society, the economy and the environment. This study proposes to describe, understand, analyze and interpret the main economic, social and environmental indicators available relating to the sustainability of the ceramics industry in Portugal. The main objective of this scientific study is to contribute to increasing the available scientific information for political decision-makers be able to adopt more efficient strategic measures to increase sustainability in this key sector in Portugal.

Keywords: Ceramics Industry; Portugal; Sustainability.

1. INTRODUCTION
The idea of “sustainability” is far from new, having been widely accepted throughout the world since ancient times. In fact, in indigenous societies, it was common to combine religion and cult with nature, calling on people to protect the environment. This primitive behavior can be considered a demonstration of sustainability [1,2]. Currently, in the 21st century, based on the extensive scientific literature on sustainability, it is possible to state that it is a very rich and broad concept, for which there are different interpretations, depending on the researchers` adopted approach [3]. Different organizations participated in the development of the sustainability concept, but the most significant is the United Nations (UN), founded in 1945 with several goals, namely the promotion of sustainable development at a global level. At the end of the 20th century, the concept of sustainability gained particular international relevance with the publication “Our Common Future”, according to which,"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” [4, p.43]. In 1992, the United Nations Conference on Environment and Development (UNCED) brought together 179 countries for a massive effort to focus on the impact of human activities on the environment, recognizing that integrating and balancing economic, social and environmental dimensions requires new perceptions of the way we produce and consume [5, 6]. Aware of these key issues, the Portuguese ceramics industry is committed to the three pillars of sustainable development, including environmental sustainability, in order to achieve Europe's ambitious climate goals. However, it recognizes that it belongs to an interconnected industrial value chain, with diverse stakeholders and participants, both upstream and downstream. It is urgent to converge on the decarbonization of electricity and the development of new, more environmentally friendly technologies. But the concern does not only lie on the producers' side, but also on the consumers' side. In fact, there is an increasingly careful selection of consumers by companies that hold sustainability certificates, focusing on environmental aspects, forcing greater awareness [7].

2. MATERIALS AND METHODS
In this study, the methodology used is essentially descriptive, using the detailed analysis of an extensive review of the most recent literature of the various studies on the sustainability of the ceramics industry.

Additionally, this study collected and analyzed the most recent statistics and indicators available on the ceramics sector in Portugal, allowing us to assess the degree of sustainability of this industry.

3. RESULTS AND DISCUSSION

According to APICER [8], the Portuguese ceramics is a sector driven by ecological and social principles, manufacturing hight value products in harmony with people and environment. The Table 1 summarizes the main observations regarding the three dimensions of sustainability.

Table 1. Sustainability of the Portuguese Ceramics Industry

Economic Growth: . spirit of cooperation . deep knowledge of the market . proactive behaviour . creation of added value	Environment Protection: . rational use of natural resources . management and recovery of extraction sites . incorporation of environmental management systems . durability and optimisation of the lifecycle of products	Social Responsability: . continuous dialogue . high levels of hygiene and safety in products sites . continuous training . creation of values through natural and healthy products

4. CONCLUSION

The Portuguese ceramics industry has increasingly established itself as a key sector in the national economy, driving economic growth, innovation and Portugal's competitiveness in the global market. This sector represents not only a traditional industry, but also a vector of innovation and competitiveness for the Portuguese economy. As such, it is important that this sector grows sustainably and contributes to a more prosperous and sustainable future. Through the analysis of a series of indicators in the areas of economic, social and environmental responsibility, this study concludes that the ceramics industry presents a considerable level of sustainability.

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E037-A

Investigations on the responses of biomarkers belonging to the antioxidant and osmoregulation systems of freshwater mussels (Unio tigridis) following copper exposures

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ABSTRACT

Mussels are known as good bio-indicator animals due to their sedentary lifestyle and filter-feeding characteristics. Therefore, they are often used in ecotoxicological investigations of aquatic environments. In this study, freshwater mussels (*Unio tigridis*) were exposed to different concentrations (0, 30, 90 µg/L) of copper for different durations (0, 7, 14, 21 days) and then the responses of biomarkers belonging to the antioxidant and osmoregulation systems were investigated. Data showed that copper exposures did not cause any mussel mortality, though the responses of many biomarkers altered significantly. There were significant increases in the responses of biomarkers belonging to the antioxidant systems in the gill and hepatopancreas, with exposure durations playing predominant roles. There were significant increases in the activities of antioxidant enzymes. Likewise, ATPase activities in the gill and muscle of mussels altered significantly following exposure to copper. There were significant increases in Mg-ATPase activity and decreases in Na-ATPase and Ca-ATPase activities in both tissues, especially higher concentrations. Nevertheless, the values of biomarkers in control mussels did not change significantly between 0-21 days. This study showed that sublethal and low copper concentrations could have toxic effects on mussels, emphasizing the alterations in the antioxidant and osmoregulation system of mussel.

Keywords: Antioxidant, ATPase, Metal, Mussel, Toxicity

1. INTRODUCTION

All pollutants released into the environment mostly end up in aquatic environments due to washing up by rain waters. Therefore, monitoring aquatic environments and the health of organisms living in these environments is a priority for environmental scientists. Freshwater bodies, compared to oceans, have much smaller volumes, which makes them more susceptible to pollution. Consequently, freshwater ecosystems are more delicate ecological environments than marine ecosystems.

Directly observing the impact of metal contamination in aquatic environments is often challenging. For this purpose, various enzymatic or non-enzymatic molecules called biomarkers are frequently used to assess the effects of pollutants. These biomarkers provide concrete data on the stress experienced by aquatic organisms and their physiological condition [1,2]. Antioxidant enzymes are a group of enzymes that work to prevent oxidative stress caused by the organism's own metabolism or external chemicals in aerobic organisms [3]. Likewise, ion-ATPases are very important for the osmoregulation of aquatic animals and also highly sensitive to environmental contaminants [4].

Freshwater mussels (*Unio tigridis)* were exposed to different copper concentrations (0, 30, 90 µg/L) for varying durations (0, 7, 14, and 21 days), and antioxidant enzyme activities such as CAT, SOD, GPX, GR, and GST were measured in gill and hepatopancreas tissues. This study aimed to understand how copper exposure affects antioxidant defence mechanisms in mussel tissues. Laboratory experiments have shown that exposures to metals, including copper, affect the osmoregulation system of mussels, with significant fluctuations in ion ATPase activities [4,5]. These studies emphasized that while metals affected the osmoregulation system in mussels, several other factors such as metal concentration, duration, chemical properties of water and biology of the species were found to be important.

2. MATERIALS AND METHODS

This study was carried out to investigate the effects of copper on the ion ATPases in the gill and muscle of freshwater mussels *U. tigridis*. For this aim, the osmoregulation enzyme activities such as Na-ATPase, Mg-ATPase and Ca-ATPase in the gill and muscle were measured following exposure to different copper concentrations (0, 30, 90 µg/L) at different durations (0, 7, 14 and 21 days). The experiments were carried out at following conditions; pH; 8.3 0.08, total hardness; 304.2 21.2 mg CaCO3/L, alkalinity; 195±11.4

mg Ca2CO3/L, conductivity; 580 10.8 µS/cm, temperature; 22±1.0 oC, oxygen; 6.0 1.0 mg/L, light regime; 12 h light/12 h dark. Mussels were fed with unicellular freshwater algae (*Cholorella vulgaris*) before each water change (approximately 300,000 algae/ml), serving the algae at total darkness for 5 h. Measurements of Ion ATPase Activities were done as explained in Canli and Canli [6] and the measurements of antioxidant system parameters were done as explained in Canli and Canli 2021 [7].

3. RESULTS AND DISCUSSION

There were significant alterations in control mussels regarding the activities of osmoregulation and antioxidant enzymes, emphasizing low stressful experimental conditions. Likewise, mussels did not have feeding problems, as there was no change in algae filtering capacity. However, there were significant ($P<0.05$) increases in antioxidant enzyme activities in the gill and hepatopancreas tissues of mussels. Accordingly, the most significant increase in antioxidant enzyme activities occurred during the longest effect period. Enzymes such as CAT and SOD were the enzymes with the highest increase since they are the precursor enzymes of the antioxidant defense system. Similarly, ATPase activities in the gill and muscle of mussels altered significantly ($P<0.05$) following exposure to copper, especially at the higher concentration. Literature data demonstrated that metals altered ATPase activities in mussels, metal types, concentrations, durations and biology of animals playing predominant roles in occurred toxicity.

4. CONCLUSION

This study showed that copper at sublethal levels caused significant alterations in the activities of antioxidant and osmoregulation system enzymes which are vital for the metabolisms of mussels. Thus, data emphasised that metal discharges to freshwater systems must be limited and controlled to control pollution and save biodiversity.

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E039-A

Wind and Solar Power: An Overview of Environmental, Social and Economic Impacts

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ABSTRACT
Climate change has prompted the development of renewable energy technologies, accelerated by the recent Russia-Ukraine/Israeli-Palestinian conflicts, raising the energy security concerns. As such, a renewed interest in solar and wind energy technologies has emerged. Based on the literature overview, economic, environmental, and social impacts ascribed to wind and solar power were identified and classified, considering their nature and scale. The main findings showed that studies focusing on solar power impacts tend to prevail over wind power. Besides economic and environmental aspects, social aspects are also contemplated, reinforcing the need to promote a holistic impact assessment based on a sustainability perspective. However, the need to develop more targeted studies is emphasized to overcome the challenges of identifying and measuring impacts and better inform policymakers of the benefits and costs of wind and solar power projects at regional and local scales.

Keywords: Renewable energy; sustainability; impact assessment

1. INTRODUCTION
The concept of sustainability combines social, environmental, and economic dimensions [1] that are required to assess in a holistic manner, the impact of renewable energy (RE) technologies [2]. In fact, the sustainability perspective has been considered crucial to guide decision-makers regarding the development of RE projects [3], particularly in the present context. It is crucial to provide policymakers with accurate information regarding potential conflicting impacts that make the decision-making process challenging in the context of sustainability [4]. This work presents an overview of the main economic, environmental, and social impacts and their assessment metrics. By considering impacts across different scales, regional and local impacts are focused, allowing their capture in greater detail.

2. MATERIALS AND METHODS
The following research string was used: “wind energy” OR “solar energy” AND "economic impact" AND "social impact" AND "environmental impact", and all articles containing these words were considered in the Scopus database. The rationale behind retrieving the articles from a singular database is that Scopus offers scholars exhaustive and wide-ranging literature [5]. This led to a total of 82 articles. The following criteria of exclusion were followed: articles not written in English; articles not accessible; articles focusing on renewable energy technologies other than wind or solar power; and articles focusing on sectors other than energy generation (e.g. transportation). The final number of papers was reduced to 20 studies. The investigation encompassed the timeframe until May 2024.

3. RESULTS AND DISCUSSION
According to the main impact areas, environmental, social, and economic, the impacts are assessed under scale (regional/national or local scope) and regarding the nature of the impact (positive or negative consequences). Five categories of environmental impacts were identified in 10 out of 20 studies. The economic impact (4 categories) was discussed in 10 articles, and the social impact (5 categories) in 12 articles. Macro studies prevail when studying climate change and GHG emissions, focusing on cross-country comparisons for the future deployment of concentrated solar power (CSP) [6,7]. Although emissions from this solar power alternative are considered higher than other alternatives, they could be overcome through technological advances [6] and improved supply chain alternatives [1]. Land use also seems to have a common environmental impact, for solar and wind power require extensive land use [8]. Soil erosion also seems to be a concern [9], and conflict with other land uses (e.g. farmland) seems to

overlap with social impacts [4]. Using unproductive land, such as deserts, could mitigate this issue [8]. Bird mortality and the location near natural reserves have been recognized as a potential risk for biodiversity preservation [3]. The reduction of householders' exposure to fossil fuel combustion has been recognized as a positive impact. Moreover, this could also have implications at social dimension, namely regarding health impacts.

At a macro level, investment in solar projects seems to positively contribute to economic growth and employment generation [7], despite the high investment and operation and maintenance costs. According to [10], end-of-life private costs for solar PV panels are associated with transport, landfilling, and less to the recycling process. Micro-level studies regarding social impacts on employment, health and safety, and cultural issues seem to prevail. As previously mentioned, although improved air quality can promote better health, the manufacturing process of solar power often implies exposure to toxic materials that pose a risk to human health [7]. Access to decentralized energy alternatives has also contributed to improving education [8] poverty [11], and local community income [9]. Despite these advantages, few studies considered a connection to SDGs [8].

4. CONCLUSION

Although assessed separately, results showed that impacts are interconnected, emphasizing the need to undertake a sustainability perspective for impact assessment. Future research should promote an integrated assessment of impacts across different project deployment phases; besides identifying impacts, its interconnections with SDGs should be promoted to elucidate policymakers further, mitigate negative impacts, and maximize positive impacts across regional and local scales. Analysis at multiple scales enables us to capture in greater detail both the benefits and costs of wind and solar power.

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Towards More Resilient and Sustainable Food Supply Chains through Environmental Traceability under a life cycle NEXUS approach

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ABSTRACT

In the contemporary food industry, the importance of traceability and food supply chain management is widely recognized for their critical roles in safeguarding food safety, ensuring quality standards, and enhancing transparency throughout the production and distribution processes. However, environmental problems have been tackled in isolation, considering the production on the one hand, and the consumption of products on the other. Therefore, the most advanced management models are changing towards integrated approaches that allow for establishing relationships between production and consumption, as well as environmental and quality aspects. According to this, it is imperative a multidisciplinar strategy, including the environmental performance of food products and the quantification of the environmental consequences of food fraud under a life cycle approach. This work develops the concept of Water-Energy-Food (WEF) nexus, with the aim of raising awareness of the connections between the universal rights to water supply, energy security and food provision, in addition to this a life cycle apoproach has been considered for this purpose.

Keywords: Ecolabel; Food; Life cycle assessment; Nexus.

1. INTRODUCTION

The food industry requires more advanced tools for traceability, authenticity, and sustainability monitoring to aid environmental and socio-economic issues at the same time boosting consumers' trust in sustainability-oriented certification schemes. The solutions in use these days are outdated and do not match the fast-moving and highly complex global market. There is an urgent need to provide the food industry with reliable tools which are simple in operation with high speed/turn-around harnessing recent technical developments. According to this, it is imperative a multidisciplinar strategy, including the environmental performance of food products and the quantification of the environmental consequences of food fraud under a life cycle approach.

Indicators from life cycle assessment methodologies (i.e., footprints) have emerged as useful tools for identifying and communicating the environmental impacts of a system thanks to they are accessible and intuitive and easy to understand to non-expert public [1]. However, the focus on a single environmental problem is one of their main drawbacks. From this idea arises the concept of Water-Energy-Food (WEF) nexus, with the aim of raising awareness of the connections between the universal rights to water supply, energy security and food provision [2]. Regarding the latter, the fisheries sector stands out as a fundamental pillar in the fight against malnutrition. In this sense, this work aims to provide technical guidance to calculate a single WEF nexus index for ecolabelling food products. Therefore, through this, it is expected to create a useful communication channel between producers and consumers through an easy-to-read ecolabel. Nonetheless, certain aspects, such as the footprints selected or the calculation procedures selected have to be reconsidered to refine the methodology proposed, apart from broadening the approach to other food sectors with the aim that the proposed eco-certification can be present in major supply and retail chains.

2. MATERIALS AND METHODS

The two international standards relative to the LCA (i.e., ISO 14040 and ISO 14044) were taken as reference to carried out the assessment of the environmental impacts related.

Accortding to the NEXUUS apoproach, four environmental footprint are calculated: i. water footprint (WF); ii. energy footprint (EF) and carbon footprint (CF); and iii. food footprint in terms of nutritional content (NF). The results of the four environmental footprints obtained can be interpreted individually to identify the main hotspots of the food products assessed from an environmental point of view. Later, the NF, WF, CF and EF together, will then form the basis for a process of normalisation, weighting and integration to obtain a single indicator, the WEFni. Finally, the WEFni is expressed in a front-end ecolabelling format to be applied to seafood products with the purpose of serving as a communication channel for consumers, allowing an easy interpretation through a single value, as well as a direct comparison with other food products [3]. Additionally, taking into account the life cycle approach, the environmental traceability is obtained from results.

3. RESULTS AND DISCUSSION

Addressing LCA studies applied to seafood products that focus on a single indicator may provide useful information regarding the system assessed. However, in seeking to broaden the scope following a WEF nexus perspective, it becomes crucial to take into account the interdependencies between water demand (WF), energy requirements (EF) and nutritional supply of produced seafood (NF) in a context of climate change (CF). Bearing in mind the above, the integration of several indicators through a single value (i.e., the WEFni) varying in a percentage could imply a potential option to gain in the visualisation of the results, especially for the average consumer, who often has no prior knowledge of environmental or nutritional issues. On the downside would be the increased difficulty in identifying major hotspots, such as a non-optimised energy production process or an excess of fuel burned in relation to the catches obtained. The above, in turn, would lead to a lack of precision in masking the individual contributions of some of the indicators (e.g., the individual influences of each nutrient within the NF).

Having analysed the advantages and disadvantages of the methodological framework proposed, the main challenge is to build the foundations of a harmonised procedure for assessing both the negative environmental burdens and the beneficial nutritional values of food products through a novel single index shown in an ecolabel, allowing comparisons to be made between them.

4. CONCLUSION

The methodological guidelines described in this work lay the foundations for estimating a new WEFni that attempts to provide a holistic approach for the comparative assessment of seafood products by penalising their environmental burdens while positively considering their nutritional profiles. Furthermore, this composite indicator has been illustrated in an easy-to-understand ecolabel that tries to pave the way for producers and consumers to manufacture and purchase, respectively, seafood products in a reliable manner, communicating their compliance with sustainability criteria. Likewise, with the goal that the proposed ecolabel can be applied in a near future to the main products of the supply chains in the food market, it could be necessary to carry out multiple iterations of the proposed methodology, modifying certain aspects such as the footprints, FU or allocation methods selected, as well as the normalisation and weighting procedures considered to achieve an approximation as close as possible of the true state of the seafood sector under the umbrella of the WEF nexus thinking.

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