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Contemporary Problems of Thermal Engineering
Gliwice, Poland, 23-26 September 2024

TOWARDS SUSTAINABLE & DECARBONIZED ENERGY SYSTEM: THE ROLE OF THERMAL ENGINEERING IN GREEN GROWTH

CONFERENCE PROCEEDINGS

Silesian University of Technology

Edited by Tomasz Simla

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Preface

On behalf of the CPOTE 2024 Organizing Committee, it is our greatest pleasure to welcome and host you during the 8th International Conference on Contemporary Problems of Thermal Engineering – CPOTE 2024. CPOTE 2024 conference is organized in Gliwice as a hybrid event and is devoted to problems faced by power engineers on a way towards sustainable and decarbonized energy system. CPOTE 2024 continues the tradition of bringing together distinguished scientists, engineers and professionals as an outstanding international community of experts in the domain of energy systems and their sustainable development, energy and exergy analysis, as well as other research areas.

We are very grateful to all the participants from 14 countries who have decided to continuously support the CPOTE conference series by submitting and presenting 72 topics. We hope that all our participants have the possibility to disseminate their work, to share and exchange opinions and knowledge within the conference sessions. The conference would not have been possible without all the excellent papers contributed by the authors, as well as without the prestigious invited lectures given by professors: Sandro Nizetic, Wojciech Adamczyk, Tetyana Morozyuk, Ricardo Chacartegui, dedicated to important topics: "Photovoltaic technologies and applications in ongoing energy transition", "Ammonia seen as alternative free-CO2 fuel", "Hydrogen technologies and Power-to-X: State of the art and multicriteria evaluation" and "Recent trends in seasonal thermal energy storage".

We would like to thank all the authors for their contributions and their participation in CPOTE 2024 conference. During the conference, 72 scientific presentations are scheduled, of which 61 are presented in an oral form during hybrid sessions, and 11 are presented in the form of a poster or a presentation on the conference's online forum. Selected papers presented within the CPOTE 2024 Conference will be invited to publication in Special Issues of prestigious scientific journals: Archives of Thermodynamics, Energy, International Journal of Exergy, International Journal of Hydrogen Energy, Journal of Energy Resources Technology, Journal of Power Technologies, Journal of Sustainable Mining and Renewable Energy.

Finally, we are pleased to present the Proceedings of the 8th International Conference on Contemporary Problems of Thermal Engineering containing 55 scientific articles.

Prof. Wojciech STANEK

CPOTE2024 Chairman

Silesian University of Technology, Gliwice, Poland

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Promoting life cycle thinking in higher education

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Abstract
The objective of the "Promoting life cycle thinking in higher education", Life-C project is to provide education and practical training in the life cycle assessment (LCA) field to minimize the environmental, economic, and social impact of the products and activities on future economies and industries. To this aim, the Consortium from Finland, Greece, Italy, and Poland has the specific objective of raising Life Cycle Thinking (LCT) awareness among Higher Education students, especially those from engineering and economic faculties, soon joining the modern industry. LCT awareness is spread by preparing and disseminating an e-learning course, made of a basic level, devoted to introducing students to LCT, Life Cycle Assessment (LCA), Social-LCA (S-LCA), and Life Cycle Costing (LCC)), and an advanced one devoted to the LCA application. This article will present and discuss the review of practical challenges for students developed in the project, formulated as project-based assignments in the field of LCA prepared within the project. The challenges aim to provide meaningful training for the students on the current state-of-the-art of LCA application in modern industry in terms of problem subjects, methodologies, problem background, and motivation, all based on the input of modern Companies and Researchers from different industry branches.

1 Introduction

One of the priority objectives of the European Union (EU) is environmental protection and the fight against climate change [1]. In this context, the environmental impact of any product, service or activity must first be assessed in order to anticipate the possible reduction of the resulting burden [2]. The LIFE-C project aims to promote life cycle thinking (LCT) and educate students and professionals from all

sectors of industry and higher education, by providing them with knowledge and tools to support future choices and decisions, minimising the environmental impact of their activities. The project will develop didactic and pedagogical materials along with a special free course in life cycle assessment (LCA) based on innovative teaching methods.

The overall objective of the project is to provide tools in the form of knowledge and lectures on minimizing the environmental impact of products and activities, supporting the development of a modern economy and an informed society for the future needs and requirements of a sustainable and circular economy and industry.

The partners proposed to contribute to this goal by raising awareness of life cycle thinking by preparing a free LCA e-learning course, available on a special e-learning platform, available to foreign students of engineering and economics, which aims to provide the necessary technical and economic knowledge needed to understand the sustainability of production processes and technologies with the LCT approach. All activities support the achievement of the UN Sustainable Development Goals no. 11 "sustainable cities and communities" and no. 12 "responsible production and consumption". The project and the prepared results take into account all three pillars of sustainable development – environmental, economic and social.

The specific objectives of the project relate to the expected changes, and the results to be achieved by the end of the project are:

- defining students' training needs based on their background (interdisciplinary student equality),
- collecting and evaluating the list of available IT tools for conducting LCA for teaching purposes;
- development of an LCA course for different levels of advancement;
- introducing innovative teaching methods and lifelong learning;
- building a modular course on the e-platform for lecturers/teachers of universities in the field of LCT;
- to teach students of partner universities, to strengthen their competences and skills in LCT and LCA, to provide the knowledge necessary to understand the impact of industrial activities on ecosystems, natural resources and human health on LC and to provide students with an open badge;
- coaching students in solving a project/challenge;
- making the course available on a free e-platform;
- creating a course manual containing challenge coaching methodologies;
- striving to increase the employability of university students in industries;
- increasing awareness and visibility of LCA as an entity with a large impact on the ecology and sustainability of supply chains among engineers and economists in modern society; increasing the competence of students and society in the field of green and soft skills.

The project is coordinated by the Silesian University of Technology (SUT) in Gliwice. The project partners and members are the Niccolò Cusano University (Unicusano) in Italy, the Lappeenranta-Lahti University of Technology (LUT) in Finland, the National Technical University of Athens (NTUA) in Greece.

1.1 Motivation and structure of the LIFE-C project

The LIFE-C project was submitted and funded under Key Action 2: Cooperation between organisations and institutions. Cooperation Partnerships in the Higher Education (HE) sector are international projects aimed at developing, transferring and promoting innovative practices and implementing joint initiatives promoting cooperation, peer learning, lifelong learning and exchange of experience at the European level.

The main motivation and inspiration for taking up the subject of the LIFE-C project is the need to increase awareness of LCT and LCA in contemporary societies, in particular, providing accessible education in the field of methods of qualitative and quantitative analysis of the environmental and social effects of human activity – materializing sustainable development, making it tangible; familiarizing

young people, students (and adults!) of technical and non-technical faculties with the general idea of LCT – educating future staff in order to search for and implement, for example, EU goals in the field of Climate and Energy, and increasing the competitiveness of future workers in the labour market for smart industry.

The main objective of the project is to develop a modular LCA/LCC/S-LCA course for higher education along with a set of teaching materials to be implemented at the universities involved.

The main expectations for the LIFE-C project are:

creating academic networks and laying the foundations for international cooperation for future projects;

- promoting life-cycle thinking both in academia and among the general public;
- providing an innovative course on an e-learning platform and a handbook containing complete guidelines and materials, consisting of three modules: (1) *Introduction to the life cycle thinking and assessment*, (2) *Application of the life cycle assessment*, and (3) *Social life cycle assessment*, all different in scopes and advancement levels for the students.
- enabling the implementation and adaptation of the modular LIFE-C course for each interested university.

The LIFE-C project started in September 2022 and is scheduled to end in August 2025. So, at the time of writing, the LIFE-C project is already halfway through. The project consists of five work packages (WPs):

- WP1: Project Management, Management, Quality Assurance and Internal Evaluation of Consortium Results;
- WP2: Survey and Need Analysis aims to define the needs and state of knowledge in the LCA teaching sector, in order to provide solutions and responses to identified educational gaps; this work package has already been completed;
- WP3: Designing and preparing teaching materials and assessment criteria, which aims to prepare a complete set of teaching materials and educational and coaching methodologies for students and teachers to implement and deliver the Life-C course at their universities; This work package is under development;
- WP4: Piloting the course and delivery of the final output, the main package of work dedicated to delivering the Life-C course to interested students, collecting grades and recognizing the ECTS credits earned. The WP4 package started in June 2024 and will last almost until the end of the project;
- WP5: Dissemination and exploitation – promoting life cycle thinking in higher education and building the presence of the Life-C project in social media during conferences, newsletters, profiles and webinars throughout the project.

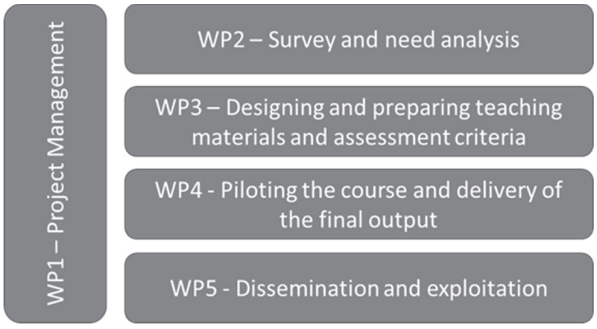

Figure 1: Structure of work in the LIFE-C project

1.2 Aim of the paper

The aim of the presented conference paper is to present the challenges for the students, collected from the Companies and project Partners as the real challenges of the modern industry and science in the field of the LCA. The challenges are the substantial part of the LIFE-C course, module 2 titles *"Application*

of the life cycle assessment", aimed for more in-depth and practical teaching of the LCA, based on the project-based tasks *i.e.*, challenges, given by the modern industry. The challenges, their scope, goals, motivation and backgrounds will be presented.

2 Collecting real challenges from companies to be solved by the students

2.1 Scope and goal of the collected challenges

The goal of the project team was to assembly the set of state-of-the-art challenges provided by the modern industry, capable of teaching the students how to approach and solve modern LCA-related problems. The scope of the challenges prepared within the LIFE-C project covers the student-company interaction, with a novel coaching approach using the LIFE-C coaching methodology, from the general problem statement *e.g.*, LC analysis of specific product manufacturing, or hotspots identification, to the specific solution supported with meaningful and well-develop LCA. The challenges were aimed to cover all aspects of LCA methodology, with significant field for students creativity, soft-skills training, and interpretation of the obtained results. The fields of collected 16 challenges can be listed as follows:

- Power engineering, renewable energy
- Civil engineering,
- Logistics and transport,
- Chemical engineering and manufacturing,
- Environmental engineering,
- Waste and biomass conversion for alternative fuels.

It must be stated that collected challenges are provided voluntarily by the Companies, and no commercial benefits are provided by the companies as the results of the project. The challenges are teaching-orientated tasks provided by the companies resembling current status of the industry problems that could be faced by the students in their future jobs and careers.

2.2 Overview of the collected challenges

The list of 16 challenges collected and prepared for the students are presented in Table 1. The tasks were provided by both companies and the researchers, covering a wide range of engineering applications. Nevertheless, used methodologies for LCA and in general an environmental impact assessment can be virtually applied to any scenario and field.

Table 1: List of the practical LCA challenges developed within the project.

Challenge topic	Provider	Goal and scope
1. Manufacturing of a torque transmission shaft, made with the filament winding method and carbon fibres	Company	The goal of the challenge is to assess the environmental impact of a torque transmission shaft manufacturing process with respect to inventory data provided by the company. The students will construct an LCA model based on educational database, recognize the potential environmental hotspot and try to provide potential areas for process improvement in terms of its environmental performance.
2. Multivariate life cycle analysis of heating and construction of a single-family house	Research	The challenge is focused on comparative life cycle analysis of the construction and heating of a different variants of a single family houses. Apart from regular LCA the life cycle cost (LCC) analysis is also considered.
3. Repowering analysis of the 50 MW windfarm in Poland	Company	Challenge is aimed for a theoretical analysis of a repowering of 50 MW wind power plant located in Poland. The LCA is carried out for different sets of wind turbines with specified inventories.
4. Acetate frame glasses manufacturing	Research/Teaching	The simple teaching-orientated challenge is aimed to introduce the students to the LCA methodology based on an example of acetate frame glasses manufacturing process for a simplified inventory.
5. Comparative analysis of life cycle of different carrier bags	Research/Teaching	The simple teaching-orientated challenge is aimed to introduce the students to the LCA methodology based on an comparative analysis of different carrier bags life cycle.
6. Comparative analysis of life cycle of different takeaway coffee cups	Research/Teaching	The simple teaching-orientated challenge is aimed to introduce the students to the LCA methodology based on an comparative analysis of different coffee cup types life cycle.
7. Analysis of different water desalination techniques from coal mines	Research	The challenge is based on a comparative analysis of different water desalination techniques defined for one of the coal mines located in Upper Silesia, Poland.
8. Comparison of two systems for evaporators manufacturing	Company	The challenge focuses on impact assessment of two different technologies for a evaporators manufacturing, based on two sets of inventories.
9. Analysis of wastewater treatment plant operation	Research	The task is based on a life cycle analysis of a simplified model of a wastewater treatment plant. The students will have a chance to familiarize with a industrial-scale, yet simplified multi-input model.
10. Analysis of biochar production from gasification	Company	The simple teaching-orientated challenge is aimed to introduce the students to the LCA methodology based on an innovative small-scale plant to produce biochar and energy from agricultural waste.

11. Logistic analysis of the food containers	Company	The simple teaching-orientated challenge is aimed to introduce the students to the LCA methodology based on a comparative analysis of different containers for the delivery of fish to large scale distribution supermarkets.
12. Comparative analysis of the digestion and composting as the organic waste management method	Company	The simple teaching-orientated challenge is aimed to introduce the students to the LCA methodology based on a comparative analysis of two alternative biological processes for the treatment of the organic fraction of municipal solid waste: simple composting and anaerobic digestion.
13. Natural refrigeration in supermarkets – impact of the ejector implementation into the CO2 “all-in-one” supermarket refrigeration system	Research	The LCA analysis of the "all-in-one" refrigeration supermarket system required the selection of the parameters to determine the sustainability of the novel technology based on the natural working fluid, which is the carbon dioxide. Therefore, the following criterion should be considered in the investigation: the environmental footprint to the special respect of the carbon and water footprints.
14. Comparison of environmental-friendly heat pumps in domestic application	Research	The LCA analysis of the air-to-water propane heat pump for domestic applications required the selection of the parameters to determine the potential of the use of the heat pump as the sustainable solution for domestic heating. Therefore, the following criterion should be considered in the investigation: the environmental footprint to the special respect of the carbon and water footprints.
15. Lyophilisation as a future solution for domestic food preservation - a comparison between the lyophilisation and standard freezing in the domestic fridge.	Research	The LCA analysis of the freeze—drying unit for domestic applications required a comparison together with a standard freezing in the domestic to determine the potential of the use of the lyophilisator as the sustainable solution for domestic food preservation. Therefore, the following criterion should be considered in the investigation: the environmental footprint to the special respect of the carbon and water footprints.
16. The power transformer equipped with environmentally friendly natural ester fluids	Research	The LCA analysis of the oil-immersed power transformer required the selection of the parameters to determine the potential of the use of biodegradable oil in power transformers as a sustainable solution for the electric grid. Therefore, the following criterion should be considered in the investigation: the environmental footprint to the special respect of the carbon and water footprints.

3 Expected results

3.1 Results of the solved challenges

The main expected results of the challenges are the obtained teaching effects of the students during the course, as well as valuable information for the companies and researchers. The students will present the solved challenge in a form of brief report, consisting of short introduction to the study's topic, detailed presentation of the LCA methodology, with defined functional units, analysed system boundaries and assumptions, and finally the results interpretation part. Apart from the *hard* effects of the challenge, students will also present their soft skills during the final project conference, with oral presentation of the challenges results for the beneficiaries and general audience.

3.2 Delivery and presentation of the results

The final presentation of the challenges are planned for the fall of the 2024, at the Environmental Protection in Power Engineering (EPAE) conference organized in Gliwice, at Silesian University of Technology. The students will present their challenges during regular sessions, presenting their own-performed LCA for the companies and regular conference audience. The goal of the final conference is to spread information about the LCA applicability, usefulness, and general life cycle thinking idea among the researchers, the industry representatives, and general public.

4 Conclusion

In this conference paper, a brief overview of the LIFE-C project, and collected challenges for the students is presented. The Consortium collected 17 challenges, covering wide ranges of backgrounds and applications, what significantly enhances teaching offer, students experience, and overall credibility of the prepared course for the higher education, and general education, including self-implemented long life learning for interesting beneficiaries. All of the LIFE-C project results will be made publicly available, free of charge, on the Erasmus+ results dissemination platform after the duration of the project.

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