ENV-510
SYLLABUS - FALL 2025

TUESDAY 04:00 PM-07:00 PM
ROOM: GC C3 30

Title: Life Cycle Assessment in energy systems

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3 credits
(presence in class/online attendance: 2 h./week)
(practical work through tutorial sessions: 1 h./week)
(personal work: 3 h./week)

LEARNING GOALS

This course aims to enable students to use modern environmental analysis tools for the life cycle of products and processes and to understand their limits of applicability.
At the end of this course, the student should:

- Understand the principles, mathematical foundations and methodological choices of life-cycle assessment
- Perform a transparent and consistent comparative life-cycle assessment study
- Critically evaluate a life-cycle assessment to guide a decision-making process

Specific objectives

- Describe the theory and principles of Life Cycle Assessment (LCA), as defined in ISO 14040 and ISO 14044.
- Define the objectives and the scope of an LCA study from a real problem (objectives, functional unit, system boundaries, etc.);
- Distinguish key life cycle inventory databases and impact assessment methodologies;
- Collect primary data and scale inventory at the process level and at the functional unit;
- Model realistic product systems, calculate life cycle impacts, and compare the impacts of various products with equivalent functionality;
- Use the basic functionalities of an LCA software;
- Interpret the results of an LCA study and make recommendations in the context of decision-making;
- Distinguish requirements associated with different types of study (internal study, third-party report, publicly disclosed comparative statement);
- Determine the limits of the LCA as well as the contexts of appropriate applications

COURSE'S UTILITY

Bombarded for years by expressions such as "sustainable development" and "green", consumers are becoming increasingly demanding about the quality and availability of environmental information associated with the products they consume. Producers have to fulfil these new demands, but the tools they have are limited. Product design is one of the biggest levers towards a green economy. The engineer, as a designer, is at the forefront of acting to significantly reduce the environmental footprint of products and services.

Life cycle assessment (LCA) is a method of assessing the potential environmental impacts of a product, process, or service. The method covers all phases of the life cycle (extraction of natural resources to waste disposal, through the use of the product) and considers a wide spectrum of impacts affecting human health, ecosystem quality, climate change, resource depletion. The LCA method was developed to meet the specific needs of companies wishing to minimize their impact on the environment in the development and improvement of their products and services. It is above all a decision-making tool whose methodology is governed by the International Standards Organization (ISO) with the series of environmental standards ISO 14040 and 14044:

The LCA assesses the potential impacts generated on a product's life cycle, identifies hot spots across its value chain, and trade-offs in environmental problems.

LCA can be used to:

- Provide information on the potential environmental impacts of a product to communicate to buyers or other stakeholders (support environmental declarations);
- Find, internally, the most environmentally friendly way to manufacture and manage the product through its eco-design chain;
- compare, from an environmental perspective, different types of products that offer the same service;
- assess the environmental consequences of implementing public policy or business strategy.

The implementation of *Life Cycle Assessment* (LCA), has four major phases:

- "Goal and Scope Definition,", which defines why, for whom, and how to conduct an LCA, including defining the function of the product and identifying all interconnected processes, mobilized by its production, use, and disposal;
- "Life Cycle Inventory" (LCI), during which environmental emissions and resource extractions are accounted for each of the value chain processes in relation to the functional unit;
- "Life Cycle Impact Assessment" (LCIA) of the emissions and extractions identified and quantified in the previous phase in a few relevant impact indicators; and,
- "Interpretation of results" to identify significant points in the results of an LCA study in relation to methodological choices made in previous phases, assess their robustness and limitations to finally draw conclusions and recommendations.

Given the amount of data considered and the complexity of the processes involved, an LCA cannot be carried out without the reliance on databases and software for analysis and interpretation. An important part of the work of an engineer involved in the conduction of an LCA study will therefore be to learn how to master these computer tools and interpret the results according to the modeling choices and primary data collected in the field or via the literature.

KEYWORDS

Detailed study of life cycle assessment (LCA). ISO 14040 and 14044. Defining the goal and scope of the study. Inventory analysis: mathematical aspects, bottom-up and top-down approaches, attributional and consequential approaches, multi-functionality. Life cycle impact assessment: cause-and-effect chains, models and characterization factors, life cycle impact assessment methodologies. Environmental impacts and indicators. Classification, characterization, standardization, and weighting. Interpretation of results: analysis of contribution, sensitivity, uncertainty, scenario. Use of LCA databases and software. Critical analysis of a public LCA study. Conduction of a LCA project in the student's area of expertise. Types of LCA studies: internal, third-party report, comparative assertion disclosed to the public.

TEACHING AND LEARNING METHODS

The methodology for conducting a life-cycle assessment will be presented through a mix of traditional lectures, of "flippedclassrooms", and supervised active learning activities. The analysis of a few real cases will allow students to realize the breadth and complexity of these studies.

In addition, a project-based approach ensures that the students get hands-on experience. The student teams will progressively conduct a complete comparative LCA for a selected product system. Each team will be mentored by an experienced LCA analyst or teaching assistant. A preliminary report and oral presentation will allow for early feedback on their LCA project, which should be taken into consideration in the process leading to the final report and oral presentation.

LEARNING ASSESSMENT

LCA PROJECT = 50%
PRELIMINARY DELIVERABLE, ORAL & REPORT (10%);
FINAL DELIVERABLE, ORAL & REPORT (40%)

FINAL EXAM = 50%

Exam

The final exam aims to evaluate the student's understanding of the methodological foundations and practical aspects of life-cycle assessment. A recto-verso sheet of personal notes on A4 paper is permitted.

A minimum grade of 3.5 over 6 is required in the final exam, otherwise, the grades for the project will not be considered and a failing grade is assigned.

LCA-PROJECT AND TEAMWORK

An important part of this course is devoted to the conduction, as a team, of an analysis of the life cycle of a product or service. The completion of this project allows students to apply the concepts and methods seen in class. More generally, through this project, students will demonstrate that they are capable of:

- Defining the goal and scope of the LCA study in a coherent way, i.e. defining the function, functional unit, product system, and its boundaries, etc.;
- Collecting the necessary primary data, scaling it up and using the available databases to model the entire lifecycle inventory;
- Using LCA software;
- Assessing the life cycle impacts and understanding the differences between outcomes generated by different impact assessment methods;
- Conducting contribution analysis and sensitivity analyses;
- Interpreting results in relation to modeling choices and inventory data and identify study limitations.
- Provide recommendations in respect of the goal of the study

The working groups will be made up of five to six students (depending on the number of registrations). While task-sharing can be done within each group, all students must ensure that they understand and assimilate all elements of the LCA.

Teamwork will be evaluated through two reports and two oral presentations. The preliminary report (max 10 pages) includes the goal and scope of the comparative LCA. The final report (max 25 pages) builds on the preliminary one and presents the overall results of the comparative LCA study. Specific requirements for reports and presentations will be communicated to students during the session. Note that each student's participation in at least one of the two presentations is required.

Please note that all team members are equally responsible for the project deliverables which will be evaluated by the teaching team at several progress stages. Feedback will be provided to students at each step allowing them to continuously improve the LCA project across the whole process. **The overall evaluation of the LCA project will be subsequently tailored to each team member based on a peer evaluation from team members.**

It is allowed to use generative artificial intelligence systems (GAIS) as a writing aid and for inspiration, provided that (1) you cite the tools used and (2) the ideas and opinions expressed reflect your own thinking. In addition, any factual assertion must be supported by a credible reference (scientific article, report, etc.) available during the evaluation by the teaching team.

REFERENCE BOOKS

Highly advised (and subject to review):

- **Jolliet, O., M. Saade-Sbeih, S. Shaked, A. Jolliet. Environmental Life Cycle Assessment. CRC Press. Boca Raton, Florida. 302 pp. ISBN 978-1-4398-8766-0**
  Freely available ebook version: https://doi.org/10.1201/b19138

Or its alternative the French version:

- **Jolliet, Saadé, Crettaz, Jolliet-Gavin, Shaked (2017). Analyse du cycle de vie : Comprendre et réaliser un écobilan. 3e Edition. Presses polytechniques et universitaires romandes.**

Or

- MOOC Introduction à l'Analyse du Cycle de Vie
- ISO 14040: 2006 and ISO 14044: 2006 (A copy of these standards is available at the library)

Other key support works:

- Heijungs and Suh 2002. The Computational Structure of Life Cycle Assessment. Kluwer Academic Publishers 241p.
- JRC (2009a) General guide for Life Cycle Assessment (LCA). ILCD Handbook. European Commission, Joint Research Center, Ispra. http://lct.jrc.ec.europa.eu/publications
- Hauschild, M.Z., Rosenbaum, R.K., Irving Olsen S. 2018. Life Cycle Assessment: Theory and Practice. Springer. https://link.springer.com/book/10.1007/978-3-319-56475-3

Other references/readings will be recommended during the lectures and posted on Moodle. (If necessary, specify the required and optional documentation for the course.).

COURSE PLAN

Week	Date	Activity	Tasks before each course
1	09 Sept	**Introduction to Life Cycle Assessment (LCA) (M.Margni)** - Overview of LCA and getting familiar with the life cycle concept - Examples of LCA applications - Presentation of professor and students - Presentation of the course syllabus - Introduction to LCA group project	
2	16 Sept	**Methodological LCA framework, goal & scope, functional unit, product system (M. Margni)** - The conceptual model of LCA - Methodological LCA framework according to ISO 14040 - Defining the goals and scope of an LCA o Function, functional unit, reference flows o Product system, process flow diagram, and system boundaries	
3	23 Sept	**The systemic view of an integrated energy system through the life cycle approach (F .Maréchal)**	
4	30 Sept	**Life cycle inventory (M. Margni)** - Computation of the life cycle inventory (LCI) o Sequential vs. Matrix approaches - Introduction to life cycle inventory databases - Attributional vs. consequential life cycle assessment	LCA teams need to be built with a defined LCA project approved by the teachers
5	07 Oct	**LAB1: Define the scope and model the carbon footprint of Aluminum cans of carbonated water (TAs)** - Modeling on paper: Scope definition, calculate the life cycle inventory and the carbon footprint, preliminary interpretation - A quick overview of the openLCA software - Modeling the case study with the openLCA software	openLCA needs to be installed on your own laptop/PC
6	14 Oct	**LAB2: Define the goal & scope (G&S) and modeling with openLCA (TAs)** - Define the G&S of a comparative LCA between three different hand dry systems - Aluminum can case study: Adaptation of unit processes and product systems in openLCA	
	21 Oct	**Interruption des enseignements**	
7	28 Oct	**Modeling multifunctional processes & the end-of-life, exploring of ecoinvent database (M. Margni)** - Introduction to the issue of multifunctionality in LCA - Dealing with multifunctional processes - The case of recycling - The life cycle inventory database ecoinvent v3 **LAB3: Multifonctionality and endo-of-life in openLCA (TAs)** - Allocation and recycling in openLCA - Modeling the End-of-Life of Aluminum can - Exploration of ecoinventv3.6 in openLCA	
8	04 Nov	**Oral presentations of LCA group projects: G&S** - preliminary deliverable on the G&S	Presentations uploaded on Moodle **at noon at latest** Reports upload on Sunday 23h59 at latest

Week	Date	Activity	Tasks before each course
9	11 Nov	**Life Cycle Impact Assessment (LCIA) (M.Margni)** - Midpoint-Damage LCIA framework - Mandatory and optional elements of LCIA	
10	18 Nov	**LCA Interpretation fundamentals (M.Margni)** - Overview of the interpretation phase - Contribution analysis - Sensitivity/scenario analysis **LAB4: Impact assessment and basic interpretation in OpenLCA (TAs)** - Import of impact assessment methodologies - Calculating impact scores and environmental profiles - Contribution analysis	
11	25 Nov	**Advanced LCIA considerations (LCIA) (M. Margni)** - Good practices and state-of-the-art LCIA - Key points and limitations - Main impact categories and characterization methods - Calculating a carbon footprint (Accounting for biogenic carbon) **LAB5: Interpretation in openLCA** - Sensitivity/scenario analysis	Describe the causality chain and indicators of a specific impact category (short presentation: 5 min) The modeling of the different options of sparkling water needs to be finalized
12	02 Dec	**LCA Interpretation (M.Margni)** - Overview of the type of analysis in the interpretation phase - Sensitivity/scenario analysis - Uncertainty analysis - Assessment of data quality	
13	09 Dec	**Revision of the course (M. Margni)** - Case study on waste to energy valorization - Critical analysis of LCA studies / environmental declarant. - How to account for biogenic carbon? - Q&A Quiz	
14	16 Dec	**Oral presentations of LCA group projects: LCA results and interpretation** - final deliverable	Presentations uploaded on Moodle **at not at latest hours** Reports uploaded on Moodle on Sunday at 23h59 at latest
	Jan 2025	**Exam** *Exact date set by the administration*	