

## **Student project – coupling energy system models to life cycle inventories and quantify environmental burdens.**

Various (industrial) energy system models – such as Integrated Assessment Models (IAMs)<sup>1</sup> – have been developed to explore future decarbonization pathways at (industrial) cluster, European, and global scales. These models typically optimize technology deployment for the energy system under socio-economic pathways. However, they do not quantify the full life cycle environmental impacts associated with such development pathways, meaning potential environmental trade-offs, co-benefits, and potential burden shifting to other regions remain invisible<sup>2</sup>. To address this gap, model outputs can be coupled with environmental life cycle assessment (LCA), thereby enabling the assessment of environmental impacts, such as greenhouse gas emissions, resource use, and other sustainability indicators. Currently, we have already coupled some IAMs using Python package *premise*<sup>2</sup>, but we lack coupling between smaller (industrial) scale models. To couple local energy and industrial system models, we can match the model outputs with life cycle inventories by mapping model variables (technology/product/region/year) to appropriate life cycle inventory datasets matching the ecoinvent database<sup>3</sup>. This student project will focus on coupling such energy system models to LCA, potentially with the help of AI, but with careful validation.

### **Main objectives**

Generate, validate, and document the mapping between output variables from energy system models and life cycle inventory datasets. In addition, operationalize a reproducible workflow for those model couplings.

### **Student requirements**

We are looking for an MSc student (intern or MSc thesis) with (~6 months):

- Knowledge on environmental life cycle assessment;
- Familiarity with programming language Python;
- A strong plus is familiarity with Brightway2 and potentially *premise*.

### **Main tasks**

The objective is to support the coupling of industrial and energy system model outputs with life cycle inventories in a consistent and validated manner, the main tasks foreseen are as follows:

1. Understand the outputs of the energy system models used (likely in IAMC-format<sup>1</sup>-like) that need to be coupled to life cycle inventories.
2. Next, couple those model outputs to LCI mappings (main task). As such, the main goal is establish mappings between IAMC variables (technology, product, region) and corresponding life cycle inventory datasets (those from ecoinvent/*premise*). Thoroughly validate each mapping to identify and resolve potential inconsistencies. This will be the most important and time-intensive part of the work.
3. Apply and test it using the in-house developed tool *pathways*<sup>4</sup>. Implement the validated mapping for multiple model contexts, including the Antwerp-Rotterdam-Rhine-Ruhr Area (ARRA) cluster, the Port of Rotterdam, and potentially European-scale models (like PyPSA-Eur<sup>2</sup>). Ensure

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<sup>1</sup> <https://www.iamconsortium.org/scientific-working-groups/data-protocols-and-management/iamc-time-series-data-template/>

<sup>2</sup> <https://github.com/PyPSA/pypsa-eur>

consistency of units, system boundaries, and aggregation across cases. The testing also implies generating first LCA results of entire energy system transformation pathways.

4. Optional extension: Primary vs. secondary material implementation in *premise*. Improve how changing primary and secondary material shares can be integrated into *premise*. Develop and test a (simple) implementation for selected materials.

#### **Expected Deliverables/outputs**

- A validated mapping table (variable → LCI dataset) with confidence levels and documentation.
- A reproducible script-based workflow to couple LCIs with model outputs for at least one energy transition model.
- A short technical note summarizing key decisions, limitations, and recommended best practices.
- Potential LCA results.

#### **How to apply**

Please send your CV, motivation, and transcript of records to [tom.terlouw@psi.ch](mailto:tom.terlouw@psi.ch) and [christian.bauer@psi.ch](mailto:christian.bauer@psi.ch).

#### **References**

1. Riahi, K. *et al.* The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global environmental change* **42**, 153–168 (2017).
2. Sacchi, R. *et al.* PProspective EnvironMental Impact asSEment (premise): A streamlined approach to producing databases for prospective life cycle assessment using integrated assessment models. *Renewable and Sustainable Energy Reviews* **160**, 112311 (2022).
3. Wernet, G. *et al.* The ecoinvent database version 3 (part I): overview and methodology. *Int. J. Life Cycle Assess.* **21**, 1218–1230 (2016).
4. Sacchi, R. & Hahn-Menacho, A. J. pathways: life cycle assessment of energy transition scenarios. *J. Open Source Softw.* **9**, 7309 (2024).