Towards a techno-economic and life-cycle assessment simulation tool for H_2 / Natural gas CHP-based systems to help local energy policies

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Context and objectives

The **CO2InnO project** is a France-Germany cross-border living laboratory, one of its key objectives being an comprehensive assessment of H_2 use in potential decentralized energy systems[1]. It involves use of **H_2** as a fuel for **combined heat & power** (**CHP**) **plants**, due to their high efficiency.

The goal is to provide users (e.g. local authorities, NGO, companies, etc.) with a tool allowing to test various configurations of system components and functioning, evaluate their feasibility (technical), interest (economical), and impact (environmental).

This is part of a contemporary trend to try and combine what is known as **techno-economic analysis** (**TEA**) and its environmental counterpart, the **life cycle assessment** (**LCA**)[2]. This combination is challenging due to methodological considerations, but also because there is nearly no operational tool at disposal to conduct such integrated assessments. Moreover, the most advanced propositions are based on proprietary software[3].

Our ongoing work propose a framework for such a task, while incorporating an **open science approach wherever possible**. It is built on a case study of the Offenburg municipality buildings energy requirements.

Firstly, a simulated energy system have been developed in **OpenModelica** by our project partners to investigate the boundaries of technical feasibility[4]. Based on these results, we are conducting a **parametric prospective LCA** of every system components[5-6]. Indeed, even though the burning of **H_2** can be considered climate neutral if considered in the use phase only, the environmental impact during the whole life cycle is not – nor the assessment should be limited to CO_2 emissions[7-8]. Disaggregated results will then be imported back into the **OpenModelica** simulation to allow dynamic access to **LCA** results, depending on simulation parameters set by users. **This would act as a decision support tool helping these actors plan their local energy transition.**

References

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[5] Mutel, C., 2017. Brightway: An open source framework for Life Cycle Assessment. J. Open Source Softw. 2, 236. DOI.
[6] Sacchi *et al.* 2022. PRospective EnvironMental Impact asSEment (premise): A streamlined approach to producing databases for prospective life cycle assessment using integrated assessment models. Renew. Sustain. Energy Rev. 160, 112311. DOI.
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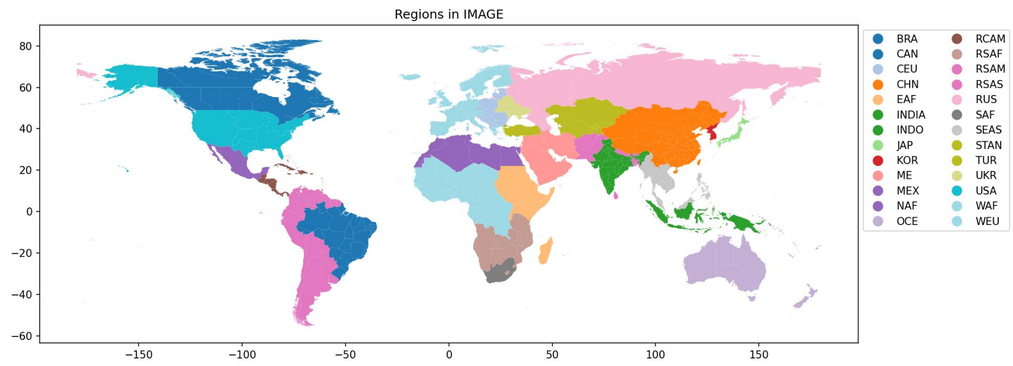
[8] Zhao *et al.* 2020. Life cycle assessment of H2O electrolysis technologies. Int. J. Hydrog. Energy 45, 23765–23781. DOI.

Currently missing regionalization

The IAM models (IMAGE/REMIND) used in the premise tool have slightly different geographical definitions and resolution. **None of them display a country-level resolution regarding Europe**. This prevents comparative assessment of the relevance of the H_2 / Natural Gas CHP-based systems to guide local planning policies in FR/DE.



Premise documentation: Geographical mapping of IMAGE. https://premise.readthedocs.io/en/latest/transform.html#geographical-mapping

To resolve this limitation, **we need to integrate (*via* premise) additional specific scenarios regarding the evolution of the electricity mix in FR and DE**, on the model of what is already available for CH.

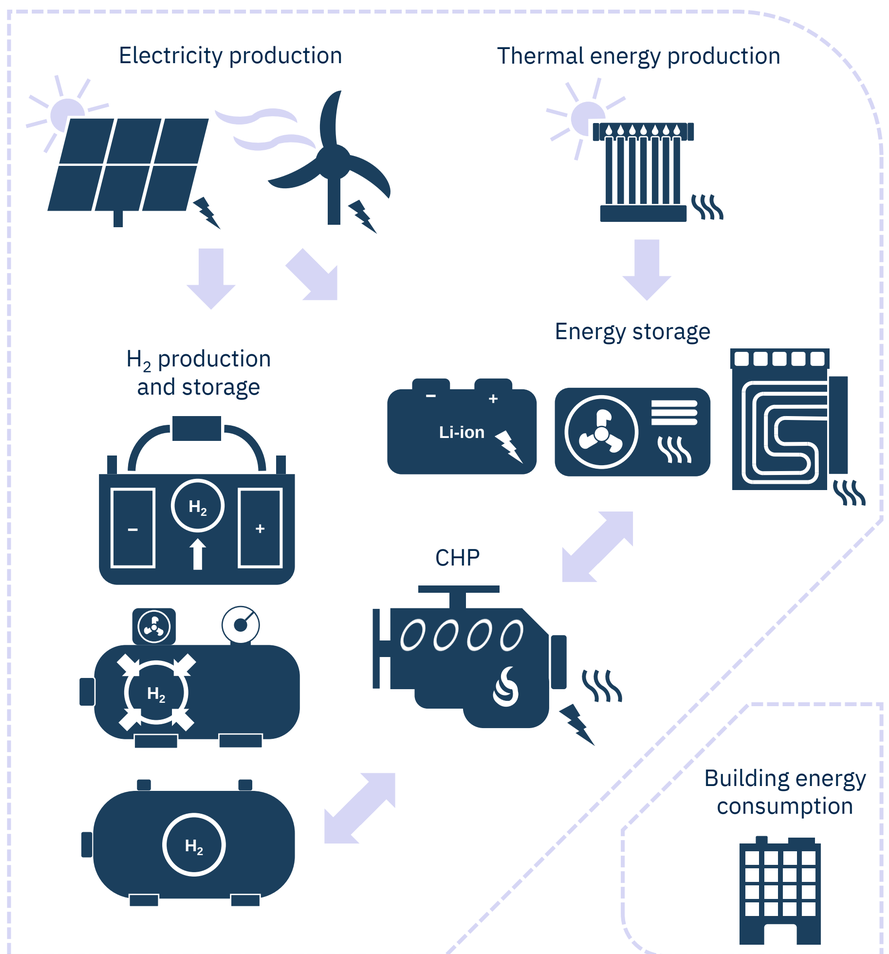
Indeed, based on the literature, it is reasonable to consider that this parameter is the most critical for the relevance of modeling the life-cycle impacts of such systems.

Creation of FR scenarios based on the RTE & ADEME reports have been realized by R. Sacchi and his colleagues, and should be available at the end of 2024.

We are currently looking forward to realize the same kind of work for DE based on the Fraunhofer ISE & GEA reports.

System description

A simulated energy system have been developed in **OpenModelica** by partners in the **CO2InnO project**[4].



Real data of thermal and electrical energy consumption of municipality buildings
Provided by the Offenburg city, with 1 h time resolution for one year
➔ Determination of energy system requirements for 2 main cases:
1 building alone (decentralization at building level)
5 buildings, shared equipment (decentralization at building complexes level)
➔ Multiple what-if situations tested to obtain reasonable dimensioning intervals for each single system component

	For 1 building			For all 5 buildings		
	From	To	Unit	From	To	Unit
PV	0	1000	m²	7000	15000	m²
Wind turbine	0	1	MW	0.5	1.5	MW
Battery	3	20	kWh	200	500	kWh
Electrolyzer	14	40	kW	400	700	kW
Thermal Storage	0,05	1	m³	10	20	m³
Gas Engine CHP	2,85	20	kW_{el}	30	115	kW_{el}
Heat Pump	5	40	kW_{th}	135	220	kW_{th}
Solar Thermal	5	15	m²	0	30	m²
H_2 Tank	1	100	m³	5	1000	m³
Compressor	80 bar and 4,44 Nm³/h			80 bar and 77 Nm³/h		

Framework for integration of LCA results into the TEA tool

System dimensioning via the OpenModelica simulation

First round of technical simulations
➔ Reasonable value intervals for dimensioning of each system component
➔ **Separate LCAs of each system component**

Open science tools for LCA

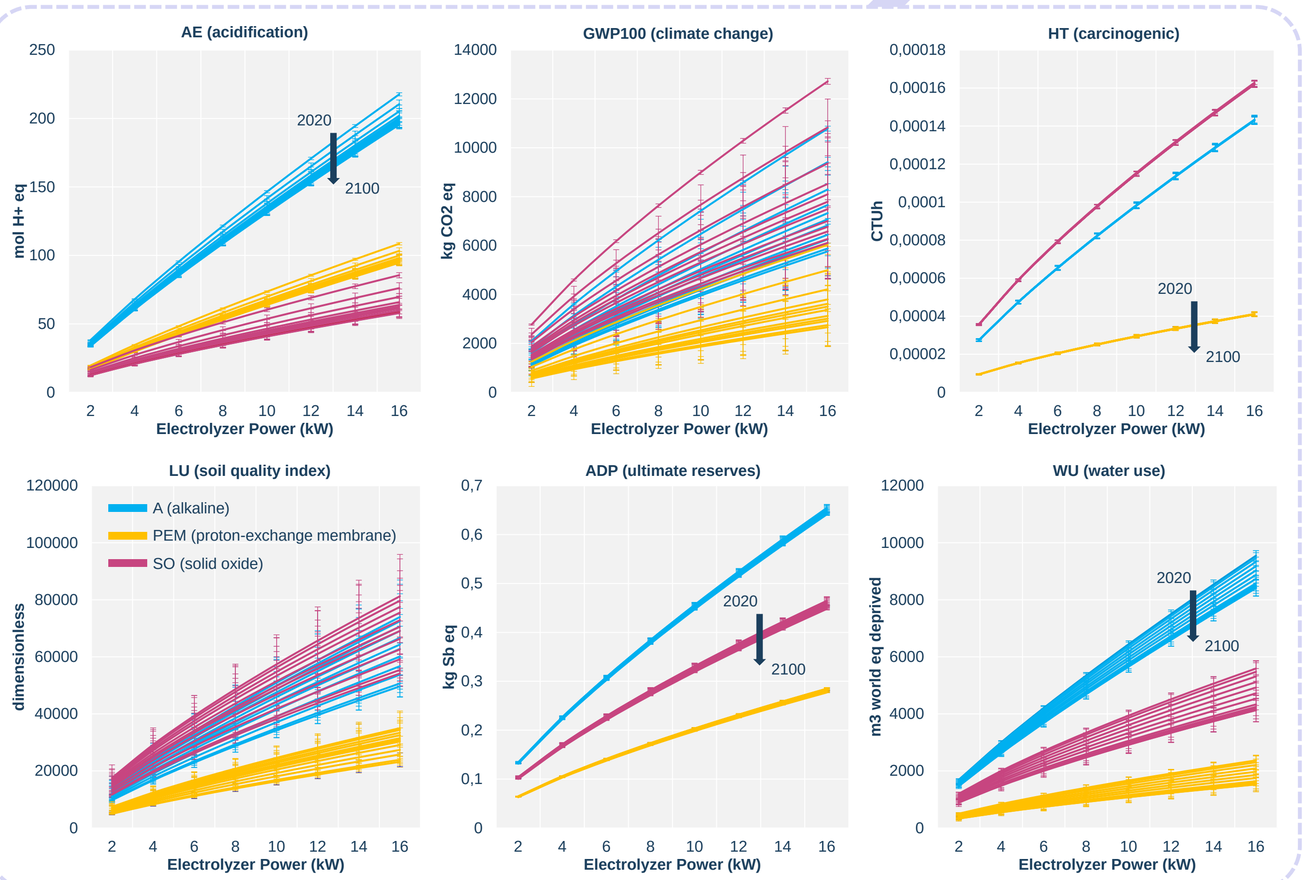
Brightway2: open-source software for LCA (in python)[5]
➔ Breaking the limits of the conventional LCA software
➔ Modular design, collective development of functionalities
➔ Advanced parametrization and prospective modeling

Taking into account the prospective dimension

Prospective LCA, using the **premise v2.0.1 tool**[6].
SSP (Shared Socioeconomic Pathways) scenarios
➔ Ecoinvent database (*not open source*) modification
➔ Consistently futurized databases

Illustrating example: Electrolyzer fabrication process

State of the art LCI[7]
➔ LCIA method: **Environmental Footprint v3.1**
➔ scaling of “Stack” and “Balance of Plant” subparts
➔ All variants of available SSP scenarios (SSP1, SSP2, SSP5)



CURRENT WORK

Extension to all components for all stages of the life cycle

Pre-calculated results for the 2 main cases
Disaggregated database

PERSPECTIVES

Data imported back into OpenModelica simulation for combined TEA-LCA

Investigating optimization opportunities Helping local plans for energy transition

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