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Uncertainty and hybrid life cycle assessment

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Capturing uncertainty in life cycle assessment is necessary to ensure the robustness of environmental impact results, and of subsequent policy recommendations in case of comparative studies. Hybrid LCA consists in extending a system's data relying on environmentally input-output (EEIO) databases, to include processes that are not usually covered in traditional life cycle inventory databases. However, EEIO databases do not provide uncertainty data. We present a method to derive uncertainty data from a symmetric input-output table, in order to make hybrid life cycle inventories more consistent. We exemplify this protocol by applying it to the *EXIOBASE2* database, and by analysing the results from a case study on mobility scenarios in Luxembourg.

I. INTRODUCTION

In the field of life cycle assessment (LCA), data collection for life cycle inventory (LCI) building is often highly resource-demanding, due to the extensive amount of specific process data to collect and the harmonisation efforts linked with the diversity of data sources. Despite existing ISO norms defining LCA practice [1], no universal quality standard yet exists on LCI compilation. Therefore, individual review is often needed, yet an additional effort towards higher LCI data quality [2]. Uncertainty information is therefore necessary to capture the degree of accuracy of LCA results. Extending process-based LCI with environmentally-extended input-output (EEIO) data, for the practice of "hybrid LCA", aims at improving the completeness of a life cycle system. A common example of issue addressed by hybrid LCA is the "truncation bias" inherent to LCIs built from databases representing mostly industrial data, while neglecting services [3]. Hybridizing an inventory introduces further parameter uncertainty, as well as uncertainties arising from assumptions, simplifications and aggregation. While LCA databases provide uncertainty data, no EEIO database does [4].

The CONNECTING project aims at analysing various mobility scenarios for cross-border commuting between France and Luxembourg. This consequential LCA study combines agent-based modelling, to simulate commuters' behaviours, and hybrid LCA, to quantify the environmental impacts of vehicles and infrastructure. In this context, we propose a protocol to derive uncertainty data for the hybrid LCA part of the model.

II. MATERIAL AND METHODS

The hybrid database used to model the transportation modes used by cross-border commuters over the years 2015 to 2025 is based on *ecoinvent 2.2* [5] and *EXIOBASE2* [6]. It is also adapted to follow future energy and industry scenarios [7], and is aggregated to contain data for Europe, China, and North America. The so-called "foreground" inventory consists in electricity generation processes that are absent from *ecoinvent 2.2* and the mobility inventories. Figure 1 shows a simplified representation of the complete database. The *ecoinvent 2.2* database comes with uncertainty data, estimated following a "pedigree" approach, a method to quantify data quality and representativeness, and therefrom, derive standard deviations. *EXIOBASE2* does not contain such data.

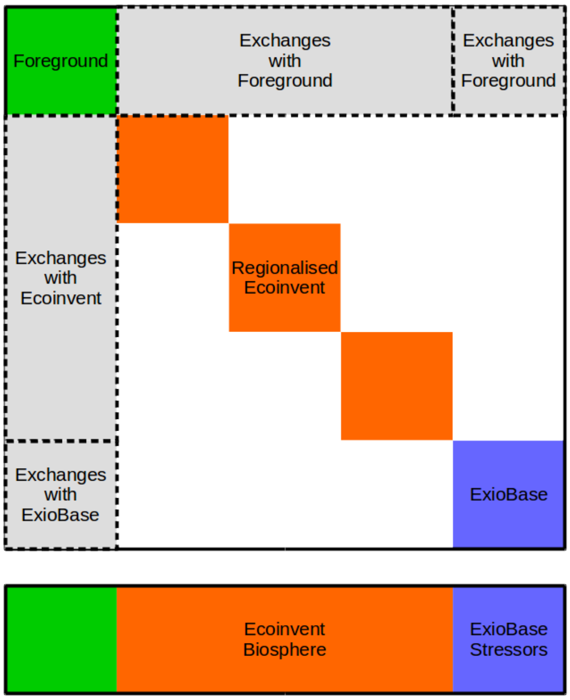

FIGURE 1: HYBRIDIZED INVENTORY.

III. RESULTS AND DISCUSSION

To quantify uncertainty in a consistent way, all elements of the hybrid database, both in the technosphere (interindustry data) and the biosphere (environmental data), need uncertainty characterization. Input-output tables are compiled at the national level from the annual reporting of activities of economic sectors; such information is therefore missing for input-output data (depicted in blue in Figure 1). In absence of any data quality information, we suggest the following protocol:

- Assume a normal distribution for each element of the technosphere and biosphere (respectively EXIOBASE and EXIOBASE stressors in Figure 1), with a mean given by the reported value of the parameter, and a standard deviation equal to 10% of that mean,
- Perform a numerical uncertainty analysis (a Monte Carlo analysis in our case) to propagate parameter uncertainty, by sampling each element at each iteration.

At the current stage, inventories are built, while the agent-based model simulator is still under development. We therefore test the model preliminarily without the connection with the simulator, and for a given foreground inventory (namely, buses) analyze the uncertainty, and identify the most contributing input-output processes. As an example, the emissions from the input-output database contribute to about 5% of the total life cycle emissions of diesel bus transportation. We determine here whether that contribution may in fact be higher once uncertainty is taken into account.

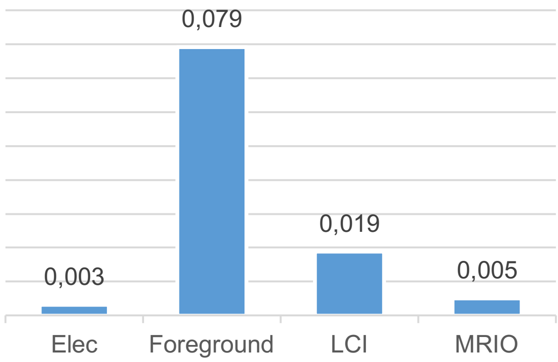

FIGURE 2: GREENHOUSE GAS EMISSIONS FROM 1 PASSENGER-KM, DIESEL BUS, IN EUROPE, 2010, BROKEN DOWN BY DATABASE CONTRIBUTION (ELEC = FOREGROUND ELECTRICITY, FOREGROUND = DIRECT EMISSIONS FROM BUS INVENTORY, LCI = PROCESS-BASED LIFE CYCLE EMISSIONS, MRIO = EMISSIONS FROM THE MULTIREGIONAL IO DATABASE).

IV. CONCLUSIONS

Hybrid LCA aims at improving the accuracy of products' and services' system description in order to improve the robustness of environmental impact assessments. However, this extension is done with input-output data, which do not contain uncertainty information. Input-output table compilation undergoes a lot of steps that modify primary data, so this primary data quality is lost and cannot be measured realistically. By deriving uncertainty information for input-output data, our approach is a first step towards consistency in hybrid LCI compilation, in which all flows are associated with quantitative uncertainty measures.

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