A user-friendly tool based on Simplified parametrized LCA to eco-design reusable bottle scenarios

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INTRODUCTION

LCA is a reference methodology to assess the environmental impacts of agri-food systems. Non-practitioner stakeholders often find LCA **complex**, notably due to its resource-intensive nature and specialized knowledge requirements. It leads to:

- Preference for simpler methods *(e.g., Carbon Footprint)*
- Use of generic environmental profiles despite potential variability within systems
- Late integration of LCA in the development process (check and justify rather than eco-design)

Simplified tools are needed to help stakeholders to involve LCA in their decision process, **combining simplicity and scientific accuracy**.

OBJECTIVE

Simplified parametrized LCA models developed in the past decade, mostly applied to electricity production (Padey et al., 2013, Douziech et al., 2021)

We developed a user-friendly LCA software for **reusable bottle systems**, based on the generation of multiple simplified parametrized LCA models for various archetypes of a typology of systems. It aims to simply compare scenarios at the early stage of the development of a reusable bottles system within a territory.

The work consisted in:
(1) Develop a **typology** of systems with stakeholders
(2) Generate **simplified parametrized LCA models for each archetype**
(3) Develop a **user interface**

METHODOLOGY

1. Typology of systems:

- Developed by interviewing eight stakeholders involved in the sector of reusable bottles
- Based on the main organisational parameters for the systems
- Each combination of modalities defines an archetype

RESULTS

Stock of bottles	Cleaning	Distance to cleaning	Production and bottling sites	Sale channels	Third-party for logistics	Bottle manufacturer	Market	Reverse vending machine	Collection	Bottle type[1]	Maturity of the system
Individual (to one producer)	Internalized	< 100 km	Same	Mix	Yes	In the area	Regional	No	Not integrated	75 cl brown bottle (beers)	< 5 years
Mutualized (between producers)	Externalized	> 100 km	Different	Direct sale	No	In the Country	National	Yes	Integrated	75 cl white bottle (sparkling drinks, lemonade type)	5 to 10 years
				Catering		In Europe	International			75 cl green bottle (cider type)	> 10 years
				Supermarkets						1 l white bottle (juices)	
				Groceries							

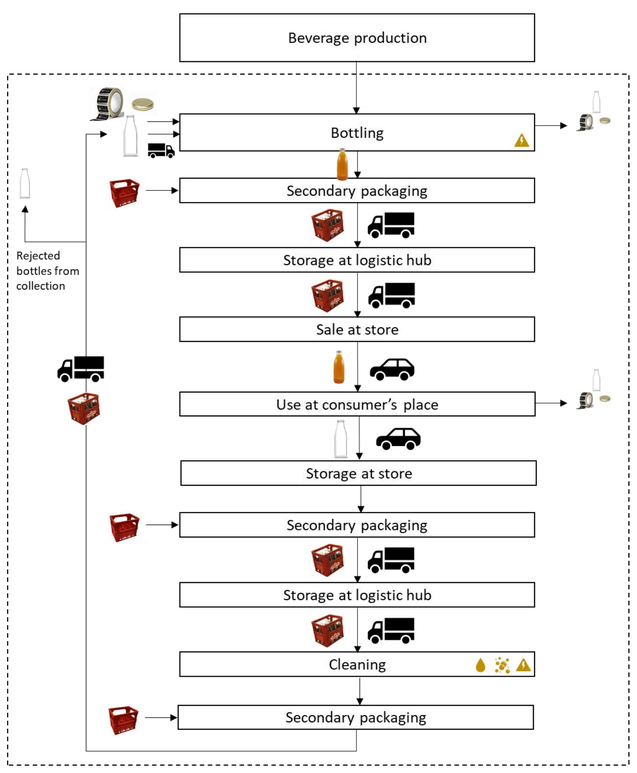
Typology (Example of Archetype #122111211111)

Simplified parametrized models generated for 1 672 archetypes

2. Simplified parametrized LCA models (for each archetype):

- Model a reference LCA model and the associated impact equations
- Simulate random systems through Monte-Carlo simulations
- Identify the key input parameters through Global Sensitivity Analysis and Sobol indices estimation
- Simplify the impact equations by setting non-key input parameters

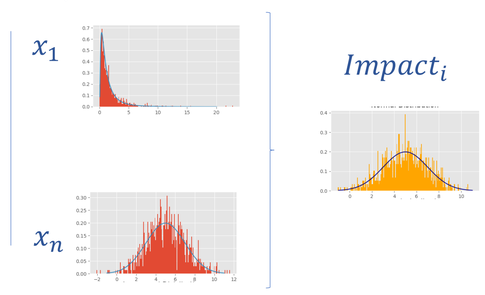
LCA model (Example of Archetype #122111211111)



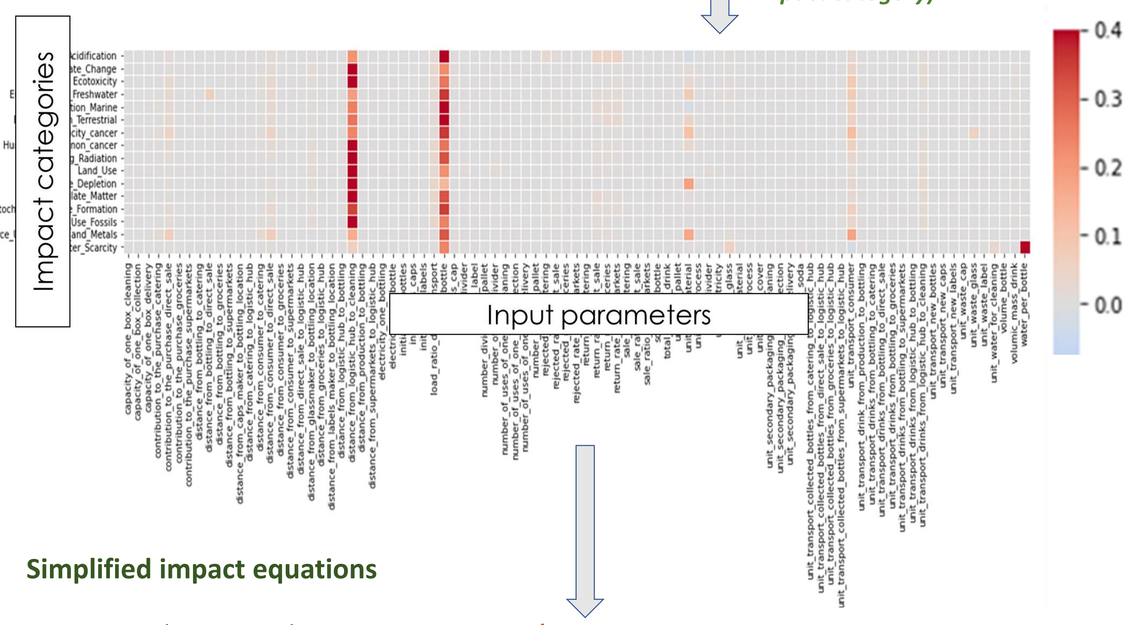
$Impact_i = f(x_1, \dots, x_{89})$

89 input parameters for Archetype #122111211111

Monte Carlo simulations



Identification of key input parameters (Sobol indices)
(Sobol index > 5% for at least one impact category)



Simplified impact equations

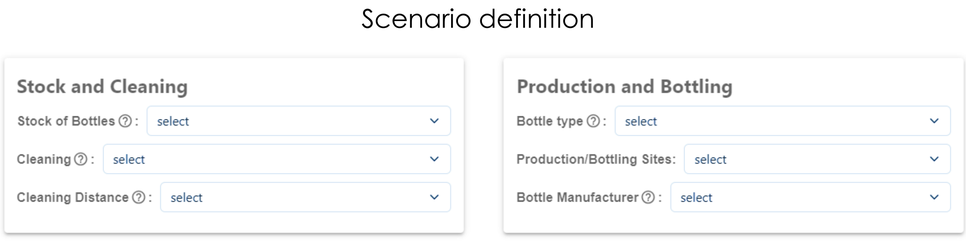
$Impact_i = f(x_1, \dots, x_{89})$ *becomes* $Impact'_i = g(x_5, \dots, x_{89})$

89 initial input parameters for Archetype #122111211111

8 key input parameters for Archetype #122111211111

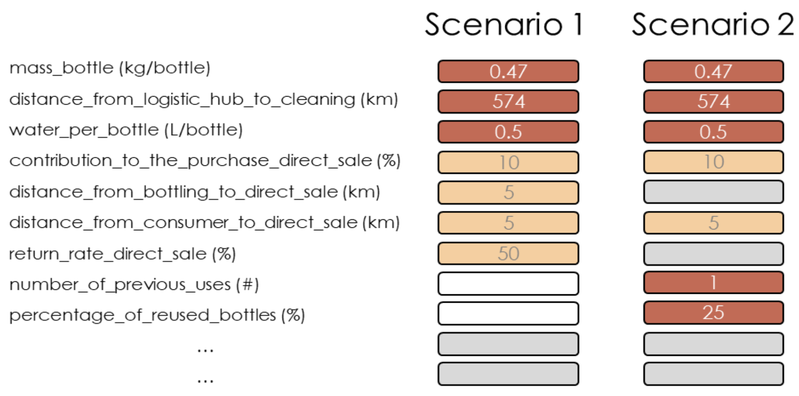
SEAMPLE – the user-friendly interface

In Toolboxes, **the user is asked for simple information** concerning the system(s) to assess

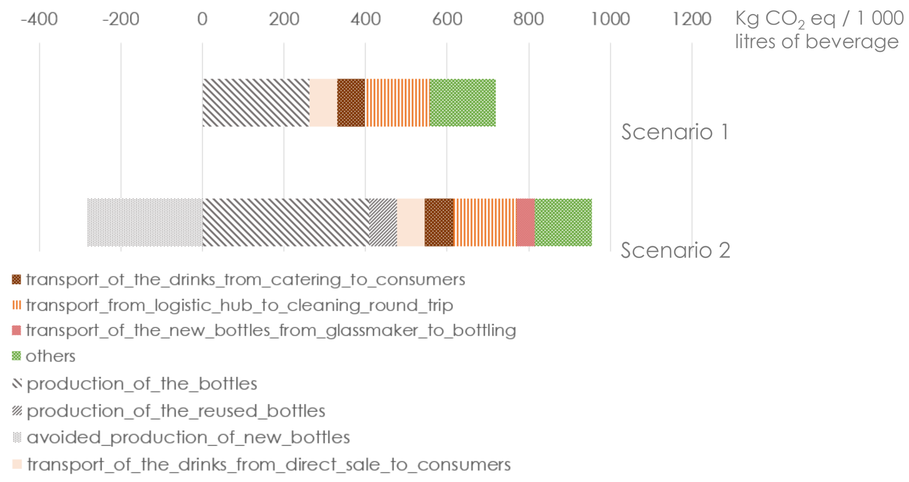


Depending on these information, **the user is asked to complete key data**

In this example the user models 2 scenarios of different archetypes



Finally, the user obtains **comparison and contribution analysis** of his scenarios *(only climate change in the figure)*



CONCLUSIONS

Simplified parametrized LCA models offer a valuable solution to the demand for simplification argued by stakeholders while preserving scientific accuracy. A key challenge in developing such models is ensuring their broad applicability. In this work, we address this by creating with experts a detailed typology of reusable bottle systems and generating simplified parametrized models for numerous archetypes. We've then developed a user-friendly interface that guides users through a simple process of selecting an appropriate archetype by providing simple information, then providing minimal key data. While these tools cannot replace comprehensive LCA studies, they empower stakeholders to make informed decisions by incorporating environmental considerations at the early stage of projects. Future work will focus on enhancing the representativeness and improving the comprehensibility of the LCA results provided by the software.

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