Superstructures: Making background scenarios practically viable

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Problem definition

Prospective / ex-ante LCA looks into the future

Future background data may be as important as future foreground data (**temporal consistency of scenarios**)

**We have future background databases**!

- E.g. coupling of LCA and IAM (Integrated Assessment Model) data:
  - Energy sector (mainly electricity): ecoinvent + IMAGE model (Mendoza Beltran et al. 2018)
  - Electricity + clinker/cement: ecoinvent + REMIND (https://github.com/Loisel/rmnd-lca)
- IEA data + ecoinvent …

Now we have, instead of 1, about **20+ background databases** (1 for each scenario and year…)

A very practical problem: **how to make practical use of this data in LCA software?**

How traditional LCA software can deal with this

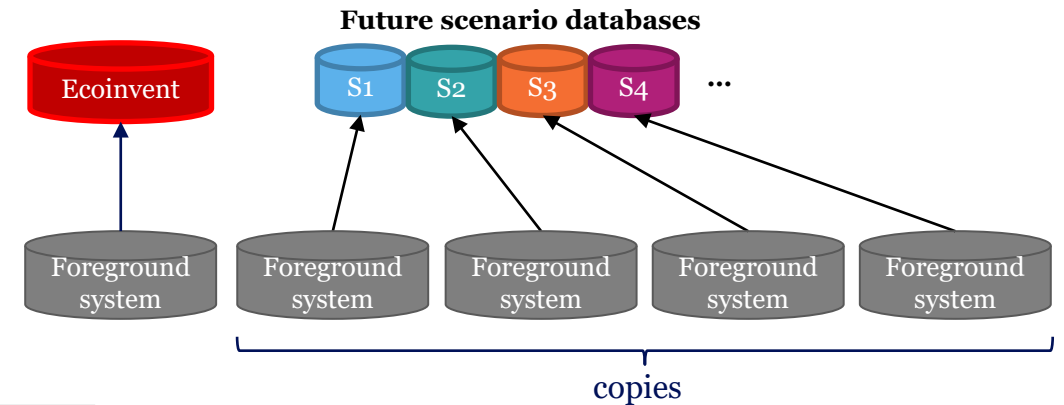1. **Re-link** your FG system before each LCA calculation
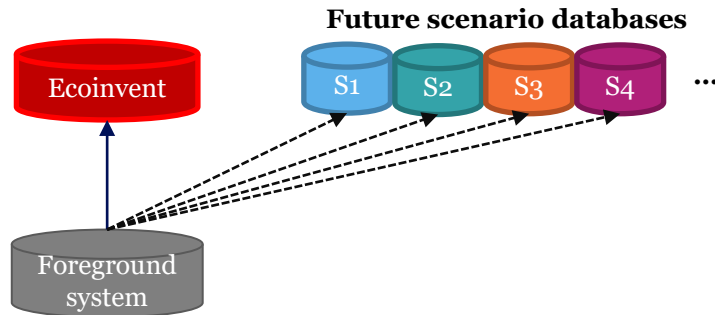
How to do the re-linking (efficiently)?

(inefficient unless the software provides a smart way for re-linking…)

2. **Duplicate** your FG system for each scenario database

How to maintain sanity…

(not recommended)

Additional concerns:
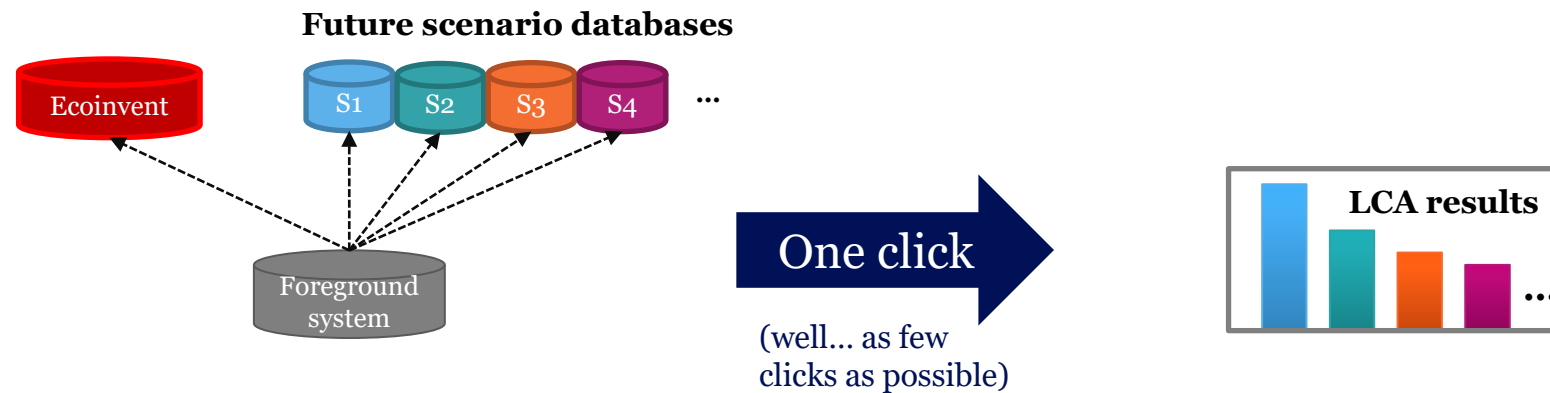- storing a lot of big databases
- Loading all of these takes time → slow LCA calculations

What I would want as an LCA practitioner?

1. Model my FG system **only one time**

2. Assess my FG system against different BG scenarios **with one click**

Future scenario databases

Ecoinvent   S1   S2   S3   S4   ...

Foreground system

One click

(well... as few clicks as possible)

LCA results

Superstructure approach

Superstructure: Mathematical representation that embeds all possible alternatives
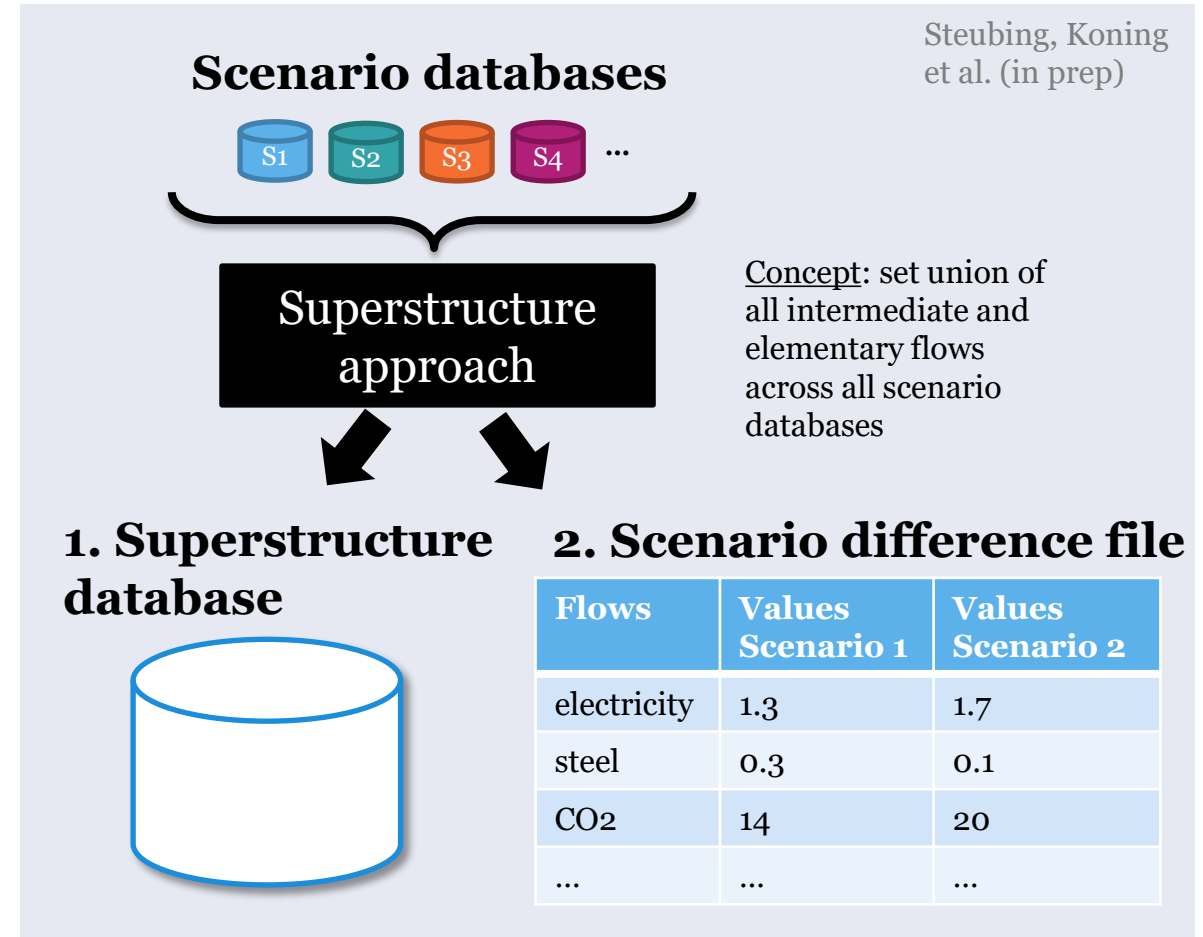
Solution: (inspired by presamples)

1. A **"superstructure" database**, which contains all unique activities and flows that occur *across* all future scenarios. This is like a "template" database.

2. A **spreadsheet with the flow values that differ in between the scenarios**

Advantages:

- Only 1 future BG / superstructure database required
- avoids storing duplicate data and saves disk space
- FG systems can link to this superstructure
- fast LCA calculations
- scenarios can easily be added or modified
- Human-readable format

Scenario databases

S1 S2 S3 S4 ...

Steubing, Koning et al. (in prep)

Superstructure approach

<u>Concept</u>: set union of all intermediate and elementary flows across all scenario databases

1. Superstructure database

2. Scenario difference file

Flows	Values Scenario 1	Values Scenario 2
electricity	1.3	1.7
steel	0.3	0.1
CO2	14	20
...	...	...

Scenario difference file

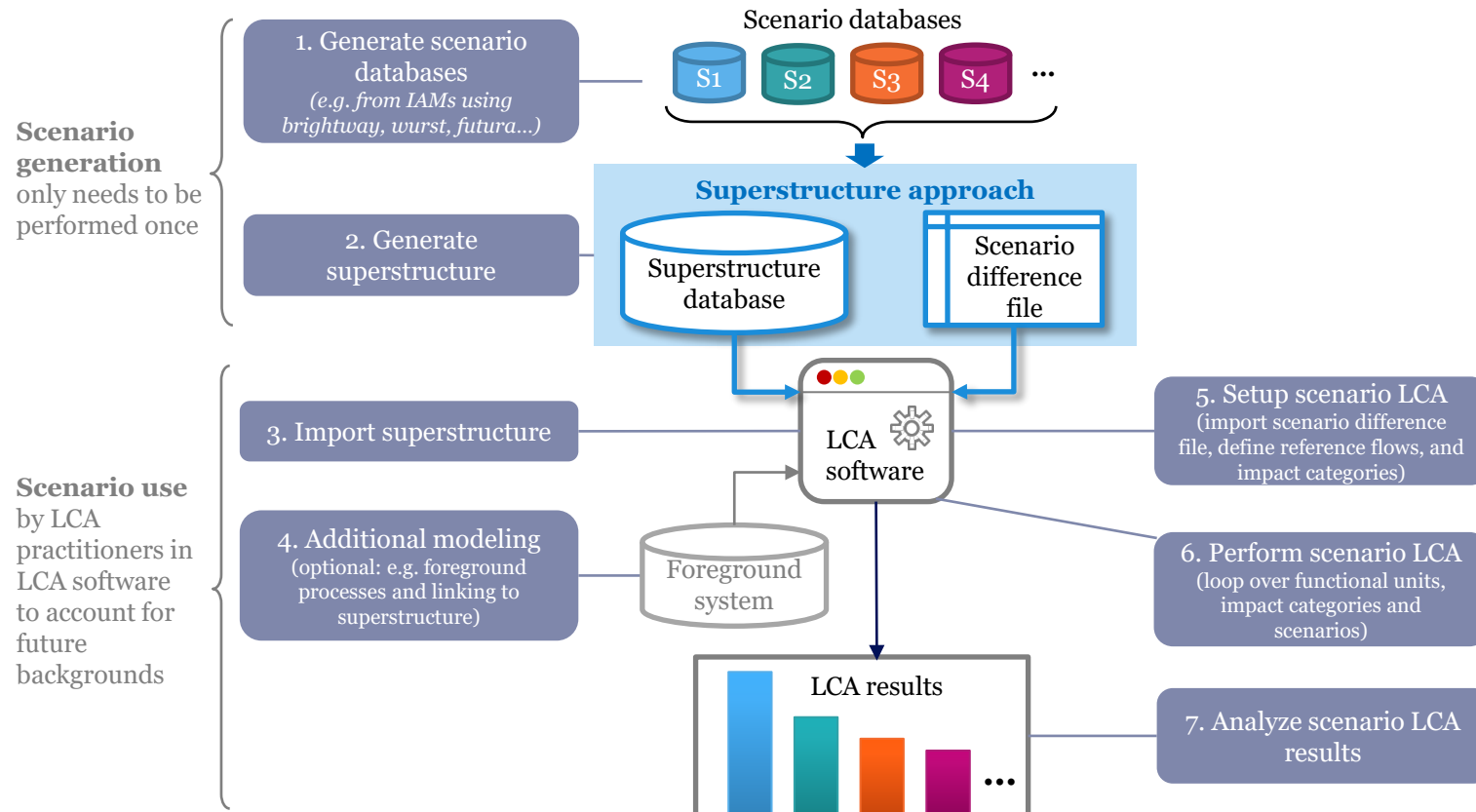|	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Flow from...						... to						Exchange values; each column	
2	from activity name	from reference product	from location	from categories	from database	from key	to activity name	to reference product	to location	to categories	to database	to key	Scenario 1	Scenario 2
3	market for natural gas, high pressure	natural gas, high pressure	US		ei37_cutof f_IMAGE_ SSP2		electricity production, natural gas, combined cycle power plant	electricity, high voltage	US-NPCC		ei37_cutof f_IMAGE_ SSP2		0.18	0.15
4	Manganese			('air', 'non-urban air or from high stacks')	biosphere 3		electricity production, natural gas, combined cycle power plant	electricity, high voltage	US-NPCC		ei37_cutof f_IMAGE_ SSP2		0.058	0.043

You can download the file template here:
https://github.com/dgdekoning/brightway-superstructure/blob/master/Scenario_difference_file_template.xlsx

This is a *generic* way of modifying flow values in an existing LCA database.

It can thus be used to **assess *any* scenario** in your product system...

Workflow scenario generation and use

Scenario generation only needs to be performed once

- 1. Generate scenario databases *(e.g. from IAMs using brightway, wurst, futura...)*
- 2. Generate superstructure

Scenario databases
S1 S2 S3 S4 ...

Superstructure approach
Superstructure database — Scenario difference file

Scenario use by LCA practitioners in LCA software to account for future backgrounds

- 3. Import superstructure
- 4. Additional modeling *(optional: e.g. foreground processes and linking to superstructure)*

LCA software

Foreground system

- 5. Setup scenario LCA *(import scenario difference file, define reference flows, and impact categories)*
- 6. Perform scenario LCA *(loop over functional units, impact categories and scenarios)*

LCA results

- 7. Analyze scenario LCA results

Live demo in Activity Browser

How to use this practically?

If you are generating future scenario databases (e.g. ecoinvent-IAMs**), you can generate a superstructure and scenario difference file from here:**

- https://github.com/dgdekoning/brightway-superstructure

If you are an LCA practitioner and you have (been provided) a superstructure database and a scenario difference file:

- You can perform Scenario LCA (and even combine FG and BG scenarios) using the Activity Browser:

  - https://github.com/LCA-ActivityBrowser/activity-browser

- Check out our AB Youtube tutorials (video on scenario modeling planned):

  - https://www.youtube.com/channel/UCsyySKrzEMsRFsWW1Oz-6aA

The future of future scenario databases?

- Which future background scenarios to choose if we start to develop a whole ecosystem of scenarios... ?

- How can these scenarios be updated as source databases (e.g. ecoinvent and IAMs) continue to evolve?

- Where can LCA practitioners obtain scenario databases or superstructures?

- ...

Thanks! Questions?