Linking Integrated Assessment Models (IAMs) with Life Cycle Assessment (LCA) for improved prospective product assessment

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What is prospective LCA?

• **Prospective LCA:**

• **Time representation in prospective LCA** is thus a crucial aspect:
  - Different socio-technical configurations influence products’ impacts.

• Accounting for future socio-technical changes is a **methodological issue** to be resolved for prospective LCA applications.
Prospective LCA state of the art

- Typically, scenarios are developed by integrating scenarios drawn from multiple databases exogenous to LCA with LCA data helps account for future socio-technical configuration.

  - Examples of databases used by different studies include:
    - GTAP database (GE model scenarios)
    - IEA scenarios (energy scenarios)
    - NEEDS scenarios (LCA future inventories)
    - ...

- Two examples of LCA models derived after integration of such databases include:
  - Integrated LCA (Gibon et.al, 2015; Hertwich et.al, 2014)
  - Macro-LCA (Dandres et.al 2011, 2012)
Research gap and question

• Gap:
  - Inconsistencies due to unharmonized databases integration
  - Increase inherent uncertainties

**Research Question**

*How can IAM scenarios be systematically linked with parameters in LCA databases to account for future changes in prospective LCAs?*
Method

1. **Scenario development**: Deeply embed time-resolved IAM scenarios with current life cycle inventories (LCIs), to create future inventories and capture changes in the so called “LCA background” system*.

   * Those processes and emissions that are part of the supply chain of the studied product system, for example, the electricity mix used to charge and produce EV batteries.

2. **Calculate the prospective LCA of the product of interest**: Using the future LCIs to study the future environmental impacts of products, while accounting for future socio-technical change in a consistent* way.

   * Consistent among technologies, economic sectors, and regions.
Scenario Development (1)

1. Scenario Generation:
The IAM “Integrated Model to Assess the Global Environment” (IMAGE) is used as a platform for calculations of coherent, worldwide scenarios.

2. Scenario Evaluation:
Hard linking scenario data from IMAGE, with one of the most broadly used life cycle inventory databases, the ecoinvent v3.3 database. We do this in three steps:

   2.1. Parameter identification
   2.2. Parameter adaptation
   2.3. LCI calculation

We addressed two types of socio-technical future changes

   1. Technology changes
   2. Market changes
Scenario Development (2)

Scenario Evaluation (1)

2.1 Parameter identification

2.2 Parameter adaptation

2.3 LCI calculation

Wurst model (v0.1)

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Scenario Evaluation (2)

**Illustrative Case Study**

- Prospective LCA of an electric vehicle (EV) and an internal combustion engine vehicle (ICEV).
- We adapted the life cycle inventories of *electricity* technologies in *ecoinvent* according to the *IMAGE SSP* scenarios.
- A variety of scenario from the SSPs family are used to address uncertainty.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Database used for background</th>
<th>IMAGE scenario (SSP) - Riahi et al. 2017 and Van Vuuren et al. 2017b</th>
<th>Year(s)</th>
<th>Label in this study</th>
</tr>
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<tbody>
<tr>
<td>ICEV/EV</td>
<td>ecoinvent</td>
<td>n.a.</td>
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<td>ICEV/EV-ecoinvent</td>
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<td>Green Road (SSP1)</td>
<td>2020,2030,2040,2050</td>
<td>ICEV/EV-GreenRoad</td>
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<td>ICEV/EV</td>
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<td>ICEV/EV-GreenRoad-2.6</td>
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<td>ICEV/EV-MidRoad</td>
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<td>ICEV/EV-RegRivalry</td>
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<td>ICEV/EV</td>
<td>ecoinvent adapted with IMAGE scenario</td>
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<td>2020,2030,2040,2050</td>
<td>ICEV/EV-RegRivalry-3.4</td>
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</tbody>
</table>
Results (1)

Climate Change

Particulate Matter Formation

Fossil Cumulative Energy Demand

Metal Depletion

- ICEV-GreenRoad
- ICEV-MidRoad
- ICEV-RegRivalry
- ICEV-GreenRoad-2.6
- ICEV-MidRoad-2.6
- ICEV-RegRivalry-3.4
- ICEV-Ecoinvent

- EV-GreenRoad
- EV-MidRoad
- EV-RegRivalry
- EV-GreenRoad-2.6
- EV-MidRoad-2.6
- EV-RegRivalry-3.4
- EV-Ecoinvent

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Results (2)

Climate Change

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Main findings

• The limited set of background changes accounted for (electricity sector) proved to be important in the case of some key impacts for EVs and can influence the relative environmental performance differences between EVs and ICEVs.

• Linked to the background of an LCA, IMAGE scenarios enable more robust comparison of the environmental impacts of similar products, as their impacts may or not be driven by the same sectors on the background, which would in any case be adapted according to the consistent IMAGE scenarios.

• Including temporal developments in the background system can contribute to improving the temporal consistency of modeling product systems of emerging technologies by means of prospective LCA.
Some difficulties

• Not all IMAGE technologies exist in ecoinvent.
  - CCS and CSP

• More than 1 ecoinvent technology could match one IMAGE technology.
  - E.g. Coal_IMAGE = Hard Coal and Lignite in ecoinvent

• No ecoinvent dataset in a region
  - Go up one regional level

• Some future emissions for electricity technologies were adapted using best available data rather than using specific emission factors. Therefore, future emissions for these substances should be carefully assessed.
  - E.g. PM emissions, changes were made according to future technology efficiency, as IMAGE does not explicitly model different sizes of PM emissions despite modeling black carbon emissions, which cover several PM sizes altogether.
Further research

• The impacts of the use phase are not calculated using yearly updates of background systems, which could offer more refined comparisons between the studied vehicle technologies.

• We focused on the electricity sector, leaving all other sectors unchanged (as a proof of concept). Adapting other sectors would provide further consistency.

• We relied on inventories of technologies that are yet to be deployed, in particular CCS and CSP. Uncertainties of these inventories are large and should be further considered.
Thank you!

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