Uncertainty-aware Ecodesign: Assessment and Visualisation of Uncertainties in LCA during early Product Development

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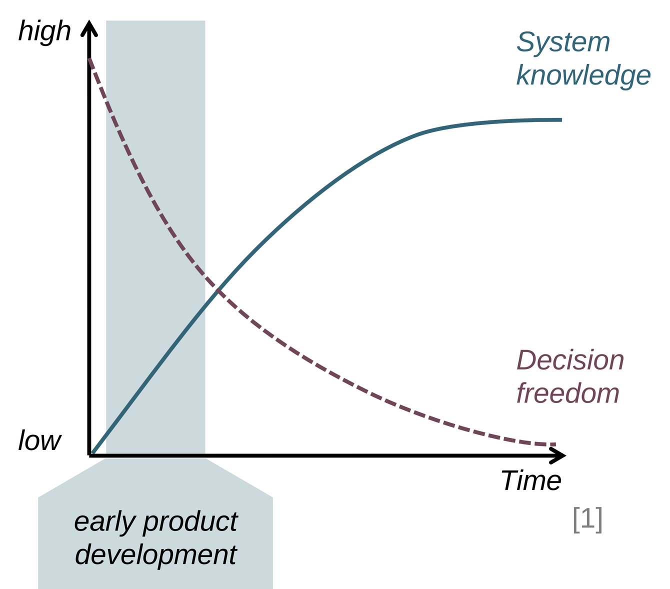
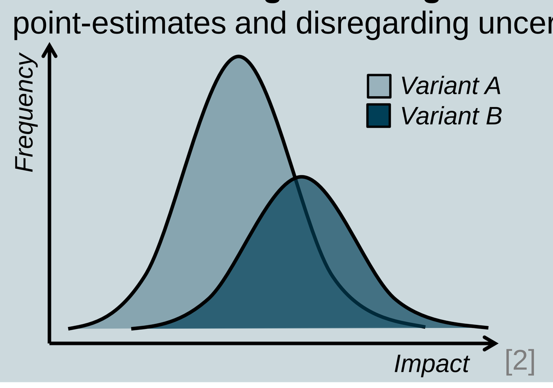
Motivation & Objective

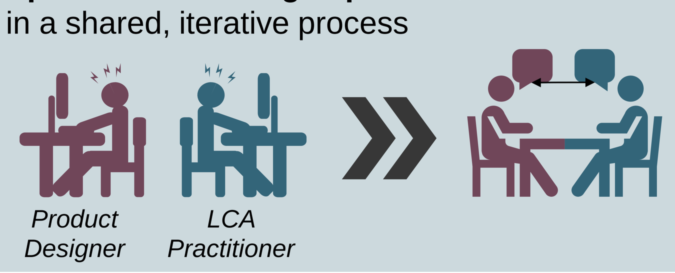
The **ecodesign paradox** hinders the integration of Life Cycle Assessment (LCA) into early product development



1 Risk of **"choosing the wrong variant"** when using point-estimates and disregarding uncertainties.



2 **Specialists working in parallel**, instead of in a shared, iterative process



A Framework **aligning information flows** between LCA experts and product designers, providing **uncertainty-aware visualisations** for informed decision-making and **parameterised equations** for downstream use in the PDP.

Treatment of Uncertainties

Classification

- **Epistemic** Uncertainty:
  - from inaccurate measurements, lack of data, assumptions, etc.
  - Can be reduced
- **Aleatory** Uncertainty (aka Variability):
  - Caused by inherent variations in the real world
  - Irreducible, can only be assessed

	Uncertainty Types \ Location	Goal and Scope	Inventory Analysis	Impact Assessment
Epistemic	Parameter		✓	✓
	Model		✓	✓
	Scenario and Choices	✓	✓	✓
Aleatory	Temporal		✓	✓
	Spatial or Geographical		✓	✓
	Sources and Objects		✓	✓

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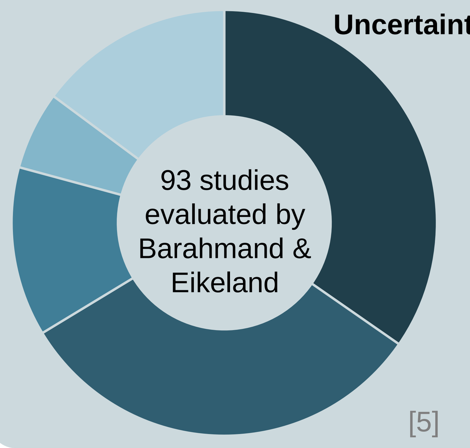
Uncertainty and Sensitivity Analysis Methods used in LCA studies



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Assessment

- ISO 14044 recommends a combination of gravity (aka contribution), uncertainty and sensitivity analysis
- In order to determine key issues based on their influence, both sensitivity and uncertainty have to be assessed

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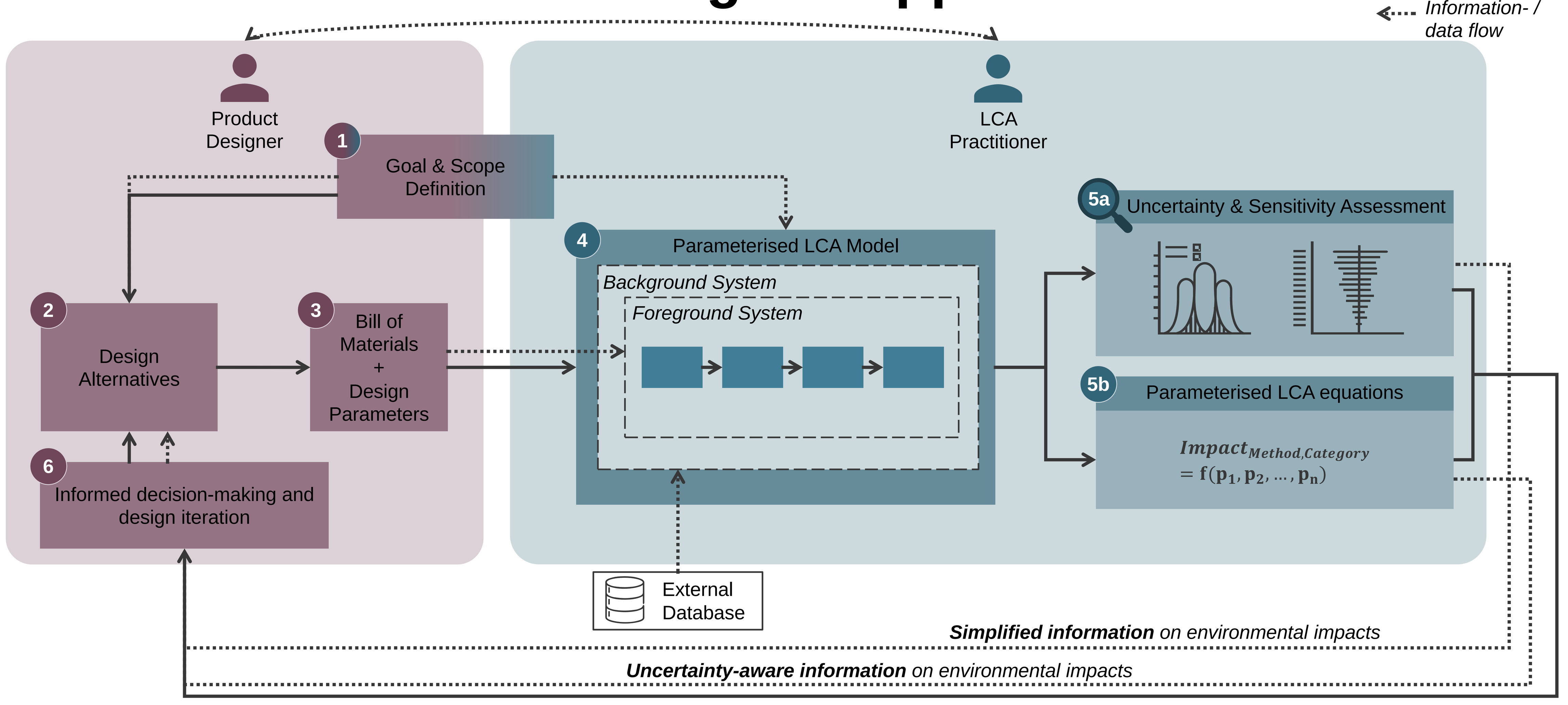
Methodological Approach



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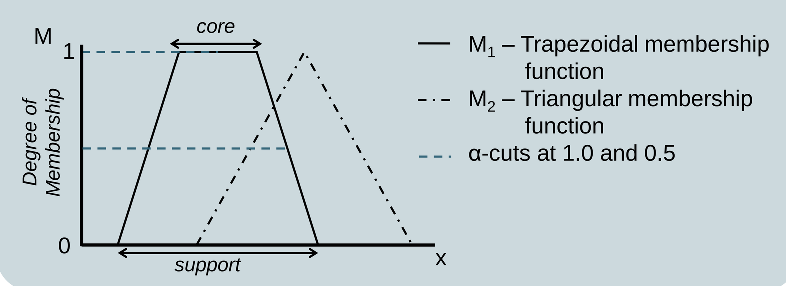
5a Fuzzy Logic offers an alternative way of uncertainty operationalisation and propagation

Fuzzy Logic Principle



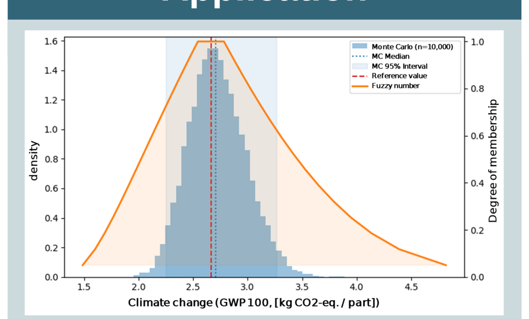
Procedure

I. Extraction of uncertainty data

II. Choice of corresponding fuzzy membership function

III. Propagation by α-cut

Application



- Reduction of calculation time >90%
- Propagation of foreground and background uncertainties

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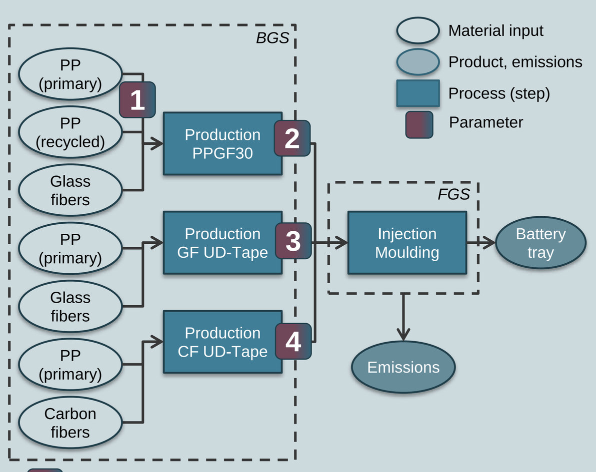
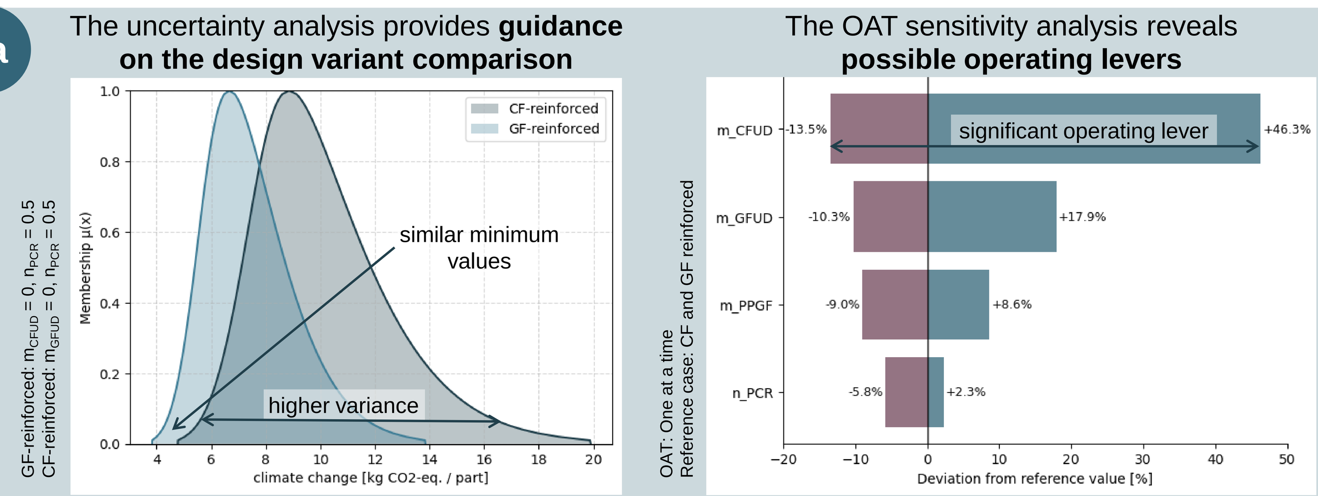
Application and Results

4 LCA model and parameter set



1. n_{PCR}: Share of recycled polypropylene [-]
2. m_{PPGF}: Mass of PPGF30 compound [kg]
3. m_{GFUD}: Mass of glass fibre tape [kg]
4. m_{CFUD}: Mass of carbon fibre tape [kg]

5a The uncertainty analysis provides **guidance on the design variant comparison** | The OAT sensitivity analysis reveals **possible operating levers**



→ Thereby, parameterisation and uncertainty-awareness **support informed decision-making**

5b

$$GWP100_{Battery\ tray} = m_{GFUD} * 4.802 + m_{CFUD} * 24.3875 + m_{PPGF} * (3.606 - n_{PCR})$$

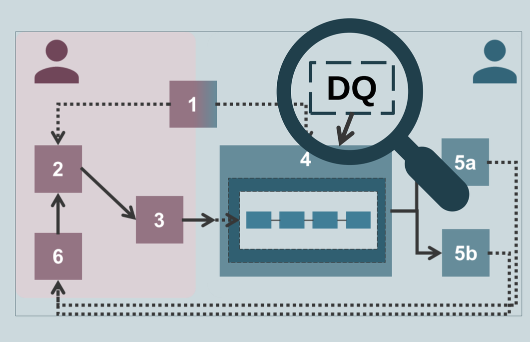
- An **automatic extraction of equations** for simple parameterisations is provided
- Equations can **simplify a further use** of LCA results, e.g. in multi-criteria optimisations

PP: Polypropylene, PPGF30: Compound with 30w.% glass fibres, BGS: Background system, FGS: Foreground system, UD-Tape: Unidirectional tape, GF: glass fibre, CF: carbon fibre

Conclusion and Outlook

- The flexible parameterisation and evaluation of environmental impacts supports **transparent and reproducible design decisions**
- Uncertainty visualisation and LCA model equation serve as valuable additions to an **iterative ecodesign workflow**

- Future research should incorporate **data quality** and granularity
- An empirically supported selection of **suitable visualisation methods**



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