ADDRESSING PARAMETER UNCERTAINTY IN PROSPECTIVE INVENTORY MODELING

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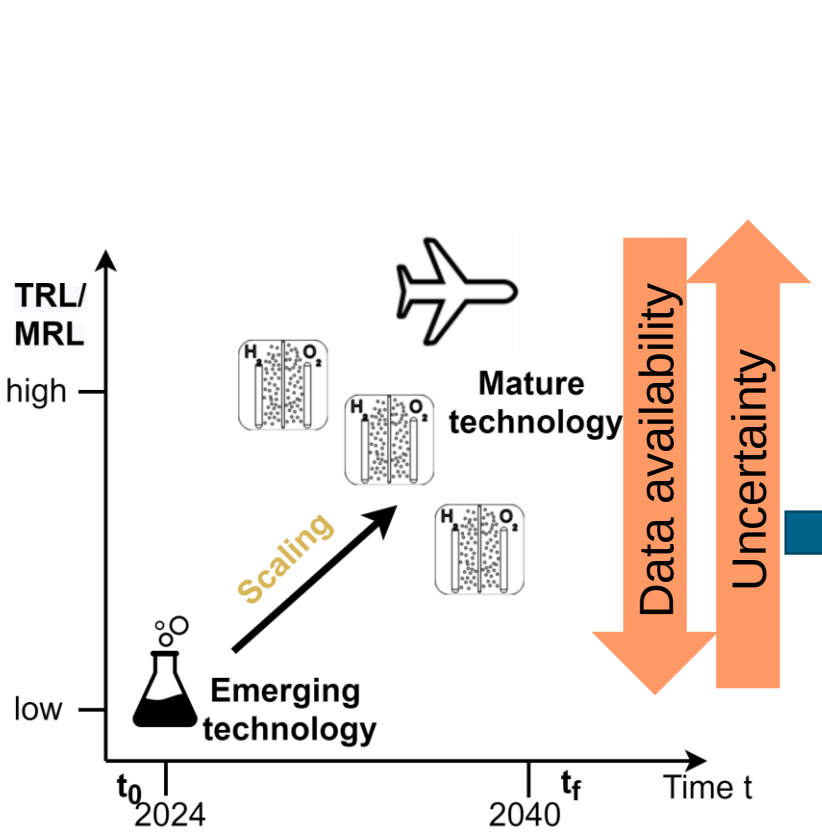
SETAC Europe 26th LCA Symposium

Background and Motivation

Parameter Uncertainty in Prospective LCA „Future Energy Technology Concepts“



Current challenges of Prospective LCA (own source based on [1])
* TRL: Technological readiness level
* MRL: Manufacturing Readiness Level
* $t_{0:}$ Current time
* $t_{f:}$ Future point time when technology reaches maturity (TRL=9 and MRL= 10)

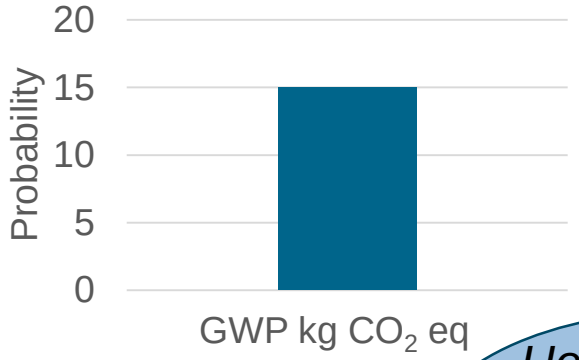
pLCI model

Deterministic approach

Fixed stack cell area

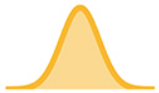
Fixed electrolyzer efficiency

pLCA



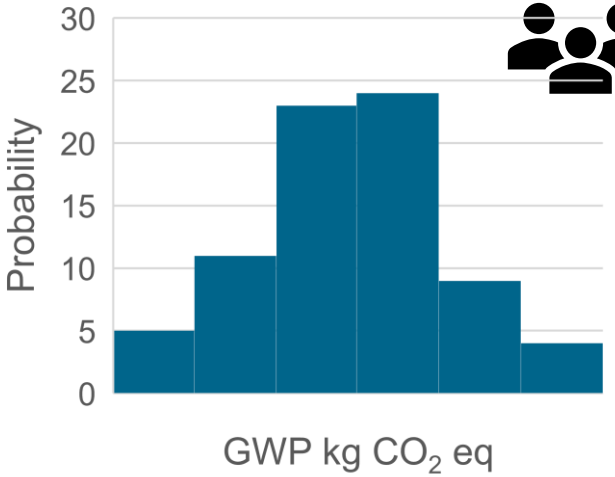
Probabilistic approach

Uncertain stack cell area



Uncertain electrolyzer efficiency

pLCA



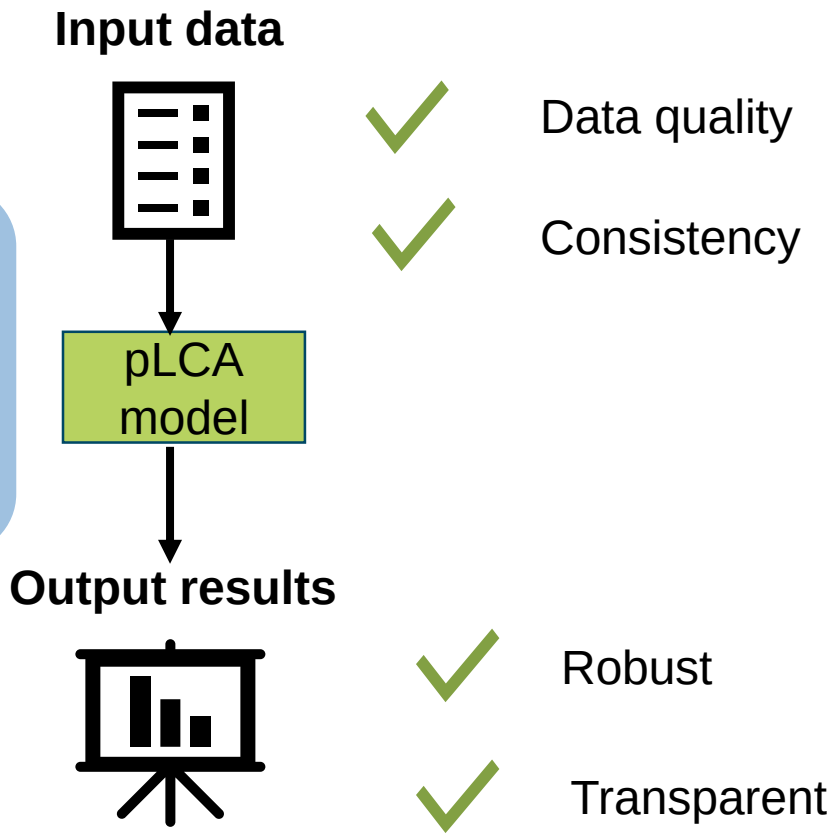
How to consider parameter uncertainty in pLCI modeling?

Proposed Approach

Systematic framework based on previous work

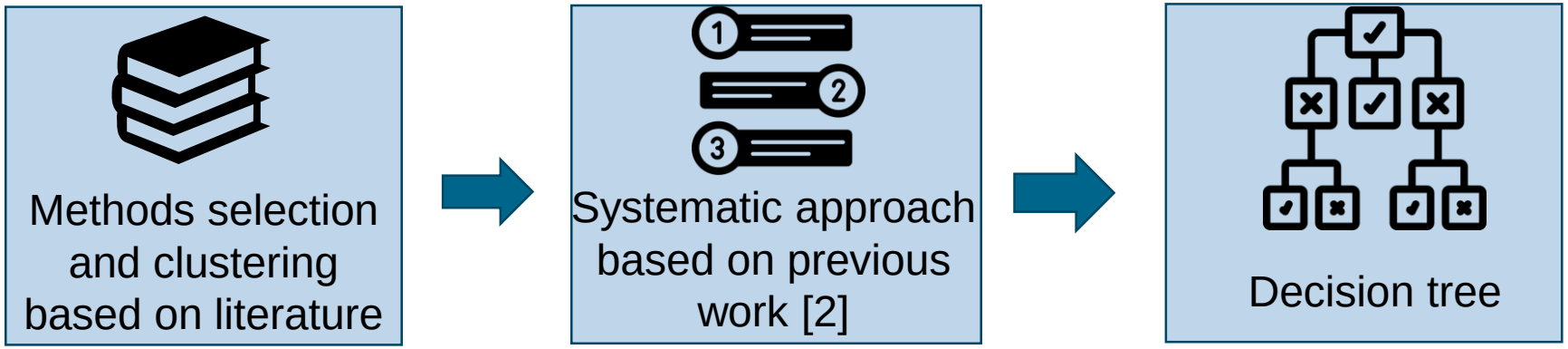
Guide the LCA practitioners

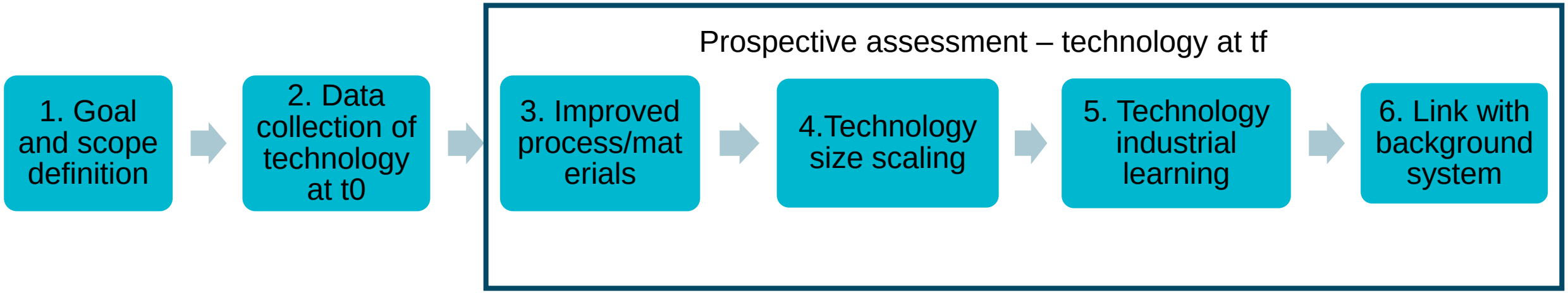
Identify and characterize parameter uncertainty with probability distribution functions (PDFs)



Methodology

Framework to generate pLCI an parameter uncertainty data [1]

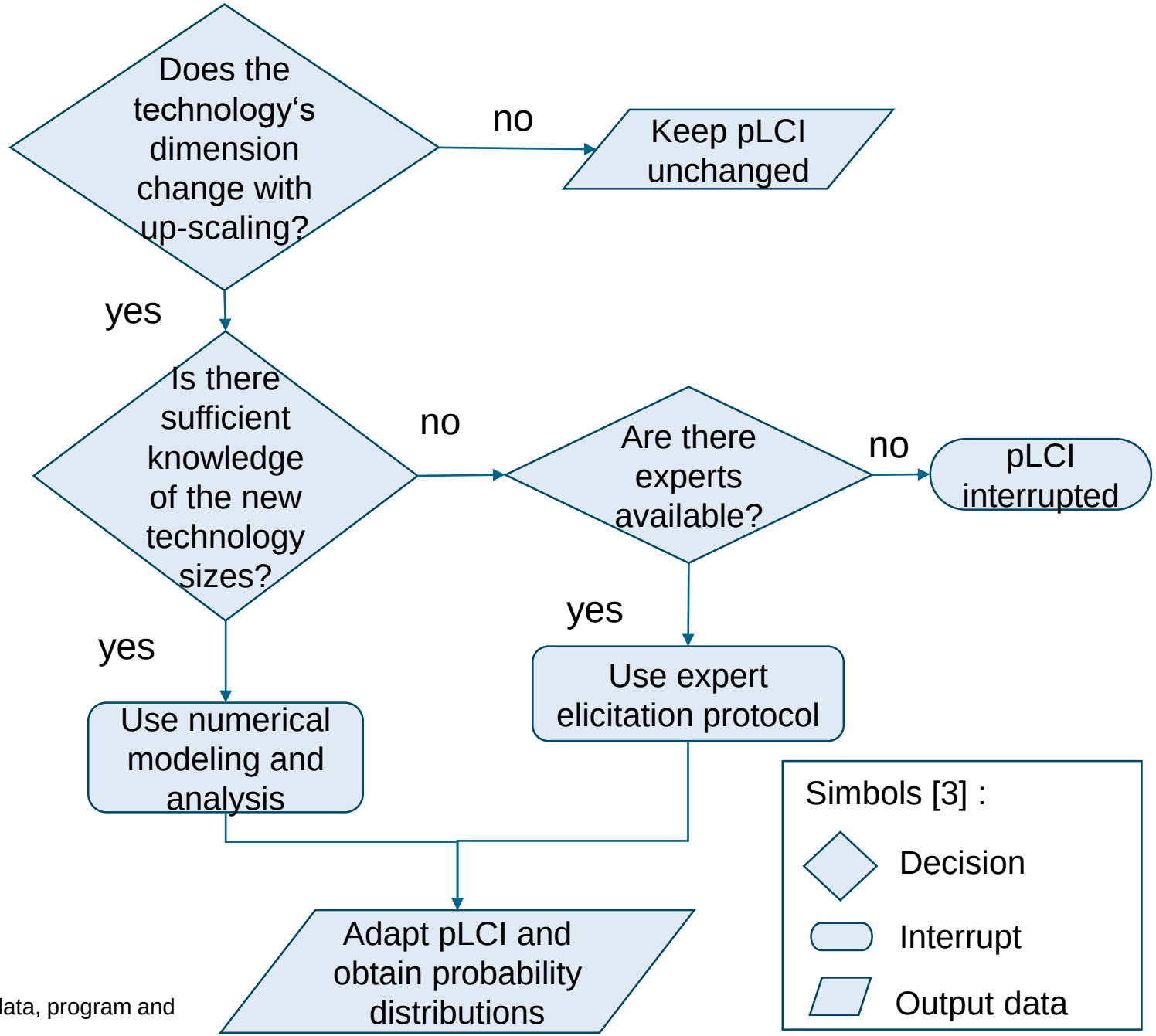




1. Villacis, S., Papantoni, V., Brand-Daniels, U., Vogt, Th. (2024) „A decision-support framework for including parameter uncertainty in prospective life cycle inventory modeling: Application to a PEM fuel cell-based APU system for a hydrogen-powered aircraft “, Energy, Sustainability and Society *(under review)*
2. van der Hulst MK, Huijbregts MAJ, Loon N et al. (2020) A systematic approach to assess the environmental impact of emerging technologies: A case study for the GHG footprint of CIGS solar photovoltaic laminate. J Ind Ecol 24:1234–1249. https://doi.org/10.1111/jiec.13027

Methodology

1. Goal and scope definition
2. Data collection of technology at current time
3. Improved process/ material
4. Technology size scaling
5. Technology industrial learning
6. Link with background system



3. ISO 5807:1985(en)
Information processing — Documentation symbols and conventions for data, program and system flowcharts, program network charts and system resources charts

Case Study

Application of the framework to a Solid Oxide Electrolysis Cell (SOEC) to produce hydrogen in 2040

1. Scope

Production of liquid hydrogen for aviation
Manufactured in DE
2024: TRL-5-6 – 2040: *TRL 9/MRL: 10

2. Data

Primary and secondary data collection

3. Material changes

Materials of the Electrolyte: 2024-> ceramic, zirconia
2040-> scandia stabilized zirconia

4. Size scaling

Active area SOEC stack: 2024-> 100 cm^2
2040-> ?

5. Industrial learning

Production scale stack: 2024->
2040-> ?

6. Background

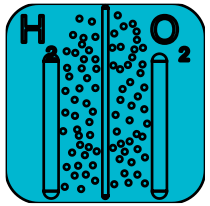
2024-> current DE mix
2040-> future DE mix

*TLR: Technological readiness level
MRL: Manufacturing readiness level

Case Study

Application of the framework to a Solid Oxide Electrolysis Cell (SOEC) to produce hydrogen in 2040

4. Size scaling



SOEC stack active area

Does the technology's dimension change with up-scaling? ✓

Is there sufficient knowledge of the new technology sizes? ✗

Are there experts available? ✓

Literature review → Lab and pilot scale data

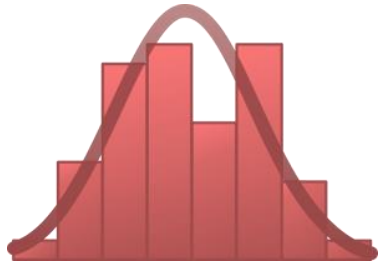
+

Expert elicitation → Minimum and maximum values

=

SOEC stack active area

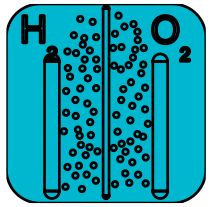
2024	2040
100 cm^2	400 cm^2 – 800 cm^2



Case Study

Application of the framework to a Solid Oxide Electrolysis Cell (SOEC) to produce hydrogen in 2040

5. Industrial learning



Electricity demand for production of SOEC stack

Is there sufficient knowledge of learning effects for reaching industrial scale? ✗

Are there experts available? ✓

Learning effect methods

+

Expert elicitation

=

Electricity demand for production of SOEC stack

Uncertainty: ± 30%

c_2 = mode

2024

1 MW electrolyzer

122 MWh

2040

7.13 MW electrolyzer

695 MWh

486 MWh – 903 MWh

Output power at t_f

Electricity demand at t_f

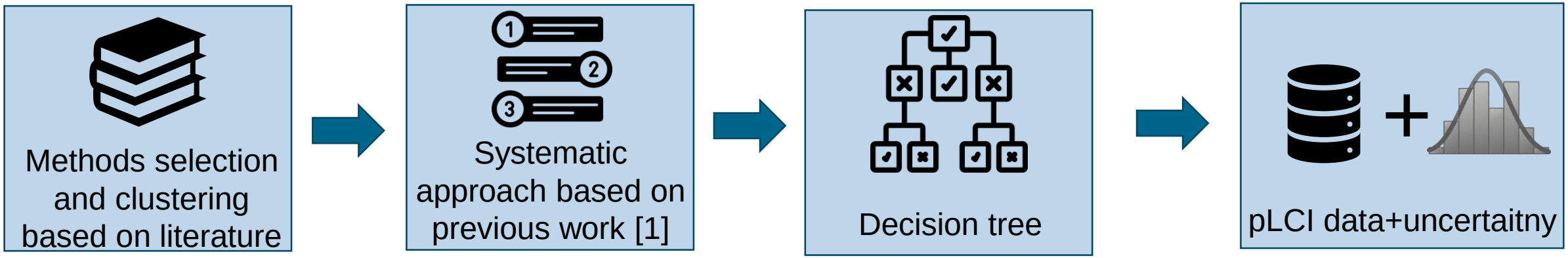
$$\frac{c_2}{c_1} = \left(\frac{x_2}{x_1}\right)^b$$

b: Scaling factor from literature

Electricity demand at t_0

Output power at t_0

Summary and Conclusions



- Depict the framework's applicability with an energy technology case study
- Our approach helps to improve transparency and consistency in pLCI modeling
- Aids to better understand uncertainty in pLCI and to support more informed decision-making

1. van der Hulst MK, Huijbregts MAJ, Loon N et al. (2020) A systematic approach to assess the environmental impact of emerging technologies: A case study for the GHG footprint of CIGS solar photovoltaic laminate. J Ind Ecol 24:1234–1249. https://doi.org/10.1111/jiec.13027

Thank you for your attention!

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Imprint

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