THE FUTURE ENVELOPE

TOWARDS ZERO CARBON BUILDINGS

15-16 December 2022 Bolzano/Bozen

Sustainability as a design parameter: tools, metrics, know-how

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Collaborations

Sponsors

Organized by

Demand for sustainability: the EU Taxonomy

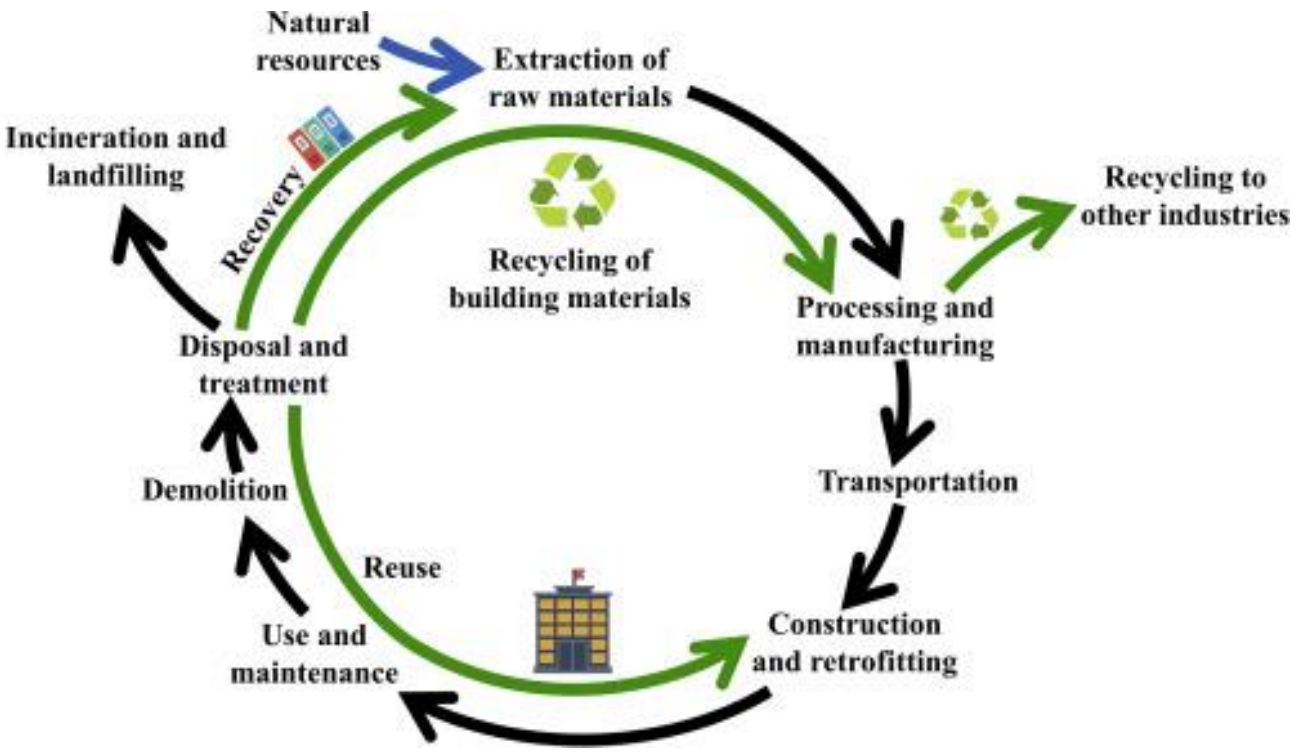
- Classification system to guide sustainable investments
- Highly affecting the building sector (directly and indirectly): new construction, renovation, installation, maintenance and repair, and acquisition & ownership
- **Life Cycle Assessment of the whole building according to Level(s) and EN15978 is required to comply with circular economy criteria**

https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en
https://environment.ec.europa.eu/topics/circular-economy/levels_en

Life Cycle Assessment (LCA)

- Methodology for quantification of environmental impacts of products, processes and services across the life cycle
- Based on standards:

- ISO 14040, ISO 14044
- EN 15804 (construction products)
- EN 15978 (buildings)
- …

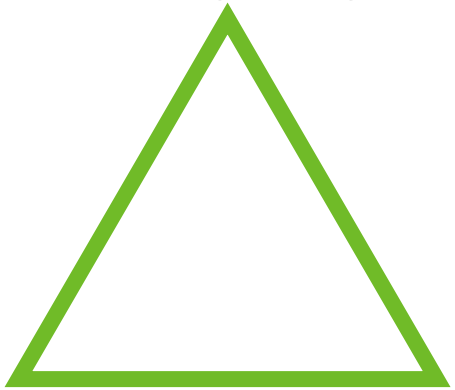


Huang, B. et al. (2020) A Life Cycle Thinking Framework to Mitigate the Environmental Impact of Building Materials https://doi.org/10.1016/j.oneear.2020.10.010

How to tackle complexity of sustainability

- Sustainability should not be isolated from the technical building envelope performance
- How to integrate sustainability assessment in the design process and benefit from it?

Know how: Sustainability consultancy and research, and capacity building



Sustainability metrics

Tool development for data management and sustainability assessment

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Tools

Calculation of building LCA

Impacts and risks need to be **calculated** across the life cycle

- Professional LCA software, free or licensed

OpenLca One Click LCA SimaPro GaBi Software umberto® know the flow.

- LCA calculators (e.g. spreadsheets, baubook construction calculator)
- LCA screening tools (e.g. spreadsheets, rating 1-5)
- LCA software linked to a Common Data Environment (e.g. BIM)
- Frontiers of LCA software: link with Artificial Intelligence
- …

Collecting construction data for LCA

Lack of **representative data and benchmarks** is one of the main challenges when performing sustainability assessment of buildings

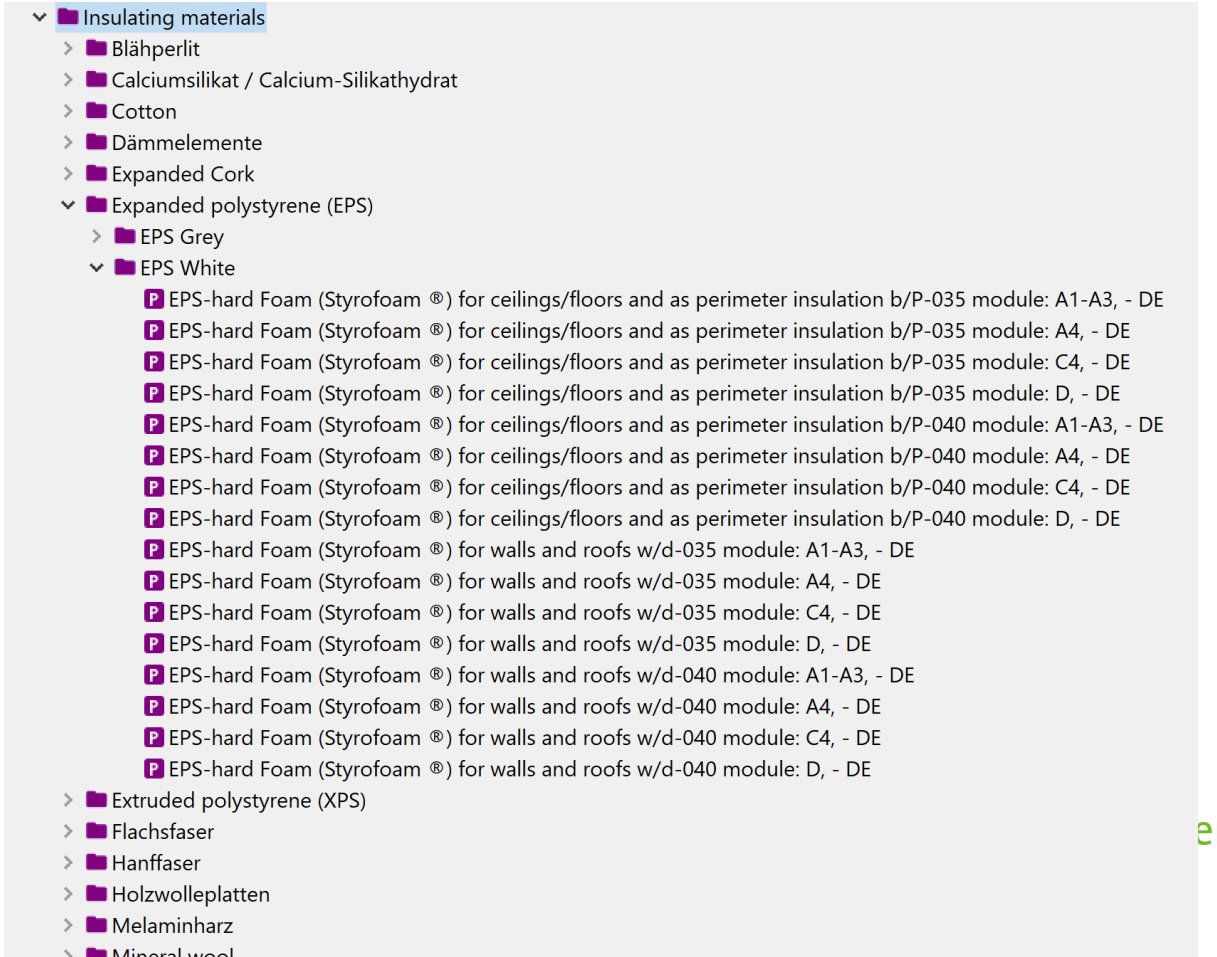
Common data sources (not exhaustive):

- **Generic LCA databases** with building products: ecoinvent, GaBi, PEF…
- **Standardized LCA database** of building products: Ökobaudat (DE)
- **Environmental Product Declarations**: reports of LCA of specific construction products (usually as PDFs, but can be added to some LCA software: One Click LCA and openLCA)

https://nexus.openlca.org/databases
https://www.oekobaudat.de/

Example 1: Ökobaudat in openLCA

- Construction materials database, provided by the German Federal Ministry of Transport, Building and Urban Development
- 13,000 datasets representing EPDs



https://nexus.openlca.org/database/%C3%96kobaudat

Example 1: Ökobaudat in openLCA

- Calculate life cycle stages (production, transport, use, end of life…)
- Combine datasets to create your own case studies (building components or full buildings)

EPS-hard Foam (Styrofoam ®) for ceilings/floors and as perimeter insulation b/P-035 module: A1-A3,

Impact analysis: EN 15804:2012

Subgroup by processes ☑ Don't show < 1 %

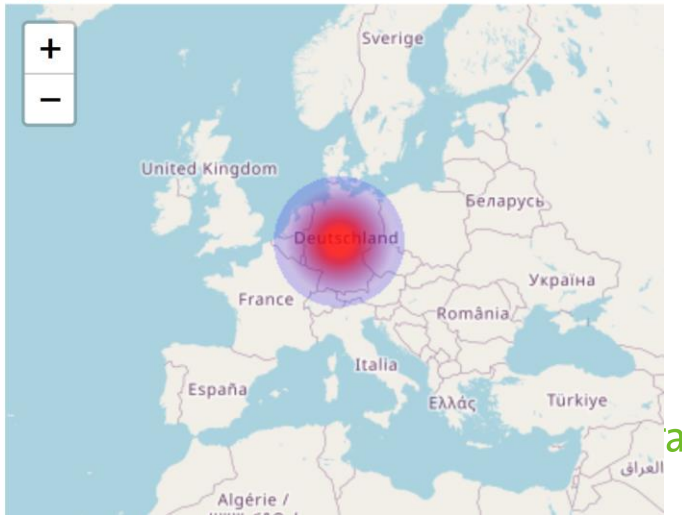
Name	C…	Inv…	Impact result	Unit
Total use of non renewable primary energy resource (PENRT)			2230.00000	MJ
Abiotic depletion potential for fossil resources (ADPF)			2170.00000	MJ
Use of non renewable primary energy (PENRE)			1204.36000	MJ
Use of non renewable primary energy resources used as raw materials (PENRM)			1025.64000	MJ
Global warming potential (GWP)			75.40000	kg CO2 eq.
Total use of renewable primary energy resources (PERT)			27.50000	m3
Use of renewable primary energy (PERE)			27.50000	MJ
Formation potential of tropospheric ozone (POCP)			0.54200	kg C2H4 eq.
Use of net fresh water (FW)			0.33200	MJ
Non hazardous waste dispose (NHWD)			0.31100	kg
Acidification potential of soil and water (AP)			0.17100	kg SO2 eq.
Radioactive waste disposed (RWD)			0.02190	kg
Eutrophication potential (EP)			0.01550	kg (PO4)3- eq.
Hazardous waste disposed (HWD)			0.01320	kg
Abiotic depletion potential for non fossil resources (ADPE)			2.79000E-5	kg Sb eq.

Impact category: Global warming potential (GWP)

Contribution tree for locations

Location/Process	Amount	Unit
Germany - DE	75.40000	kg CO2 eq.

Map



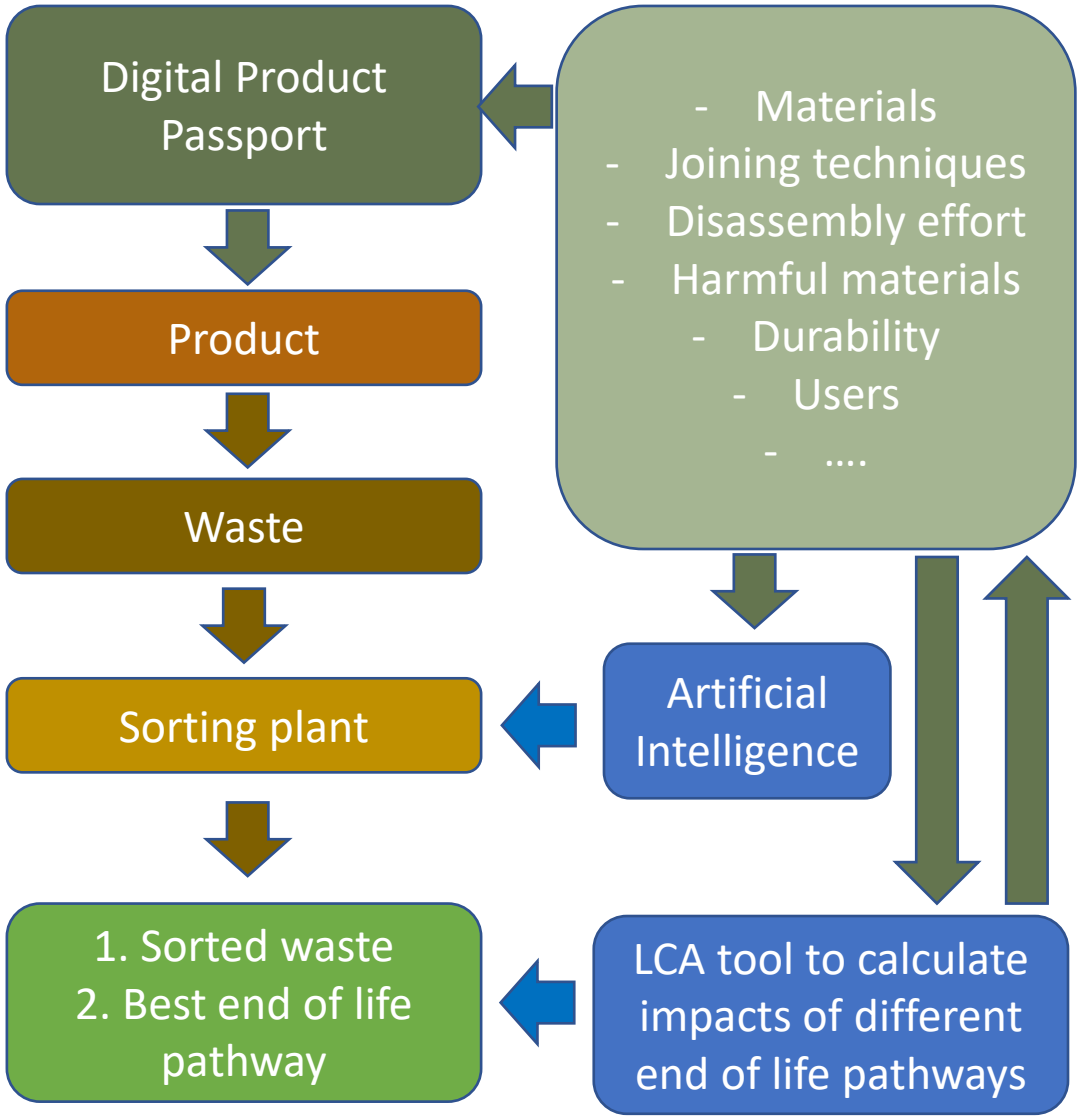
https://nexus.openlca.org/database/%C3%96kobaudat

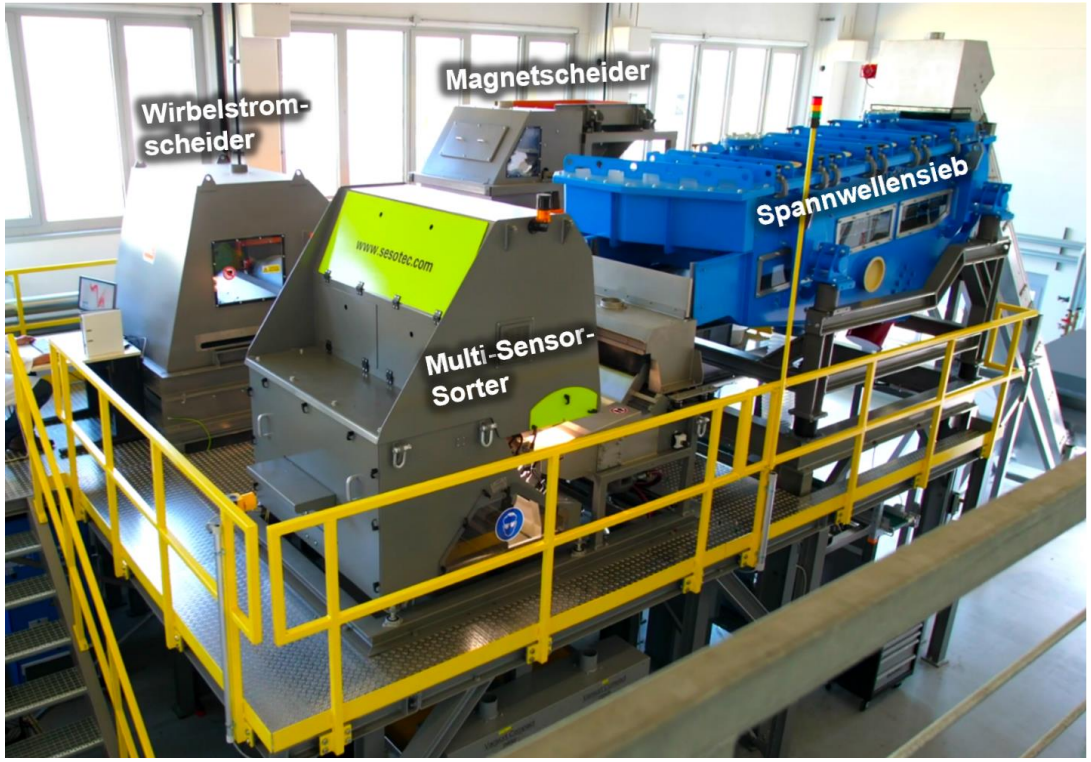
Example 2: LCA and artificial intelligence tool

- **End of life** is one of the most uncertain stages of building component life cycles
- Construction and demolition waste is a major problem (1/3 of all waste in EU)
- Proposal: combining a digital product description – **the "Digital Product Passport"**– with intelligent sorting technologies supported by artificial intelligence (AI)

https://environment.ec.europa.eu/topics/waste-and-recycling/construction-and-demolition-waste_en

Example 2: LCA and artificial intelligence tool





https://www.recirce.de/

ReCircE

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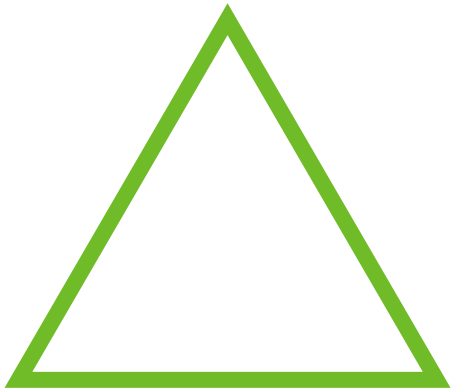
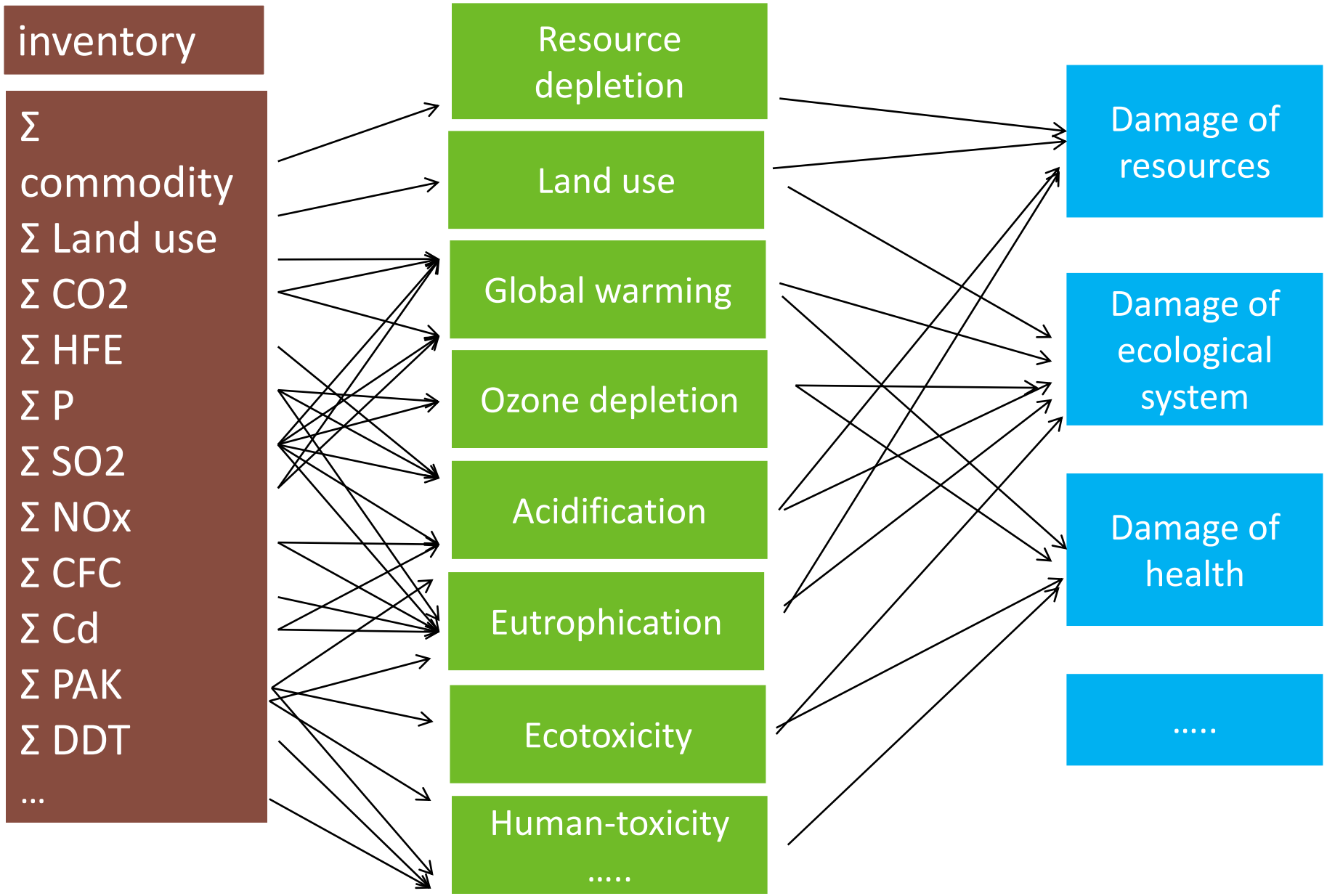
Metrics



Areas of protection



Impact assessment methods: Environmental Footprint, Recipe, CML…

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Metrics beyond carbon and LCA indicators

- **Circularity**: Material Circularity Indicator (Ellen MacArthur Foundation), Circularity Index (Cullen, 2017)
- **Criticality**: raw materials important for the EU economy but with high supply risks (e.g. PV cells)
- **Costs**: Life Cycle Costing
- **Social impacts and risks**: Guidelines for social Life Cycle Assessment of Products and Organizations (UNEP/2020)

https://ellenmacarthurfoundation.org/
Cullen, Jonathan M. 2017. "Circular Economy: Theoretical Benchmark or Perpetual Motion Machine?" Journal of Industrial Ecology 21 (3): 483–86. doi:10.1111/jiec.12598.
United Nations Environment Programme (2020). Guidelines for Social Life Cycle Assessment of Products and Organisations 2020. https://wedocs.unep.org/20.500.11822/34554
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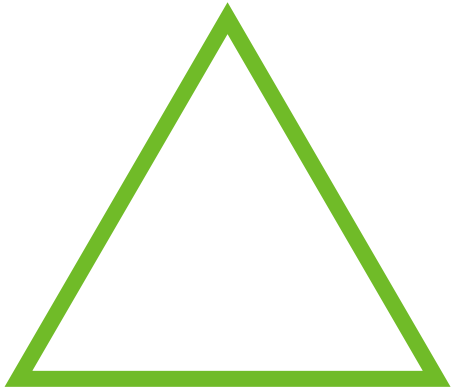
Know-how

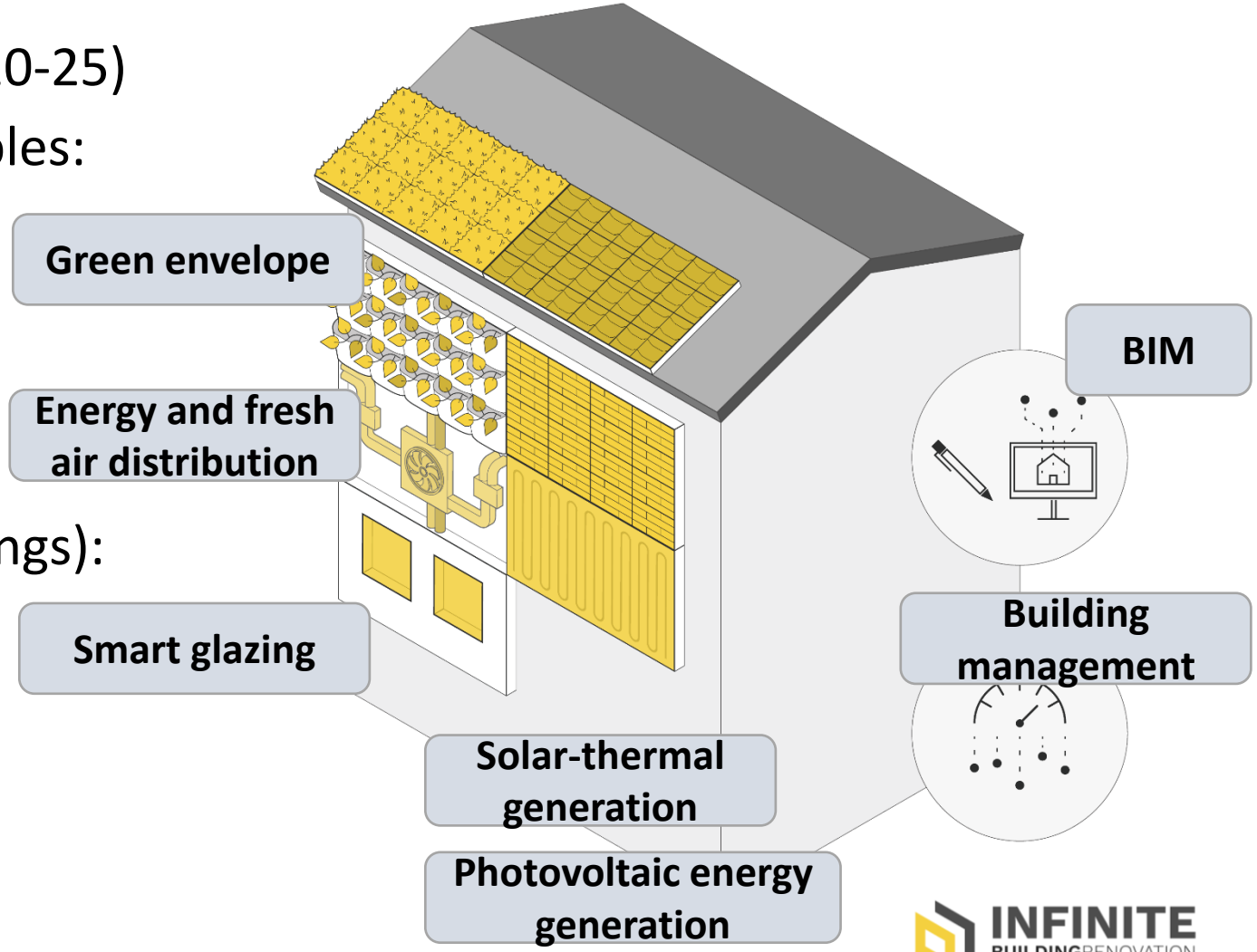


Life Cycle Assessment in practice

- Application of LCA for the design of building envelopes for renovation

  - H2020 EU project: INFINITE (2020-25)
  - Industrialized retrofitting principles:
  - **OFF-SITE PREFABRICATION**
  - **MULTI-FUNCTIONAL ENVELOPE**
  - **DIGITALIZATION**

  - 3 case studies (residential buildings):
  - **ITALY**
  - **SLOVENIA**
  - **FRANCE**



https://infinitebuildingrenovation.eu/

The Italian case

- Location: Greve in Chianti, Tuscany, Italy
- Destination: social housing
- 2 twin buildings with 4+4 dwellings
- Year of edification: 1978-79
- Reinforced concrete frame structure
- Autonomous heating and domestic hot water systems
- Number of residents: 15
- Residents: elderly, retired (most residents have lived there for 30-40 years)

Comparative LCA: industrialized vs traditional retrofit

- Traditional and industrialized retrofit need to achieve **the same function**: *providing a living environment to the inhabitants of the Italian demo building over a reference study period of 50 years and achieving the following performance:*

Parameter	Value	Unit
Indoor air temperature (winter)	19-21	°C
Indoor air temperature (summer)	25-27	°C
Indoor humidity	30 winter, 50 summer	%
Max CO_2 concentration	1000	ppm
Illuminance		lux
Self-sufficiency	48	%

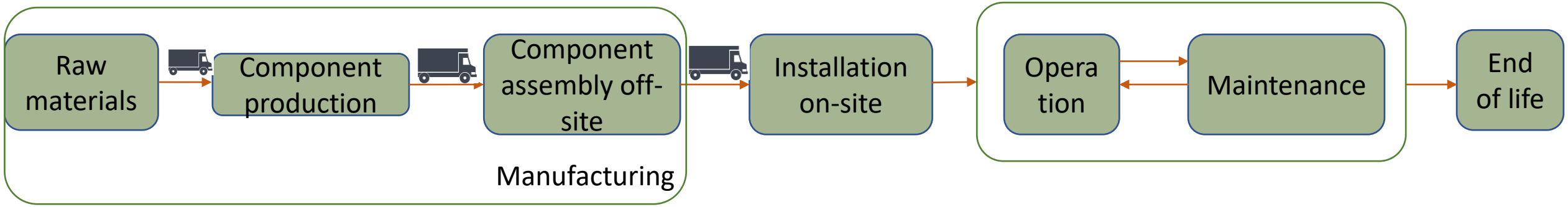
Setting a comparative LCA study: data collection

- **Industrialized retrofit**: primary data from technology providers and energy simulations
- **Traditional retrofit**: bill of quantities adapted to the specific building

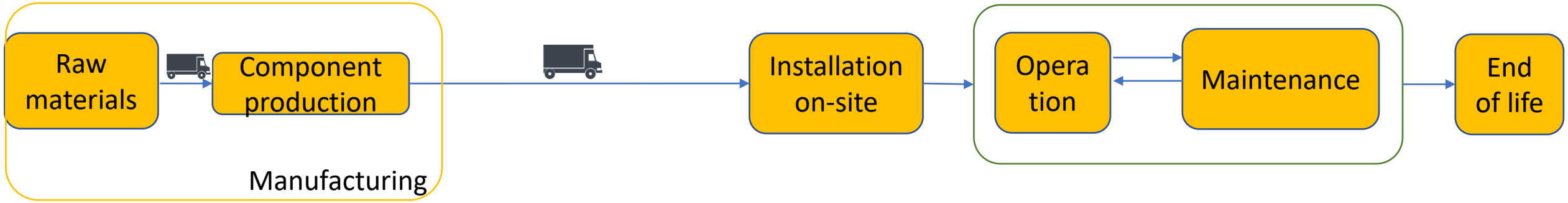
	Industrialized retrofitting	Traditional retrofitting
Envelope	Timber-based insulated façade (ventilated) Timber-based insulated roof (ventilated) New windows	Insulated façade (ventilated) Insulated roof (ventilated) New windows
Systems	Centralized heat pump Semi-decentralized ventilation, heating and cooling per dwelling PV panels (integrated in roof and façade) Solar thermal panels (integrated in façade)	Centralized heat pump connected to split units per dwelling Centralized ventilation PV panels (roof)

Life cycle stages

- **Industrialized retrofit**



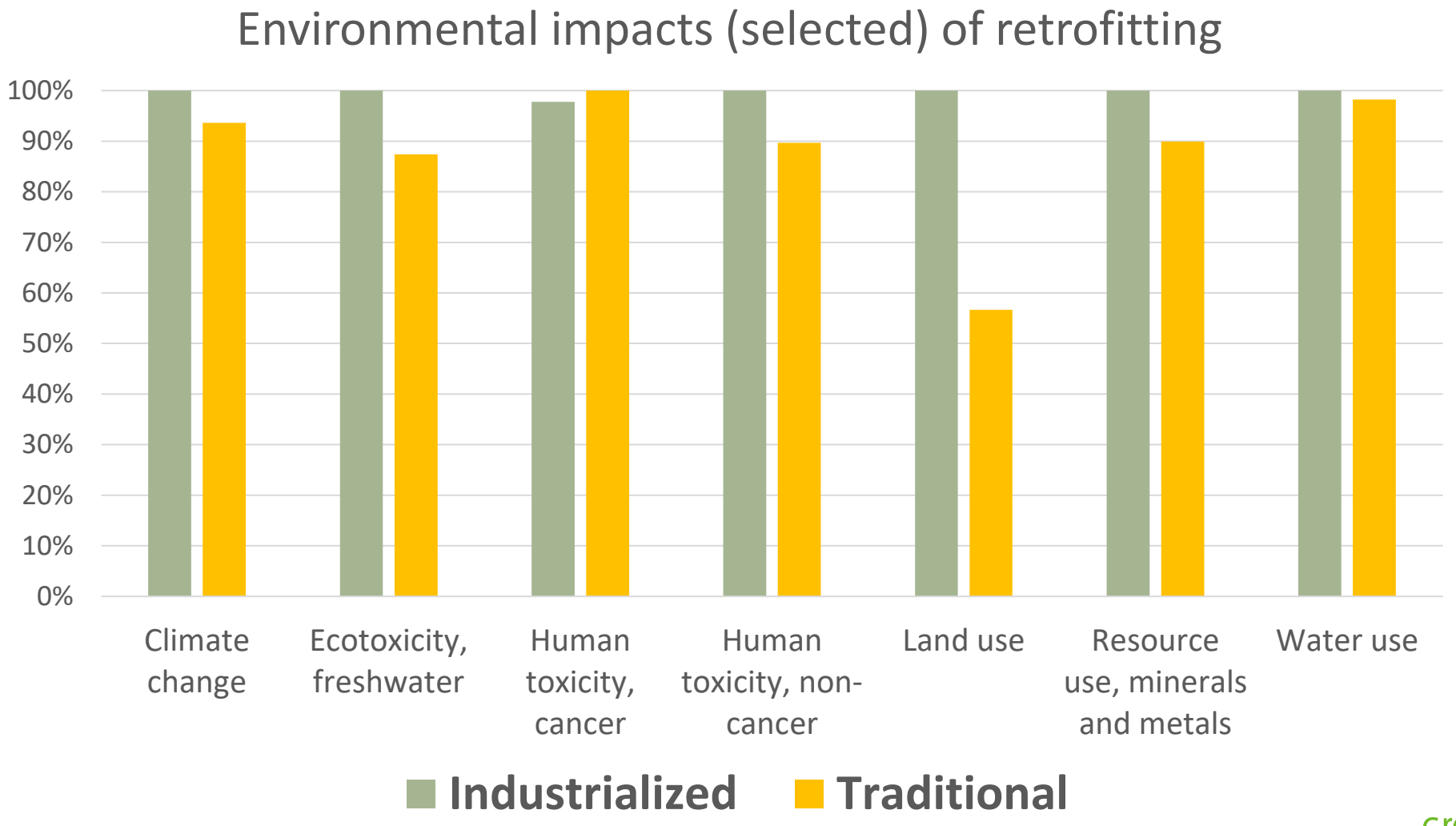
- **Traditional retrofit**



LCA results (starting point)

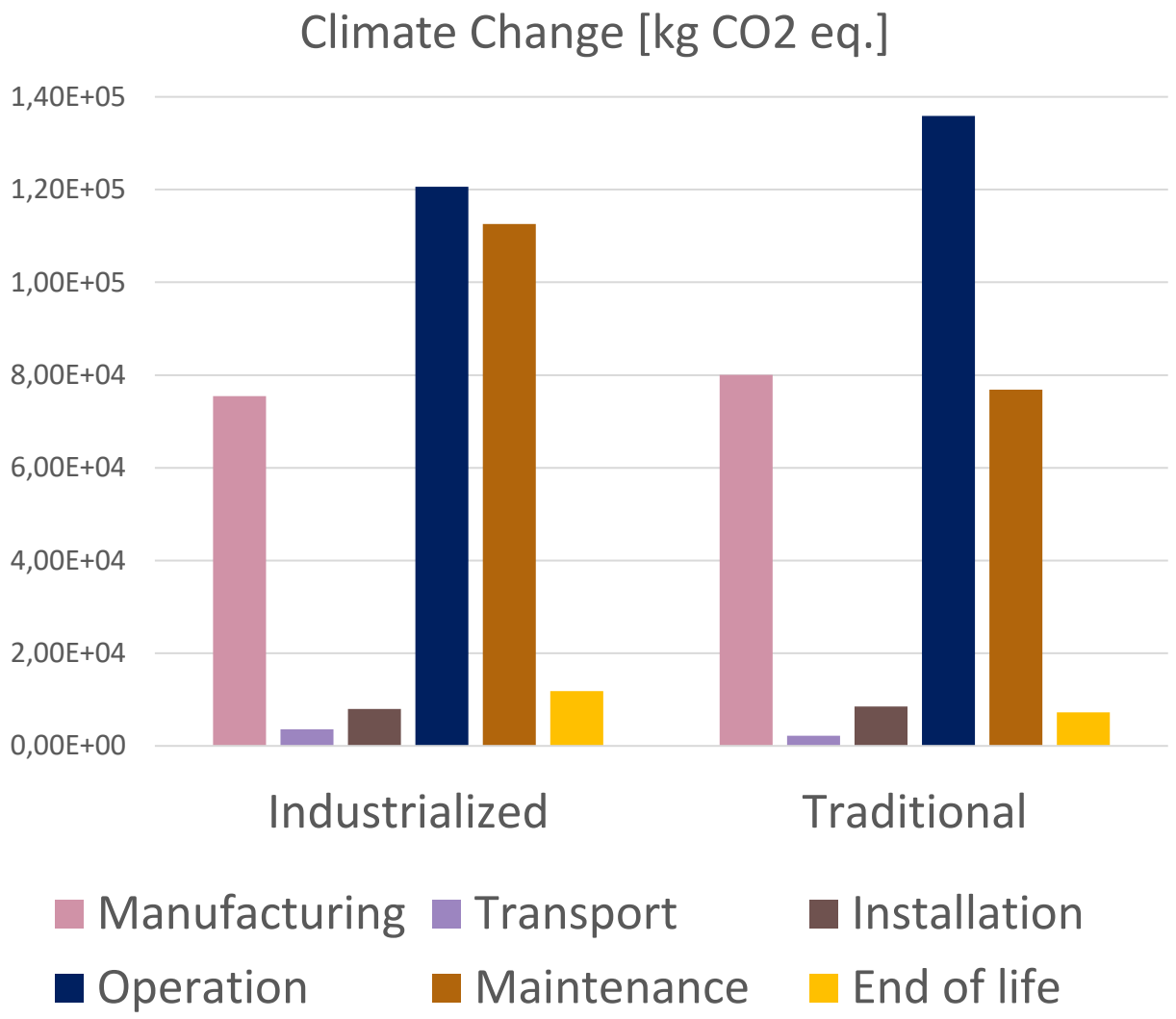
The higher the worse

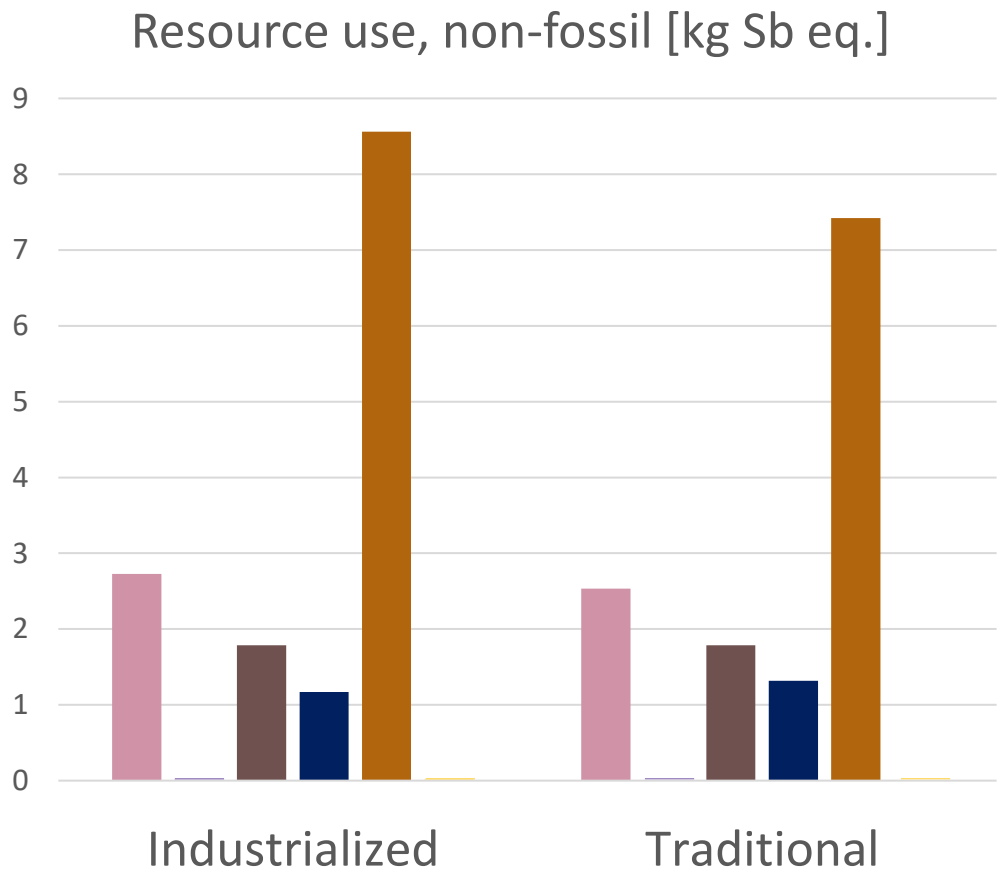
Software: openLCA
Database: ecoinvent 3.8 cut-off
Method: EF 3.0



*Results referred to 1 building, reference life time: 50 years

Life cycle stage contribution

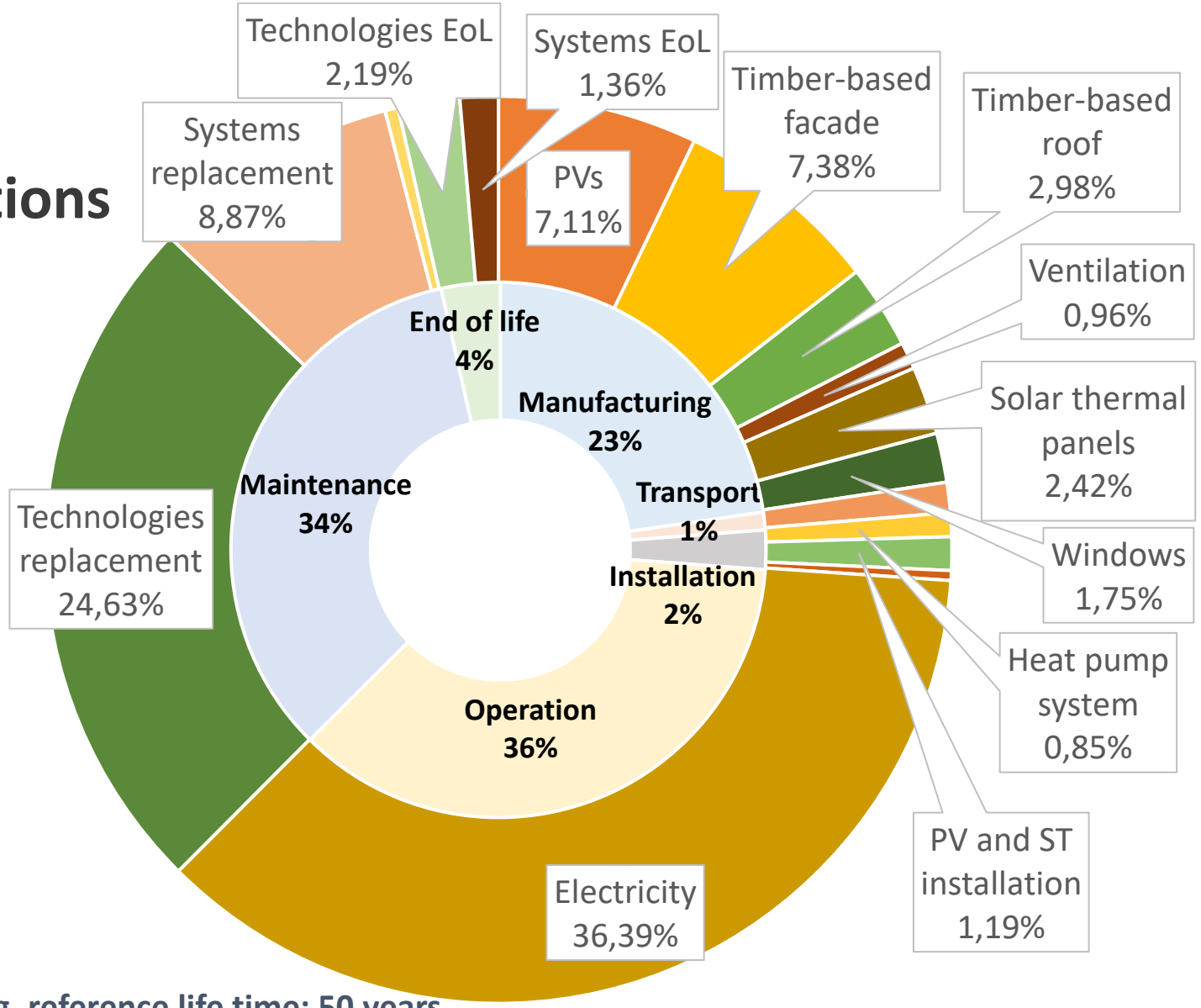




***Results referred to 1 building, reference life time: 50 years**

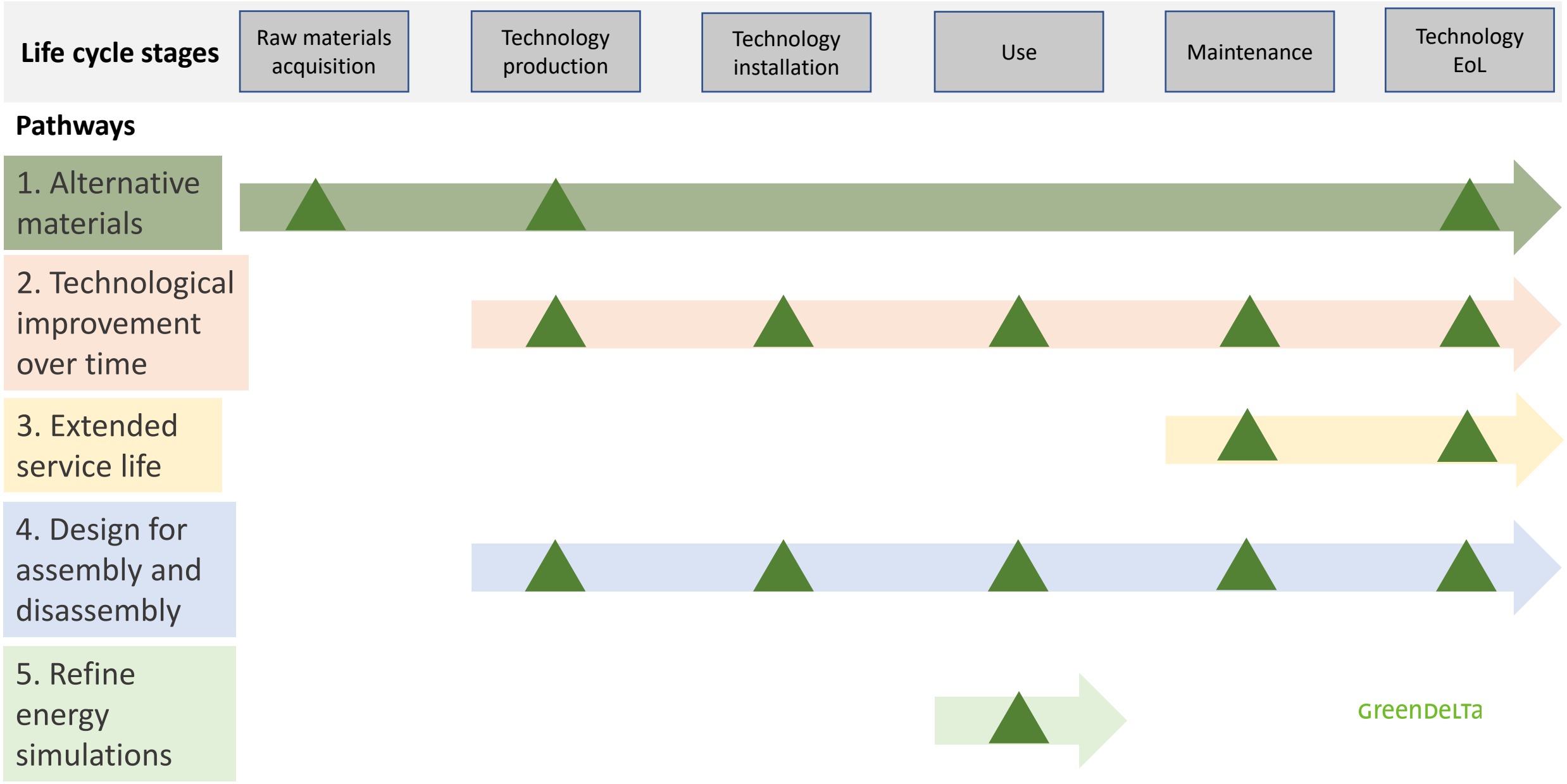
Industrialized retrofit impacts/ analysis

- **Carbon footprint contributions**



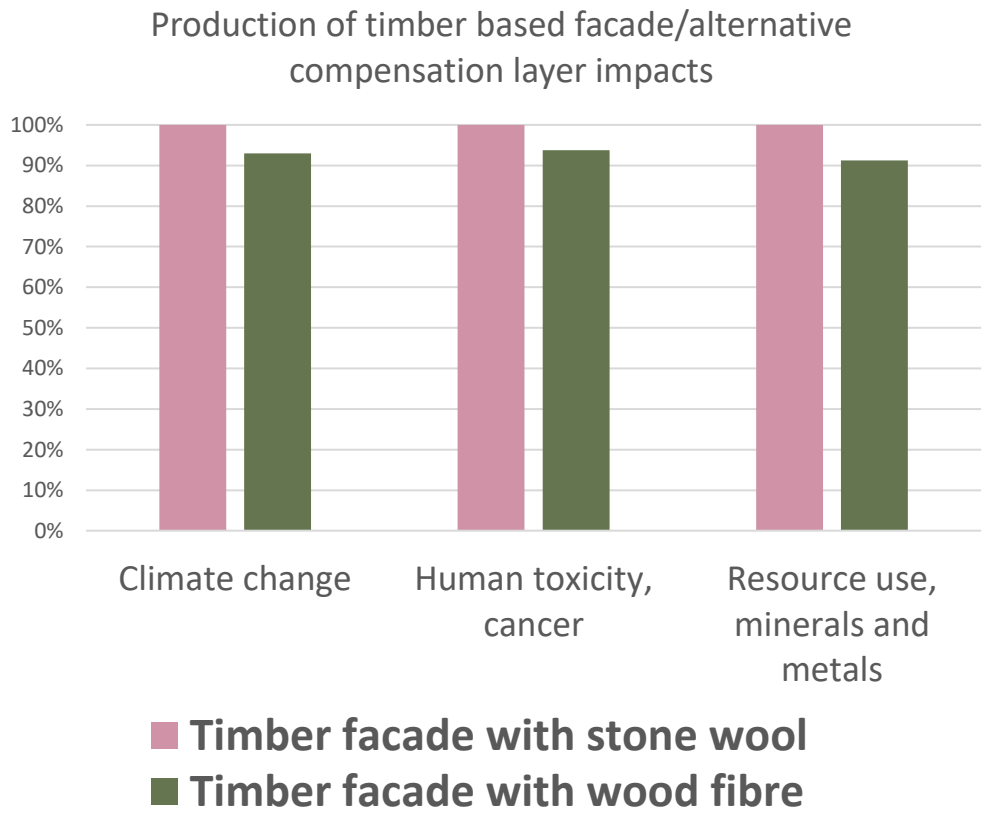
*Results referred to 1 building, reference life time: 50 years

Where to improve in industrialized design?



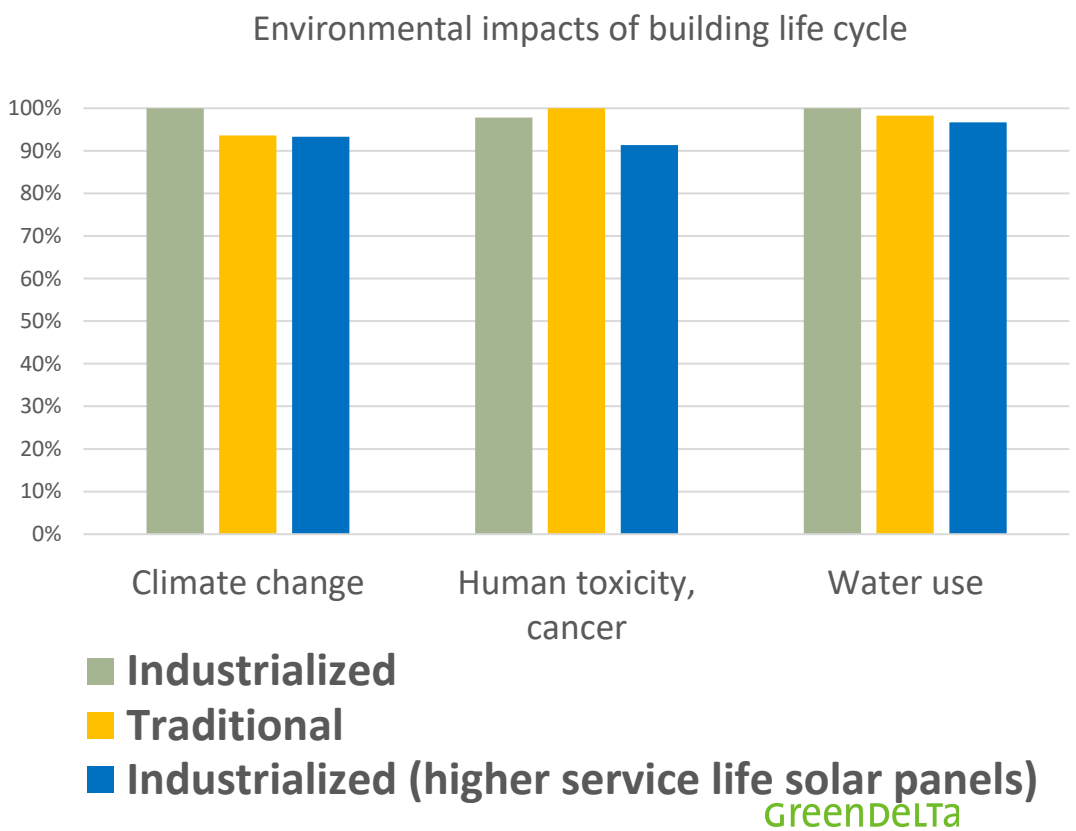
Testing the pathways

- **Pathway 1**: alternative material-> change compensation layer in timber façade (stone wool -> wood fibre)



*Results referred to 1 m² of timber façade, without cladding

- **Pathway 3**: extended service life -> increased service life of solar panels (10->25 years)



*Results referred to 1 building, reference life time: 50 years

Conclusions and the way forward

- We have tools and metrics, we need to apply them
- Empower AEC professionals
- Empower countries (e.g. national databases)
- Work on communication of results
- Work on setting benchmarks
- Connect sustainability research with industry

The European Green Deal: “Companies making ‘green claims’ should substantiate these against a standard methodology to assess their impact on the environment”.

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sustainability consulting + software

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