Heat Pump (Re-)Cycle

What do we actually do if the heat pump breaks down?

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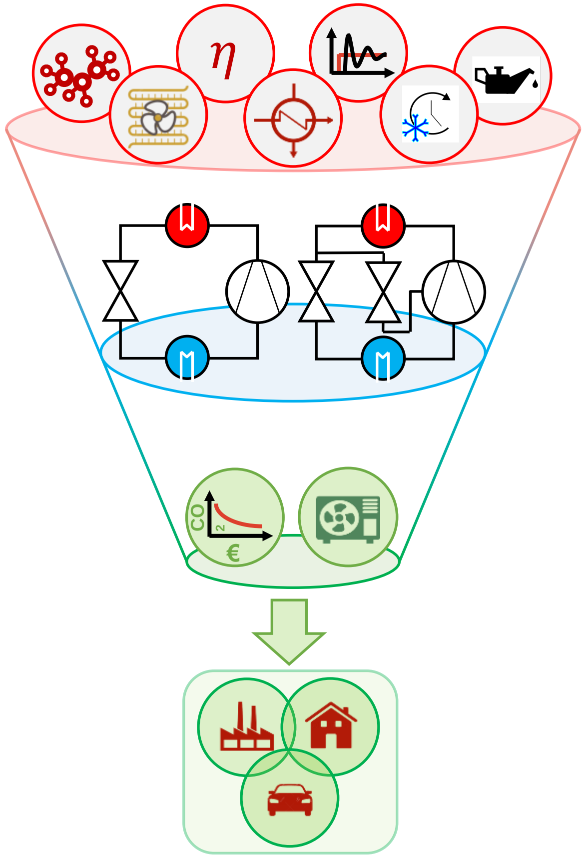
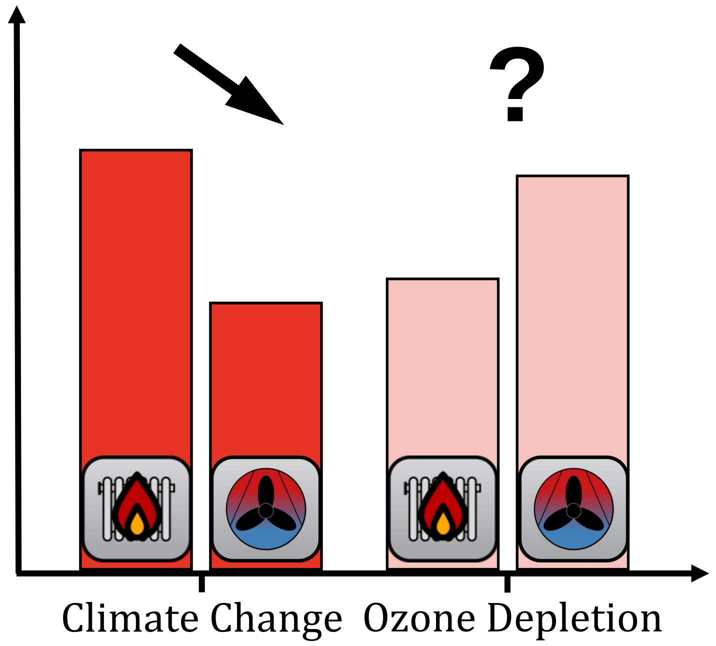
Team Refrigeration Cycle

Our vision is energy-efficient and sustainable heat supply through systematic development of the refrigeration cycle process - from the molecule to the operating strategy



Integral Assessment

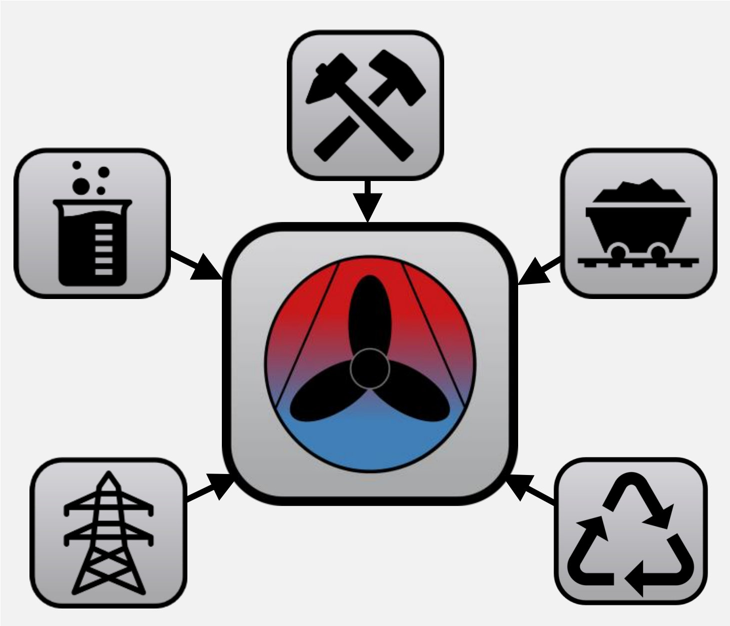


Heat pumps to decarbonize the residential heating sector

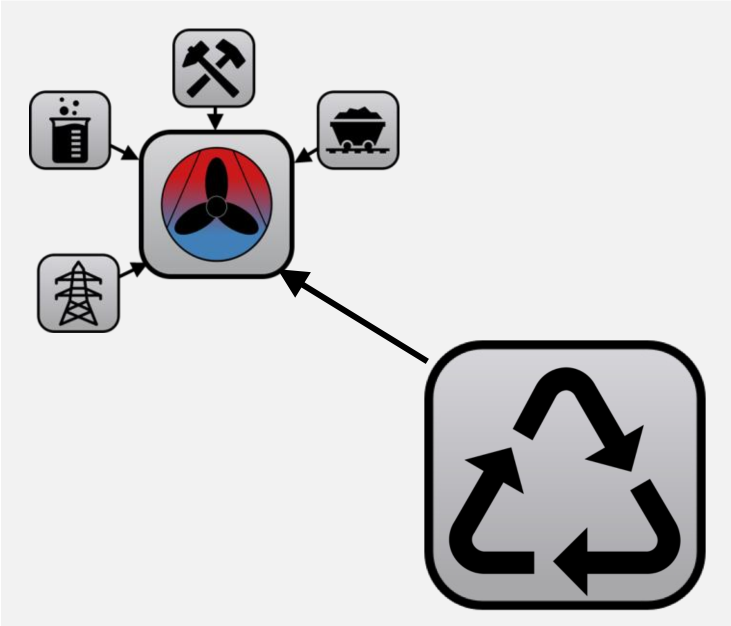
Life Cycle Assessment (LCA) for a holistic environmental assessment

Agenda

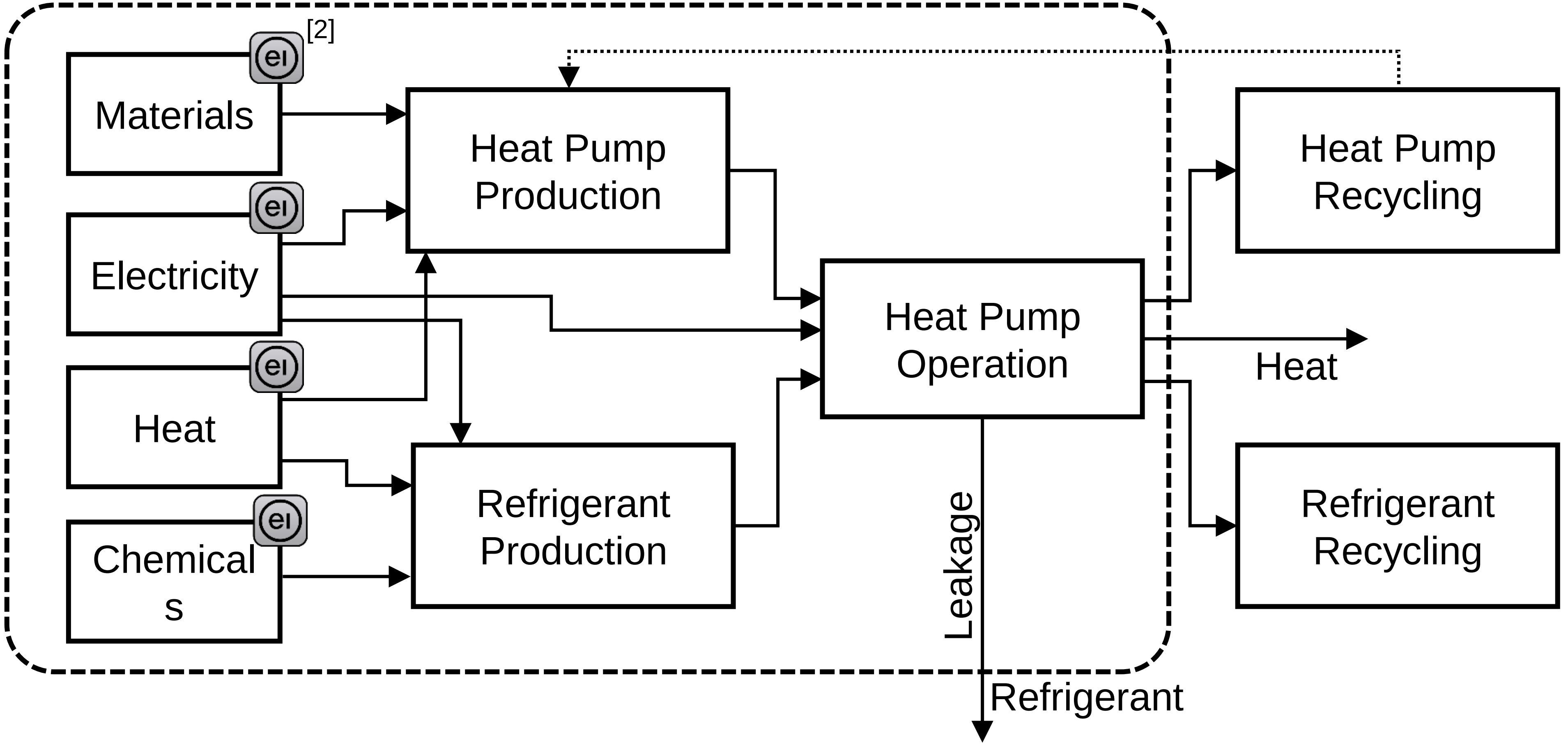
1 Life Cycle Assessment



2 Circular Strategies



Life Cycle Assessment: No benefits from recycling as conservative estimation



Life Cycle Modelling: Refrigerant Production

Refrigerant Production

- Natural Refrigerants
  - Ecoinvent data
- R410A, R32, R1234yf
  - Modelling of production process[3-5]
- Specific refrigerant mass
  - Datasheets
  - UNEP report[6]

	ei	$m_{\mathrm{ref,HP}}$
R410A	✗	
R32	✗	
R1234yf	✗	
R290	✓	
R1270	✓	
R600a	✓	
R717	✓	

$$\mathrm{e.g.\ R32:}\ \mathrm{CH_2Cl_2} + 2\,\mathrm{HF} \rightarrow \mathrm{CH_2F_2} + 2\,\mathrm{HCl}$$

heat

electricity

Leakage

- Assumed leakage rates[2]
  - Per year: 5 %
  - End of life (EOL): 30 %

- Refrigerant dependent characterization factors
  - E.g. Global Warming Potential (GWP)

	GWP
R410A	2256
R32	771
R1234yf	0,501
R290	0,02
R1270	1,8
R600a	4
R717	0

total refrigerant emitted

leakage operation

refrigerant mass HP

$$m_{\mathrm{ref,leakage}} = (n \cdot L_{\mathrm{operation}} + L_{\mathrm{EOL}}) \cdot m_{\mathrm{ref,HP}}$$

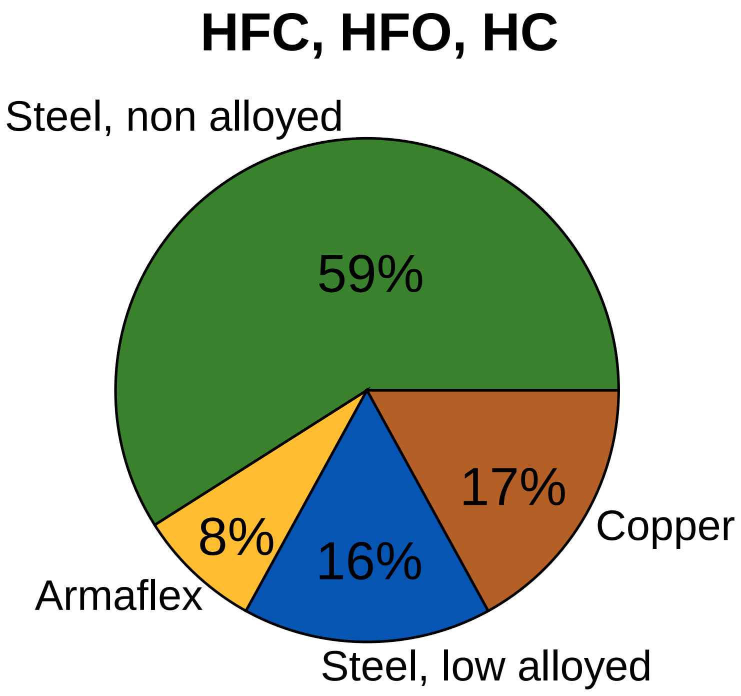
operating years

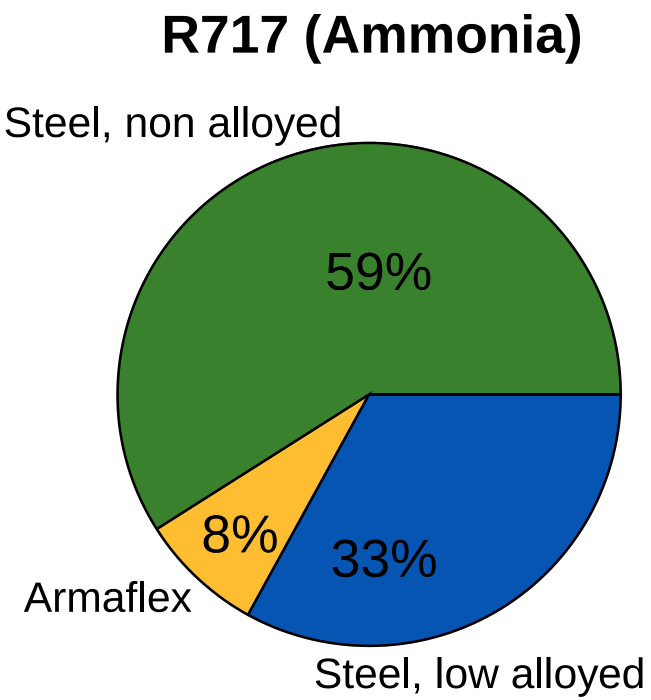
leakage EOL

Life Cycle Modelling: Heat Pump Production

Heat Pump Production

- Mass composition
  - Based on an exemplary heat pump[7]
- Specific weight of 18 kg/kW
  - Based on data sheets
- Heat pumps and subcomponents assembly
  - Generic metalworking data set

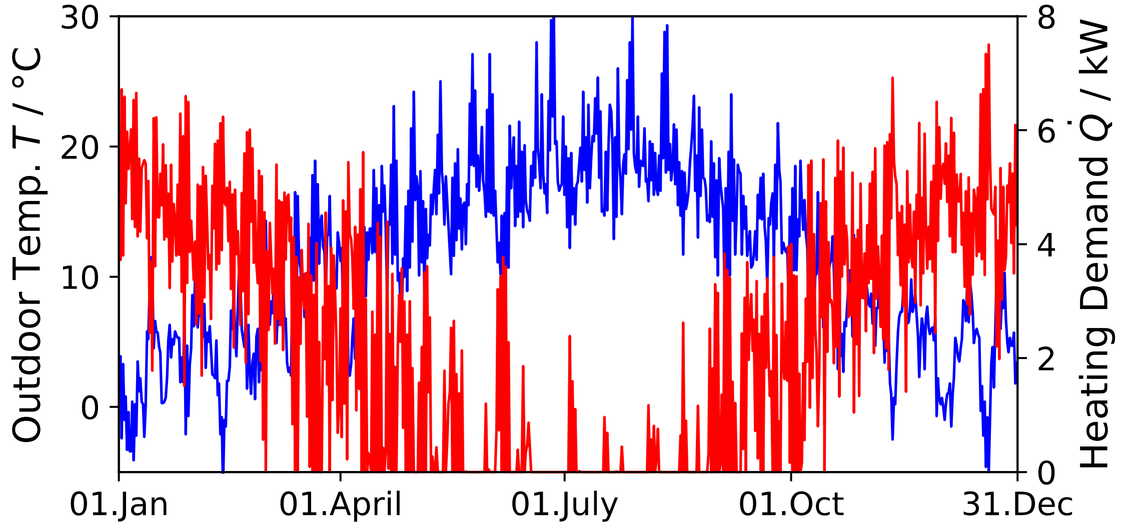


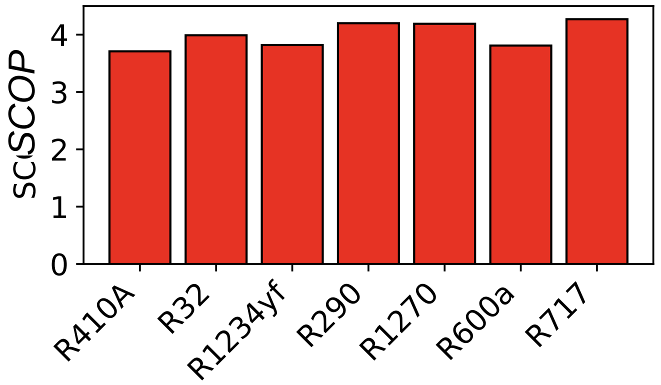


Life Cycle Modelling: Heat Pump Operation

Heat Pump Operation

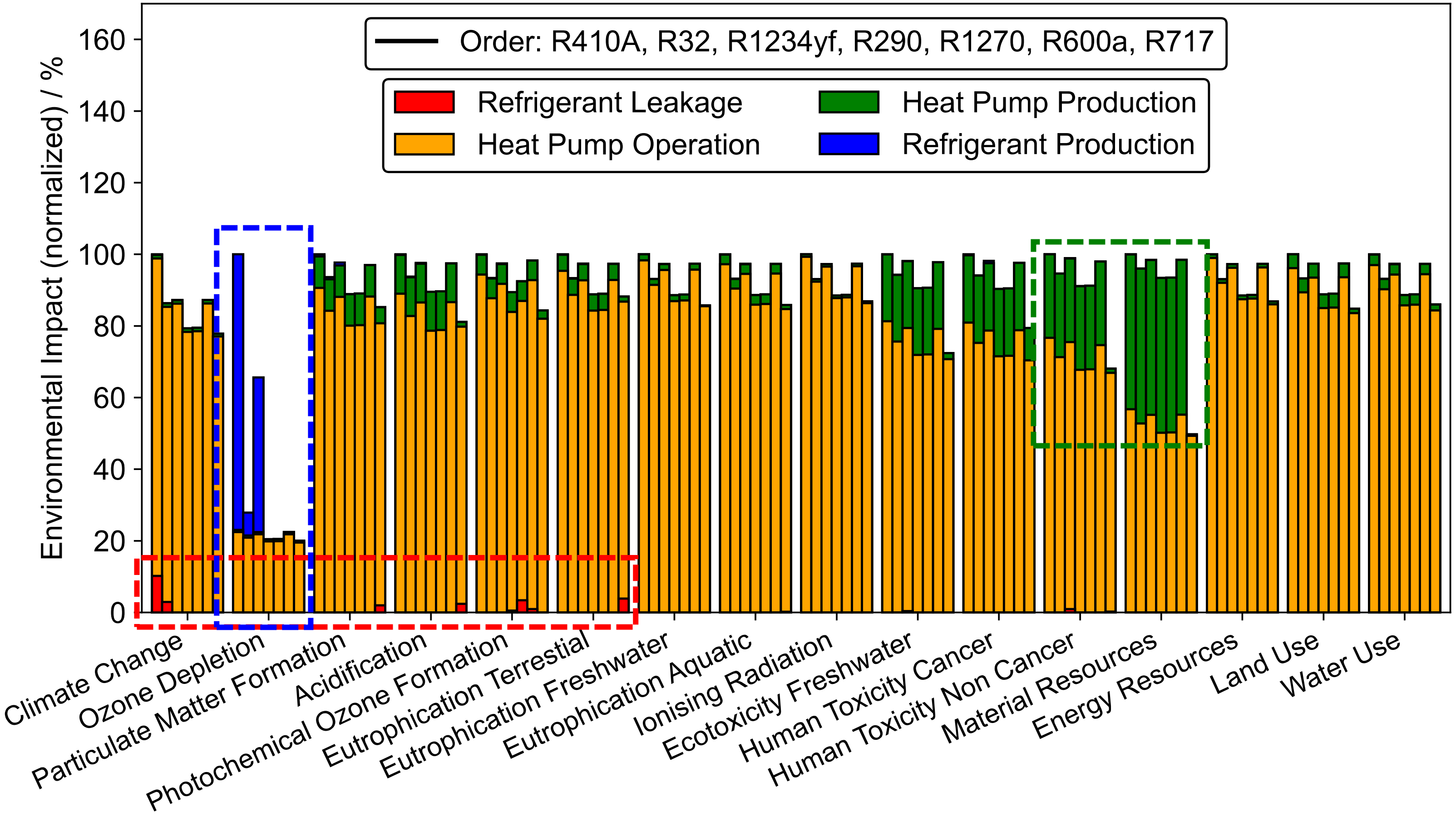
- Annual temperature profile
  - Test Reference Year 2015
- Buildings heat demand
  - TEASER[8]: two-story single-family house
- Heat pump model[9]
  - Fluid dependent efficiency
  - Determines optimal COP by varying pressure levels





Refrigerant dependent required electrical input power

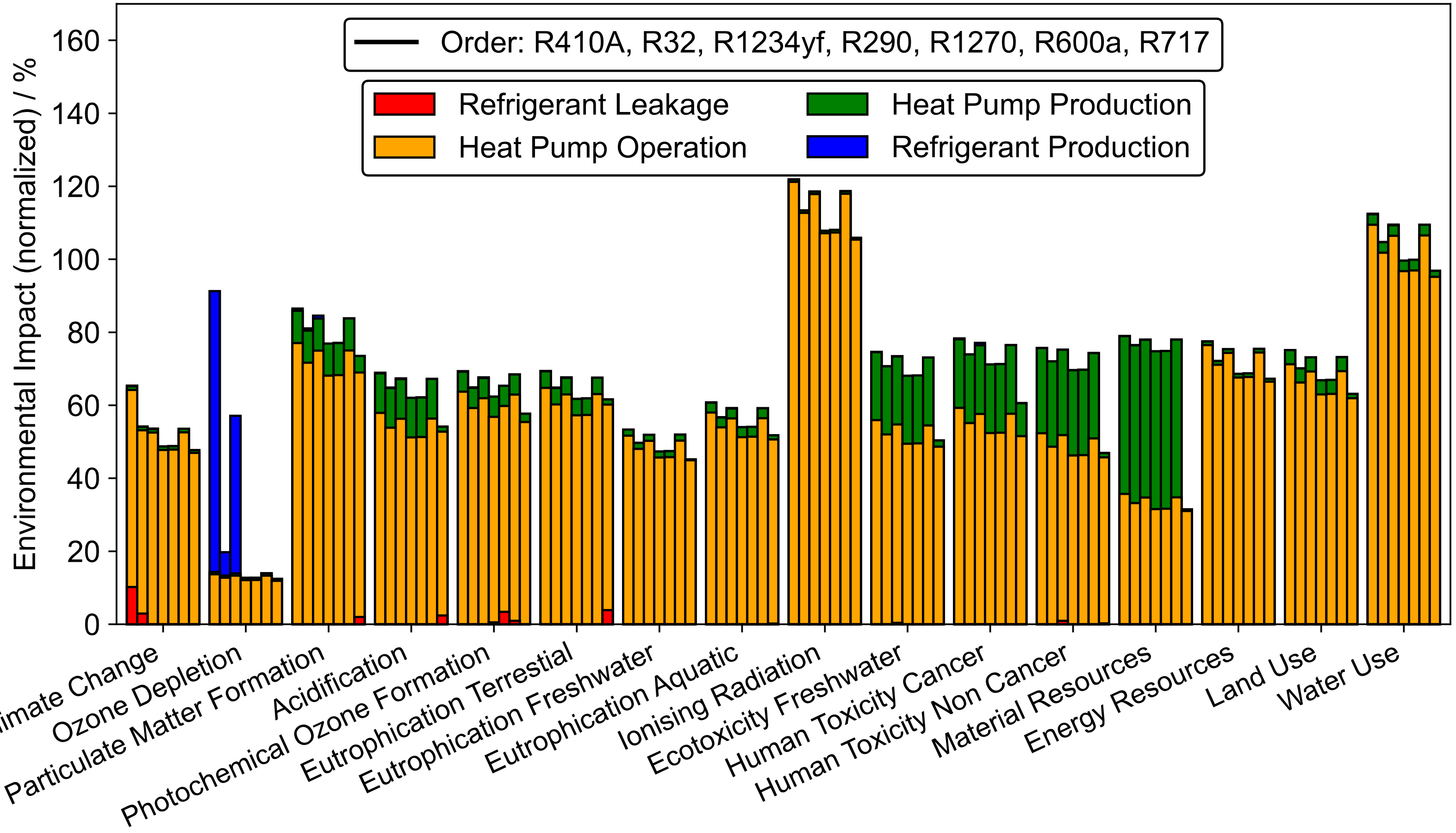
Results: Environmental Impacts of a Heat Pump



Findings

- Electricity demand biggest influencing factor
- Heat pump efficiency most important evaluation criterion
- Other life cycle stages only secondary influence

Sensitivity Analysis:
Influence of the Electricity Mix

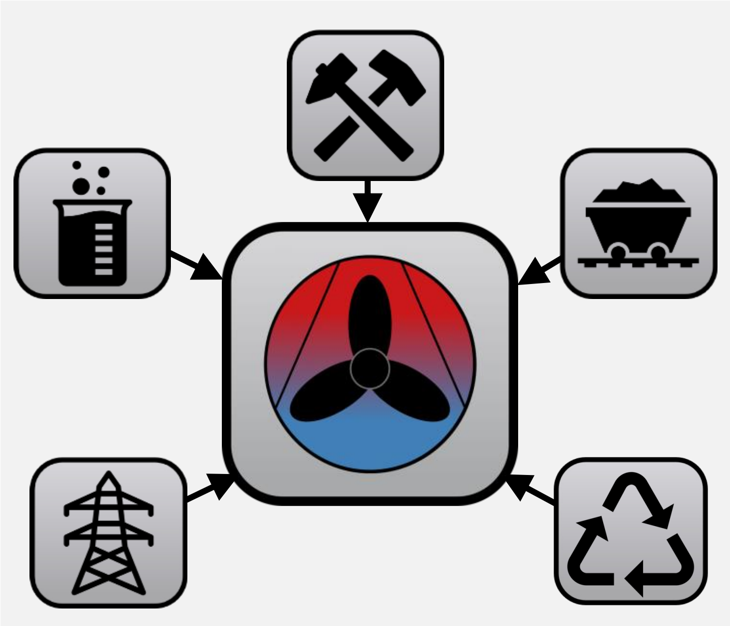


Findings

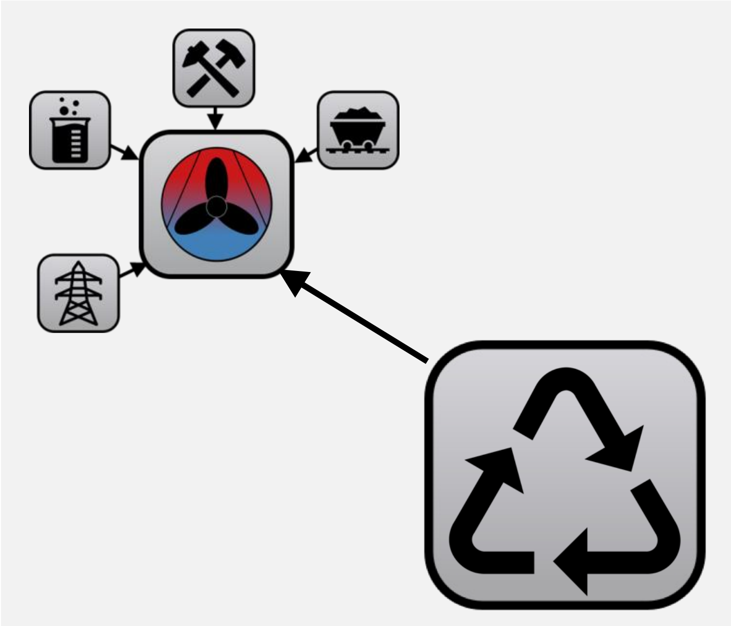
- Change in electricity mix → significant impact reduction
- Other life cycle stages gain relevance

Agenda

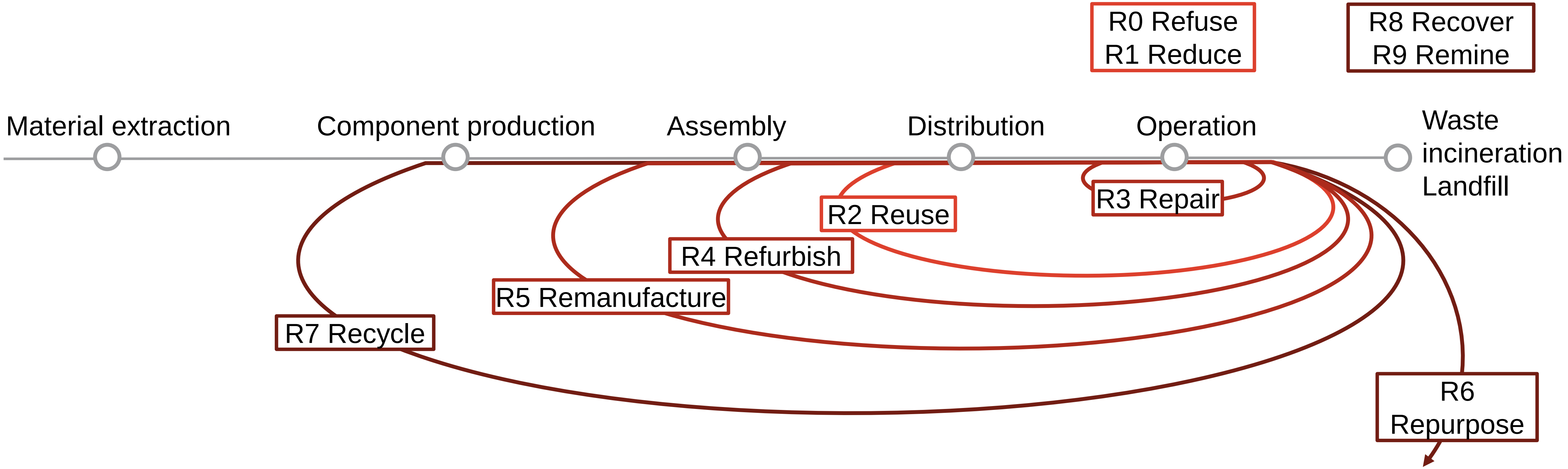
1 Life Cycle Assessment



2 Circular Strategies

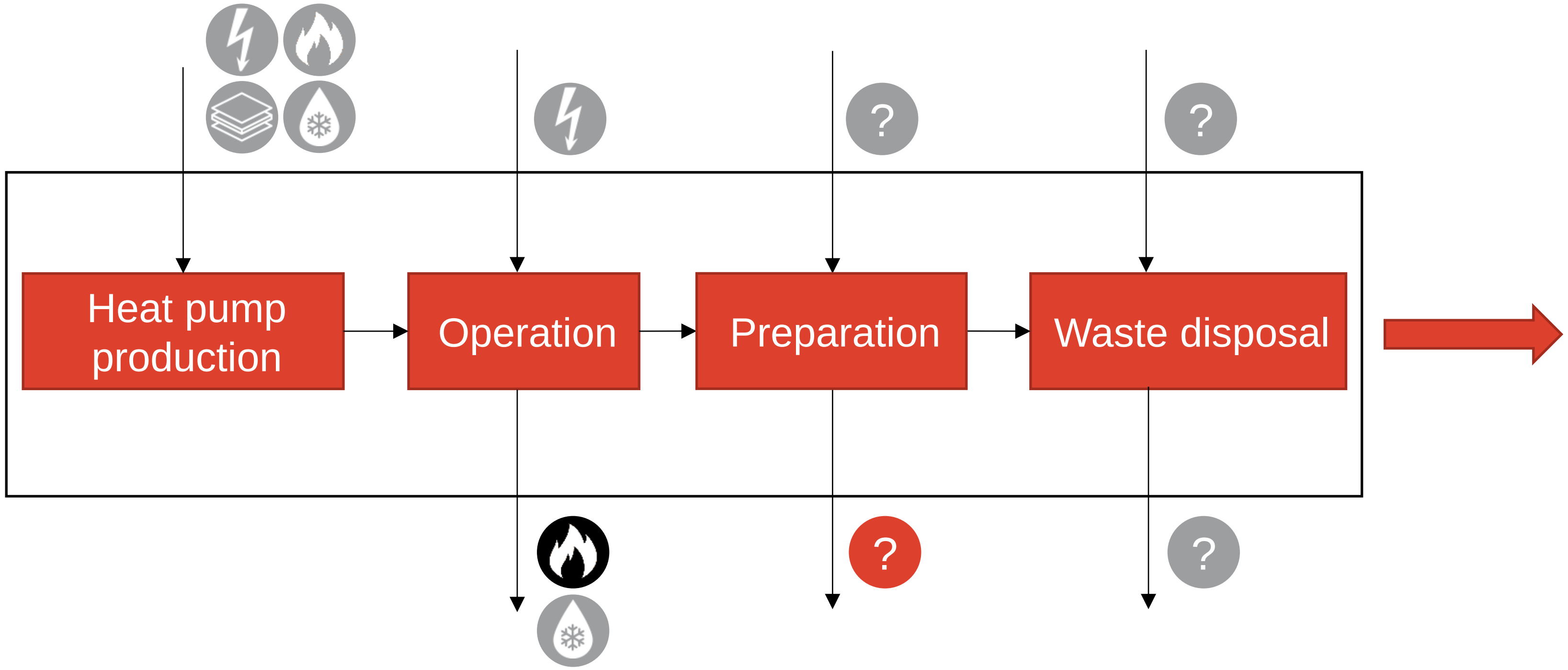


Circular strategies[4]

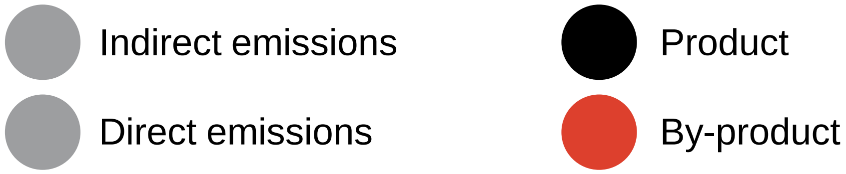


Today: Ecological investigation

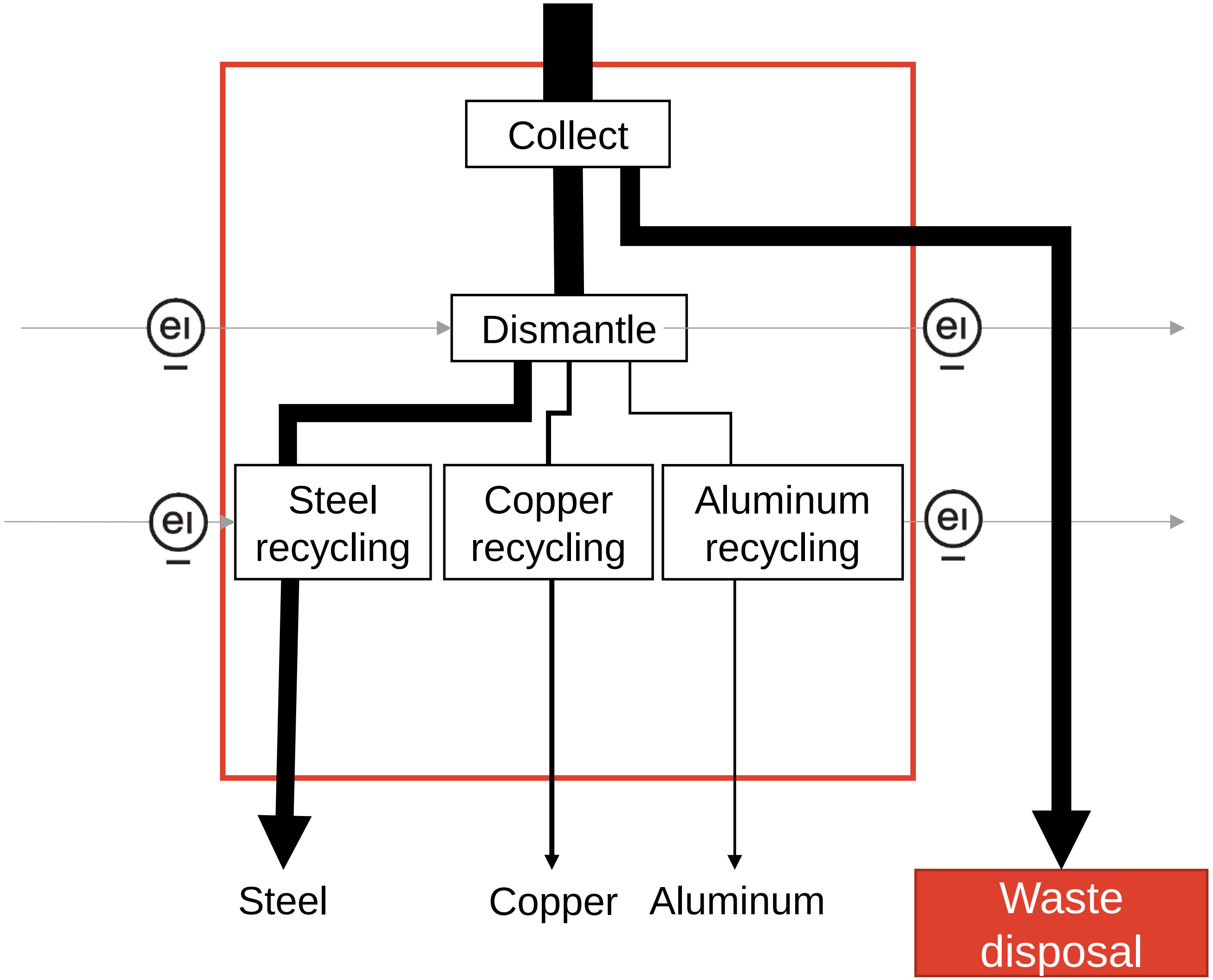
Results framework



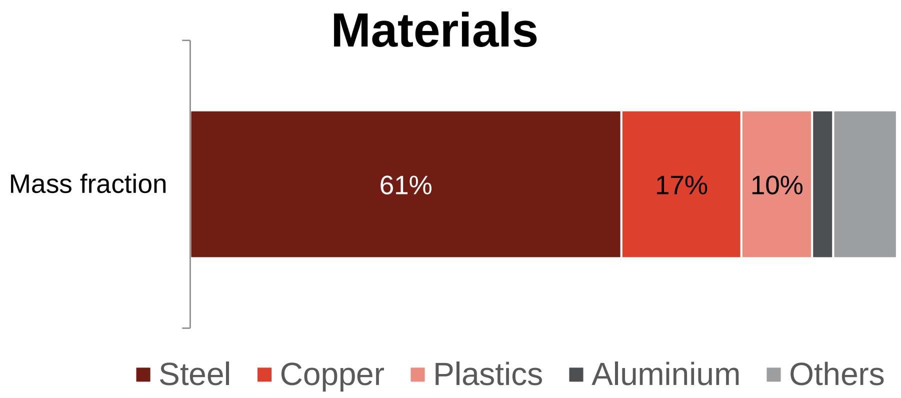
Environmental impacts in the categories
- Human health
- Ecosystem
- Resource availability



Modeling of recycling



- Mass fractions of the materials
- Current end-of-life recycling rates
  - Collection
  - Utilization



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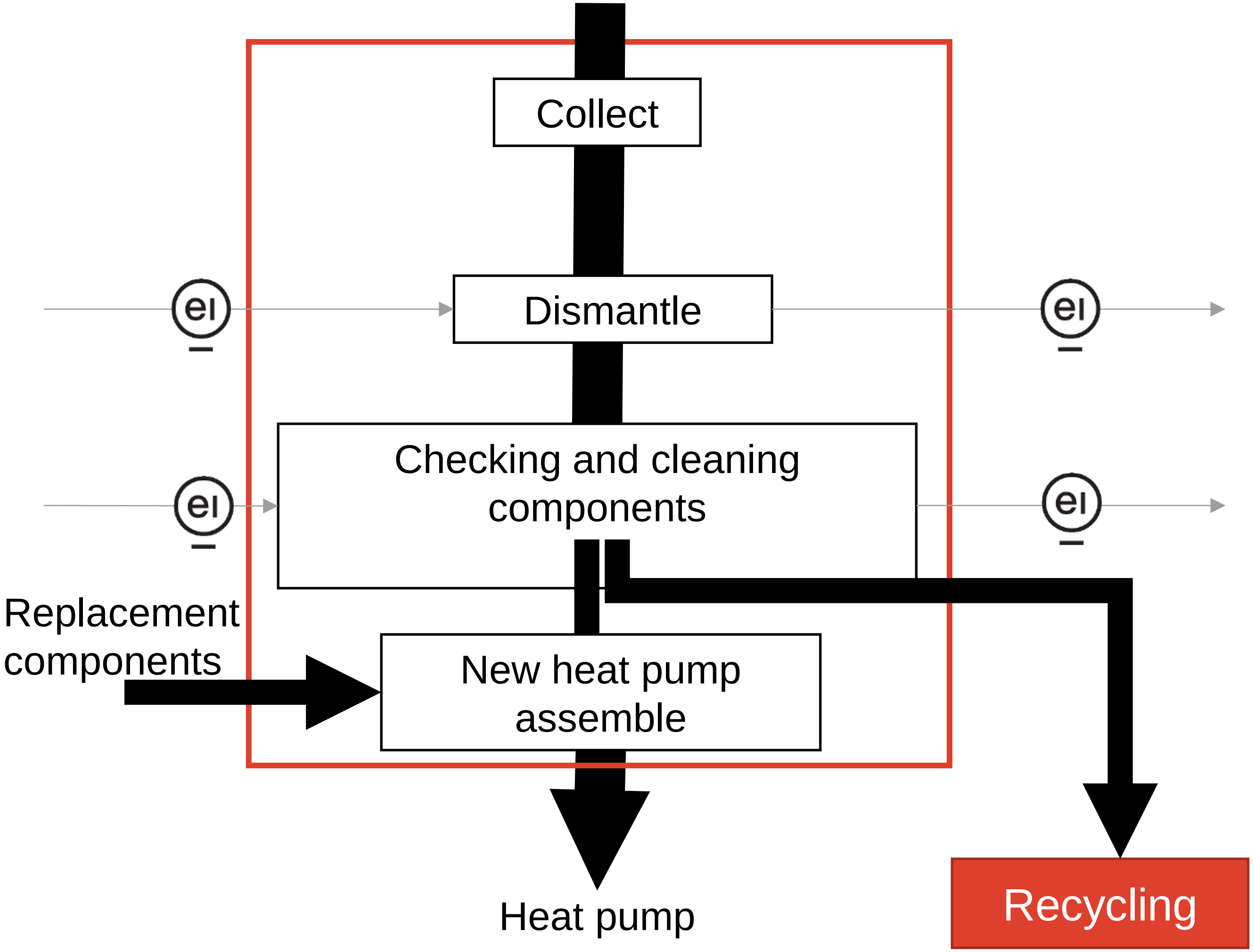
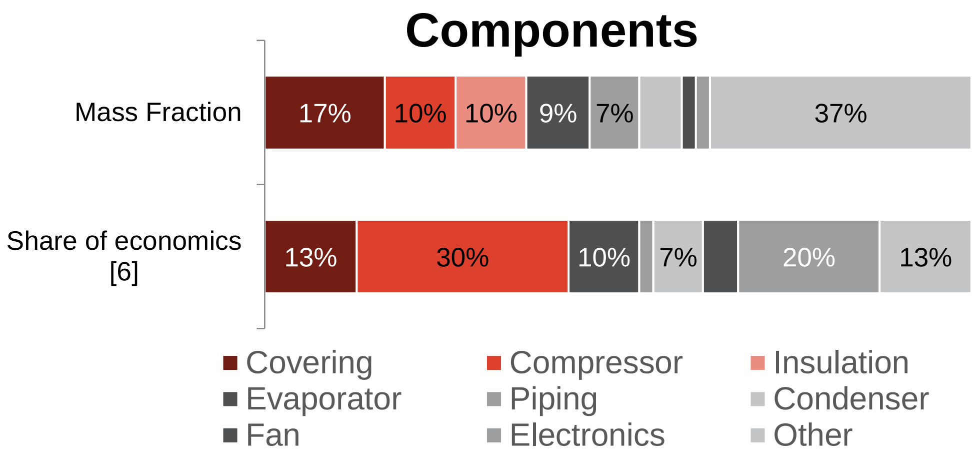
Modeling of remanufacturing



- Which components are prone to faults?[5]
  - Compressor
  - Control/electronics
  - Blower
- Indirect emissions Replacement components
  - Mass fractions of the components in the heat pump
  - Materials per component



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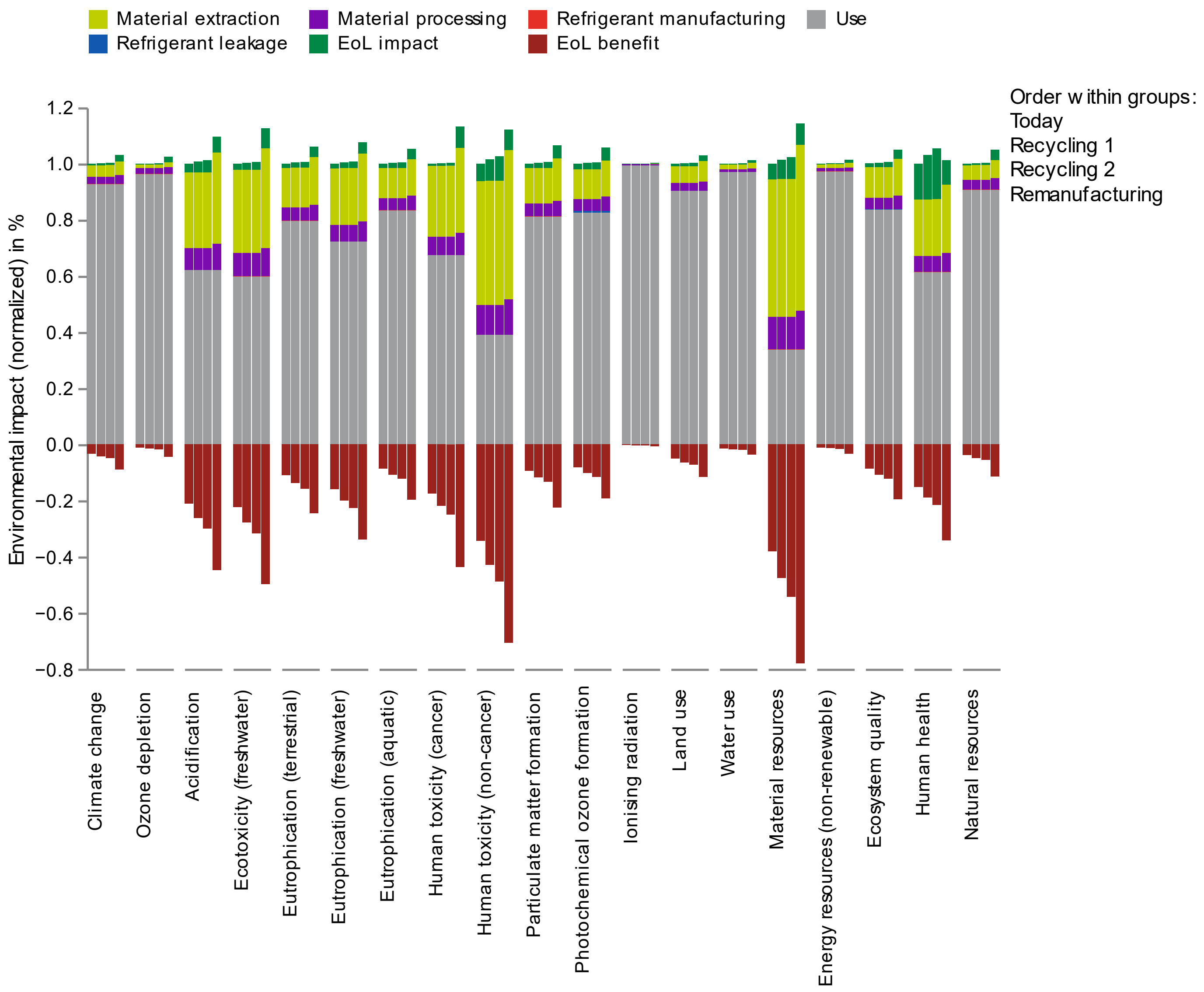
Case Study: Recycling with todays grid mix



- It is possible to model R-Strategies and compute reasonable results
- It is possible to compute the share of phases
- Depending on the environmental metric, R-Strategies have major impact
- Next steps:
  - Sensitivity Analysis
  - Scenario Analysis
  - Economical assessment

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(9) C. Höges, V. Venzik, C. Vering, and D. Müller, “Bewertung alternativer Arbeitsmittel für Wärmepumpen im Gebäudesektor,” 2022, doi: 10.1007/s10010-022-00584-0.

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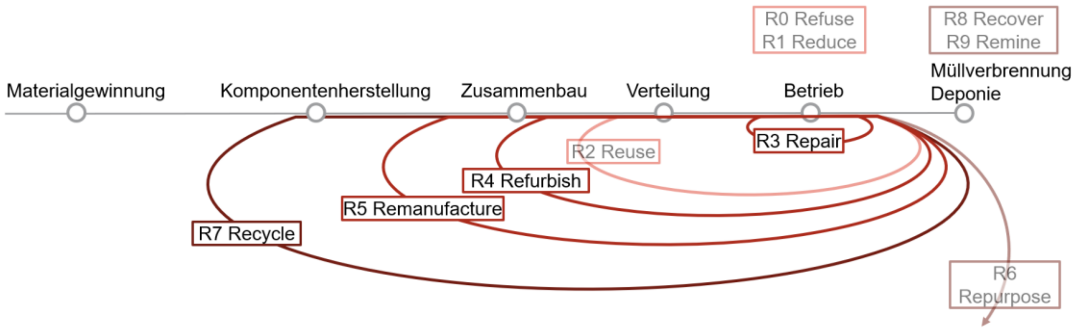
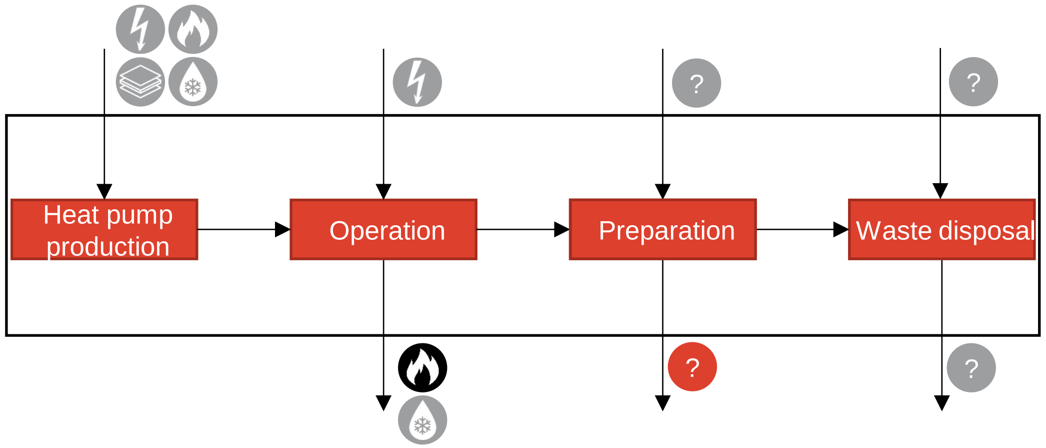
Summary and perspectives

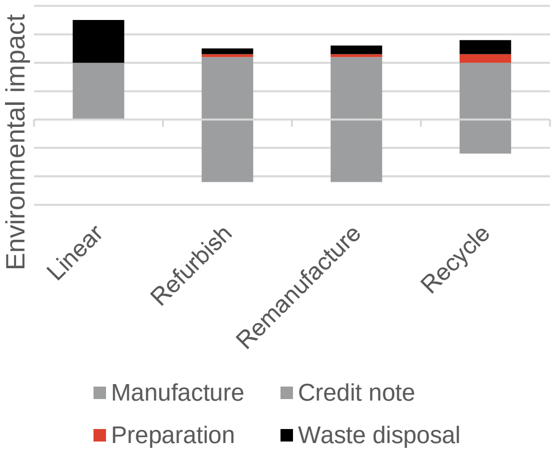
Summary

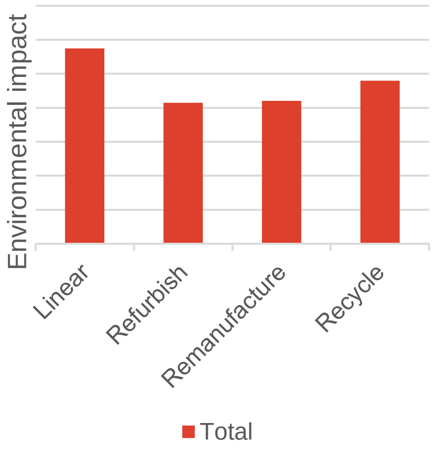




Next steps

- Results of the LCA





- Modeling the economy