Towards Integral Assessment of Heat Pumps and Refrigerants Using LCA

A Case Study for the German Building Stock

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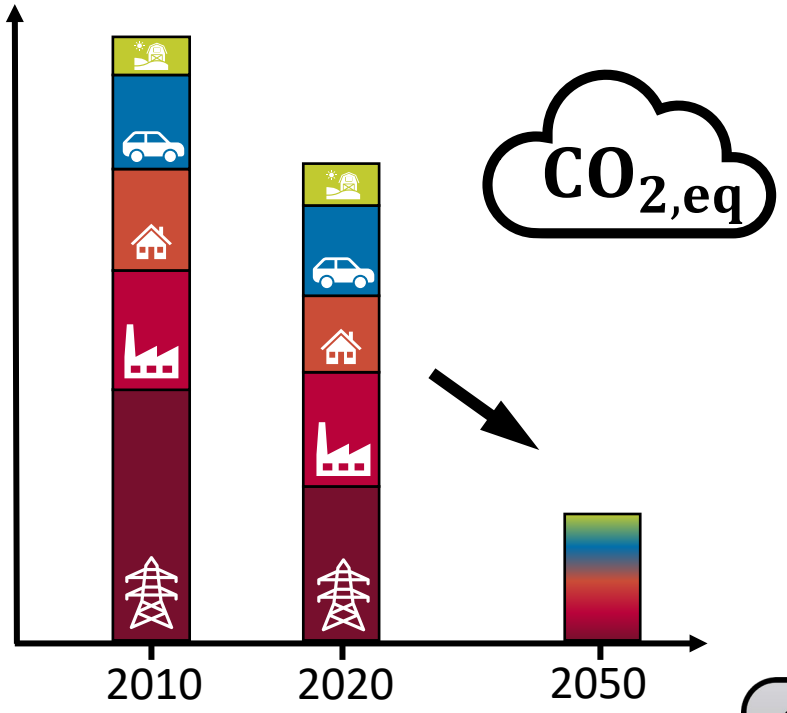
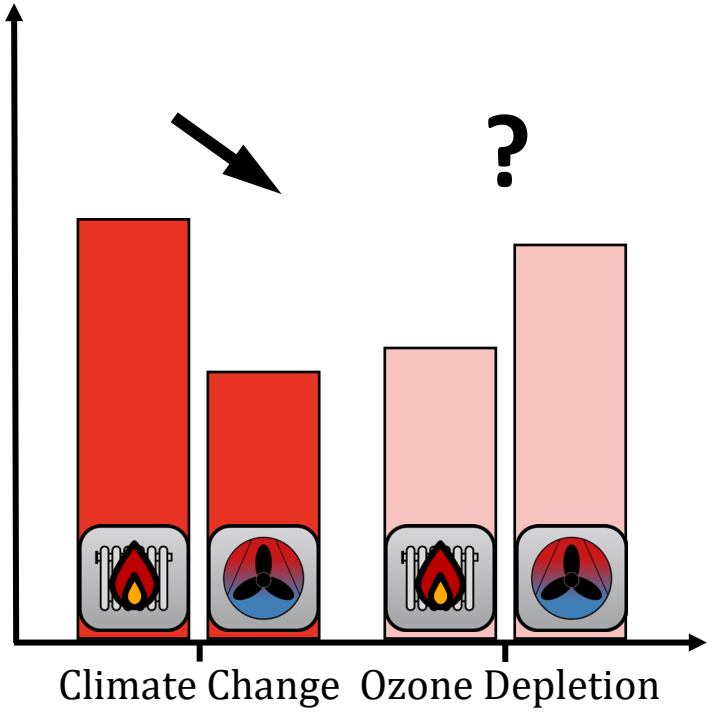
Motivation: Integral Assessment



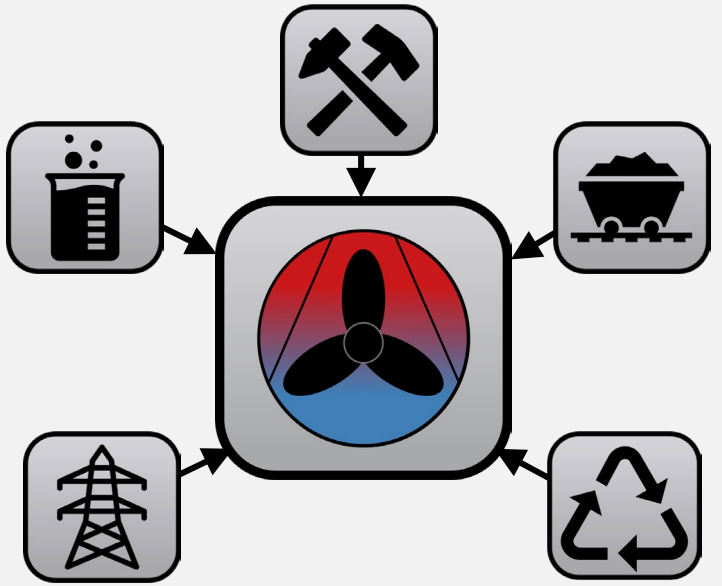
Heat pumps to decarbonize the residential heating sector



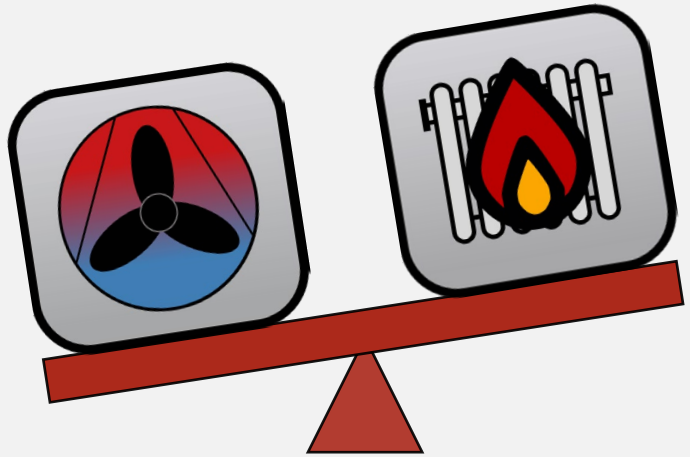
Life Cycle Assessment (LCA)[1] for a holistic environmental assessment

Agenda

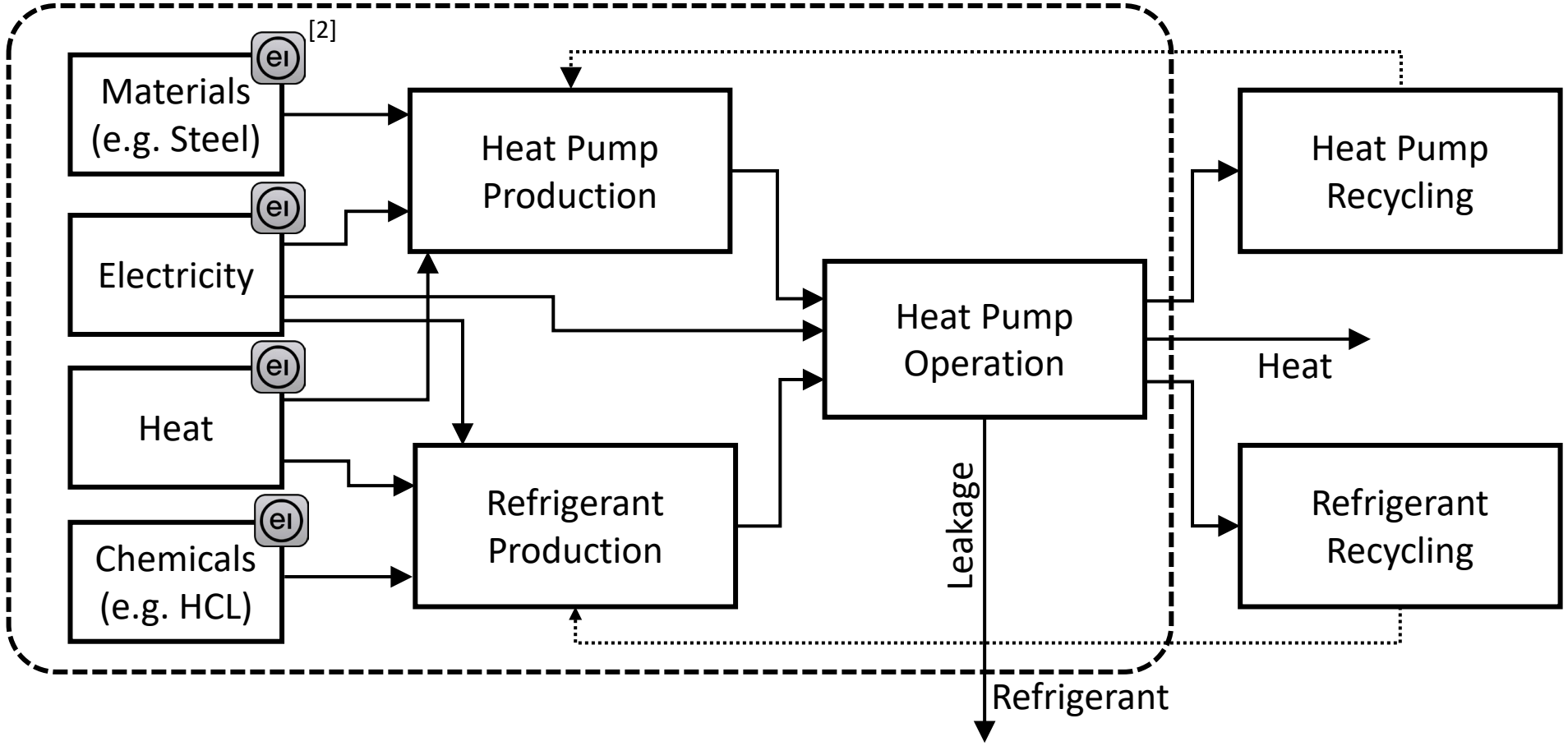
1 Life Cycle Assessment



2 Heat Pump vs. Gas Boiler



Life Cycle Modelling

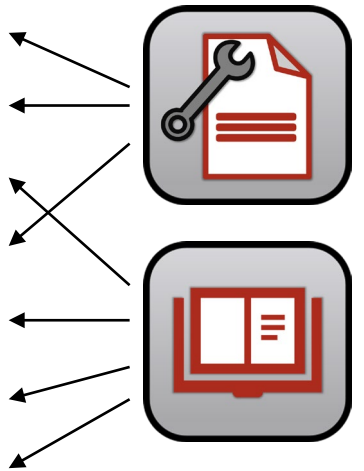


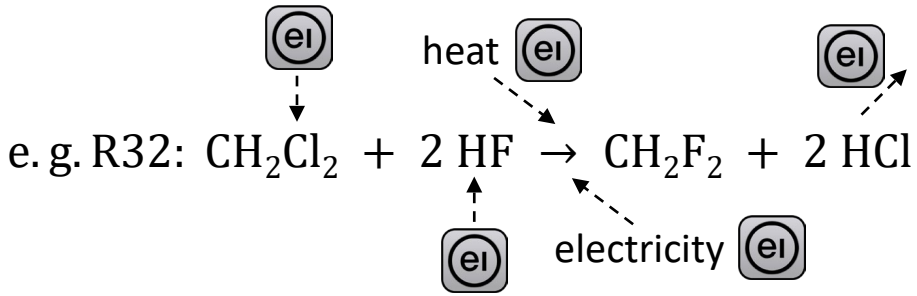
Life Cycle Modelling: Refrigerant Production

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	✓	





Life Cycle Modelling: Refrigerant Leakage

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

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

leakage operation

refrigerant mass HP

operating years

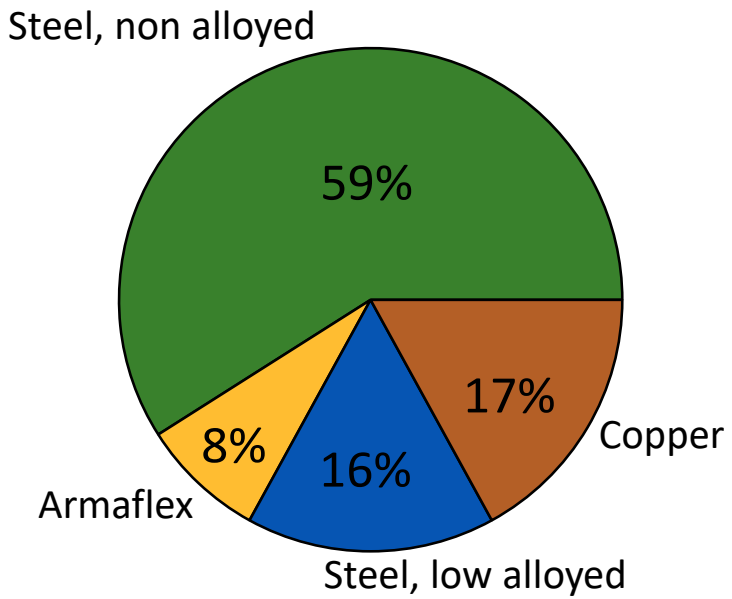
leakage EOL

Life Cycle Modelling: Heat Pump Production

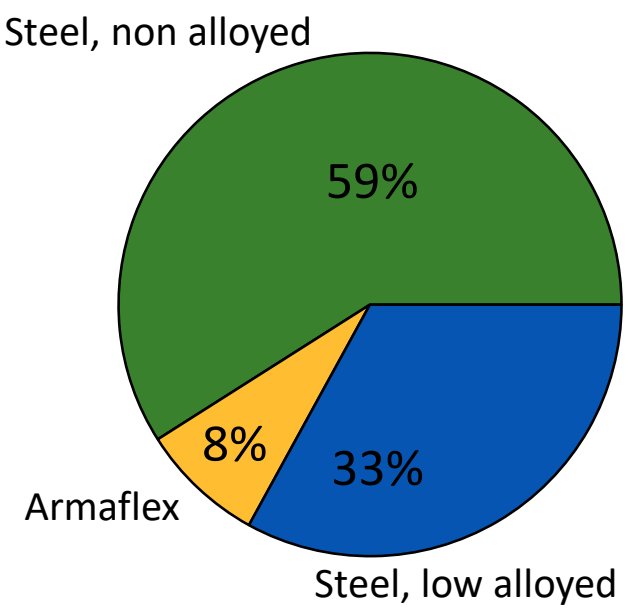
Heat Pump Production

- 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

HFC, HFO, HC



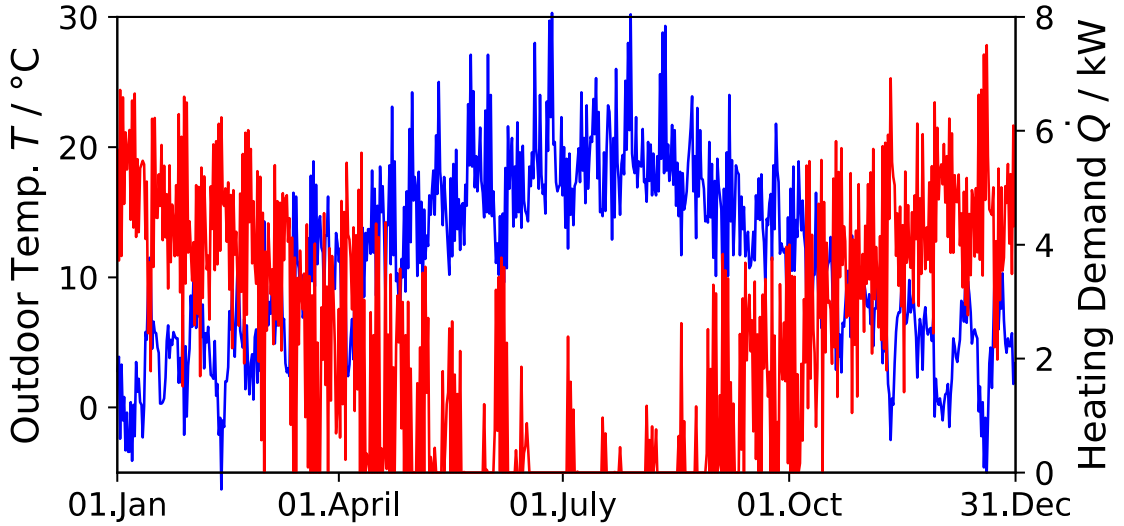
R717 (Ammonia)

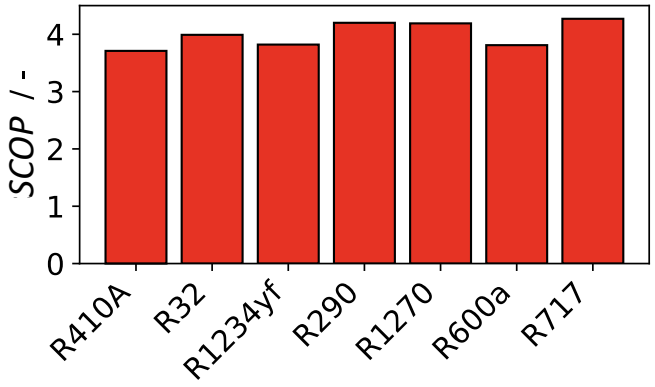


Life Cycle Modelling: Heat Pump Operation

Heat Pump Operation

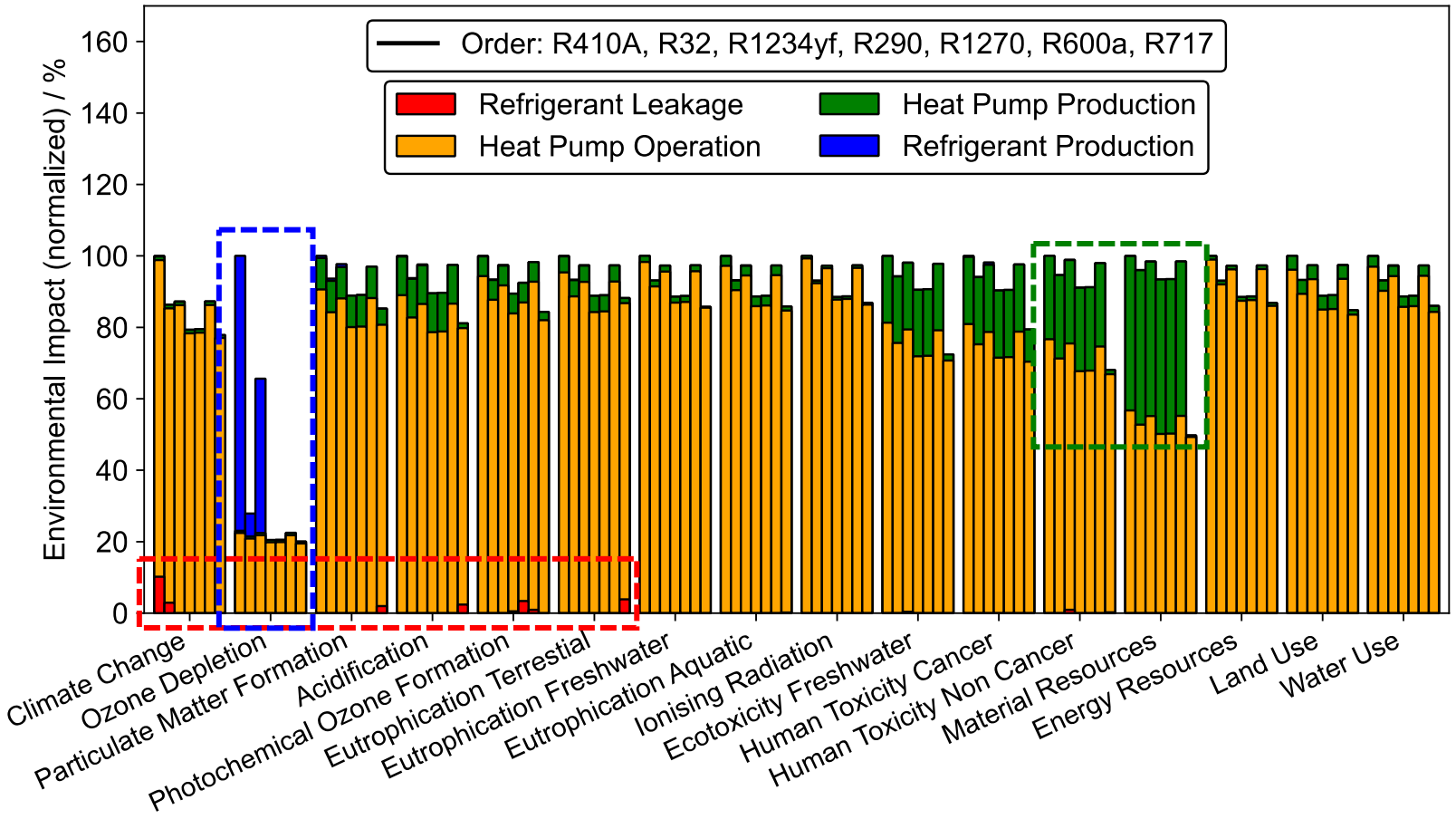
- Annual temperature profile
  - Test Reference Year 2015
- Buildings heat demand
  - TEASER[8]: two-story single-family house
- Heat pump model[9]
  - Fluid dependent efficiency
  - Determines optimal COP by varying pressure levels





Refrigerant dependent required electrical input power

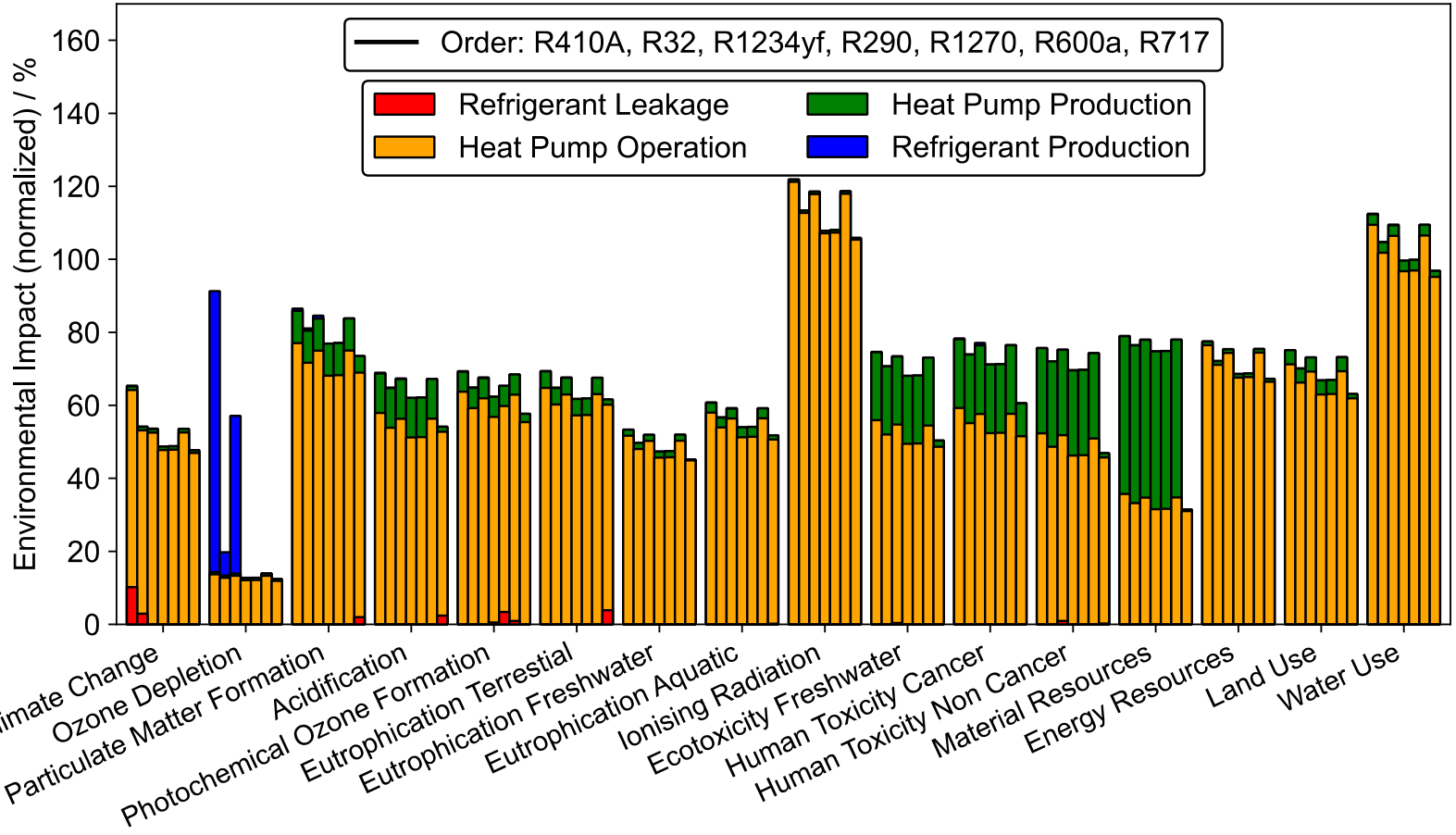
Results: Environmental Impacts of a Heat Pump



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

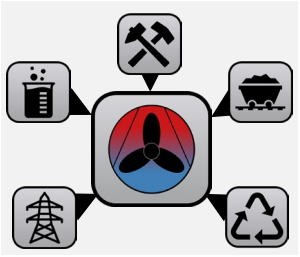
Discussion: Gas Condensing Heating System vs Air-to-Water Heat Pump

	1	1 → 2	2
Climate Change	-30 %	-54 %	-79 %
Ozone Depletion			
Particulate Matter Formation			
Acidification			
Photochemical Ozone Formation			
Eutrophication Terrestrial			
Eutrophication Freshwater			
Eutrophication Aquatic			
Ionizing Radiation			
Ecotoxicity Freshwater			
Human Toxicity Cancer			
Human Toxicity Non Cancer			
Material Resources			
Energy Resources			
Land Use			
Water Use			

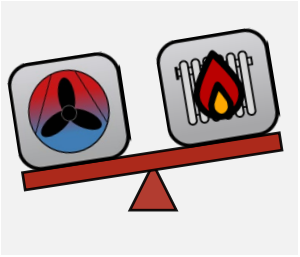
Findings

- Use of a heat pump leads top GHG emission reduction
- **But** Burden-Shifting towards other environmental categories
- Change in electricity mix reduces environmental impact
  - Burden-Shifting is inevitable

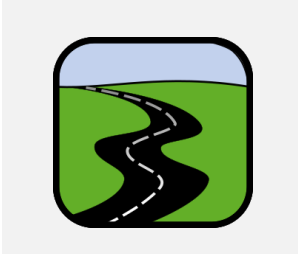
Conclusion and Outlook



- Electricity demand during operation is the main influencing factor
- Efficiency of the HP most important evaluation criterion
- Other phases have only a secondary influence



- GHG reduction when switching to HP is possible
- **But:** Burden shifting towards other environmental categories



- Investigation of environmental categories affected by burden shifting
- Include modelling of recycling process

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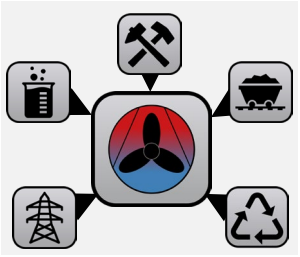

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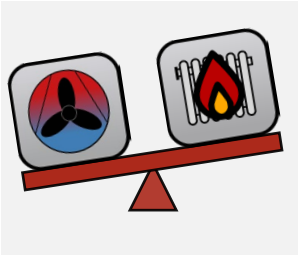

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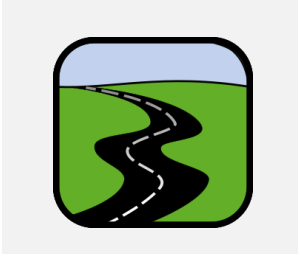

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