Heat pumps and Chillers with Natural Refrigerants

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Technologies for Biofuel Hybrid Micro Gas Turbines

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Fit4Micro Workshop

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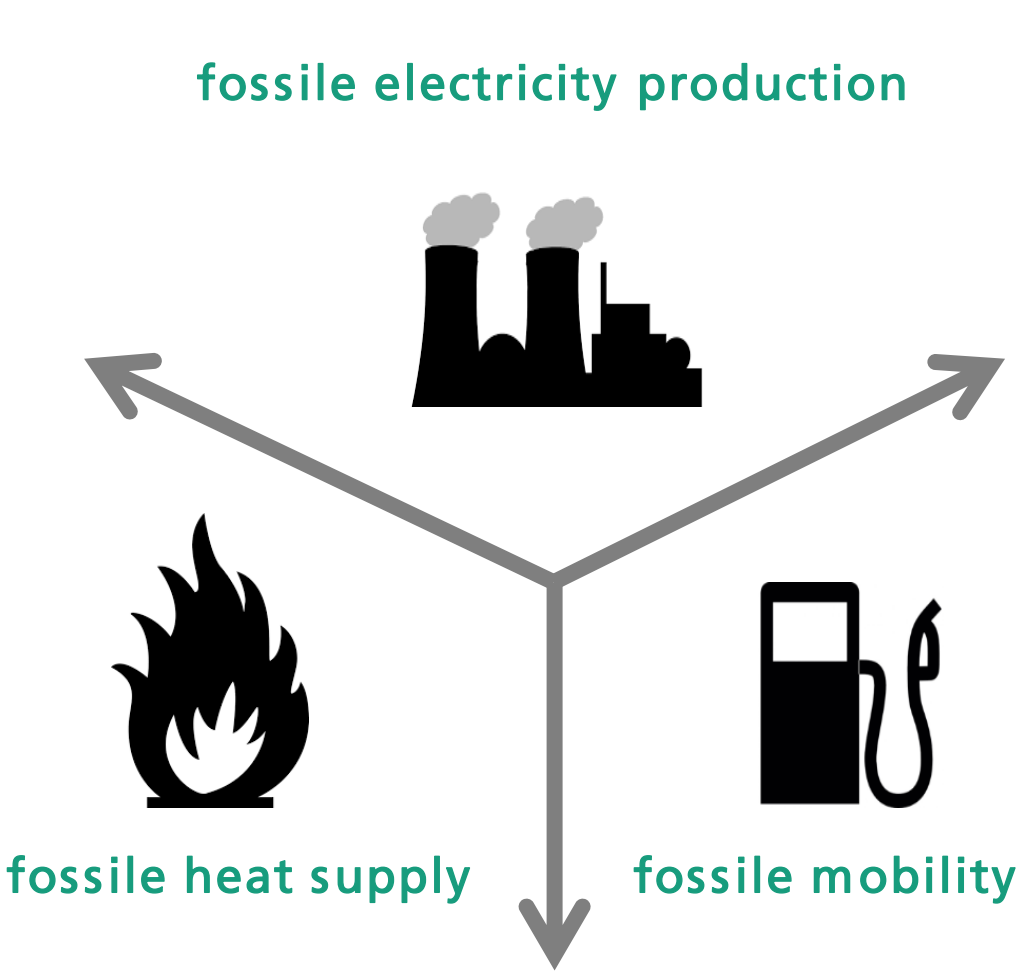
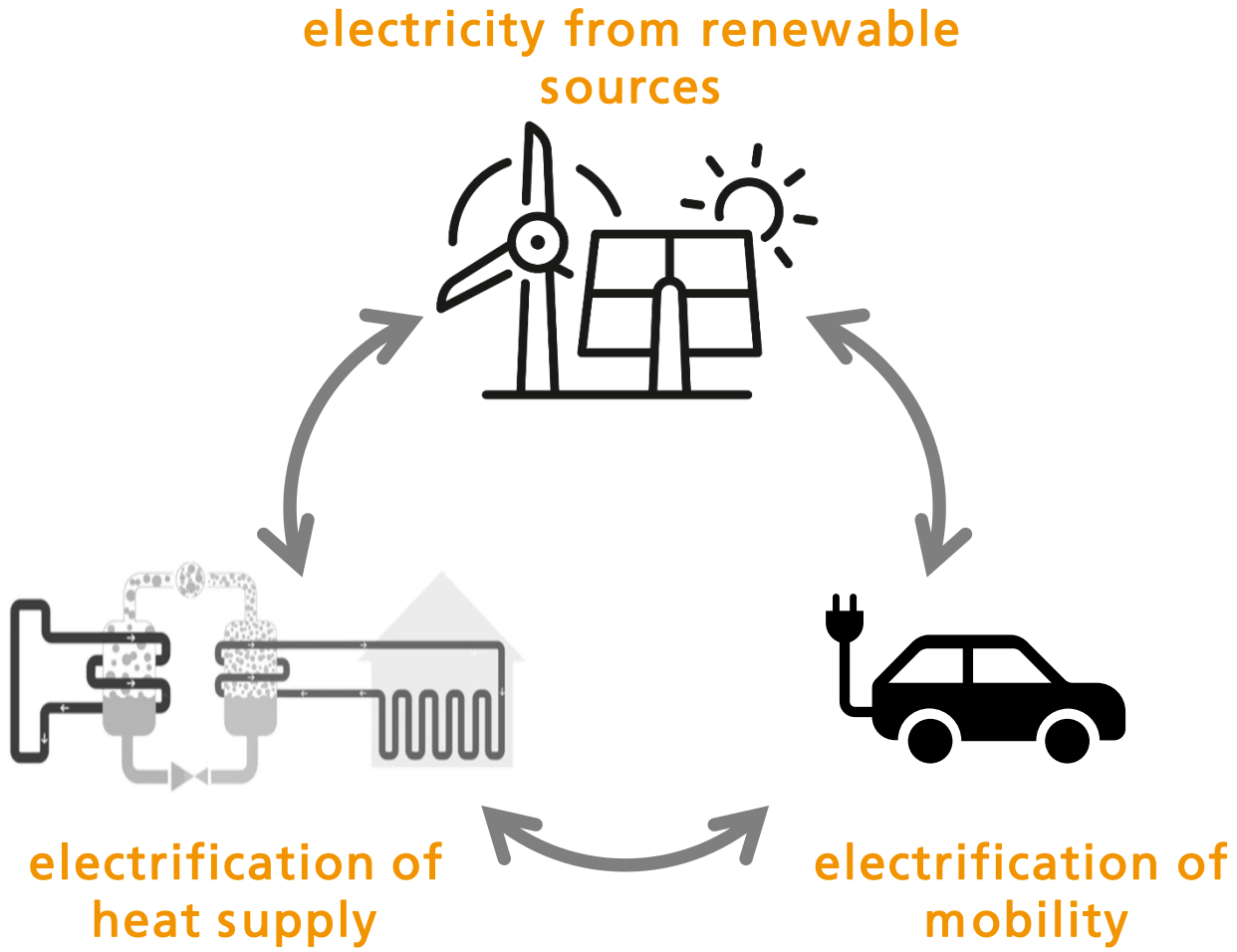
Fraunhofer ISE

Transformation of Heating Sector

Centralized to decentralized, stand-alone to interactive?

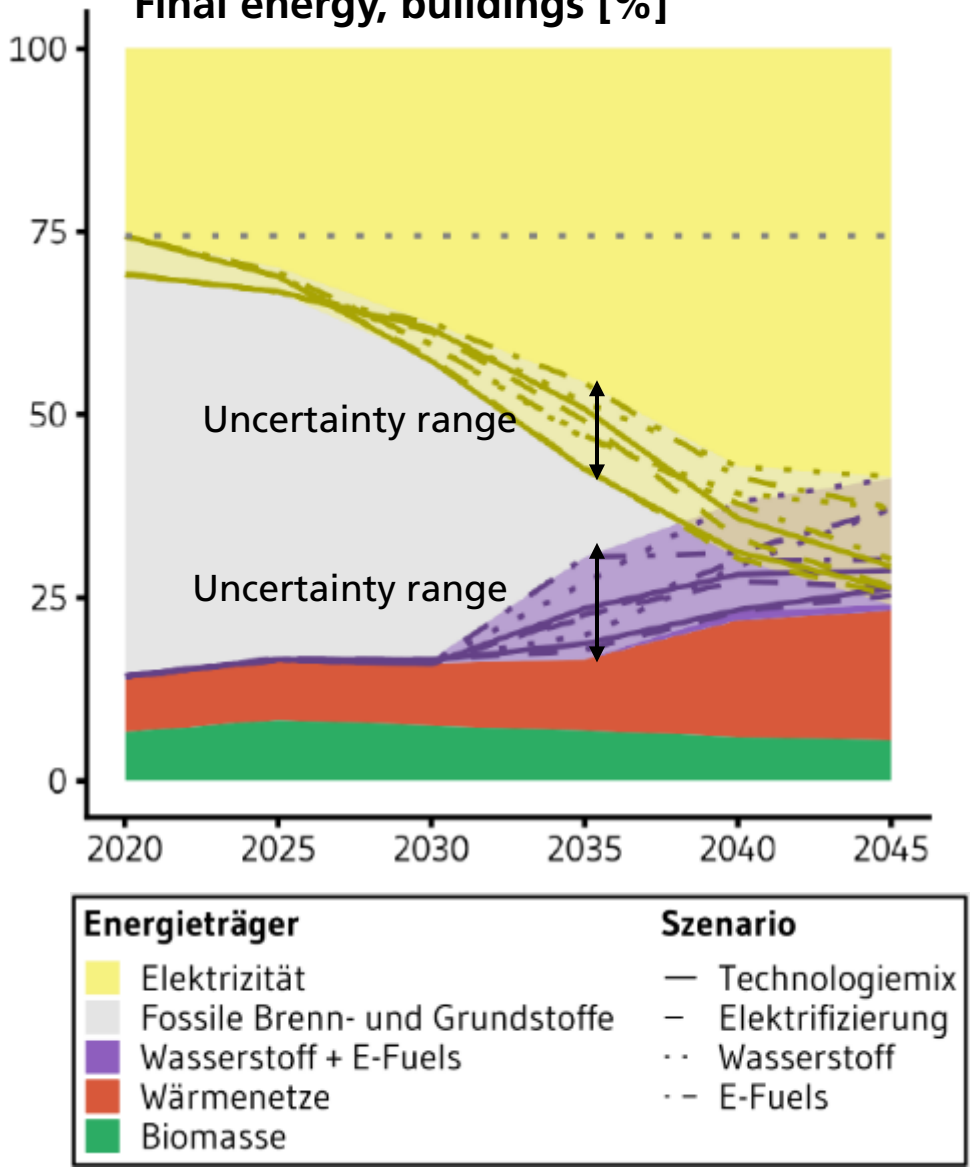




Energy carrier building sector

Results of energy system analysis – top-down approach

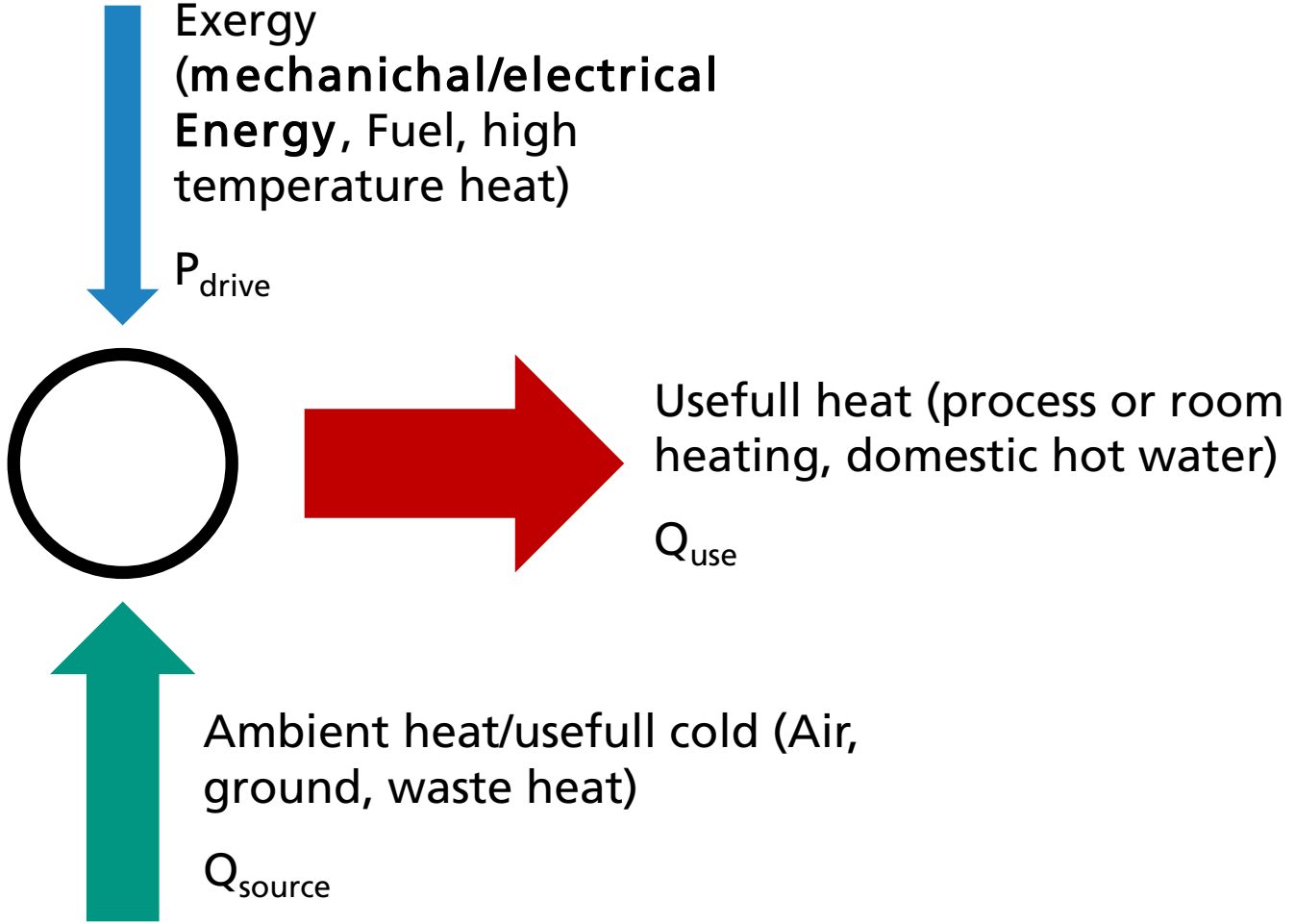
- Direct electrification vs. H2 and E-Fuels
  - Comparison of recent studies (Ariadne, BDI, DENA, Agora, long time scenarios) shows, that indirect electrification will not play a role in building sector until 2030
  - Direct electrification (heat pumps) and heating networks will be central components of heating transformation
  - From 2030 larger uncertainty:
    - Some scenarios: H2 and E-Fuels negligible for building sector
    - Other scenarios show relevant shares in 2045
  - Impact on (necessary) infrastructures only in combination with local bottom-up considerations possible



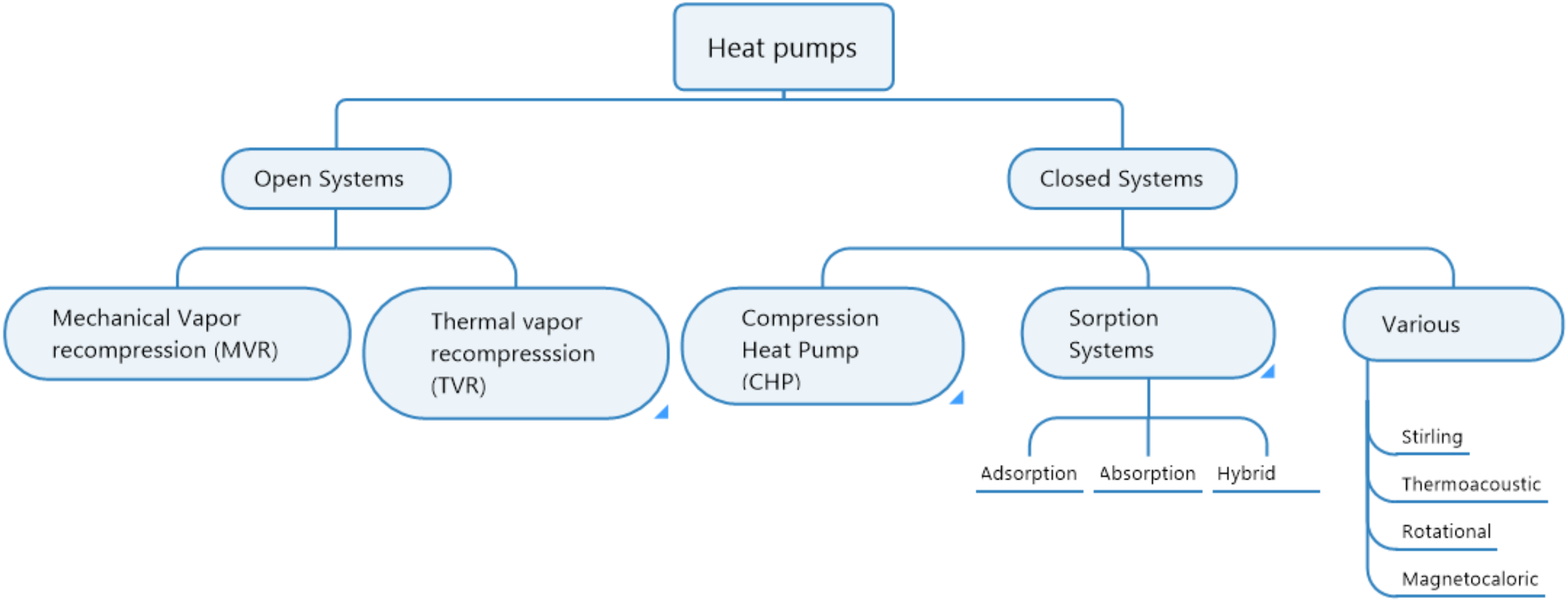
Source: Ariadne Kurzdossier 2021: Durchstarten trotz Unsicherheit, 16.11.2021, https://ariadneprojekt.de/publikation/eckpunkte-einer-anpassung wasserstoffstrategie/

What is a heat pump?

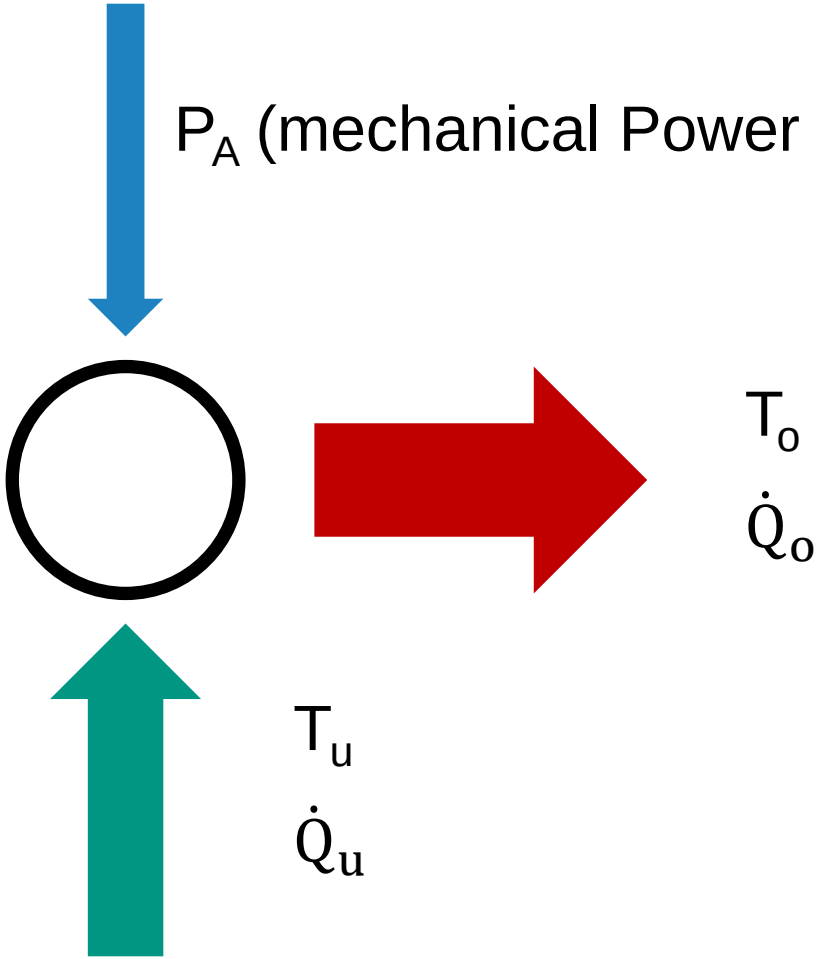
- Heat flows from higher to lower temperature level (2. law of thermodynamics)
- To lift a heat flux from lower to higher temperature, a thermodynamic process is necessary which uses external driving energy/exergy
- Driving energy: pure exergy (mechanichal or electrical energy) or heat at higher temperature (energy with share of exergy)
- Processes that lift heat from a lower to a higher temperature level are called **»heat pumps«**



Classification



Mechanical/Electrical HP (Compression HP)



Drive

Upper T-Level

Lower T-Level

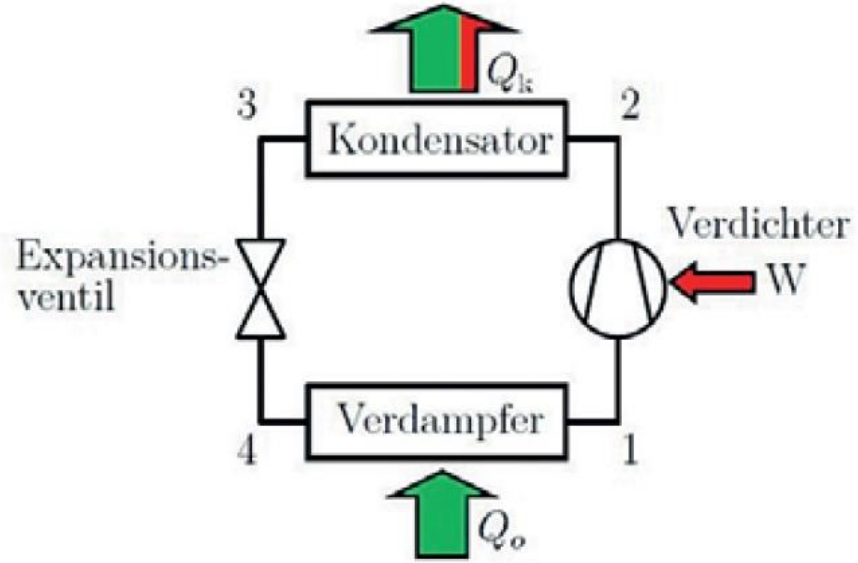
Ideal Process in log(p)–h Diagram

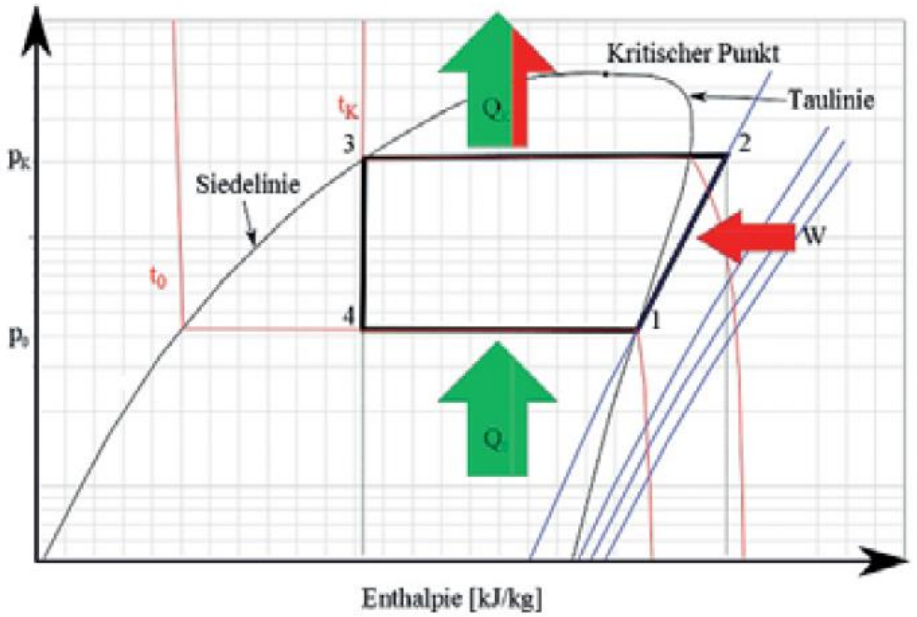
4➔1 isothermal Evaporation

1➔2 isentropic Compression (in gas phase)

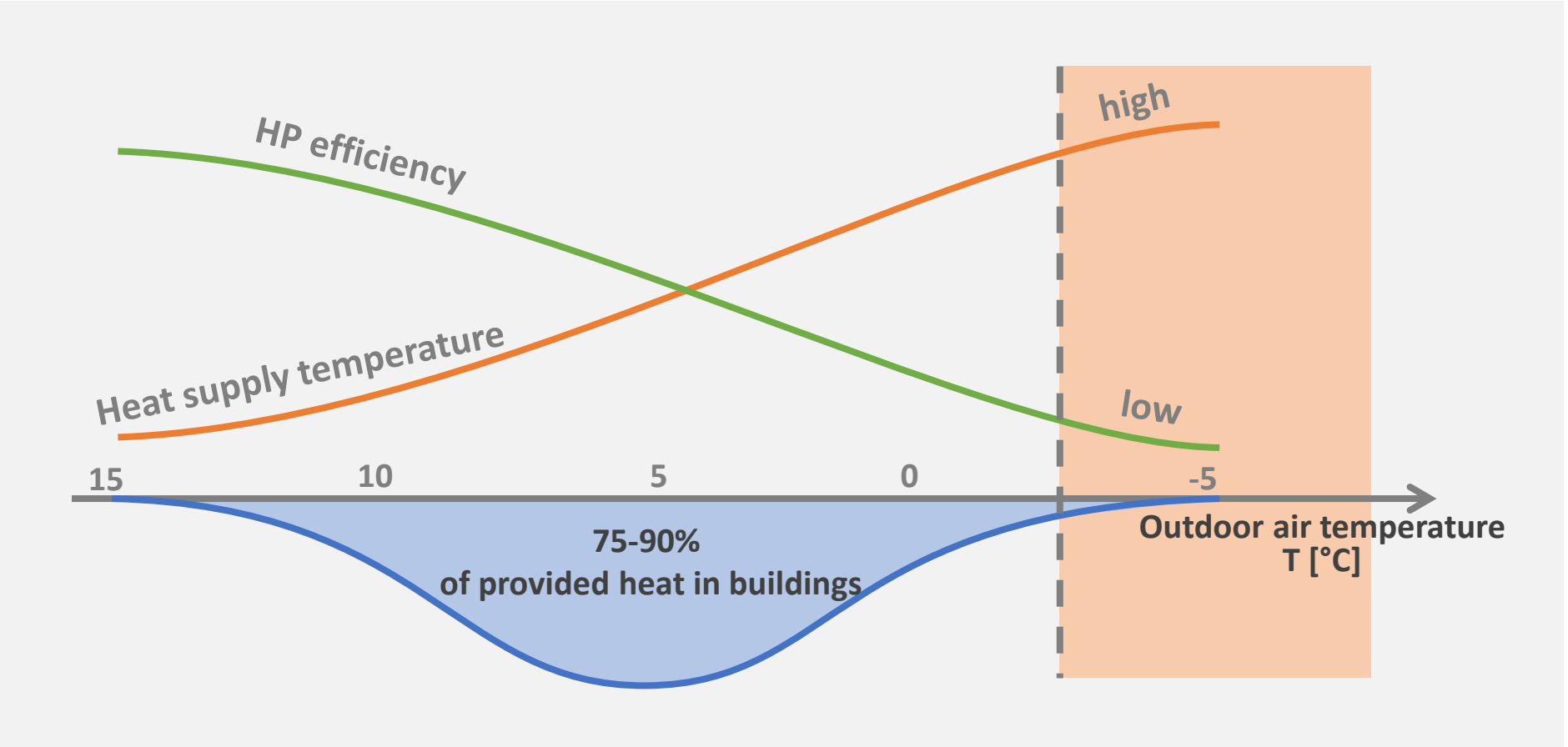
2➔3 isobarical Condensation

3➔4 isenthalpic Expansion (of Condensate)





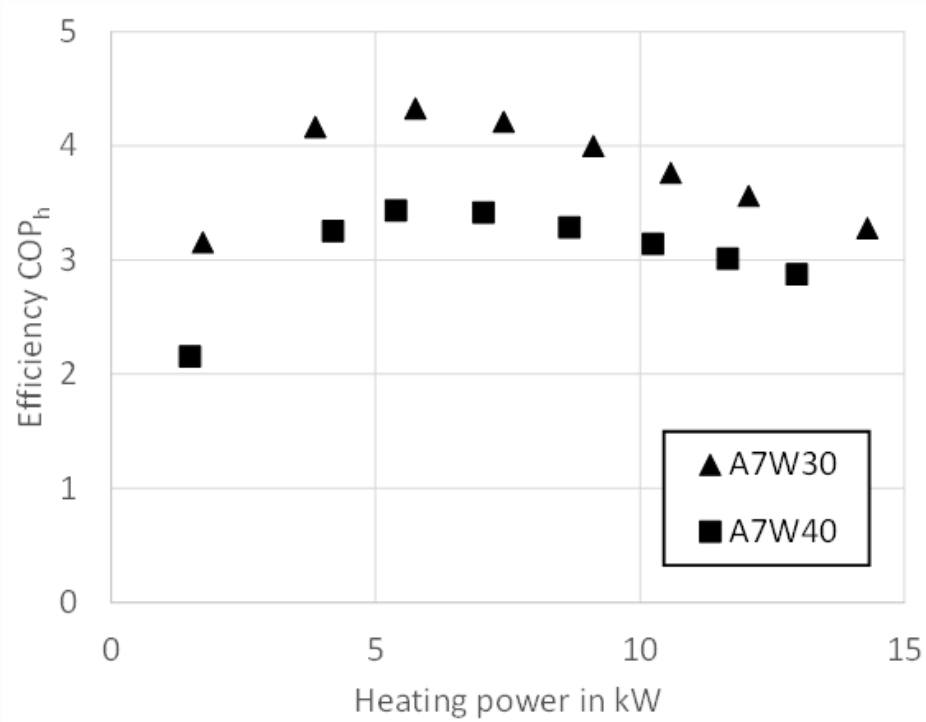
Efficiency of Heat Pumps
When is heat provided?



Fit4Micro: Propane Heat Pump (R290)

- MITIS R290 heat pump in climate chamber at Fraunhofer ISE

- Measured under different temperature boundary conditions at various compressor (and ventilator) speeds



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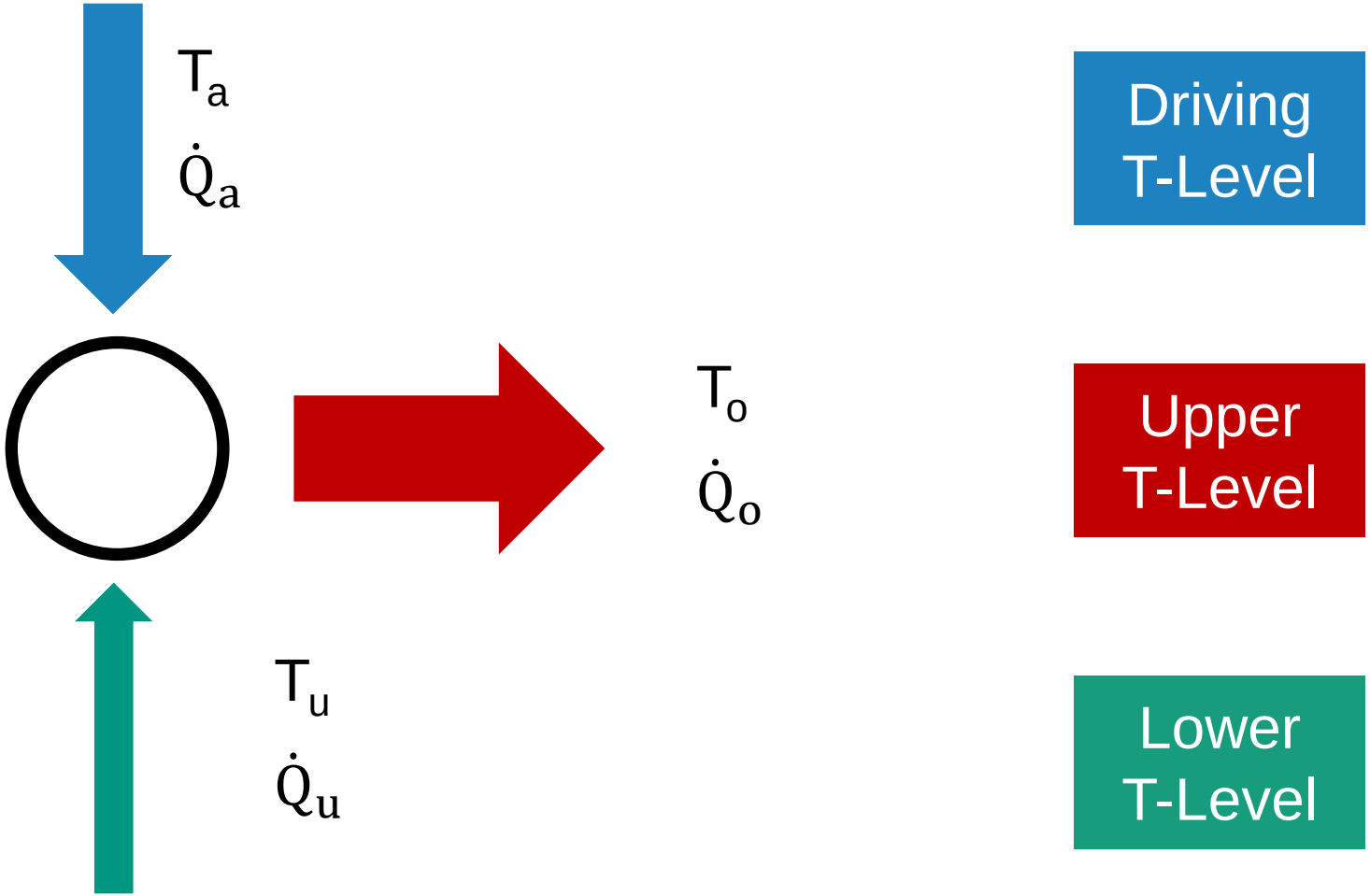
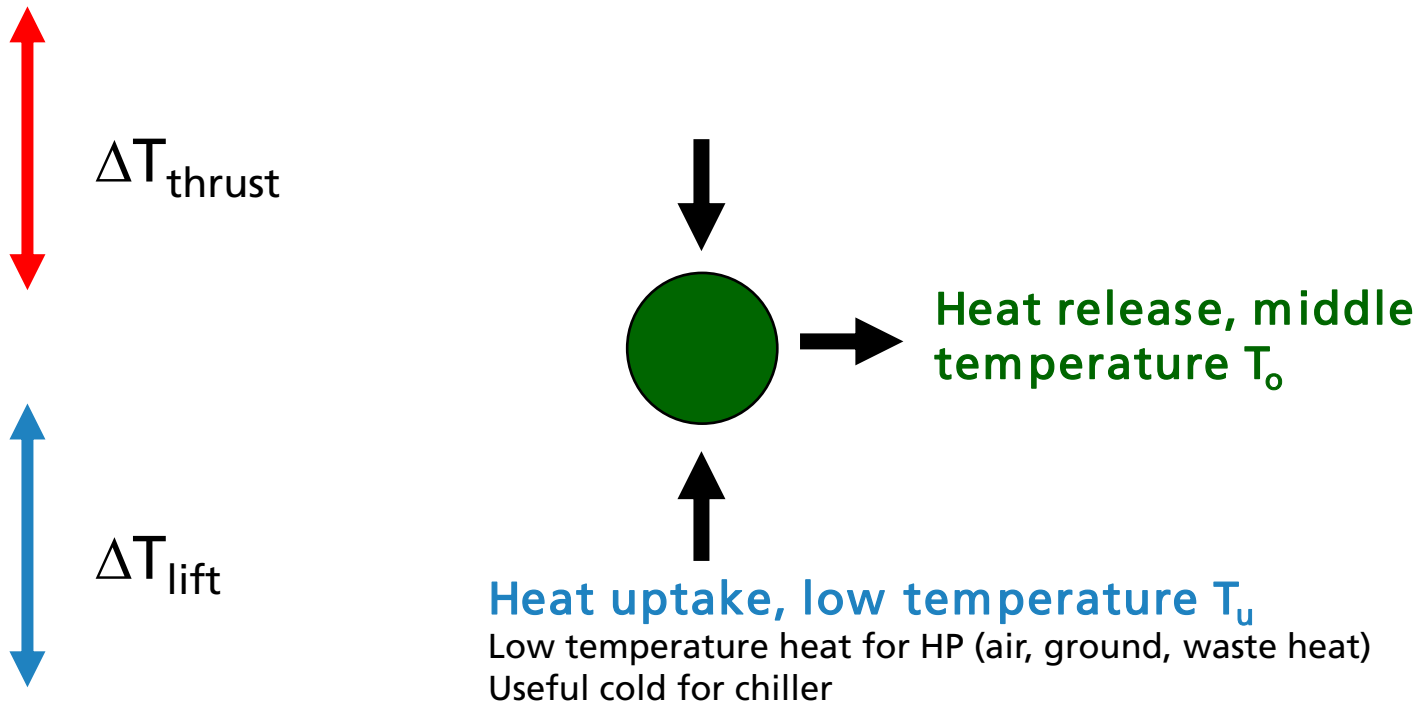
Thermally Driven Heat Pump/Chiller



Thermally Driven Heat Pump/Chiller

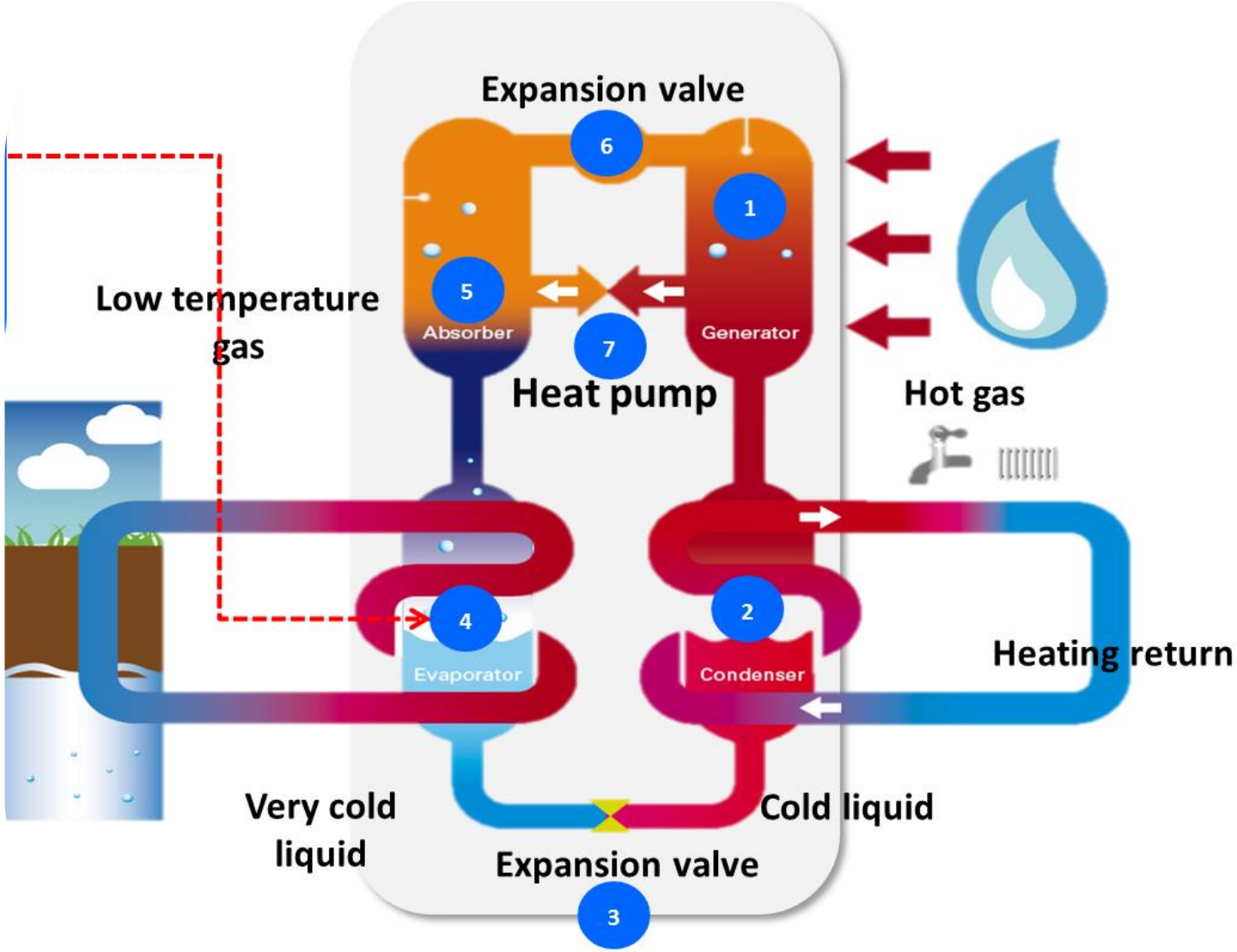
Driving heat, high temperature T_a
e.g. combustion process, flue gas, waste heat



Heat uptake, low temperature T_u
Low temperature heat for HP (air, ground, waste heat)
Useful cold for chiller

Functional Principle Absorption Heat Pump

- For Heating with air as ambient source: Water-**Ammonia**
- Source/cooling temperatures >5°C: Lithiumbromide-**Water**
- Market available products
- Thermal efficiency/Fuel Utilisation Efficiency 1,3 – 1,7 at high heating temperatures >50°C
- Could also be run with renewable fuels -> where and when?



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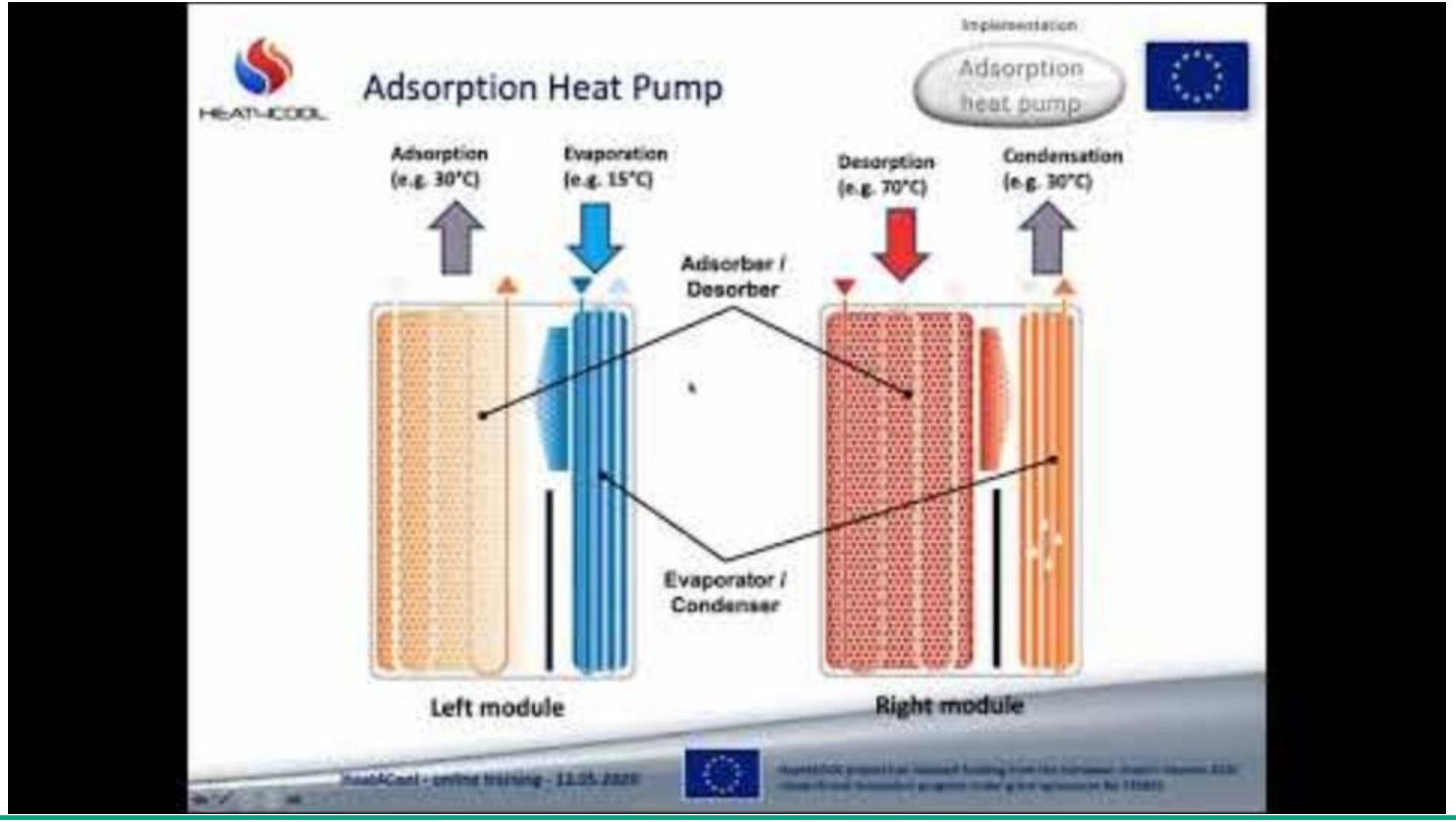
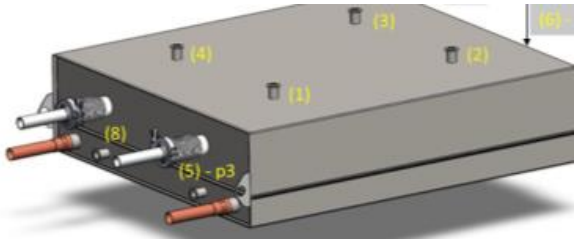
Functional Principle Adsorption Heat Pump/Chiller

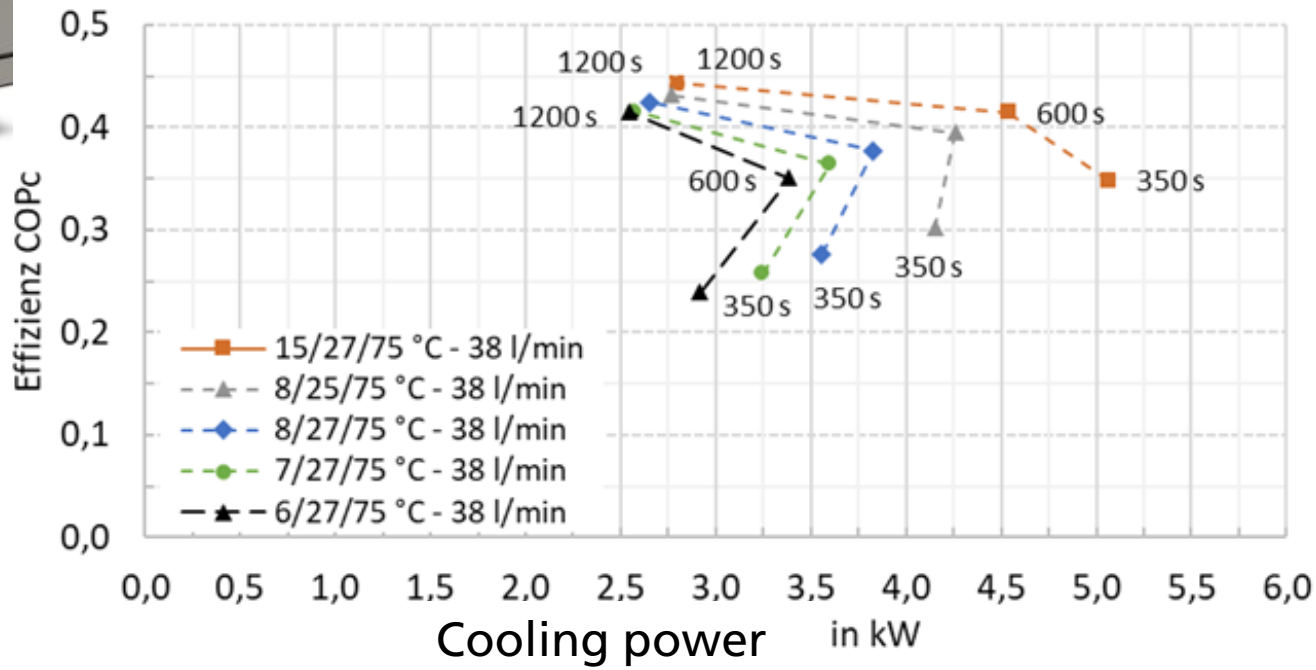


Fit4Micro: Silicagel and zeolite adsorption modules with refrigerant water

- Fahrenheit adsorption module on test bench at Fraunhofer ISE



- Measured under different temperature boundary conditions at various cycle times



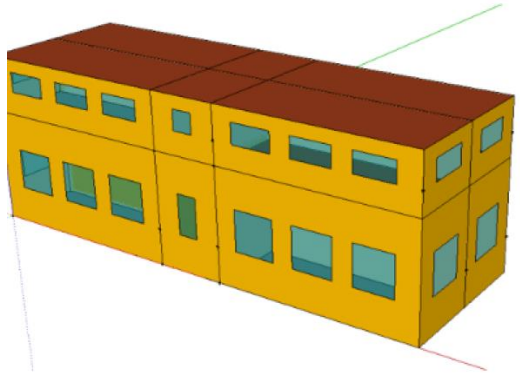
Impact on Fit4Micro

System design and use cases

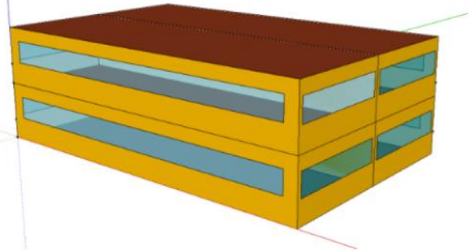
- Consideration of
  - Infrastructure (quality gas/electricity grid, district heating available?) -> What is the reference/competition?
  - Fuel costs
  - Demand profiles (heat, electricity, cooling), full load hours

- Preliminary use case evaluation based on Excel tool

Multi-family home (MFH)



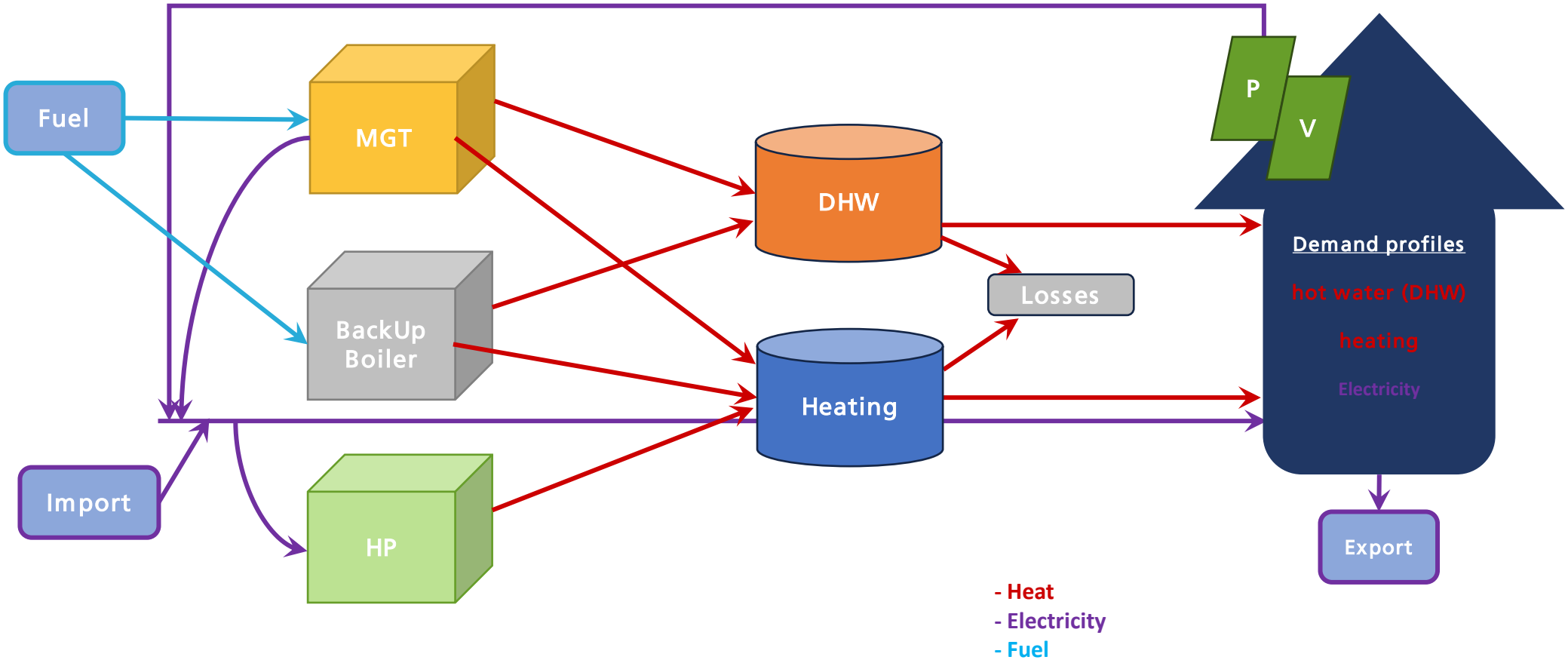
Office Building



Machine cooling

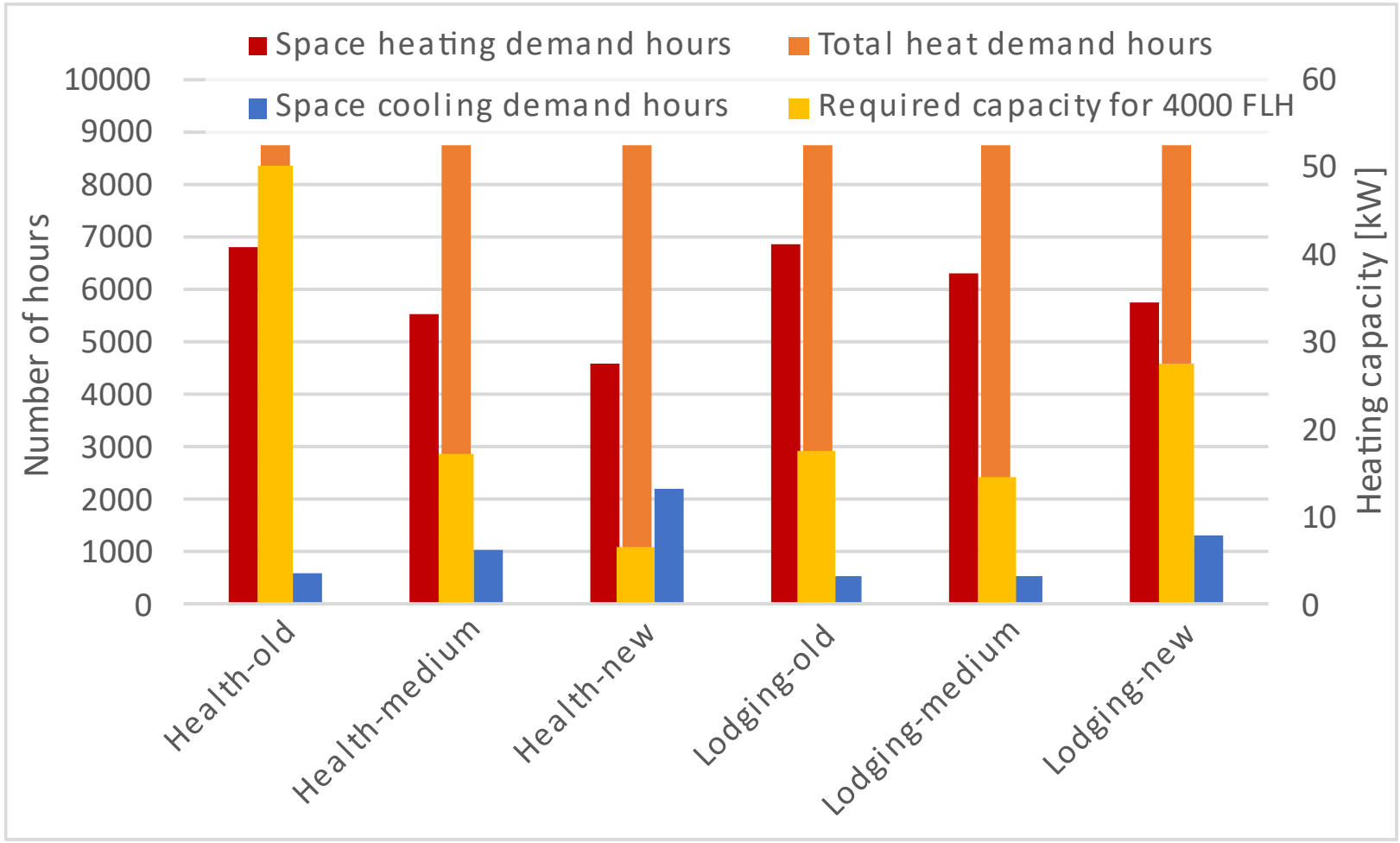
Fit4Micro – Heating Use Cases

System design

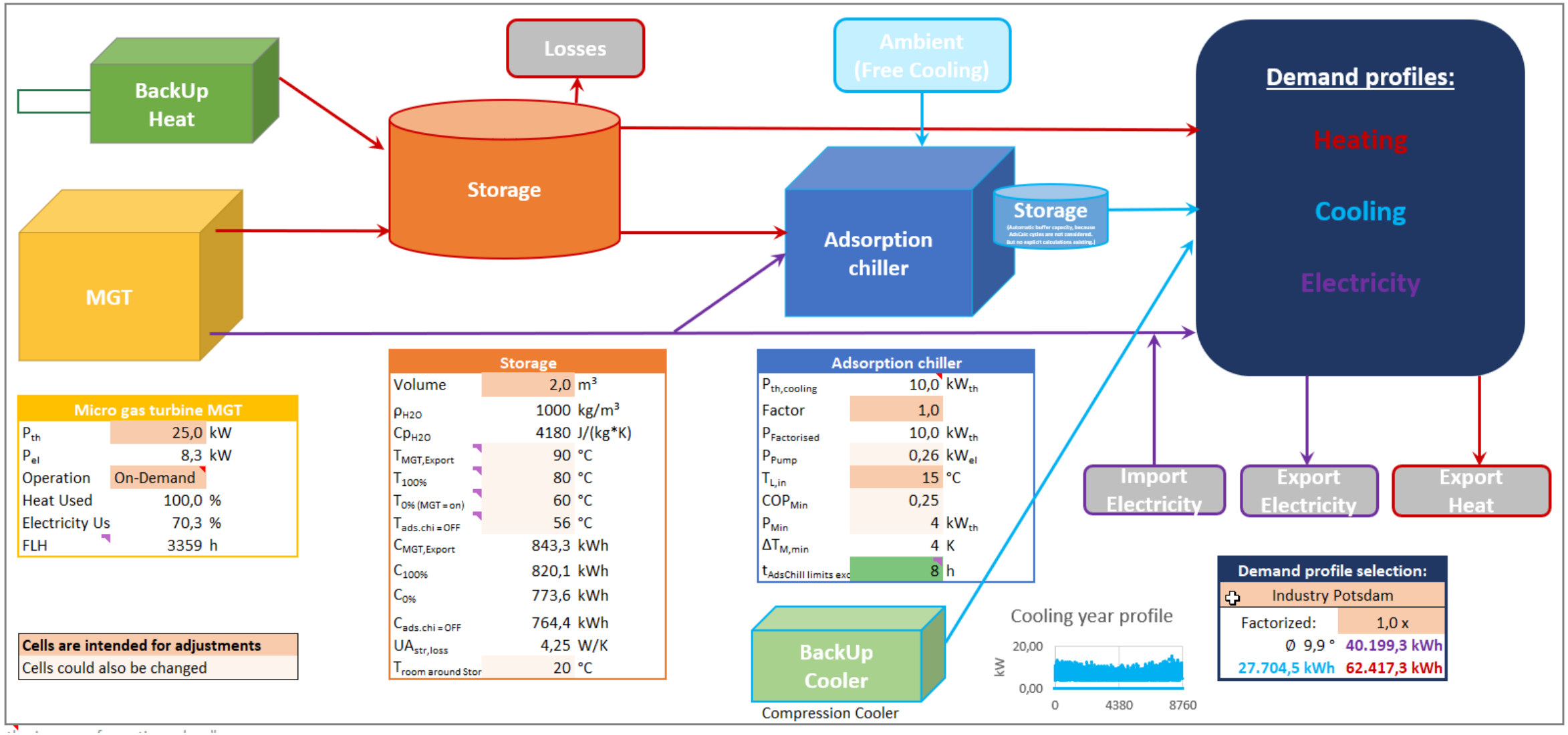


Impact on Fit4Micro - Heating

Example health and lodging – rough system sizing



Fit4Micro – Heating and Cooling Use Cases



Micro gas turbine MGT		
P_{th}	25,0	kW
P_{el}	8,3	kW
Operation	On-Demand	
Heat Used	100,0	%
Electricity Us	70,3	%
FLH	3359	h

Storage		
Volume	2,0	m^3
ρ_{H2O}	1000	kg/m^3
Cp_{H2O}	4180	J/(kg*K)
$T_{MGT,Export}$	90	°C
$T_{100\%}$	80	°C
$T_{0\%\ (MGT=on)}$	60	°C
$T_{ads.chi=OFF}$	56	°C
$C_{MGT,Export}$	843,3	kWh
$C_{100\%}$	820,1	kWh
$C_{0\%}$	773,6	kWh
$C_{ads.chi=OFF}$	764,4	kWh
$UA_{str,loss}$	4,25	W/K
$T_{room\ around\ Stor}$	20	°C

Adsorption chiller		
$P_{th,cooling}$	10,0	kW_{th}
Factor	1,0	
$P_{Factorised}$	10,0	kW_{th}
P_{Pump}	0,26	kW_{el}
$T_{L,in}$	15	°C
COP_{Min}	0,25	
P_{Min}	4	kW_{th}
$\Delta T_{M,min}$	4	K
$t_{AdsChill\ limits\ exc}$	8	h

Demand profile selection:		
Industry Potsdam		
Factorized:	1,0 x	
Ø 9,9 °	40.199,3 kWh	
27.704,5 kWh	62.417,3 kWh	

Cells are intended for adjustments
Cells could also be changed

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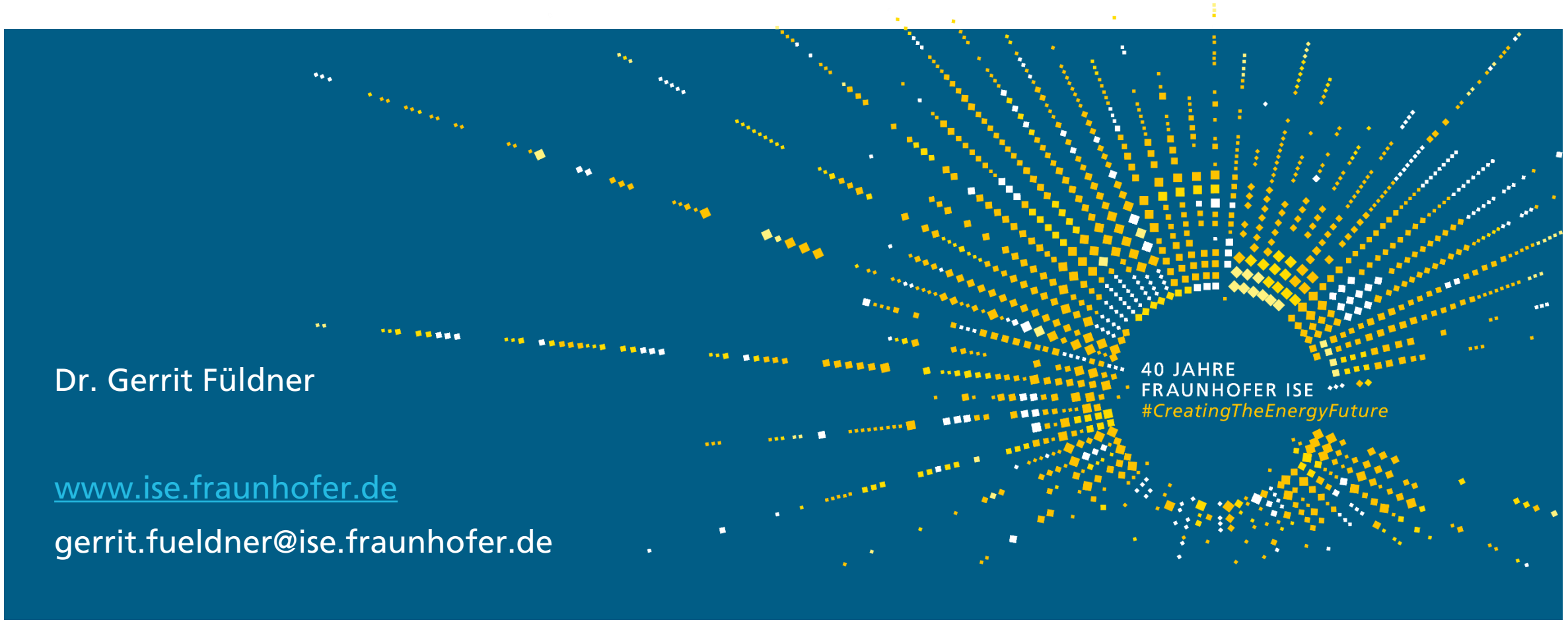
Summary

- Heat pumps make use of exergy to upgrade low temperature heat
- Heat pump (and system) efficiency is sensitive to temperature levels (source and sink)
- Heating systems that integrate heat pumps need to be well designed to fit respective needs (load, ambient conditions, heat distribution system)
- Potential use cases for combination of MGT, HP, PV and/or adsorption chillers will be evaluated more in detail within the Fit4Micro project



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