Flexibility from heat for power systems - future applications for CHP and P2H

Christine Brandstätt, M.Sc.
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AGENDA

- Introduction
- What is CHP and P2H?
- What flexibility for power systems can come from heat?
- How does that compare to electricity storage and gas options?
- Summary and Conclusion

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Christine Brandstätt

Education & Career

- Research Associate at Fraunhofer IFAM, Energy Systems Analysis and at Jacobs University Bremen
- Research Associate at Bremer Energie Institut
- Master in Management and Engineering of Environment and Energy at Politecnic University of Madrid, École des Mines Nantes and Royal Institute of Technology, Stockholm
- Bachelor in Industrial Engineering / Environmental Planning at Environmental Campus of the University of Applied Sciences, Trier

Current Research

- Multi-Grid-Storage: power system flexibility from heat and gas links
- Electricity Network Regulation: network charging in distribution systems with renewable generation

Fraunhofer IFAM, Energy Systems Analysis

Institute for Manufacturing Technology and Advanced Materials

- components and materials for energy applications
- heat and electricity storage
- electric mobility
- …

Energy Systems Analysis

- efficient and renewable supply of heat and electricity
- energy efficiency in buildings and manufacturing
- regulatory framework for energy markets and networks
- climate and energy supply concepts
- …

We offer internships, student jobs and supervision of study projects or Bachelor & Master theses as well as PhD Projects.

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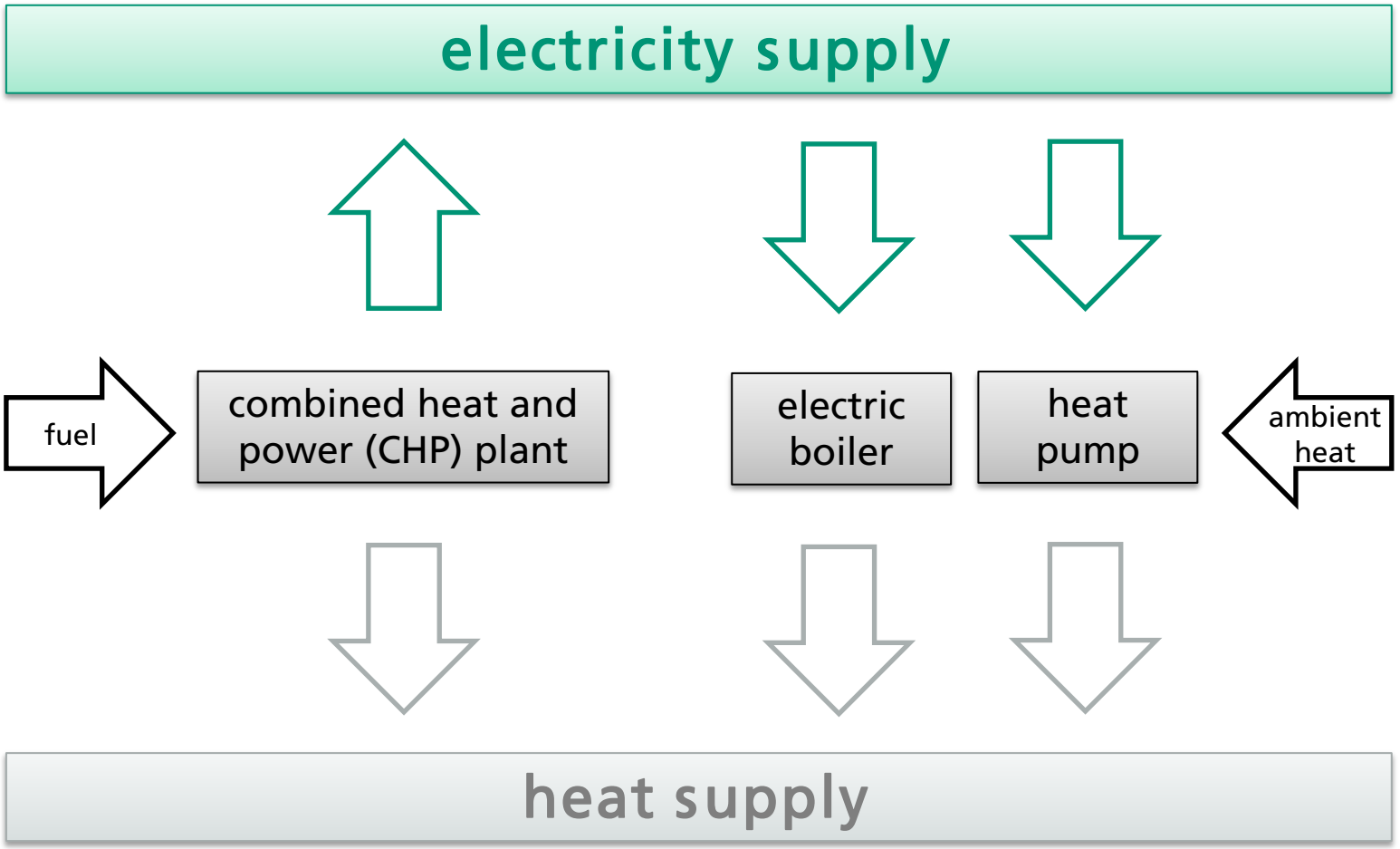
links between electricity and heat supply



Electric Heat Pump

- moves heat from a lower to a higher temperature level
- provides heating and cooling
- consumes electricity for compression of the heating/ cooling fluid
- conversion efficiency: 2 – 5
- high initial investment

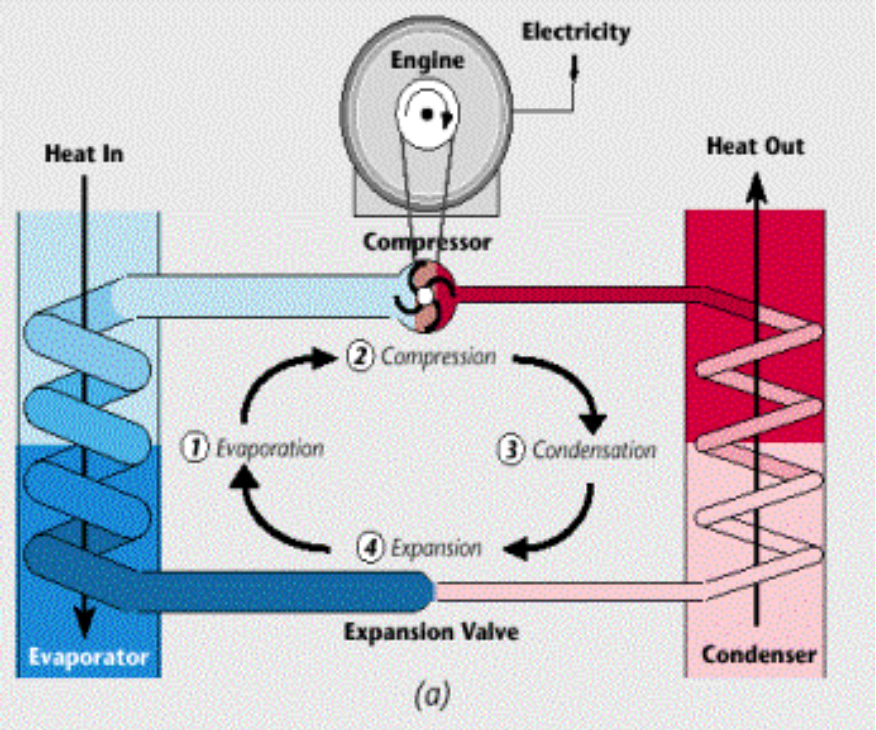


image source: daviddarling.info

Electric Boiler

- heats water in a tank via electr heating elements instead of a gas burner
- consumes electricity directly for the heating process
- conversion efficiency: almost 1
- low initial investment

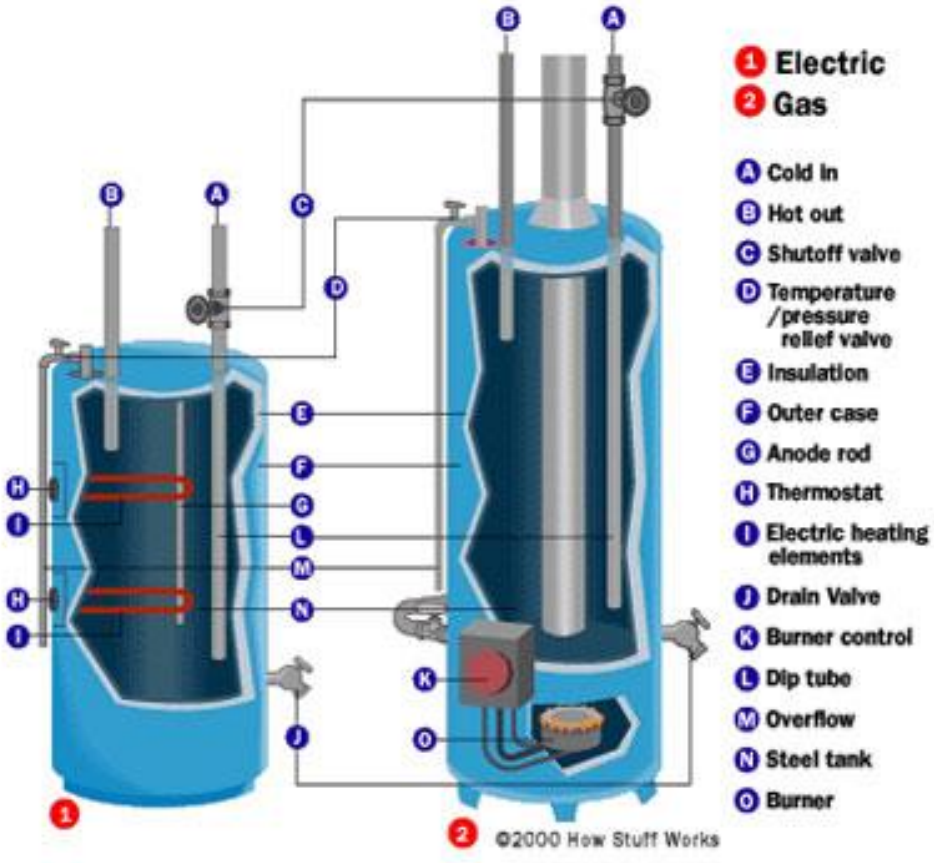


image source: ctadsonline.com

Combined Heat and Power Plant

- generates heat and electricity at the same time
- uses the waste heat from an engine or turbine
- conversion efficiency: almost 1 (varying relation between electricity and heat)
- high initial investment

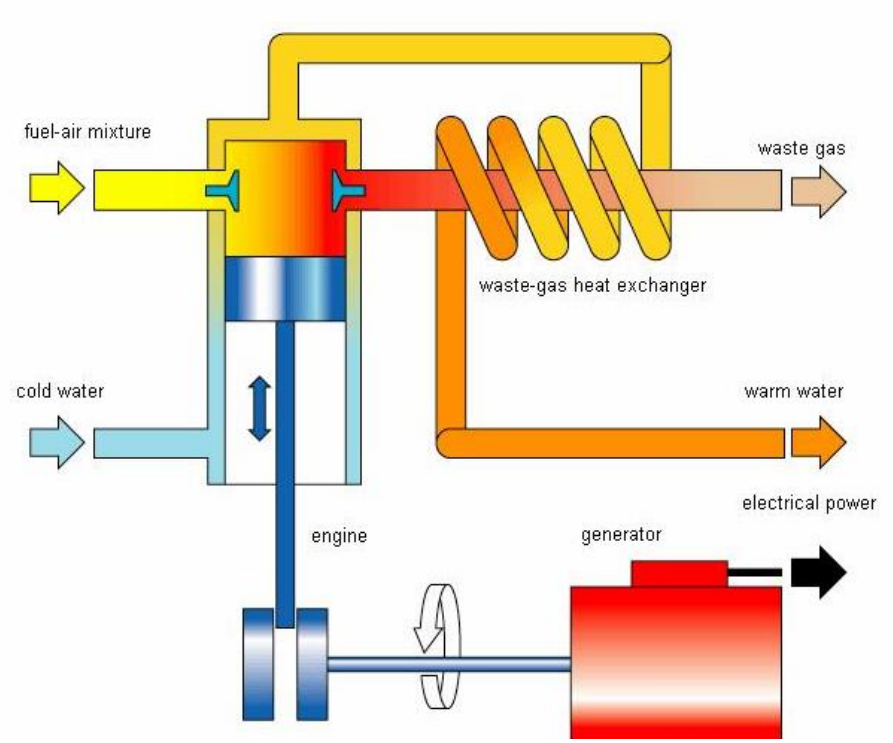


image source: responsiblebusiness.com

Thermal Store

- stores heat over time
- can continuosly take in and release heat
- heat losses decrease with surface and insulation
- efficiency depends on storage duration
- low initial investment

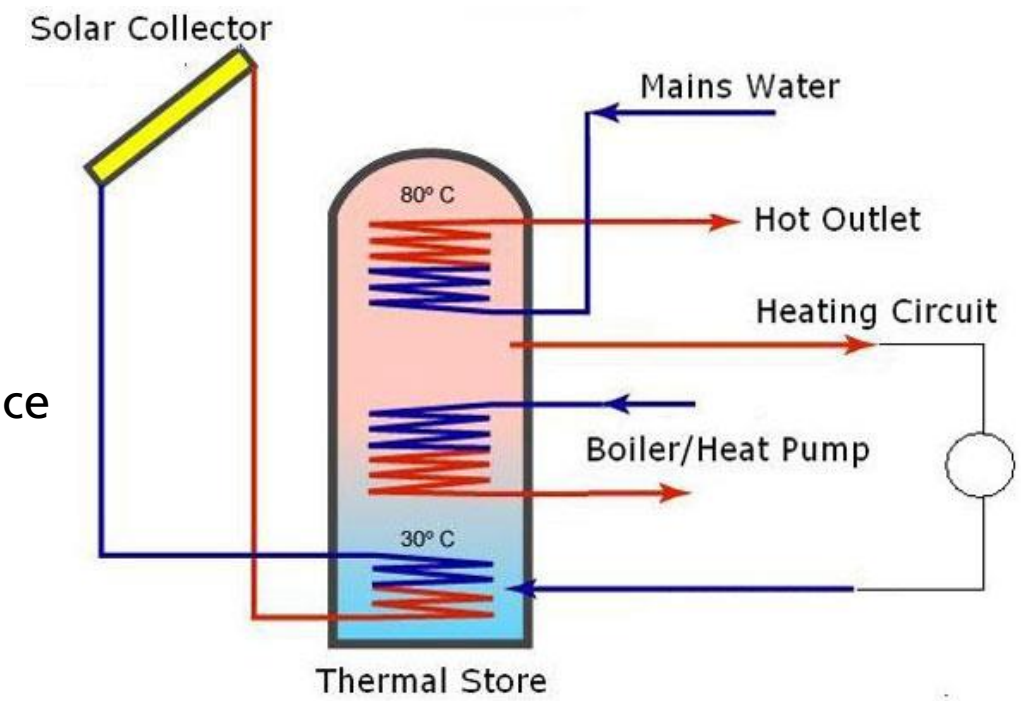


image source: heatingsolutions.biz

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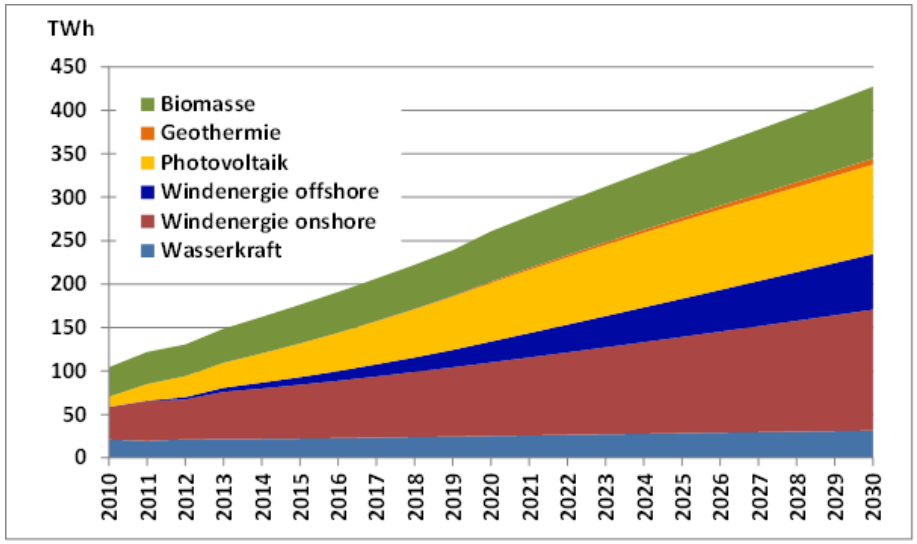
Why flexibility is needed: future electricity supply

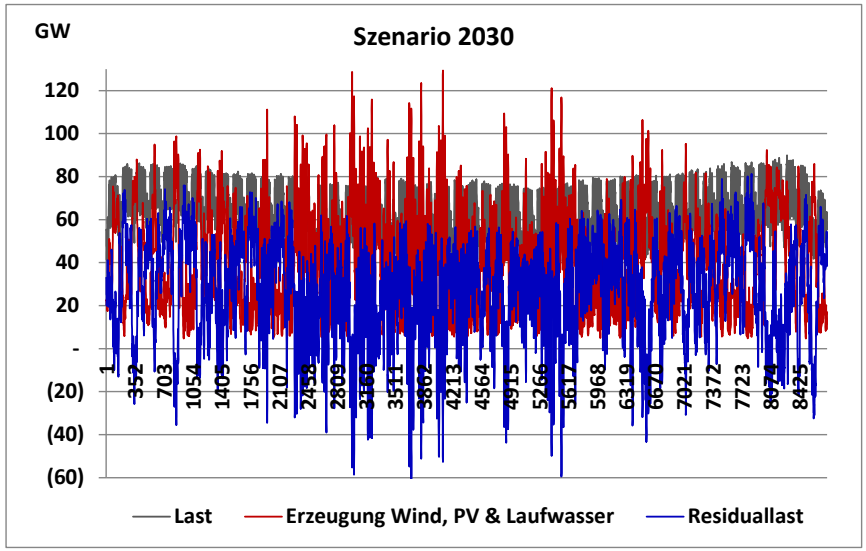
- electricity supply will be based on renewable energy sources (RES), mainly wind power and photovoltaics

RES feed-in until 2030



Quelle: Krzikalla et al. 2013

electricity supply in 2030



Quelle: Krzikalla et al. 2013

- significant differences between availability of RES and the demand for electricity expected
- high spikes in residual load

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Why flexibility is needed: challenges with RES

Electricity Supply

- supply electricity efficiently when wind power and photovoltaics are not available in sufficient quantity (shortage)
- reduce supply from other sources when wind power and photovoltaics are available in abundance (surplus)

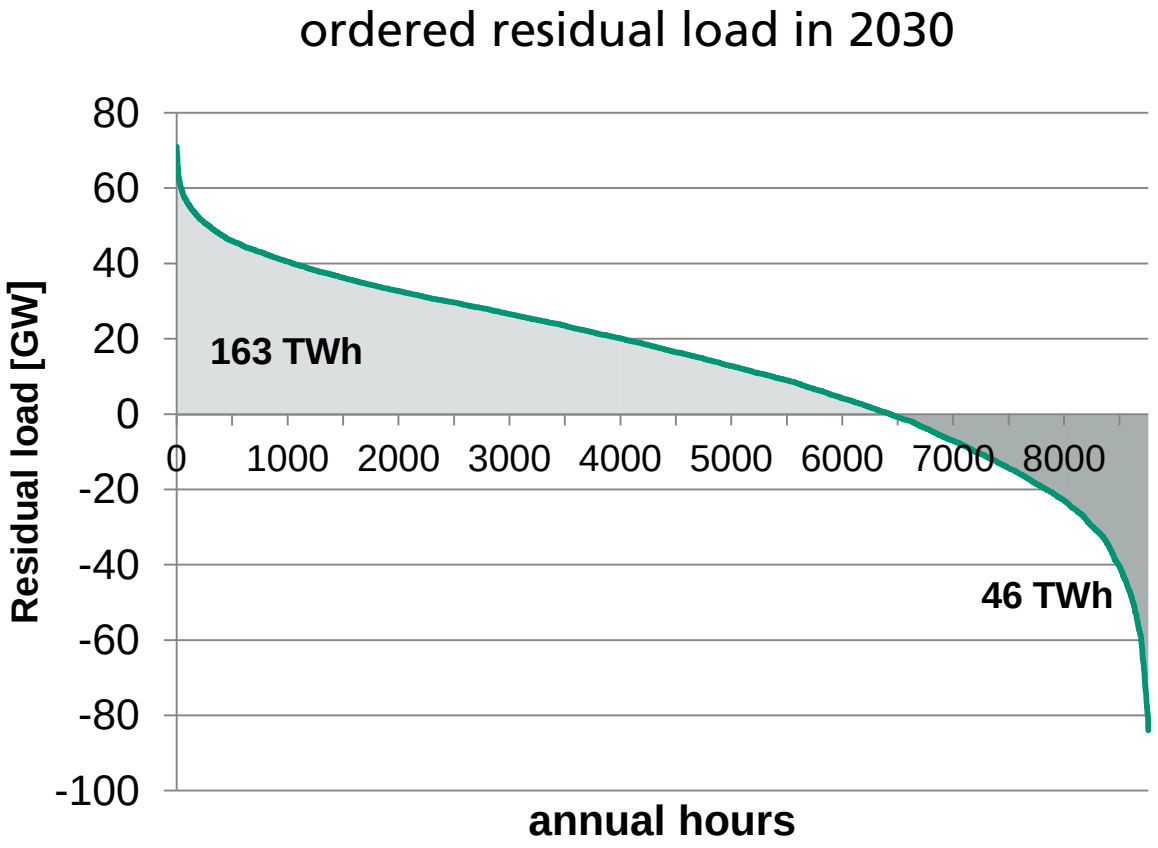
Heat Supply

- reduce heat demand (especially for space heating)
- supply remaining heat demand in a sustainable way (renewable electricity vs. fossil gas)

➢ both is addressed by extensive use of CHP

➢ best effect with electric conversion efficiency

How much flexibility is needed (tech.)



- pos. residual load (shortage)
  - 163 TWh/a
  - 6.384 h/a
  - max. 71 GW
- neg. residual load (surplus)
  - 46 TWh/a
  - 2.286 h/a
  - max. -84 GW

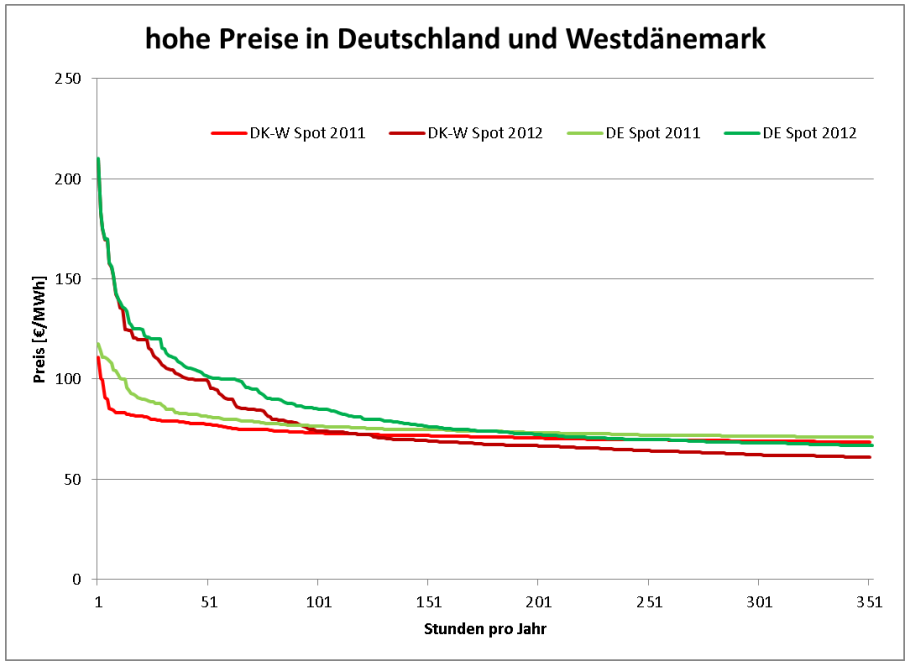
Quelle: Krzikalla et al. 2013

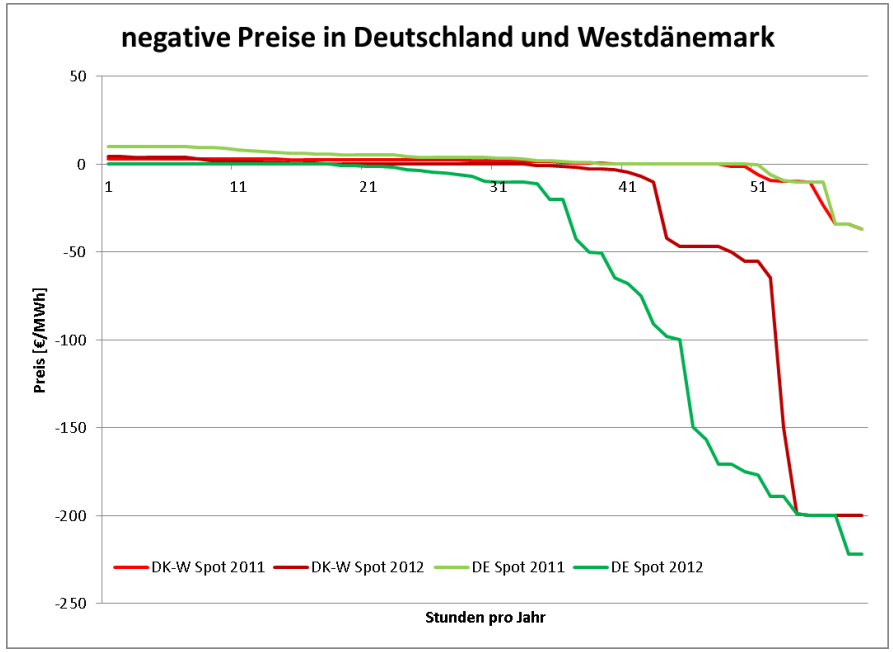
- ‚surpluses' to take into storage occur more and more often
- ‚shortages' to supply from storage dominate

How much flexibility is needed (econ.)

extreme electricity wholesale prices in Germany and Denmark 2011 and 2012

- prices above 75 € / MWh only in several hundred (of over 8000) hours (good conditions for CHP, + feed-in support)
- negative prices in less than 50 hours (good conditions for P2H, + taxes and surcharges)





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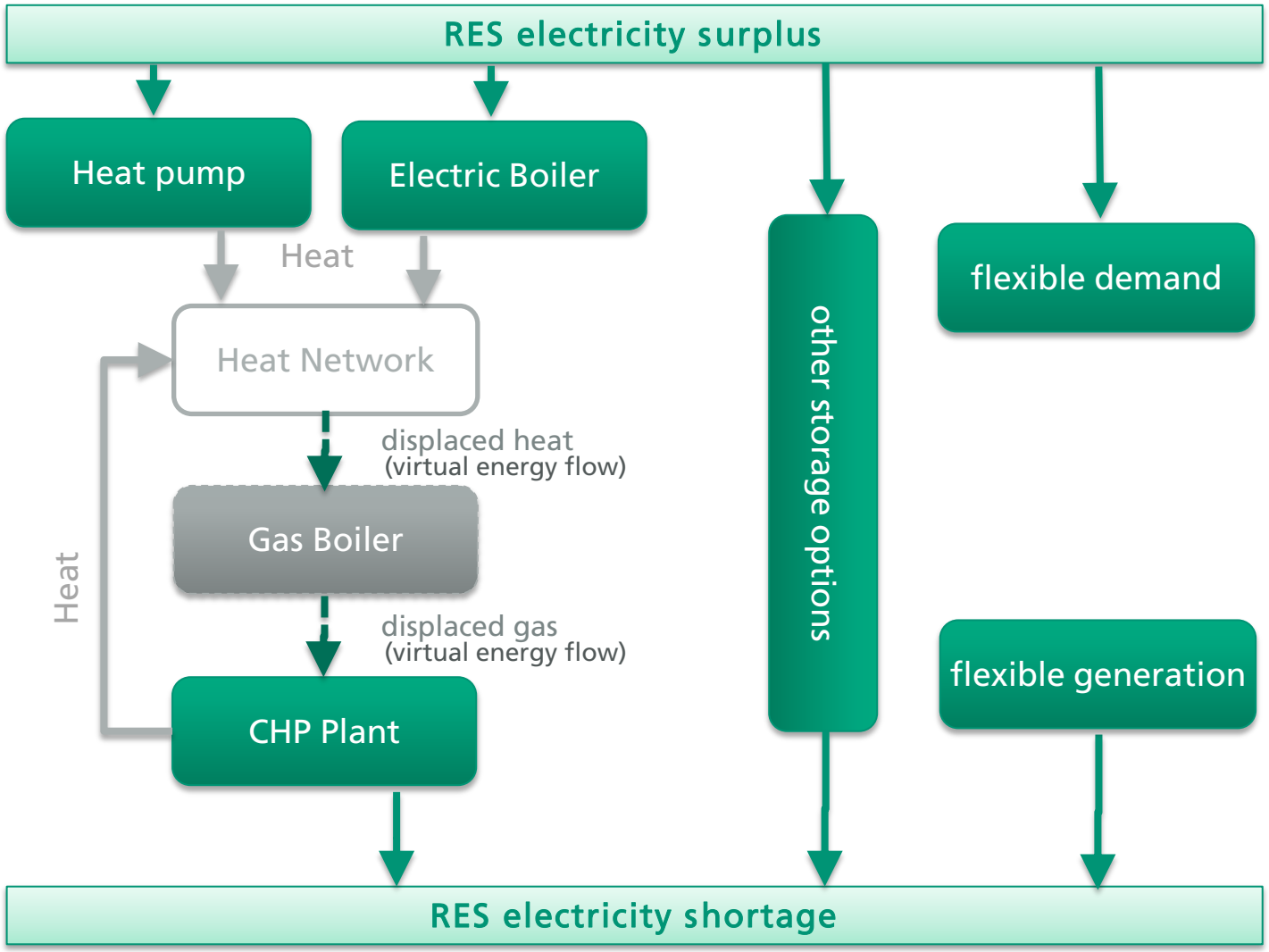
Flexibility from CHP and P2H and other sources



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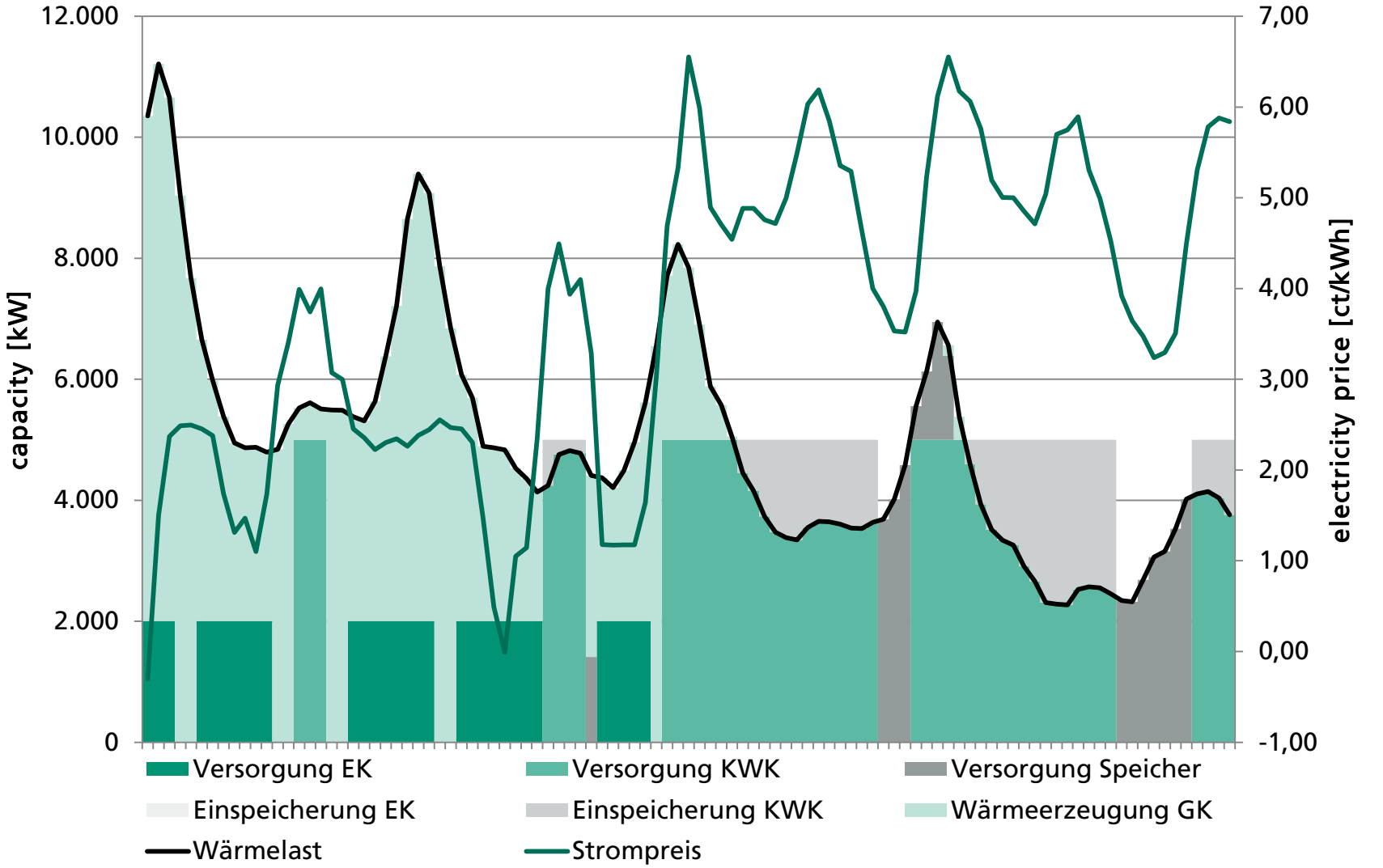
Flexible operation of CHP and P2H



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IFAM study on flexibility from heat

for the German Renewable Energy Federation & the Association for Efficiency in Heating, Cooling and CHP

together with Wolfgang Schulz

- modelling of CHP heat supply
- economic analysis of heat and electricity driven CHP operation
- optimization of heat storage volume
- analysis of a combination with heat pumps and electric boilers
- flexibility potential from heat supply

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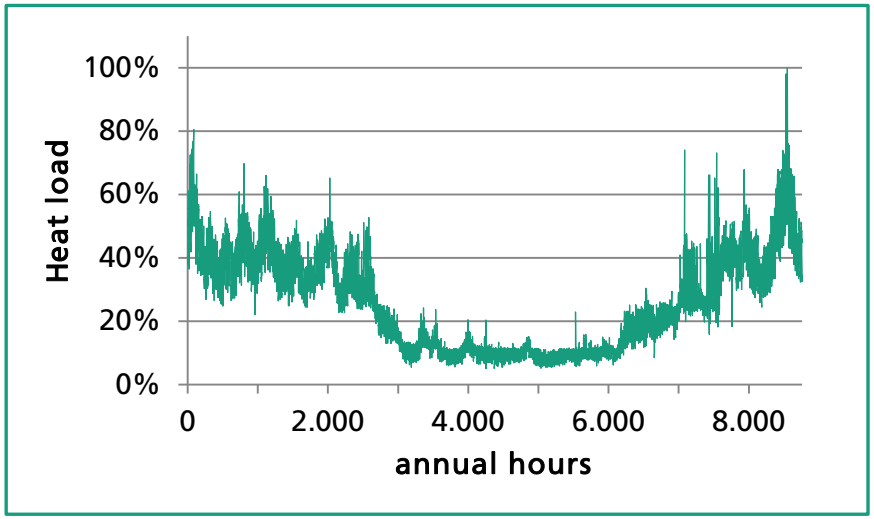
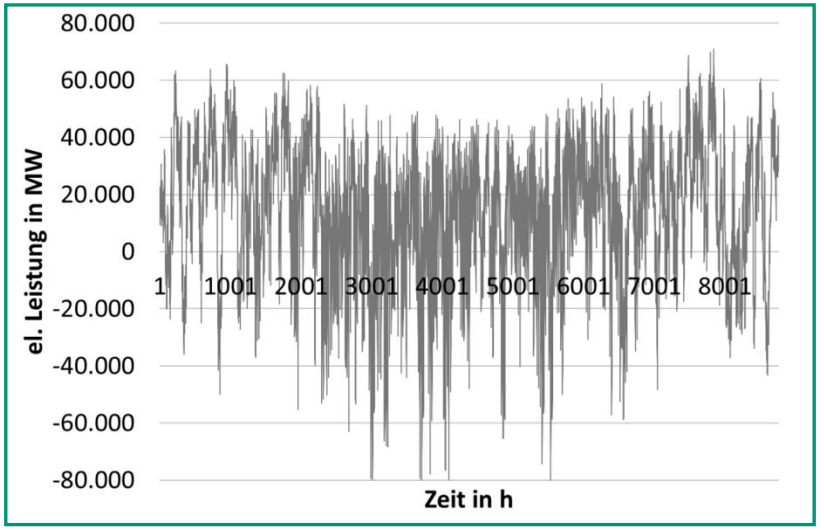
Modelling of CHP heat supply

- CHP production influenced by
  - heat demand
  - dimensioning
  - energy prices
  - support schemes
- present and future data

	detached house	multiple dwelling	reg. heat network	large heat network
electr. capacity (kW_{el})	1	20	1.000	88.000 (100.000)
therm. capacity (kW_{th})	5,7	32,7	1.122	80.000
elektr. efficiency (η_{el})	15%	33%	41%	46,3% (52,6%)
therm. efficiency (η_{th})	81%	54%	46%	42,1%





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Analysis of electricity and heat driven operation of CHP

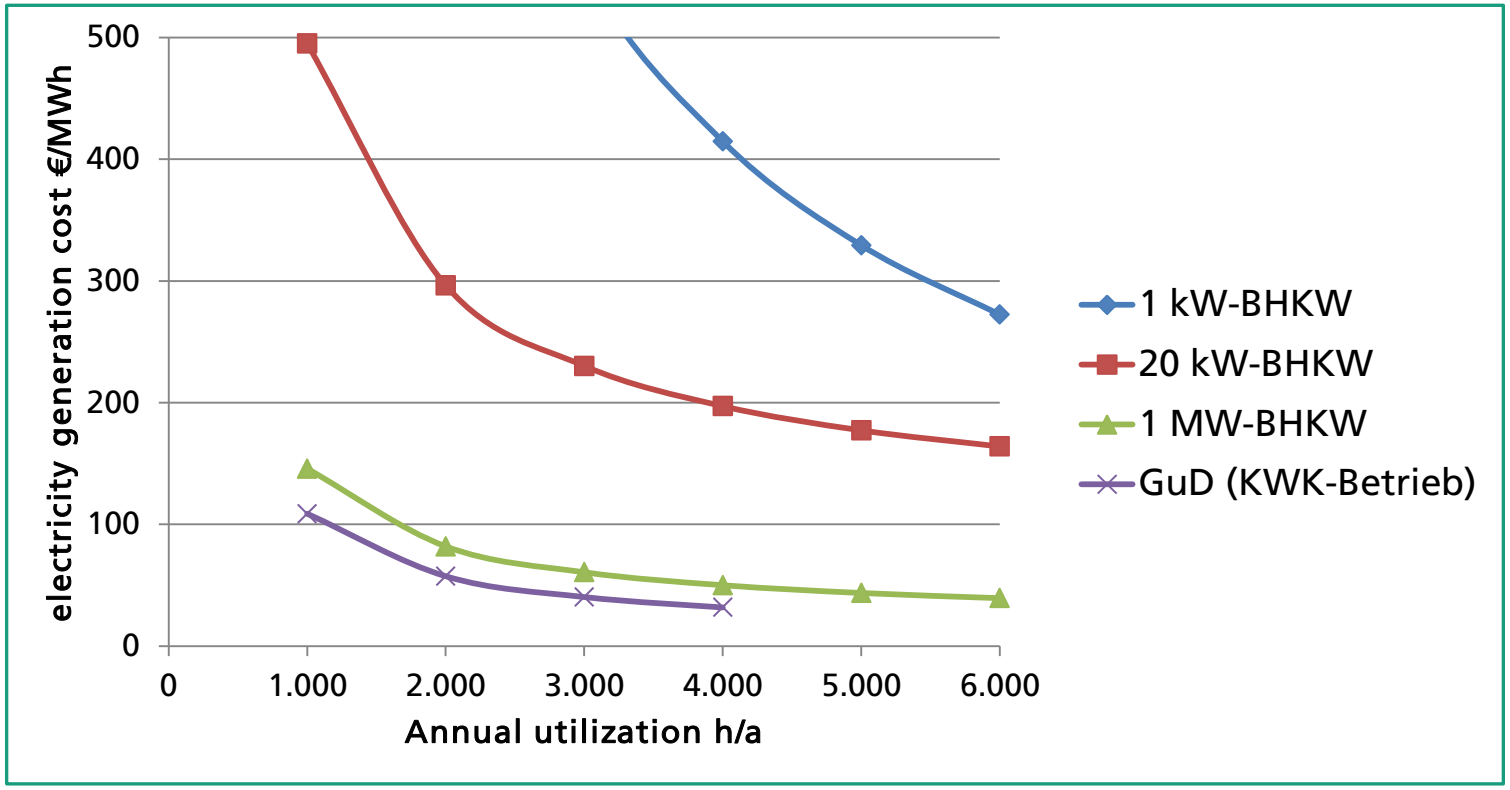
- lesser full load hours in electricity driven than in heat driven operation
  - high dimensioning (capacity high compared to average heat demand):
    2.938 full load hours per year instead of 4.000
  - low dimensioning (capacity low compared to average heat demand):
    4.418 full load hours per year instead of 6.000

- higher electricity revenue (support scheme + exchange prices) required to recover investment assuming constant heat prices

➢ additional cost for flexibility from CHP

Analysis of electricity and heat driven operation of CHP

- electricity cost with lesser full load hours for different CHP sizes



- lesser cost increase for larger plants

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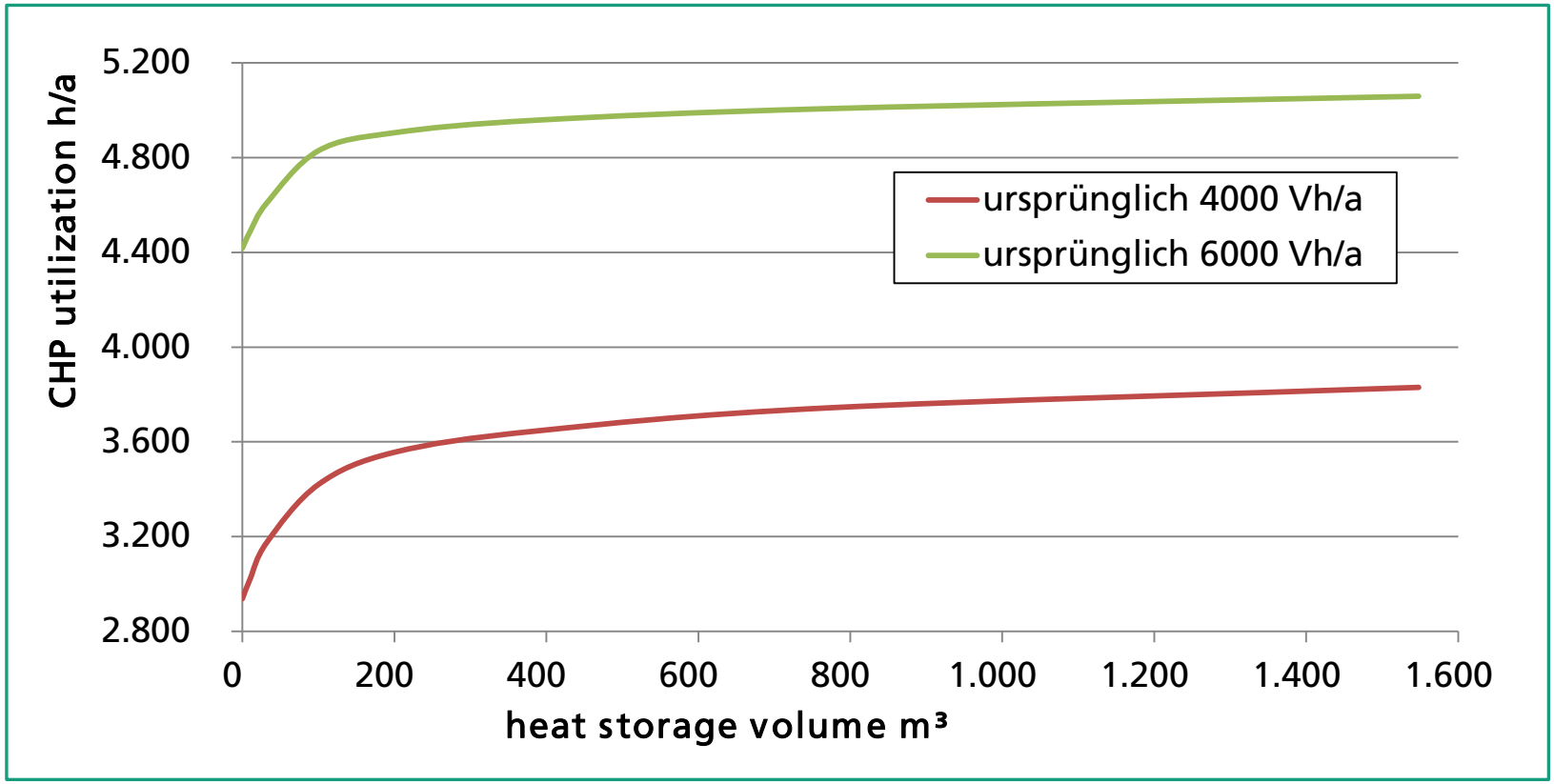
Optimization of heat storage: potential

- Heat storage can partially recover ‚lost' full load hours



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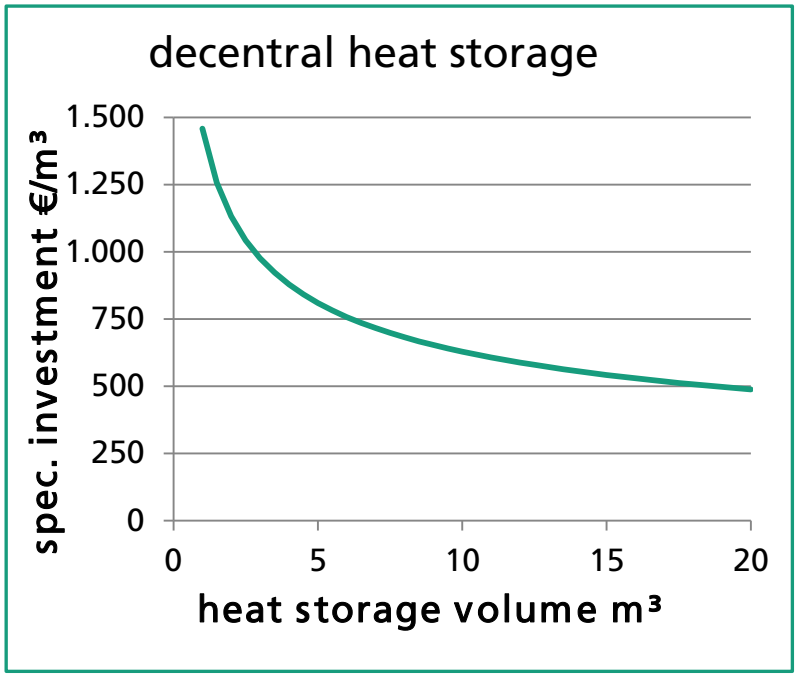
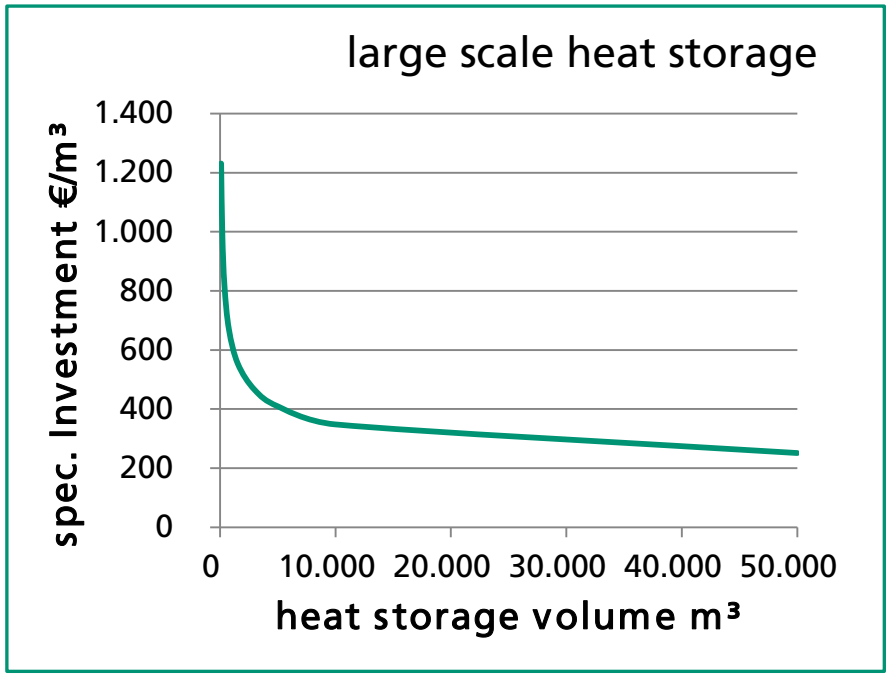
Optimization of heat storage: cost

- Specific investment decreases with volume





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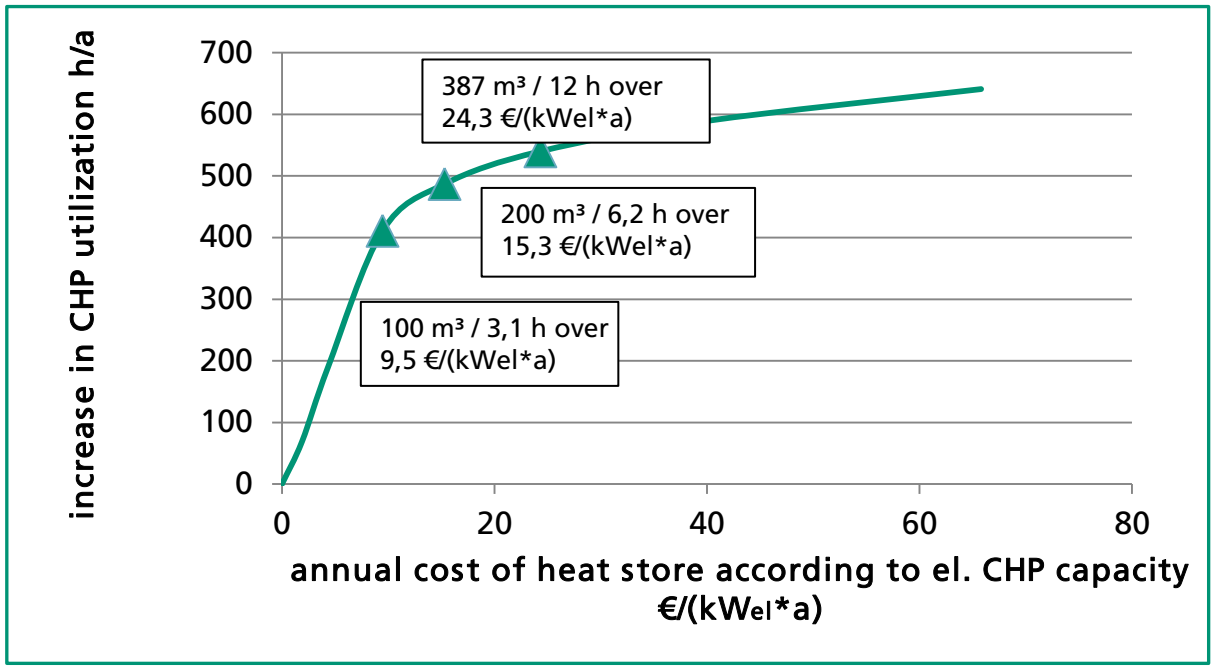
Optimization of heat storage

- optimal storage size depends on cost and recovered full load hours: (for the example of 1 MW CHP) between 200 and 400 m³



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Combination with P2H

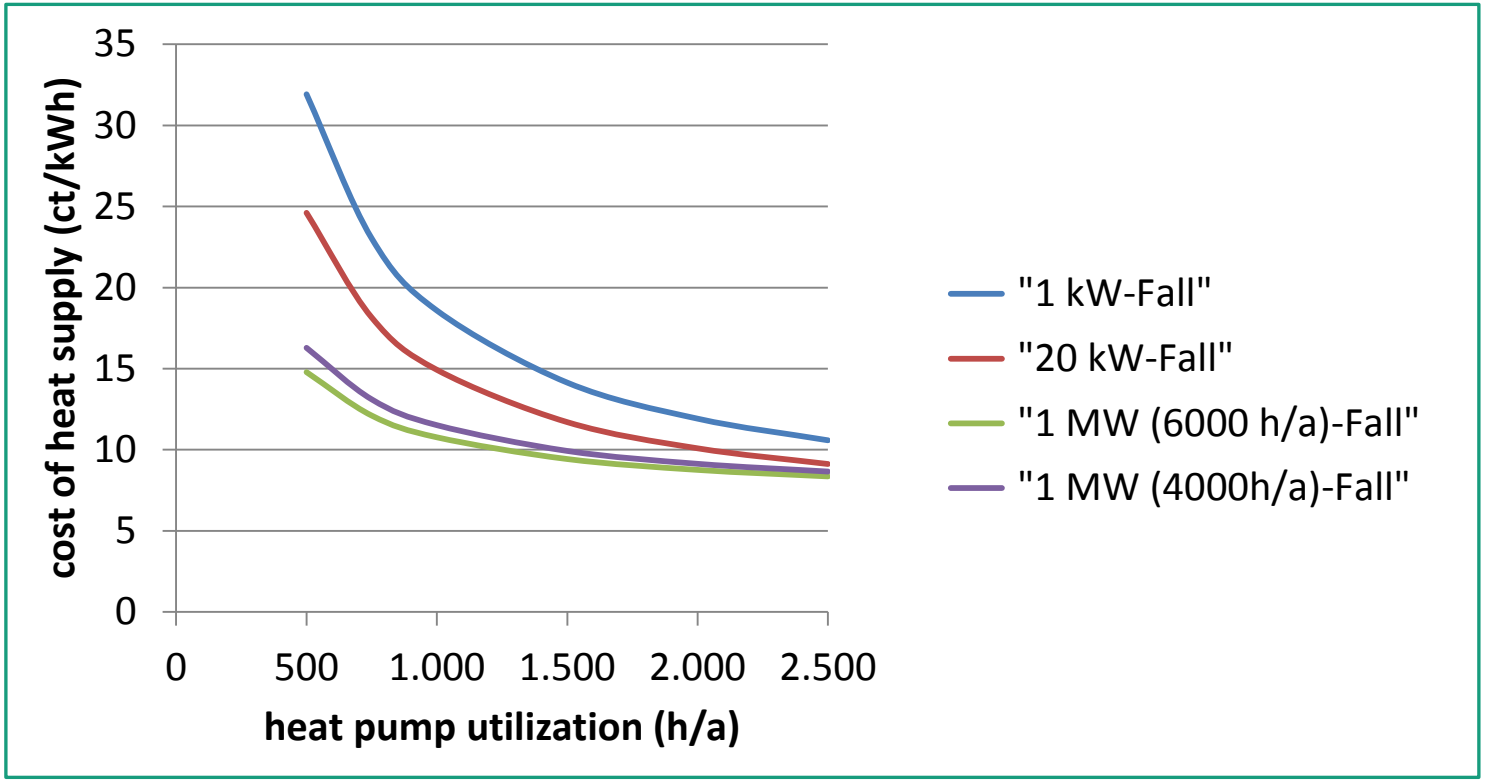
- supplying heat from P2H in hours with significant surplus
  - reduces CHP full load hours
  - requires higher electricity revenues (if heat revenue remains constant)

Fall			1 MW			
	1 kW	20 kW	6000 Vh/a	4000 Vh/a	GuD	
CHP full load hours per year [h/a]						
wärmegeführt	4.000	4.000	6.000	4.000	4.000	only CHP
ohne E-Heizer	3.522	3.335	4.958	3.647	3.647	
E-Heizer: 200 h/a	3.468	3.270	4.808	3.497	3.497	CHP with P2H
E-Heizer: 400 h/a	3.438	3.232	4.774	3.411	3.411	
required revenue for CHP electricity [ct/kWh]						
wärmegeführt	14,9	14,9	5,6	5,6	5,6	only CHP
ohne E-Heizer	21,3	16,9	5,9	6,0	5,8	
E-Heizer: 200 h/a	22,1	17,1	6,1	6,0	5,9	CHP with P2H
E-Heizer: 400 h/a	22,6	17,3	6,2	6,1	6,0	

➢ moderate increase of required revenue only for larger plants

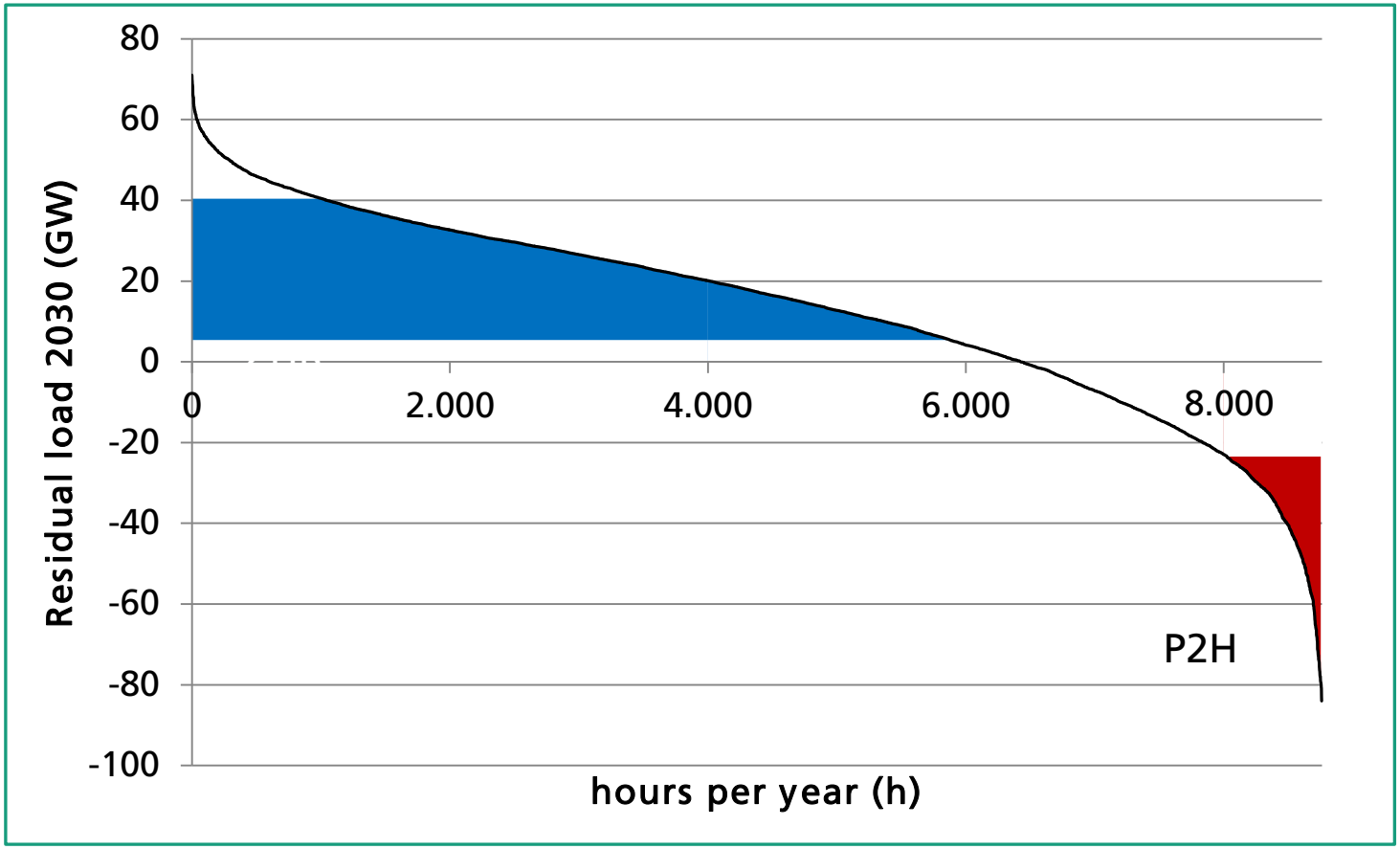
Combination with heat pumps

- cost of heat generation through heat pumps depend on utilization



- lesser effect of reduced full load hours for larger heat pumps

Flexibility potential of P2H and CHP



- CHP and P2H together can provide a large share of the flexibility needed in the future (2030)

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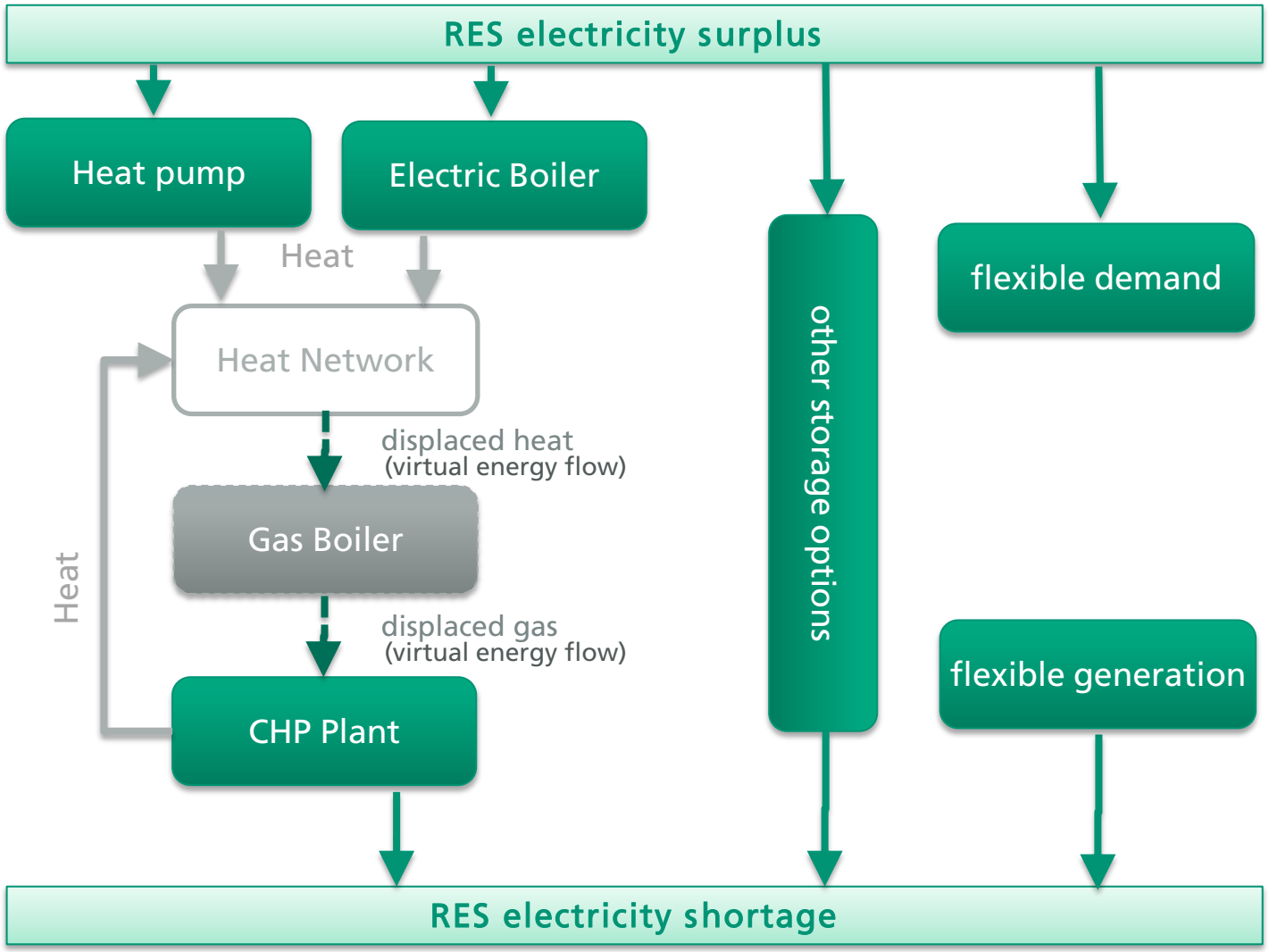
Flexibility from CHP and P2H and other sources



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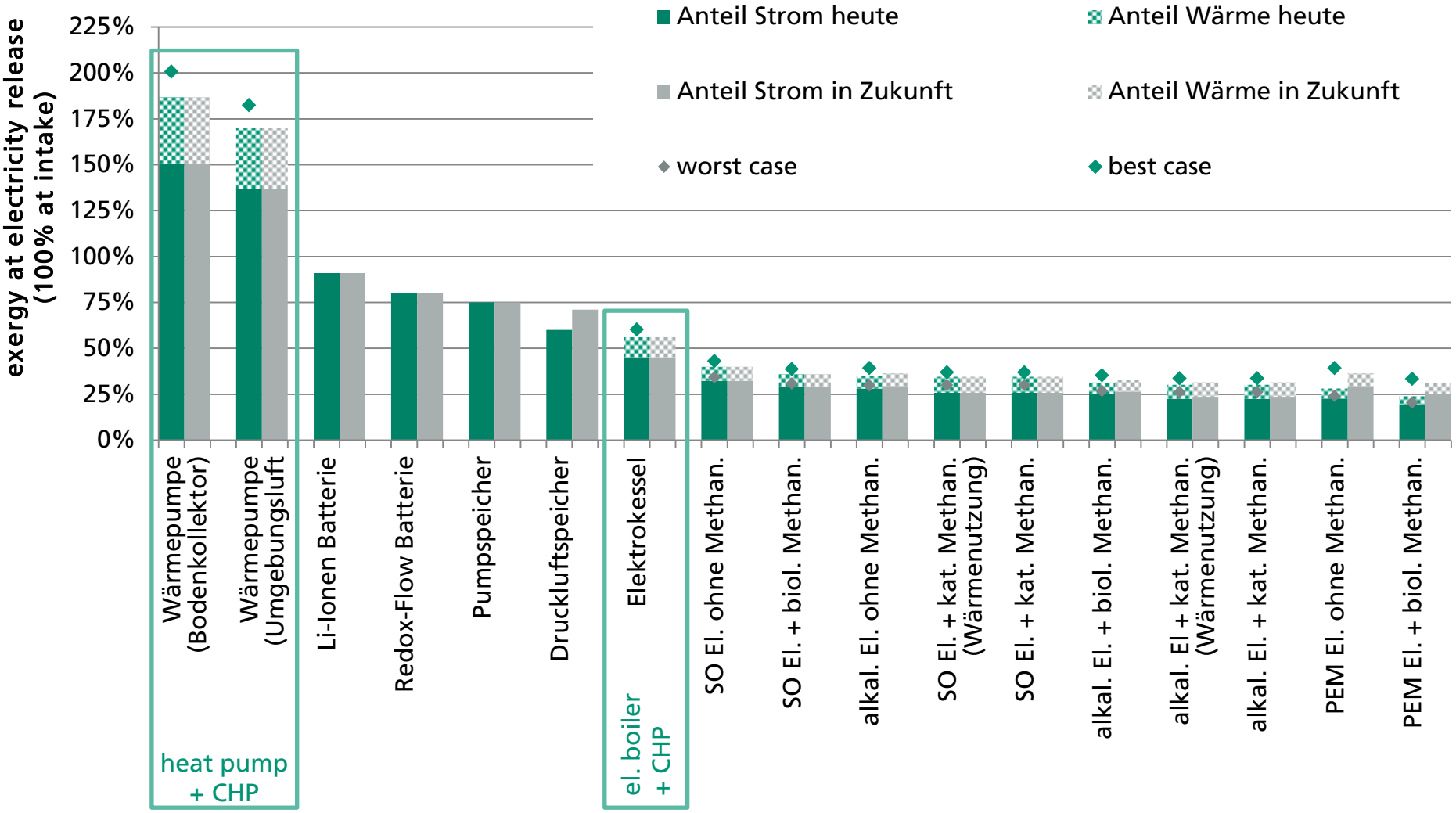
exergy balance of shifting el. from surplus to shortage



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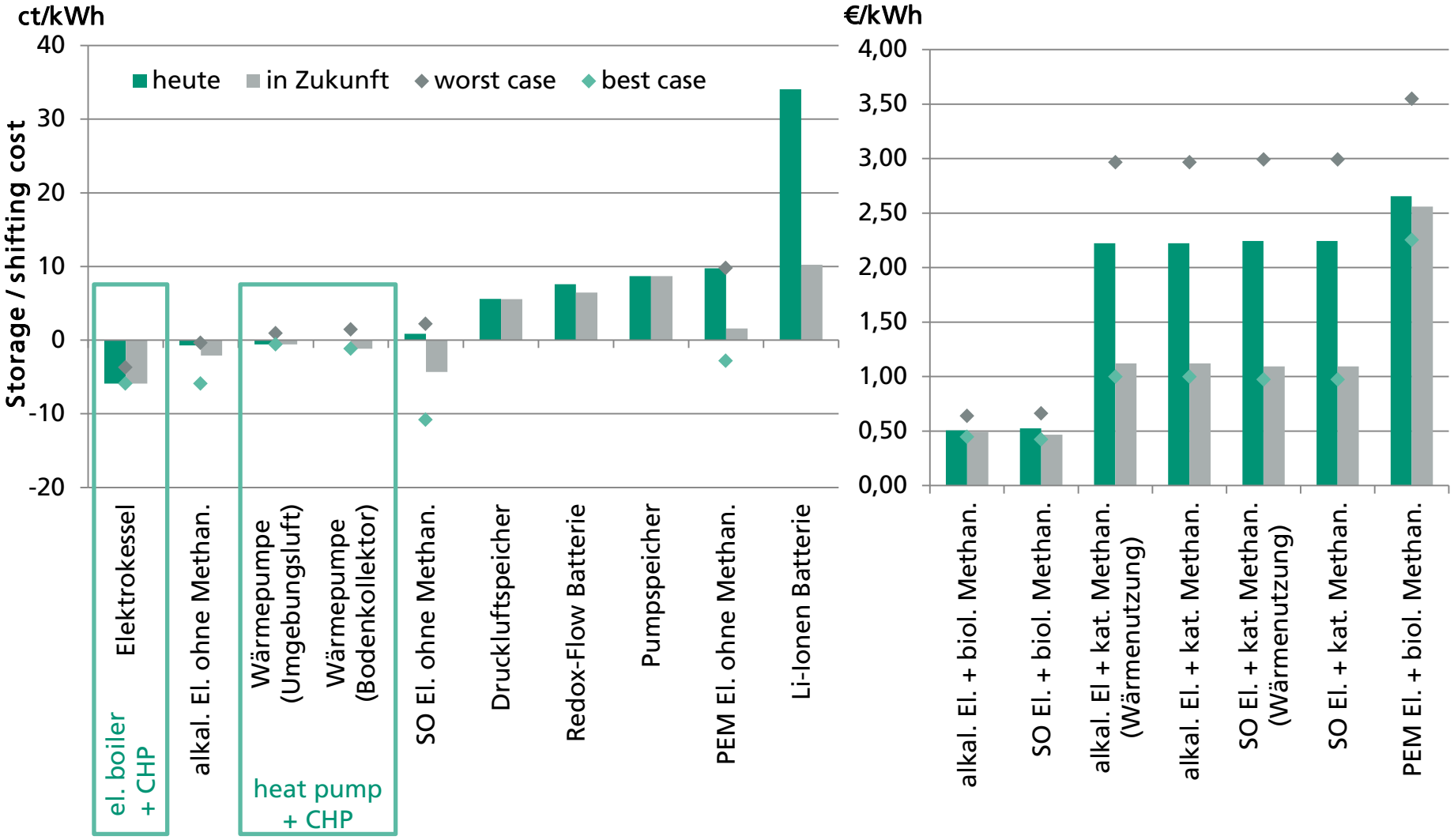
cost of shifting electricity from surplus to shortage



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Conslusion

- future electricity supply is likely to require additional flexibility
- CHP and P2H (among other options) can provide flexibility
- provision of flexibility requires
  - alternative dimensioning (peak supply, heat storage)
  - additional revenue options (electricity prices, support schemes)
- larger systems can provide flexibility more efficiently and at lower cost

Thank You for your time and Attention.

Feel free to ask questions.

Christine Brandstätt M.Sc., Fraunhofer IFAM, Energy Systems Analysis

christine.brandstaett@ifam.fraunhofer.de, +49 (0) 421 2246 - 7027

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