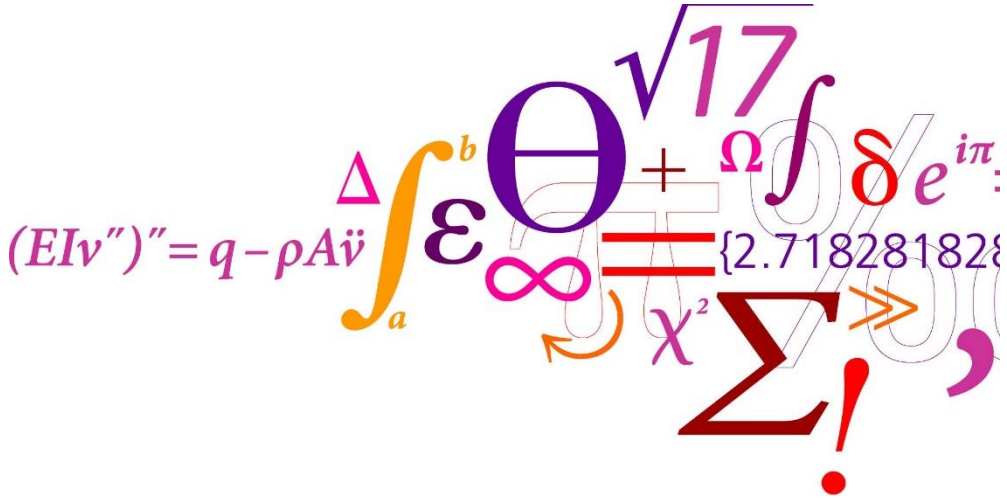
Evaluation of the flexibility provided by integrating energy systems

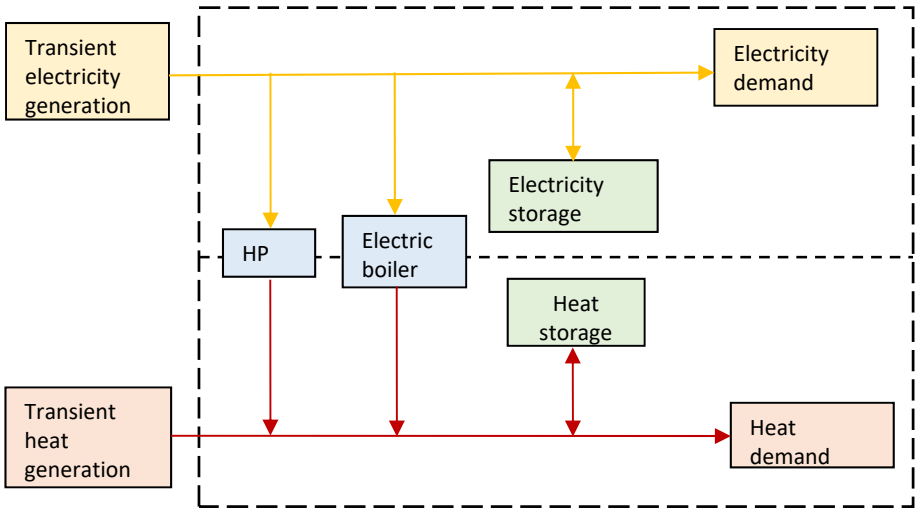
Dynamic exergoeconomic analysis

Wiebke Meesenburg



DTU Mechanical Engineering
Department of Mechanical Engineering

Integration of electricity and DH systems

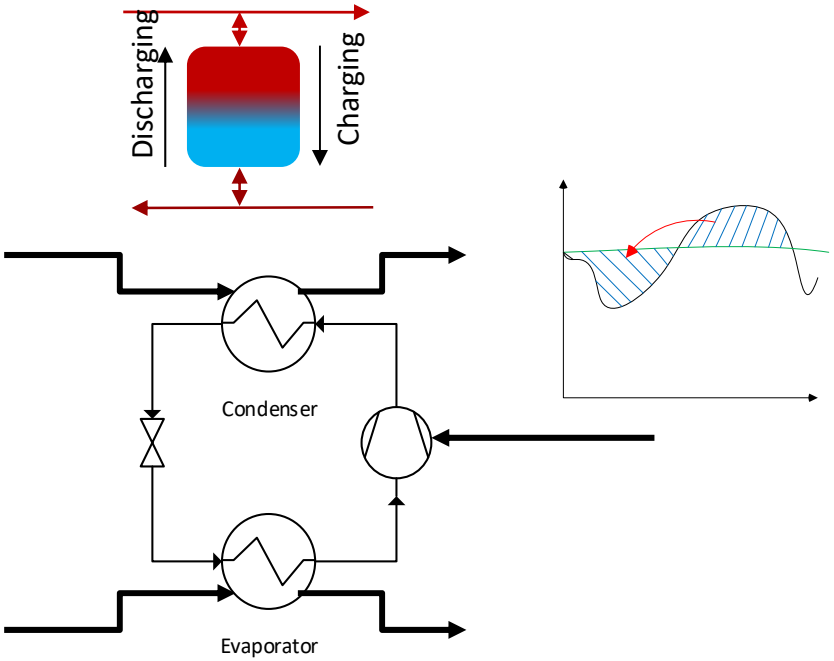


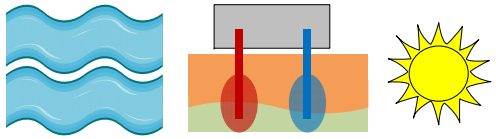
Key to smart integrated energy systems:

Flexible operation of integrating technologies, e.g.

- Heat pumps, electric boilers
- EV charging stations
- Power-to-gas systems
- Smart home appliances

The heat pump as conversion unit



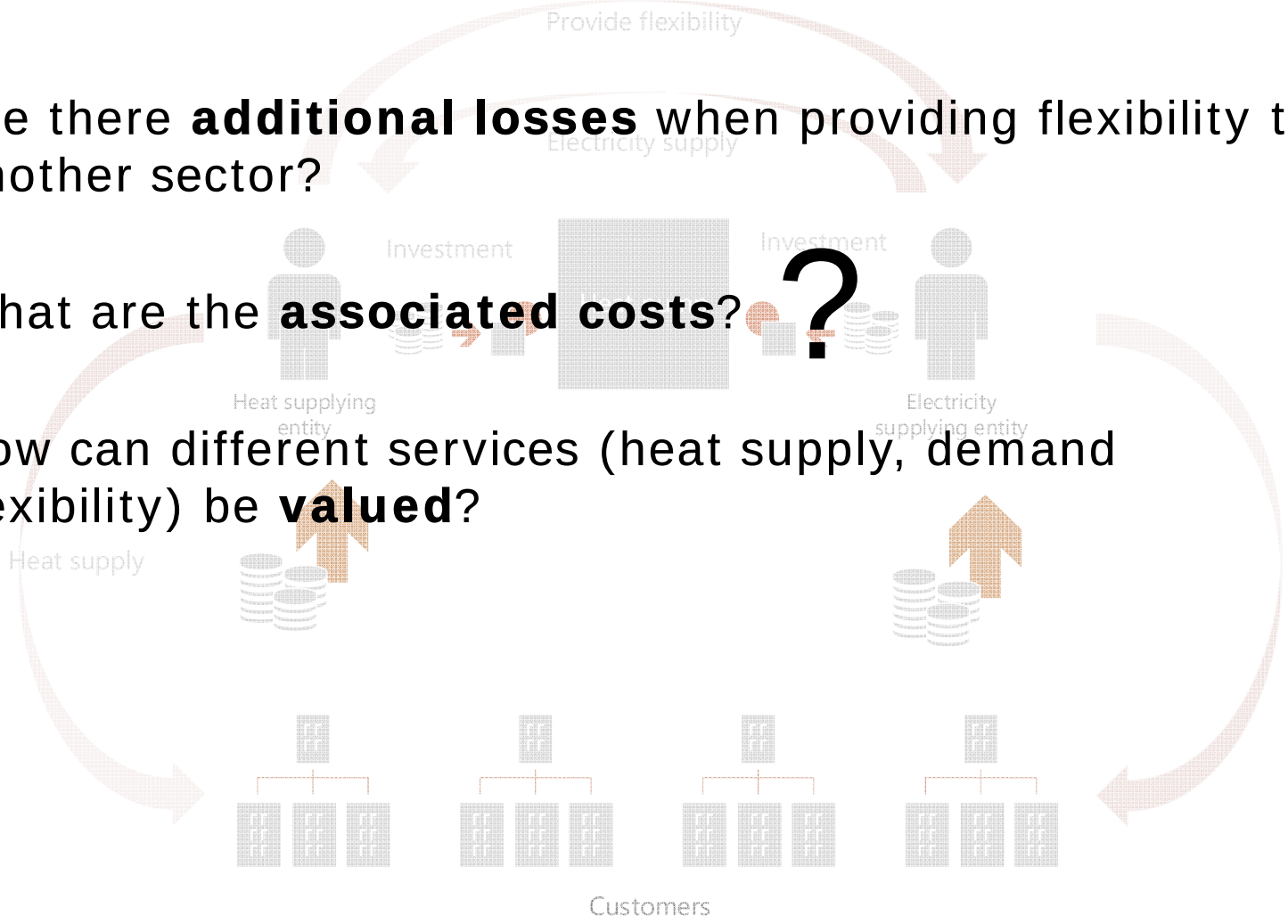


- Large scale storage of heat is cheap and easy
- System immanent storage capacity
- Cost effective provision of demand flexibility
- Integration of low temperature heat sources

Flexible operation ?
Start-up losses ?

Research questions

- Are there **additional losses** when providing flexibility to another sector?
- What are the **associated costs**?
- How can different services (heat supply, demand flexibility) be **valued**?



Method – exergoeconomic approach

Dynamic exergo-economic analysis

Dynamic model of the system

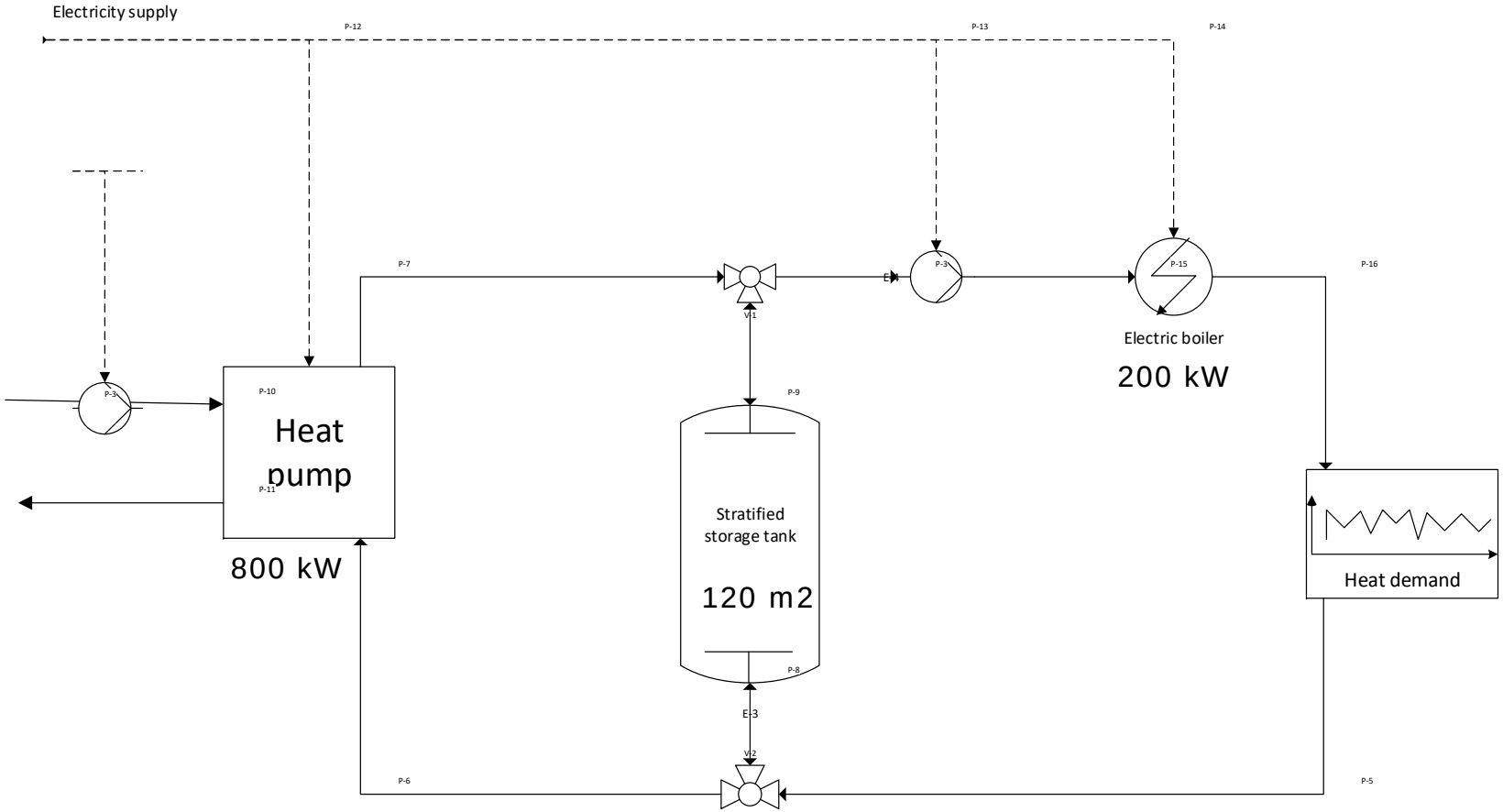
Maximum theoretically useful part of energy

Assign cost to exergy streams

Exergy analysis includes the quality of different types of energy
-> energy products / services are rated according to their quality

- Expected results:
  - Cost of flexible operation for every component
  - Location of exergy destruction and related cost
  - Information how to improve the integration of electricity and heating sector

Case Study – Heat pump island system



Results - Yearly simulation

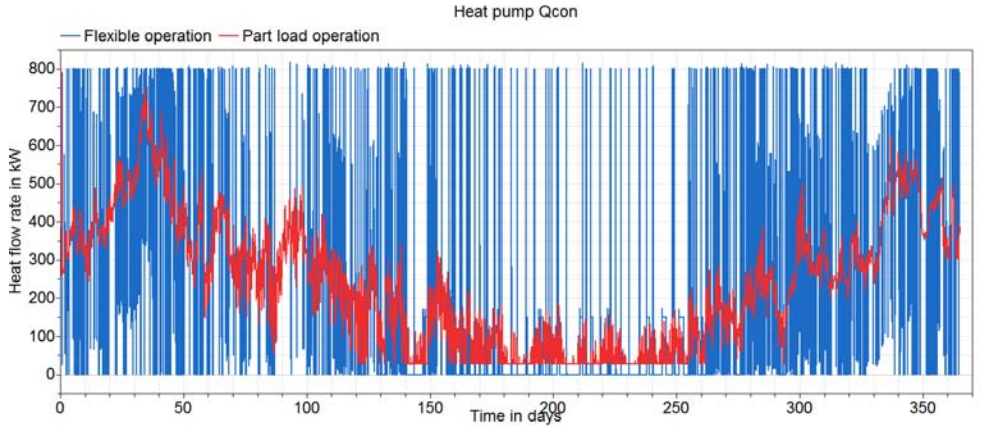
Yearly simulation for 2 cases:

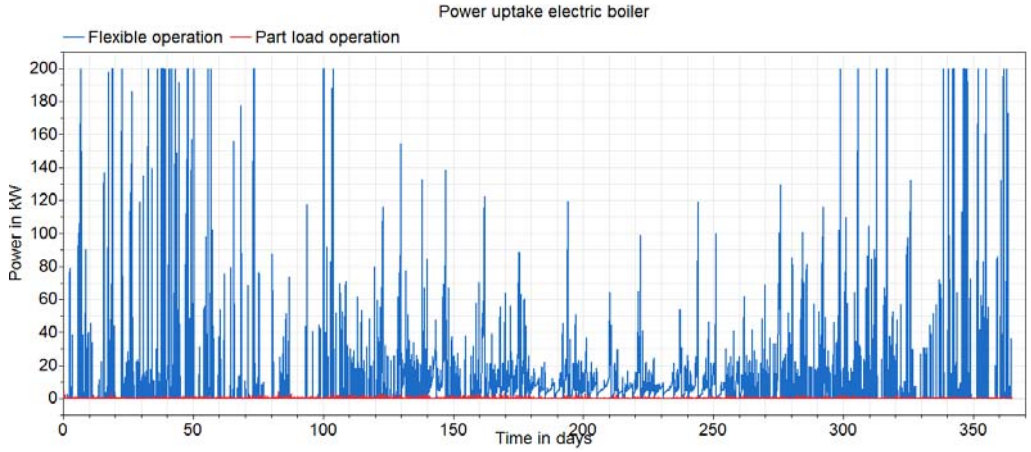
Flexible operation

Reacts to regulation system and storage state

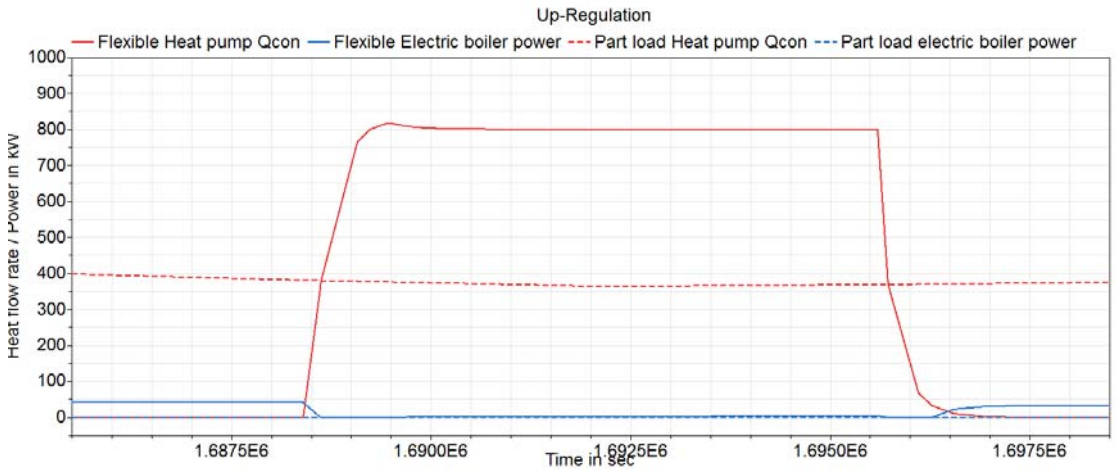
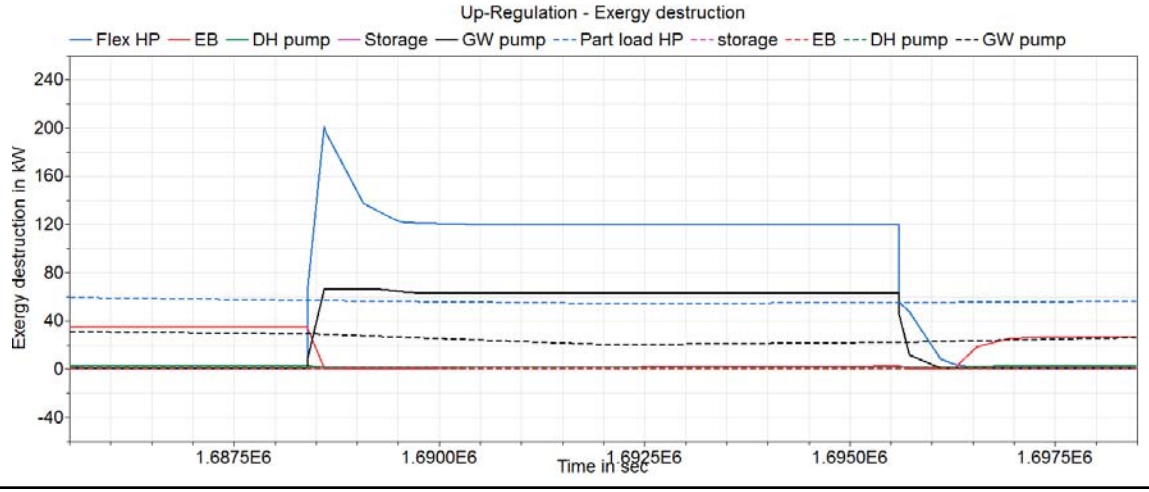
Part load operation

Heat pump supply = heat demand

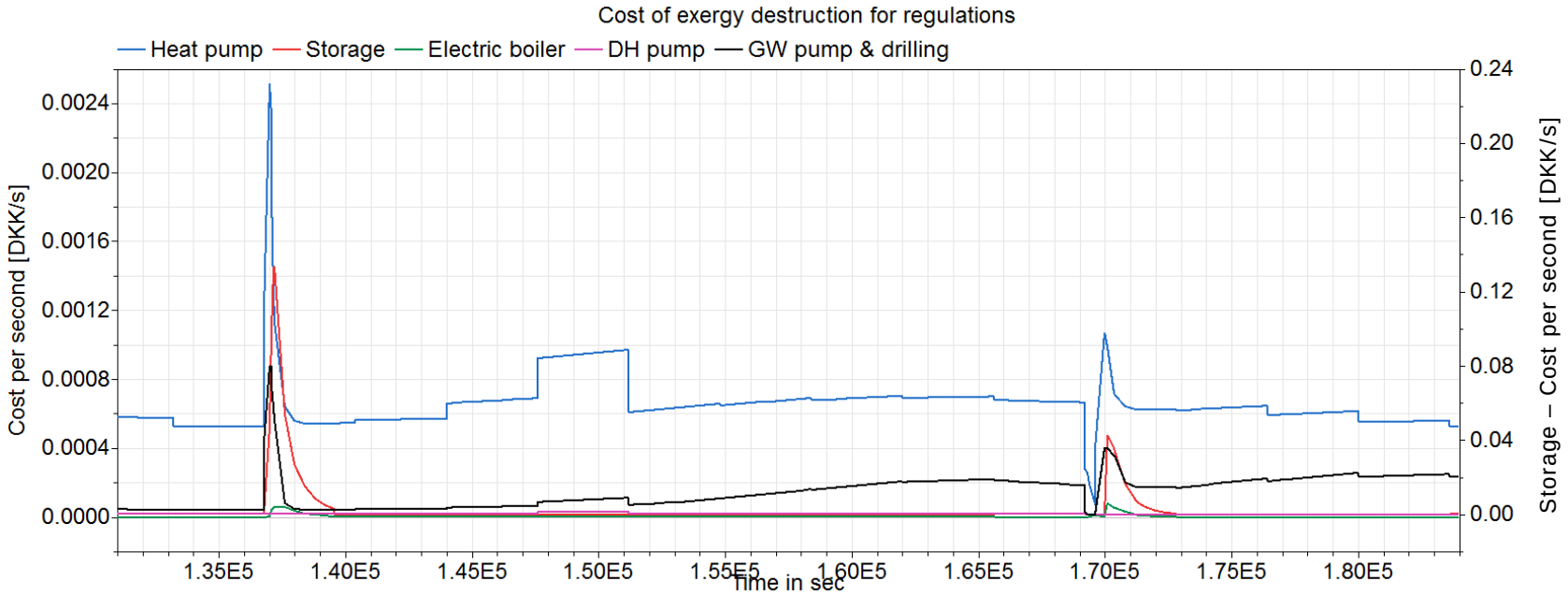




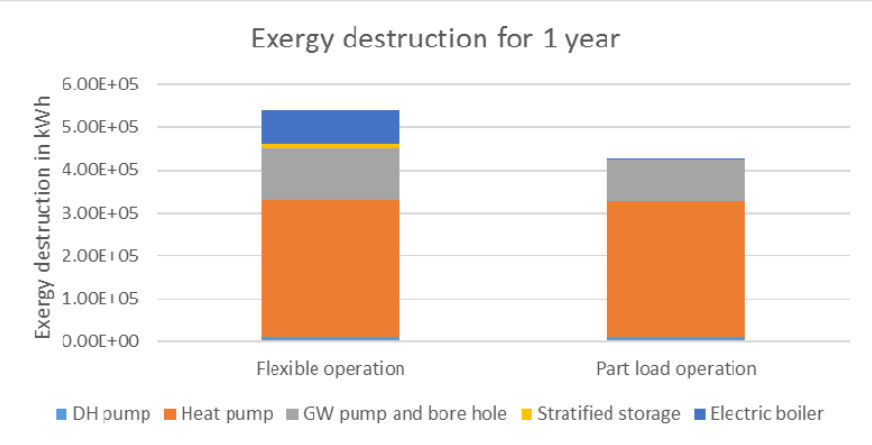
Up-regulation of heat pump

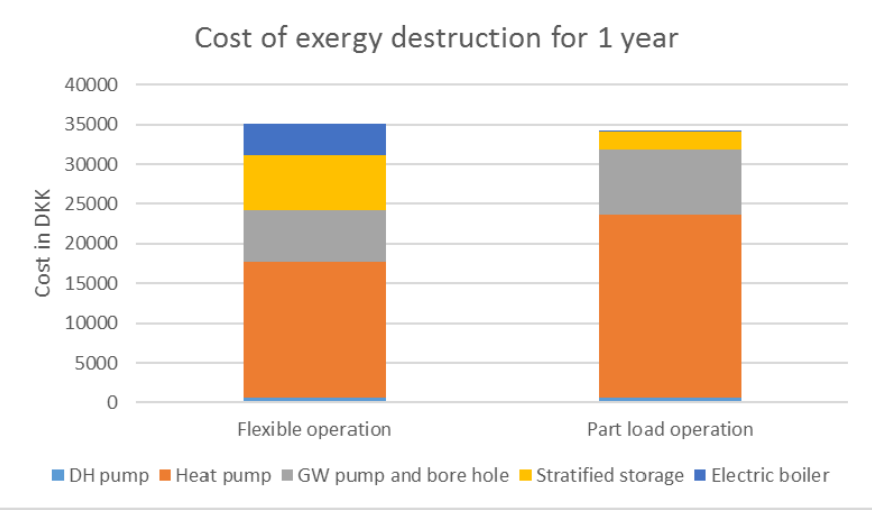
Condenser heat flow rate Heat demand	
Exergy destruction & Associated cost	

Regulation of heat pump



Exergoeconomic results for full year





	Flexible operation	Part load operation
Energetic efficiency	37 %	42 %
Exergetic efficiency	90.9 %	94.4 %
Specific generation cost	0.34 DKK/kWh	0.135 DKK/kWh

Conclusion

Case study

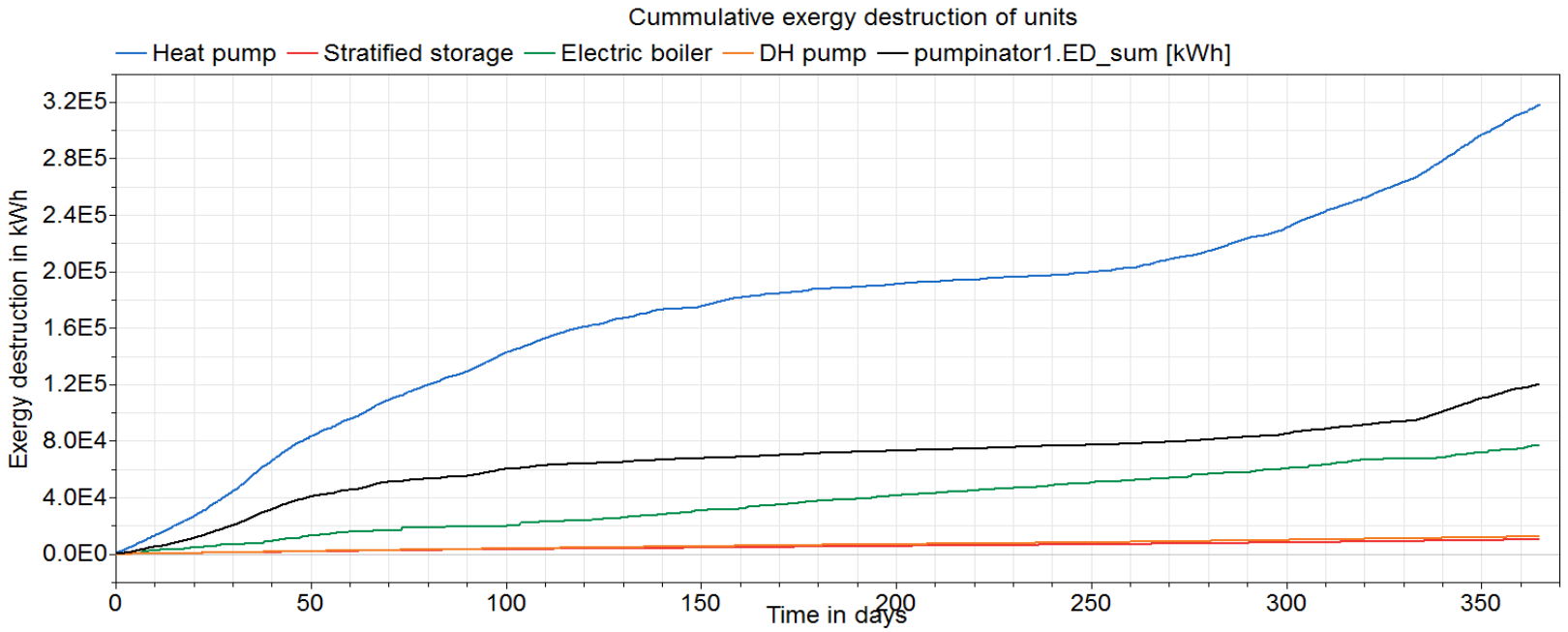
- Losses due to flexible operation occur especially in the storage unit and the electric boiler
- Frequent start-ups and shutt-offs od the heat pump leads to increased cost and decreased efficiency.
- Generic algorithm for the flexible operation mode will be optimized

General

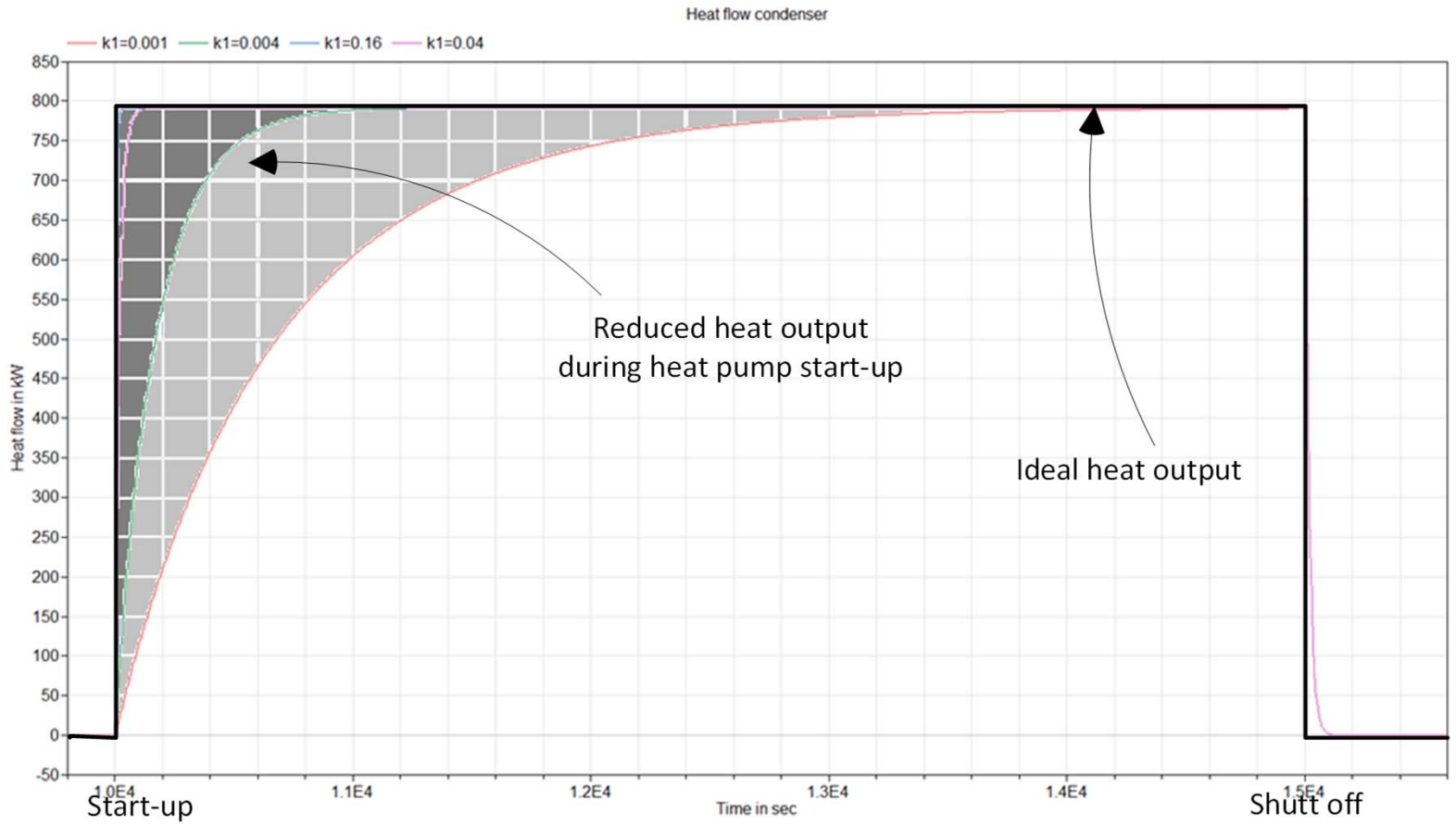
- Dynamic exergo-economic analysis is a feasible tool to identify and losses and associated cost that occur due to flexible operation

Thank you for your attention

Exergy destruction during up regulation

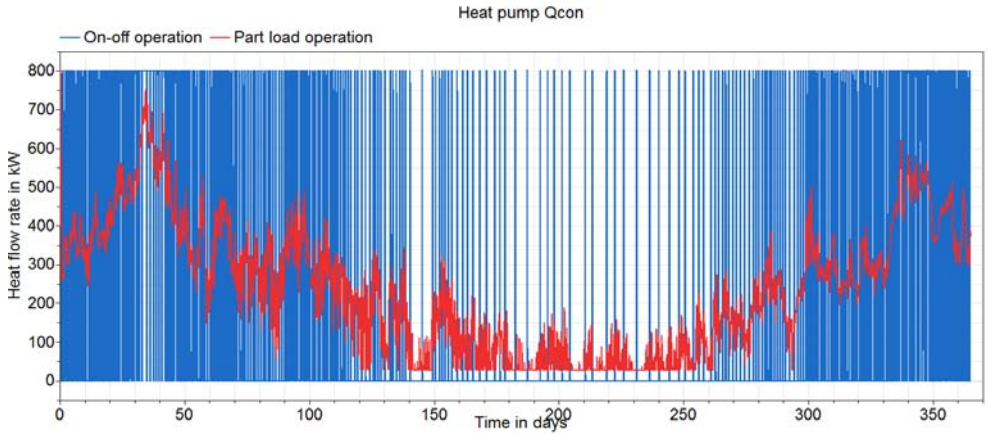


Losses during dynamic states

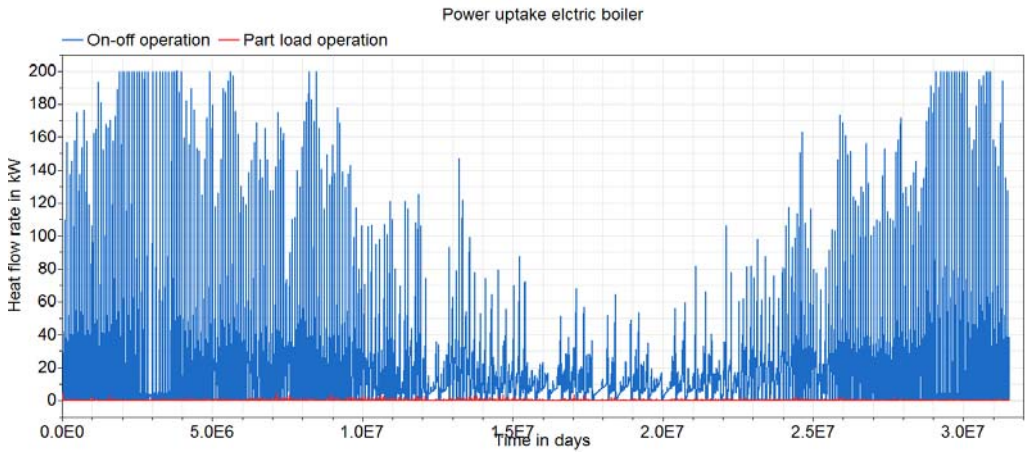


Results - Yearly simulation

Part load operation
Heat pump supply = heat demand



On-Off operation
On-off according to storage state

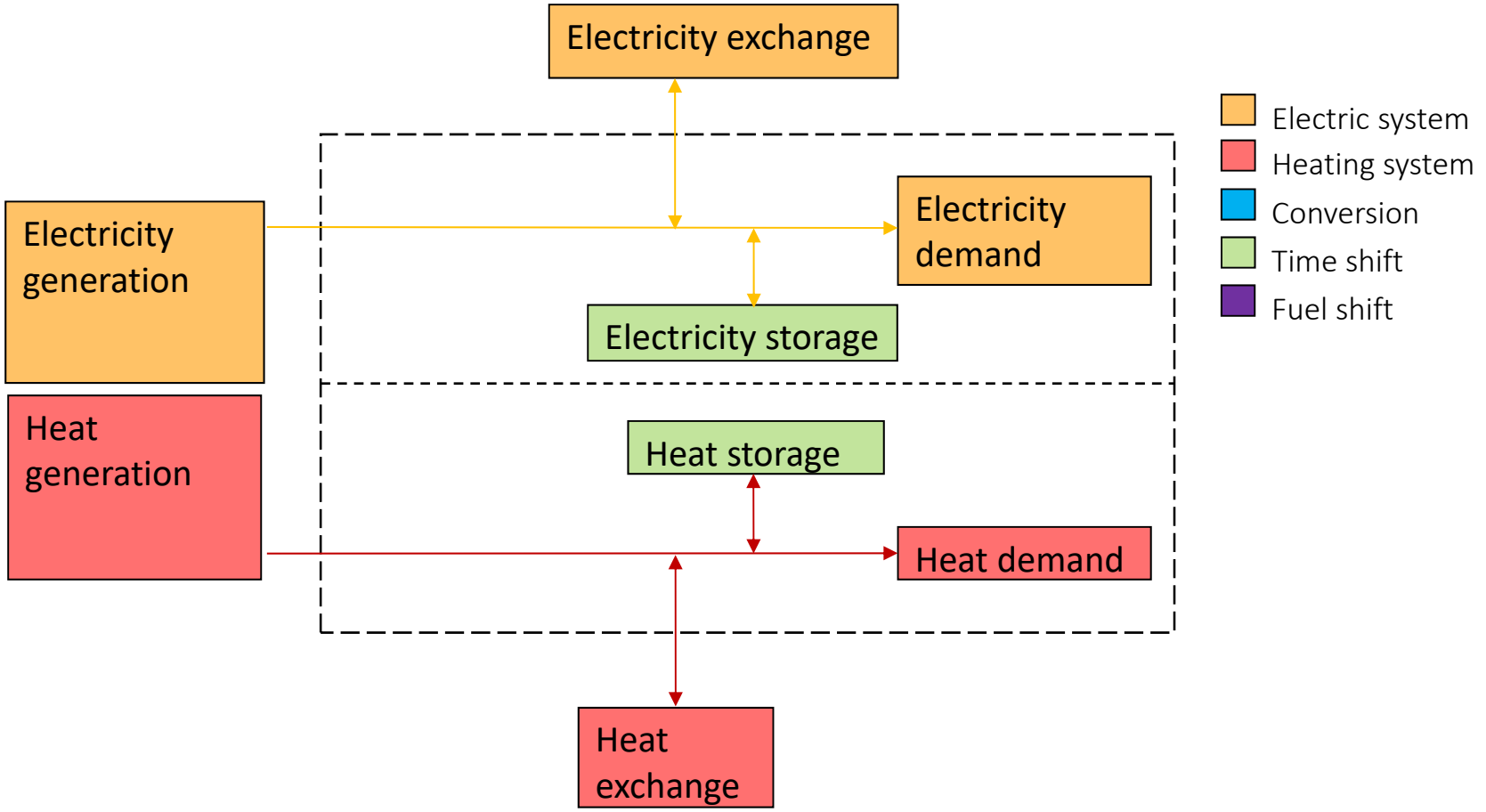


Exergy destruction during up regulation

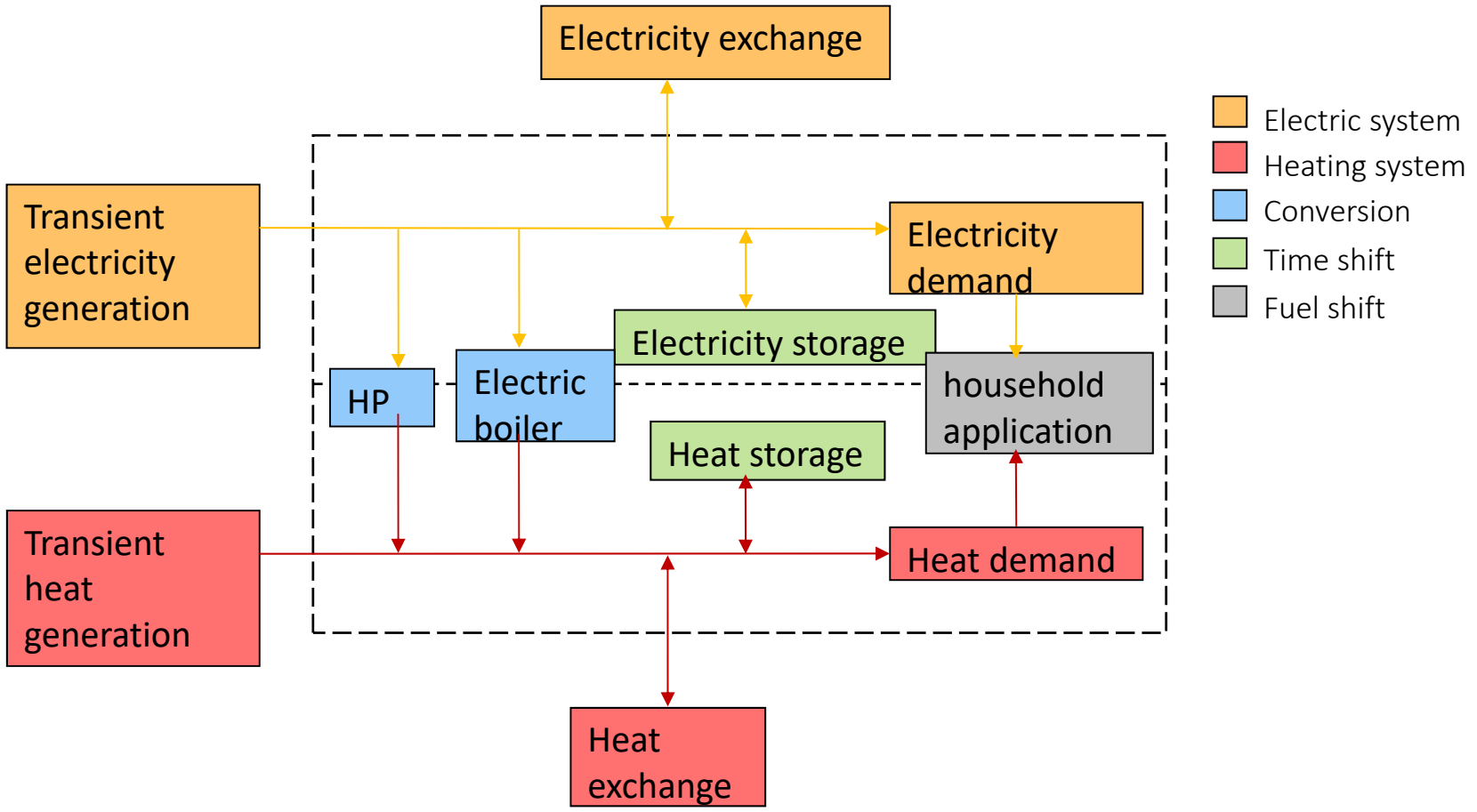
	Regulation Up[kWh]	Part load [kWh]	Gain
Heat pump Qcon	1569.4	1125.0	140%
ED HP	14151.4	180.6	7838%
ED storage	4.0	-	-
ED EB	36.7	0.8	4552%
ED DH pump	6.6	4.4	152%
ED GW pump	126.4	348.6	36%

-> Depends on current state of the system, no general numbers

Traditional heating system

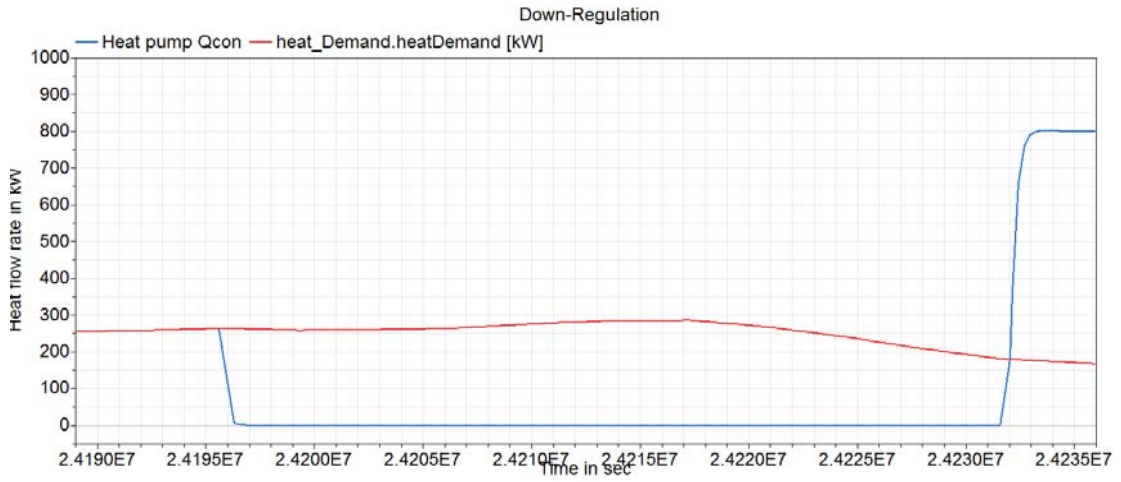


Integrated system



Down-regulation of heat pump

Condenser heat flow rate Heat demand



Exergy destruction & Associated cost