



## Performance analysis of heat pumps utilizing different low temperature heat sources to supply district heating

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# Performance analysis of heat pumps utilizing different low temperature heat sources to supply district heating

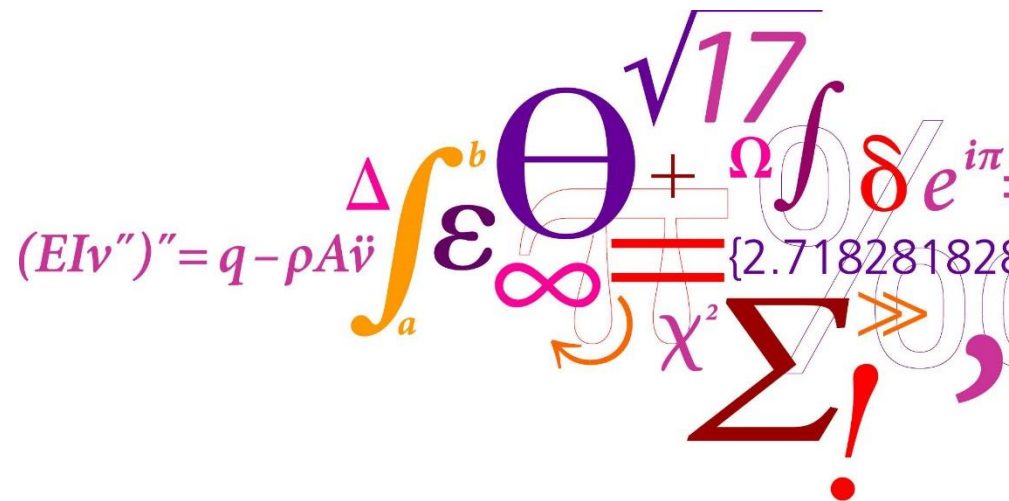
3<sup>rd</sup> international Conference on Smart Energy Systems and  
4<sup>th</sup> Generation District Heating  
12.-13. September 2017, Copenhagen

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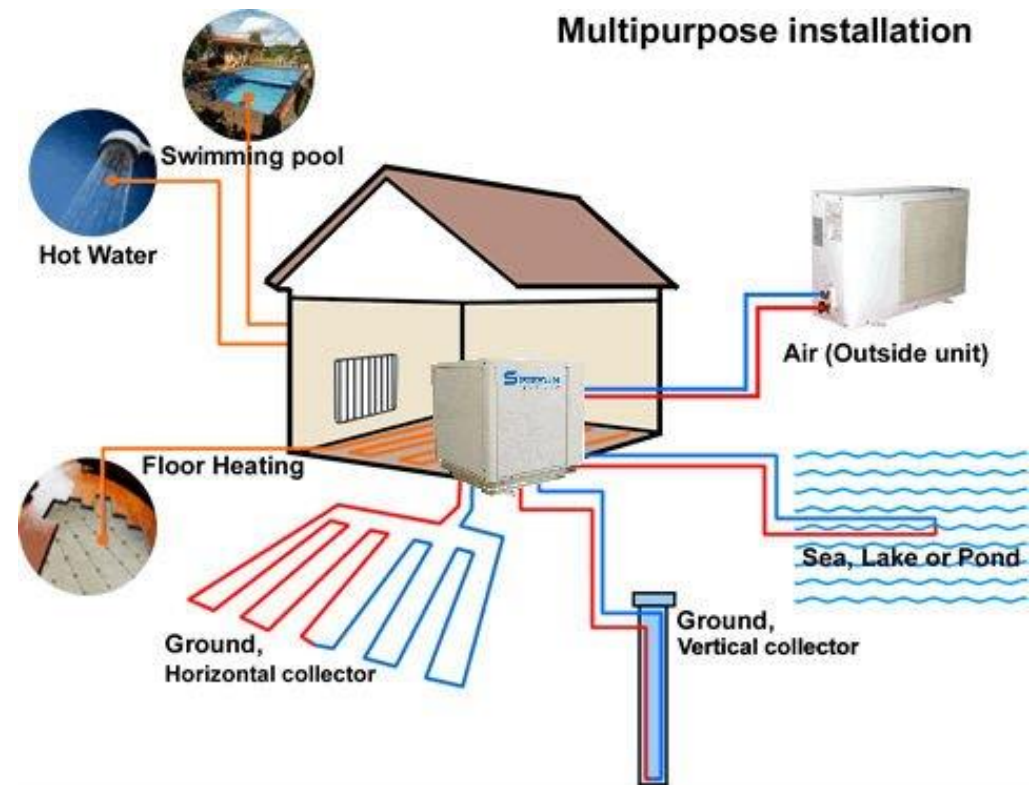
Wiebke Brix Markussen

Brian Elmegaard



# Agenda

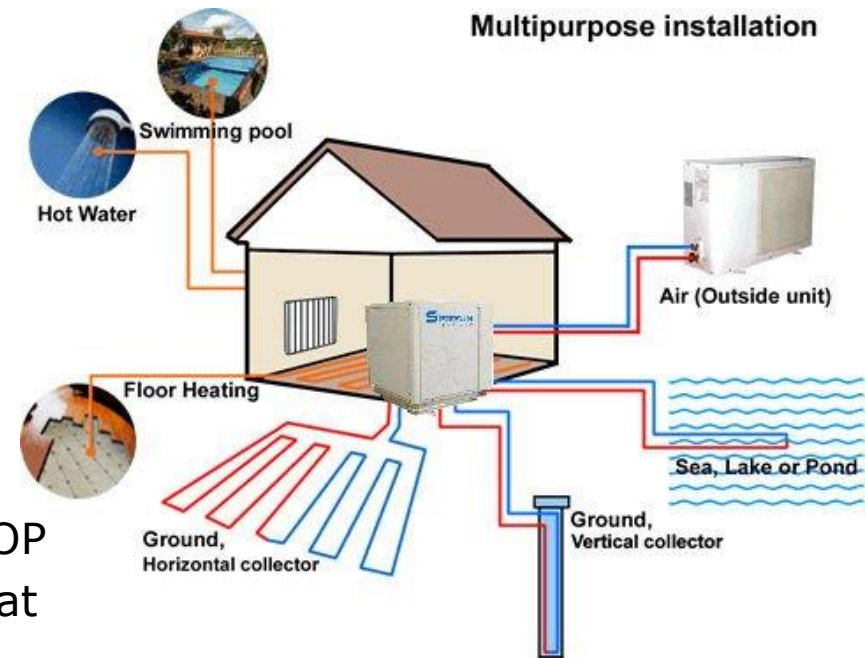
- I. Introduction
  - Motivation
- II. Method
  - Model development
  - Key parameters
  - Case description
- III. Results
  - Comparison of scenarios
- IV. Discussion
  - Model limitations
- V. Conclusion



Source: <http://www.heatpumpcritique.com/>

# I. Introduction

- Energy planning:
  - Constant COP of heat pumps (HP)
- Different heat sources:
  - Seawater, lakes, rivers
  - Air, solar energy
  - Groundwater, geothermal energy
  - Sewage water, waste heat
- Varying temperatures:
  - Influence COP
- How to get highest COP?
  - Investigating hourly variations in COP
  - Comparing scenarios with single heat sources and a combination of those



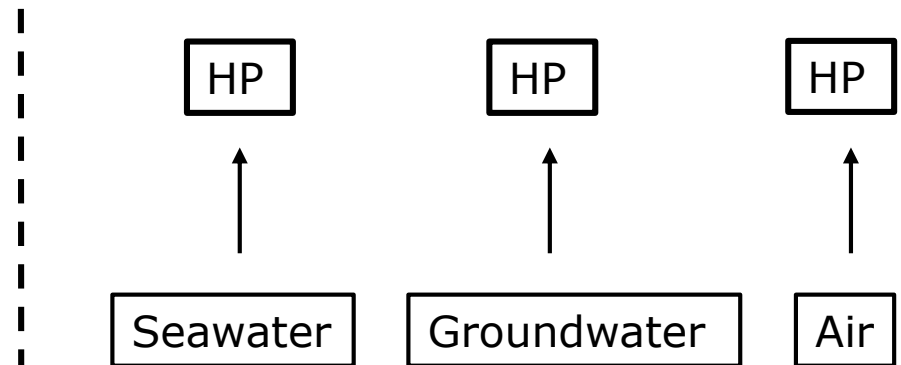
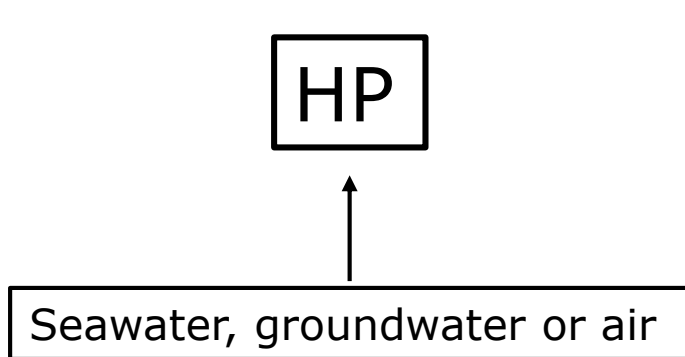
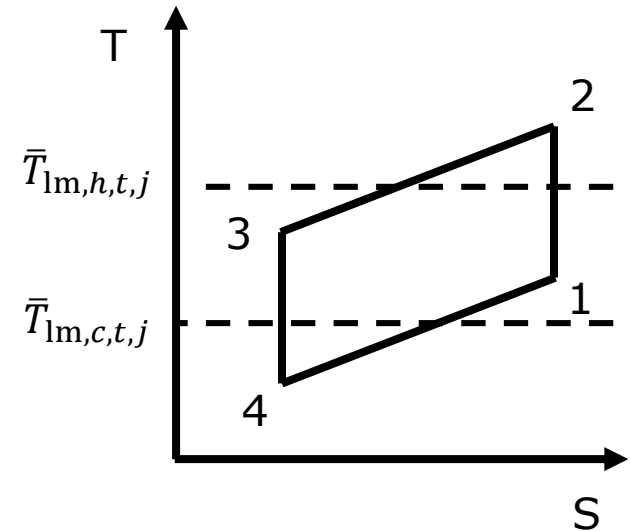
## II. Model

- GAMS
- Linear programming
- Lorenz cycle for COP:

$$\text{COP}_{\text{HP},t,j} = \eta_L \text{COP}_{\text{HP},L,t,j} = \eta_L \frac{\bar{T}_{1m,h,t,j}}{\bar{T}_{1m,h,t,j} - \bar{T}_{1m,c,t,j}}$$

$\eta_L$ : Lorenz efficiency

- Comparison of 3 heat sources in 4 scenarios



Optimal HP capacities found by GAMS

## II. Key parameters

- Annual mean COP:

$$\text{COP}_{\text{avg}} = \frac{1}{n} \sum_{t=1}^{n=8760} \text{COP}_{\text{HP},t}$$

- Weighted annual system COP:

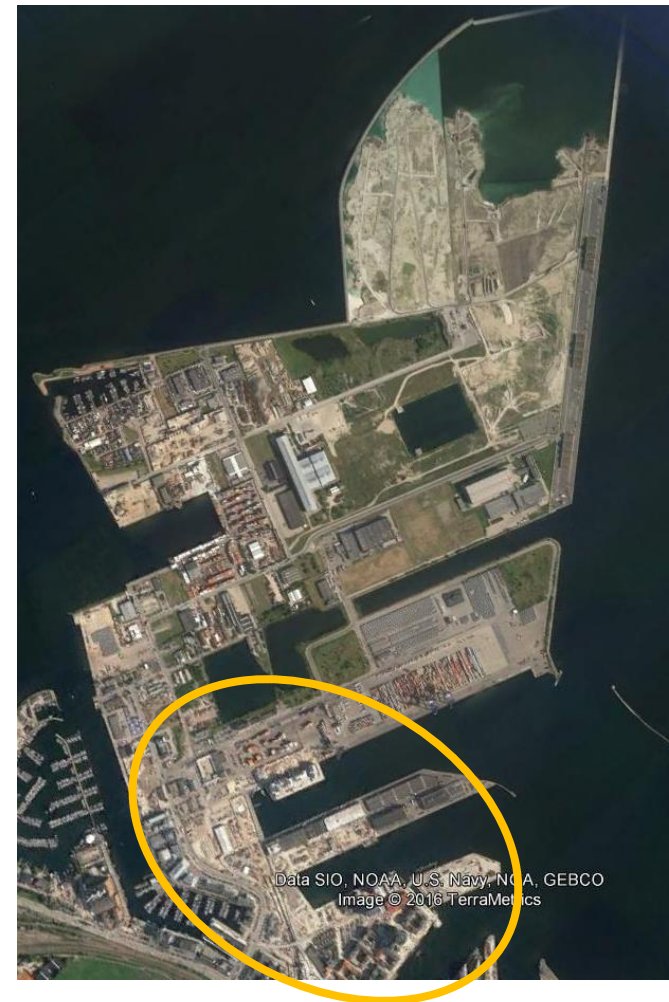
$$\text{COP}_{\text{Sys}} = \frac{\dot{Q}_{\text{sink,sys,tot}}}{P_{\text{sink,sys,tot}}}$$

- Full load hours [h]:

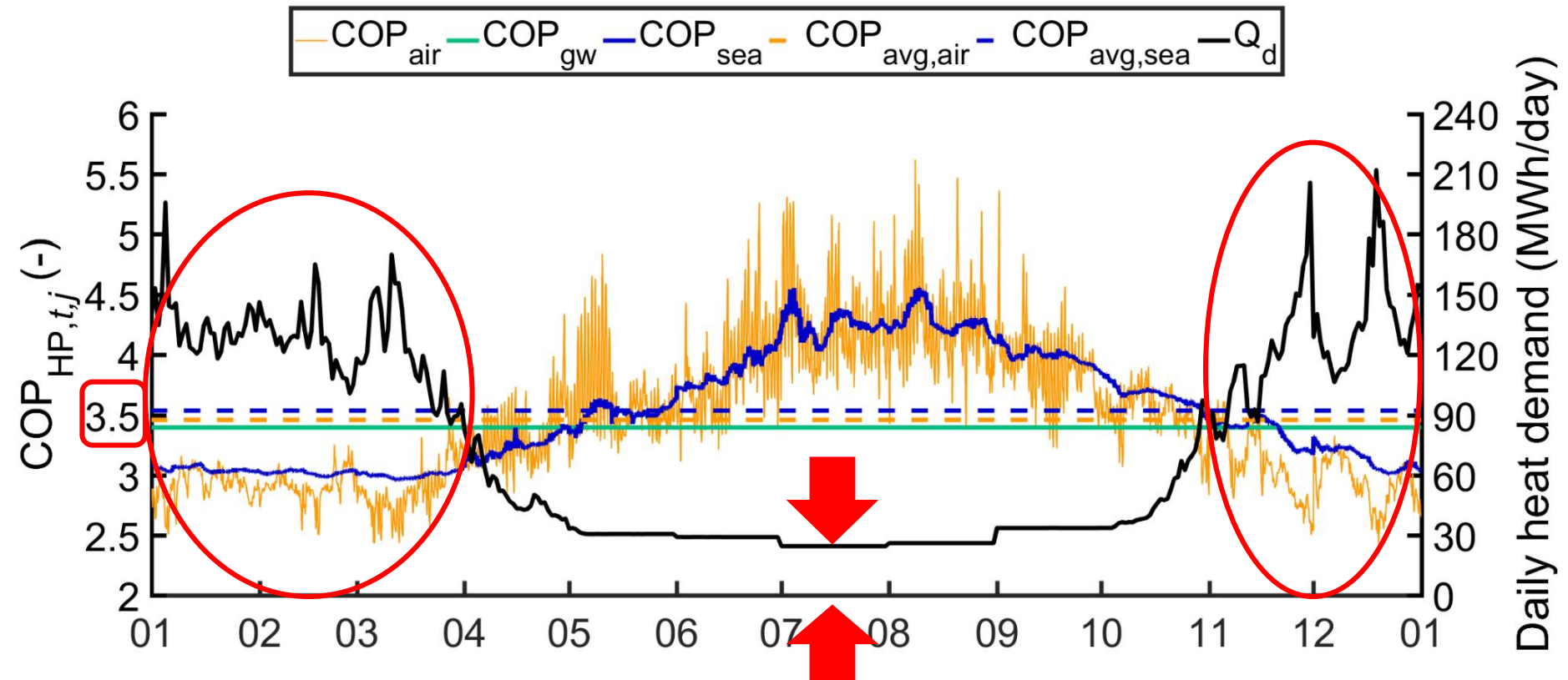
$$\text{FLH}_j = \sum_{t=1}^{n=8760} \frac{\dot{Q}_{\text{sink},t,j}}{\dot{Q}_{\text{sink},d,j}}$$

## II. Case description: Nordhavn

- Large development district in Europe
- [www.energylabnordhavn.dk](http://www.energylabnordhavn.dk)
- For this study:
  - Inner Nordhavn: 670,000 m<sup>2</sup>
  - New residential buildings
  - Space heating: 18 kWh/m<sup>2</sup>/yr
  - Domestic hot water: 16 kWh/m<sup>2</sup>/yr
  - Peak demand: 12.4 MWh/h
- 2 cases:
  - *No base load (& Base load)*
    - Total capacity: 80% of peak demand
    - 15 MWh storage
    - Peak boiler when needed



### III. COP and heat demand





# III. Key parameters

1 MW/7 MW/2 MW

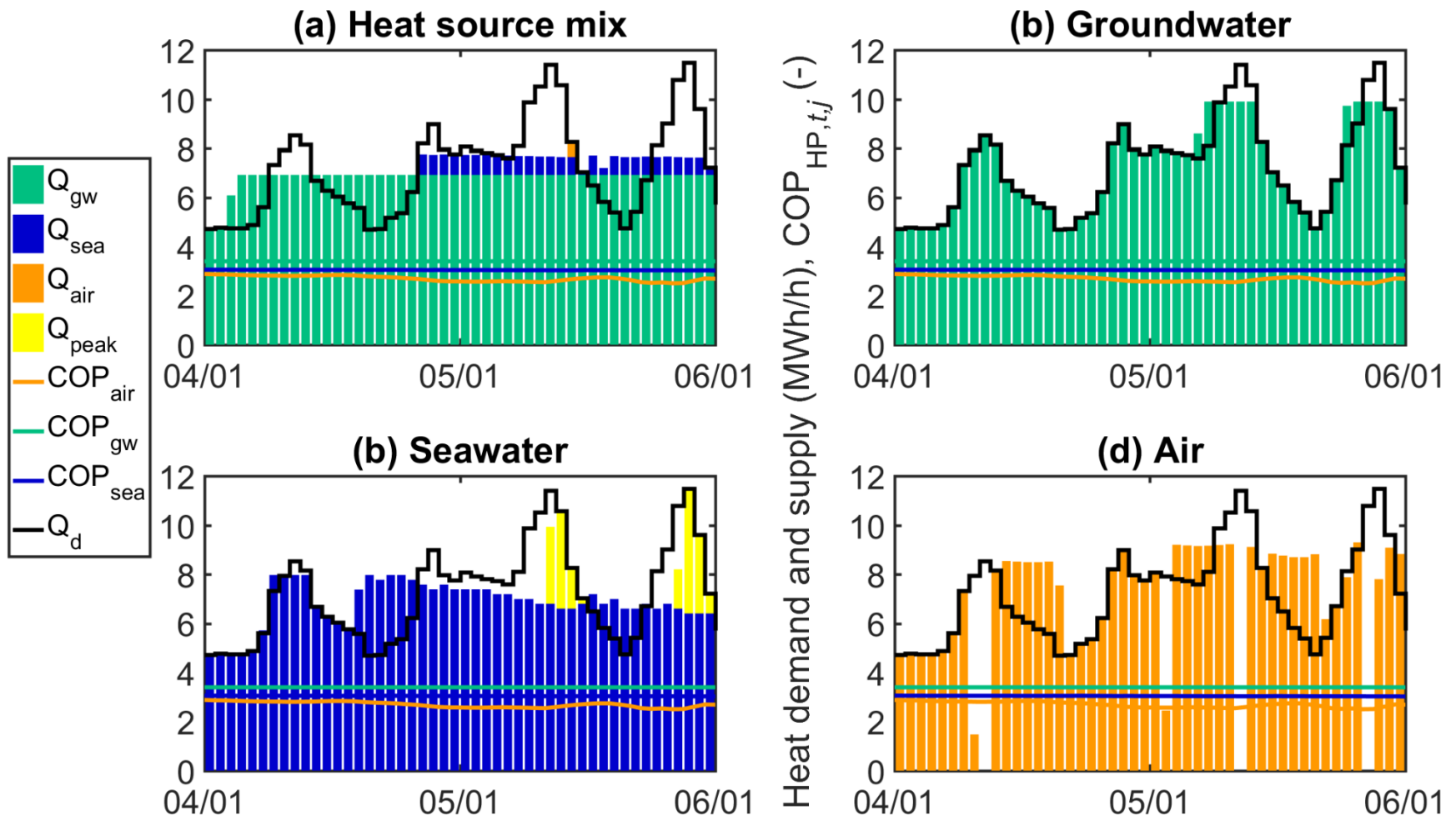
Parameters	Unit	Seawater	Groundwater	Air	Heat source mix: Sea/GW/Air
<i>no base load case</i>					Shares: 9%/56%/15%
Average COP <sub>avg</sub>	(-)	3.54	> 3.40	< 3.46	3.43
Weighted COP <sub>sys</sub>	(-)	2.90	< 3.40	> 3.12	3.50
Full load hours HP	(h)	2576	2704	2710	3214/2893/1736

-18%

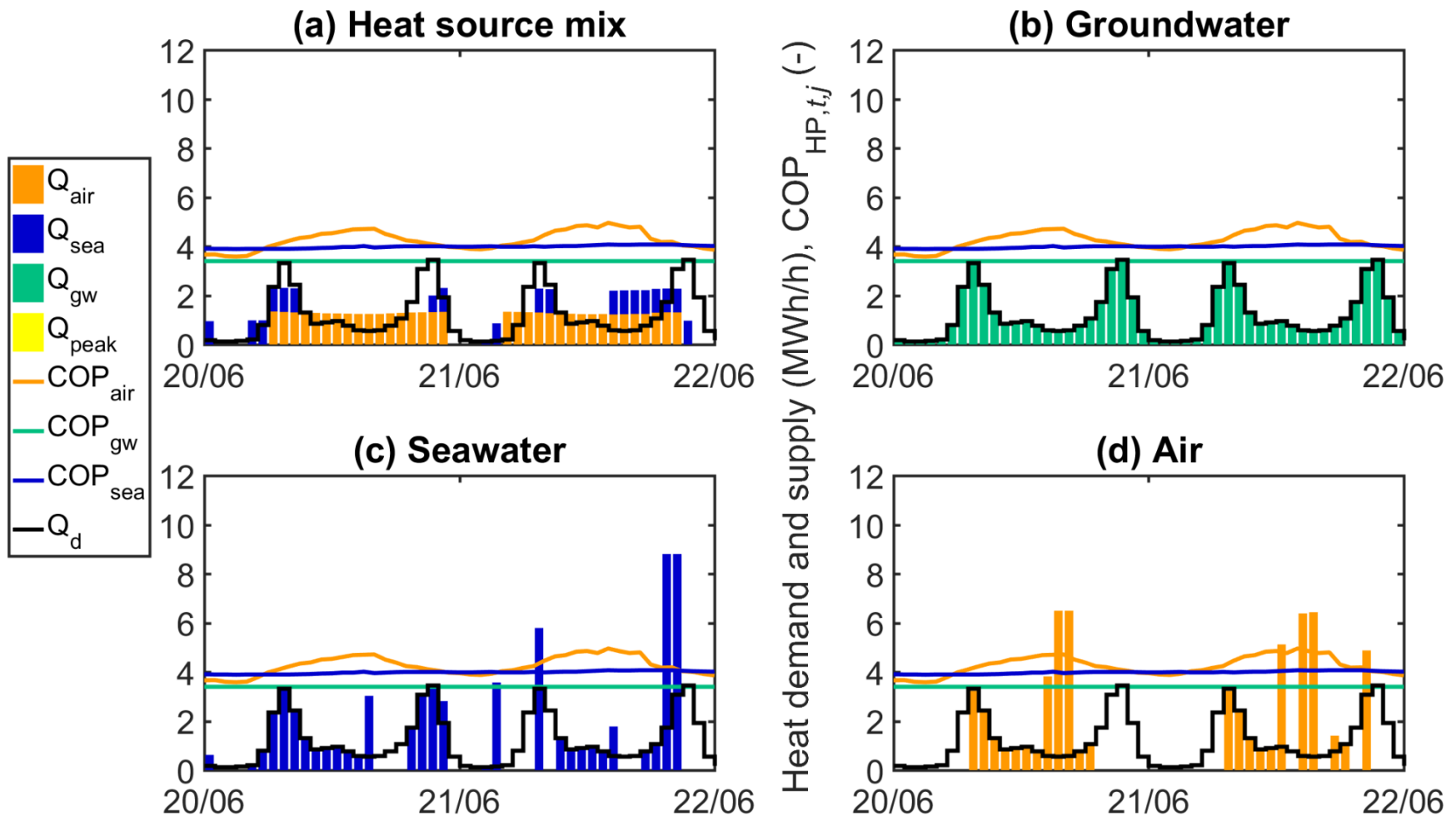
7 MW peak boiler capacity

COP: +3%

### III. Winter: *no base load case*

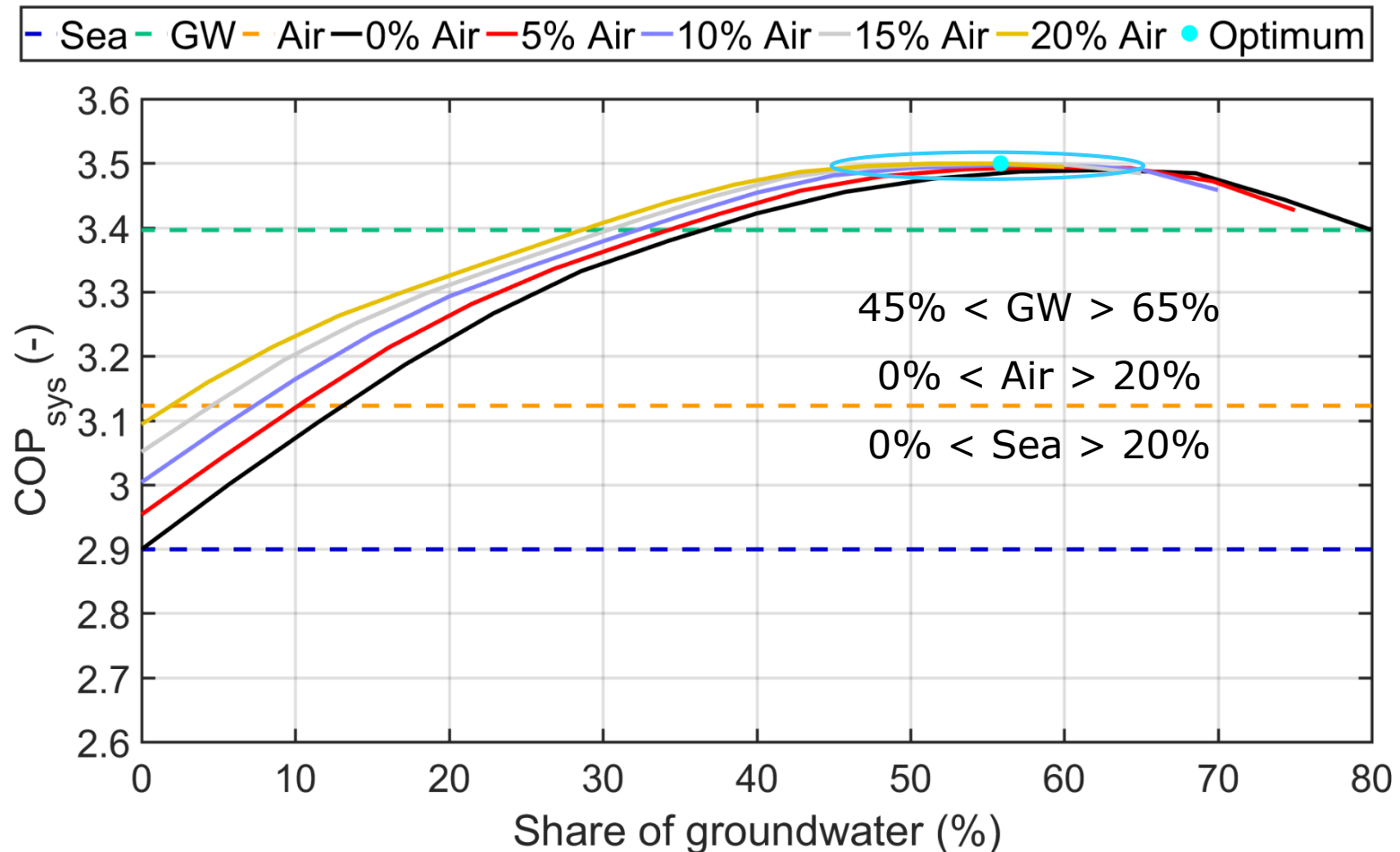


### III. Summer: *no base load case*



# III. Variation of heat source capacity shares

*no base load case*



## IV. Discussion

Model limitations:

- No auxiliary electricity consumption
- No investment costs
- Constant Lorenz efficiency
- No minimum HP operation level
- Constant electricity price
- Limited to groundwater, seawater and air
- No cooling demand

## V. Conclusion

- COP of seawater and air varies a lot
  - Fixed annual COP not recommended without heat demand
  - Weighted COP identified true performance & ranking of heat sources
- High peak unit capacity required for seawater HP
- HPs with combination of heat sources
  - perform better than HP with single heat source
  - utilize heat sources and capacity more effectively
- Recommended range of HP capacities based on peak demand

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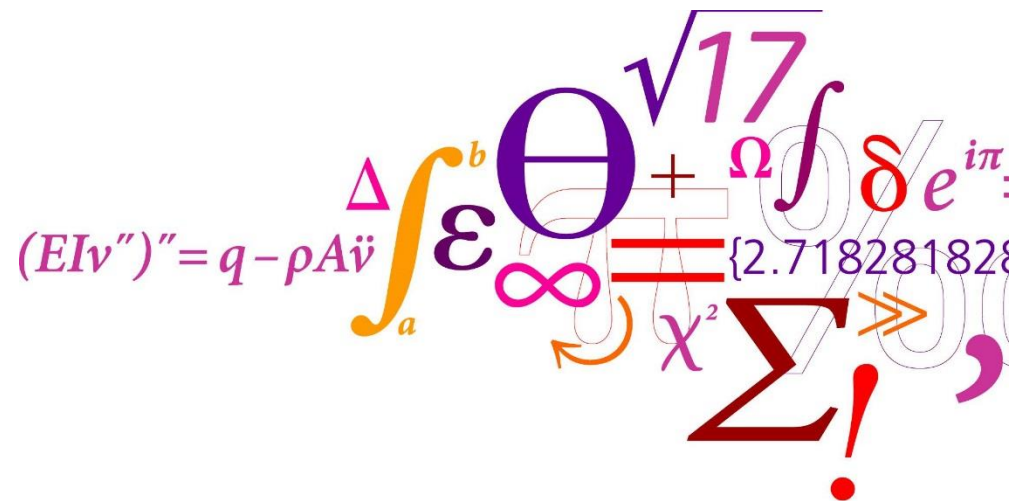
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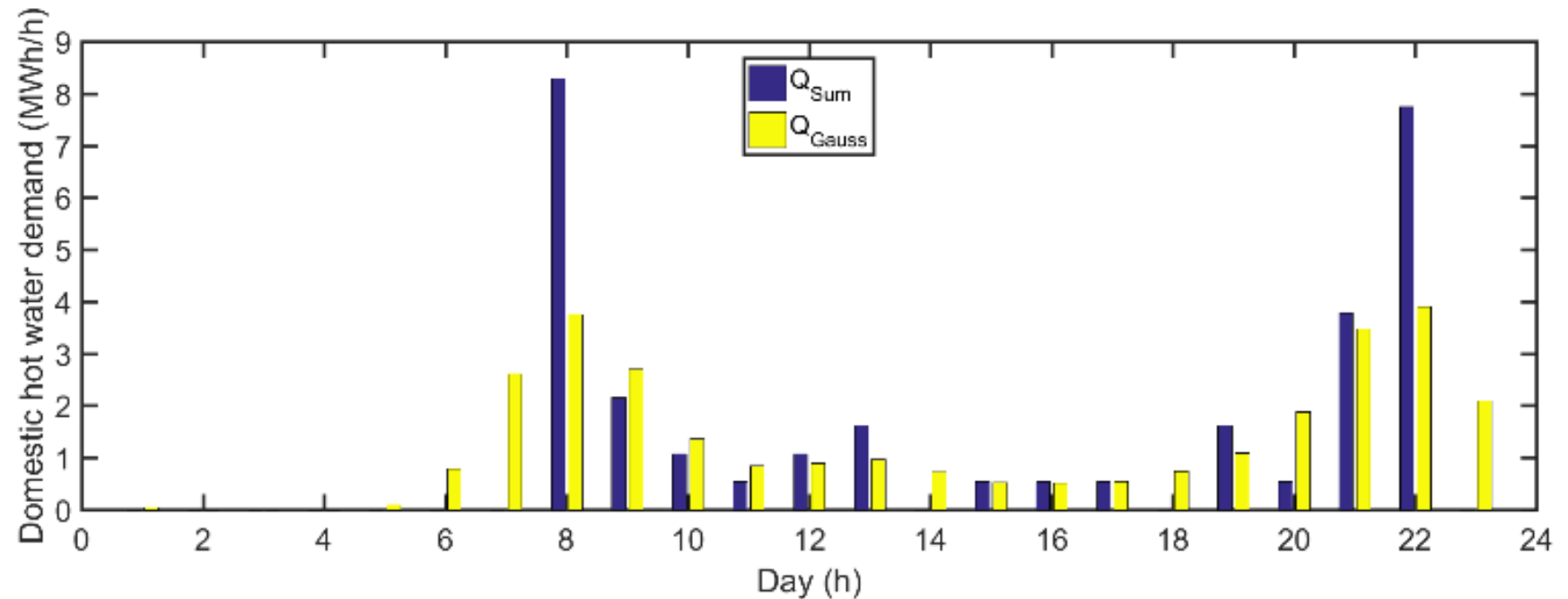
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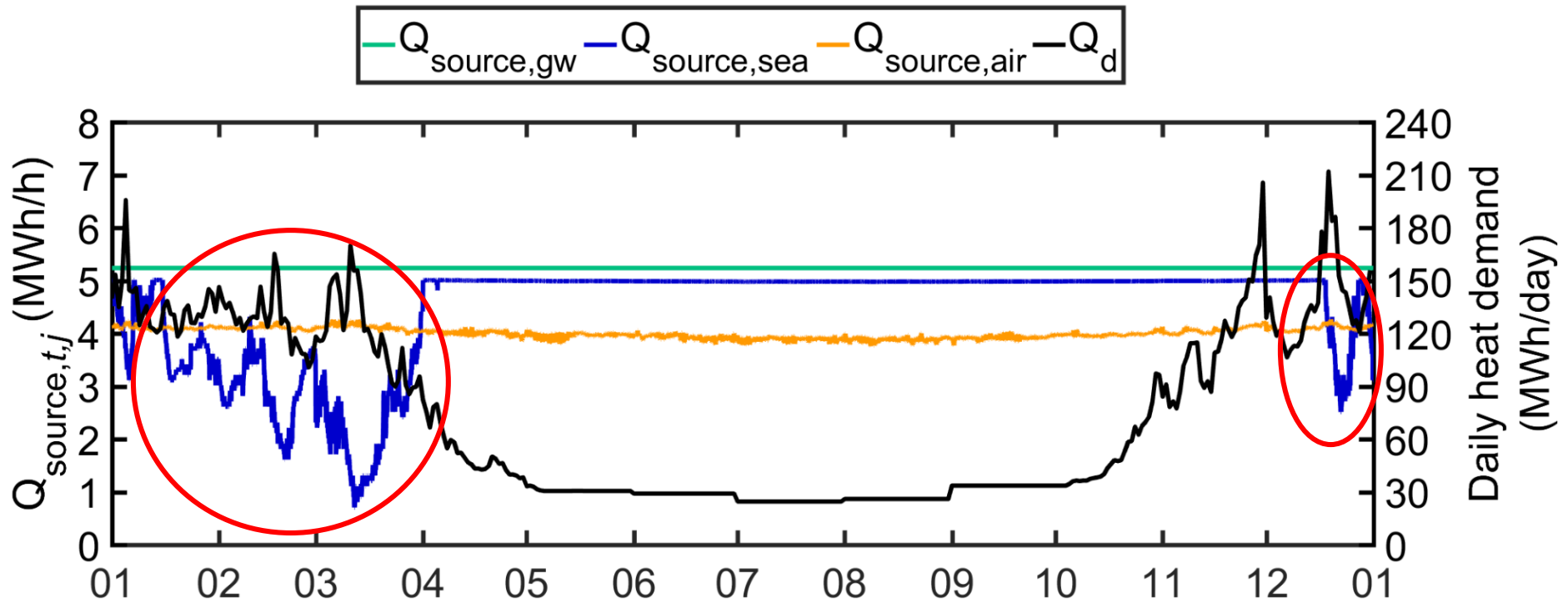


## II. DHW + SH demand profile

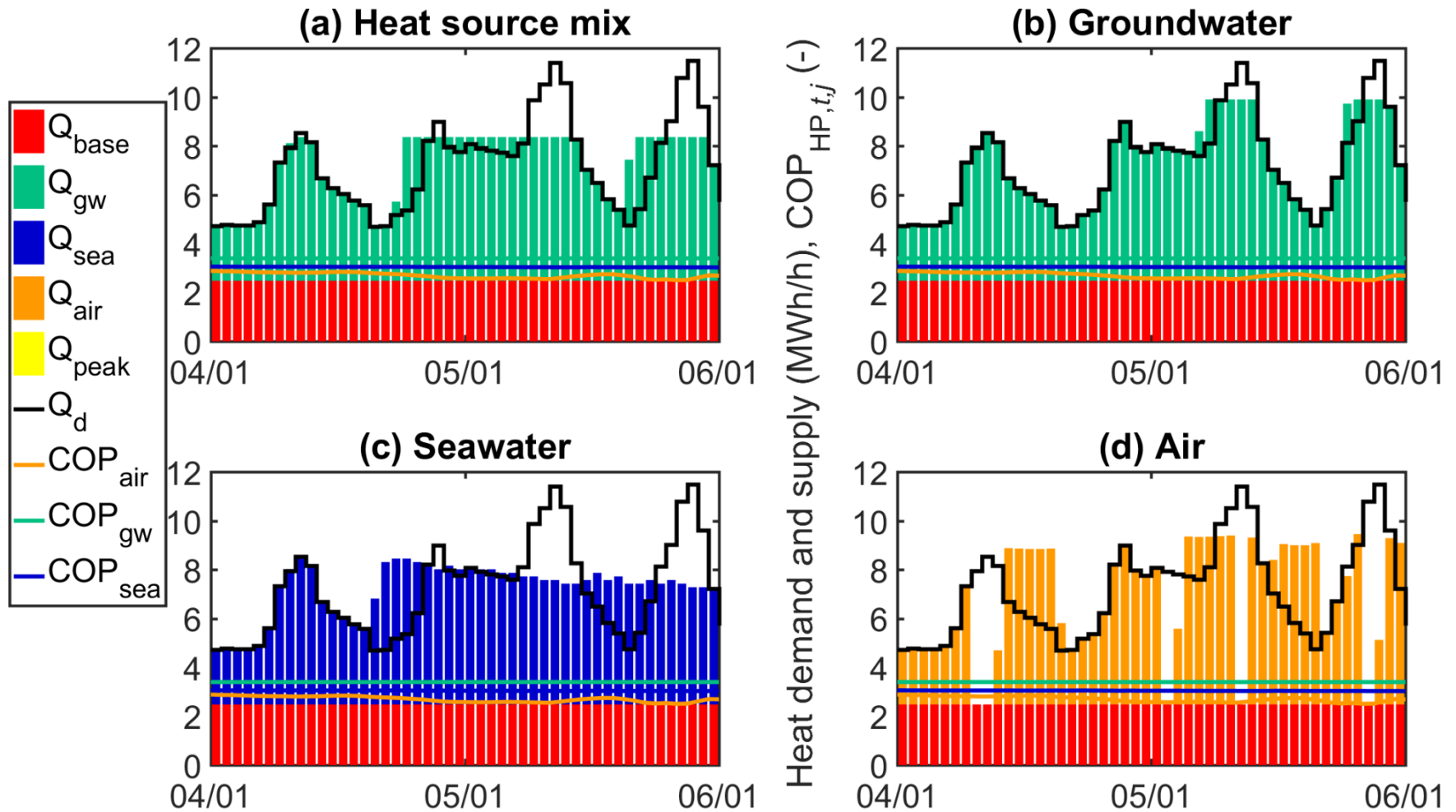




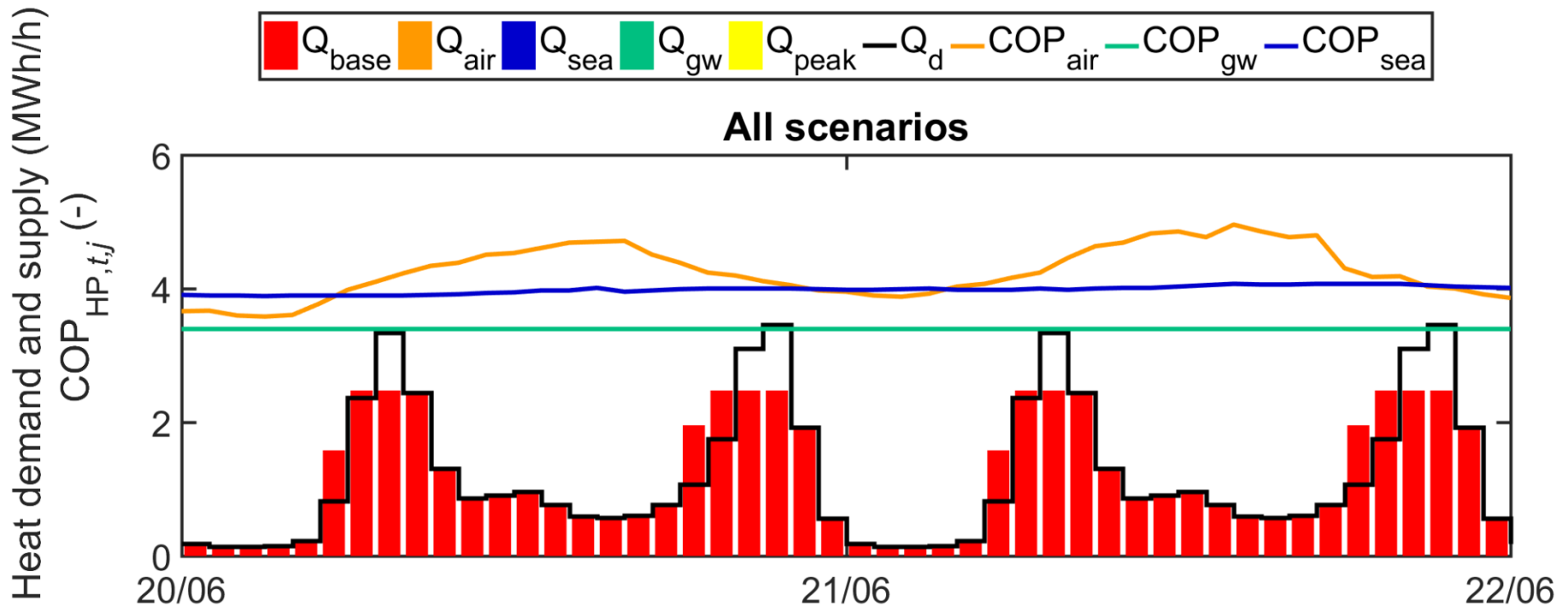
### III. Available heat source capacities



### III. Winter: *base load case*

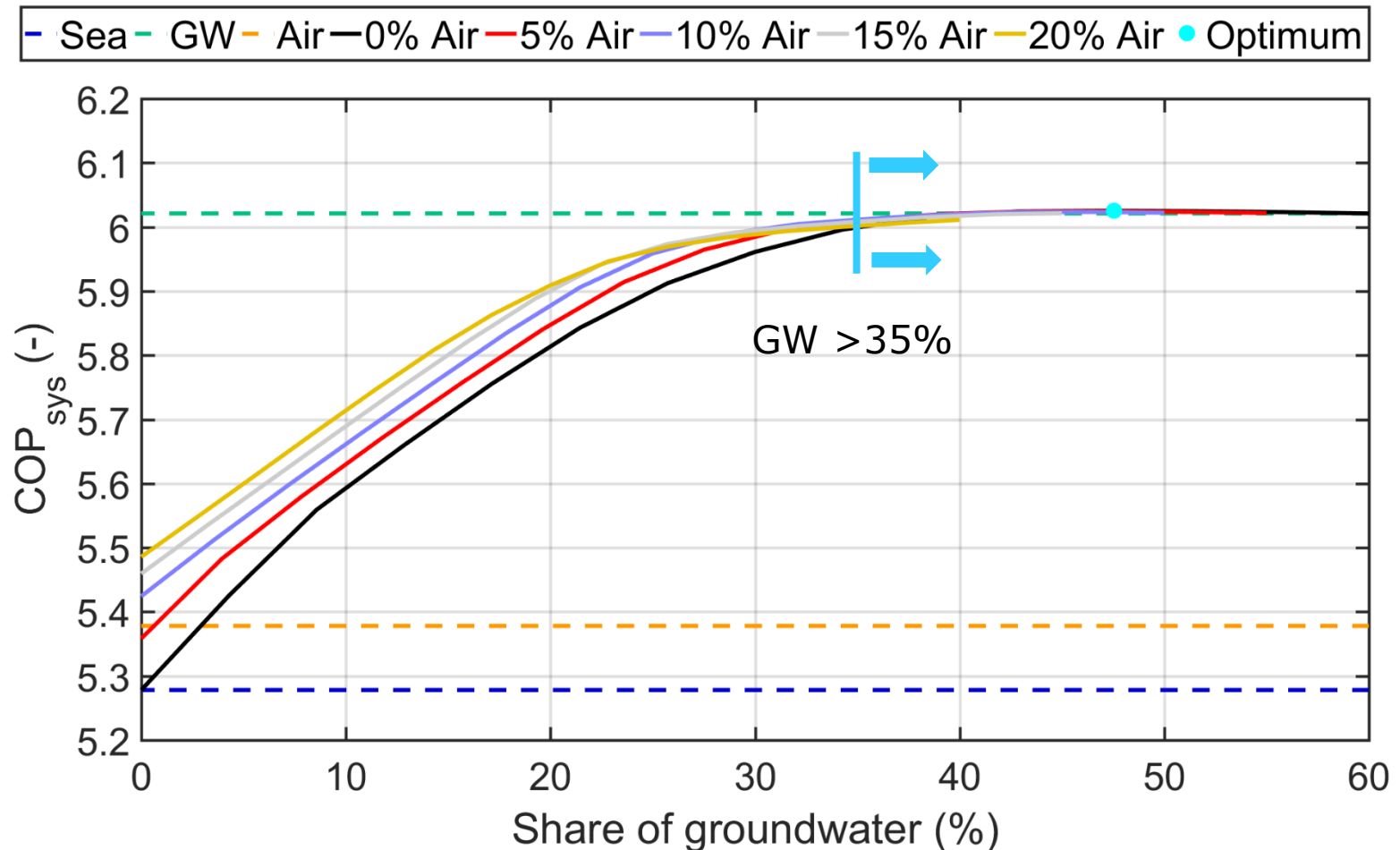


### III. Summer: *base load case*



# III. Variation of heat source capacity shares

*base load case*



# III. Key parameters

Parameters	Unit	Seawater	Groundwater	Air	All heat sources: Sea/GW/Air
		<b>-12%</b>	<i>base load case</i>		Shares: 12%/48%/0.0%
Average COP <sub>avg</sub>	(-)	3.54	3.40	3.46	3.43 <b>-16%</b>
Weighted COP <sub>HP,w</sub>	(-)	3.10	3.40	2.90	3.40
Weighted COP <sub>Sys</sub>	(-)	5.28	6.02	5.38	6.03
Full load hours HP	(h)	1358	1414	1417	446/1668/0
			<i>no base load case</i>		Shares: 9%/56%/15%
Average COP <sub>avg</sub>	(-)	3.54	3.40	3.46	3.43 <b>-10%</b>
Weighted COP <sub>HP,w</sub>	(-)	3.27	3.40	3.12	3.50
Weighted COP <sub>Sys</sub>	(-)	2.90	3.40	3.12	3.50
Full load hours HP	(h)	2576	2704	2710	3214/2893/1736

7 MW peak boiler capacity

-18%

-8%

COP: +3%

FLH for no base case 90% higher