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Joint Research Centre

The joint effect of centralized CHP plants and thermal storage on the flexibility of the power system

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European Commission

Background

- ✓ Heating and cooling sector has become a priority to decarbonise the European energy sector in the coming years.
- ✓ To facilitate the penetration of renewable energy sources, holistic approach is required, integrating the Heating and Cooling sector.
- ✓ Heating and cooling sector offers cheap storage solutions compared with electricity storage options.
- ✓ Coupling of heating and electricity sector could be achieved by centralised cogeneration plants connected to district heat networks.
- ✓ Heating and Cooling Strategy COM(2016) 51

  "Combination with thermal storage increases the efficiency of CHP as heat production can be stored rather than curtailed if not needed at that moment"

- ✓ Energy efficiency directive 2012/27/EU

  "High-efficiency cogeneration and district heating and cooling has significant potential for saving primary energy, which is largely untapped in the Union"

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Research question

What is the effect on:

- System costs
- System efficiency
- Integration of renewables

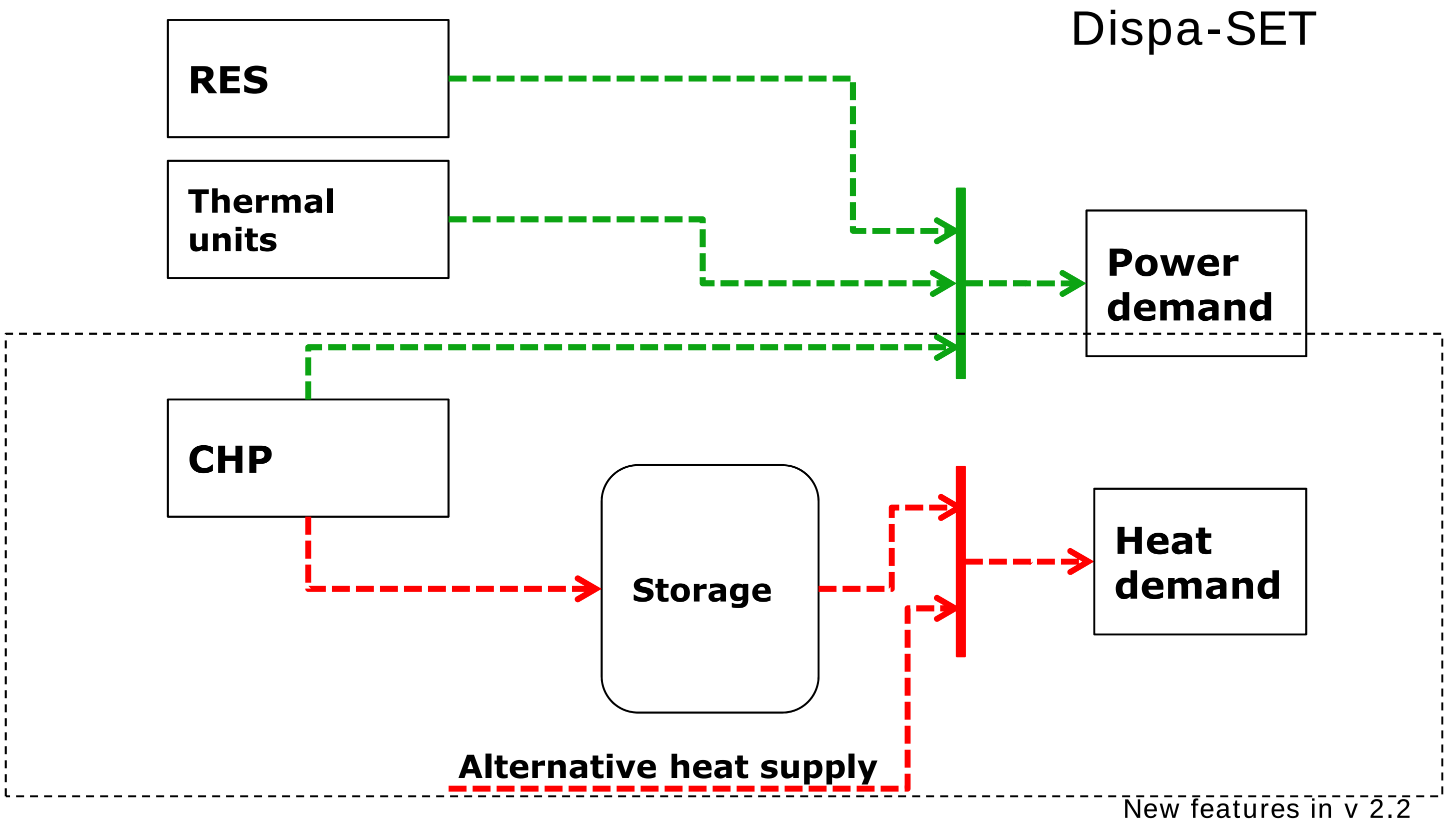
of an increased share of centralized CHP plants on a power system?

Goal

- Development of a method to optimise and analyse the operation of cogeneration plants combined with thermal storage in the power system.
- Application in a real energy system in which different scenarios are tested to assess the impact of the heating-electricity coupling in the efficiency and costs of the power systems and the energy system as a whole.
- High and low temperatures district heating systems are also investigated.

Methods. Model background

Dispa-SET model. Economic co-optimisation of power and heat on the systems



[1]Quoilin S, Hidalgo González I, Zucker A. Modelling Future EU Power Systems Under High Shares of Renewables. The Dispa-SET 2.1 open-source model. 2017. doi:10.2760/25400.

Methods. CHP plant model

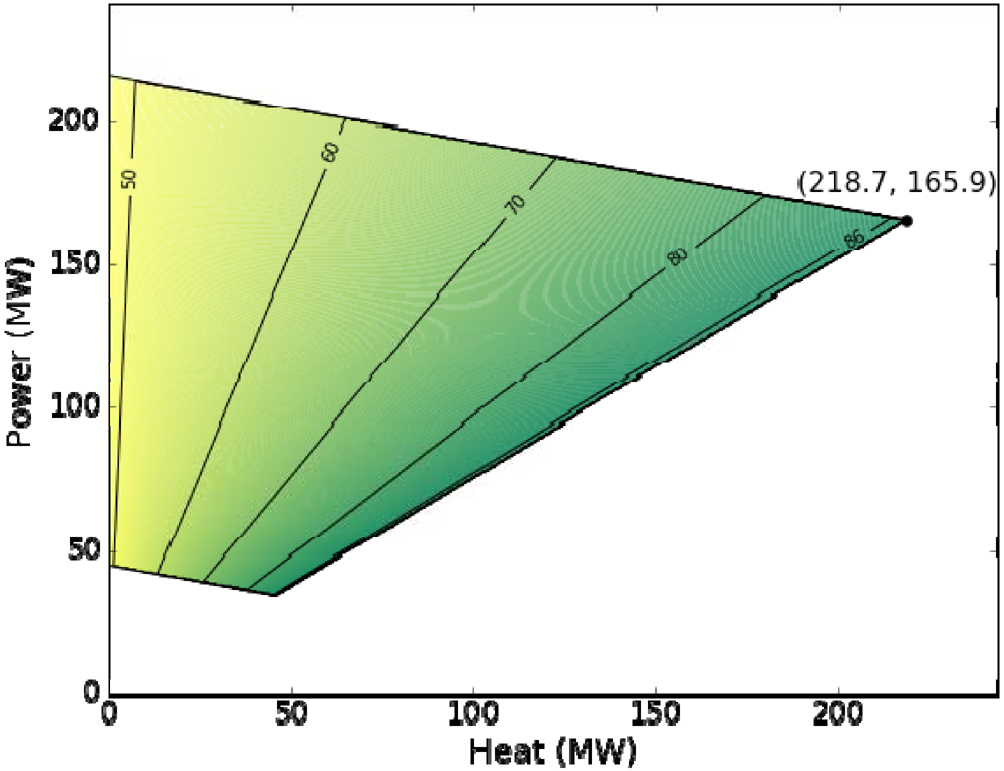
2 designs:

- **Back pressure units**
- **Extraction condensing units**

4-parameters CHP model;

- **σ ≡ back pressure ratio**
- **β ≡ power-to-heat ratio**
- **P_{max} ≡ Maximum output power**
- **P_{min} ≡ Minimum output power**

Feasible operation region



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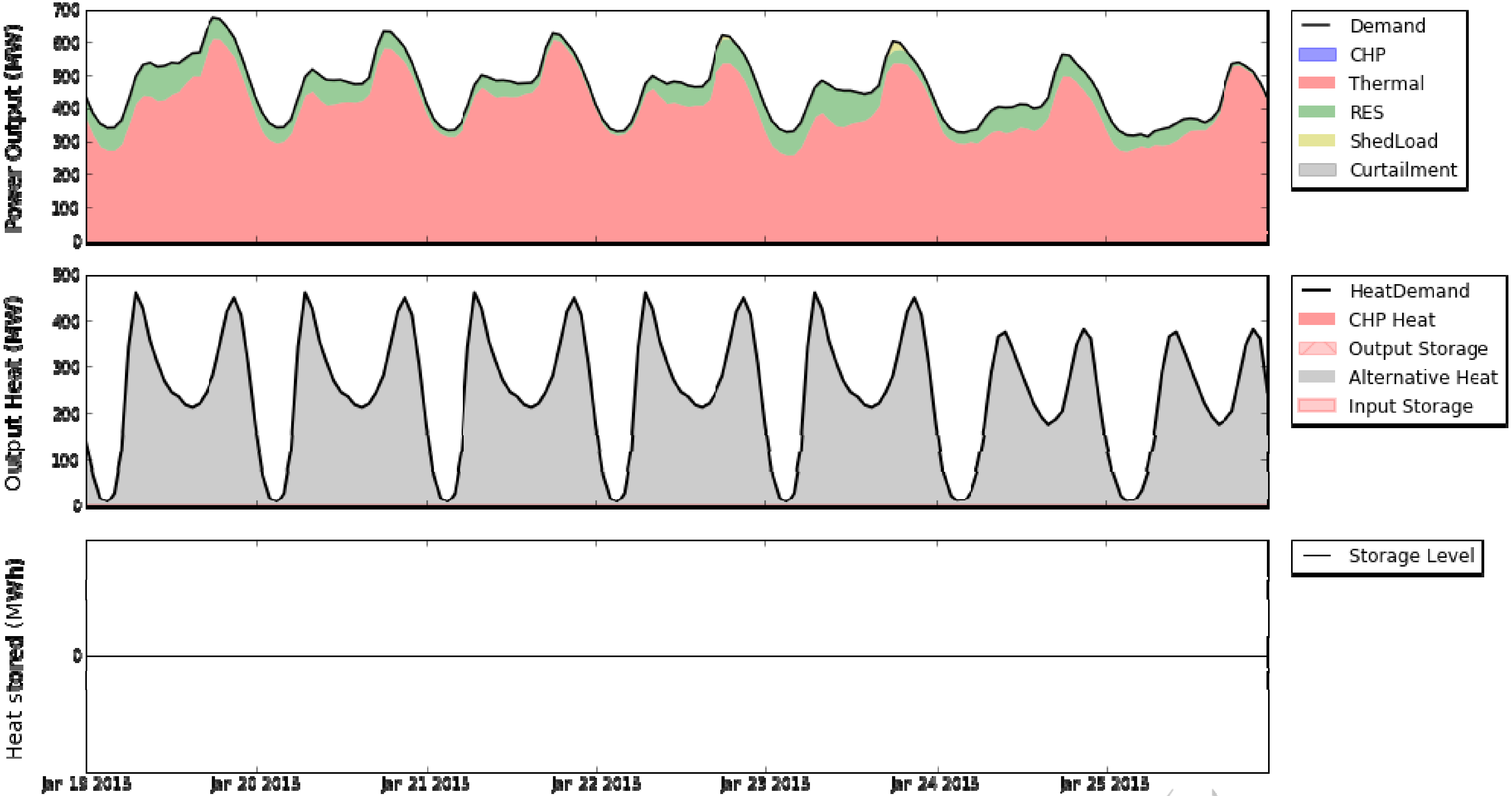
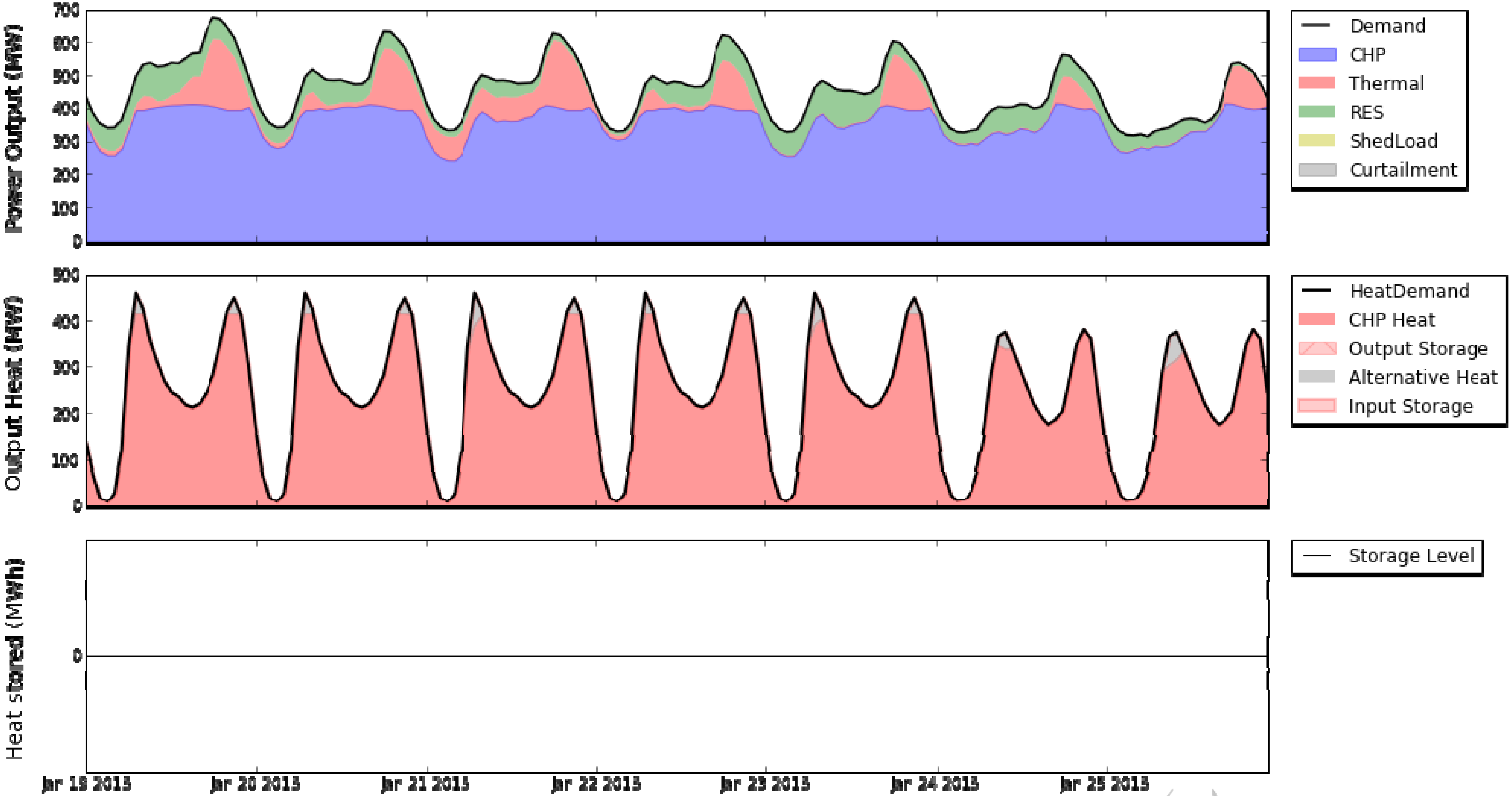
Methods. Model dispatch

No CHP



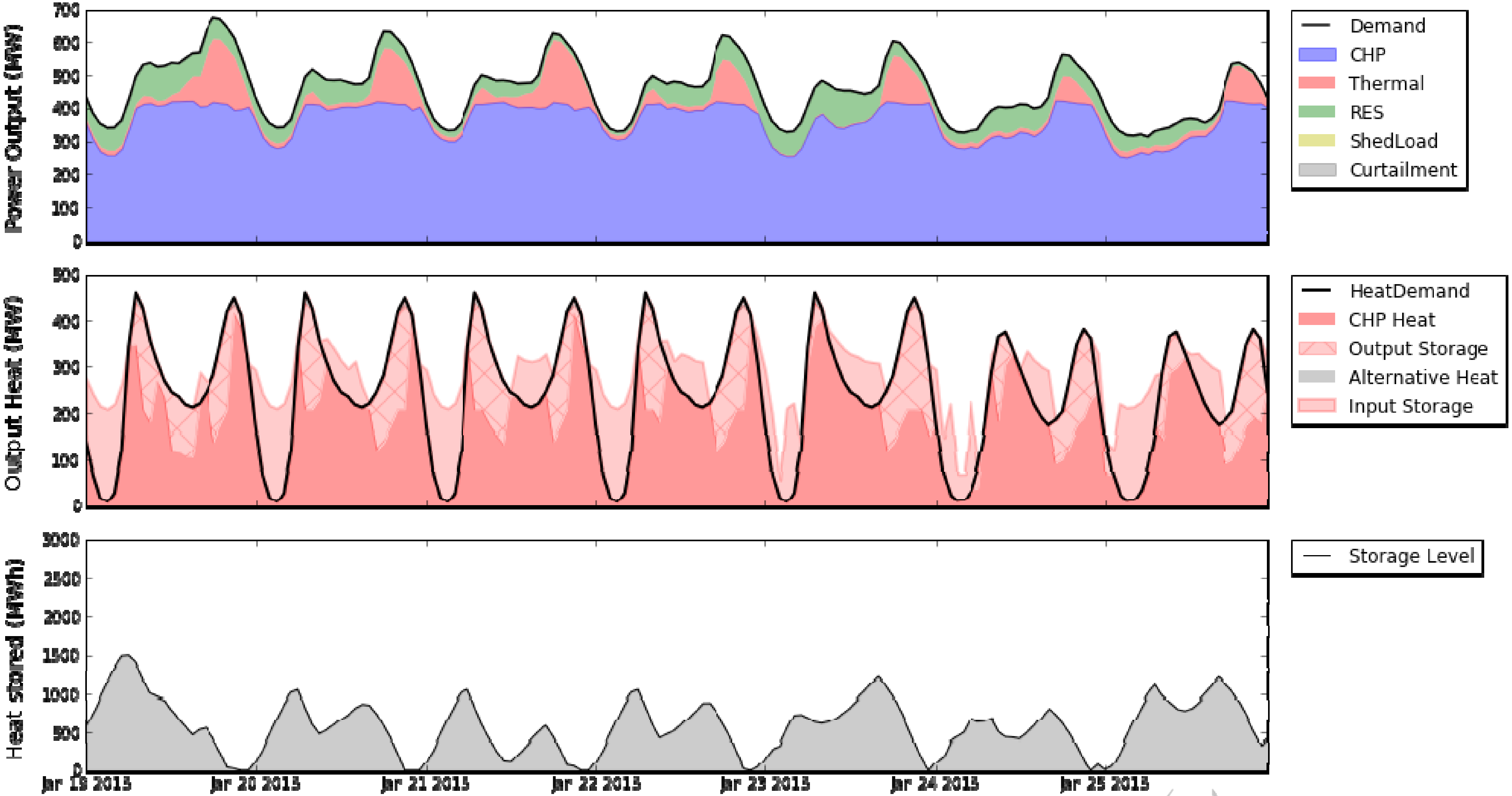
Methods. Model dispatch

CHP



Methods. Model dispatch

CHP + Thermal Storage



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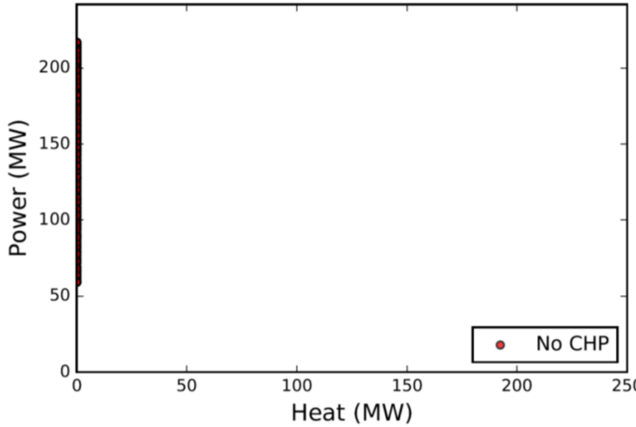
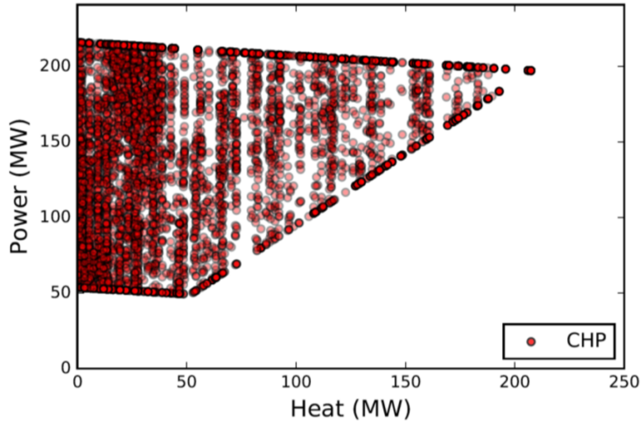
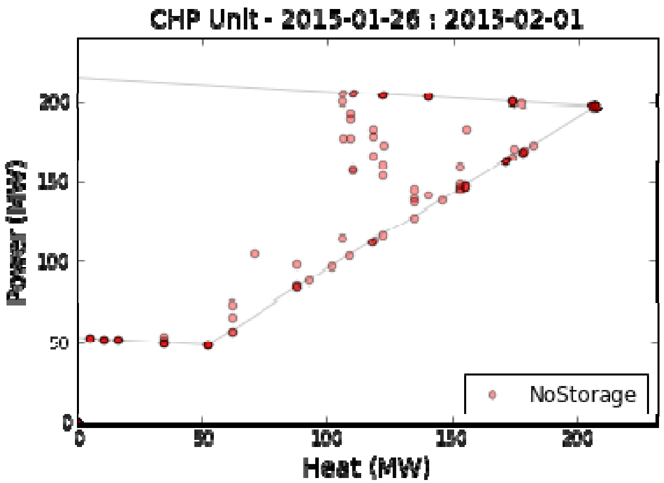
Methods. CHP operation

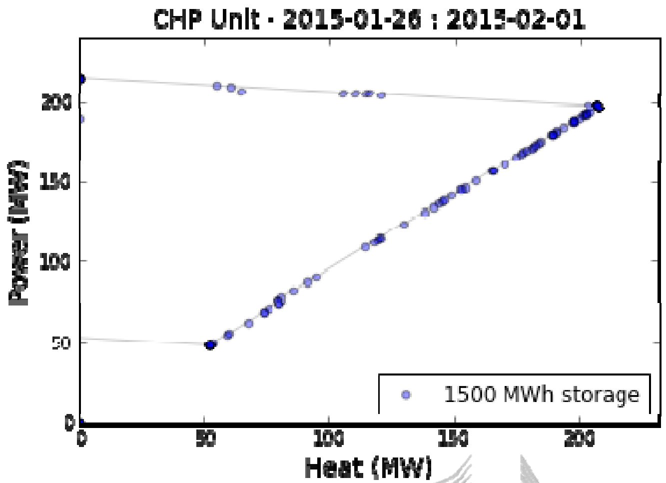
No CHP vs. CHP





CHP without storage vs. CHP with storage





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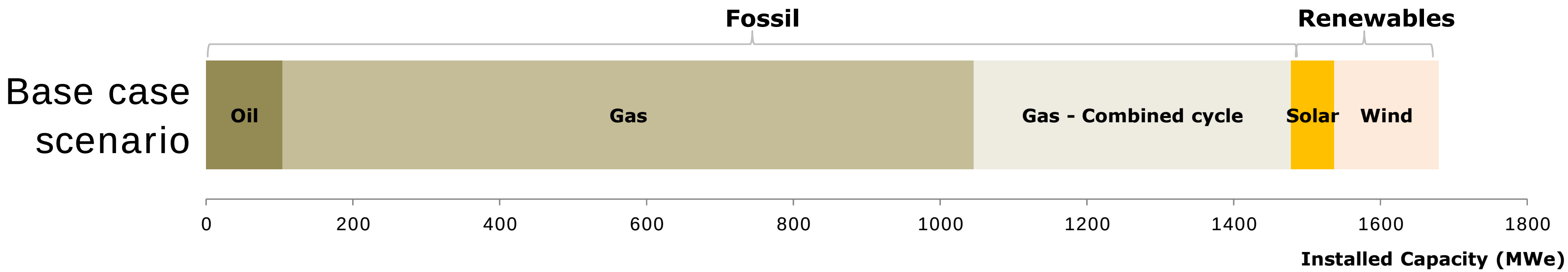
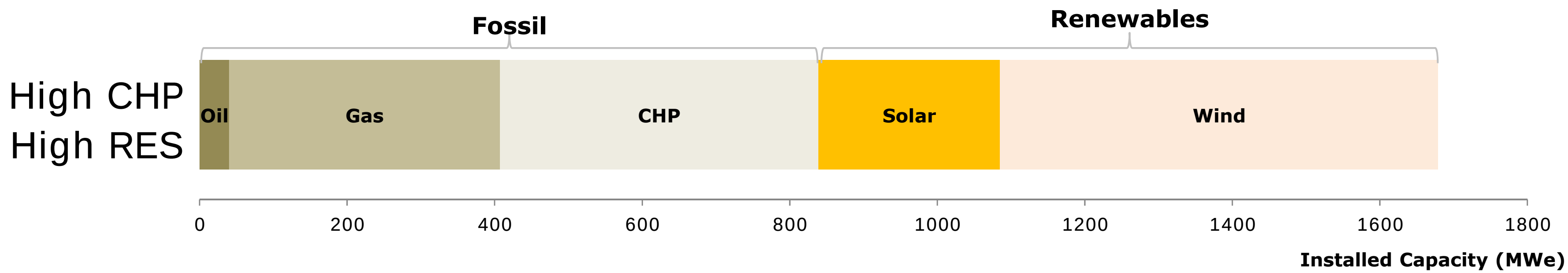
Case study

Small Mediterranean power system





Range of Scenarios

Share of RES *(% of total capacity)*		Share of CHP *(% of total capacity)*			Storage level *(MWh)*[a]		
Low	High	Low	Medium	High	Low	Medium	High
12%	50%	-	13%	26%	-	1,500	3,000

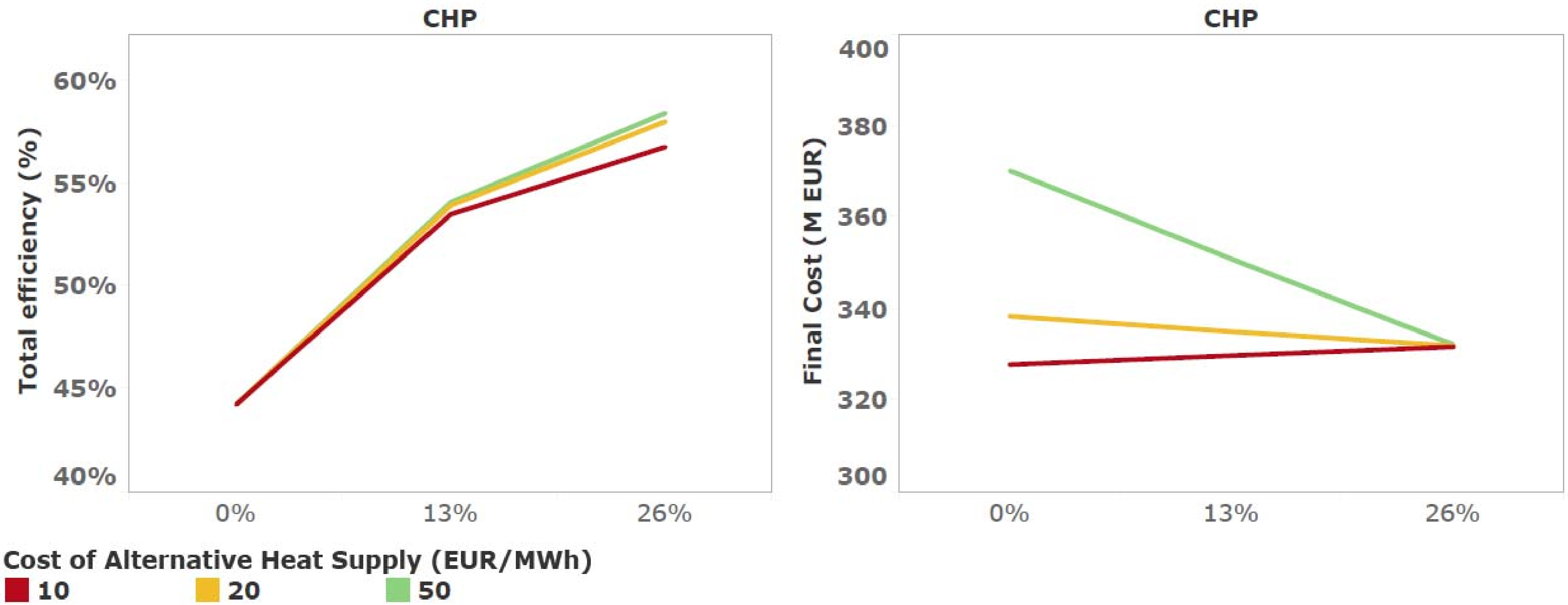
Parametric analysis

AHS prices *(€/MWh)*			Temperature of extraction *(˚C)*[a]	
Low	Medium	High	Low	High
10	20	50	60	120

Total cases assessed: 435

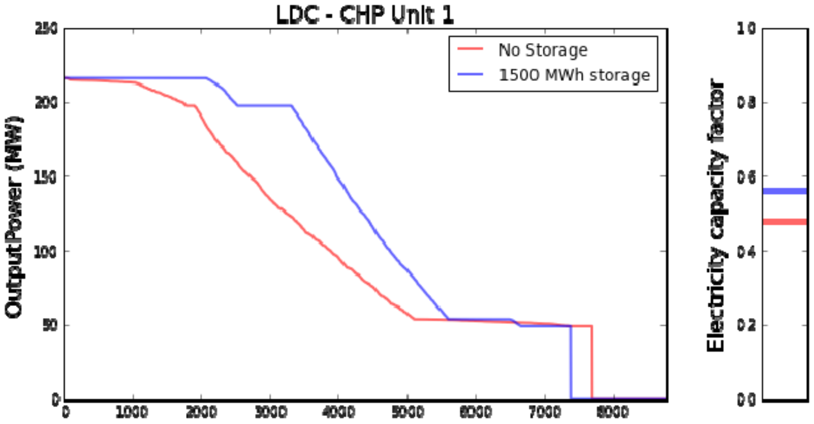
Results. The effect of CHP

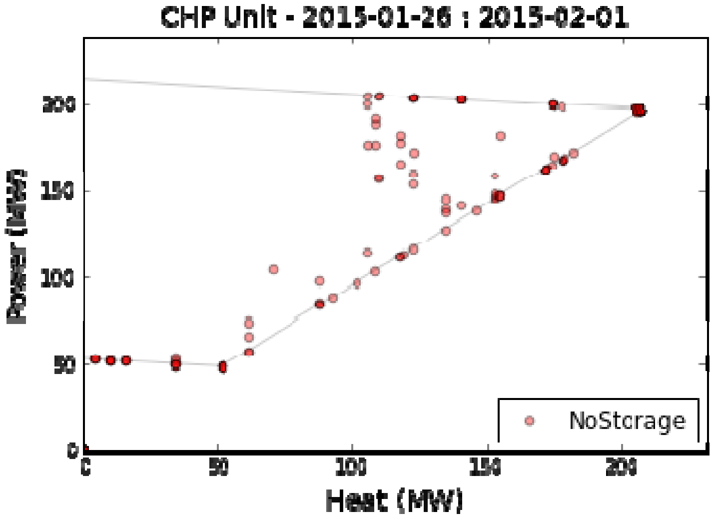
The conversion of CCGT into CHP lead to an increase of the system efficiency and a reduction of costs when high alternative heat supply costs.

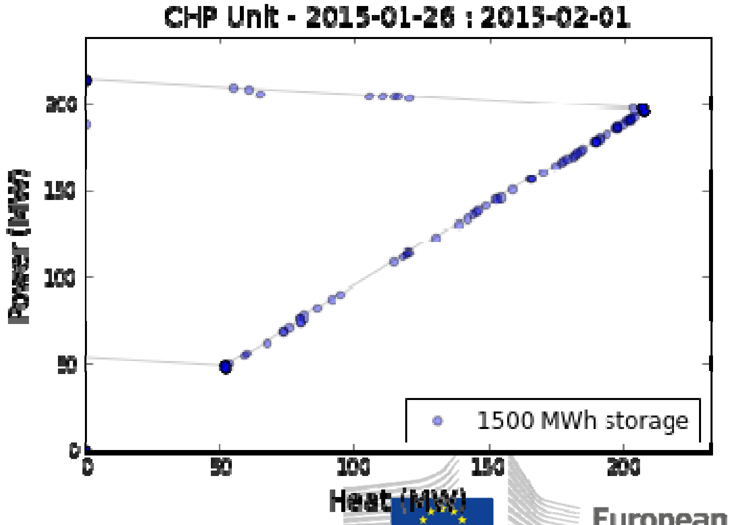


Results. The effect of thermal storage

- Heat storage leads to higher capacity factor and more efficient operation







Results. The effect of thermal storage

- Thermal storage slightly improves efficiency or cost of the system

- Storage mainly reduces curtailment for high RES scenarios

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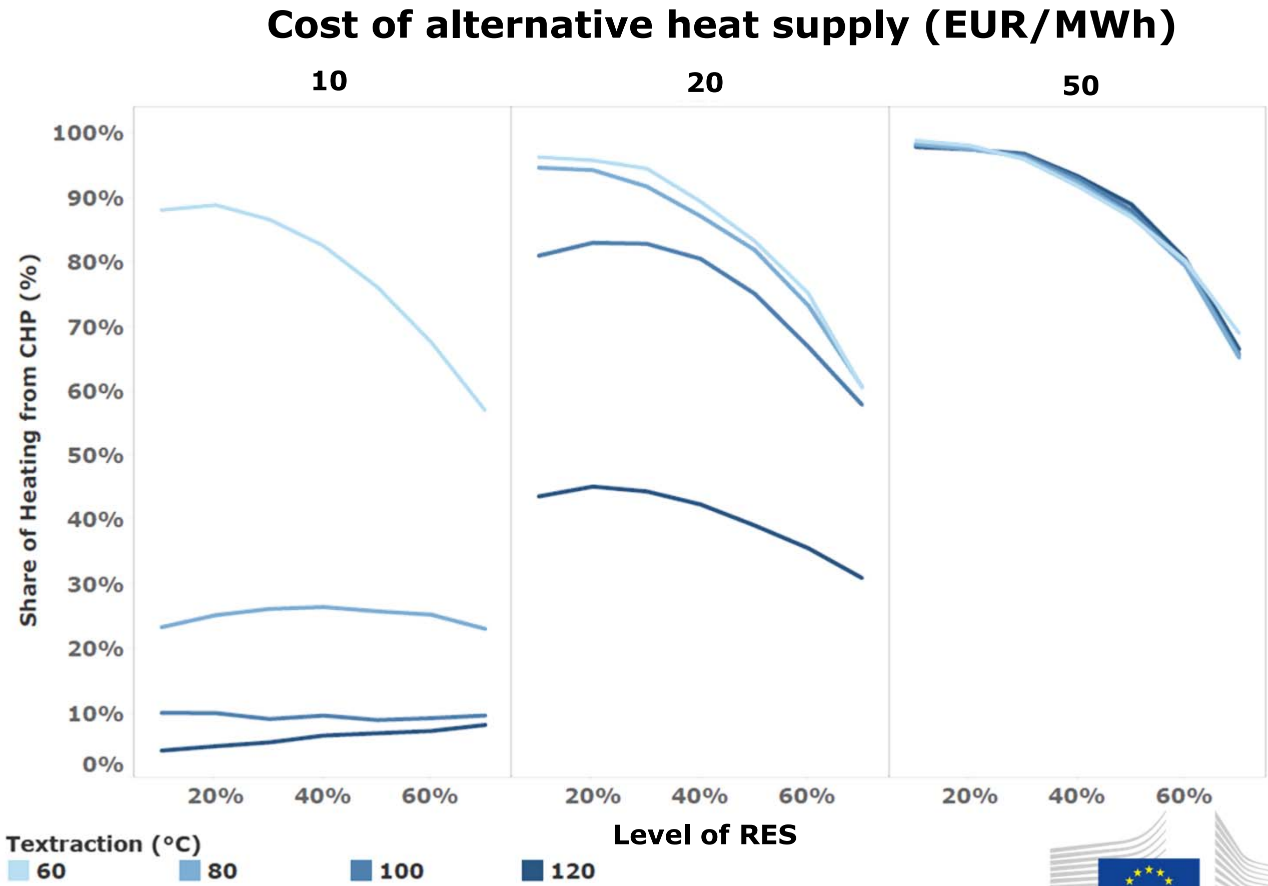
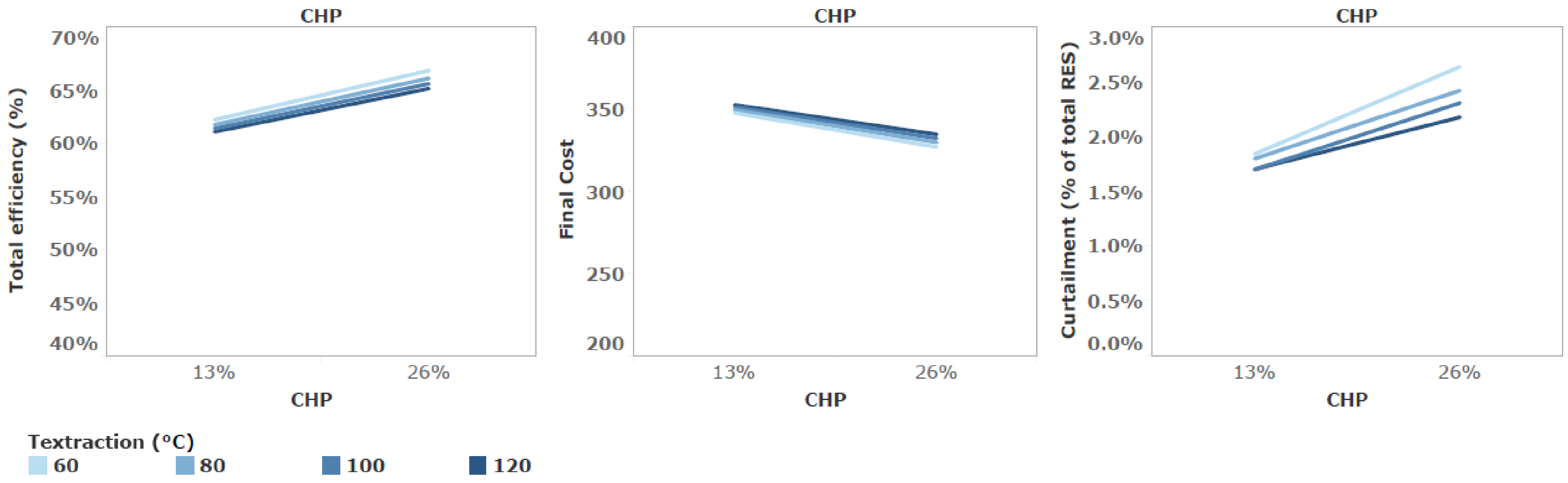
Results. The effect of temperature of heat extraction

Lower temperatures make CHP the optimal solution even when the alternative heat supply options are cheap

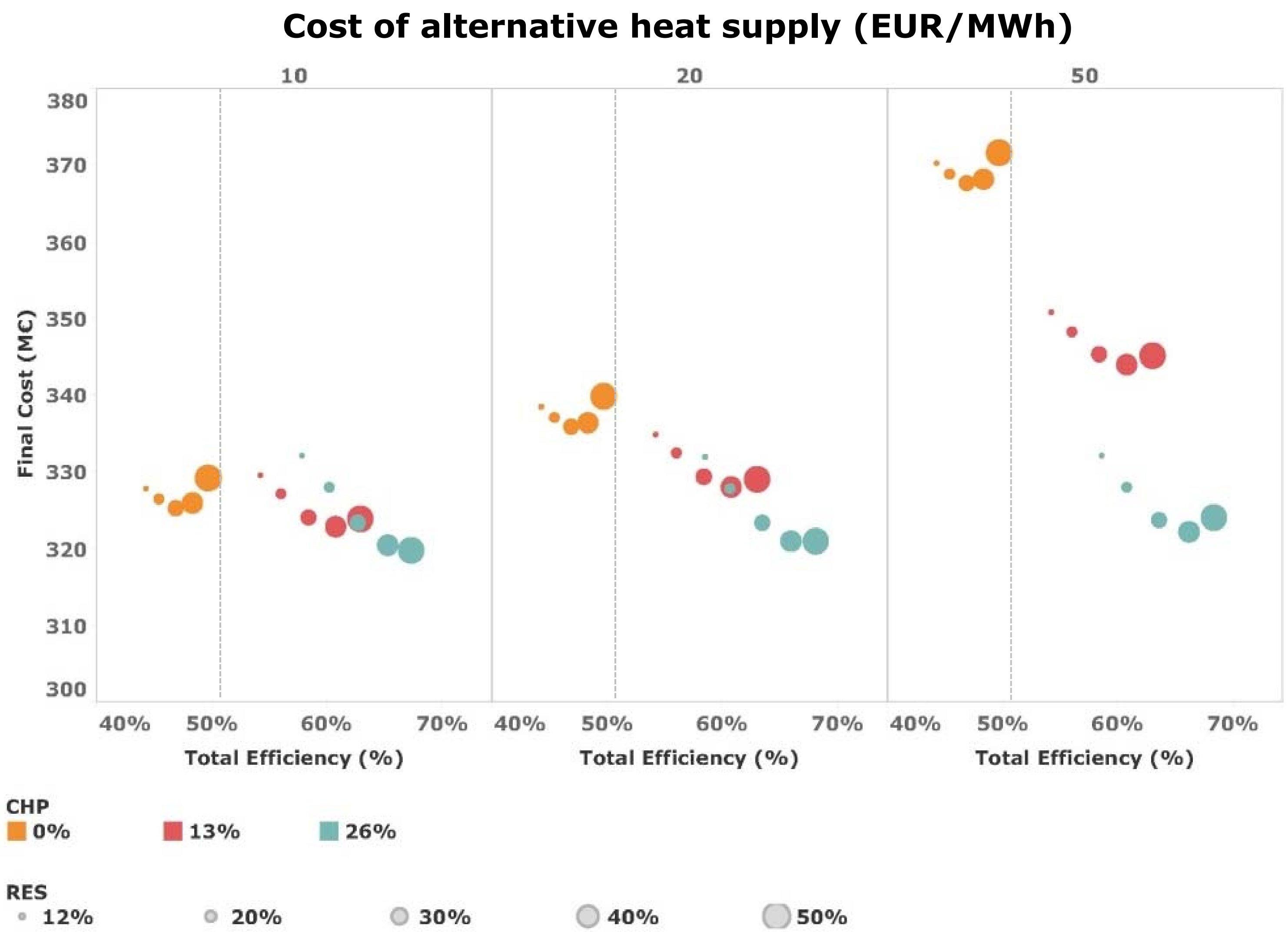


Results. The effect of temperature of heat extraction

- Low temperatures of heat extraction leads to higher efficiencies and lower costs
- Low temperatures of heat extraction leads to high curtailed energy for high RES scenarios

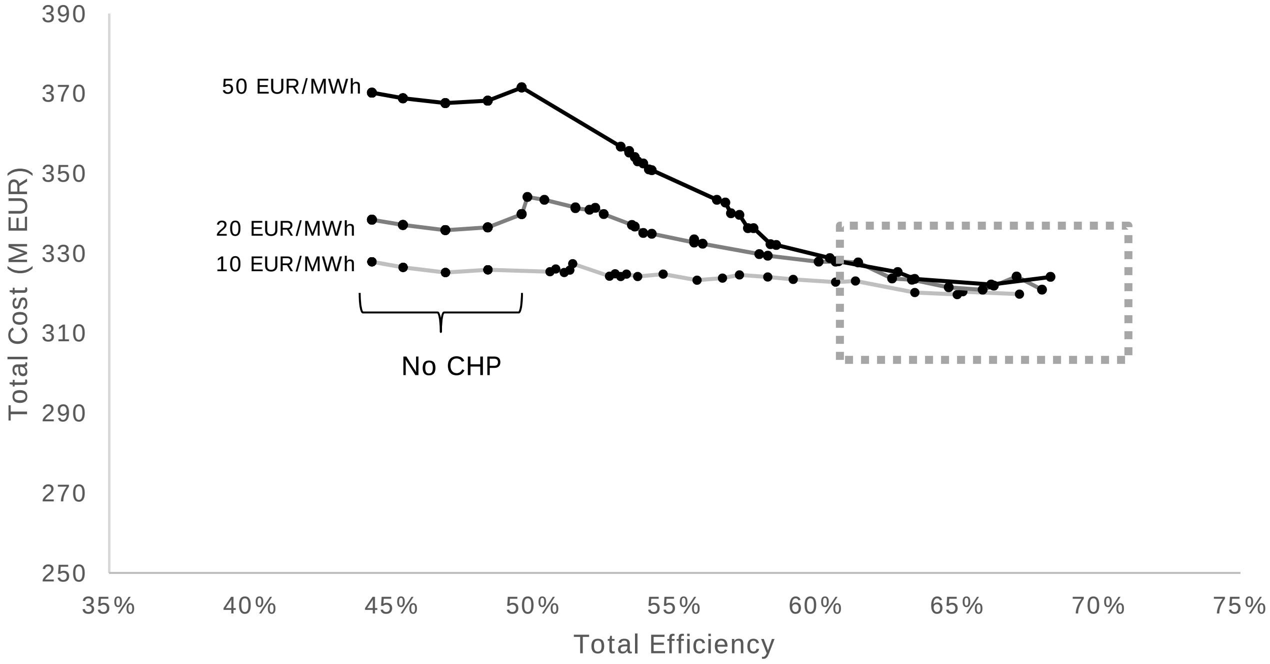


Scenario analysis



Scenario analysis. Pareto optimal solutions

- CHP improves efficiency and costs
- Pareto optimal point includes solutions with low temperature and thermal storage



Conclusions

1. Successful implementation of a unit commitment model with heating features
   - Dispa-Set open source accesible via GitHub
2. CHP leads to an increase of total efficiency and cost reduction in the power system
3. Low alternative heat supply cost leads to a less efficient optimal solution but slightly cheaper
4. Low heat extraction temperatures lead to higher efficiencies and lower costs. (4DH applications)
5. Thermal storage has limited impact in the efficiency of the system but reduces curtailed renewable energy
6. In high RES scenarios
   - CHP leads to high curtailed RES power
   - CHP reduces overall system costs

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