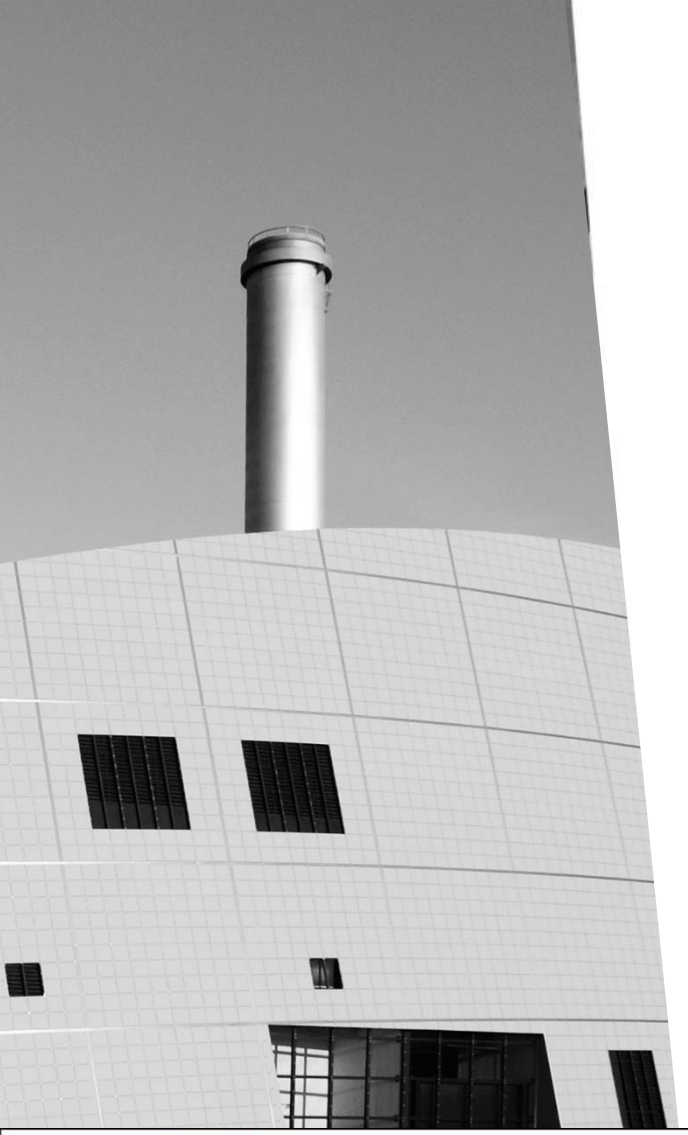


Market optimization of district heating and cooling plants (DHCP)

4th of April 2019

Head of Energy Systems ***Anders N. Andersen***, ana@emd.dk, www.emd.dk

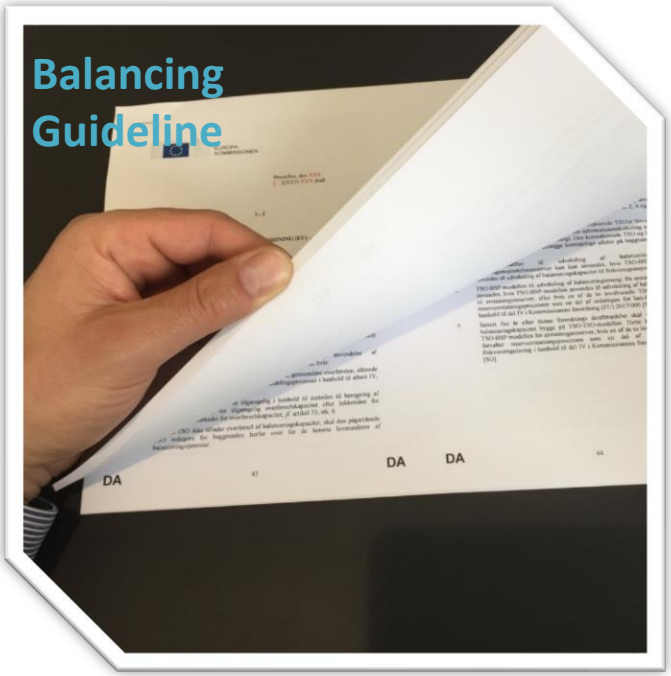
My presentation

- European electricity markets
- The Danish energy system in a glance
- When electrifying heating and cooling demands – what is the right ratio between the central heat pumps and distributed heat pumps?
- Energy stores are needed at District Energy plants – to provide flexibility
- Examples of intelligent market-based operation of District Energy plants – thereby integrating intermittent production

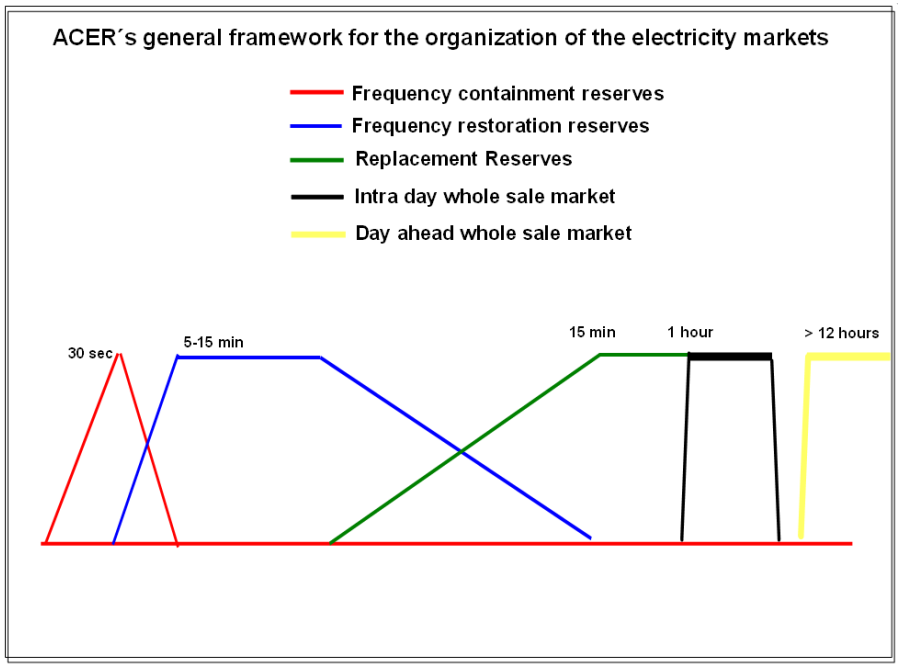
In the perspective:
"Heating and cooling constitutes around half of the EU's final energy consumption and is the biggest energy end-use sector, ahead of transport and electricity"

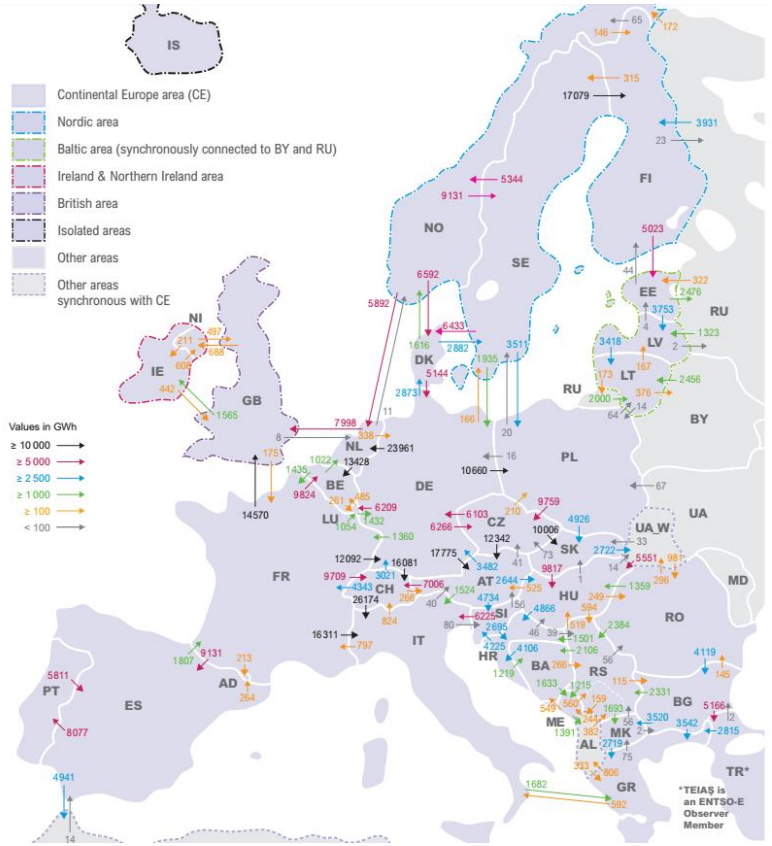
European electricity markets

- A new bible has been decided in EU called Guideline on Electricity Balancing
- Requirement for minimum electrical capacity in each price area
- Electricity balancing markets organized similar to Scandinavia



The 5 European electricity markets that integrates intermittent production from photo voltaic and wind energy





The Danish energy system in a glance

The electrical infrastructure in Denmark in 1985. Red circles indicate central power plants, yellow circles DHCP CHP and secondary producers above 500 kW

The electrical infrastructure in Denmark in 2015. Red circles indicate central power plants, yellow circles DHCP CHP and secondary producers above 500 kW

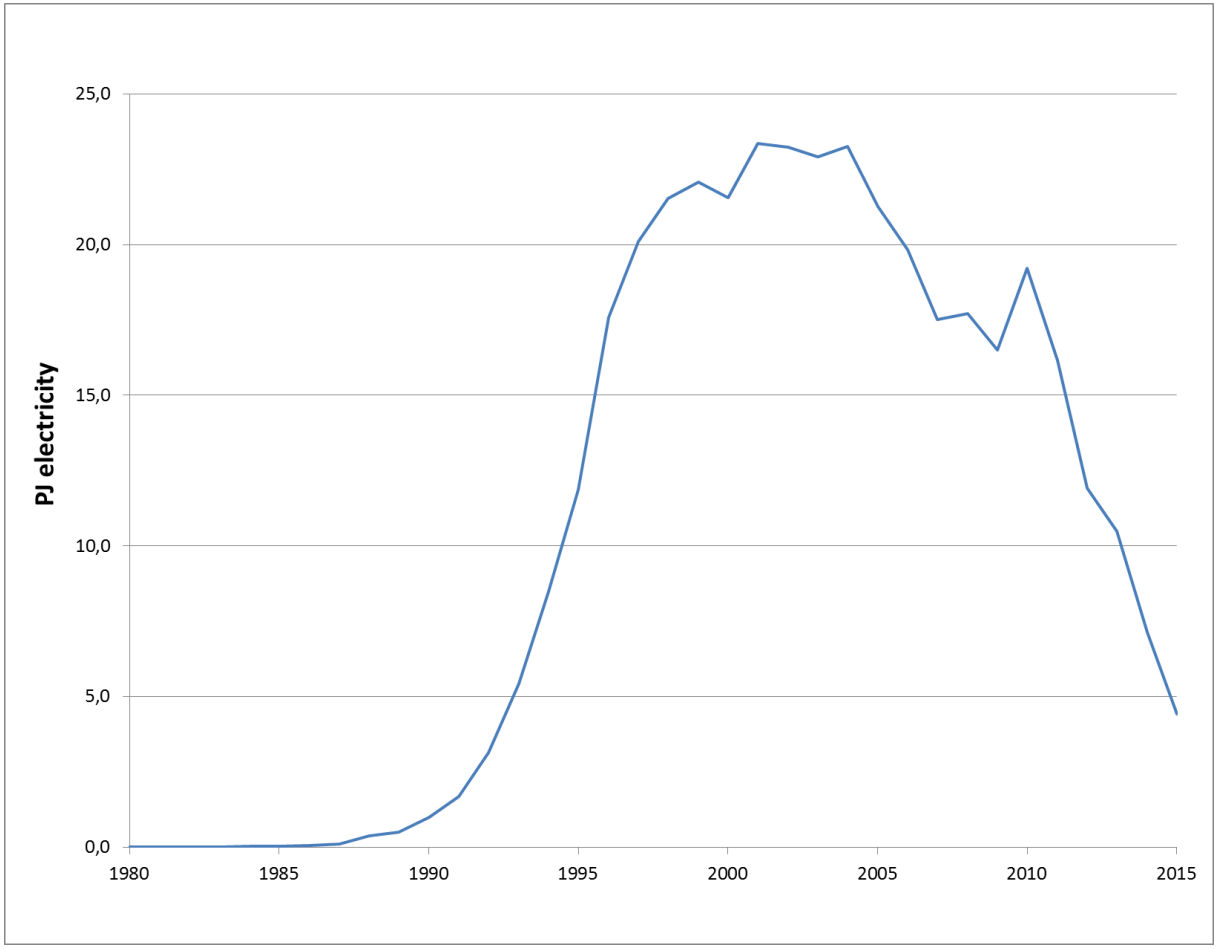
The radically changing role of CHPs in Denmark

Phase 1: CHP displaces fossil fuelled power plants

Phase 2: CHP participates in the integration of fluctuating RES

Phase 3: CHP primarily delivers needed electrical capacity in few hours

Yearly electricity productions at Danish distributed CHP



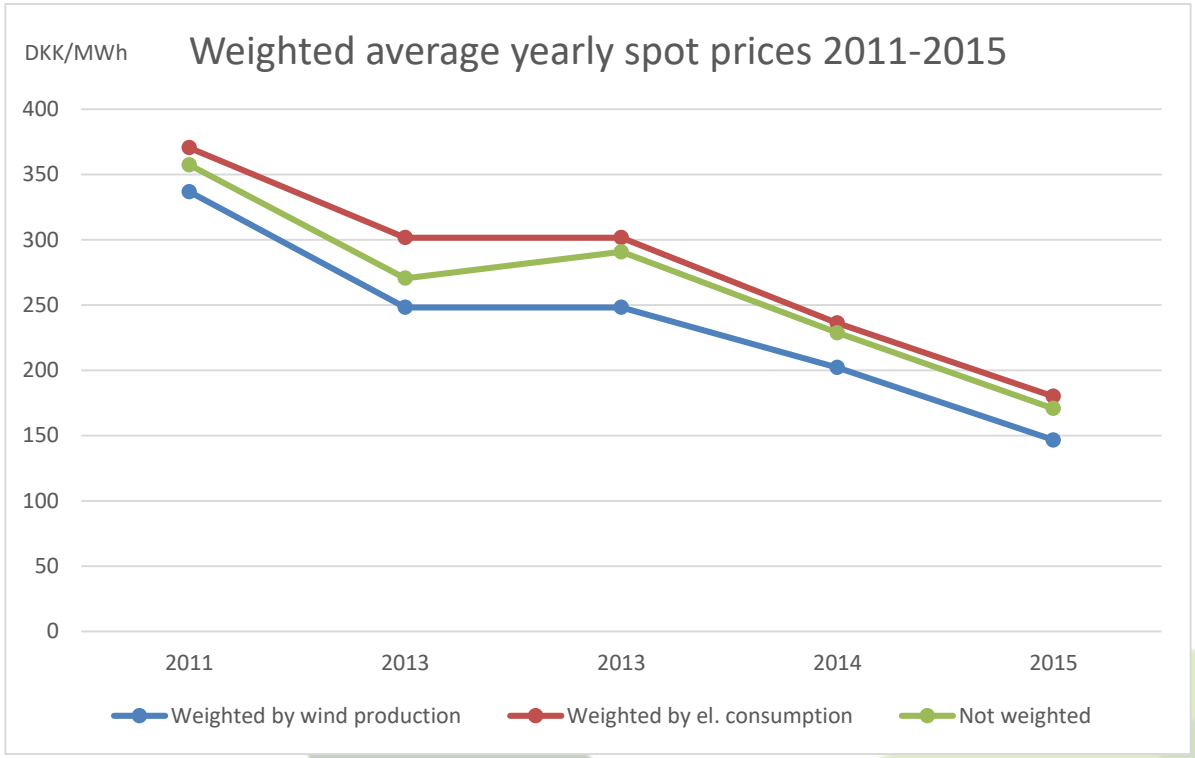
NOTICE:

There is very limited room for CHP in a renewable energy system

CHP is a transitional technology

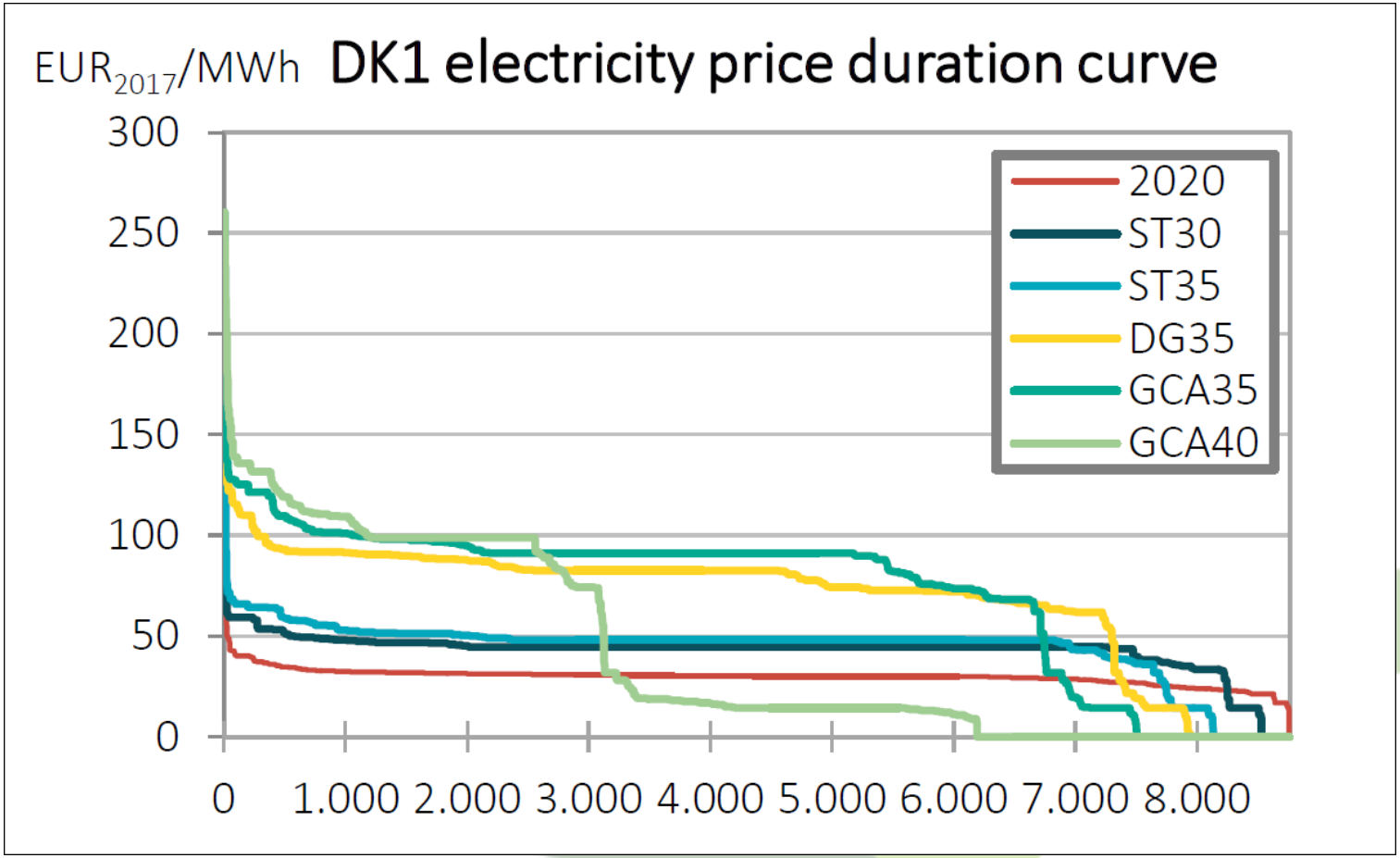
The Danish TSO, Energinet.dk´s plans for 100% renewable energy shows that the present CHP production in Denmark of 90 PJ-heat is in 2035 down to 40 PJ-heat and in 2050 down to 5 PJ-heat.

Average Day-ahead prices (spot prices) in West Denmark

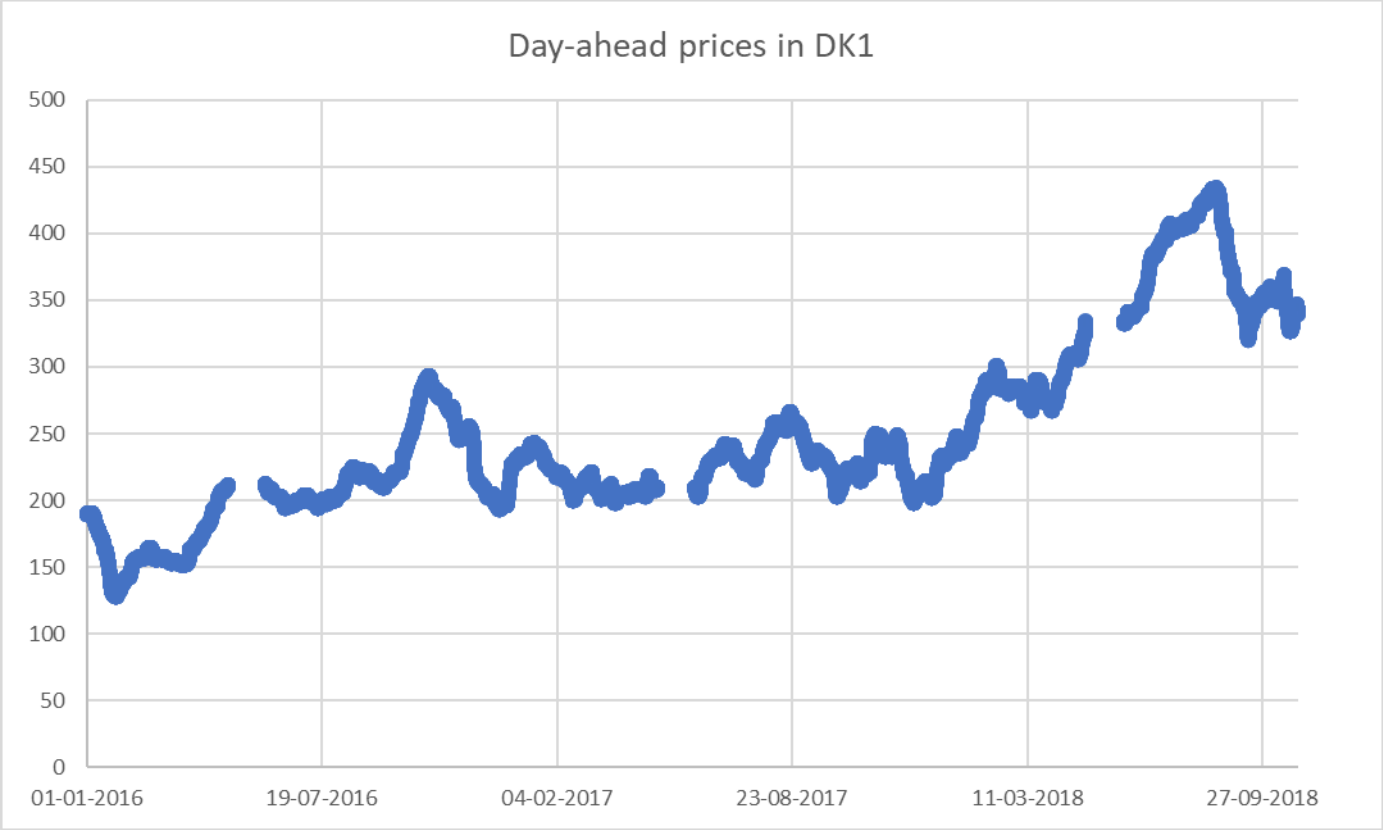


Energinet: System Perspective 2035 - Main Report_English

Scenarios for market price dynamic



But prices are going up ?



When electrifying heating and cooling demand – what is the right ratio between the central heat pumps and distributed heat pumps?

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Booster heat pumps and central heat pumps in district heating

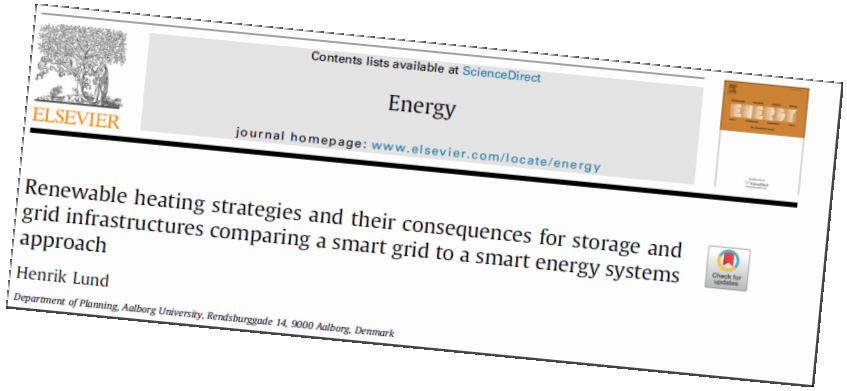
Poul Alberg Østergaard [a,*], Anders N. Andersen [a,b]

[a] Aalborg University, Skibbrogade 5, 9000 Aalborg, Denmark
[b] EMD International, Niels Jernesvej 10, 9220 Aalborg Ø, Denmark

Energy stores are needed at District Energy plants – to provide flexibility

Table 1
Storage cost assumptions.

Storage type	Investment range [EUR/MWh]	Investment (chosen in this study) [EUR/MWh]
Large electricity storage (PHS)	125–600,000	200,000
Household electricity storage (Tesla)	600,000	300,000[a]
Large thermal storage	500-2500	1500
Household thermal storage	24,000–180,000	20,000[a]
Large gas storage		60
Liquid fuel		20

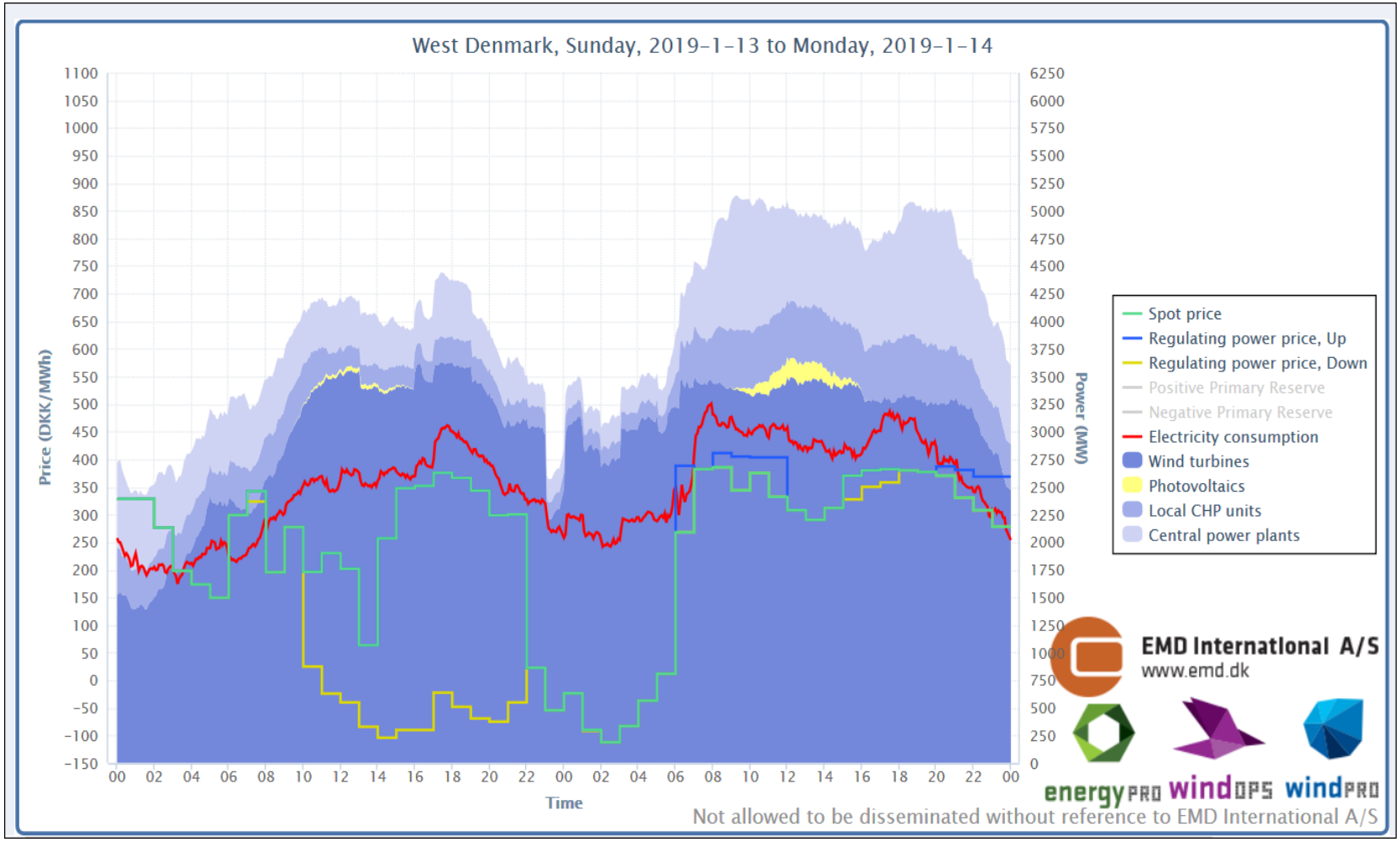


Examples of intelligent market-based operation of District Energy plants – thereby integrating intermittent production from PV and wind energy

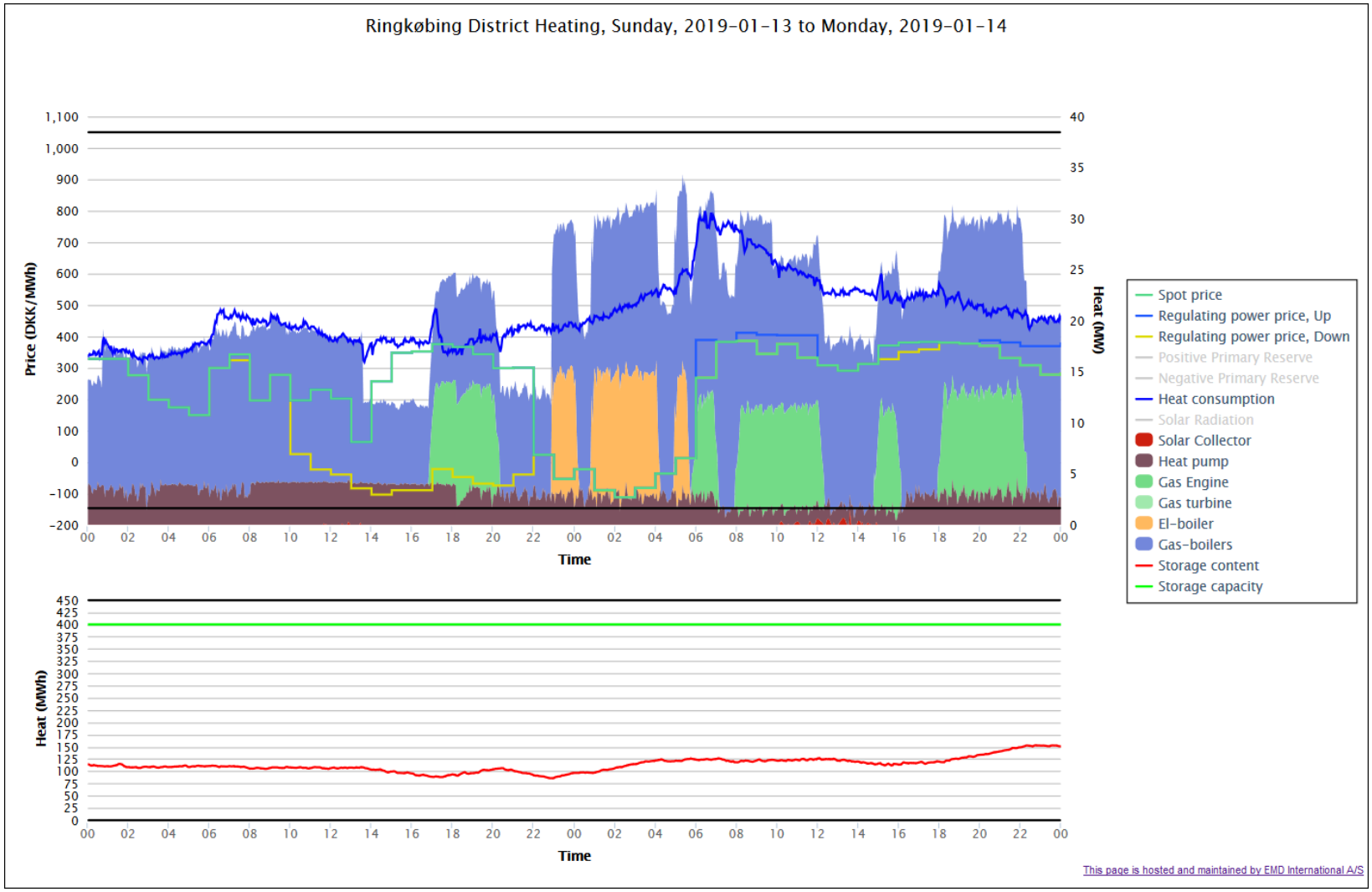
Shown online at

www.emd.dk/energy-system-consultancy/online-presentations

www.emd.dk/energy-system-consultancy/online-presentations

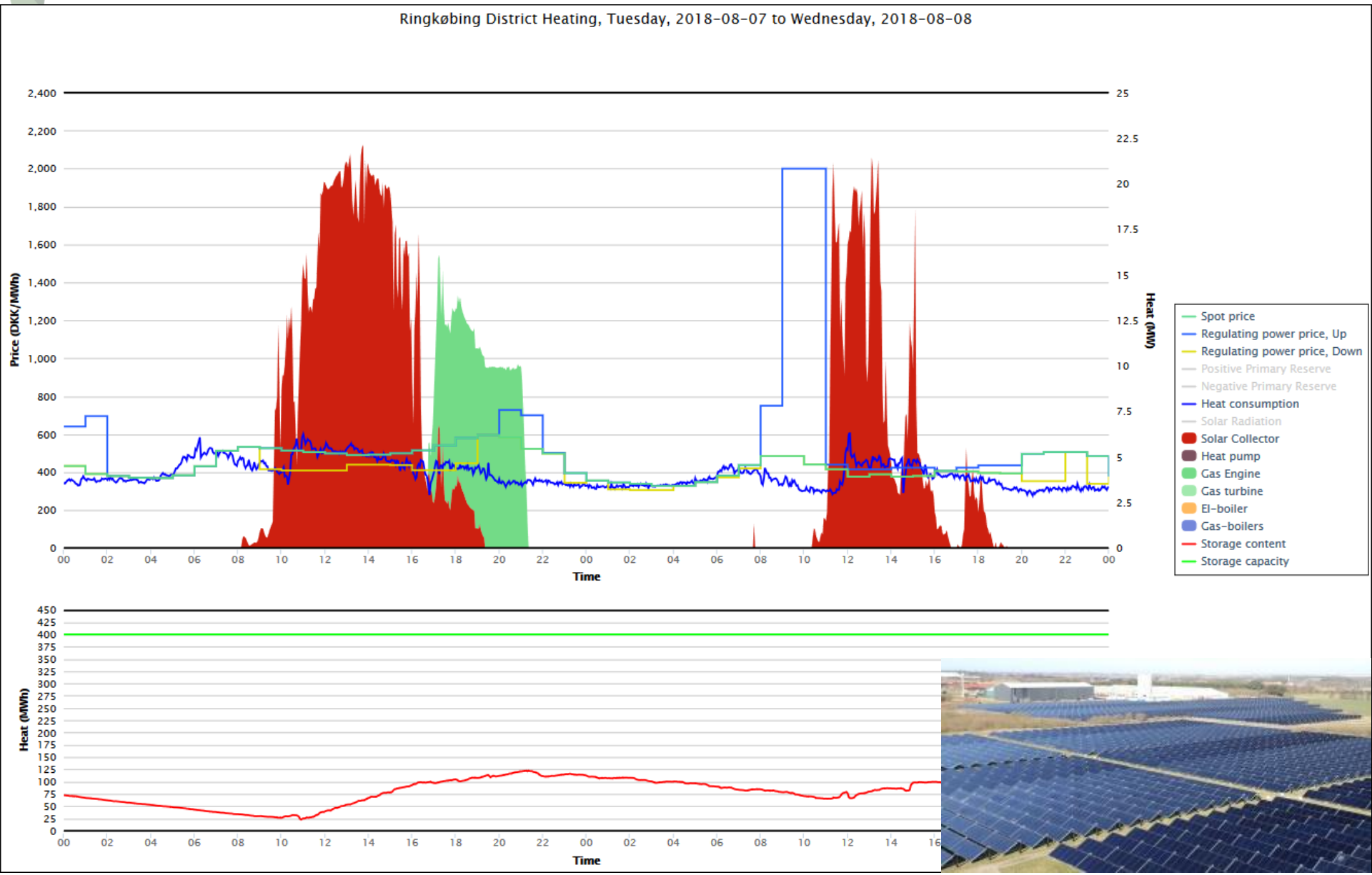


www.emd.dk/energy-system-consultancy/online-presentations



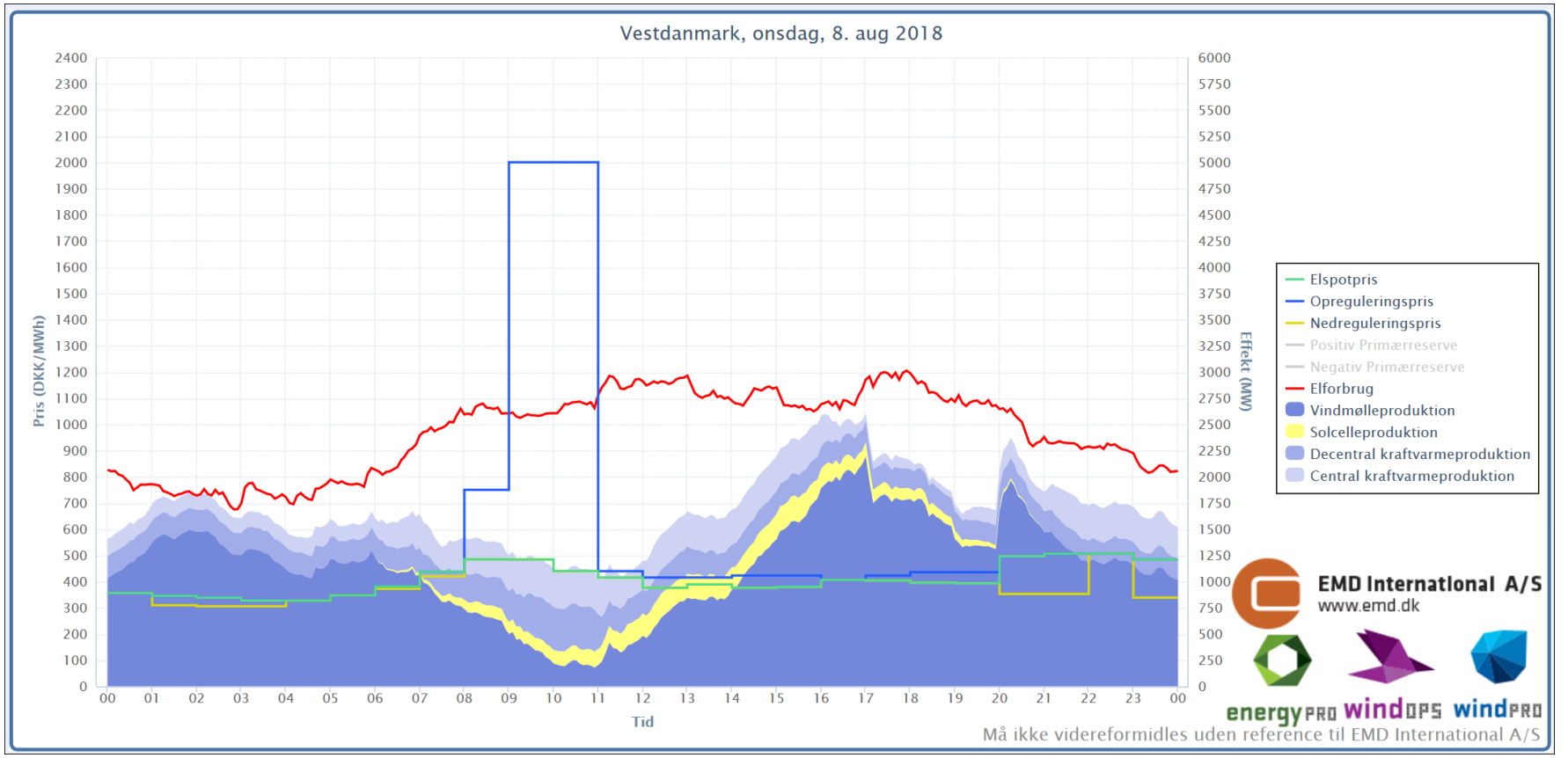
Ambient temperature as heat source for heat pumps. However regular deicing is needed

www.emd.dk/energy-system-consultancy/online-presentations

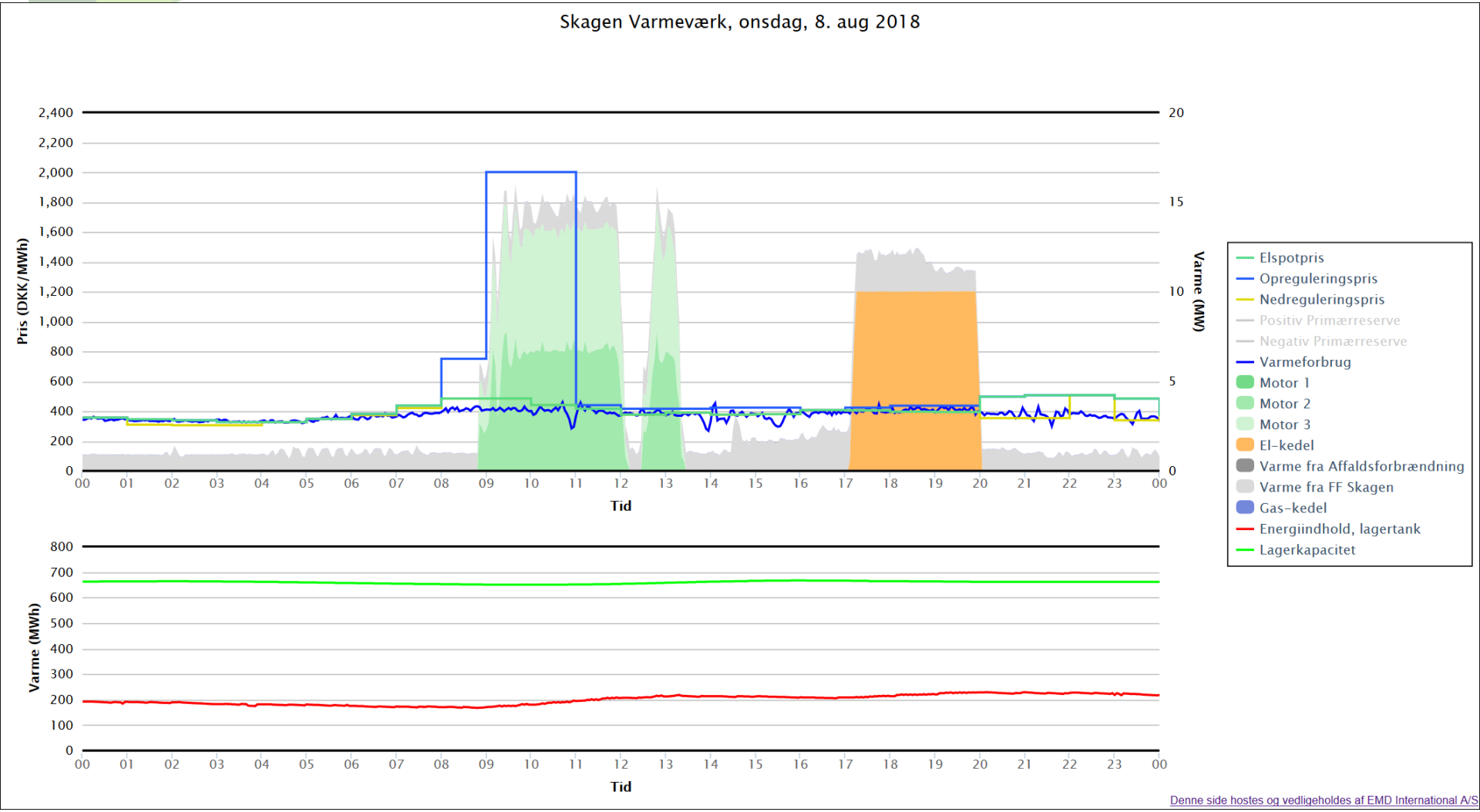


An example of participation in balancing markets in West Denmark

www.emd.dk/energy-system-consultancy/online-presentations

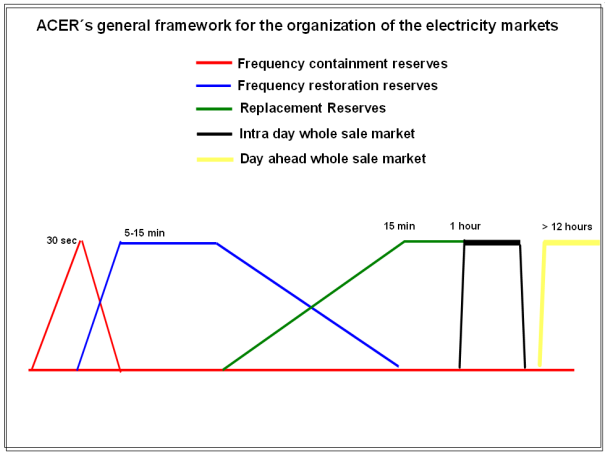


www.emd.dk/energy-system-consultancy/online-presentations



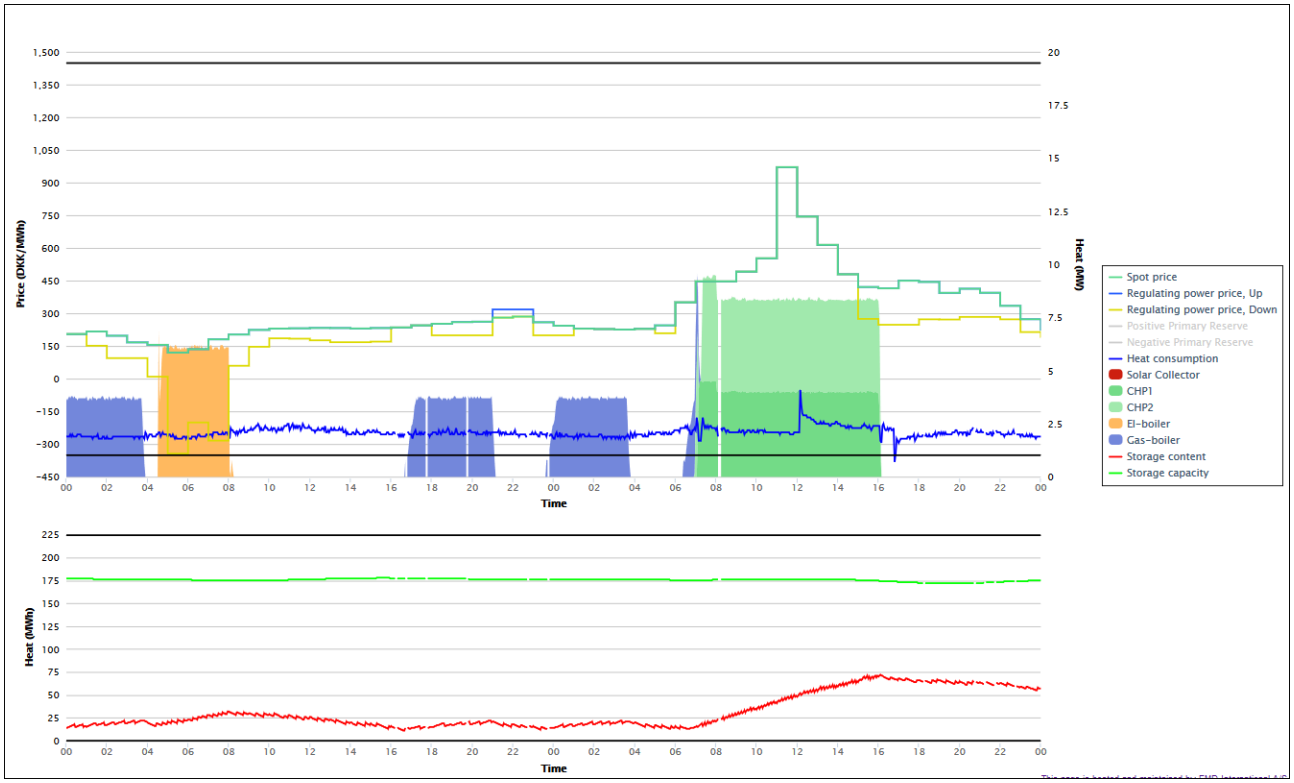
www.emd.dk/energy-system-consultancy/online-presentations

Hvide Sande District Energy plant participating in three different electricity markets in two days



www.emd.dk/energy-system-consultancy/online-presentations

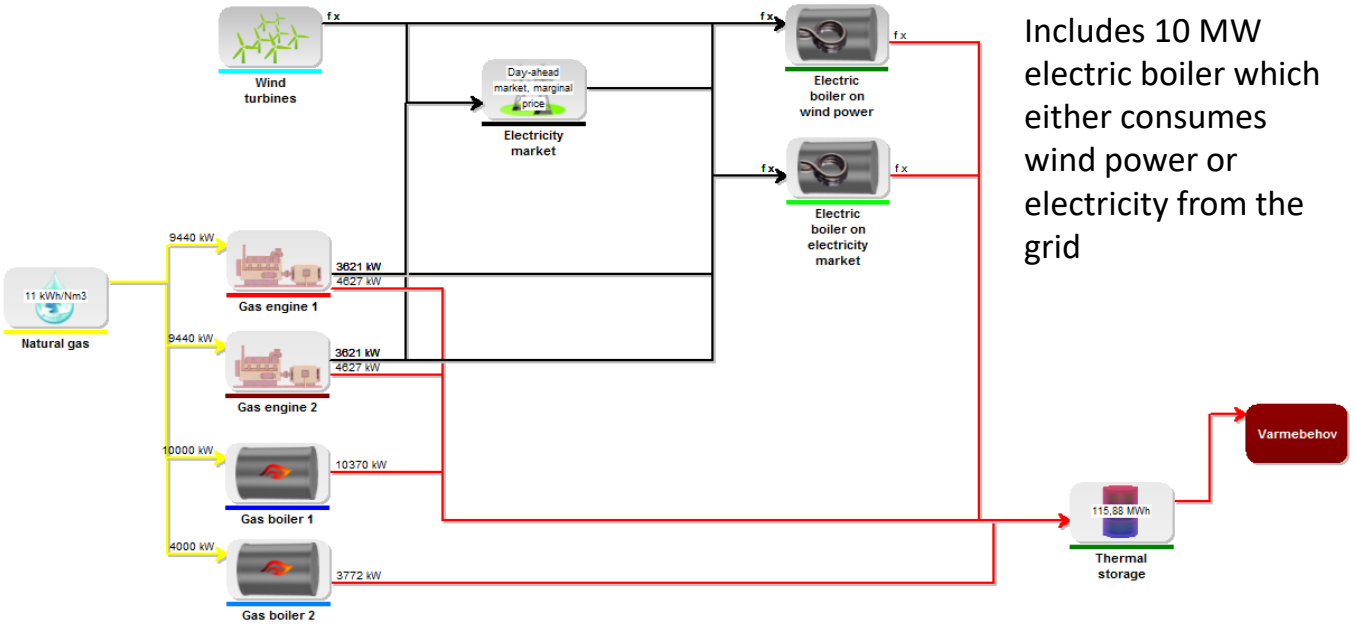
- Electrical boiler being activated in Regulating power market from 5-8 in Day 1.
- CHP being full loaded in Day-ahead market from 7-8 in Day 2
- CHP being 80% loaded in Day-ahead market from 8-16 in Day 2, allowing for offering 20% in two 4-hour periods in Primary reserves.



Future private wire operation of Hvide Sande District Energy plant

Hvide Sande District Heating

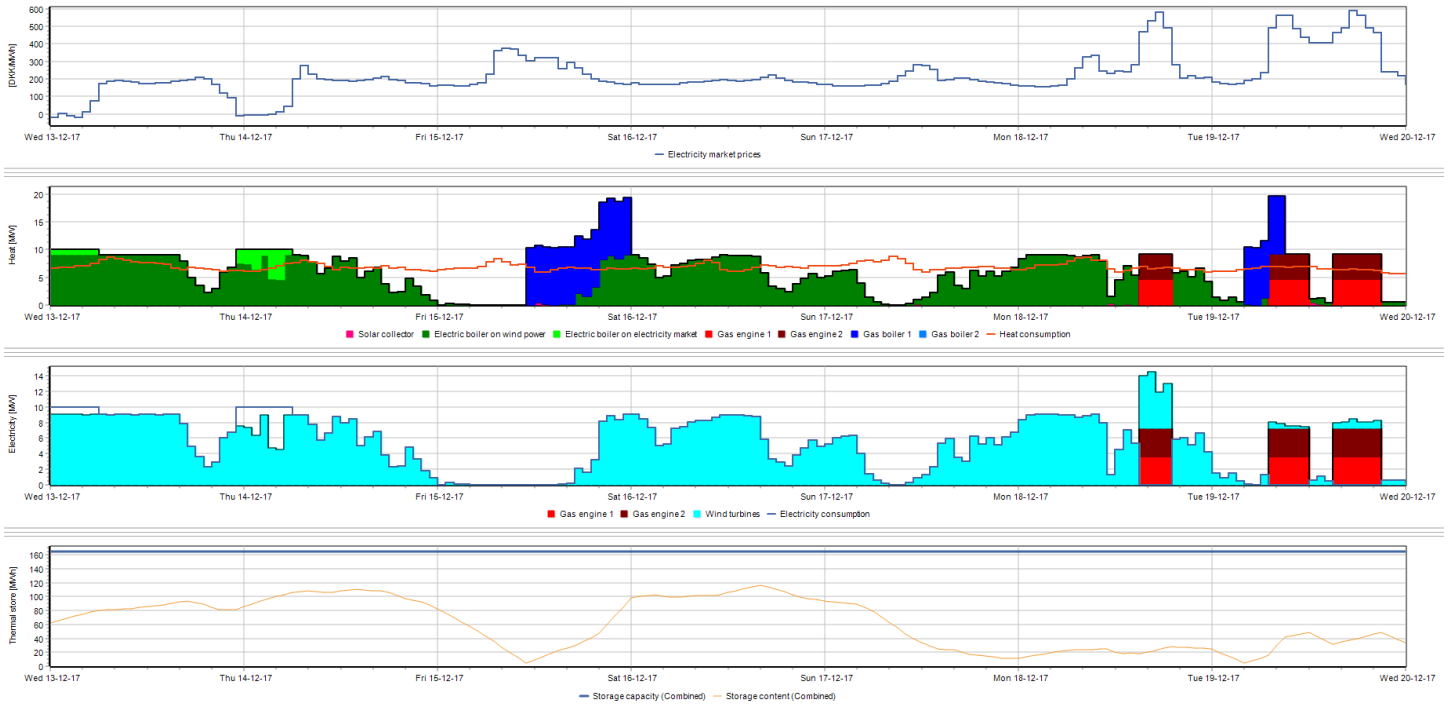
energyPRO model



Includes 10 MW electric boiler which either consumes wind power or electricity from the grid

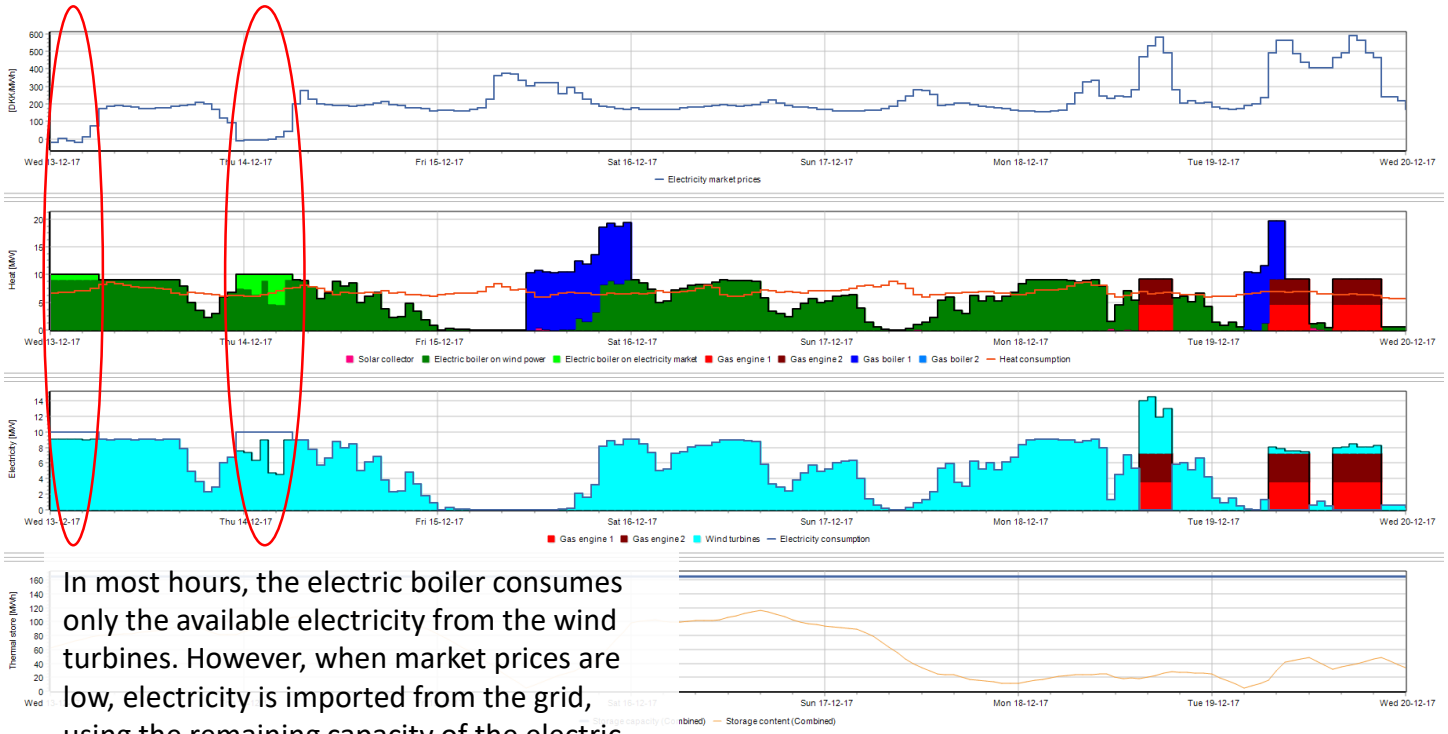
Hvide Sande District Heating

energyPRO simulation



Hvide Sande District Heating

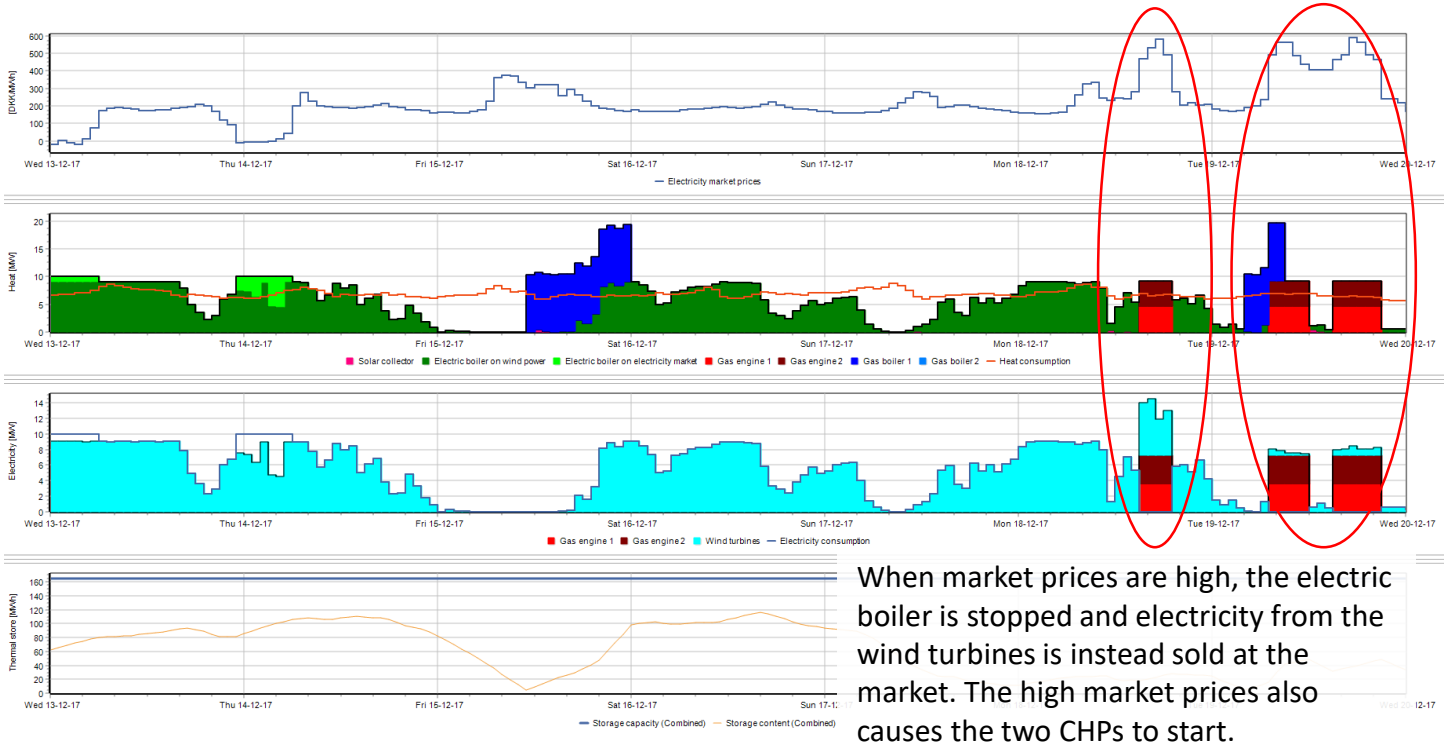
energyPRO simulation



In most hours, the electric boiler consumes only the available electricity from the wind turbines. However, when market prices are low, electricity is imported from the grid, using the remaining capacity of the electric boiler.

Hvide Sande District Heating

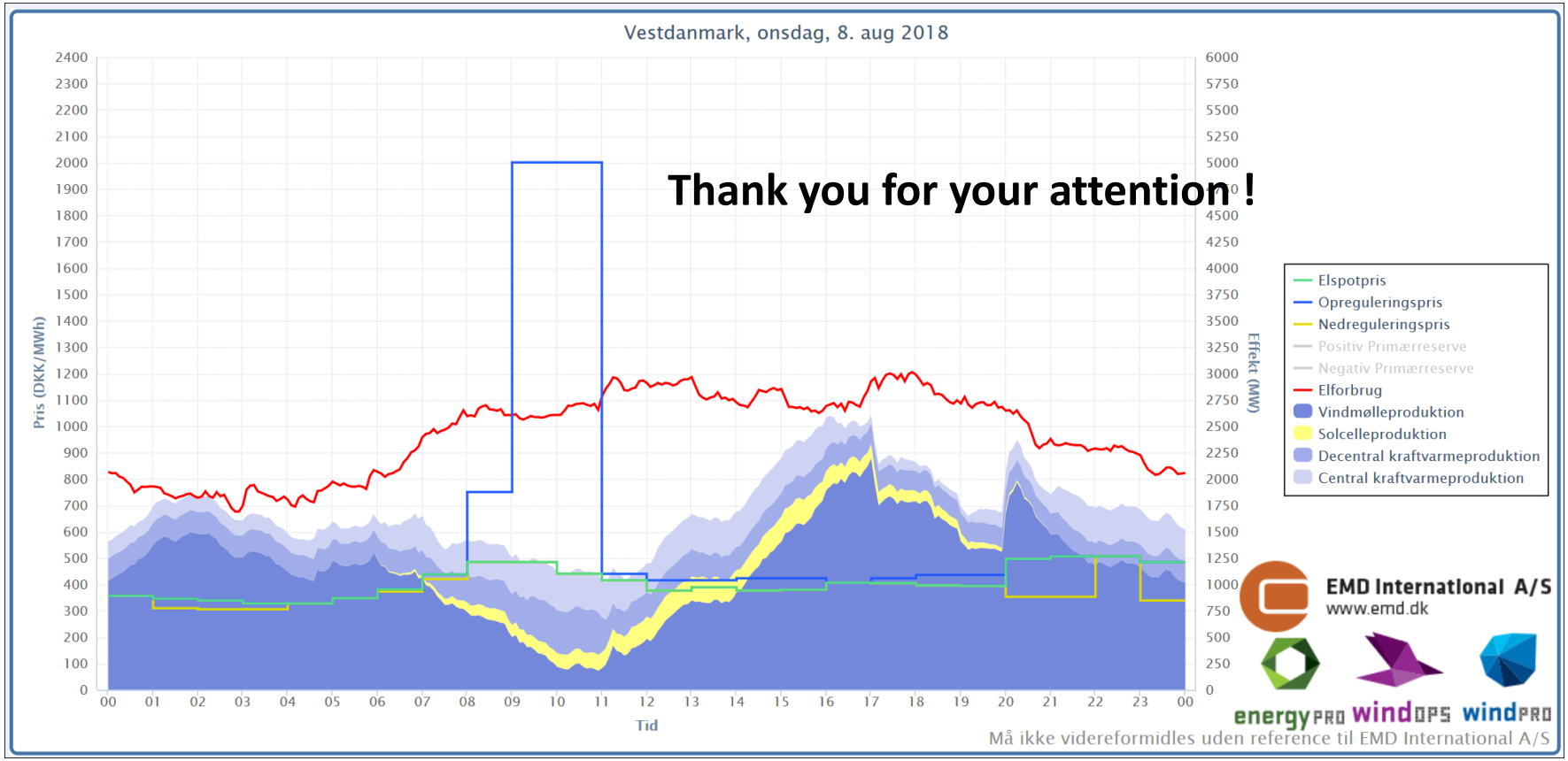
energyPRO simulation



When market prices are high, the electric boiler is stopped and electricity from the wind turbines is instead sold at the market. The high market prices also causes the two CHPs to start.

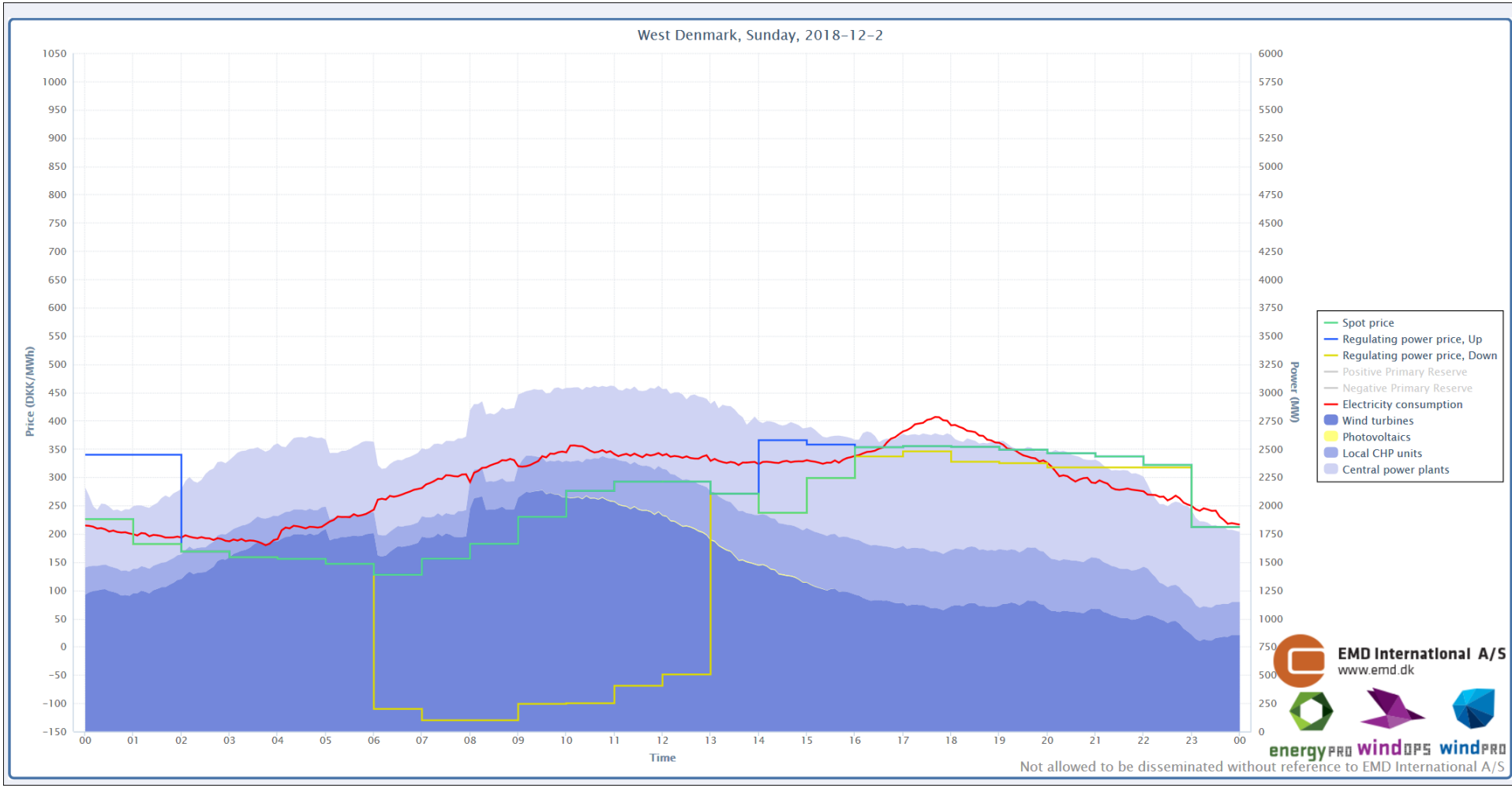
In a situation where the wind turbines and the electrical boiler in the Day-ahead market both is operated at 5 MW, three bidding prices to be used in the next hour in the Scandinavian Regulating power market (gate closure 45 minutes before the operating hour).

One upward regulation bid of 5 MW (by closing the electrical boiler), and two downward regulation bid each of 5 MW (by raising the power of the electrical boiler from 5 MW to 10 MW and closing the wind turbines and). The chosen bidding prices will be highly dependent on the expected production at the solar collector and wind turbines in the next days and the content in the thermal storages.

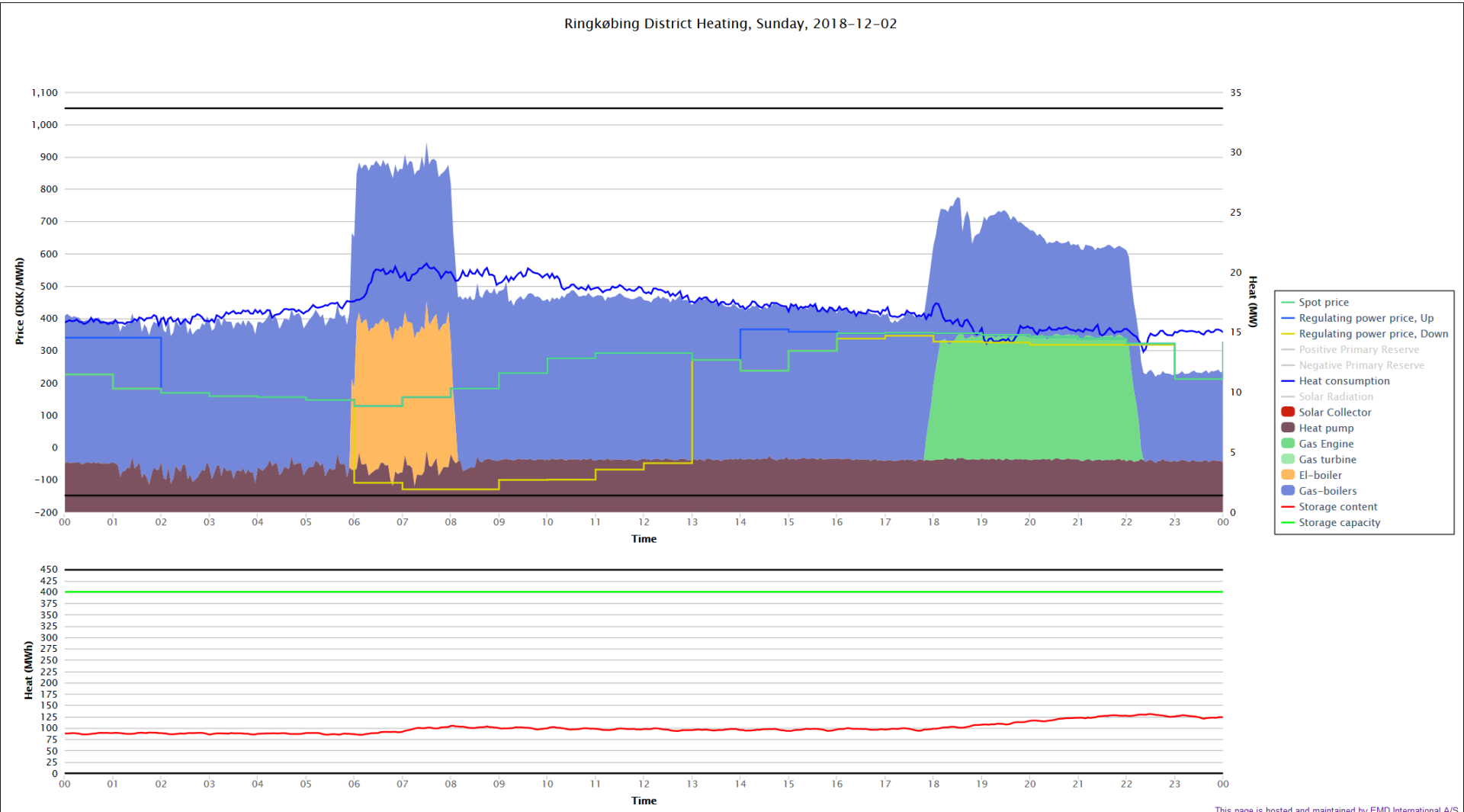


http://smart-cities-centre.org/

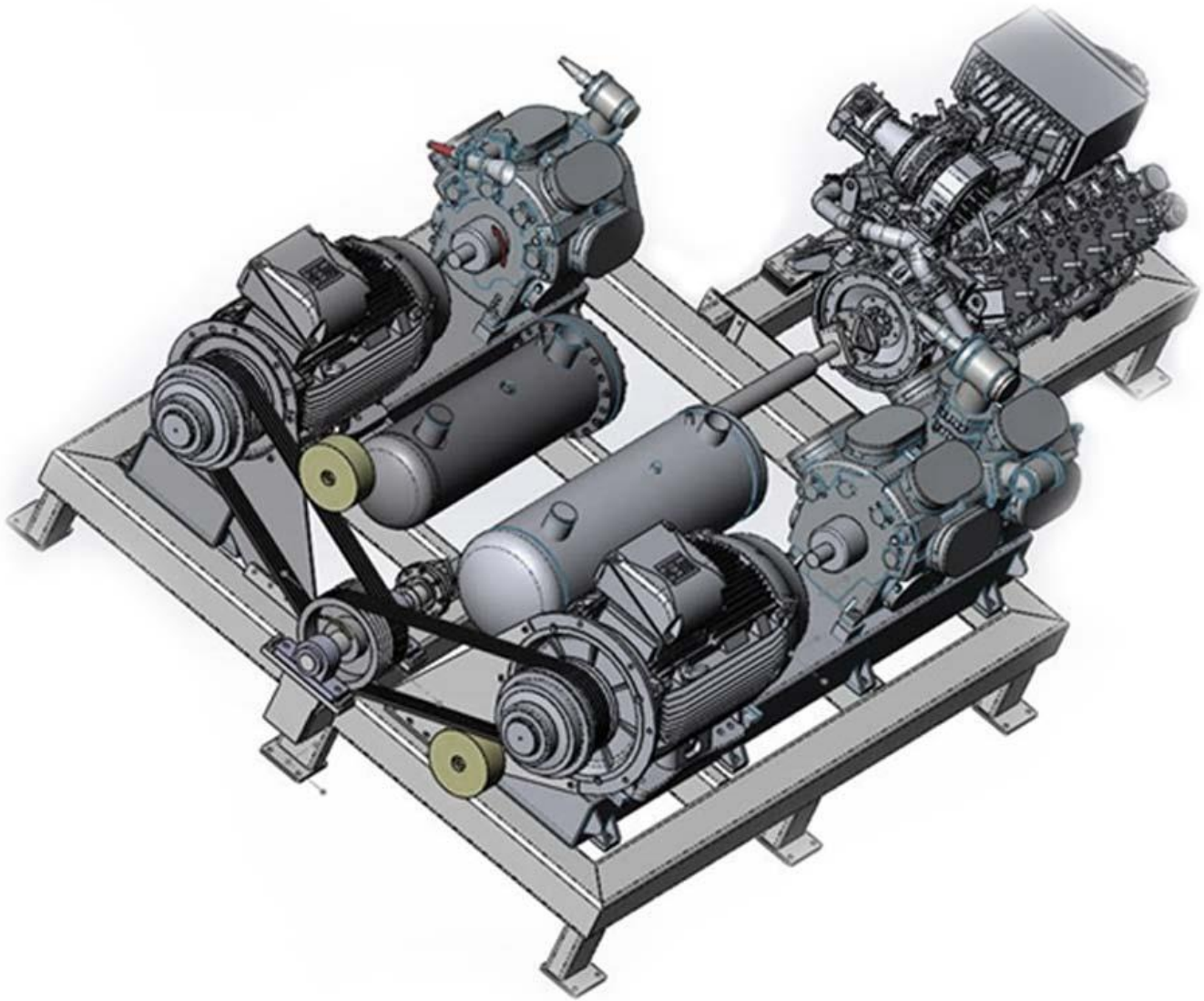
www.emd.dk/energy-system-consultancy/online-presentations



www.emd.dk/energy-system-consultancy/online-presentations



Solid Energy anlæg installeret ved https://www.emd.dk/plants/rfvv/



District Energy an important part of a 100% Renewable Energy System

Reasons for District Energy *:*

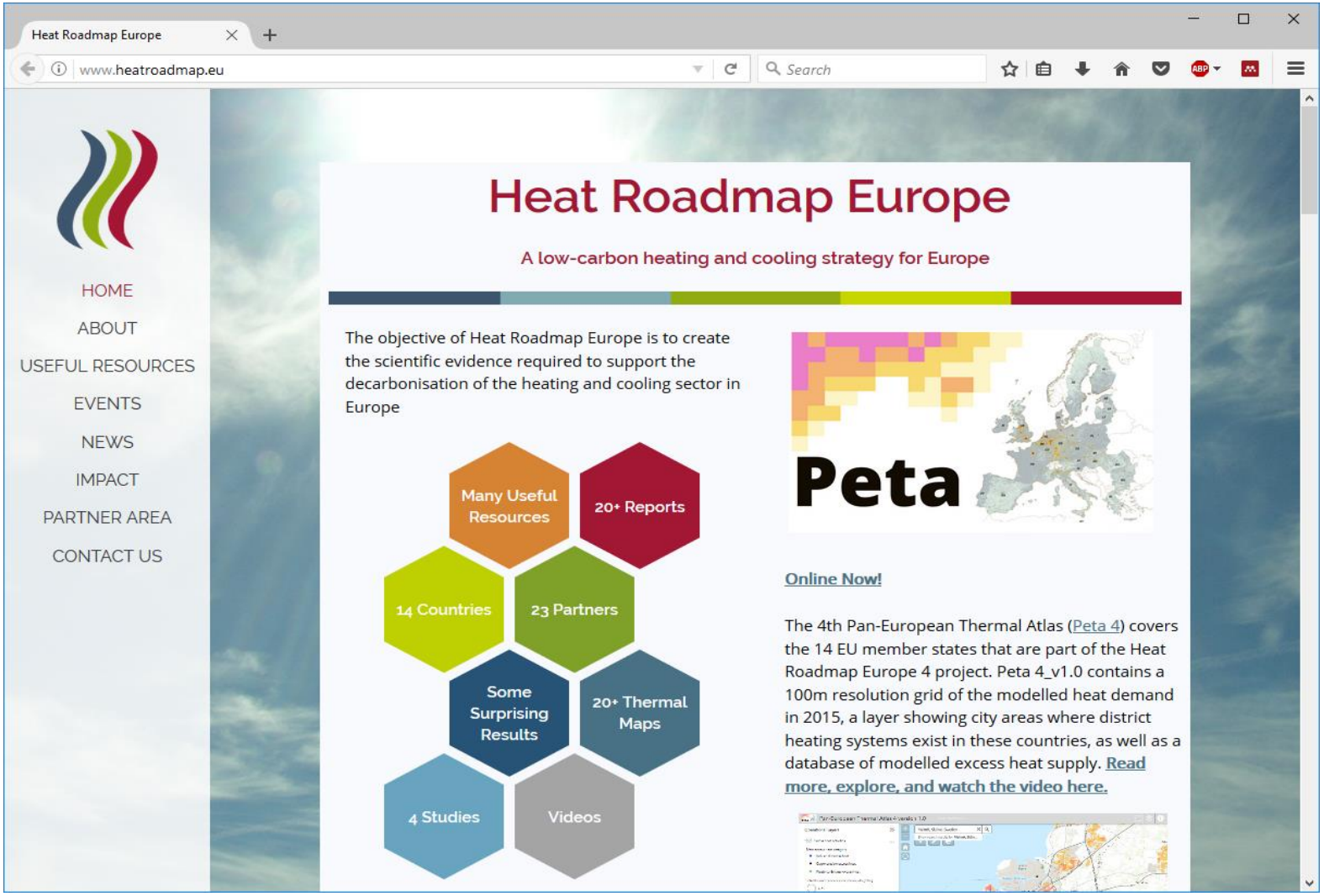
- Exploitation of waste heat from power plants and industry
- Significant economy of scale-effect in solar collectors making communal systems much cheaper to build compared to solar collectors at each building
- Heat pumps gets access to a broader range of heat sources, e.g. heat from sewage systems
- Exploitation of geothermal energy
- More cooling sources becomes available, e.g. free cooling from lakes, rivers or seas.

EU Horizon 2020 Work Programme 2016 – 2017 concerning the final energy consumption in Europe:
"Heating and cooling constitutes around half of the EU's final energy consumption and is the biggest energy end-use sector, ahead of transport and electricity"

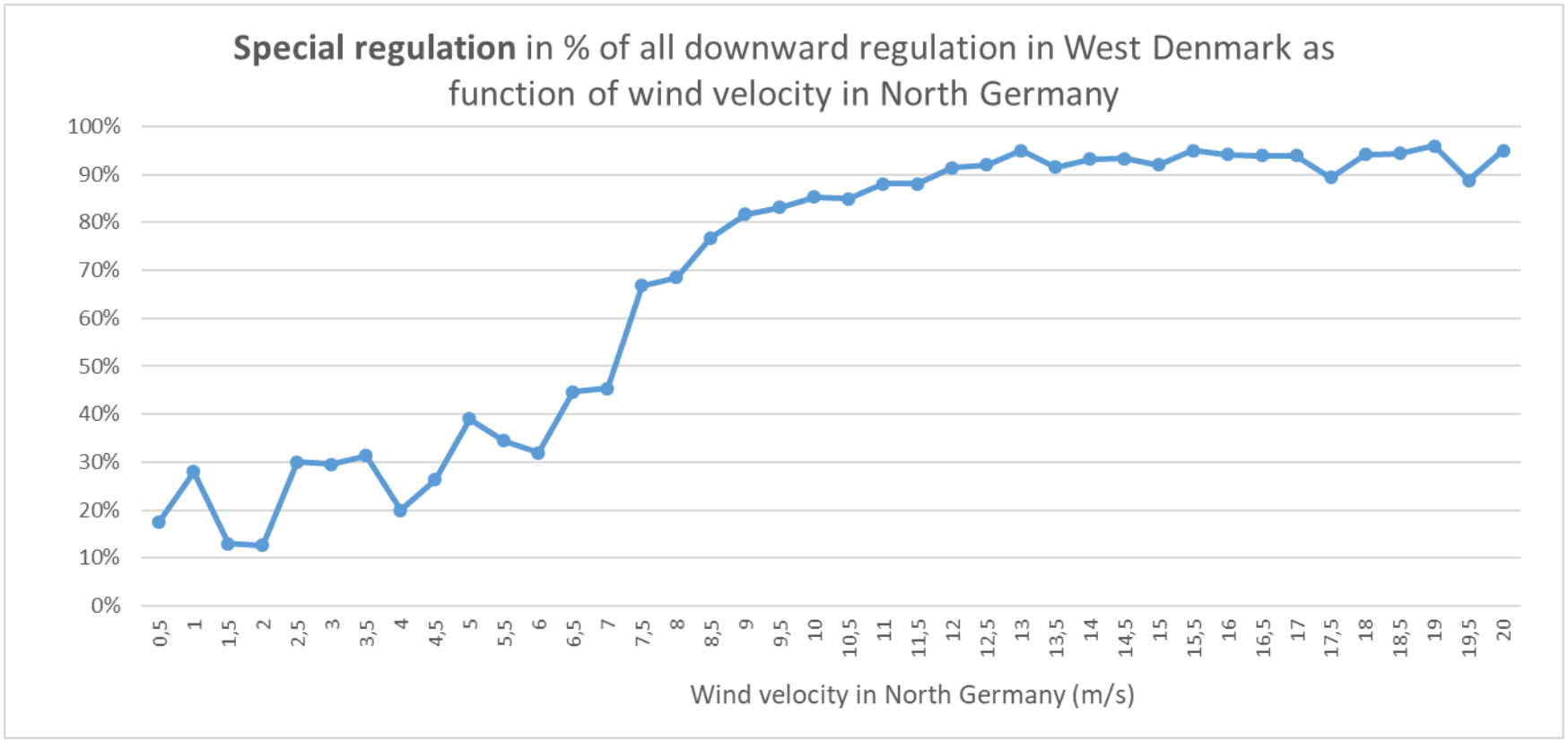
In which cities in Germany is it socioeconomic the cheapest to cover heating and cooling demand with District Energy?

Is it cities with heating and cooling densities of
120 TJ/km^2 or 60 TJ/km^2 ?

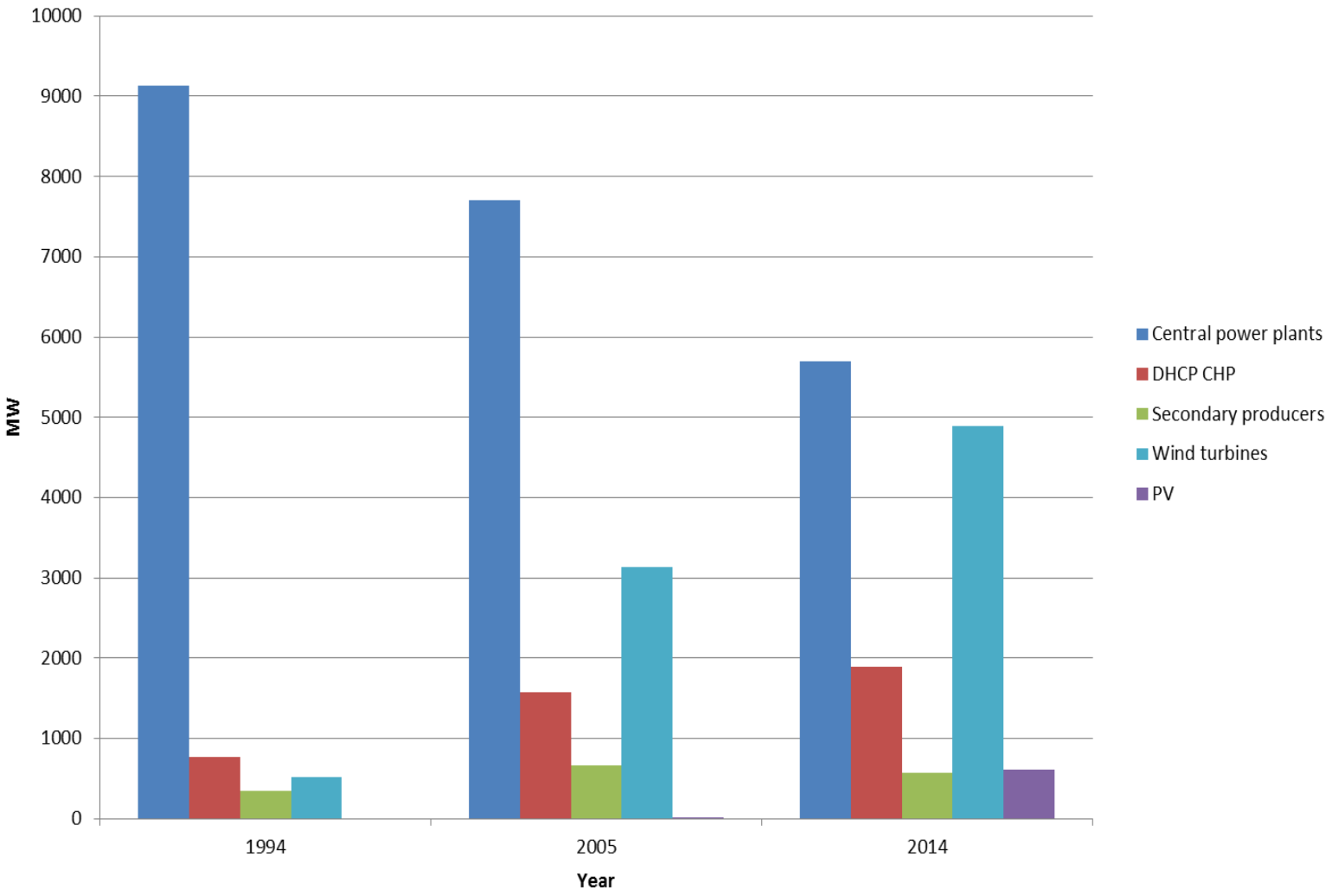
Heat Roadmap Europe has dealt with that question, concluding that the overall heating and cooling demand in Europe should be reduced with 30%, half of the rest should be supplied from District Energy plants.



Special regulation in West Denmark due to wind in North Germany


Special regulation in % of all downward regulation in West Denmark as function of wind velocity in North Germany
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0,5
1
1,5
2
2,5
3
3,5
4
4,5
5
5,5
6
6,5
7
7,5
8
8,5
9
9,5
10
10,5
11
11,5
12
12,5
13
13,5
14
14,5
15
15,5
16
16,5
17
17,5
18
18,5
19
19,5
20
Wind velocity in North Germany (m/s)

Electrical capacity in Denmark



The Danish energy system in a glance

		Denmark
Population (mio.)		5,70
Total Final Consumption per capita (MWh/cap)		27,16
Electricity consumption per capita (MWh/cap)		5,81
Emissions per capita (tCO2/cap)		5,63
Gross Domestic Product per capita (1000 EUR/cap)		38,18
Area per capita (m2)		7.368
Heat demand supplied from District Energy plants		**64%**