Market optimization of district heating and cooling plants (DHCP)

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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

Weighted average yearly spot prices 2011-2015

- Weighted by wind production
- Weighted by el. consumption
- Not weighted

DKK/MWh
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?
Energy stores are needed at District Energy plants – to provide flexibility

<table>
<thead>
<tr>
<th>Storage type</th>
<th>Investment range [EUR/MWh]</th>
<th>Investment (chosen in this study) [EUR/MWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large electricity storage (PHS)</td>
<td>125–600,000</td>
<td>200,000</td>
</tr>
<tr>
<td>Household electricity storage</td>
<td>600,000</td>
<td>300,000&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>(Tesla)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large thermal storage</td>
<td>500–2500</td>
<td>1500</td>
</tr>
<tr>
<td>Household thermal storage</td>
<td>24,000–180,000</td>
<td>20,000&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Large gas storage</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Liquid fuel</td>
<td>20</td>
<td></td>
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</table>
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
West Denmark, Sunday, 2019-1-13 to Monday, 2019-1-14

- Spot price
- Regulating power price, Up
- Regulating power price, Down
- Positive Primary Reserve
- Negative Primary Reserve
- Electricity consumption
- Wind turbines
- Photovoltaics
- Local CHP units
- Central power plants

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Ambient temperature as heat source for heat pumps. However regular deicing is needed.
Ringkøbing District Heating, Tuesday, 2018-08-07 to Wednesday, 2018-08-08

Legend:
- Spot price
- Regulating power price, Up
- Regulating power price, Down
- Positive Primary Reserve
- Negative Primary Reserve
- Heat consumption
  - Solar Radiation
  - Solar Collector
  - Heat pump
  - Gas Engine
  - Gas turbine
  - El-boiler
  - Gas boilers
  - Storage content
  - Storage capacity
An example of participation in balancing markets in West Denmark

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

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• 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
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.
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.
Thank you for your attention!

http://smart-cities-centre.org/
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/km² or 60 TJ/km²?*
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
Electrical capacity in Denmark

<table>
<thead>
<tr>
<th>Year</th>
<th>Central power plants</th>
<th>DHCP CHP</th>
<th>Secondary producers</th>
<th>Wind turbines</th>
<th>PV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>9000</td>
<td>700</td>
<td>200</td>
<td>500</td>
<td>100</td>
</tr>
<tr>
<td>2005</td>
<td>7000</td>
<td>2000</td>
<td>500</td>
<td>3000</td>
<td>500</td>
</tr>
<tr>
<td>2014</td>
<td>5500</td>
<td>2000</td>
<td>500</td>
<td>2000</td>
<td>500</td>
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Sources:
- www.4dh.eu
- www.reinvestproject.eu
- www.heatroadmap.eu
<table>
<thead>
<tr>
<th></th>
<th>Denmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (mio.)</td>
<td>5,70</td>
</tr>
<tr>
<td>Total Final Consumption per capita (MWh/cap)</td>
<td>27,16</td>
</tr>
<tr>
<td>Electricity consumption per capita (MWh/cap)</td>
<td>5,81</td>
</tr>
<tr>
<td>Emissions per capita (tCO2/cap)</td>
<td>5,63</td>
</tr>
<tr>
<td>Gross Domestic Product per capita (1000 EUR/cap)</td>
<td>38,18</td>
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<tr>
<td>Area per capita (m²)</td>
<td>7.368</td>
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<tr>
<td><strong>Heat demand supplied from District Energy plants</strong></td>
<td><strong>64%</strong></td>
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</tbody>
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