HOW TO USE DISTRICT ENERGY SYSTEMS AS A VIRTUAL BATTERY IN MICROGRID SYSTEMS

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INTEGRATED SMART ENERGY SYSTEM WITH THERMAL STORAGES THAT WORKS LIKE A VIRTUAL BATTERY
MAIN COMPONENT OF THE SMART ENERGY SYSTEM TO INTEGRATE WIND AND SOLAR

- Interconnected grids with storages
  - International power grid, Nordpool market, with some hydro storage
  - National natural gas grid with gas storage
  - City-wide district heating grids with thermal storages
  - Local district cooling grids with thermal storages
  - Buildings with Low-temperature heating and High-temperature cooling

- Conversion technologies (interconnecting the grids)
  - CHP plants
  - Heat pumps for co-generation of heating and cooling
  - Electric boilers
  - Absorption heat pumps
  - P2GAS
THE THERMAL VIRTUAL ELECTRICITY STORAGE (BATTERY)

- The baseline
  - Small heat pumps without storage or gas boiler back-up
  - Can-not adjust consumption to the fluctuations of the wind

- The virtual electricity storage
  - DH&C grids
  - Large heat pumps, which can be interrupted
  - Electric boilers, operates only at low price
  - CHP plants, operates only at high price
  - Hot and cold water storage, daily and seasonal
COST OF HEAT STORAGE TANKS AND PITS

<table>
<thead>
<tr>
<th>Capacity in MWh storage</th>
<th>Investment EUR1000/MWh storage</th>
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<tbody>
<tr>
<td></td>
<td>160°C Heat storage tank</td>
</tr>
<tr>
<td></td>
<td>95°C Heat storage tank</td>
</tr>
<tr>
<td></td>
<td>85°C Heat storage pit</td>
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</tbody>
</table>

- Heat storage tank 160°C
- Heat storage tank 95°C
- Heat storage pit 85°C
THE SIMPLE HEAT STORAGE TANKS PRESSURELESS AND DIRECT CONNECTION

- All CHP plants have heat storage tanks in Denmark
- Optimize operation of the CHP plant > 8 max load hours
- Can integrate surplus heat from waste, solar, wind etc.
- Optimize the operation of the DH system
- Maintain the pressure
- Provide peak capacity the coldest day
- Fynsværket power plant, Odense
  - 70,000 m³
  - Direct connection
  - Maximum temp 95°C. 90/40
  - Storage capacity, 3,6 GWh, e.g. 300 MW in 12 hours
Temperature above 100 °C can be necessary due to consumer needs (poor heating installations),

But - the larger temperature - the larger investment.

Pressure sectioning can be necessary due to the pressure level in the DH grid and due to necessary pressure variations at the location

Pressure sectioning increase costs, but is cheaper and more efficient than a heat exchanger connection

Avedøre CHP plant, Copenhagen

- 2 x 24,000 m³
- Maximal temp 120 °C  actual temp. 105/50
- Pressure diff: 10 Bar
- Storage capacity 2,400 MWh, e.g. 300 MW in 8 hours
HEAT STORAGE PITS
PRESSURELESS AND SECTIONED BY HEAT EXCHANGER

- Heat storage pit, an innovative combination of:
  - Landfills for establishing liners to a waterproof pit
  - Heat storage tank for diffusers
  - Offshore technology for diffusers and pipes
  - A floating cover (newly developed)
- Impossible to avoid oxygen in the water, therefore sectioned by heat exchanger
- Maximal temp 85 °C
- Storing weekly or monthly fluctuations
- The driver for this development in Denmark has been to increase share of solar heat up to 60%
HEAT STORAGE PITS PRESSURELESS AND SECTIONED BY HEAT EXCHANGER

- Test plants with subsidy
  - 10,000 m³ Test plant in 2010 in Marstal
  - 70,000 m³ Full-scale test plant 2012 in Marstal
  - 62,000 m³ Full-scale test plant 2014 in Dronninglund

- Commercially, without subsidy, new floating cover
  - 125,000 m³ Gram district heating 2015
  - 200,000 m³ in Vojens district heating 2015
  - 70,000 m³ in Toftlund district heating 2017
  - 150,000 m³ in Løgumkloster district heating 2017/18

Several more in the pipeline, may be 100 in 2025
CHILLED WATER STORAGES, REDUCING THE DAILY COOLING PEAKS

- Steel tank, district heating technology
- Concrete chamber, water supply technology, e.g. under new road in Carlsberg city
- Cold water storage, heat storage pit technology
- Ground source cooling (ATES)
## Economy of Scale for Hot Water Storages

### EUR/MWh Heat Storage Capacity

<table>
<thead>
<tr>
<th>Description</th>
<th>Capacity</th>
<th>Economy</th>
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<tbody>
<tr>
<td>One family house, 0.16 m³</td>
<td>300,000</td>
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</tr>
<tr>
<td>Large building, 4 m³</td>
<td>40,000</td>
<td></td>
</tr>
<tr>
<td>DH tank, 160° C</td>
<td>7,000</td>
<td></td>
</tr>
<tr>
<td>DH tank, &lt; 95° C</td>
<td>4,000</td>
<td></td>
</tr>
<tr>
<td>Storage pit, 150,000 m³</td>
<td>800</td>
<td></td>
</tr>
<tr>
<td>Pit alone, 100,000-200,000 m³</td>
<td>500</td>
<td></td>
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<tr>
<td>Marginal extension of the pit</td>
<td>200</td>
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- Sources: Henrik Lund and Ramboll
THE VARIABLE COST OF HEAT PRODUCTION DEPENDS ON ELECTRICITY PRICES, GRAM (EXCLUDING TAXES)
THE ELECTRICITY CONSUMPTION FOR DH RESPONDS TO THE ELECTRICITY PRICES
DH MINUS 1,7 MW\textsubscript{ELEC} SMALL HEAT PUMPS – IT’S LIKE A VIRTUAL BATTERY
THE HEAT STORAGE BEHIND THE VIRTUAL BATTERY
FOR THIS PERIOD 350 MWH STORAGE IS NEEDED
QUESTIONS & ANSWERS

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