Simulation based assessment of storage integration & operation in the district heating network of Aarhus

THE READY PROJECT

Resource Efficient cities implementing ADvanced smart citY solutions

Objectives:

• Demonstrate new solutions for CO2 neutral districts:
  – Retrofitting
  – New solutions for LTDH
  – Storage solutions for flexible combined energy grids
  – Electricity and water efficiency
Temperatures:
- Transmission grid: 120-50°C
- Distribution grid: 70-40°C

Total Energy demand 4.5GWh/y

CHP Boilers (oil, electric and biomass)
Waste incineration
Industrial waste heat

http://transmissionsnet.varmeplanaarhusapps.dk/
CASE STUDY OF AARHUS

• **Scenario1:** Impact of retrofitting
  Impact of different retrofitting shares (10%-50%-100%) of the building stock before 1972 on the heat load and network return temperature.

• **Scenario2:** Integration & operation of centralised / decentralised storages.

• **Scenario3:** Integration & operation of alternative heat supply units (seawater HP and waste heat producers).
CASE STUDY OF AARHUS - CHALLENGES

• City densification +4.7% by 2030

• Morning peaks
**SCENARIOS DESCRIPTION**

*Sc2a (REFERENCE SCENARIO):* Storage 1: Price strategy

*Sc2b:* Storage 1: Price strategy
Storage 2: Peak strategy

*Sc2c:* Price/Peak strategy

*Sc2d: Sc2c +4,8% heat demand*
**SCENARIOS DESCRIPTION**

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Storage 1: Price strategy

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Price/Peak strategy

**Sc2d:**
Sc2c +4.8% heat demand
**SCENARIOS DESCRIPTION**

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**Sc2d:** Sc2c +4.8% heat demand
CONTROL STRATEGIES

**Price based Strategy**

**Peak based Strategy**
OPTIMIZATION TOOL – OPTIVAR

(Optimised variables)
Optimization of the scheduling of all supply units and storages on hourly basis (Mixed Integer Linear Programming)

Inputs

Demand data:
- Heat load

Supply data:
- Heat plants characteristics
  Storages characteristics
- Operation costs
- Priorities
- Specific constraints

Optimisation tool

Objective function:
- Minimisation of costs
- Maximisation of profit

Set of constraints:
- Balance constraints
- Operational constraints

Outputs

Operation profiles:
- Operation profiles
- Fuel/electricity consumption

Economic costs breakdown:
- Operational costs of components
- Total cost of the system

Example of plant scheduling

![Graph showing plant scheduling](chart.png)
### RESULTS – HEAT SUPPLY TO THE NETWORK

<table>
<thead>
<tr>
<th>Storage 1: 2000 MWh Storage discharge</th>
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</thead>
<tbody>
<tr>
<td>Storage 2: 768 MWh Storage discharge (Scenario 2b) or decentralised storages discharge (Scenario 2c &amp; Scenario 2d).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Heat supply to network (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario a</td>
<td>45.9%</td>
</tr>
<tr>
<td>Scenario b</td>
<td>58.9%</td>
</tr>
<tr>
<td>Scenario c Price strategy</td>
<td>59.9%</td>
</tr>
<tr>
<td>Scenario c Peak strategy</td>
<td>58.9%</td>
</tr>
<tr>
<td>Scenario d Price strategy</td>
<td>61.3%</td>
</tr>
<tr>
<td>Scenario d Peak strategy</td>
<td>61.3%</td>
</tr>
</tbody>
</table>

- CHP
- Electric boiler
- Waste incinerator
- Waste incinerator
- Biomass boiler
- Waste incinerator & biomass boiler
- Storage 1
- Storage 2
RESULTS – STORAGE CYCLES

![Diagram showing storage cycles]

- Storage 1
- Storage 2

- Sc a
- Sc b
- Sc c Price strategy
- Sc c Peak strategy
- Sc d Price strategy
- Sc d Peak strategy
RESULTS – STORAGE CYCLES

Bar chart showing total operational costs (DKK) and savings (DKK) for different scenarios:
- Sc a
- Sc b
- Sc c - Price Strategy
- Sc c - Peak Strategy
- Sc d - Price Strategy
- Sc d - Peak Strategy

The chart indicates a comparison of costs and savings across these scenarios.
RESULTS – STORAGE CYCLES

![Bar chart showing investment costs (DKK) and payback time (years) for different strategies.]

- **Sc b**
- **Sc c - Price Strategy**
- **Sc c - Peak Strategy**
- **Sc d - Price Strategy**
- **Sc d - Peak Strategy**

**Investment costs (DKK)**
- **Sc b**: 30 million DKK
- **Sc c - Price Strategy**: 50 million DKK
- **Sc c - Peak Strategy**: 50 million DKK
- **Sc d - Price Strategy**: 50 million DKK
- **Sc d - Peak Strategy**: 50 million DKK

**Payback time (years)**
- **Sc b**: 4 years
- **Sc c - Price Strategy**: 4 years
- **Sc c - Peak Strategy**: 4 years
- **Sc d - Price Strategy**: 4 years
- **Sc d - Peak Strategy**: 4 years
MAIN CONCLUSIONS

• Centralised storage / Peak strategy:
  – ¼ of the energy supplied to the network
  – Negligible rise of operational costs

• Decentralised storages / both strategies:
  – Small contribution to the heat supplied to the network
  – Decrease of more 7% of operational costs

• Decentralized storages are more costly, centralized storages allow more savings on the long term.

• Scenarios with price strategy more expensive than scenarios with peak strategy.

➔ Centralised/decentralised storages and the operation strategies depends on the characteristics of the heat demand and on the challenges that should be addressed.
Thank you for your attention