Power-to-Heat in Industry

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Content

- Dutch energy system
- Power to Heat
- Flexibility options
- Electrification options
- Summary
A sustainable Dutch energy system

Dutch final energy use 2015
- excluding feedstock
- excluding transport

Source: CBS
Why & when P2Heat?

• Flexibility
  – Making use of increased volatility of electricity market
  – Response time - short
  – Operating hours – relatively low
  – Allowable investment costs – low

• Electrification
  – Making use of electricity as energy carrier for your processes
  – Response time – less an issue
  – Operating hours – high (base load)
  – Allowable investment costs – higher
Flexibility options
Flexibility
- Direct electrical heating -

• Characteristics
  – Electrode boilers
  – Commercially available
  – Fast response time (< 1 minute)
  – High steam pressures

• Economics

Up to 60 MW in 1 unit

Price duration curve 2030
Direct electrical heating
- Business case -

• Marginal cost comparison
• Efficiency for heating
  – Gas = 100%
  – Electric = 100%
• Room for investment based on simple pay back time of 3 years
• Investment costs electric boiler 60 – 200 k€/MW (Source: Energinet)

<table>
<thead>
<tr>
<th>Gas price (€/m³)</th>
<th>Gas price (€/GJ)</th>
<th>Operating hours</th>
<th>Room for investment (k€/MW)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>6</td>
<td>164</td>
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Flexibility
- Flex CHP -

- Electricity system requires more flexible power generation
- Industry needs reliable and affordable steam/heat
- CHP with heat storage offers operational flexibility
  - Decoupling heat and power production (for a limited time)
  - Deliver electricity during high prices
  - Operate CHP at highest efficiency
  - High-temperature heat storage for reliable heat delivery
- Examples in operation
  - Agriculture: gas engine + hot water buffer
  - District heating: CHP + hot water buffer
Industrial CHP with HT-heat storage

• Heat storage technologies
  – Sensible heat storage
    – Ceramics 1000°C
    – Molten salts 550°C
    – Steam accumulator 250°C
  – Latent heat storage
    – Phase Change Materials (PCM)
    – Commercially available 80°C
    – Under development 100 - 250°C

• Heat storage capacity 10 GJ – 10 TJ
• Thermal power >> 1 MW
CHP + Heat storage
- Business case -

• Profits
  – Price level differences in E-market

• Investments
  – Storage system & integration
  – PCM costs ≈ 750 €/GJ
  – Optimize the thermal storage capacity

• Operating hours
  – Requirements for CHP ramp-up / ramp-down
  – Maximize number of charge-discharge cycles
  – Accept small E-price differences in flexible operation to increase the number of cycles

• Pay back time
  – Work in progress
Electrification options
Electrification
- Direct electrical heating -

- Electrode boilers (as with flexibility)
- Infrared heating
- Induction heating
- Microwave heating
- Resistive heating

- Business case not feasible for base load operation (for the near future) based on marginal energy costs

- Other drivers
  - Product quality
  - Safety
  - Process control
  - Producing other products
  - Scale of operation
## Electrification - Electrical heat pumps -

<table>
<thead>
<tr>
<th>Steam boiler</th>
<th>Heat pump</th>
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<td>Steam demand (kton/yr)</td>
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<tr>
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<td>Electricity use (GWh/yr)</td>
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<td>Steam price (€/ton)</td>
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<td>Electricity price (€/MWh)</td>
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<td>Primary energy use (TJ/yr)</td>
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<td>Primary energy use (TJ/yr)</td>
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**Electrical heat pumps**  
- Business case -

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<td>0.4</td>
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</table>

- COP = 4  
- Simple pay back time = 3 years

Typical investment for industrial heat pumps is **250 – 500 k€/MW**, depending on size and temperature conditions, excluding integration.
Electrical heat pumps
- Technology -

- **Vapor compression cycles**
  - Reversed Rankine cycle
  - Phase transition – limited operating window
  - High efficiency & heat transfer
  - Working media like CO$_2$, NH$_3$, hydrocarbons, H$_2$O, R245fa, ...

- **Gas cycles**
  - Stirling, Brayton cycle
  - Wide operating window
  - Somewhat lower efficiency & heat transfer
  - Working medium Helium, Air, ...
Electrical heat pumps
- Developments -

- **T\_source** = 55°C
- **T\_sink** = 150°C
- **Q** = 150 kW
- Ongoing

- **T\_source** = 55°C
- **T\_sink** = 120°C
- **Q** = 200 kW
- COP = 3.6

- **T\_source** = 50-120°C
- **T\_sink** = 100-180°C
- **Q** = 10 kW
- Exp ongoing
Electrical heat pumps
- Technology needs -

- Higher operating temperatures
- Cost reduction
- Integration aspects
- Increase thermal power output
- Higher temperature lifts
- Increase efficiency
- New working media
- New thermodynamic concepts
Summary Power-to-Heat

- Power-to-Heat can provide a solution for industry to cope with a flexible energy system with an increasing share of electricity.

- **Flexibility**
  - Direct heating
  - Heat storage
  - Business case challenging due to limited operating hours

- **Electrification**
  - Long term option for high-temperature heat (> 250°C) is direct heating
    - Electricity price < gas price
    - Other drivers
  - Electrical heat pumps for heat supply up to 250°C
    - Business case within reach
    - Technology developments ongoing to extend working range and reduce costs
Thanks for your attention

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