Power-to-Heat in Industry

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ECN
Your energy. Our passion.

Power-to-Heat in Industry

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Den Bosch
5 October 2016

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- Dutch energy system
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- Flexibility options
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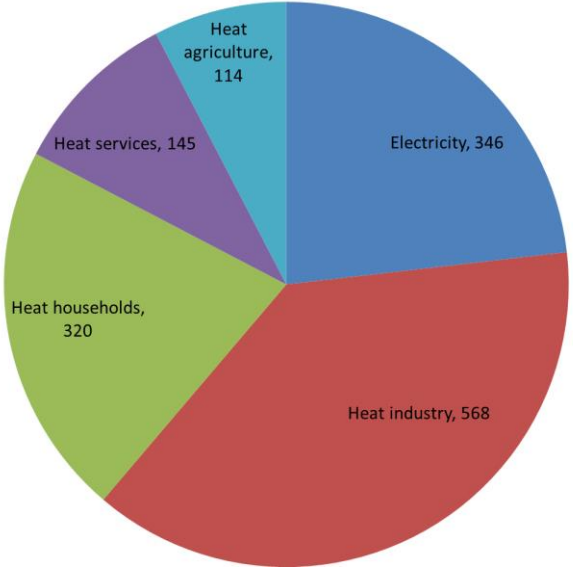
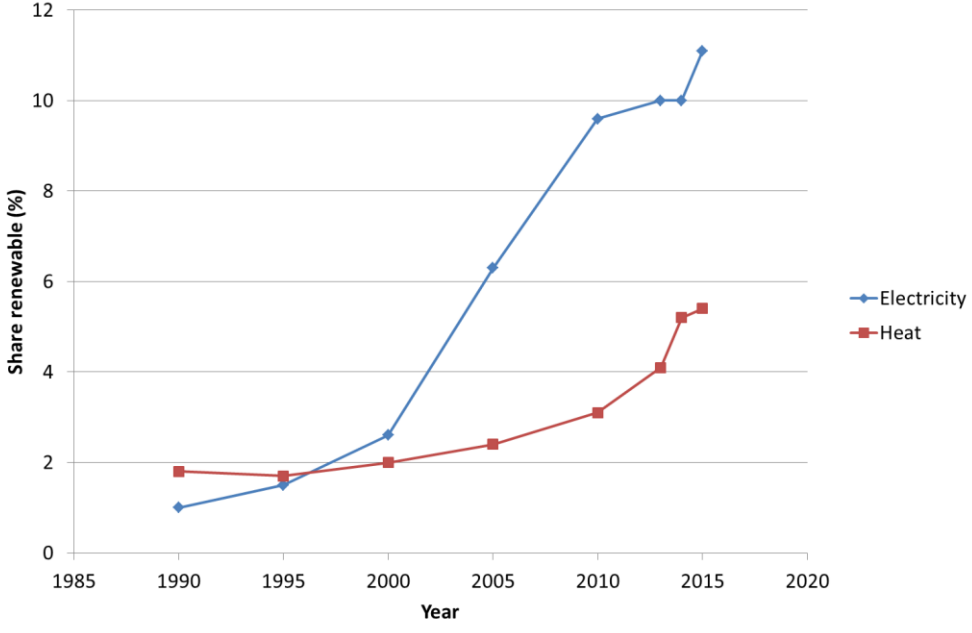
A sustainable Dutch energy system





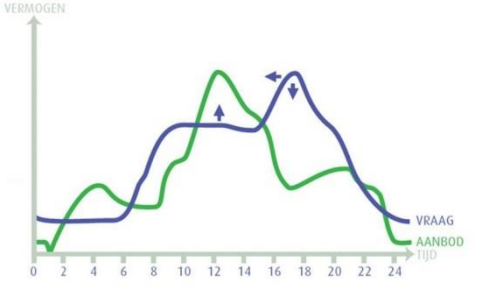
Dutch final energy use 2015

- excluding feedstock
- excluding transport

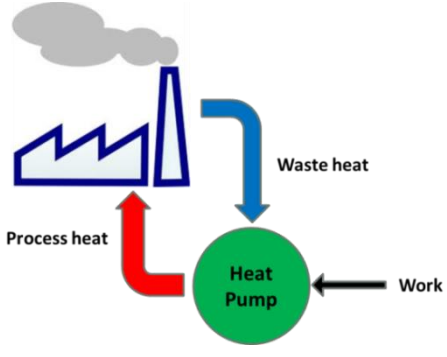
Source: CBS

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

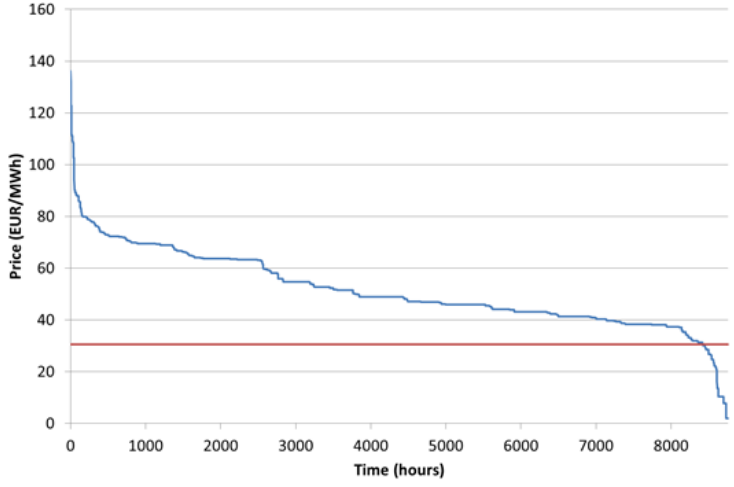
Flexibility

- Direct electrical heating -

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

Up to 60 MW in 1 unit

- Economics



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)

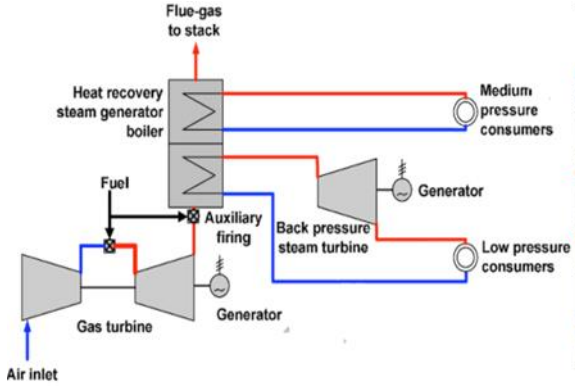
Gas price (€/m³)	Gas price (€/GJ)	Operating hours	Room for investment (k€/MW)
0.20	6	164	6
0.26	8	298	11
0.33	10	617	20
0.4	12	2848	53

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

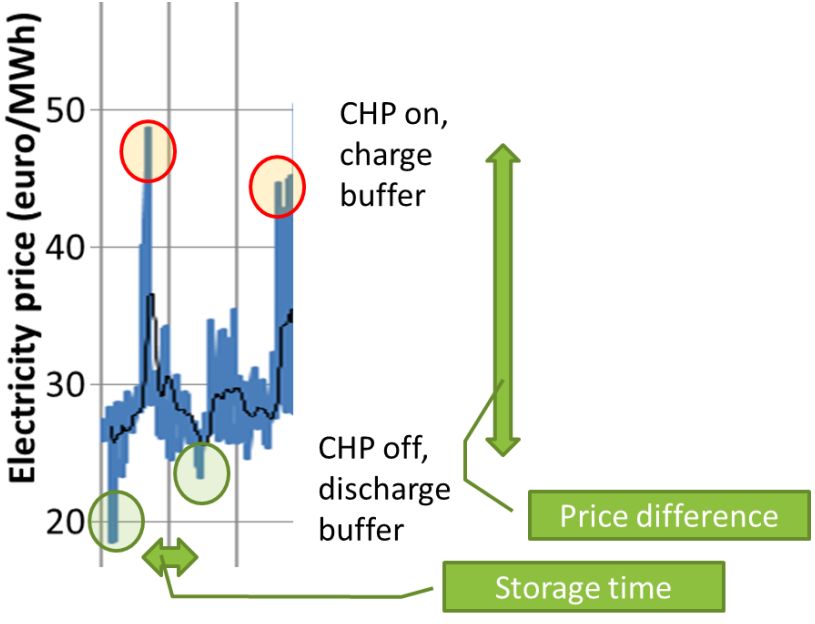
Industrial CHP with HT-heat storage

- 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

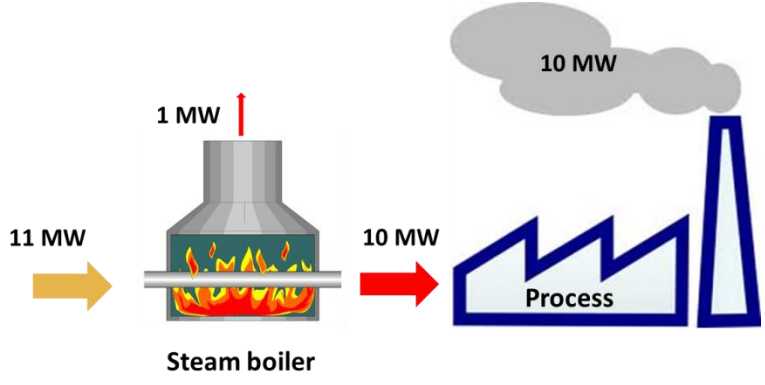
- Direct electrical heating -

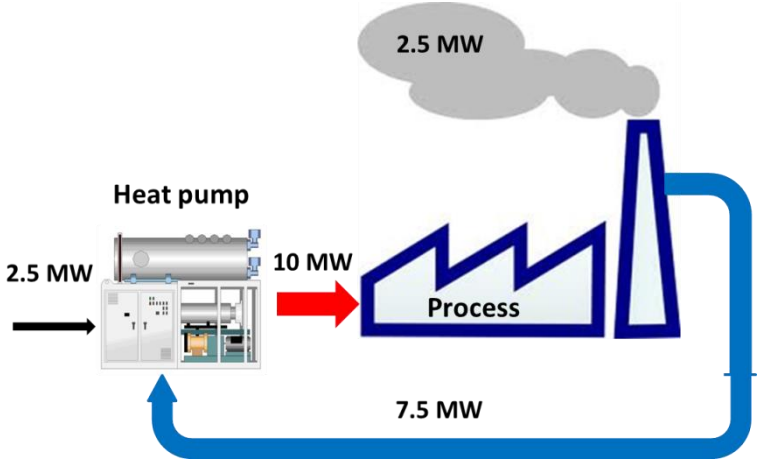
- Electrode boilers (as with flexibility)
- Infrared heating
- Induction heating
- Microwave heating
- Resistive heating

- 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 -

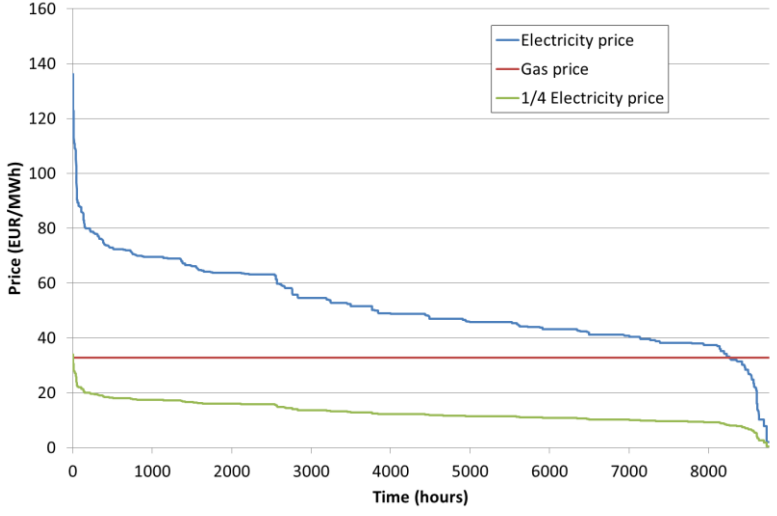




Steam boiler		Heat pump	
Steam demand (kton/yr)	128	Steam demand (kton/yr)	128
		Electricity use (GWh/yr)	20
Steam price (€/ton)	20	Electricity price (€/MWh)	50
Primary energy use (TJ/yr)	317	Primary energy use (TJ/yr)	174
Energy costs (M€/yr)	2.6	Energy costs (M€/yr)	1.0

Electrical heat pumps
- Business case -

Gas price (€/m³)	Gas price (€/GJ)	Operating hours	Room for investment (k€/MW)
0.20	6	8653	231
0.26	8	8750	420
0.33	10	8760	609
0.4	12	8760	798

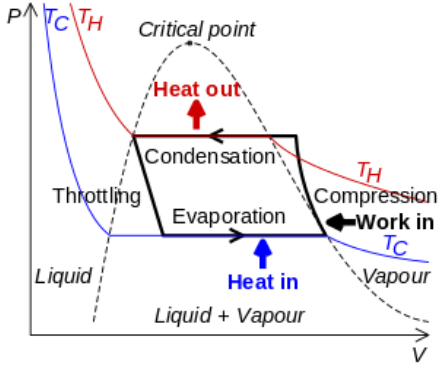


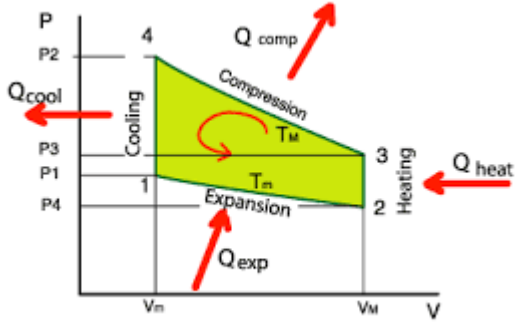
- COP = 4
- Simple pay back time = 3 years

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

Electrical heat pumps
- Technology -

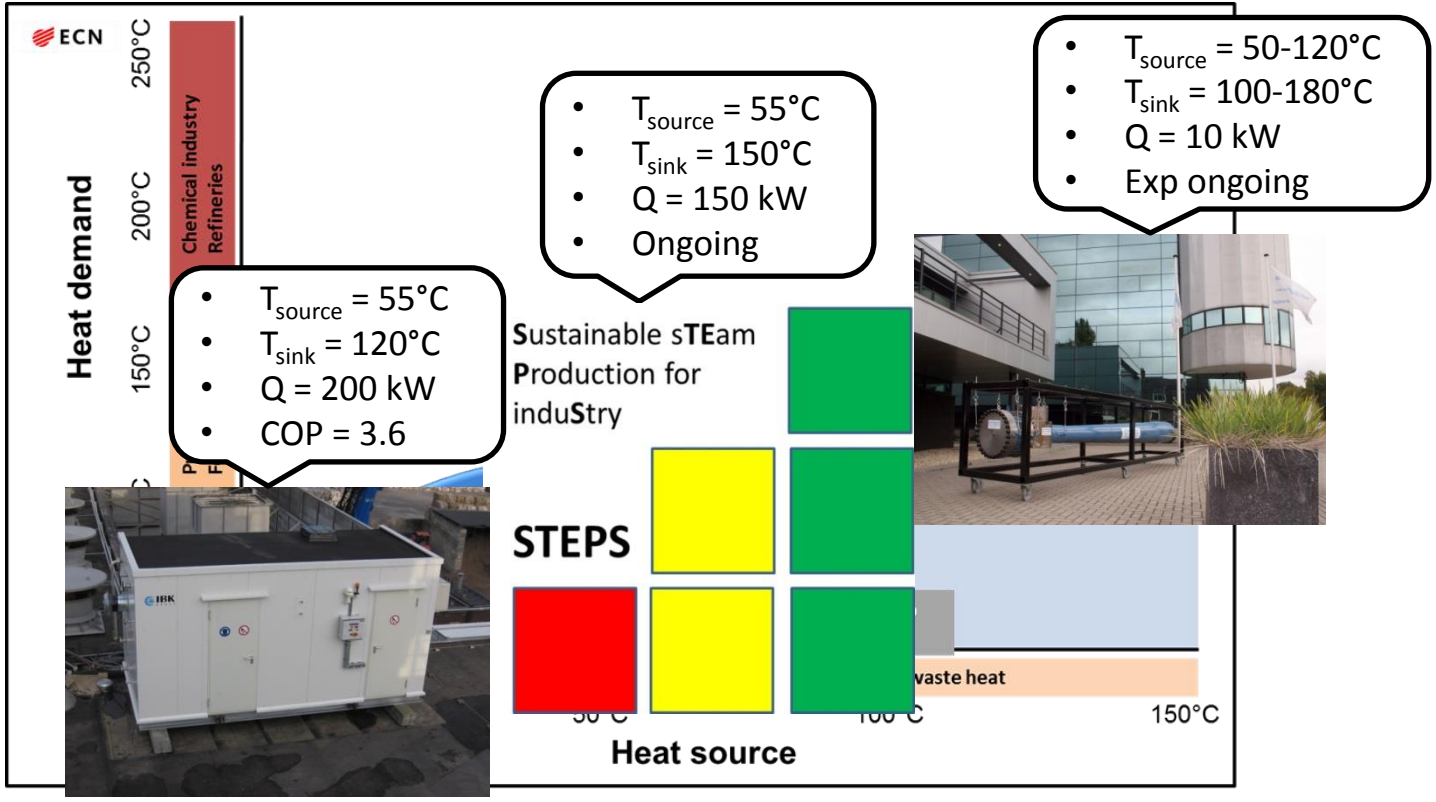
- Vapor compression cycles
  - Reversed Rankine cycle
  - Phase transition – limited operating window
  - High efficiency & heat transfer
  - Working media like CO_2, NH_3, hydrocarbons, H_2O, R245fa, ….
- Gas cycles
  - Stirling, Brayton cycle
  - Wide operating window
  - Somewhat lower efficiency & heat transfer
  - Working medium Helium, Air, …





Electrical heat pumps

- Developments -

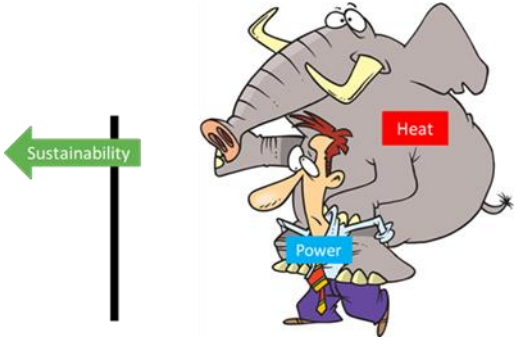


Electrical heat pumps
- Technology needs -

- 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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