

High Temperature Heat Pumps in Dutch Industry

Market Potential and Challenges in Implementation

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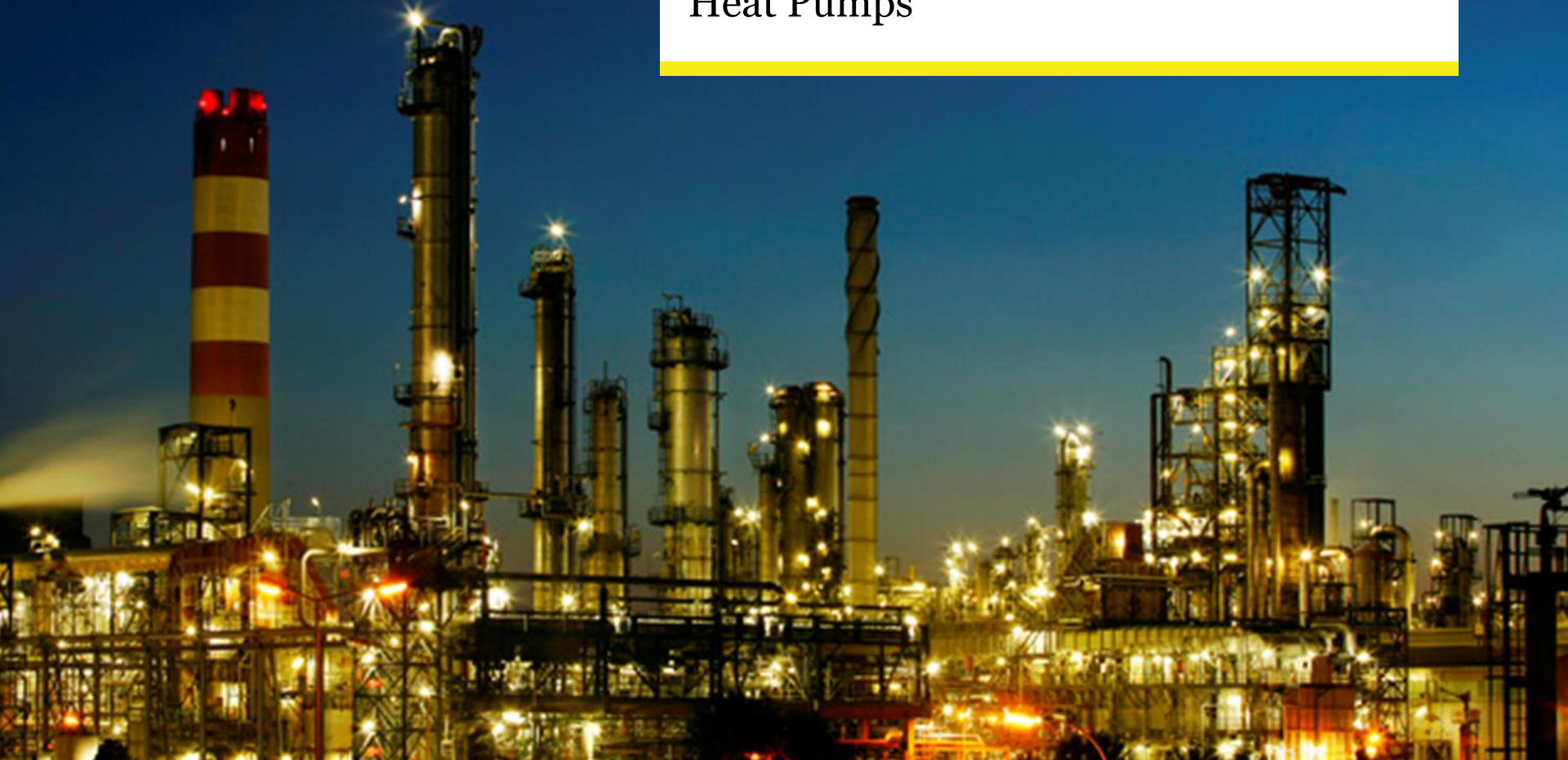
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Heat Pumps - Copenhagen*

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Presentation Outline

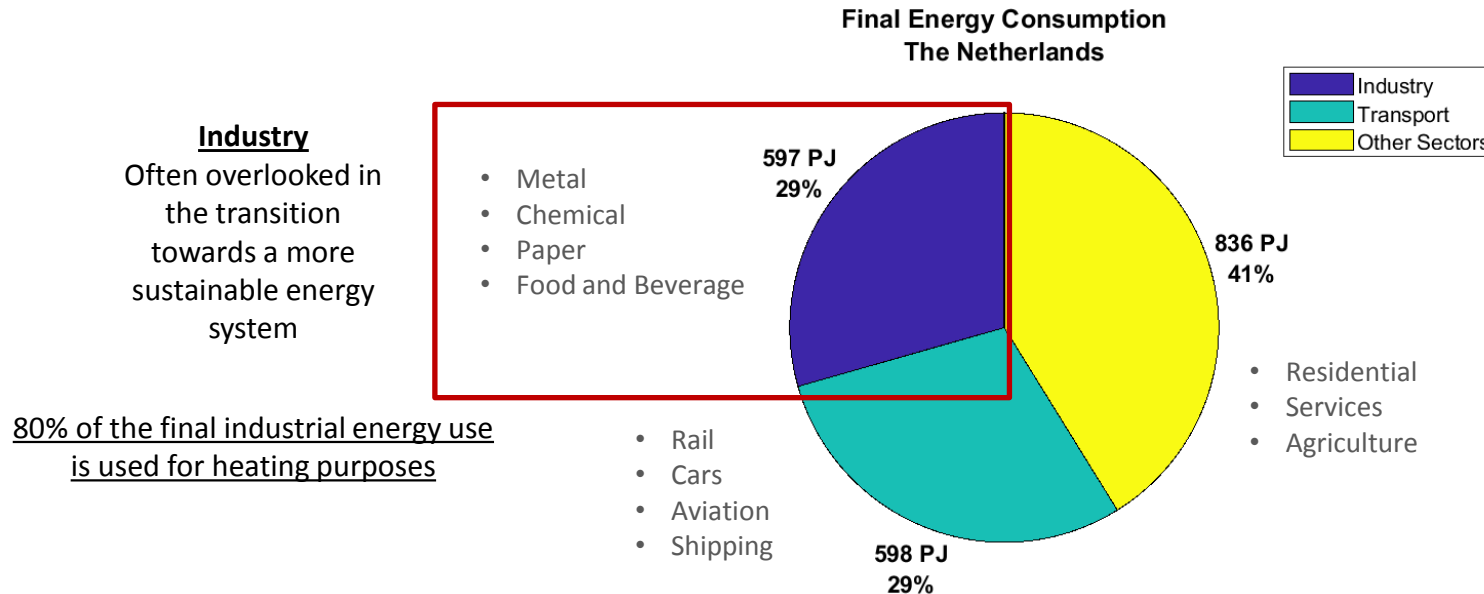
- Industrial Energy use in the Netherlands
- Requirement for active heat recovery technologies (heat pumps) in industrial processes
- Results of industrial heat pump market study
- Challenges in implementing heat pumps in practice

Industrial Energy Usage & Case for Heat Pumps



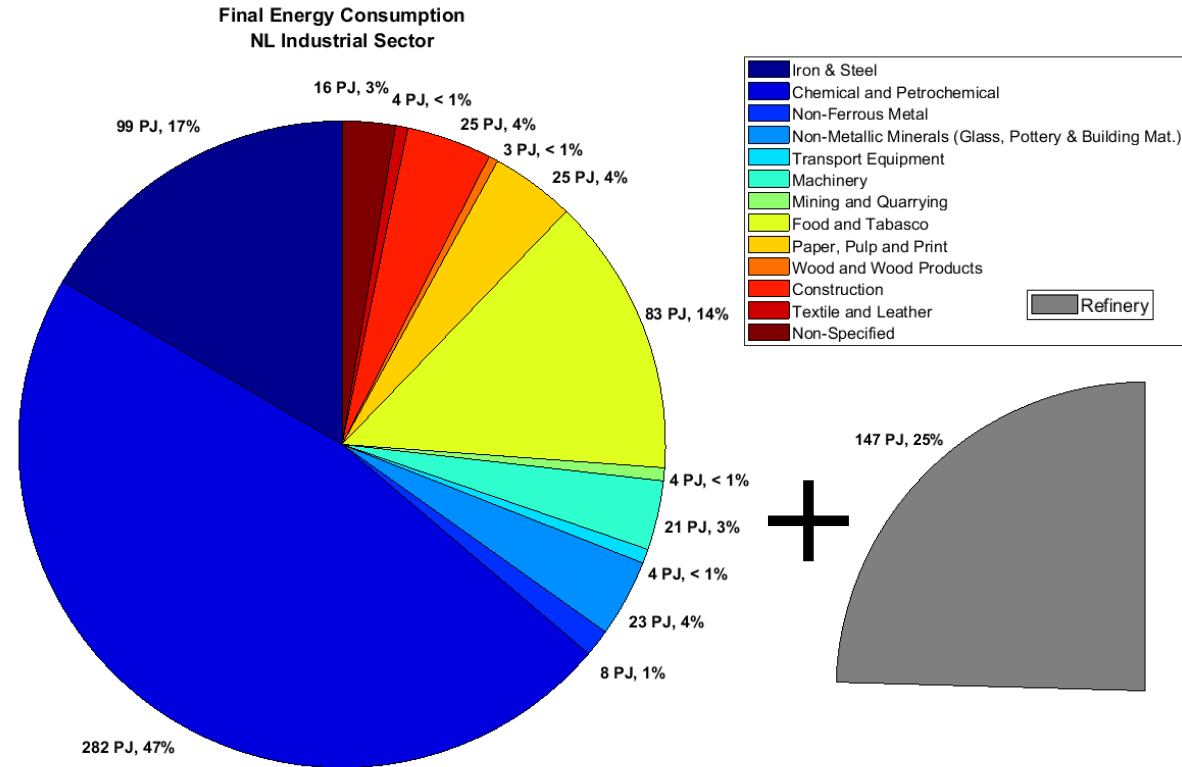
Introduction

- Requirement for a transition to a sustainable energy system
 - Move away from our reliance on fossil fuels
- Sustainable energy system can be achieved through a combined approach:
 - Transition to renewable energy sources - Wind, solar, etc.
 - Reductions in final energy consumption (FEC) through energy efficiency measures



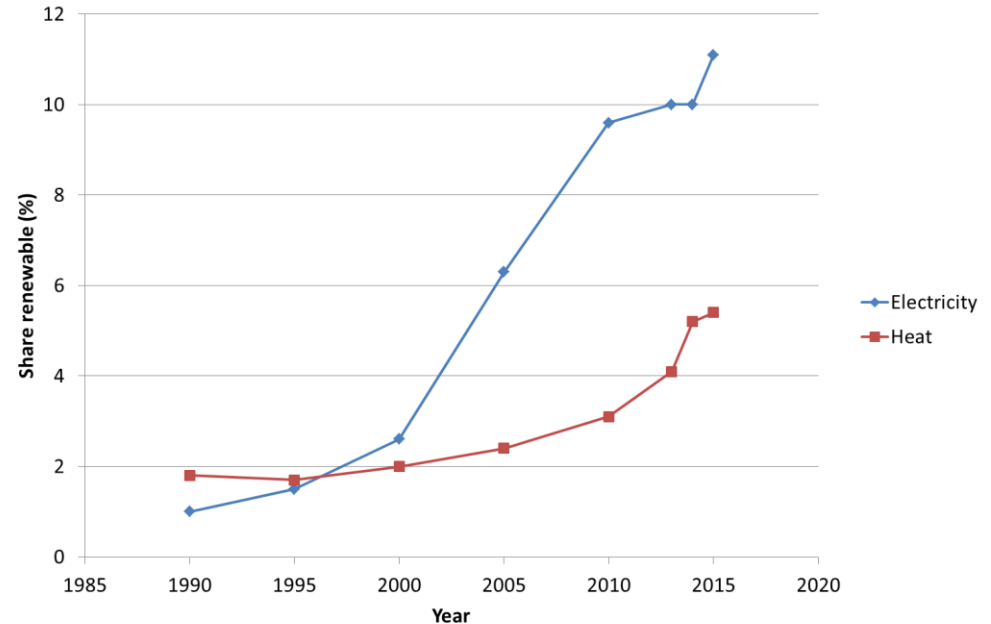
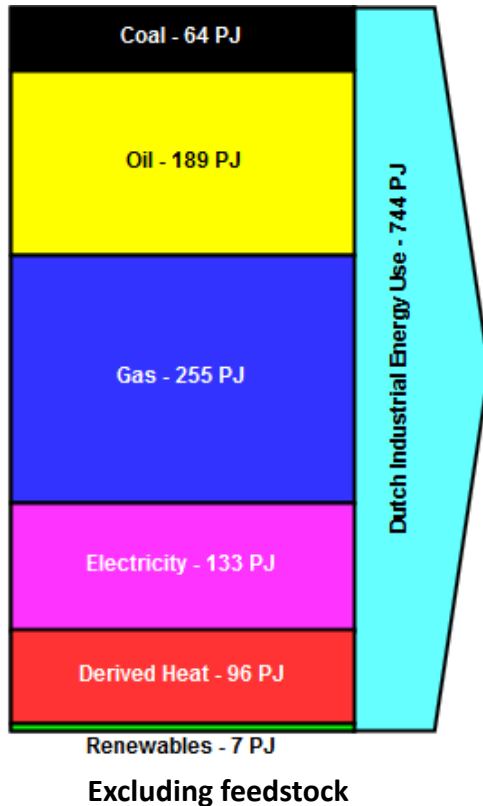
Dutch Industry

- Final energy consumption
 - 597 PJ
- Energy use dominated by selected sectors
 - Chemical and petrochemical
 - Iron and steel
 - Food and beverage
- Refinery sector is the additional piece of the pie
 - Similar processes to the chemical sector
- Total combined energy consumption
 - 744 PJ



Transitioning to Sustainable Energy Sources

Current Industrial Energy Mix (Incl. Refinery)

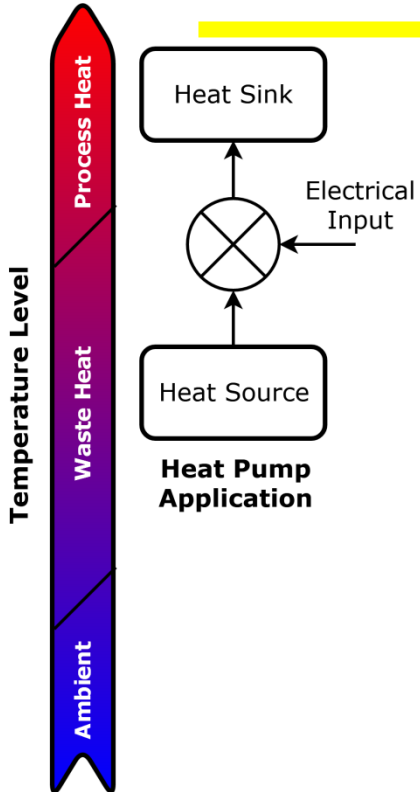


- Share of renewables in electricity system growing at greater rate than heating system
- Increasing shares of renewable electricity enable alternate heating technologies

Utilising Waste Heat in Industry

- Heat is the primary driver for a number of industrial processes
 - Low temperature after use in the process → heat is discarded to ambient
- Waste heat is an untapped energy source
 - Recovery can lead to large reductions in primary energy consumption
- Technologies for waste heat recovery – Active or Passive:
 - Passive: Heat is reused directly in the process
 - Active: Heat is converted to a higher temperature or another form of energy (electricity, cold)
- Limits to the amount of passive heat recovery
 - Industrial processes designed for passive reuse of waste heat
 - Elaborate heat exchanger networks
- Integration of active technologies is essential to fully exploit the potential for waste heat in industry

Heat Pumps in Industrial Processes

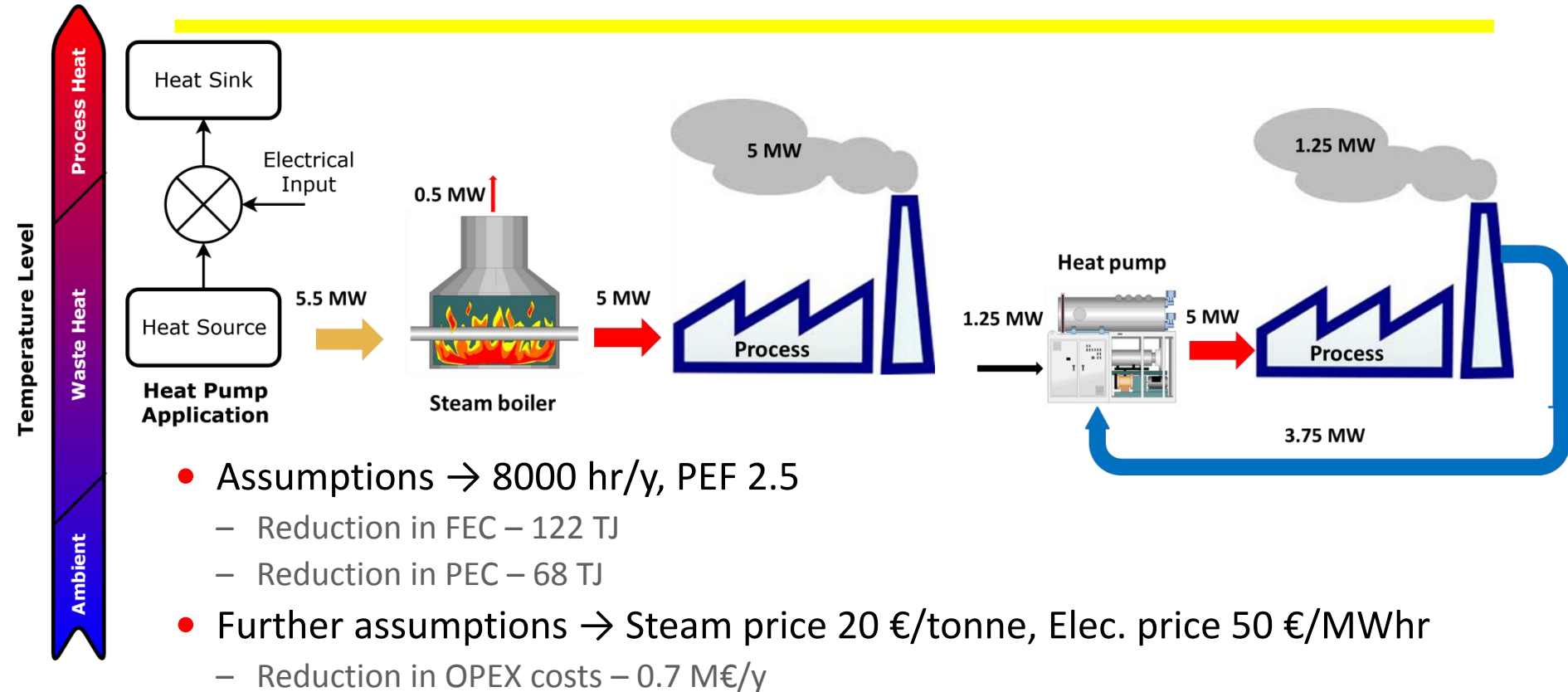


- Heat pump is an active technology able to upgrade the temperature of a waste heat source with electrical energy input
 - Performance limited by thermodynamic laws:

$$COP_{THEORETICAL} = \frac{T_{SINK}(K)}{T_{SINK}(K) - T_{SOURCE}(K)} = \frac{\dot{Q}_{SINK}}{\dot{W}_{IN}}$$

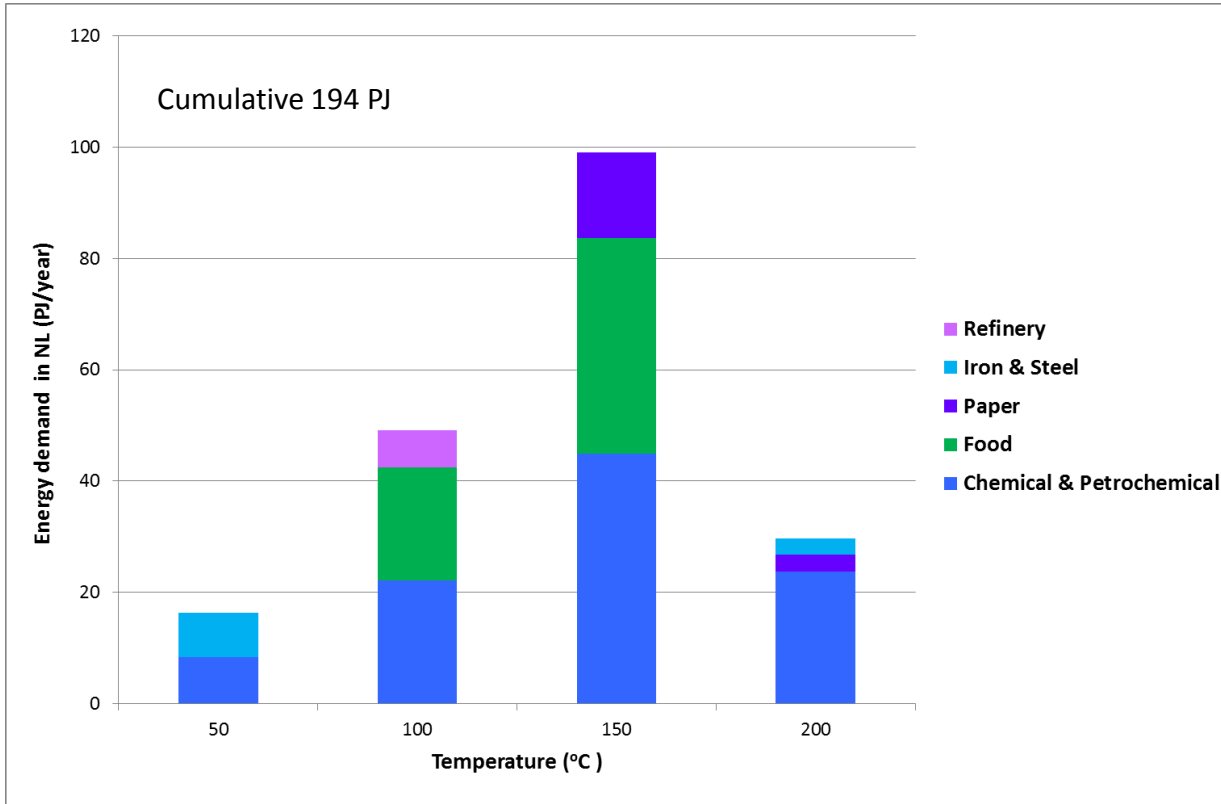
- Growing drivers for the implementation for heat pumps
 - Take advantage of renewable electricity and waste heat
 - Electrical input a factor of 2 – 5 lower than process heat output
 - Falling CAPEX
 - Increases in technology development
 - Ability to operate at high temperatures
 - Low payback times

Heat Pump in Industrial Process



Process Heat Demand

Dutch Industry



- Heat pumps well suited to deliver process heat temperature below 200°C
 - Paper and pulp industry (25 PJ)
 - Food and beverage industry (83 PJ)
 - Chemical industry (282 PJ)
 - Refinery industry (147 PJ)
- Focus on these sectors within market studies
 - 72% of the industrial energy usage
 - Heat <200°C accounts for approximately 194 PJ
 - 36% of energy consumption in these sectors, 26% of total industrial consumption

Determining the Heat Pump Market Methodology

- Bottom up approach for determining the heat pump market
- Focus on sectors which have high heating requirements at $T < 200^{\circ}\text{C}$
- Collate generalized information from processes within these industries
 - Partial process heat and waste heat information
 - Temperature levels
 - Heat quantities
 - Media contained
 - Focus on heat streams suitable for heat pump utilization
 - Determine typical production rates and operating hours for processes
- Couple with production statistics from PRODCOM or industry bodies
- Verification utilizing top down approach
 - Energy usage statistics - EUROSTAT

Case Study – Heat Pump Assisted Distillation Column

- Production of Styrene through the dehydrogenation of ethylbenzene
 - Energy usage of approx. 11 PJ in NL

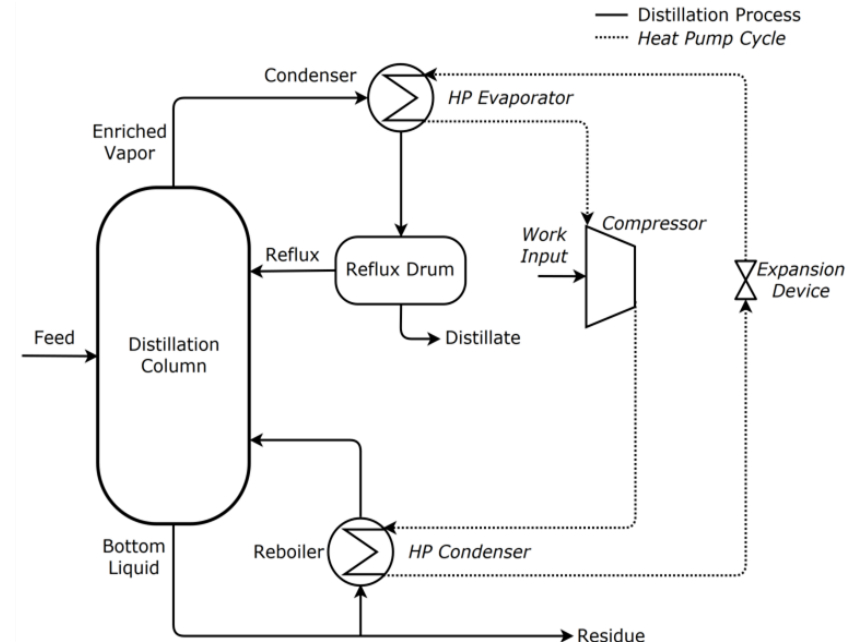
Reboiler Temperature	102°C
Condenser Temperature	45°C
Pinch Temperature	90°C
Reboiler Duty	2.2 GJ/tonne
Condenser Duty	1.7 GJ/tonne
Typical Plant Capacity	200 kT/a
Columns in NL	5

- Calculation of the thermal performance through
 - Estimation based on Carnot limitations

$$COP_{THEORETICAL} = 0.5 \frac{T_{SINK}(K)}{T_{SINK}(K) - T_{SOURCE}(K)} = \frac{\dot{Q}_{SINK}}{\dot{W}_{IN}}$$

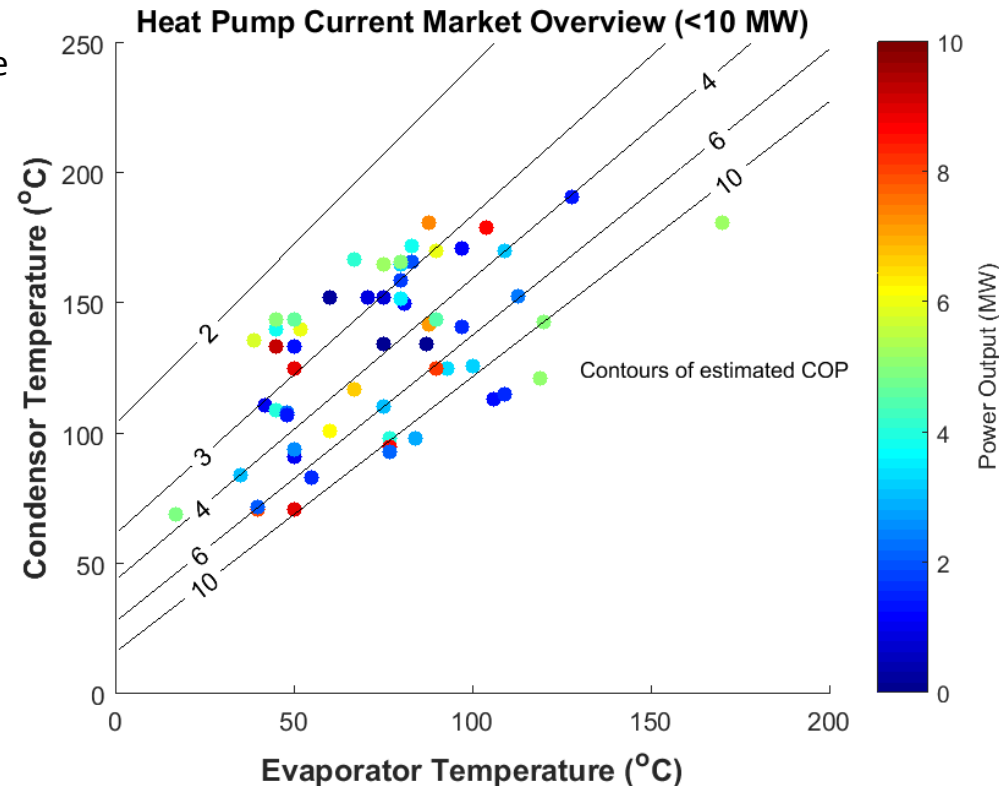
COP	Reduction in FEC (PJ)	Reduction in PEC (PJ)
3.3	1.62	0.56

- Total in database - 57 distillation columns in chemical industry covering manufacture of 19 chemical products



NL Heat Pump Market Overview

- Overview of the NL industrial heat pump market can be achieved through use waste heat and process heat signatures and quantities
- Key parameters:
 - HP evaporator (source) temperature
 - HP condenser (sink) temperature
 - HP thermal output power
- Key figures:
 - Total cumulative potential:
2.4 GW
 - Number of individual applications:
108
 - Total possible heat pump installations:
340
 - Average condenser power:
7.0 MW
 - Reduction in FEC/PEC:
45 PJ / 15 PJ

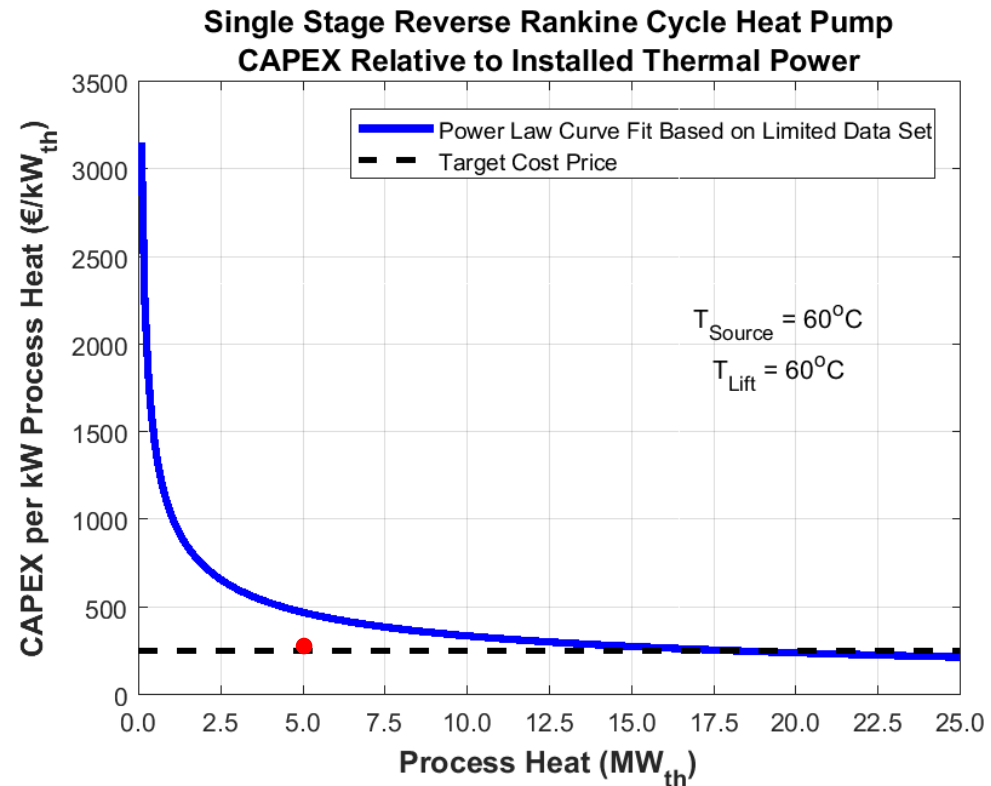




Challenges in Implementation

Challenging Economics

- Low cost of energy as well as process utility equipment makes economics for heat pumps challenging
 - Cost target of $<200 \text{ €/kW}_{\text{th}}$ for heat pumps to be competitive
- Previous example:
 - 5 MW_{th}
 - Cost saving 0.7 M€/year
 - Payback time of 3 years $\rightarrow \text{CAPEX} = 210 \text{ €/kW}_{\text{th}}$
- Differing temperature conditions and thermal powers lead to differing business cases
 - Average condenser power of 7 MW
 - Higher frequency of occurrences of lower power machines $\rightarrow$ More challenging economics
- What about integration costs?
 - Limited electrical infrastructure on-site
 - No standard method for integration



Other Challenges

- Perceived risks as emerging technology
- Coupling to existing heat integrated plants
- Conservative energy efficiency targets
 - Limited subsidies for energy efficiency compared to renewable energy
 - Focus on process equipment or process techniques
- Energy is not the core business
 - But... changing due to customer demands
- Competing technological options
 - Government intervention

Summary

- Large industrial sector in the Netherlands
 - Energy use dominated by chemical, iron and steel, food and beverage and refinery sectors
- Growing driver for heat pumps in industry
 - Take advantage of renewable electricity generation and waste heat from processes
 - Suitable for delivering process heat temperatures up to 200°C
- Utilized a bottom up approach to determine the industrial heat pump market in NL
 - Potential 2.4 GW installed capacity over 340 installations
- Industrial heat pumps face a number of challenges preventing implementation
 - High capital costs combined with low energy prices
 - Perceived technology risk and conservative energy efficiency targets

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