Webinar: 12 September, 2022

IMPLEMENTATION OF HEAT PUMPS IN DISTRICT HEATING SYSTEMS

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AGENDA

1. Introduction of PlanEnergi
2. General information about heat pumps
3. Technical aspects
4. Economic aspects
5. Examples of heat pumps in Danish DH systems
6. Discussion

WHO IS PLANENERGI?

- Consulting engineering firm
- Over 38 years of
  sustainable and renewable energy
- 49 employees
- Offices in:
  - Skoerping
  - Aarhus
  - Copenhagen
- Turnover 2021: 35 mio DKK
- Capital: 8.3 mio. DKK
- 11 teams with each one professional area
- A board with 8 members. Five from outside and 3 elected by the employees

- District heating
  - Master plans and basis for decision making
  - District heating expansions and conversions
  - Large-scale heat pumps
  - Excess heat
  - Solar District Heating
  - Thermal Energy Storages
  - Hydraulic and thermal analyses and optimization of networks
- Strategic Energy Planning
  - Mapping
  - Strategies
  - Action plans
  - Heat planning
- Biogas
- Spatial planning for PV-parks and wind turbines
- International research and development projects (IEA, Horizon etc.)

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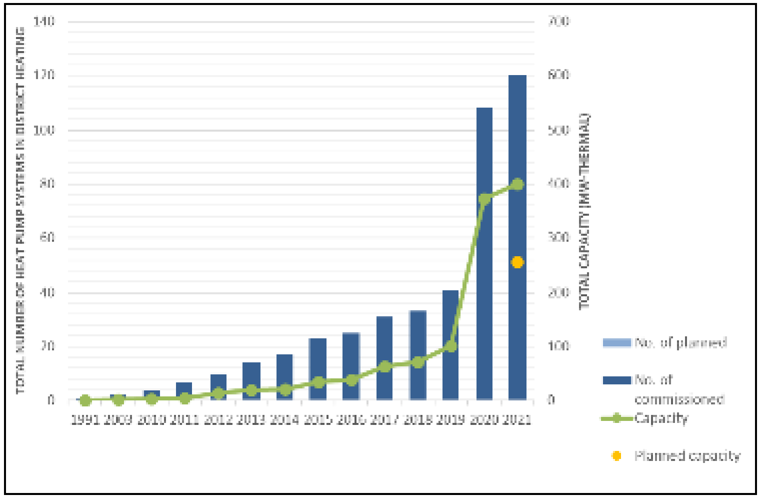
Heat pumps in the Danish district heating

Lowering of the taxation of power in 2019 made it boom:

- Total plants in operation: 120
- Total heat capacity: 400 MW



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Heat pumps in the Danish district heating

Drinking and ground water	5	7 MW
Sea water	3	9 MW
District Cooling	2	10 MW
Solar (thermal) cooling	6	9 MW
Flue gas	15	24 MW
Sewage water	4	32 MW
Waste heat	18	104 MW
Air	66	204 MW

TECHNICAL ASPECTS
Heat pump principle

Power supply

Heat source in
4 ^{o}C

Heat source out
0.5 ^{o}C

photo: Horfor A/S

District heating out
85 ^{o}C

District heating in
45 ^{o}C

$$\text{Coefficient of Performance (COP)} = \frac{\text{heat out}}{\text{electricity in}}$$

TECHNICAL ASPECTS
Heat pump principle

5 MW heating capacity
Heat source: sea water
Heat sink: District heating in Copenhagen

photo: Horfor A/S

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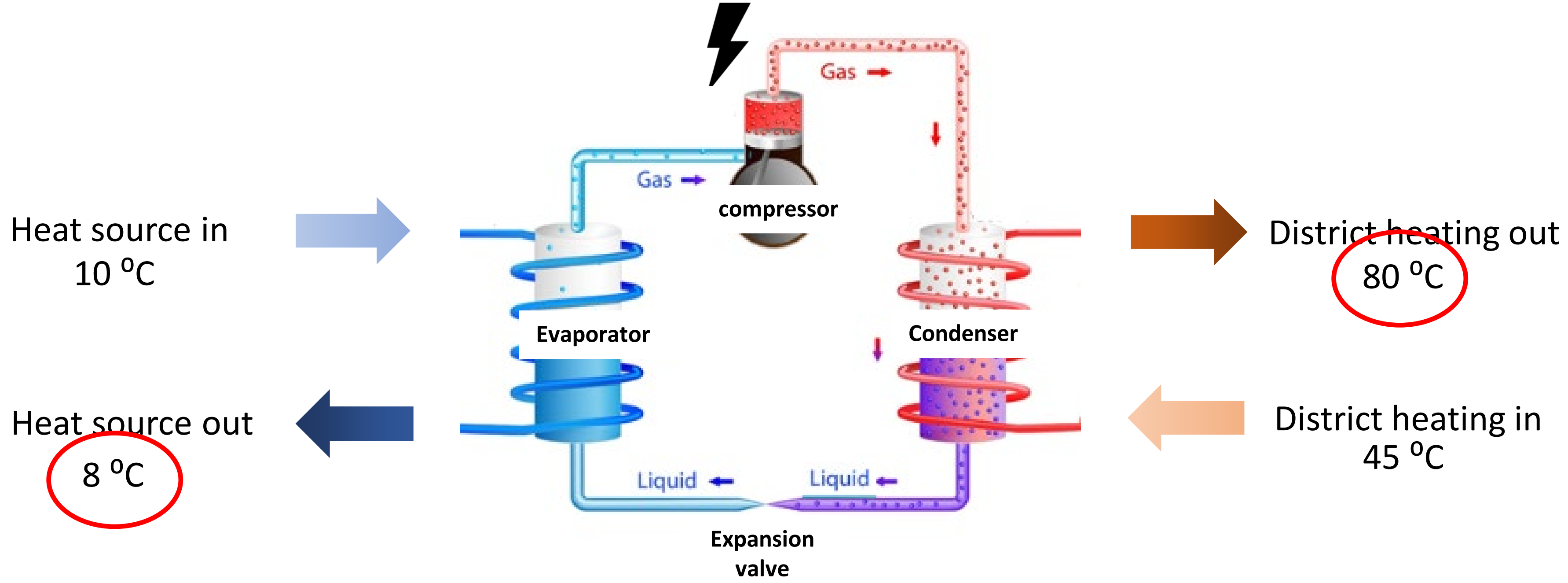
TECHNICAL ASPECTS
Heat pump technology

Vapour compression cycle



The same thermodynamic cycle as a refrigerator

Important for the COP:
Lower temperature difference → higher COP

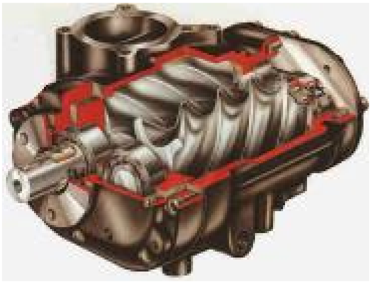
TECHNICAL ASPECTS

Heat pump components

- Compressor

capacity

piston

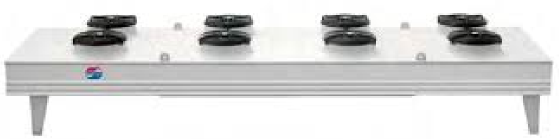


Screw

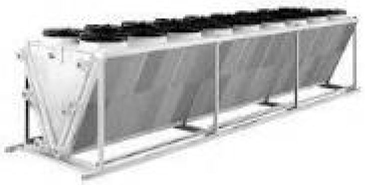
Centrifugal

- Evaporator

Plate heat exchanger
For liquid fluids



Flatbed for air



V-coil for air

TECHNICAL ASPECTS
Refrigerants

- Natural (Ammonia, CO_2 , propane, water, etc.)
- Synthetic/HFC/HFO (R32, R134a, R1234yf)

- ODP = Ozone depletion potential
- GWP = global Warming potential

- New HFO refrigerants
  - Synthetic, but low GWP
  - To some extend unknown side effects.

Impact of Refrigerants: Fact Sheet #1 (V.1.1.)

Real GWP: 20 years vs.100 years

Refrigerant	Type	Composition	GWP 100 years	"Real" GWP 20 years
R404A	HFC	44% R125 / 4% R134a / 52% R143a	4,200	6,600
R22	HCFC	100% R22	1,760	5,310
R407A	HFC	20% R32 / 40% R125 / 40% R134a	2,100	4,500
R410A	HFC	50% R125 / 50% R32	2,100	4,400
R407C	HFC	23% R32 / 25% R125 / 52% R134a	1,700	4,100
R134a	HFC	100% R134a	1,360	3,810
R448A (Solstice N40)	HFC/ HFO	26% R32 / 26% R125 / 21% R134a / 7% R1234ze / 20% R1234yf	1,400	3,100
R449A (Opteon XP40)	HFC/ HFO	24,3% R32 / 24,7% R125 / 25,7% R134a / 25,3% R1234yf	1,400	3,100
R449C (Opteon XP20)	HFC/ HFO	20% R32 / 20% R125 / 29% R134a / 31% R1234yf	1,200	2,900
R32	HFC	100% R32	704	2,530
R452B (Opteon XL55)	HFC/ HFO	67% R32 / 7% R125 / 26% R1234yf	710	2,100
R513A (Opteon XP10)	HFC/ HFO	44% R134a / 56% R1234yf	600	1,700
R454B	HFC/ HFO	68.9% R32 / 31.1% R1234yf	490	1,700
R450A (Solstice N13)	HFC/ HFO	42% R134a / 58% R1234ze	570	1,600
R744	Natural	CO_2	1	1
R600a	Natural	Isobutane	<1	<1
R290	Natural	Propane	<1	<1
R1270	Natural	Propylene	<1	<1
R717	Natural	NH_3	0	0
R718	Natural	H_2O	0	0
R729	Natural	Air	0	0

TECHNICAL ASPECTS

Heat sources

Braedstrup district heating

Air source

HOFOR, Copenhagen

Sea water

Other sources:

- Ground water
- Geothermal heat
- Sewage water
- Industrial waste heat
- Co-production of heating and cooling
- Flue gas

TECHNICAL ASPECTS
Technical challenges

- Power supply
- Stable heat source
  - Temperature variations
  - Fouling
  - Availability
- Temperature limitations
  - Sink: Maximum 85 C in forward temperature
  - COP decreases with high forward temperature
- Intelligent defrosting of air-sourced heat pump is difficult
  - COP decreases with low source temperatures

Questions?

ECONOMIC ASPECTS

Factors that influence heat pump economy:

- Investment costs
- Loan parameters (interest rate, loan period, etc.)
- Operation and maintenance costs
- *Cost of heat production in the reference scenario

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ECONOMIC ASPECTS
Investment costs

Investment costs in compression (electricity-based) heat pumps typically consist of the following categories:

- Heat pump
- Connection fee to the electricity grid
  - *High voltage cable
- Technology building
- Land purchase
- *Heat storage tank

ECONOMIC ASPECTS
Investment costs

Compression heat pumps:

- Ground water heat pump: 1 – 1,4 M EUR / MW heat output
- Air/water heat pump: 0,8 – 1,2 M EUR / MW heat output
- Excess heat heat pump: 0,6 – 1,1 M EUR / MW heat output
- Sea water heat pump: 0,5 – 1,2 M EUR / MW heat output

Absorption heat pumps:

- 0,6 – 0,8 M EUR / MW heat output

Compression heat pumps are most widespread in district heating systems.

ECONOMIC ASPECTS
Investment costs

Connection to the electricity grid:

- Costs depends a lot on the connection type (high voltage, medium voltage, etc.) as well as the electricity supply company.
- The distance from the closest electric substation is also important, since this could increase the connection costs.

Technology building:

- The cost of the technology building is highly dependent on material prices and cost of the workforce, as well as on the building layout and quality.

Land purchase:

- The m^2 price is very dependent on the geographic region and the type of land, but this is usually a very minor share of the overall investment costs.

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ECONOMIC ASPECTS
Investment costs

*Heat storage tank:

- It is usually a good idea to pair the heat pump with a storage tank, to increase the heat pump's flexibility and reduce the dependence on the electricity market's fluctuating prices.

- A steel heat storage tank usually costs around 130.000 – 180.000 EUR / 1.000 m^2.

- Economies of scale apply to heat storage tanks, as smaller tanks (below 1.000 m^2) are much more expensive per m^2.

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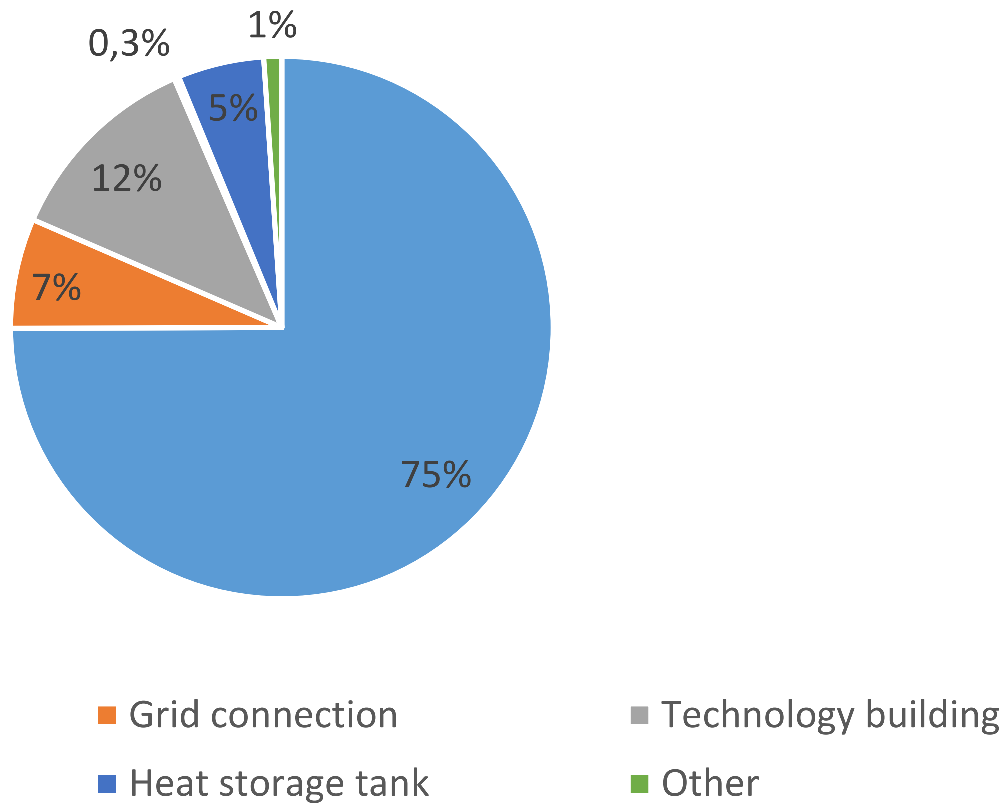
ECONOMIC ASPECTS

Investment costs

Distribution of investment costs in a 25 MW air/water heat pump



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ECONOMIC ASPECTS
Loan parameters

Due to the high inflation levels, interest rates of loans for energy projects have risen and are currently 2,5-3,5% in Denmark.

Most central heat pumps for district heating applications have a technological lifetime of approximately 20 years, so when investing in a heat pump, it is rational to obtain a bank loan that is to be paid back over 20 years.

ECONOMIC ASPECTS
Operating costs

The operating costs of a large compression heat pump consist of the following:

- Electricity costs
- Grid transport fees
- Taxes (if applicable)
- Maintenance costs
  - Usually around 2-3 EUR / MWh heat produced

ECONOMIC ASPECTS
Heat production costs

Heat production costs of compression heat pumps are very dependent on the electricity price.

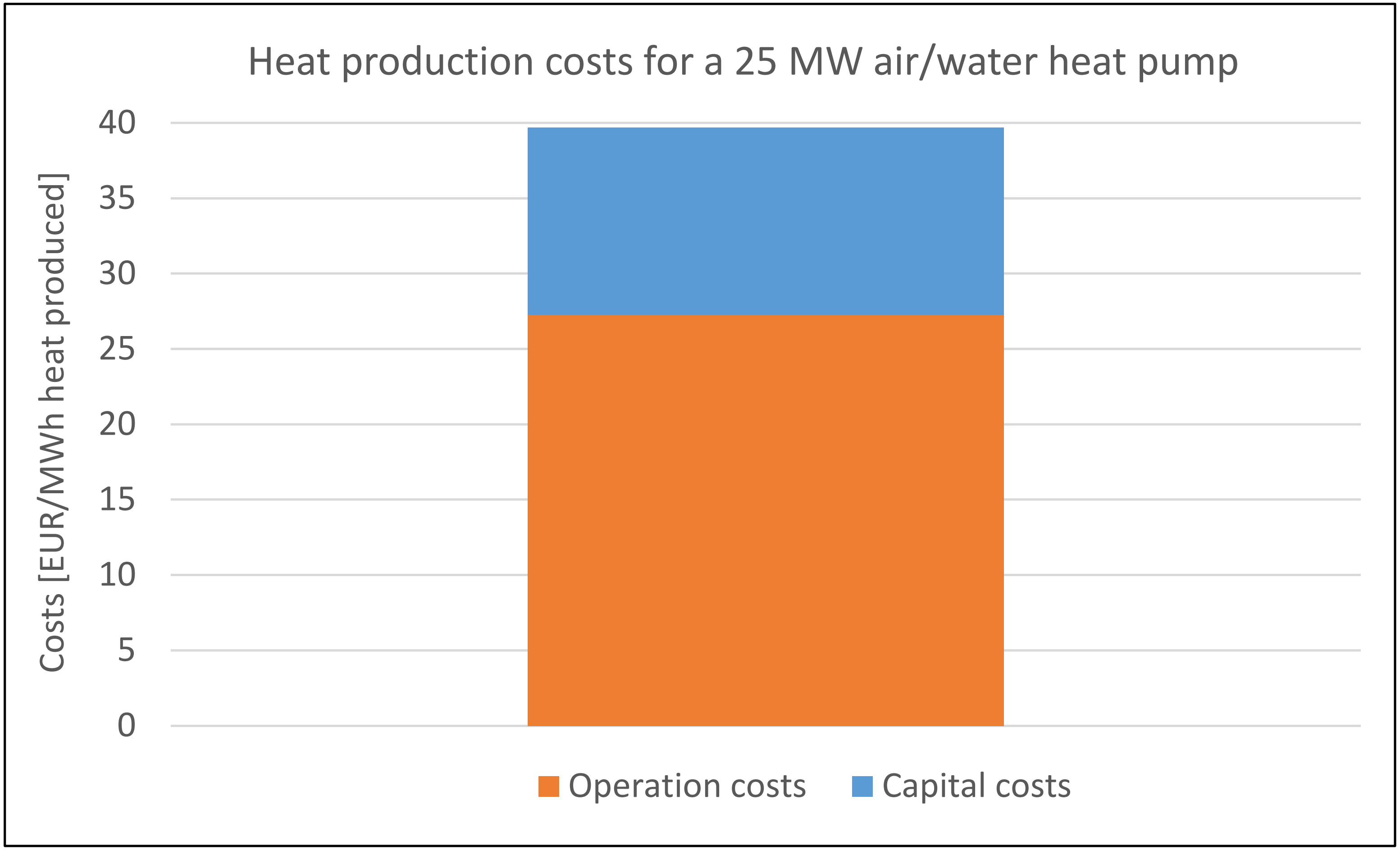
Average operation costs are around 15 – 35 EUR / MWh produced heat.

Capital cost are around 10 – 15 EUR / MWh produced heat.

The total heat production costs vary between different heat pump types and depend heavily on energy prices, but are in general in the range of 25 – 50 EUR / MWh produced heat.

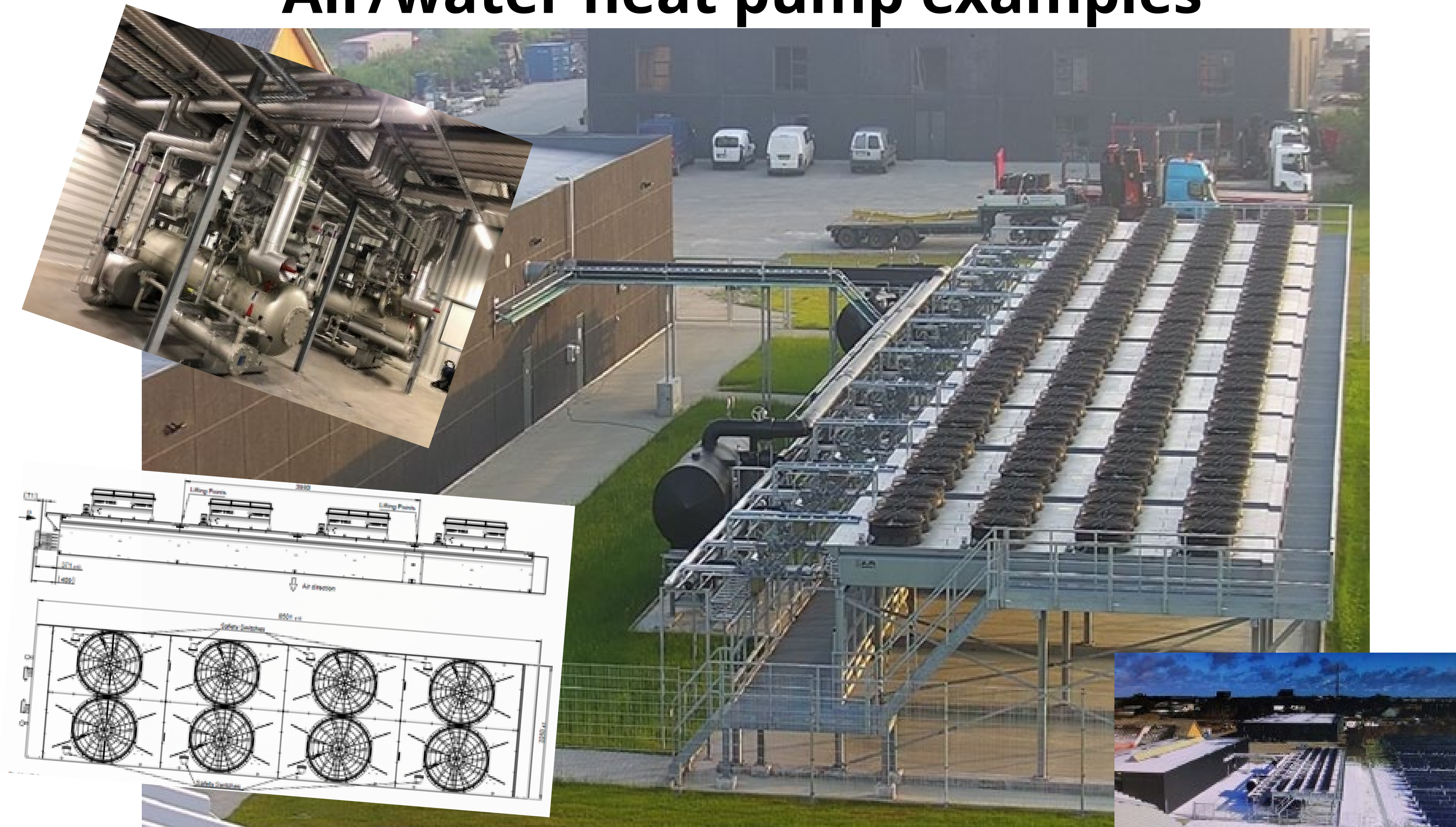
The payback period in heat pump projects in highly dependent on the costs of heat production in the reference scenarios. Calculations based on Danish examples generally show payback periods shorter than 10 years.

ECONOMIC ASPECTS
Heat production costs



Questions?

Air/water heat pump examples



Braedstrup district heating. Capacity 5,8 MW, ammonia/NH_3

Example: Faaborg 10,5 MW capacity

- Ammonia, NH_3
- 2 x screw compressors
- 3 x screw compressors +
  5 x reciprocating comp.
- 32 air coolers air upwards
- Supply directly to grid
- No storage tank

- Storage tank is being planned…

Example: Farum 15 MW capacity

- Ammonia, NH_3
- 4 x screw compressors +
  5 x reciprocating comp.
- 64 air coolers air downwards
- Supply directly to grid
- No storage tank

- Storage tank is being planned…

Questions?

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