InterHeat project

High temperature heat pumps for industrial process heat

INTER
HEAT

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Project Manager for the high temperature heat pump project ”Demonstrating high temperature heat pumps at different integration levels”, short: ”InterHeat” at the Danish Technological Institute from 2022 to 2025.

Presently employed at Nilan; a company that manufactures ventilation systems; in some cases including heat pumps.

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https://interheat.dk

The project aims to develop, build and real-life test 2 high temperature heat pumps:

- A unit to be installed at and operated by an industrial end customer, using the industry's own waste heat (40-90°C) as source and provide process heat for a drying process at up to 150°C. The unit is a 2-stage system using modified standard screw compressors, normally used at temperatures up to 90°C. Isobutane in the low stage; isopentane in the high stage. COP at design point 2,5 – 3.

- A unit to be operated by a district heat supplier (DIN Forsyning, Esbjerg), using district heat as source and providing steam at up to 150°C to an industry in Esbjerg. The unit will be a 2-stage system using a butane screw compressor to produce steam at 100°C and a steam screw compressor to raise the steam temperature to 150°C. COP 2,5 – 3.

- Perform economical analysis to identify the benefits/drawbacks of the 2 (and potentially other) setups:
    - Free waste heat as source vs district heat
    - District heat suppliers can accept longer payback times than most industries
    - Integration costs etc.

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Project setup

The project is supported by the Danish Energy Agency, providing 40 – 60% of the cost, and the rest of the economy is distributed between the project partners:

- The compressor suppliers make the compressors available to the project free of charge.
- The heat pump builders receive the compressors and build the heat pumps, which are then made available to the project free of charge.
- Valves and heat exchangers are made available by suppliers free of charge.
- DTI performs the first test of the heat pumps to ensure the function and performance.
- The industrial end user arranges the integration of the heat pump, including all costs for heat exchangers etc. and operating costs, but has the heat pump available at no cost.

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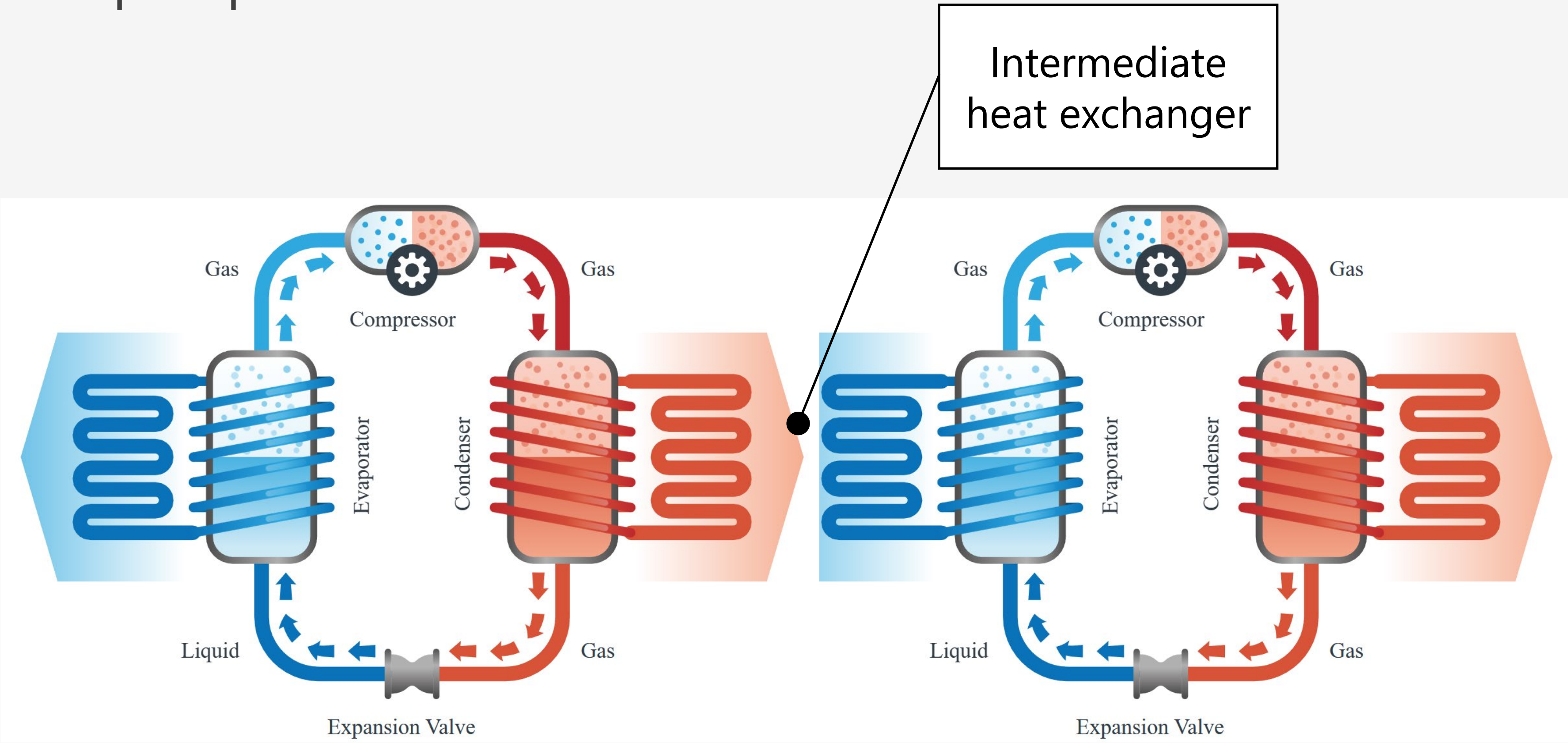
2-stage heat pump

Low temp. source



High temp. sink

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Technical challenges:

The unit to be installed at an industrial end customer:

- The low stage uses a heat pump compressor normally used at temperatures up to 90°C on isobutane. In this case, it’s operating slightly above the normal range, but without any major changes.
- The second stage uses a modified standard heat pump compressor and has more challenges:
    - The electric motor is cooled by suction gas (>100°C), so the windings must have a high temperature varnish.
    - All plastic materials checked/replaced
    - High temperature oil for lubrication
    - A special stop valve on the discharge. Available from gas industry.
    - Isopentane refrigerant. Material compatibility.
- All other components are standard cooling / heat pump parts

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Technical challenges:

The unit to be operated by a district heat supplier :

- The low stage uses a heat pump compressor that is normally used at temperatures up to 90°C on butane. In this case, it's operating slightly above the normal range, but without any major changes.
- The second stage is a gas compressor, here used to compress steam:
  - The compression of steam generates very high temperatures, so water injection is added.
  - Steam seals on the drive shafts (from steam turbine industry)
  - Separation of steam and oil areas (known from gas compressors)
  - Water safety circuit between butane and steam system
- All other components are standard cooling / heat pump parts

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Current status:

- The unit to be installed at an industrial end customer has been designed, built and tested in a test rig at DTI, Aarhus. The original industrial end customer has declined to continue in the project due to the costs of integration. A second client was found, but after investigating the cost of integrating the heat pump into the industrial production, this client has also refused to continue.

- The unit to be operated by a district heat supplier has been designed, but not built. DIN Forsyning has left the project, and has not been able to find an industrial end customer. The present status for this heat pump is unknown. The project website has no news about progress.

The economical analysis has identified a number of problems:

- The cost of integration of the heat pumps far exceeds the original budget.
- The cost of the heat pumps is much higher than expected.
- The heat pump COP's are quite low (2,5 – 3). A very low profit to pay back the investment. In many countries, Denmark included, the price of electricity is approx. 2 times the price of natural gas, so a COP of 2 means 0 profit.
- District heat is a poor heat source, at least in Denmark, where 70°C/40°C is the normal.

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Future potential for heat pumps for industrial process heat with district heat as source:

- To be economically competitive, the heat pump must have a high COP; preferably 3 – 4 or higher.

- The cost of the heat pump itself and the integration into the industrial process must be as low as possible.

This leads to the conclusion that:

  - The heat pump temperature lift must be relatively low, so if district heat is used as source, the district heat must be supplied at a high temperature; for example 95°C supply and 75°C return. This also makes it possible to produce hot cleaning water directly from the district heat (without the need for a heat pump). Return water can be supplied into the residential district heat circuit.

  - The integration costs should be considered very carefully, and the system design must be simplified as much as possible to avoid additional costs. In many cases, flammable refrigerants are unacceptable and only lead to additional costs in the form of safety brine circuits

  - The heat pump cost can be reduced considerably if the customer needs high temperature steam and low temperature steam can be produced from the source. Steam compression in MVR systems seems to be very economically competitive

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The real challenge for heat pumps for industrial process heat on district heat is not technology; it's economy. Technology for high temperatures has existed for many years, for example in the chemical industry. To be economically competitive, a number of conditions must be met:

- Low temperature lift, both to get a good COP but also to minimize the amount of machinery (investment)
- A high number of annual operating hours (heat pumps generate profit by producing heat cheaper than the alternatives)
- Only multi-MW units can be expected to have a good economy.
- The cost of the integration into the industrial process must be as low as possible. Very often, retrofitting existing process lines to heat pumps is very expensive. Thinking heat pumps into new process lines gives chances for optimization.
- If district heat is used as source, it should have a high temperature (80 – 95°C), so that high temperature heat can be produced with a low lift, and medium temperature heat can be produced directly by heat transfer.
  Consider different district heat prices for industry and residential customers. Differences in piping/pumping costs
- A long payback time may be necessary and should be accepted

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SPH high-temperature heat pumps electrify the beverage industry

Source: Water 80°C -> 70°C

Sink: Water 100°C -> 110°C

Output 2,4 MW

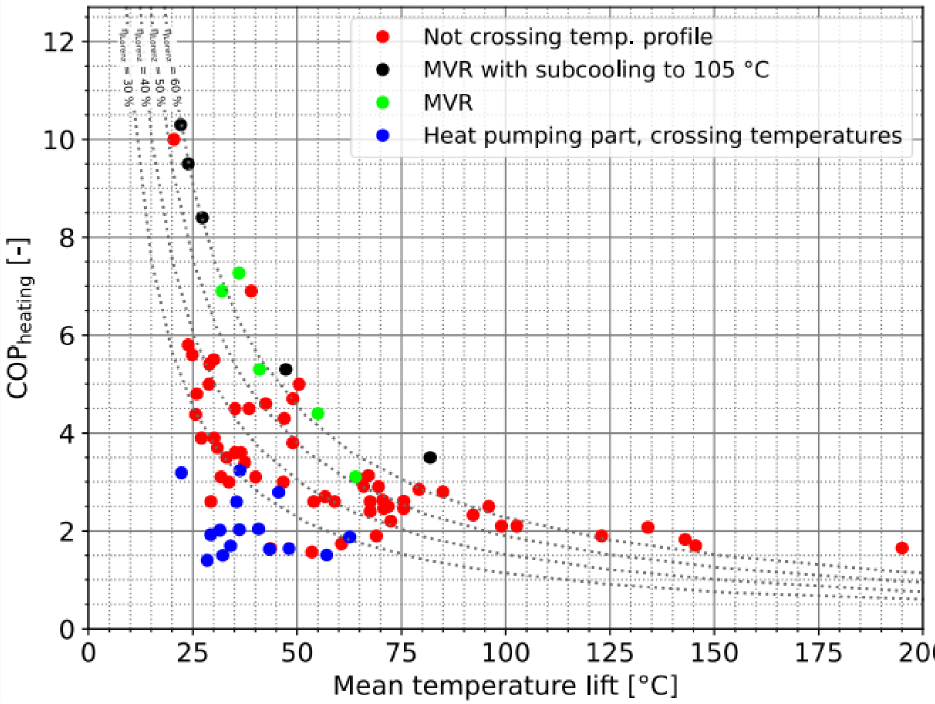
COP 5,5

Annex 58 Technologies

https://heatpumpingtechnologies.org/project58/task1/ shows a lot of available HTHP technologies and gives hints about costs / performance:

Temperature lifts above 80K result in COP<2 (= no profit) and a very high investment cost.

Investment cost is for the heat pump only, no integration or peripheral costs. Typical factor is 3.



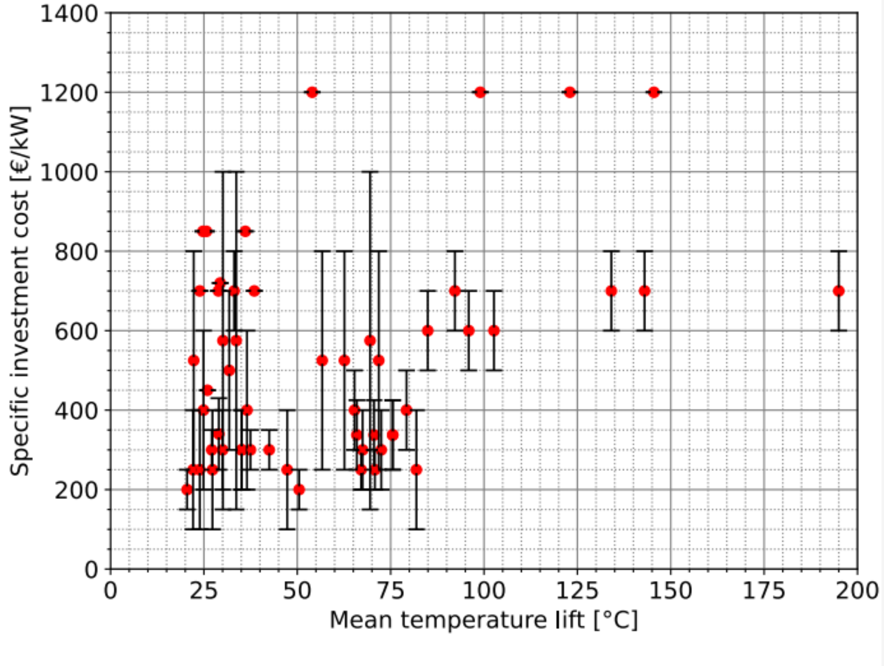


Figure 2-32: Specific investment cost as a function of mean temperature lift.

Example:
Investment 1800 €/kW
4000 hours/year
Ind. payback 6 years

Investment cost alone: 0,075 €/kWh; roughly twice the present NG price in DE (taxes etc excluded)