INDUSTRIAL HEAT PUMPS
DEVELOPMENT PERSPECTIVES AND DEMONSTRATION ACTIVITIES

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DECARBONIZATION OF INDUSTRIES AT DTI

- Holistic consultancy approach supporting process industries in their decarbonization
- Process Analysis & Target definition
- Conceptualization & Technology Overview
- Roadmap development
- Support during implementation

- Validation of technologies in full scale
- Industrial heat pump lab
- On-site demonstration at end-users

- Component development
- System design and optimization
- Testing function and performance

Technologies
- Heat pumps
- Thermal storage
- Thermal networks
- Biogas & green fuels
- Unit operations
- Electric systems
- Water recovery

Scope
- Energy
- GHG emissions
- Water
- Economy

Collaboration partners
- Technology suppliers (system manufacturers, OEMs, ...)
- Process equipment manufacturers
- End-users from various industries (Food & beverage, Pulp & paper, chemicals, minerals, utilities, industry symbioses, ...)
HTHP APPLICATION POTENTIAL
INDUSTRIAL HEAT PUMPS
FUNCTIONING PRINCIPLE

Heat pump driven

- Electric power 25%
- Process heat 100%
- Waste heat 25%
- Waste heat recovery 75%
- COP = \( \frac{\text{Process heat}}{\text{Electric power}} = 4.0 \)

0% - 33% CO₂ emissions
PROVEN PRINCIPLES

- > 300 cases in IEA HPT Annex 48
- Proven technology < 100 °C
- Proven principles > 100 °C

https://waermepumpe-izw.de/
INDUSTRIAL PROCESS HEAT DEMAND – EU28

Total energy demand - 2950 TWh/a

- Process heating (66 %)
- Space heating (11 %)
- Non-thermal (19 %)
- Process cooling (3 %)
- Space cooling (1 %)

Process heating demand - 1952 TWh/a

- > 500°C (52 %)
- 200°C - 500°C (11 %)
- 100°C - 200°C (26 %)
- < 100°C (11 %)

Heat Pump Share of process heat: 37%
CO₂ emissions: 146 Mt/a

CO₂: 552 Mt/a

- Others - RES (0.4 %)
- Biomass (11 %)
- Electricity (3 %)
- District heating (8 %)
- Others - fossil (13 %)
- Coal (20 %)
- Oil (8 %)
- Gas (36 %)

Figure based on Heat Roadmap Europe
INDUSTRIAL HP APPLICATION POTENTIAL

**HIGH POTENTIAL**
Industry Sectors

- **Food & Beverage**: 123 TWh/a
- **Pulp and Paper**: 230 TWh/a
- **Chemical**: 119 TWh/a
- **Machinery**: 41 TWh/a
- **Non Metallic Minerals**: 43 TWh/a

Transitioning industry to the use of **RENEWABLE** electricity

- **Heatpumps for DECARBONIZATION of the LOW TEMPERATURE heat supply in industry**

- **Possible CO₂ emission reductions of 146 Mt/a**
- **Potential to cover 37% of the process heat in industry**
- **RE-USE of industrial waste heat, leading to INCREASED process efficiency**
- **Reducing final energy consumption by 487 TWh/a**

**White Paper: Strengthening Industrial Heat Pump Innovation – Decarbonizing Industrial Heat** & **Webinar**
ELECTRIFICATION AND ENERGY EFFICIENCY ARE KEY FOR REACHING SUSTAINABILITY TARGETS

- IEA estimates that natural gas will be steadily phased out by heat pumps and electric heaters, especially for temperatures up to 200 °C to 250 °C

- Developed countries must go first and be front runners

- The Danish industry should reduce emissions by 1.9 mio. tons of CO2 per year. 25 % are to be obtained by “Electrification and heat pumps”, mainly implemented between 2025 to 2030 (Klimarådet)

- EU discusses an end of fossil fuel use for processes <200 °C by 2027 in the RED III, art. 21

## The Road Towards Implementation

### Technology Awareness
- Commitment to sustainability and decarbonization
- Potentials, limitations and characteristics of the technology
- How to exploit the potentials?
- Variety of stakeholders involved

### Technology Development
- Component and system development
- Testing and demonstration
- Variety of technologies
- Collaborative effort

### End-user adoption
- Technology adoption life cycle
- Retrofitting of industries for HP-based heat supply
- Decarbonization strategies

### Boundary conditions
- Cost for fuels and GHG
- Regulatory frameworks
- Subsidies & incentives
- Market developments

### Market deployment
- Technology implementation within commercial projects
- Learning curve for operators and suppliers
- Supply chain covering considerable volumes
- Business models
POTENTIAL & TECHNOLOGY AVAILABILITY

Application potential based on technology availability

Technology
- Temperature limitations
- Working fluid
- ...

Capacity
- Heat supply
- Heat source
- Operating hours

Temperatures
- Supply temperature
- Temperature glides
- Temperature lift

Integration
- Open cycle
- Closed cycle
- Process ↔ Utility

Maturity
- TRL and perspectives
- References

Cost
- CAPEX
- OPEX

Availability
- Technology availability
- Installation, Service & Maintenance
- Number of installations

Development perspectives based on application potential
IEA HPT ANNEX 58 ABOUT HTHP

- Heat pump technologies with supply temperatures above 100 °C
- Participants: Denmark (Operating Agent), Austria, Belgium, Canada, China, France, Japan, Germany, Netherlands, Norway, South Korea, Switzerland, US
- 01/2021 – 12/2023
- https://heatpumpingtechnologies.org/annex58/
HTHP TECHNOLOGY DEVELOPMENT PERSPECTIVES
ANNEX 58 – TECHNOLOGY REVIEW

- 34 Technology descriptions
- Key information includes:
  - Performance data
  - Capacity range
  - Max. temperatures
  - Working fluid
  - Compressor type
  - Spec. investment cost
  - TRL
  - Expected lifetime
  - Size & footprint
  - Project examples
ANNEX 58 – TECHNOLOGY REVIEW
ANNEX 58 – TECHNOLOGY REVIEW
MAXIMUM TEMPERATURE AS A FUNCTION OF CAPACITY

TRL level: 4-9
Average specific cost: 200 €/kW - 1500 €/kW
Capacity: 0.03 MW - 70 MW
Max. supply temperature: 100 °C - 280 °C
Availability: Geographical dependent, e.g. between Europe and Japan
Size of HTHP technology review: 34 different technologies with 85 performance use cases
• 16 two-paged descriptions of HTHP demonstration cases prepared.

• Includes key information on:
  • Performance in design point
  • Operating hours
  • System manufacturer
  • Installation year
  • Working fluid
  • Compressor technology
  • Investment cost
  • Energy savings
  • Estimated annual CO₂ savings
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<td>starch drying</td>
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<td>138</td>
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<td>LT-C: R920, HT-C: R600</td>
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<td>steam generation</td>
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<td>n. a.</td>
<td>heat transformer</td>
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<td>R718</td>
<td>centrifugal</td>
<td>n. a.</td>
<td>7.68</td>
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ONGOING DEVELOPMENT & DEMONSTRATION ACTIVITIES BY DTI

Steam compression system
- Spindle compressor: High pressure ratio and $T_{\text{lift}}$
- 2-stage turbo compressor: high flows and $T_{\text{lift}}$ up to 50 K
- Full-scale test: 2023
- On-site demo: 2024

Hydrocarbon system
- Butane (R600) $\rightarrow$ 120 °C
- Isopentane (R601a) $\rightarrow$ 160 °C
- Bock piston compressors
- Full-scale test: 04/2023
- On-site demo: Early 2024

CO₂ system
- CO₂ (R744) $\rightarrow$ 180 °C
- Bock piston compressors
- Single-stage with ejectors
- Full-scale test: 2023
- On-site demo: Early 2024

http://suprheat.dk/
ONGOING DEVELOPMENT & DEMONSTRATION ACTIVITIES BY DTI

**HC cascade system**
- Iso-Butane (R600a) → 120 °C
- Iso-Pentane (R601a) → 160 °C
- Frascold screw compressors
- 500 kW in drying process
- Full-scale test: 2023
- On-site demo: 2024
- [https://interheat.dk/](https://interheat.dk/)

**HC & steam system**
- Butane (R600) → 120 °C
- Water (R718) → 160 °C (steam)
- SRM screw compressors
- 1 MW process heat (source DH)
- Full-scale test: 2023
- On-site demo: 2024
- [https://interheat.dk/](https://interheat.dk/)

**Pentane system**
- Pentane (R601) → 145 °C (steam)
- GEA screw compressors
- Single-stage
- 4 MW for sugar production
- On-site demo: 2024
- [https://spirit-heat.eu/](https://spirit-heat.eu/)
END-USER ADOPTION
BUSINESS CASES

- **Fossil-fuel based process heating**
  - Cost for process heating ≈ Fuel consumption

- **Heat pump-based process heating**
  - Cost for process heating ≈ Electricity consumption
  - Time of operation
  - Installed capacity
  - Temperature
TEMPERATURE DEMANDS & LEVEL OF INTEGRATION

- **Boiler-based heat supply**
  - Heating Utility
  - Losses
  - COP ≈ 1.3 – 1.5

- **Heat pump integration without modifications**
  - Heating Utility
  - Losses
  - COP ≈ 1.3 – 1.5

- **Heat pump integration with utility optimization**
  - Larger HX
  - Optimized utility
  - COP ≈ 1.5 – 2.1

- **Heat pump integration with utility and process optimization**
  - Larger HX
  - Optimized utility
  - Optimized process parameters
  - COP ≈ 1.9 – 2.6

**Heat Source**
- Losses
- Cooling Utility

**Heat Sink**
- Heating Utility
- Cooling Utility

**Integration**
DEVELOPMENT OF DECARBONIZATION STRATEGIES

Mapping of existing processes

Development of concept solutions

Development of decarbonization roadmap

Definition of SMART sustainability targets

Analysis of technology availability and perspectives

Implementation of decarbonization roadmap
PERSPECTIVES
<table>
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<th>Heating Capacity</th>
<th>Temperature</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
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<tr>
<td>&lt; 120 °C</td>
<td>Prototypes available</td>
<td>Full-scale demonstrators available</td>
<td>Various HP Technologies commercially available</td>
<td>Established as preferred technology</td>
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<td>200 kW to 10 MW</td>
<td>Prototype developments</td>
<td>Technology advancement, upscaling</td>
<td>Optimization of efficiency, cost, …</td>
<td>Standardization, further improvements and novel applications</td>
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<td>120-160 °C</td>
<td>Test and demonstration of prototypes</td>
<td>Full-scale demonstrations in industrial environment</td>
<td>Commercial deployment of systems</td>
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<td>&gt;160 °C</td>
<td>Prototypes available</td>
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<td>Various HP Technologies commercially available</td>
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<td>&gt;10 MW</td>
<td>Technology transfer to HP applications</td>
<td>First demonstrations realized</td>
<td>Established as preferred technology</td>
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<td>&gt; 120 °C</td>
<td>Integration studies with end-users</td>
<td>Full-scale demonstrations in industrial environment</td>
<td>Commercial deployment of systems</td>
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**Technology Transfer**

- **First demonstrations realized**

**HP Technologies**

- Commercially offered

**Established as preferred technology**

**Standardization, further improvements and novel applications**

**Commercial deployment of systems**

**Integration studies with end-users**

- Technology transfer to HP applications

**Optimization of efficiency, cost, …**

**Full-scale demonstrations in industrial environment**
Conclusions

- High-temperature heat pumps have a considerable potential
- Variety of technologies and manufacturers required
- Process integration and decarbonization strategies are key

Outlook

- Large up-take of heat pumps in industry & district heating < 100 °C
- Establishing HTHPs as reference technology for heat supply up to 150/160 °C
- Advancing the state of the art for technologies >150 °C
- Creating awareness at variety of stakeholders

Take-aways

- Technologies must be developed and demonstrated at scale
- Industrial decarbonization is a long-term process and requires holistic strategies
- The HTHP technology supply and the market are global.
HTHP SYMPOSIUM

Focus on:
• Technology developments and trends
• Successful demonstration cases
• Integration concepts
• Market potential and demand
• Presentations & Exhibition area

Save the date:
23rd & 24th of January 2024

http://hthp-symposium.org/
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