D3.2
Overview on data and interfaces for heat pumps in industry and district heating

Contribution to the IEA HPT TCP Annex 56
Digitalization and IoT for heat pumps

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1 Introduction

This is a deliverable of the Austrian project for IEA HPT Annex 56 (Digitalization and IoT for heat pumps). The IEA HPT Annex 56 project explores the opportunities and challenges of connected heat pumps in household applications and industrial environment. There are a variety of new use cases and services for IoT enabled heat pumps. Data can be used for preventive analytics, such as what-if analysis for operation decisions, predictive maintenance, fine-tuning of operation parameters and benchmarking. Connected heat pumps allow for demand response to reduce peak load and to optimize electricity consumption, e.g., as a function of the electricity price. IoT is also associated to different risks and requirements to connectivity, data analysis, privacy and security concerning a variety of stakeholders. Therefore, this Annex has a broad scope looking at different aspects of digitalization and creates a knowledge base on connected heat pumps. The Annex aims to provide information for heat pump manufacturers, component manufacturers, system integrators and other actors involved in IoT.

This deliverable summarizes the specific findings on data and interfaces for IoT enabled heat pumps for industrial applications. It is based on research work carried out in the Austrian project for IEA HPT Annex 56, as well as on use cases from participants of IEA HPT Annex 56 that are related to industrial applications and district heating applications.

2 IoT enabled heat pumps in industry

Heat pumps that are applied in industrial applications typically differ from heat pumps for household and commercial applications with heating capacities up to the MW range, using industrial waste heat as the heat source and higher heat supply temperatures. Heat pumps for household and commercial applications are serial products that are sold in large quantities by heat pump manufacturers. By contrast, industrial heat pumps are usually designed, manufactured, and installed on a project-specific basis. They are often implemented in a pre-existing IT/OT environment, which also reflects on the aspects of connectivity. Industrial heat pumps are a comparably new market segment that is mainly driven by the development of high temperature heat pumps that can supply process heat with temperatures exceeding 100°C. Industrial heat pumps are a highly relevant decarbonization option for industrial processes requiring heat below 200°C as for example in the chemical industry, the paper industry, or the food industry.

As of now, there is no comprehensive overview on the number of heat pumps already installed in European industry. In Austria, the number of industrial heat pumps is assessed every year since 2012 in a manufacturer survey. In 2022, a total of 609 industrial heat pumps were operated in Austria. There is no further information on capacity or heat supply temperature of those units (Biermayr and Prem, 2023). IEA HPT Annex 58 provides an overview on the high temperature heat pump market with a list of suppliers, 27 different heat pump products with their technology readiness level, as well as 15 factsheets on demonstration plants (IEA HPT Annex 58).

Industrial companies have long been using digital technologies for process control. Industrial IoT (IIoT) platforms and cloud computing are increasingly being used in the manufacturing industry for online monitoring of production plants, cross-site energy management, control and monitoring of decentralized distributed machines and plants, and for centralized recording and evaluation of distributed measuring stations. For industrial applications, energy savings and cost reduction are often linked to productivity increase and optimization of resource use, which are achieved through advanced solutions (supply chain management, condition monitoring, soft sensors, predictive maintenance, etc.). Digitalization in industry can range from automated equipment, advanced process control systems to connected supply value chains. IoT enabled heat pumps allow for integration in the process control system and a higher-level energy management system, which can be used for overall optimization of the process.

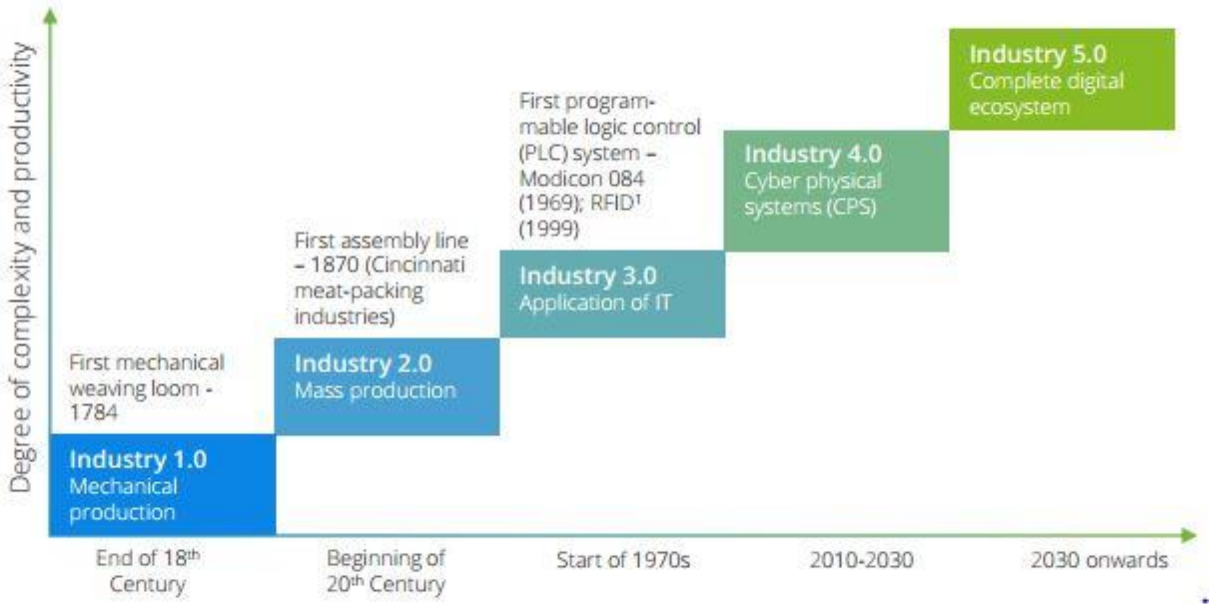

Figure 1: Industrial evolution overview (statista, 2019).

Figure 1 illustrates the industrial evolution from mechanical production to digital ecosystems. The First Industrial Revolution, marked by steam and hydropower, replaced manual labor with machinery. The Second Industrial Revolution introduced electricity, assembly lines, and mass manufacturing. The Third Industrial Revolution was based on the emergence of Programmable Logic Controllers (PLCs) in 1968, automating production processes and fostering globalization. The PLC concept, a key player in automation, evolved alongside computer technology. However, the classical automation approach faced limitations in addressing the growing complexity of modern systems. This led to global initiatives like Advanced Manufacturing, e-Factory, Intelligent Manufacturing, and Industry 4.0, aiming at the Factory of the Future (FoF).

The Fifth Industrial Revolution leads for complete convergence of digital and analogous things, what is referred to as the Internet of Things (IoT). We are currently in the middle of the Fourth Industrial Revolution, a transitional phase towards IoT realization, enabling seamless communication (machine-to-machine or M2M communication) and optimization across value chains, depicted in Figure 2. Further insights in industrial communication protocols and architectures can be found in the Task 1 report of IEA HPT Annex 56 on the state of the art.

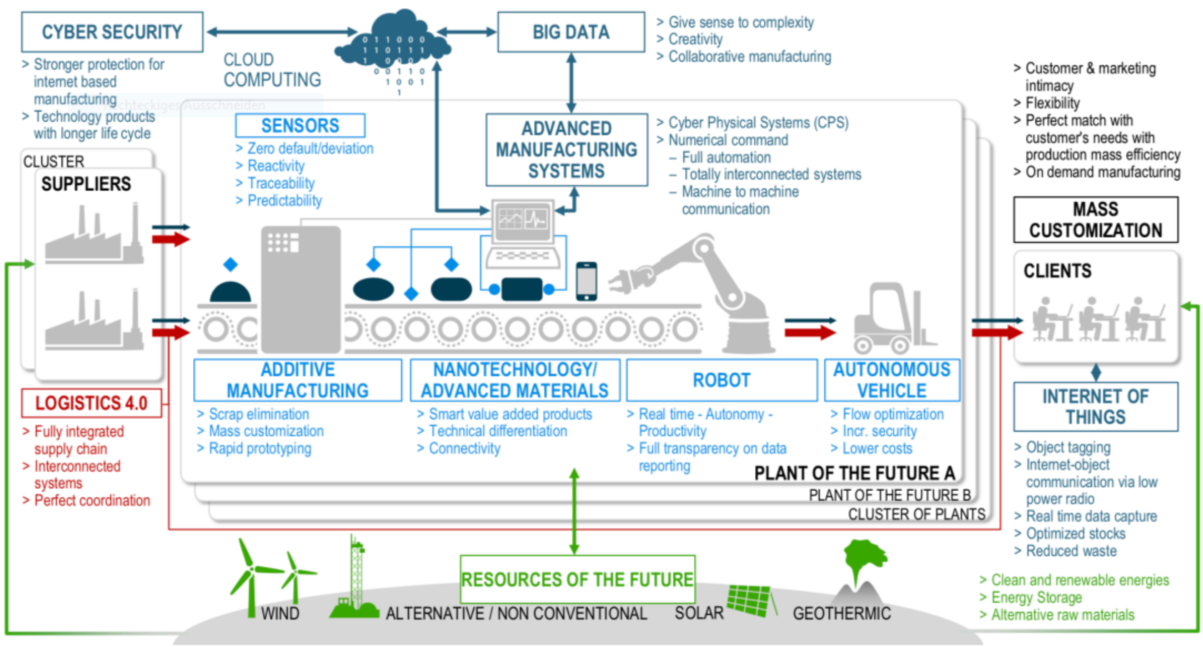

Figure 2: Trend in evolution of M2M to IoT (Roland Berger, 2017)

IoT-enabled heat pumps in industrial applications can thus be directly connected to the communication infrastructure of Industry 4.0 networks, making them relevant not only for heating and cooling in buildings or in processes, but also for optimization and decarbonization.

3 IoT enabled heat pumps in district heating

Similar to industrial heat pumps, heat pumps for district heating are also rather designed and manufactured on a project specific basis than produced as serial products such as residential heat pumps. Heat pumps in district heating use ambient heat such as river or sea water, geothermal energy, air, or industrial waste heat as heat source. The required supply temperature depends on the type of district heating grid and ranges from temperatures well above 100°C to advanced systems that supply heat as close as possible to the actual temperature demand of the connected end-users. Heat pumps in district heating generally have large heating capacities, typically in MW range. Heat pumps are already established in district heating grids, especially in the Nordic countries and they are an important measure to decarbonize district heating systems with growing demand in Europe.

Digitalization in district heating is studied in the IEA DHC Annex TS4 focusing on optimized operation and maintenance of district heating and cooling systems via digital process management. Similar to industrial automation, digitalization in district heating represents a paradigm shift in the production, distribution and consumption of heat. A detailed discussion was published in a Guidebook in 2023 summarized the findings of the project (Schmidt et al, 2023). In a smart district heating grid, heat pumps require connectivity and IoT functionality to be integrated seamlessly in the overall grid management. Because of these similarities to industrial heat pumps, heat pumps in district heating applications are also discussed in this deliverable.

4 Results of the Austrian manufacturer survey

The survey was carried out as a part of the Austrian project for IEA HPT Annex 56. The purpose of the survey was to collect feedback from companies in the Austrian heat pump market on the general sentiment on the importance of IoT and on products and services that they offer related to IoT enabled heat pumps. A comprehensive summary of the survey is published in the Task 1 report of IEA HPT Annex 56. In the following the insights in IoT heat pumps for industrial and district heating applications are discussed.

A total of 16 companies participated in the survey, thereof 6 indicated that they offer IoT products for industrial and district heating applications (Figure 3). 2 participants did not answer the question if IoT products for industrial and district heating applications are also available.

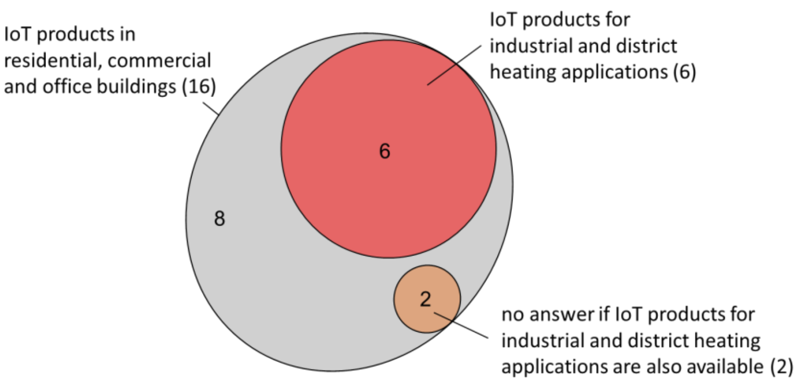

Figure 3: Market segment covered by the participants of the Austrian survey

All participants state that operational data is collected. Most companies use both, local storage, and the cloud, 2 offer only cloud storage and 1 only local storage.

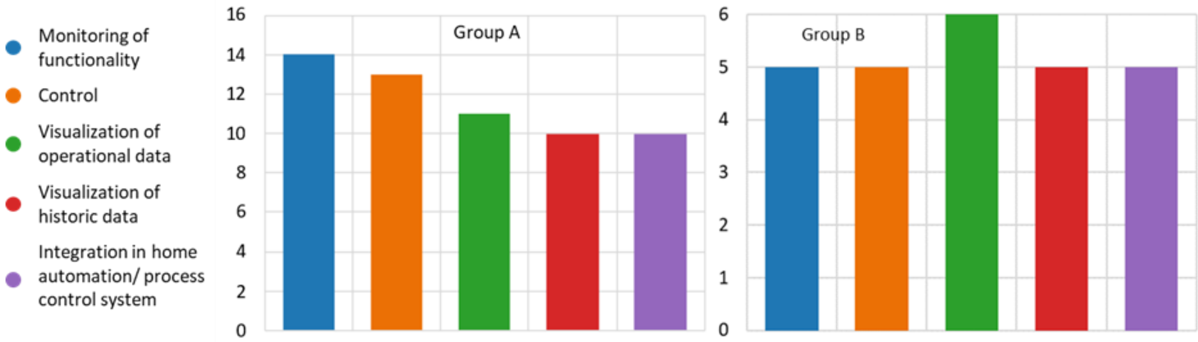

Figure 4: Functions made available to the customer; data taken from participants active on the residential, commercial or office buildings market (Group A) or the industrial heat pump market (Group B), multiple answers possible

Figure 4 shows the feedback about the functionalities made available to the customer based on this data and compares the answers for residential heat pumps (Group A) and industrial heat pumps (Group B). For industrial heat pumps, all functions such as monitoring, visualization of operational and historic data, control, integration in process control systems are available, except for one case, where only visualization of operational data is offered. For residential heat pumps (Group A), 50% of the participants offer all functions, 44% offer one or more functions and 6% none of them.

LAN and WLAN are the most common communication interfaces to collect field and operational data of industrial heat pumps. They are followed by local wired (USB, Serial, ...) and GSM. Compared to residential heat pumps, local wireless (Lora, Bluetooth) is less important. A total of 17 answers were given indicating that there are multiple interfaces offered in one product.

Modbus was mentioned most often as transmission protocol, followed by KNX and OPC UA for industrial heat pumps (Group B). The feedback indicates a diverse use of protocols and similar distribution for the residential and the industrial heat pumps, see Figure 5.

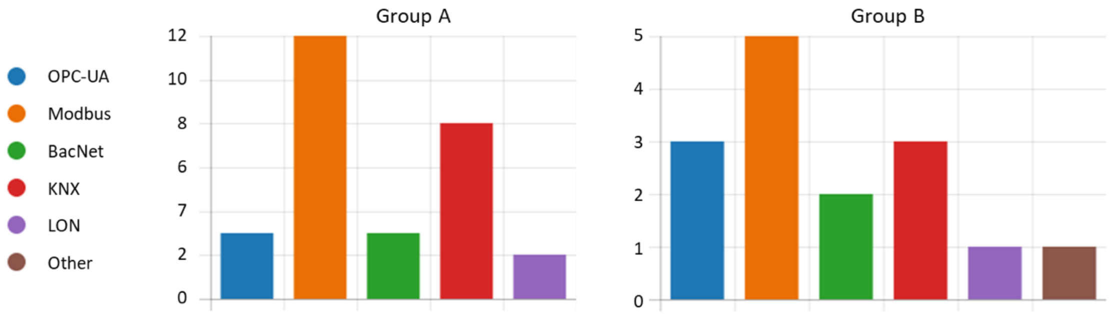

Figure 5: Transmission protocols for data collection; data taken from participants active on the residential, commercial or office buildings market (Group A) and the industrial heat pump market (Group B), multiple answers possible

Asked about the reasons for choosing the transmission protocol, the participants name data and transmission security as well as availability and adoption of the protocols in the first place, closely followed by compatibility to other systems and existing experience with the protocol. The feedback is similar for residential and industrial heat pumps.

The collected field data comprises the state-of-the-art heat pump measurements, that are flow and return temperatures, electrical power, source temperatures, heating capacity, switch cycles, set points and partial load condition. All participants that answered that question for industrial heat pumps collect all categories of field data.

The following basic data evaluation methods for industrial heat pumps are named by almost all participants (5 or 6 notes): visualization and monitoring of real time data and calculation of Key Performance Indicators (KPIs), statistical analysis based on historic data. Advanced methods for data evaluation (e.g. automated pattern recognition based on machine learning) was named 3 times. This is also similar to the residential heat pumps.

Data is processed in a proprietary cloud solution (6 notes), on-site (4 notes) or in a third-party cloud solution (2 notes). Data is either evaluated by the participants (3 notes), the clients (2) or an external party (1). The IoT enabled features comprise visualization of operation and historic data, monitoring and control and integration in the process control system. This is in good agreement with the IoT features requested by the customers. Unlike residential applications, smart tariffs are currently of less importance in industry.

5 Examples for IoT enabled heat pumps in industry and district heating

In IEA HPT Annex 56, examples of IoT applications related to heat pumps were collected. Both commercial products and research projects were considered. The examples were compactly summarized in two-page factsheets, which were created using a template for projects and for products. They provide the following information:

- Description of the technology used (hardware, platform, protocols)
- Explanation of the application (background and benefits, lessons learned)
- Info box: Data and modeling requirements, analysis methods, readiness level, etc.

The examples were collected through research and expert interviews, as well as based on ongoing or completed research projects. The factsheets were prepared together with the companies and research institutions and approved for publication. The examples were then used to describe generalized IoT categories:

- Heat pump operation optimization
- Predictive maintenance
- Flexibility provision
- Heat pump operation commissioning
- Heat as a service

These five categories summarize similar applications and were explored in more detail in Tasks 2, 3, and 4. Aspects related to interfaces, data analysis, and business models were described and compared using the generalized IoT categories in a structured manner and with concrete examples. The method of starting with concrete examples proved to be successful because it focuses the analysis on heat pump specific issues and excludes adjacent topics such as higher-level control in the energy system.

In total, 44 use cases were collected, thereof 19 products and services and 25 research projects. Most of the use cases were provided by the Danish team (23 examples), followed by Austria (10). On the website of IEA HPT Annex 56, all factsheets are available, they can be browsed by country, by technology readiness level (project or product) and by IoT category.

In the following all use cases related to industrial heat pumps and heat pumps for district heating are presented:

5.1 DIGIBatch

This is an Austrian research project, that integrates a heat pump digital twin in a legacy industrial SCADA system. A detailed description of the application, of the communication structure and orchestration, data processing, inference and action is provided in the Task 2 report.

Link to factsheet:

https://heatpumpingtechnologies.org/annex56/wp-content/uploads/sites/66/2023/06/iot-annex-56-project-case-at-digibatch.pdf

5.2 Digital Twins for Large-scale Heat Pumps and Refrigeration Systems

This is a Danish R&D project that covers multiple aspects of digital twins for large-scale heat pumps and refrigeration systems (http://digitaltwins4hprs.dk/).

In the Task 2 report, a functional architecture and comments regarding a possible implementation for a distributed digital twin are provided.

in the Task 3 report, a detailed overview on data, connection platform, protocols, quality of service, data analysis and modeling requirements for three different IoT applications are provided:

- Analysis of functionality and performance; performance benchmarking; validity checks (installation errors); soft sensors
- Current operation data is compared with historic data and other field measurements which can trigger early-stage warnings and predictive maintenance activities
- Continuous set-point tuning and scheduling of production and downtimes by optimizing heat production by considering variable power prices and changes in cooling and heating loads for both daily and seasonal variation

Link to factsheet:

https://heatpumpingtechnologies.org/annex56/wp-content/uploads/sites/66/2023/04/iot-annex-56-project-case-dk-digital-twin.pdf

5.3 Live Digital Twins

The company EnergyMachines (https://da.energymachines.com/) can deploy Digital Twins by using the platforms numerous (https://www.numerous.com/) and Energymachines.cloud which are further described in the Task 2 report. A detailed overview on data, connection platform, protocols, quality of service, data analysis and modeling requirements is presented in the Task 3 report.

Link to factsheet:

https://heatpumpingtechnologies.org/annex56/wp-content/uploads/sites/66/2023/04/iot-annex-56-case-dk-energy-machines-2.pdf

5.4 EDCSproof

The Austrian research project Energy Demand Control System – PROcess Optimization For industrial low temperature systems (EDCSproof) developed a sustainable concept for decarbonizing industrial energy supply systems through digitalization. The concept includes online predictive control, thermal energy storage, flexible consumers, system optimization, and waste heat recovery with heat pumps. A detailed overview on data, connection platform, protocols, quality of service, data analysis and modeling requirements is presented in the Task 3 report.

Link to factsheet:

https://heatpumpingtechnologies.org/annex56/wp-content/uploads/sites/66/2023/06/iot-annex-56-project-case-at-edcsproof.pdf

5.5 EnergyLab Nordhavn

In this Danish research project, spare compressor capacity from supermarket refrigeration system is utilized for heat production to local space heating and local domestic hot water heating and for the district heating grid. A smart controller using price signals is used to decide whether heat is produced for local consumption or for the district heating grid. A detailed overview on data, connection platform, protocols, quality of service, data analysis and modeling requirements is presented in the Task 3 report.

Link to factsheet:

https://heatpumpingtechnologies.org/annex56/wp-content/uploads/sites/66/2023/04/iot-annex-56-project-case-dk-energylab-nordhavn-smart-components.pdf

5.6 FlexHeat

This Danish research project investigates flexibility of large scale heat pumps to reduce heat production costs for the system and to ensure that heat pumps can help stabilize the current and future electricity system. It is presented as an example for flexibility provision in the Task 4 report.

Link to factsheet:

https://heatpumpingtechnologies.org/annex56/wp-content/uploads/sites/66/2023/04/iot-annex-56-project-case-dk-flexheat.pdf

5.7 Contracting solutions for industrial heat pumps

In the Task 4 report, two examples of contracting solutions for industrial heat pumps are presented: Aneo industry is a Norwegian company that offers steam generating heat pumps as a contracting solution.

Kelag Energie & Wärme, an Austrian company that operates a large number of district heating grids and decentralized heat stations in Austria. They offer different contracting models for heat pumps ranging from overall concepts including planning, financing, construction, operation to individual solutions for industry, public and private service providers, municipalities, housing associations, property developers etc.

6 Conclusions

IoT enabled heat pumps are already in operation in industry and district heating. The most important IoT aspect is the integration in a higher level control system e.g. the process control system. Depending on the IoT service that should be provided with the heat pump, there are different data and modelling requirements. Seven examples provide insights in specific IoT use cases for heat pumps in industry and district heating. Optimal process control and the alignment with other heat providers and predictive maintenance are important applications. The Austrian manufacturer survey provided useful insights in data and interfaces for heat pumps in industry and district heating. Similar to residential heat pumps, there is not one specific architecture, but several communication interfaces and transmission protocols that are offered. Data can be processed locally or in the cloud, many participants in the survey offer both options. Data is mostly evaluated for visualization, monitoring, calculation of Key Performance Indicators (KPIs) and statistical analysis based on historic data. Advanced methods for data analysis such as automated pattern recognition (e.g. based on machine learning, ML) are emerging.

7 References

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8 Acknowledgements

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