

# Results from the IEA HPT IoT Annex 56 project about digital services for IoT connected heat pumps

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Seminar on Digitalization of Refrigeration and Heat Pump Systems



# Heat Pumping Technologies (HPT) programme

- A Technology Collaboration Programme (TCP) within **the IEA** since **1978**
- An international framework of **cooperation** and **networking** for different HP actors
- A forum to exchange **knowledge** and **experience**
- A contributor to **technology improvements** by RDD&D projects



20 member countries

Austria	Denmark	Japan	Sweden
Belgium	Finland	Netherlands	Switzerland
Canada	France	Norway	United Kingdom
China	Germany	South Korea	United States
Czech Republic	Ireland	Spain	
	Italy		

# Digitalisation and IoT for HPs - IEA HPT Annex 56

- Project duration: 2020-2023
- 4 main task (work packages):
  - Task 1: State-of-the art
  - Task 2: Interfaces
  - Task 3: Data Analysis
  - Task 4: Business Models
- Interviews and surveys on the state of digitalisation in the participating countries
- 40 factsheets of IoT use cases and projects
- Covers both household and industrial heat pumps

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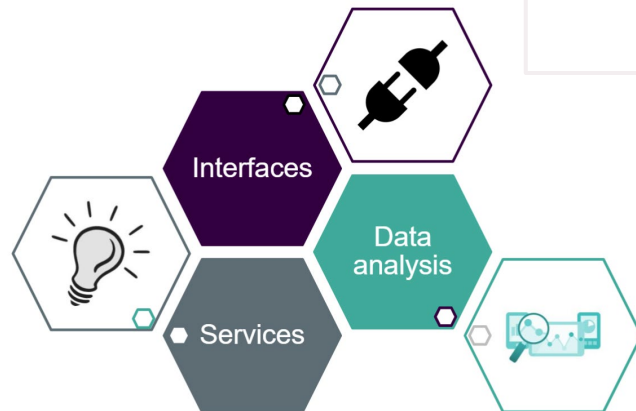
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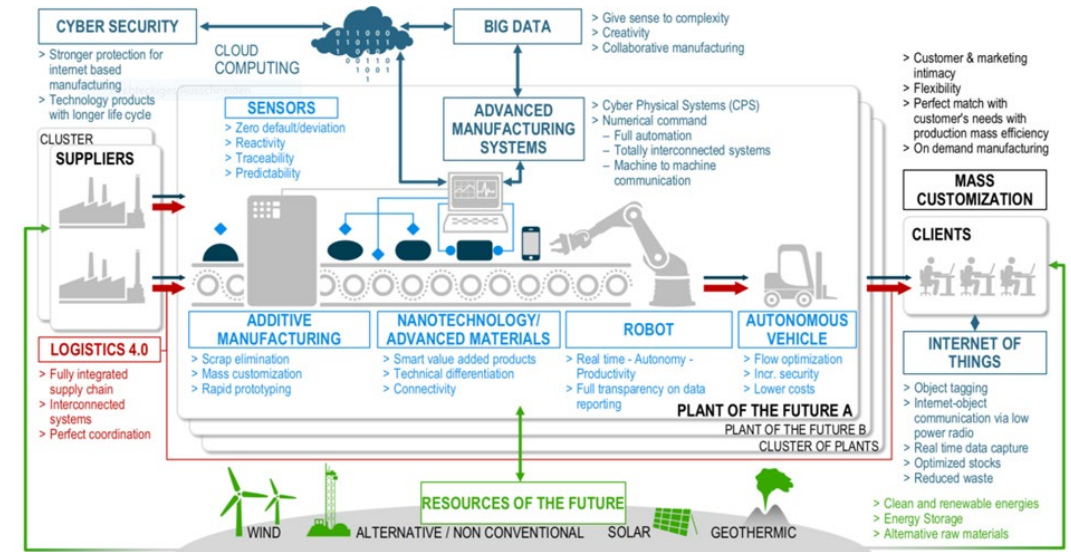
# Task 1 – state of the art

- One of the first definitions of "IoT" which creates a shift of paradigm from **internet of data and people** to **internet of things**:

*Internet of Things: "Machine-to-machine communications and person-to-computer communications will be extended to things, from everyday household objects to sensors monitoring the movement of the Golden Gate Bridge or detecting earth tremors. Everything from tyres to toothbrushes will fall within communications range, heralding the dawn of a new era, one in which today's internet of data and people gives way to tomorrow's Internet of Things." (ITU, 2005)*

- Paradigm shift lead to wider range of communication protocols:

- Industrial Ethernet fieldbuses: Modbus, KNX, BACnet, ...
- Session layer protocols: AMQP, MQTT, ...
- Opportunities, uncertainties and characteristics for protocols described in Task 1 report.



Trend in evolution of M2M to IoT, (Blanz, 2012).



The global push for new technologies brought by a large number of different consortia and standards, (Blanz, 2012).



# Task 1 – State of the art – use cases

- 40 use cases collected by the various national teams with focus on design, development, and implementation of IoT solutions for heat pump systems. Both products and services as well as research projects.
- Fact sheets includes key aspects such as stakeholders, participants, connection type and data requirements.
- Common patterns identified, resulting in 5 main categories:
  - Heat pump operation optimization
  - Predictive maintenance
  - Flexibility provision
  - Heat pump operation commissioning
  - Heat as a service

Annex 56 Digitalization and IoT for Heat Pumps

### Large scale demand response of heat pumps to support the national power system (SLAV)

RISE Research Institutes of Sweden

Figure 1: Overview of the communication flow for demand response from heat pumps using the manufacturers cloud solution.

Summary

In a power system with an increased share of electricity from intermittent renewable sources, such as wind and solar, a more flexible electricity consumption will be needed. The project has investigated possibilities and constraints for a concept where residential heat pumps are aggregated and controlled via the power system with cloud service to support the Swedish kraftnäts demand response with focus on Svenska kraftnäs ancillary services, local flexibility markets or bilateral agreements.

The project covers several aspects, such as barriers related to technical constraints in the heat pumps and the electricity markets as well as potential communication standards and cybersecurity. The results are based on expert interviews, literature review and field tests. Even though the project focuses on Swedish conditions the results are likely relevant in several countries.

Controlling individual heat pumps for demand response via the manufacturers' already existing cloud and application programming interface (API) would enable rapid deployment of heat pumps as a flexibility resource.

The manufacturers' cloud and API solutions have been in use for approximately ten years, which means that many installed heat pumps are already ready to be used for flexibility purposes once the communication is in place. In Sweden all the major manufacturers of hydronic heat pumps provide manufacturers' cloud and API solutions for controlling and monitoring their heat pumps via an app, by connecting the heat pump to the manufacturer's cloud infrastructure. From a control point of view, cloud infrastructure is still lacking to enable demand response to the power system via these cloud services, but as the hardware is in place since several years, the potential of heat pumps with the hardware already installed is assessed as large.

Factsheet for "Large scale demand response of heat pumps to support the national power system – SLAV (SE)"

Annex 56 Digitalization and IoT for Heat Pumps

### Virtual Energy Storage Network based on Residential Heating Systems

Tiko Energy Solutions AG

Figure 1: tiko system overview [1]

Summary of IoT case

To ensure stability of power grids, the energy supply and demand must be balanced. Traditionally, the demand for production-side balancing was unchangeable and the increase of fluctuating renewable energy sources, with electricity production itself becoming difficult to control, supply, flexibilization of the demand side must be achieved. Due to the high inertia of the thermal energy stored in the buildings across the demands are well suited for load side flexibilization if they are covered by heat pumps or other forms of electrical heating.

The company tiko Energy Solutions AG started with the development of its ancillary service business in 2012 and entered the market with its solution in 2014. In 2017, tiko's virtual power plant already included over 10,000 electrically based heating systems throughout Switzerland. More than half of these installations are heat pumps. The remaining installations are made up of direct electric heaters, night storage heaters and hot water boilers. In 2017, tiko managed a total capacity of up to 50 MW in Switzerland [1]. tiko offers the grid operator both primary control quality (frequency stability) and secondary control quality (balancing between planned power and actual power in the grid). Since 2017, tiko has expanded its market internationally and has established a customer base in several countries in the EU [2].

The tiko system can be divided into 4 parts (see Figure 1), as the actors and sensors, two devices are connected directly to the heating system. The "1-sensor" measures the power consumption and at the same time serves as a control switch using a relay. The "2-box" measures the room temperature, so that the room or water temperature does not drop out of the desired temperature range due to a switch action. Both devices communicate within the house power line carrier PLC with the "3-box" (gateway). The "3-box" collects all data and communicates via 3G/4G network work is performed on the cloud server. All processing system collects all information about the connected devices and combines it with additional information such as local weather forecasts, past consumption patterns and estimation of the current state of the devices. Based upon this information and employing proprietary algorithms,

Result

- Ancillary service
- The
- 
- 
- 

Factsheet for "Virtual Energy Storage Network based on Residential Heating Systems by Tiko Energy Solutions AG (CH)"

# 23 DANISH CASE DESCRIPTIONS

## Product and Service Suppliers:

- Energy Machines – Energy machines verification
- Neogrid – PreHEAT for Heat Pumps by Neogrid Technologies ApS
- LS Control - SmartConnect Center
- Centrica Energy Marketing and Trading
- Climify – Indoor Climate Monitoring Platform
- Nærvarmeværket – Community owned Heat Pump Company
- AI-nergy – Artificial Intelligence Assisted Products
- ENFOR A/S – Energy Forecasting and Optimization Platform
- Center Denmark – The Digital Data Platform
- EnergyFlexLab
- METRO THERM - MyUpway™

## IoT Project Cases:

- Digital Twins for Large-scale Heat Pump and Refrigeration Systems
- EnergyLab Nordhavn - Smart Components
- Flexheat – Intelligent and Fast-regulating Control
- Smart-Energy Operating-Systems (SE-OS) framework
- OPSYS 2.0
- Cool-Data
- SVAF phase II
- HPCOM
- Flexible Energy Denmark
- Res4Build
- Development of Fast Regulating Heat Pumps using Dynamic Models
- CEDAR

11 case descriptions for product and service providers and 12 case descriptions for R&D projects about IoT and digitalization of heat pumps in Denmark.

Full descriptions of all use cases available on homepage:  
<https://heatpumpstechnologies.org/annex56/factsheets/>



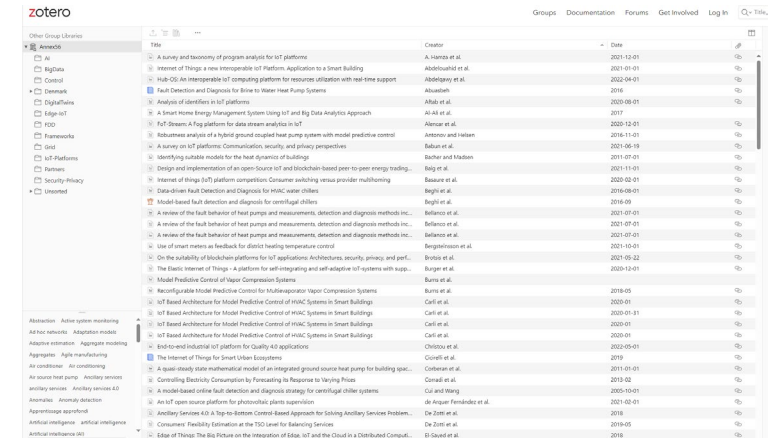
Factsheet for "Energy machines verification tool (EMV)".



Factsheet for "PreHEAT for Heat Pumps by Neogrid Technologies ApS".

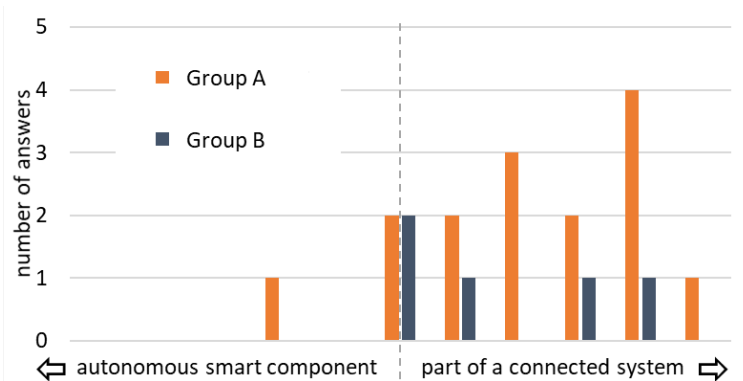
# Task 1 - Literature and survey

- To create an overview of the current state of research on IoT technologies for heat pump a large number of literature sources were collected in a public Zotero group, available at the following link: <https://www.zotero.org/groups/4871439/annex56/library>

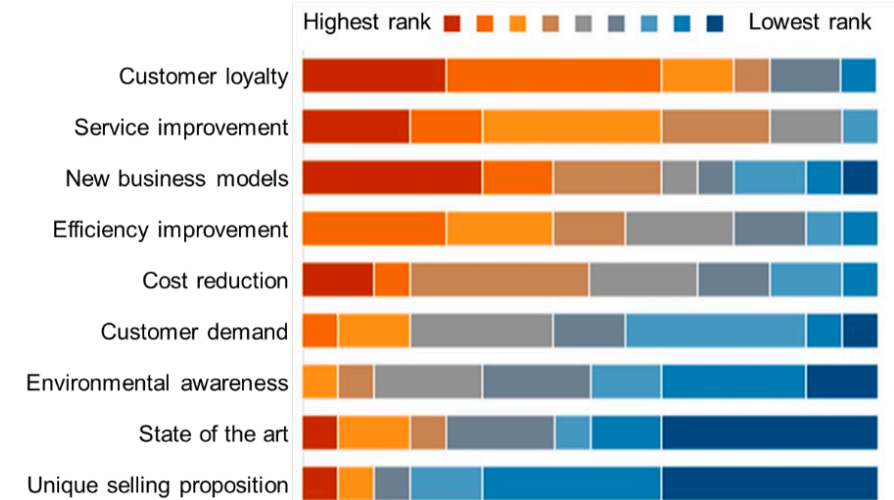


Zotero library with literature survey.

- Manufacturer survey (Austria)
  - About 50 questions to gather and evaluate the general opinion and importance of IoT and heat pumps
  - A total of 16 companies participated in the survey
  - Challenges: Data security, data protection guidelines, increase of system complexity, and availability of qualified personnel
  - Frequent answers to introduce IoT products: Customer loyalty, service improvement and new business models



IoT enabled heat pumps are expected to become a part of a connected energy system in the future rather than an autonomous smart component

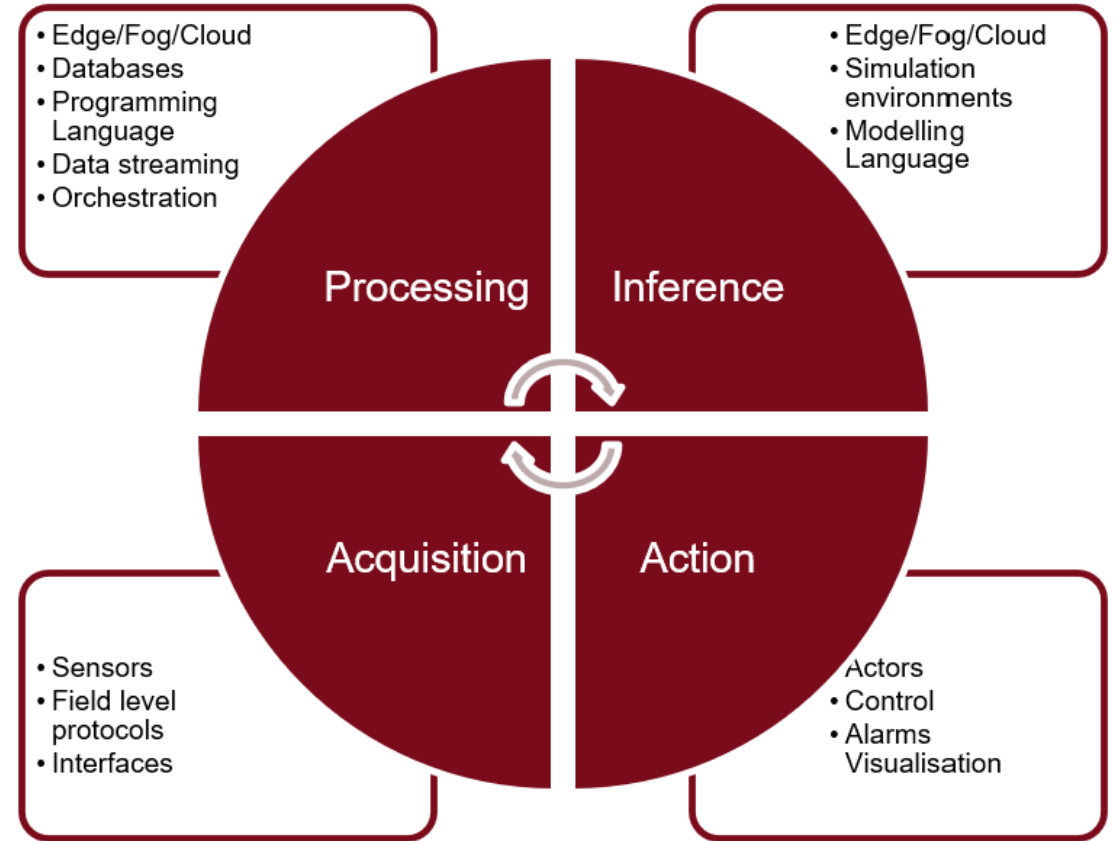


Motivation to introduce IoT products in heat pump systems.



# Task 2 – Interfaces, platforms and protocols

- Task 2: Provision of communication and processing capabilities.
- Common challenges and solutions analysed for different applications:
  - Digital twins of heat pumps
  - Connected heat pumps in building automation
  - Heat pumps in grid services
  - Retrofitting
- Completing a circle in the decision-making framework can add value.



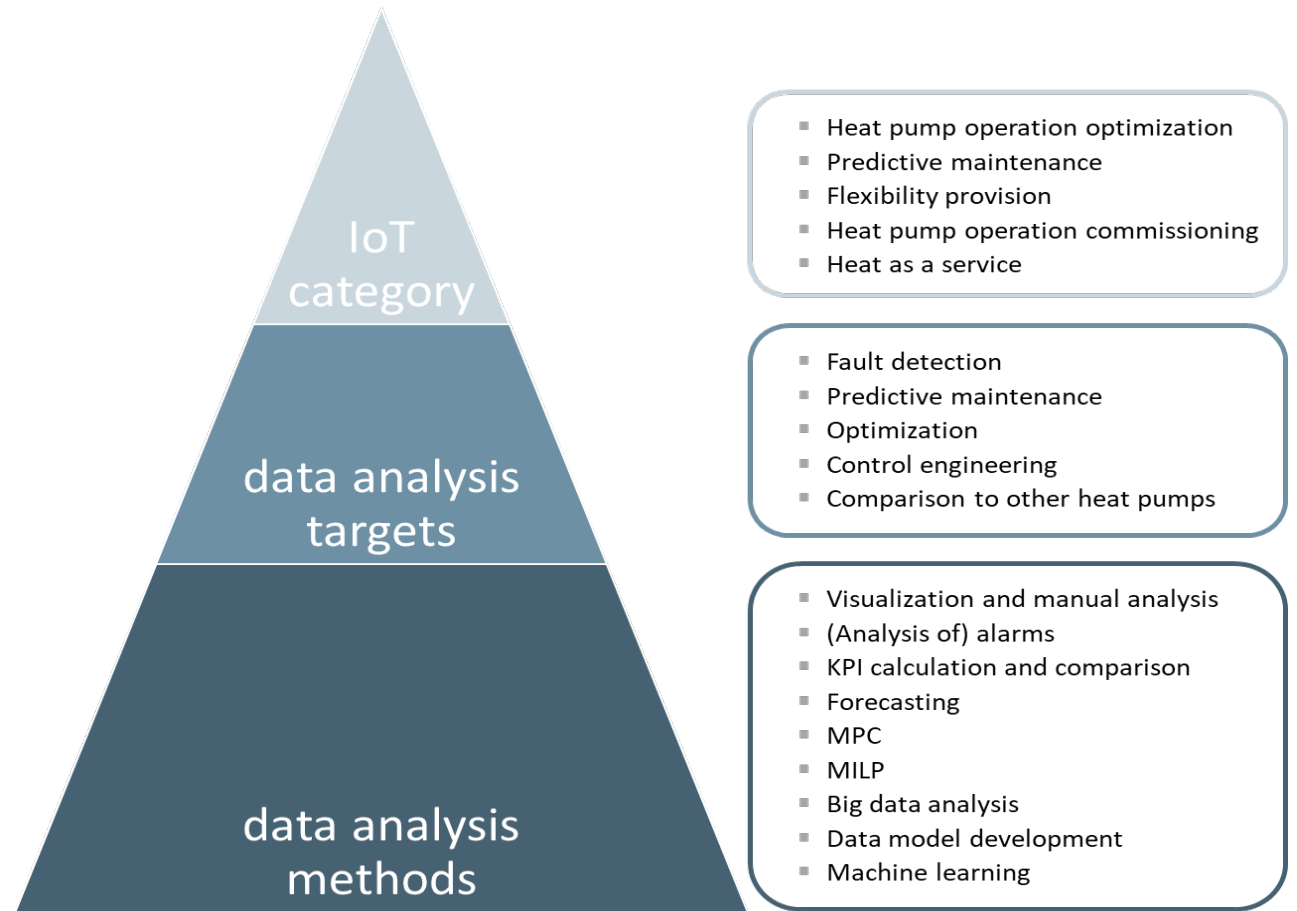
*Decision making framework of an IoT application*





# Task 3 – Data Analysis

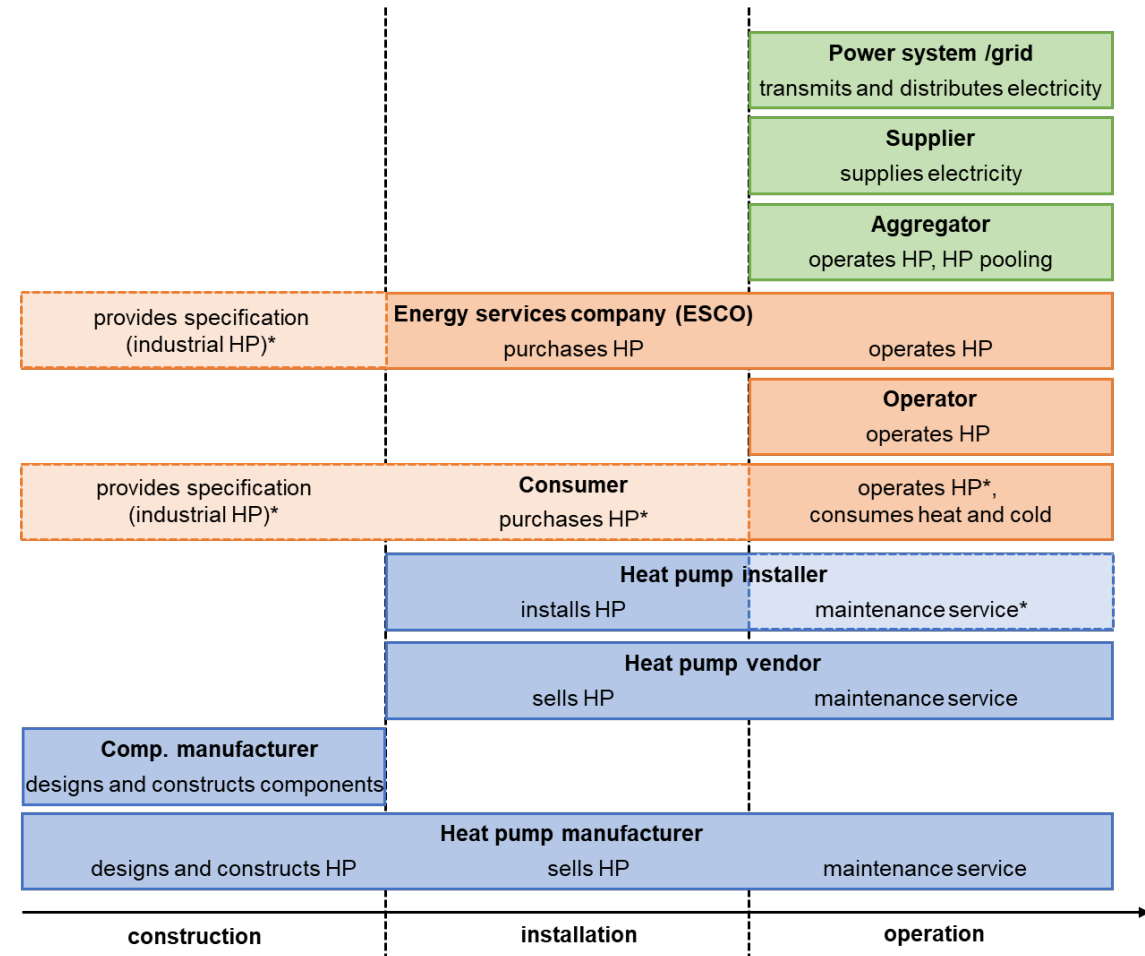
- Categorization of data analysis methods and targets based on use cases.
- Best practices given on: Pre-treatment of data, usage of data models, meta data and building information models (BIM).
- Applicable data analysis methods for certain use cases identified.



*Hierarchy derived from the use cases: IoT category, data analysis targets and data analysis methods*

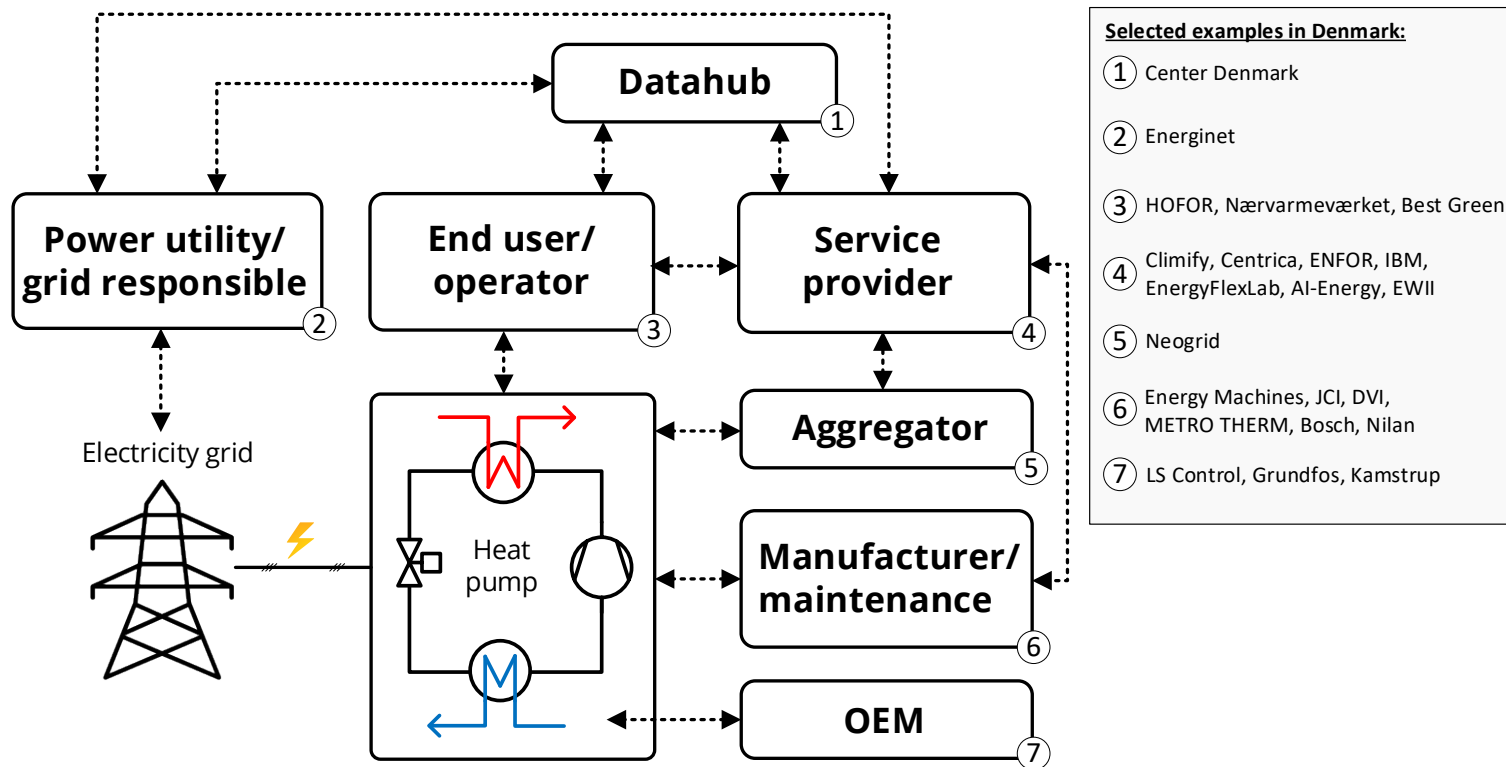
# Task 4 – Business Models

- 19 examples of business models analyzed
- SWOT analysis to compare business models, e.g.:
  - Predictive maintenance vs. Fixed interval or on demand maintenance
  - Heat as a service vs. Traditional model
  - Providing flexibility with heat pump pooling vs. Using a heat pump as an autonomous component in a building
- Key findings:
  - Value proposition for the consumers: Lower costs, higher efficiency, higher reliability
  - More responsibility for efficiency than in traditional business models.
  - Energy system (aggregators, suppliers, grid, etc.): Strong need for flexibility to compensate for fluctuating generation. Sector coupling with heat pumps (power/heat) possible.



Overview on stakeholders in the life cycle of IoT enabled heat pumps (\* indicates optional tasks).

# IoT-based energy system around heat pump(s)

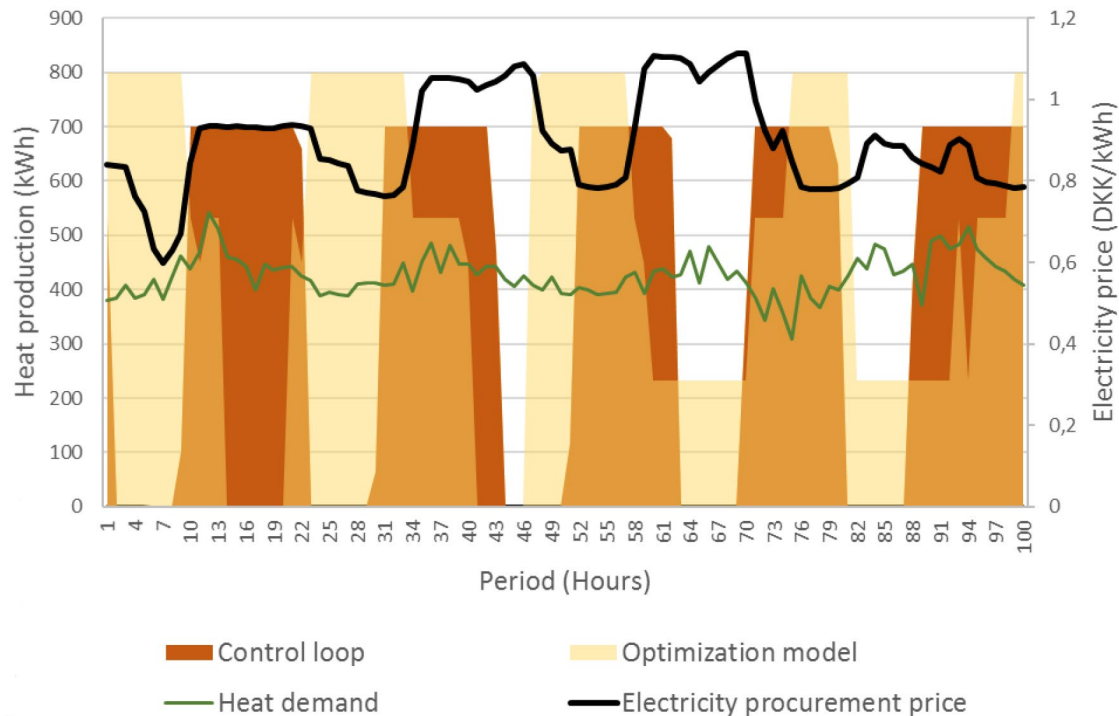


- Several stakeholders at different levels in the heat pump industry are focusing on enhancing and deploying digital and IoT-enabled solutions for heat pumps in Denmark.
- Cooperation between groups important to further develop the digitalization of the energy system around the heat pump(s).
- Overlap for companies being present in more groups, but general grouping visualized (various other companies not included in review also exists).

*Visualization of supplier groups and examples of associated suppliers in an IoT-based energy system for heat pumps – based on review results from collected case studies in Denmark.*



# Task 4 - FLEXHEAT (use case example)



*Flexible heat production during winter [HOFOR, 2021].*

- Grid services are provided with a flexible energy system consisting of an 800 kJ/s ammonia-based ground-water heat pump with reciprocating compressors, 200 kJ/s electric boiler and a thermal storage tank of 100 m<sup>3</sup>.
- System is optimized by a linear-optimization model supported by a dynamic model of the heat system to schedule optimal planning production with a real-time communication setup to control the heat pump accordingly. Furthermore, the heat pump has been modified to provide fast regulation services to the grid.
- Preliminary results indicate that operating costs can be reduced by 7 % by introducing intelligent operation with the linear optimization model, and an additional 6 % costs reduction can be achieved by delivering grid services.

# Annex 56 homepage



## Annex 56 homepage, link:

- <https://heatpumpingtechnologies.org/annex56>

## Available reports:

- [Annex 56 – Digitalization and IoT for Heat Pumps Final Report](#)
- [Annex 56 Digitalization and IoT for Heat Pumps Executive Summary](#)
- [Annex 56 Digitalization and IoT for Heat Pumps 2-page Summary](#)
- [Task 1 Report: State of the Art](#)
- [Task 2 Report: Interfaces and platforms](#)
- [Task 3 Report: Data analysis](#)
- [Task 4 Report: Business Models](#)
- [Country summary report for Denmark on digitalization and IoT for heat pumps](#)

## 40 project and use case descriptions about IoT and digitalization of heat pumps:

- <https://heatpumpingtechnologies.org/annex56/factsheets/>

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