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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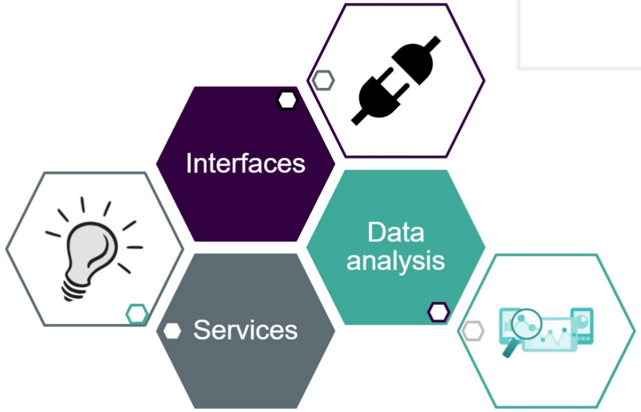
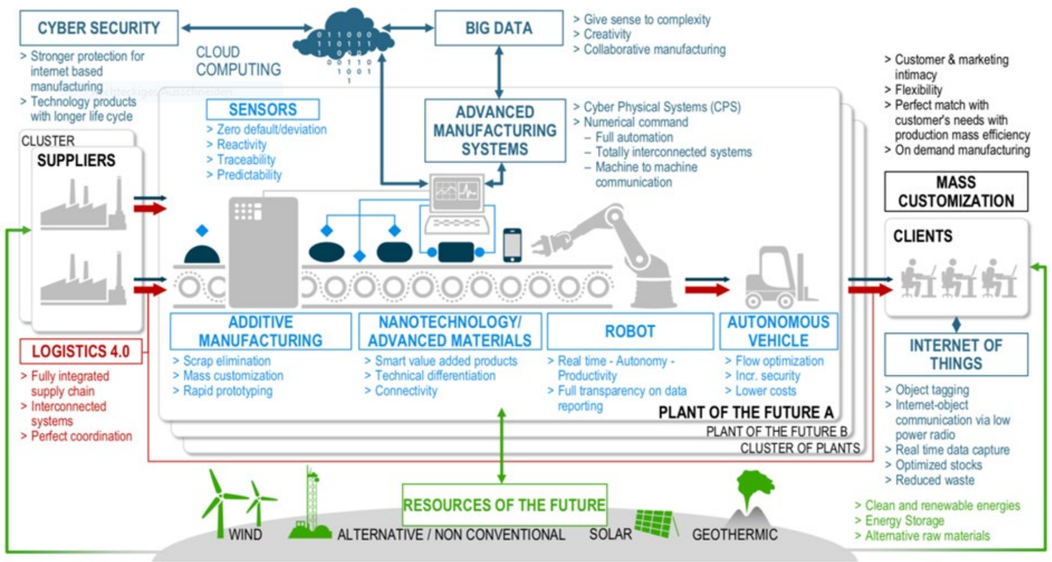


Task 1 – state of the art

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

  *<u>Internet of Things</u>: “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)*



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

- Paradigme 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.

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

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

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

23 DANISH CASE DESCRIPTIONS

<u>Product and Service Suppliers:</u>

- 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[TM]

<u>IoT Project Cases:</u>

- 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://heatpumpingtechnologies.org/annex56/factsheets/

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

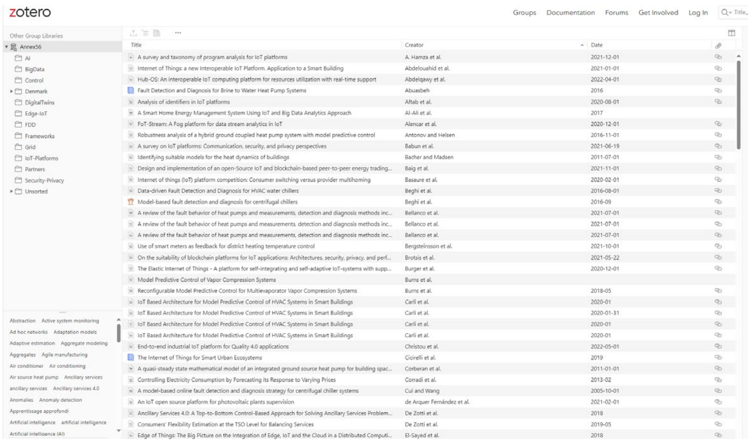
Factsheet for "PreHEAT for Heat Pumps by Neogrid Technologies ApS".

Teknologisk Institut

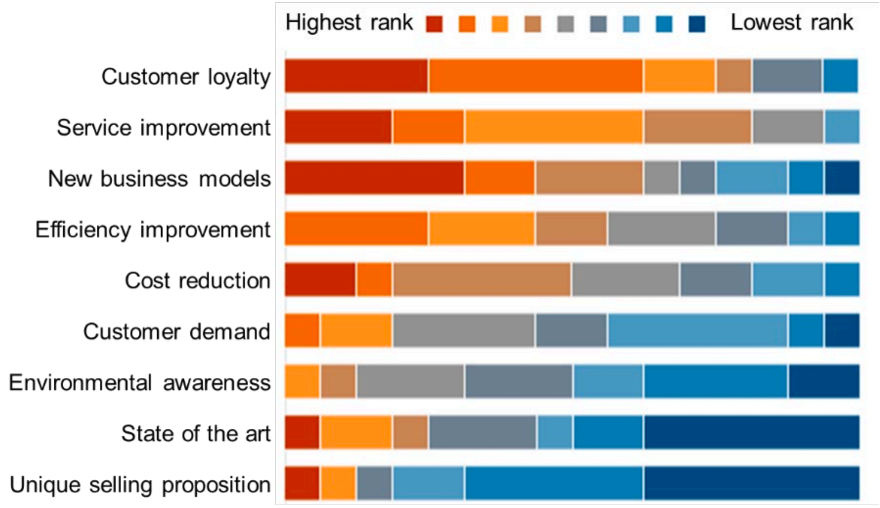
Task 1 – Litterature and survey

- 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

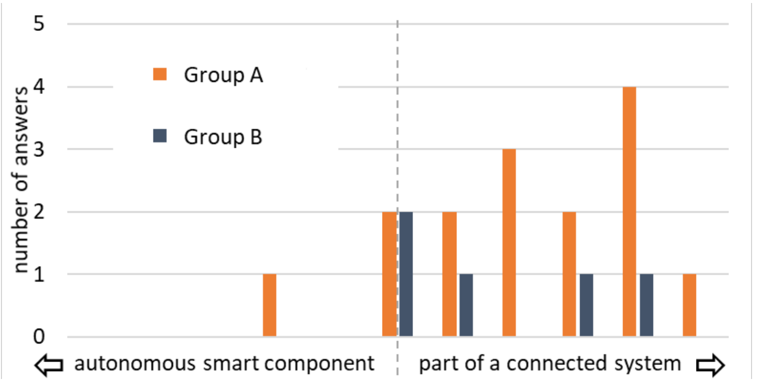
- Manufacturer survey (Austria)
  - About 50 questions to gather and evaluate the general opinion and importance of IoT and heat pumps
  - A total of 16 companies participated in the survey
  - Challenges: Data security, data protection guidelines, increase of system complexity, and availability of qualified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



Zotero library with literature survey.



Motivation to introduce IoT products in heat pump systems.

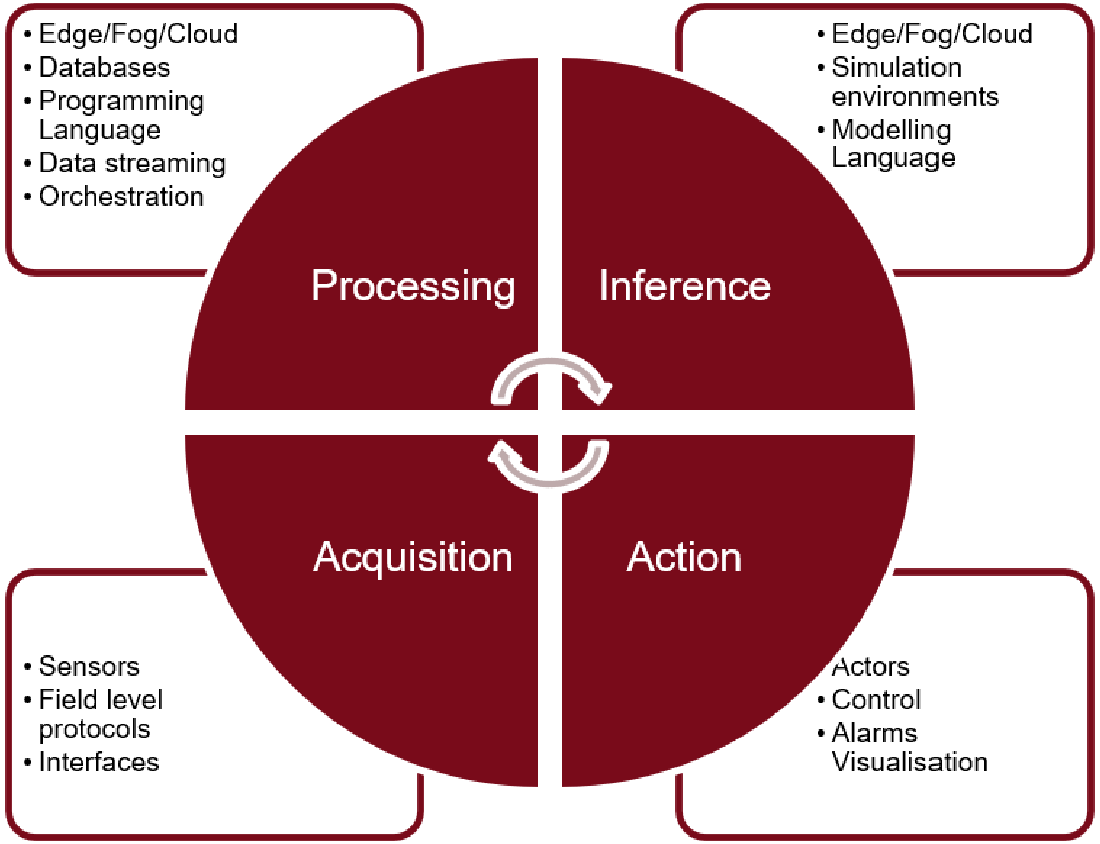


IoT enabled heat pumps are expected to become a part of a connected energy system in the future rather than an autonomous smart component

IoT for heat pumps
HPT

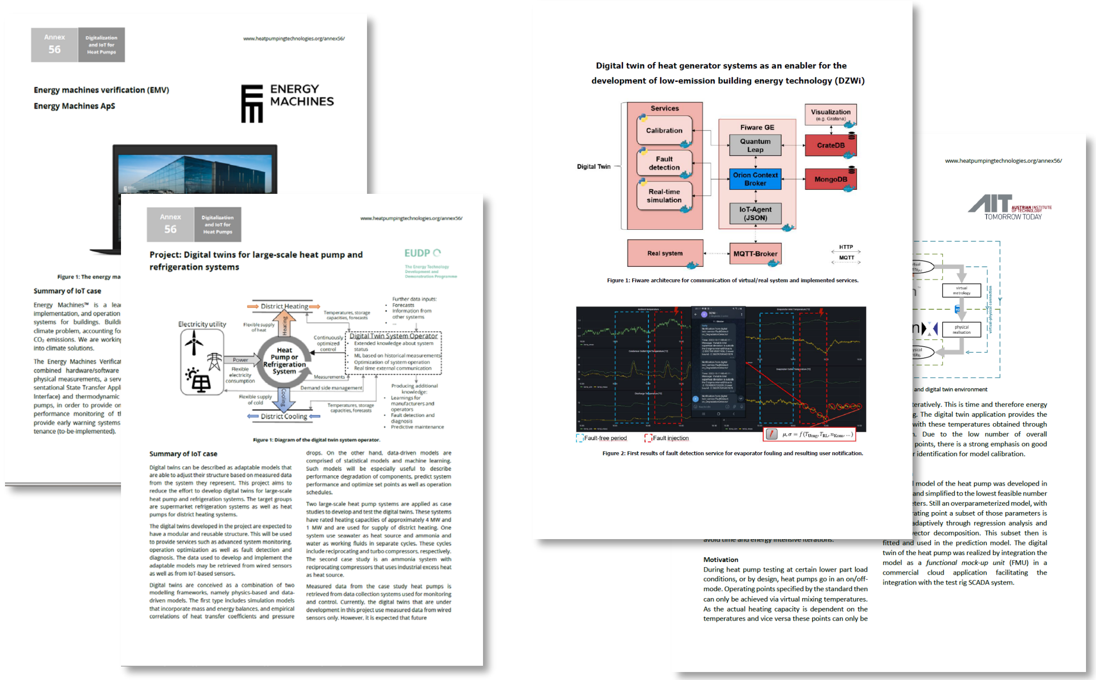
Task 2 – Interfaces, platforms and protocols

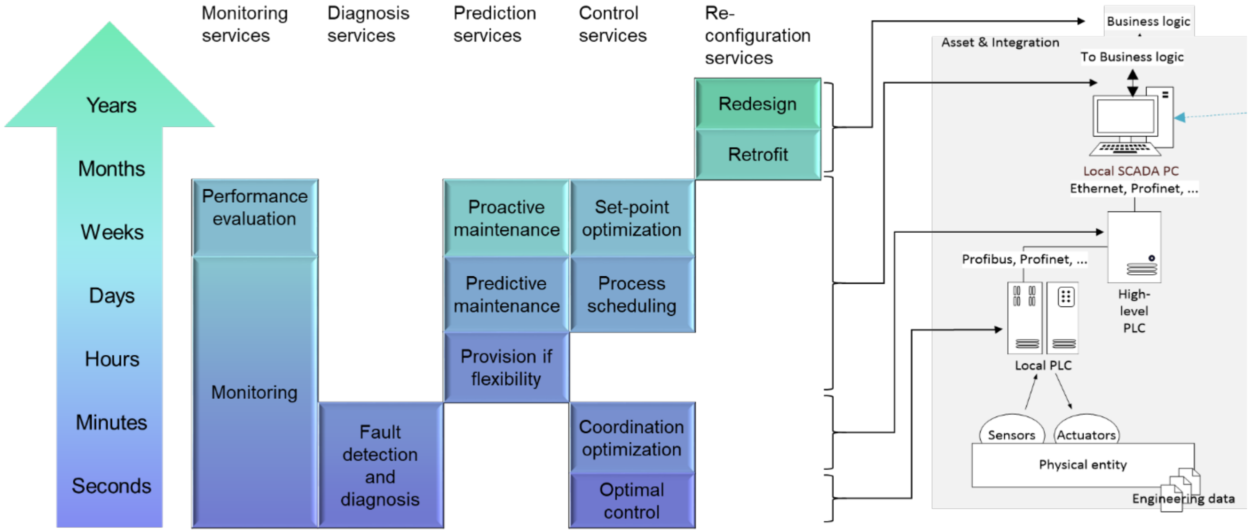
- Task 2: Provision of communication and processing capabilities.
- Common challenges and solutions analysed for different applications:
  - Digital twins of heat pumps
  - Connected heat pumps in building automation
  - Heat pumps in grid services
  - Retrofitting
- Completing a circle in the decision-making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



Decision making framework of an IoT application

Task 2 - Digital twins of heat pumps





Categorization of services provided by digital twins according to scope, response time and relevant system level on which the service is executed

4 examples of Digital Twins analysed:

- DIGIBatch: A digital twin for predicting operating points for test bench measurements of heat pumps (research project from Austria)
- Distributed Digital Twin: Architecture of a distributed digital twin (research project “Digital Twins”, DK)
- DZWI: Digital twin of heat generating systems as a pioneer for the development of low emission building energy technology (research project from Germany)
- Digital twins by EnergyMachines (IoT product from Denmark)

Challenges:

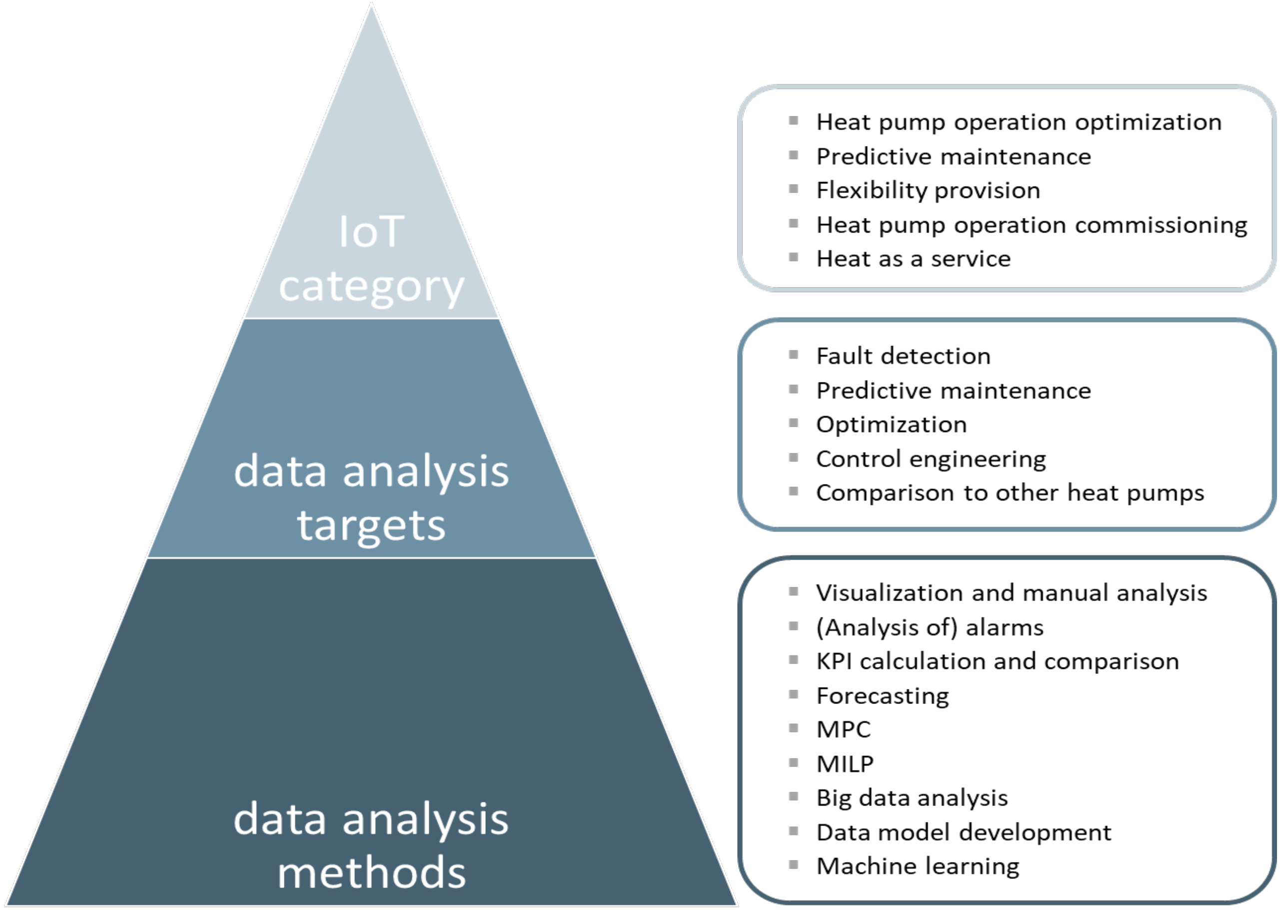
- Distributed data
- Timescales
- Simulation req.
- Configuration

Solutions:

- Data Broker (MQTT)
- Containers
- FMU
- Frameworks

Task 3 – Data Analysis

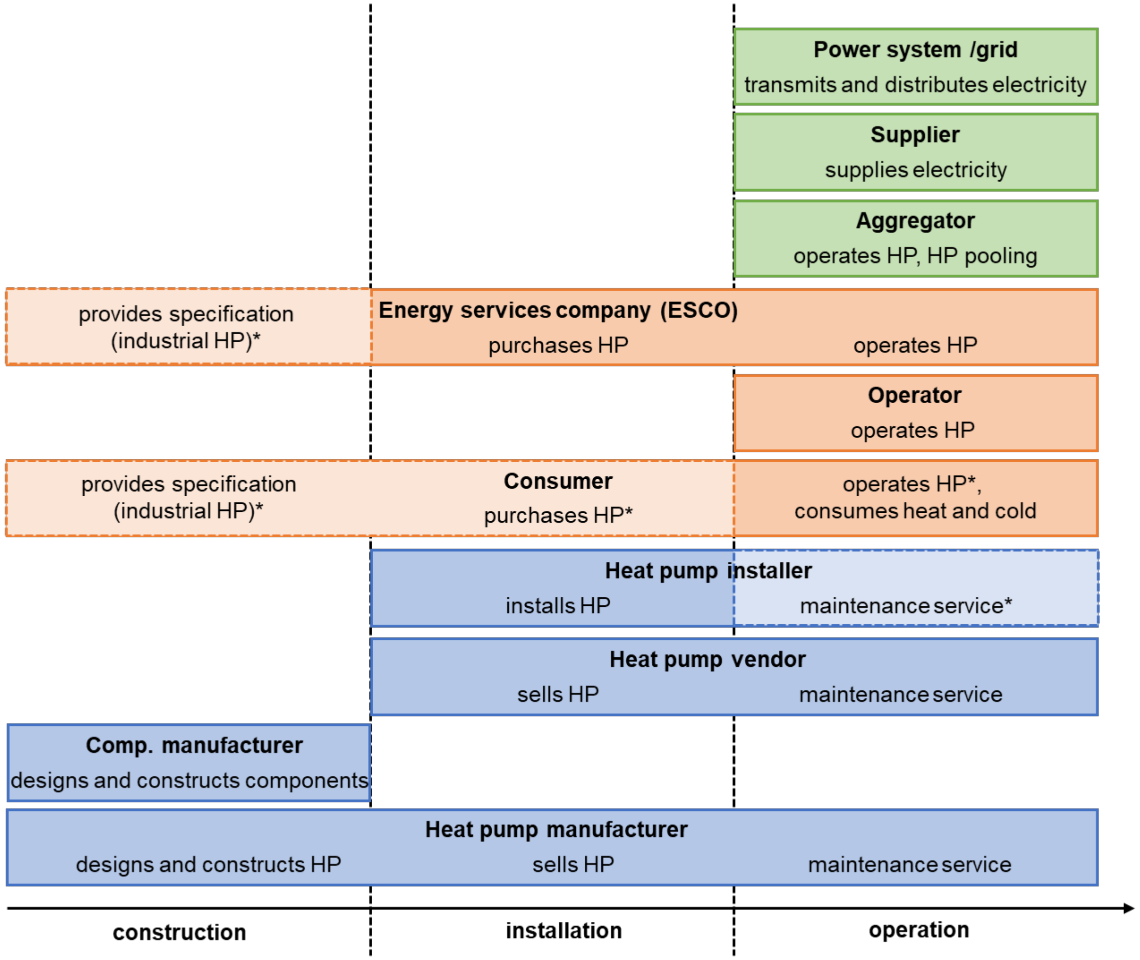
- Categorization of data analysis methods and targets based on use cases.
- Best practices given on: Pre-treatment of data, usage of data models, meta data and building information models (BIM).
- Applicable data analysis methods for certain use cases identified.



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

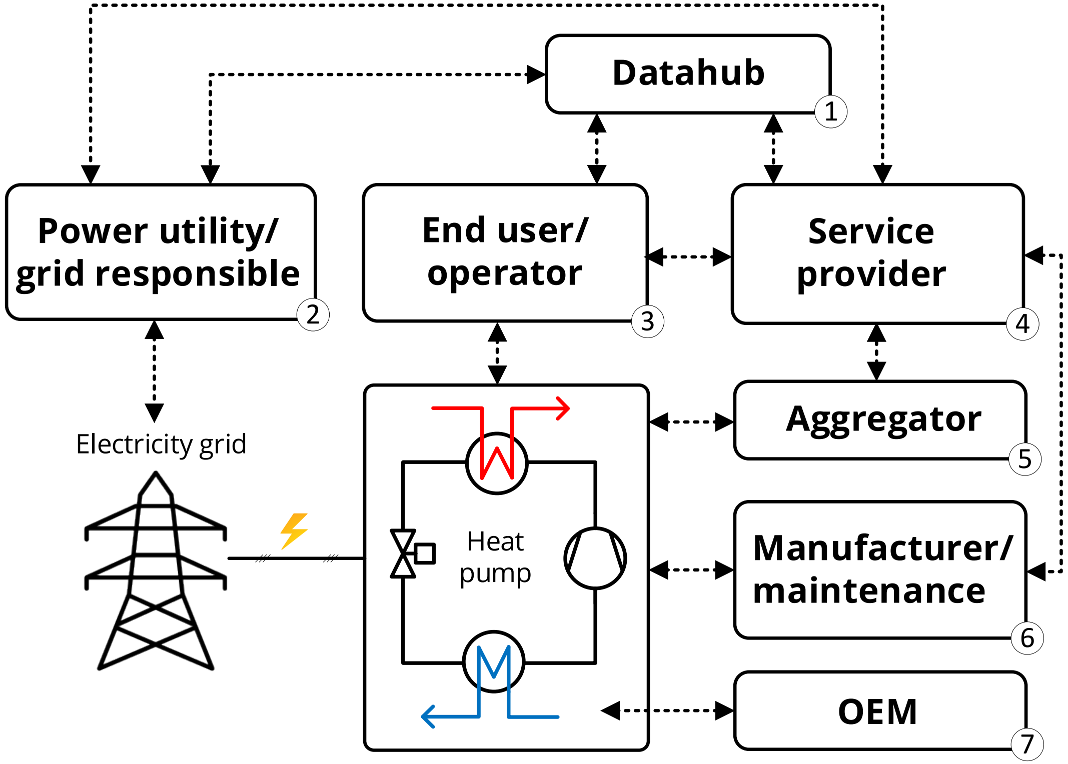
Task 4 – Business Models

- 19 examples of business models analyzed
- SWOT analysis to compare business models, e.g.:
    - Predictive maintainance 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)



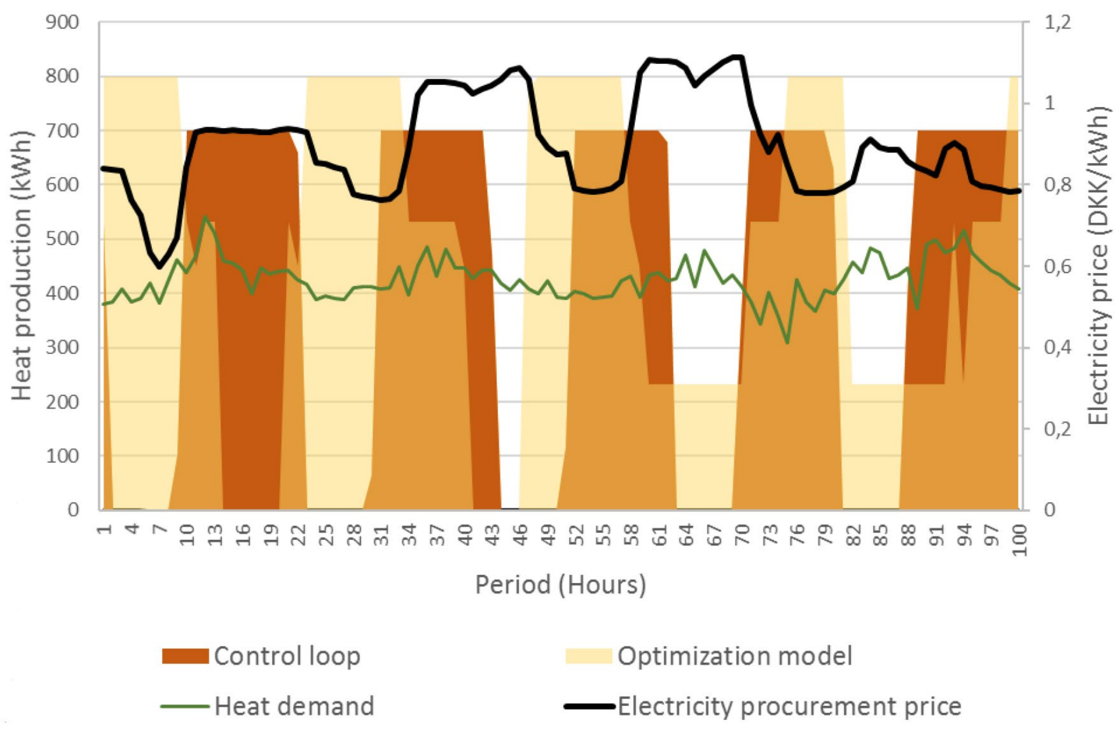
Selected examples in Denmark:

1. Center Denmark
2. Energinet
3. HOFOR, Nærvarmeværket, Best Green
4. Climify, Centrica, ENFOR, IBM, EnergyFlexLab, AI-Energy, EWII
5. Neogrid
6. Energy Machines, JCI, DVI, METRO THERM, Bosch, Nilan
7. LS Control, Grundfos, Kamstrup

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.

- 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).

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^3.
- 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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