Technology Collaboration Programme
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Technology Collaboration Programme on Heat Pumping Technologies (HPT)

Annex 56

Digitalization and IoT for Heat Pumps

Task 4: Business Models

Task Report

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Preface

This project was carried out within the Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP), which is a Technology Collaboration Programme within the International Energy Agency, IEA.

The IEA

The IEA was established in 1974 within the framework of the Organization for Economic Cooperation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster cooperation among the IEA participating countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development (R&D). This is achieved, in part, through a programme of energy technology and R&D collaboration, currently within the framework of nearly 40 Technology Collaboration Programmes.

The Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

The Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) forms the legal basis for the implementing agreement for a programme of research, development, demonstration and promotion of heat pumping technologies. Signatories of the TCP are either governments or organizations designated by their respective governments to conduct programmes in the field of energy conservation.

Under the TCP, collaborative tasks, or "Annexes", in the field of heat pumps are undertaken. These tasks are conducted on a cost-sharing and/or task-sharing basis by the participating countries. An Annex is in general coordinated by one country which acts as the Operating Agent (manager). Annexes have specific topics and work plans and operate for a specified period, usually several years. The objectives vary from information exchange to the development and implementation of technology. This report presents the results of one Annex.
The Programme is governed by an Executive Committee, which monitors existing projects and identifies new areas where collaborative effort may be beneficial.

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The HPT TCP is part of a network of autonomous collaborative partnerships focused on a wide range of energy technologies known as Technology Collaboration Programmes or TCPs. The TCPs are organised under the auspices of the International Energy Agency (IEA), but the TCPs are functionally and legally autonomous. Views, findings and publications of the HPT TCP do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries. This report has been produced within HPT Annex 56. Views and findings in this report do not necessarily represent the views or policies of the HPT TCP and its individual member countries.

The Heat Pump Centre

A central role within the HPT TCP is played by the Heat Pump Centre (HPC).

Consistent with the overall objective of the HPT TCP, the HPC seeks to accelerate the implementation of heat pump technologies and thereby optimise the use of energy resources for the benefit of the environment. This is achieved by offering a worldwide information service to support all those who can play a part in the implementation of heat pumping technology including researchers, engineers, manufacturers, installers, equipment users, and energy policy makers in utilities, government offices and other organisations. Activities of the HPC include the production of a Magazine with an additional newsletter 3 times per year, the HPT TCP webpage, the organization of workshops, an inquiry service and a promotion programme. The HPC also publishes selected results from other Annexes, and this publication is one result of this activity.

For further information about the Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) and for inquiries on heat pump issues in general contact the Heat Pump Centre at the following address:
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The Annex is operated from 01/2020 to 12/2022. Further information is available on the Annex website https://heatpumpingtechnologies.org/annex56/

Participating countries

The following countries participate in Annex 56:

- Austria
- Denmark
- France
- Germany
- Norway
- Sweden
- Switzerland

A detailed presentation of the national teams and their research work is available on the Annex website https://heatpumpingtechnologies.org/annex56/participants/

Participants and contributors to this report

This task report is the result of a collaborative effort with contributions from various authors that are listed in the table below. The report was coordinated by the Task leader Veronika Wilk, veronika.wilk@ait.ac.at

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Foreword

Today, more and more devices are connected to the Internet and can interact due to increasing digitalization – the Internet of Things (IoT). In the energy transition, digital technologies are intended to enable flexible energy generation and consumption in various sectors, thus leading to greater use of renewable energies. This also applies to heat pumps and their components.

The IoT Annex 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 the 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. 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 into a high level energy management system, which can be used for overall optimization of the process.

IoT is also associated to different important risks and requirements to connectivity, data analysis, privacy and security for 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. The Annex is structured in 5 tasks:

Task 1 – State of the Art:

This task summarizes the state of the art and gives an overview on the industrial Internet of Things, communication technologies and knowledge engineering in automation. It reviews the status of currently available IoT enabled heat pumps, heat pump components and related services in the participating countries and provides information on information security and data protection.

Task 2 – Interfaces:

This task identifies requirements for data acquisition from new built and already implemented heat pump systems and provides information on types of signals, protocols and platforms for different heat pump use cases in buildings and industrial applications.

Task 3 – Data analysis

This task gives an overview on data analysis based on examples of IoT products and services, Different targets for data analysis are derived, data analysis methods are categorized and assessed, starting with visualization and manual analysis reaching to machine-learning algorithms. The report provides insights in the pretreatment of data, the use of data models, meta data and BIM (building information modeling).

Task 4 – Business Models

This task evaluates market opportunities created by connected heat pumps and presents different types of IoT services and business models based on literature and market research including detailed SWOT analyses (strengths, weaknesses, opportunities, and threats).

Task 5 – Dissemination

This task aims at reporting results and disseminating information developed in the Annex. Interactions and synergies with other Annexes or Tasks in the IEA Technology Collaboration Programs are sought.

IoT for heat pumps

Table of content

1 Introduction

Task 4 aims to evaluate market opportunities created by connected heat pumps and identifies success factors and further development demands for software and hardware. To this end, different types of IoT services are described. Based on the work of the previous tasks, the most relevant use cases for IoT enabled heat pumps are identified. An overview on business models for connected heat pump is given based on literature and market research. For three business models a detailed SWOT analysis was carried together with the IoT Annex expert group to elaborate strengths, weaknesses, opportunities, and threats.

2 IoT Services

Gigli et al. [1] distinguish four different types of IoT services:

- Identity-related services
- Information aggregation services
- Collaborative-aware services
- Ubiquitous services

Identity-related services connect real world objects with the internet by using clear identifiers, they are the basis for other services. Information aggregation services collect and summarize raw sensory measurements that need to be processed and reported to the IoT application. Collaborative-aware services use the obtained data to make decisions and react accordingly. Ubiquitous Services aim to provide collaborative-aware services anytime anywhere to anyone. For example, smart grids are referred to as information aggregation Services, as they collect, analyze, control, monitor and manage energy consumption of a large number of smart meters. Smart homes are collaborative-aware services, providing increased comfort to the residents by controlling different devices. An example for a Ubiquitous Services is a Smart City, connecting even more devices and domains, such as health, utilities, transportation, government, homes, and buildings. [1], [2]

IoT enabled heat pumps can provide different IoT services connected to various business models. In a smart grid, IoT enabled heat pumps can be applied for smart demand response to reduce peak load and/or to optimize electricity consumption as a function of the electricity price. Preventive analytics are of interest for operators providing for example what-if analysis for operation decisions and information for predictive maintenance. IoT enabled heat pumps can be integrated in larger energy management systems, for example in buildings (BEM) or in industrial processes, where the provided data can be used for overall optimization of the process.

3 Use cases for IoT enabled heat pumps

In the IoT Annex more than 40 different use cases for IoT enabled heat pumps have been collected and analyzed (see also Task 1, 2 and 3). The use cases differ in the use of connectivity, type of data and data analysis and in the interaction with other “things” in the network. Connectivity and IoT are necessary preconditions for each use case. As outlined in Task 1, the following five IoT categories have been identified to group the use cases by their main purpose:

- *Heat pump operation optimization* e.g. by monitoring and remote control, by adaption to user habits, by adjustment of the heating curve, by scheduling of production and downtimes, by continuous set-point tuning, by interaction with other components (e.g. PV, solar thermal, storage, etc.) or to use flexible tariffs
- *Predictive maintenance* e.g. by learnings from performance benchmarks, grey box modeling, advanced data analytics, etc.
- *Heat pump operation commissioning* e.g. by set point tuning, comparison to performance benchmarks, learnings about the system layout and possible improvements for future installations, installation error analysis, grey box modeling, advanced data analytics, etc.
- *Flexibility provision* e.g. by pooling of household heat pumps, by providing flexibility as balancing reserve or flexibility to DSO/TSO for other services such as congestion management or voltage control
- *Heat as a service* e.g. by a different model of ownership (leasing, renting, buying heat instead of heating equipment)

Business models and services have been implemented already for four of the IoT categories, that will be discussed in this report. For heat pump operation commissioning, there are not yet any details available on implemented business models and services. However, research projects geared at developing and testing the prerequisites for these services are presented in the Task 1 report of this Annex project.

4 Stakeholders

Various stakeholders are involved in the lifecycle of a heat pump. In the following, the main actors are described, and their main contributions are visualized during construction, installation, and operation of the heat pump.

- *Heat pump manufacturer*: designs and constructs heat pumps, sells them to vendors or end-users, also offers maintenance service, usually does not act as installer
- *Component manufacturer*: designs and constructs heat pump components, such as compressors, valves or heat exchangers, sells them to heat pump manufacturers
- *Heat pump vendor*: sells heat pumps to end-users, also offers maintenance service, usually does not act as installer

- *Installer*: installs and commissions heat pumps, can also offer maintenance service
- *Consumer*: both residential and industrial end-users, consume heat (and cold) at a place where a heat pump is operated, can also be responsible for the operation of the heat pump, can provide specifications for the design of the heat pump (mostly for industrial heat pumps)
- *Operator*: responsible for the operation of the heat pump, provides heat (and cold) to consumers
- *Aggregator*: pools a large number of small assets into a large one to market flexibility to electricity markets or as grid services and thereby influences operation of the heat pump
- *Supplier*: supplies customers with electricity by trading at electricity markets and can also produce electricity e.g. from fossil fuels or renewable energy sources
- *Power system / grid*: transmits and distributes electricity, connects utilities and end-users, requires balancing of supply and demand
- *Energy service company (ESCO)*: offers service-based propositions for energy such as heat contracting, efficiency contracting, Heat as a service, Energy as a service, etc., can come from various sectors including energy suppliers, heat pump manufacturers and specialist startups.

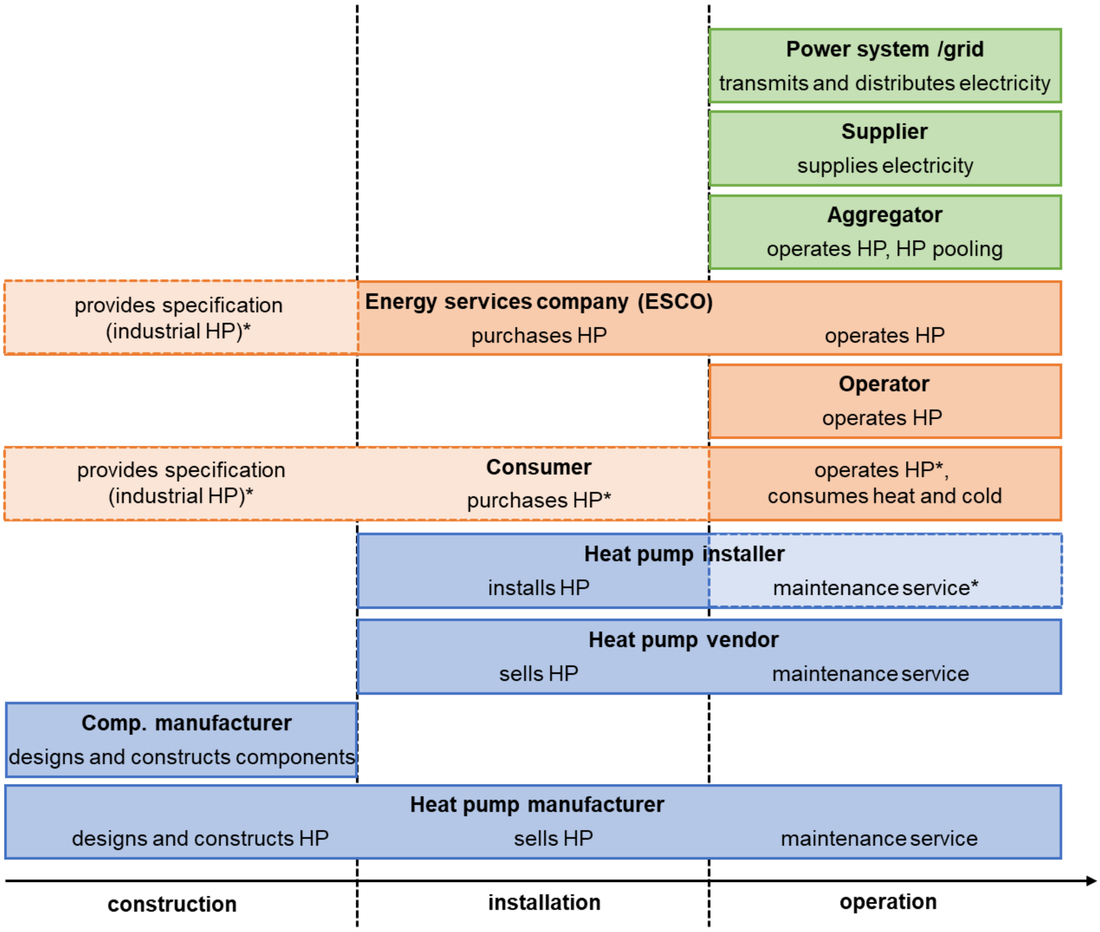

Figure 1: Overview on stakeholders in the life cycle of IoT enabled heat pumps (indicates optional tasks)*

The following matrix visualizes, which stakeholders are possibly involved in which of the most important IoT applications as listed above.

Table 1: Stakeholder and IoT application matrix (x = involved, (x) = could be involved)

Stakeholders	Heat pump operation optimization	Predictive maintenance	Heat pump operation commissioning	Flexibility provision	Heat as a service
Consumer	x	x	x	x	x
Operator	x	x	x	x	x
Heat pump manufacturer	x	x	(x)	x	x
Heat pump vendor	x	x	(x)	x	x
Heat pump installer	x	x	x	x	x
Aggregator				x	
Power system/ grid				x	
Supplier	(x)			x	
Energy service company	x	x	x	x	x

Operation optimization also includes the interaction with energy suppliers and consumers at the site, where the heat pump is operated, as well as the integration in higher level systems (building energy management or industrial process control system). These interactions are in the responsibility of the one operating the heat pump (end-user or operator or ESCO).

Heat pump operation optimization, commissioning and predictive maintenance involve the traditional stakeholders in the heat pump sector: consumers, manufacturers, vendors, and installers. There is no difference between residential and industrial applications of heat pumps. By contrast, flexibility provision involves considerably more stakeholders related to the energy system. Aggregators are especially needed for small scale residential heat pumps, heat pumps with larger capacities can provide grid services without an aggregator. Heat as a service or heat contracting is offered by ESCO and is based on a different model of ownership of the heat pumps.

5 Operation optimization

IoT services for operation optimization of heat pumps aim to save energy, emissions, and costs without compromising comfort requirements of the users. A basic version of optimization is monitoring and remote control via an app, that provides an overview on actual and historic data and allows for set point adjustment by the user. Advanced systems allow for adaption to user habits and for optimal interaction with other components e.g., to maximize self-consumption of PV production or solar thermal energy or the optimal management of a thermal or electric storage. Therefore, data analysis is typically carried out in the cloud of the service provider. More information on data analysis is compiled in the Task 3 report. Most commonly, operation optimization is offered together with other IoT applications, such as grid services or predictive maintenance.

An example for operation optimization for heat pumps in buildings is the PreHEAT heat pump controller by Neogrid that is available in Denmark. Neogrid is a cleantech supplier working with intelligent energy visualization, monitoring and control. The purpose of PreHEAT is to save energy and reduce the cost of heat, by optimizing the heat pump operation in relation to demanded energy from the building and local electricity prices and tariffs. This enables customers to adapt to market flexibility and at the same time to save energy without compromising indoor comfort requirements. Sensor data like indoor temperature, consumed electricity and delivered heat are collected and sent to the Neogrid PreHEAT Cloud. Neogrid provides several services: model predictive control (MPC) of the heat pump via the cloud, the use of variable prices and aggregator-based services for different electricity markets.

Operation optimization based on price signals for heat pumps in buildings is part of myiDM+energy, a service offered by the Austrian heat pump manufacturer iDM. The purpose is to consume electricity preferably when electricity prices are low. The customer requires an iDM heat pump, a smart meter, internet connection and a variable electricity tariff. To optimize electricity consumption, room temperature set points are tuned and hot water production is shifted as a function of the day-ahead hourly prices. The heat pump system can use the heating buffer, the domestic hot water storage as well as thermal building masses as energy storages to shift electricity consumption in time. If a PV system is available, self-consumption can be increased as well.

KNV, an Austrian heat pump manufacturer that merged with NIBE AB offers connected heat pumps for buildings since 2012. They allow for operation and monitoring via an app with automated logging of heat pump parameters and smart functions such as smart price adaption and weather control. Smart price adaption adjusts the heat pump operation to times with low energy prices based on electricity price information for the next 24h. Weather control considers the local weather forecast and adapts operation of the heat pump accordingly in advance.

A similar service is provided by METRO THERM, another daughter company of NIBE. Users of the myUpway service can monitor and control their heat pumps online, use Smart Price Adaption, and get suitable support from service providers.

An example for operation optimization in Danish district heating systems is the Centrica Energy Trading tool. It enables an optimal utilization of several asset types including heat pumps for district heating supply. This enables the optimization of energy consumption and cost savings as well as the minimization of expensive imbalances. The platform provides an estimation of the power consumption, heat production, and COP of the heat pump based on forecasted weather variables such as outdoor temperature, humidity, wind direction and speed. The services provided by the platform include coordinating heating and electricity markets, optimizing heat pumps for the provision of frequency regulation services and guaranteeing electricity prices for large-scale heat pumps and other consumption systems. To date, several Danish district heating supply companies have adopted the Energy Planning and Optimization platform developed by Centrica.

Another example for operation optimization of heat pumps in district heating has been implemented by Energie Burgenland, an Austrian utility. The existing infrastructure of a district heating network as well as the biomass boiler was extended by a direct line to the nearby wind park, a battery storage as well as four heat pumps. The aim was to create a profitable use case for wind energy after a non-beneficial change in the support system. The wind profile and the heat demand were a good fit (ca. 80% concurrency) and four heat pumps are used to produce heat from wind energy. They use flue gas condensation from the biomass boiler and air as heat source. Together with heat, cold and battery storage, the concept allows for flexibility options. The use of excess electricity leads to reduction in the consumption of biomass by 1200 t/a and reduction of natural gas by 1250 MWh/a and less CO_2 emissions (300 t/a).

Detailed factsheets of the six examples are available in the annex of this report.

6 Predictive maintenance

Predictive maintenance aims to plan maintenance as precisely as possible in advance and to avoid unexpected equipment failures. Thereby, downtime of equipment is reduced and unplanned shutdowns that typically cause costs, delays and discomfort are reduced. Also, resources for maintenance work such as spare parts and work force can be planned more precisely. Predictive maintenance requires condition monitoring of the equipment and data analysis to detect anomalies and failures. It can either focus on critical components of a heat pump e.g., the compressor or it can analyze the complete heat pump system.

Condition monitoring for critical components can be carried out with additional smart sensors that are mounted on the equipment to be monitored. Siemens offers smart condition monitoring, SITRANS SCM IQ. It is a vibration and temperature sensor that is mounted on the vibrating machine part that is to be monitored, e.g., pumps, bearings, rotors, and compressors. The sensor is connected via a gateway to the cloud application, that is an artificial neuronal network. Based on sensor data only, the application learns independently the condition of the asset and provides information on deviations and anomalies. [3]

Ziehl-Abegg offers IoT enabled fans for HVAC applications. The IoT devices are connected to the ZAbluegalaxy cloud via a gateway using MODBUS as standard. All relevant sensor values such as temperature, rotation speed, input voltage, motor temperature and power consumption are transmitted via BUS communication. The sensor data can be accessed online and is used to send alerts on critical conditions. It also used to detect vibrations and imbalance conditions that are further used for predictive maintenance, service and forecast of life expectancy. The cloud solution offers security and data protection functions and allows for integration of other IIoT platforms. Further information is available in [4] and [5].

Bitzer heat pump compressors are also enabled for predictive maintenance. With the IQ module and the Bitzer software, operation conditions of the compressors are monitored, and alarms are provided. IQ products also benefit from a warranty extension due to better monitoring. Further details on the Bitzer Eco System are available in the factsheet in the annex of the report.

Energy Machines™ offers monitoring and control for heat pumps in buildings as a part of their service offering for design, implementation, and operation of integrated energy systems for buildings to transform buildings into climate solutions. Energy Machines Verification Tool (EMV) is a combined hardware/software solution based on physical measurements, a service representational state transfer application programming Interface (REST API) and thermodynamic models of the heat pumps. It provides live online and transparent performance monitoring of the heat pumps. The EMV is the basis for an early warning system for predictive maintenance that is currently being developed and that may even reveal early signs of deterioration of the system. For more information see the factsheet annexed to this report.

Digitalization is an important requirement to facilitate maintenance for the heat as a service proposition of Nærvarmeværket. It is a community owed Danish company which provides solutions for simplified heat as a service based on heat pumps for areas without district heating. The end-users can buy into a cooperative community, which ensures an overall solution with installation, service, and maintenance of the heat pump. A one-time fee for the installation cost is paid, together with a smaller annual payment, which ensures the cost of maintenance and a free replacement of the heat pump if it breaks down or needs to be changed. Service costs are reduced by remote monitoring. As the heat pumps are typically installed in remote areas, e.g., on an island, where there is no access to a larger district heating network, the travel cost for a service technician can be saved if the technician knows the fault beforehand and has the spare part available the first time the heat pump is being serviced.

More information is available in the factsheet in the annex of this report.

7 Flexibility provision

Heat pumps are well suited to offer flexibility to the electricity grid which is in greater demand with increasing shares of intermittent renewable energy production. In the power system, there are different types of flexibility that are distinguished by their time scale in Figure 2. The type of flexibility that can be provided with heat pumps depends on the characteristics of the heat pump system as well as on national regulation.

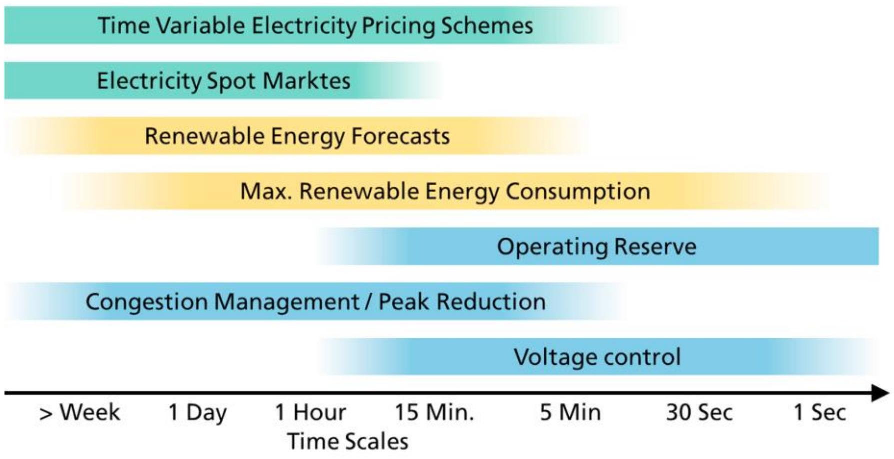

Figure 2: Time-wise characteristics of selected fields and mechanisms in the power system, where flexibility of the demand side might be used to create benefits [6]

7.1 Residential heat pumps

The Swiss company tiko started with the development of its ancillary service business in 2012 and entered the market with its solution in 2014. They offer the grid operator both primary control quality (frequency stability) and secondary control quality (balancing between planned power and actual power in the grid) by combined electricity-based heating systems throughout Switzerland into a virtual power plant. In 2017, the virtual power plant of tiko had a capacity of up to 50 MW including over 10,000 electricity-based heating system, 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. tiko has been expanding its market internationally and has established a customer base in several countries in the EU. Devices are connected to tiko via a gateway solution and electricity consumption of the devices is managed by the tiko pool within adjustable comfort criteria. End-users benefit from monitoring and alarming functions, from energy savings thanks to eco-mode and additional revenue is created by the virtual power plant. The tiko system is described in more detail in factsheet provided in the annex of this report.

The Austrian project Flex+ investigates the flexibility provision by heat pumps in the context of the provision of automatic and manual frequency restoration reserve (aFRR, mFRR) by operating a pool of heat pumps. It was found that the total simulated revenues for all stakeholders per year per heat pump amounted to 8-23€ (Day-ahead-market participation) and 65 -117 € (aFRR provision). Households can profit from reduced grid tariffs for negative balancing reserve, because in Austria balancing is partly exempt from grid tariffs. However, it was challenging to predict user behavior (hot water, heating demand, thermal load) and define the right modelling depth for technical components for optimization. Changes in market regime and in flexibility products require adaption of the optimization algorithms. The business case becomes more interesting, the simpler the processes and the lower the implementation costs are. The demonstrations have shown that the concept is technically feasible and the regulatory framework in Austria is suitable for market integration of heat pumps, for DSO TSO interaction more research is needed. Further details on the platform and the optimization are provided in the factsheet in the annex of this report.

The Austrian utility EVN has launched the EU Innovation Fund project “Green the Flex” in 2022 with the goal of integrating 3,000 households by 2025 and saving a total of around 3,500 tons of CO_2 per year and shift 4,400 MWh of load annually. The participants are connected to the energy management system of EVN, an optimization assistant “joulie” that balances demand and production of renewable energy and shifts the electricity consumption of households at times when sufficient electricity, ideally 100% green electricity, is available. More information is available in [7].

7.2 Industrial heat pumps and heat pumps for district heating

In the Danish Flex Heat Project, 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. This system delivers heat to 4 customers in an island district heating grid, which was supplied by oil-fired boilers previously. This 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. The linear-optimization model includes heat forecast with inputs from weather data, complex stratified storage tank modelling, and start-up costs for the heat pump, and an electricity price forecast is supplied to find the minimum costs for the system. Furthermore, the heat pump has been modified to provide fast regulation services to the grid. It was proven that ammonia-based heat pumps can regulate fast enough to deliver the FCR-N service (frequency stabilization service). The optimization module can additionally plan for the heat pump to deliver this service, and, still under construction, a setup is implemented to read the grid frequency and stabilize this accordingly by changing the set-points of the heat pump. The 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. Further information is provided in the factsheet in the annex of this report.

8 Heat as a service

8.1 Industrial and commercial applications

Heat contracting business model are already available in the commercial and industrial sector, where energy service companies provide heating, hot water, or process heat for industrial customers. Most typically, heat pumps with larger capacities are subject to contracting, as it is a considerable effort on the side of the contractor to set up the heat pump and operate it.

The Austrian utility Kelag Energie & Wärme [8] 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. An example for heat pump contracting is the brewery Puntigam. Two heat pumps have been installed that recover waste heat from fermentation and provide heat for a residential area “Brauquartier Puntigam” at two temperatures levels of up to

46°C and up to 70°C. Average COP values of 4.7 for the supply of 46°C and 3.5 for the supply of 70°C have been achieved. Further information is available in [9].

The Norwegian company Aneo Industry offers heat pumps supplying up to 5 bar steam for industrial customers with an Energy as a Service contract. Aneo Industry evaluates how to integrate the heat pump in the process, carries out concept design, verification, and detailed engineering of the heat pump. Aneo Industry will finance the heat pump system and the integration according to agreed boundary conditions and is responsible for the operation through an Energy as a Service agreement. They will train the personnel of the customer how to operate the system and continuously monitor and follow up on it (second line of operation), carry out service and maintenance, as well as optimization of the performance. The energy contract includes a guaranteed annual operation to the customer. A detailed description of the service and the heat pump system is provided in [10]

8.2 Heat as a service in the residential sector

Heat as a service is emerging in the residential sector. A recent study of Delta-EE provides a definition of Heat as a service and describes the actors in Europe [11].

'Heat as a Service': A definition

'Heat as a Service' usually means either/both of the following:

- *Paying an ongoing monthly fee rather than a one-off upfront fee* (the monthly fee usually includes payment for the heating system, the heat delivered, and the ongoing servicing)
- *Paying for outcomes rather than inputs* (paying for heat or comfort delivered rather than fuel input)

Delta-EE defines 'Heat as a Service' as a service where the provider takes on the following 'risks' usually borne by the end-user:

- *financial risk* – The service provider takes on credit risk by providing a heating appliance for a monthly fee and little or no upfront payment.
- *technical risk* – The monthly fee charged by the service provider includes: routine maintenance, repairs, and appliance replacement if necessary within the contract period.
- *performance risk* – The service provider charges per unit of output (heat) or for the outcome (warmth) provided by the heating appliance (or guarantees savings on heating costs).
- *energy price risk* – The service provider offers a fixed price per unit of heat or warmth generated for a period of time, typically a year.
- *behaviour risk* – the service provider charges for the outcome (warmth) provided, thereby taking on the risk that customers use heating inefficiently by, for example, opening windows.

Sub categories of 'Heat as a Service' exist, where the provide takes on only some (but not all) of the above risks. These include:

- Asset leasing
- Efficient asset leasing
- Energy payment plan
- Warmth payment plan

There are also further developments possible, beyond 'Heat as a Service', including:

- Comfort as a Service: where the outcome is a level of year-round thermal comfort in a home, including providing cooling in summer, when needed
- Energy as a Service: where the offer to the customer includes energy use for other appliances (e.g. including other electricity needs).

Figure 3: Definition of Heat as a service according to Delta-EE [11]

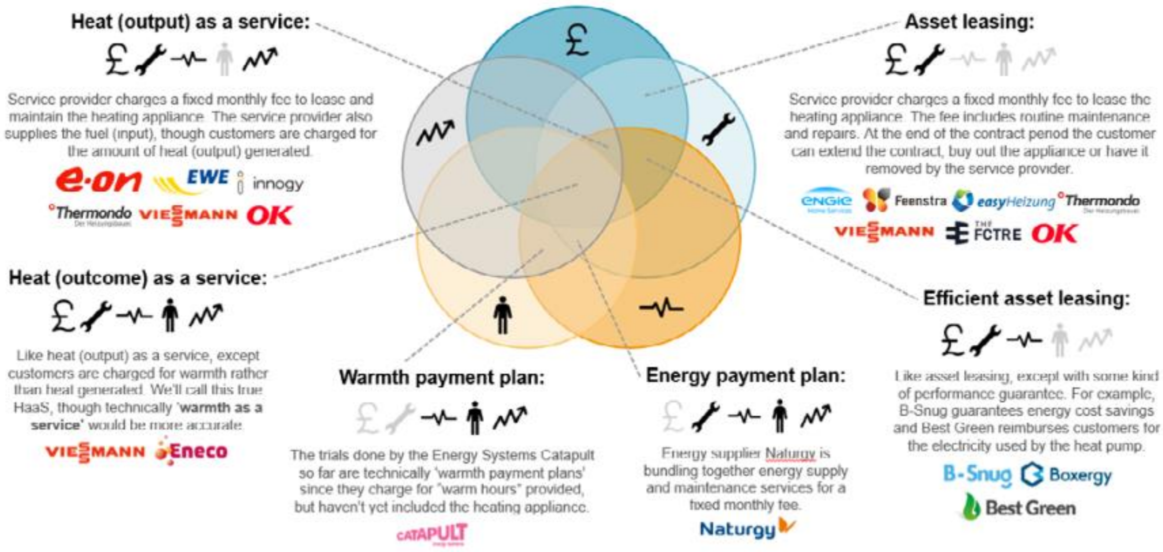

Figure 4: European actors in the field of heat as a service by Delta-EE [11]

Asset leasing: This service is offered by different actors, such as heat pump manufacturers, utilities or companies specialized in heat as a service solution.

The Danish company Nærvarmeværket [12] provides solutions for simplified heat as a service based on heat pumps for areas without district heating. The end-users can buy into a co-operative community which ensures a complete solution with installation, service, and maintenance of the heat pump. A one-time fee for the installation cost is paid, together with a smaller annual payment, which ensures the cost of maintenance and a free change of the heat pump if it breaks down or needs to be changed. In this way, the community structure ensures cheap and reliable green heat for the end-user. Nærvarmeværket cooperates with several heat pump suppliers, e.g. Vaillant, Pico Energy, DVI, and HS Tarm. They also offer a combined system with an air/water heat pump and PVT panels providing electricity with optimized operation to increase self-consumption. Further information is included in the factsheet in the annex of this report.

The German heat pump manufacturer Viessmann offers asset leasing based on their own products [13]. Thermondo a company specialized installing heating systems with a strong background in digitalization to facilitate design and construction of heating systems offers heat pumps by LG in a leasing model [14]. In Austria, the utility company Energie Burgenland has launched a leasing program for heat pumps based on several manufacturers [15].

Warmth payment plan: In traditional residential heating, consumers pay for energy, heating system and grid service separately. However, the focus of the consumers is usually the overall result: the achievable temperature within the residential building. A warmth payment plan takes up this idea and offers a fixed price based on achieved room temperature. Consumers are offered a pricing plan based on the number of hours the room shall surpass a certain temperature called “heat plan”, instead of paying for units of fuel, system installation and maintenance separately. Such a heat plan was trialed with living lab participants by Energy Systems Catapult, which had their homes fitted with heating systems accordingly. The installed heating system depended on building type and consumer preference and included hybrid heat pump/gas boiler systems, among other system configurations. The calculation of such a heat plan requires additional data about the building’s thermal isolation, heating performance and consumer preferences to operate. Data was collected using the Home Energy Systems Gateway, which also allowed temperature control on a room-by-room basis.

The main results were:

- It was concluded that Heat as a Service is as a promising approach to create economic incentives to increase the efficiency of heating systems. It can also increase the openness of consumers to switch replace gas boilers with lower carbon heating sources like heat pumps.
- The commercial viability and consumer acceptance of Heat-as-a-Service still have to be demonstrated. The selected study only included a small number of participants, which were already enrolled as part of the living lab program.
- Consumer preferences with regards to heating vary widely. While some participants configured the system to match their daily schedules, others prefer to forgo this step and spend more money to ensure their home is always warm when they are home.
- Interoperability between the IoT components and a supply chain accustomed to installing IoT components in residential buildings will be needed to ensure a good customer experience in the long run.

Further information is provided in [16], [17], [18].

9 SWOT Analysis

9.1 Methodology and aim

A SWOT analysis provides an overview on Strengths, Weaknesses, Opportunities and Threats. The analysis was carried out in an interactive group work with the participants of the IoT Annex project. Three IoT based heat pump business models were compared to the traditional, non-connected business models. For each pair of business models, the analysis was carried for the most important stakeholders. Strengths and opportunities are positive, enabling factors, weaknesses and threats are negative, hindering factors. Strengths and weaknesses are related to the stakeholder itself, opportunities and threats are related to the environment, e.g., other stakeholders.

The aim of the analysis is to provide an overview on the most important characteristics of the IoT based heat pump business models and evaluate them for the involved stakeholders. However, there is no conclusion on whether the positive or the negative characteristics prevail as this is related to individual motives and strategic decisions.

9.2 Predictive maintenance vs Fixed Interval / on demand maintenance

9.2.1 Consumers

Strengths	*Weaknesses*
• Reduction of downtime of the heat pump • Better performance of the heat pump • Cost reduction for maintenance work due to precise information on the planned task	• Higher operation costs related to the contract with the maintenance service provider • Dependency on the prediction models by e.g. the manufacturer • Vendor lock-in with no flexibility to choose maintenance service company
Opportunities	*Threats*
• Flexibility when to schedule maintenance work • Faster reaction of the maintenance service provider	• Cyber-security risk • Additional data connectivity required compared to the traditional model

9.2.2 Maintenance service providers

E.g. heat pump manufacturers, installers, or heat pump vendors

Strengths	*Weaknesses*
• Easier scheduling of maintenance work • Improved logistics and supply of spare parts • Reduction of resources possible • More efficient staff planning • Further development of service offers possible	• Additional training of personnel might be required • Dependency on the prediction models by e.g. the heat pump manufacturer or component manufacturers • Vendor lock-in: no flexibility to choose maintenance service company
Opportunities	*Threats*
• More stable relationships due to consumer lock-in • More direct access to consumers • Include mandatory maintenance work	• Access to data required compared to the traditional model • More competition in an international market

9.2.3 Heat pump manufacturers

Strengths	*Weaknesses*
• Increased value for consumers • Product design can be improved based on gathered data • More robust product with fewer breakdowns • Development of maintenance tools based on IoT	• Increased initial implementation effort e.g. defining limits for failure detection, training of the models • Accuracy of prediction is hard to validate without failures • Calibration is critical to avail false positives • Heat pump systems should be "fault free" when commissioned, avoid installation errors to ensure proper prediction
Opportunities	*Threats*
• Can improve the relationship to consumers • Establish new service agreements with maintenance service providers • Market advantage as first mover	• Data security risks • Component manufacturers might be reluctant to contribute to prediction model because of IP reasons • Inaccurate fault detection could lead to breakdowns • Change of existing stakeholder relations if a heat pump manufacturer starts offering predictive maintenance service

9.3 Heat as a service (outcome based) vs traditional model

9.3.1 Consumers

Strengths	*Weaknesses*
• Guaranteed performance of the heat pump • No additional costs in case of failure / replacement • Decrease of initial capital costs • Higher efficiency due to more professional operation • No effort needed for planning, integration, installation, and commissioning • Behavior change does not immediately change costs	• Lack of awareness of system operation • Behavior change does not immediately change costs • Difficult to assess actual cost benefit to traditional model during operation • Difficult to assess performance
Opportunities	*Threats*
• Optimized interaction with on-site electricity and heat production and storage	• Connectivity might increase vulnerability of the system in case of failures • Long term contracts • Limited choice of heat pumps offered by the service provider

9.3.2 Companies offering Heat as a Service

E.g. heat pump manufacturers, ESCOs

Strengths	Weaknesses
• Heat pump manufacturers can offer a new service based on existing products and existing sales organization • Predictable income	• Large upfront costs (provision and maintenance of the heat pump) • Responsible for more complex systems as heat as a service relies on the functioning of the complete installation (heat pump, piping, storage, etc.) • Might need to improve software and hardware • Need to accurately measure heat consumption • Requires cyber security knowledge
Opportunities	**Threats**
• Long term customer relationship • New partnerships with third parties • Energy companies can sell a new product to existing customers	• Over-consumption of heat because of non-beneficial behavior of the consumer • Regulatory changes might impact on long term contracts e.g. CO_2 prices

9.4 Providing flexibility with heat pump pooling vs using a heat pump as an autonomous component in a building

9.4.1 Consumers

Strengths	Weaknesses
• Use the thermal mass of the building to offer flexibility without compromising comfort • Reduce operating costs of the heat pump system	• User might not agree with the operation of the heat pump (loss of comfort, deviating personal preferences) • Thermal characteristics of the buildings have a strong influence on violation of comfort • Quick and frequent changes of the set point of the heat pump might compromise COP (e.g. waiting period before restart of the compressor, preheating of the suction line) • Efficiency decreases because grid flexible operation compared optimized operation without interaction
Opportunities	**Threats**
• New legislation might provide more benefits for consumers participating in pooling • Increased autonomy from the overall grid as a part of a larger pool • Cost savings depending on the market situation	• Dependency on aggregators • Increased complexity • Increased vulnerability to connectivity • Market situation hinders cost savings

9.4.2 Heat pump manufacturers

With heat pumps that are ready for pooling can offer management of heat pump pool for an aggregator.

Strengths	*Weaknesses*
• Innovative, future proof product • React to increasing demand by consumers • Offer products with higher functionality • Diversification / extension of portfolio	• Increase complexity • Might need to improve existing products for pooling • Common interfaces and standards not yet established • Increasing numbers of starts and stops of the compressor may require more robust compressors
Opportunities	*Threats*
• Attract new customers by a new service • Access to a more decentralized global market	• Common interfaces and standards not yet established • Internal control strategy of the heat pump is overruled by pooling signal • Fast regulation increases the requirements for the heat pump and the system around it

9.4.3 Heat pump installers

Strengths	*Weaknesses*
• Data access to connected heat pumps also enables other services such as predictive maintenance	• Installation is more complex • Installation personnel requires knowledge of plumbers and electricians
Opportunities	*Threats*
• Installation can be sold at a higher price compared to a non-connected heat pump	• Connected devices have more fault potential (e.g. electronics, internet connections, etc.) leading to longer commissioning times

9.4.4 Aggregators

Strengths	*Weaknesses*
• The number of heat pumps will increase in the future, there is a large potential for pooling	• Heat pumps are more complex than electric boilers or charging stations.
Opportunities	*Threats*
• The demand for flexibility will increase in the future to the more renewable energy production.	• It is unclear who can be held accountable if flexibility is not activated as planned. • No standardized way of communication yet. • Economics depend on the current electricity price.

9.4.5 Electricity suppliers

Strengths	*Weaknesses*
• Advanced forecasts/schedules can be used for better portfolio management • Active use of flexibility for minimization of imbalance settlement costs • Production optimization and efficiency increase	• Uncertainty who is providing schedules (consumers themselves?) and who can be held accountable in case of deviations • Smart operation can change conventional forecasts (if suppliers are not informed)
Opportunities	*Threats*
• Less fluctuating net demand of the grid	• actual demand of the consumers not known due many decisions being made

9.4.6 Power system / electricity grid

Strengths	*Weaknesses*
• easier to increase the share of fluctuating renewables • operation planning for grid operators can be enhanced when planned consumption and flexibility potential is known and/or can be even used • congestion management and voltage control (if TSO or DSO request flexibility)	• high standards for cyber security for connected devices required to protect the grid • potential for load shift may depend on weather and season • complex dynamics due to discharging/regeneration phases after activation/deactivation of grid connected HPs • Equipment and services heterogeneity increase complexity
Opportunities	*Threats*
• Access to a flexibility potential that would be unused without pooling. • Heat pumps can provide fast regulating reserve (e.g. FCR-N in Denmark). • Heat pumps can be autonomously used for peak shaving in combination with PV.	• high concurrency factors when activating aggregated flexibility for markets without considering the grid • when the penetration of heat pumps is high (e.g. in Sweden), heat pumps can be risk for the power system • the power system is affected already by local control of the heat pump according to price signals (without pooling) • Heat pumps will use more electricity when being controlled.

10 Conclusions

The analysis of the business models showed that multiple stakeholders are involved. A total of ten different stakeholders were identified: heat pump manufacturers, component manufacturers, heat pump vendors, heat pump installers, consumers, operators, energy service companies, aggregators, suppliers, and the power system /grid.

Examples for new business models have been found for:

- Operation optimization
- Predicative maintenance
- Flexibility provision
- Heat as a service

The main value proposition for the consumers are lower costs, more efficient heating systems and higher reliability.

For the heat pump value chain (component manufacturers, heat pump manufacturer, vendors, installers) digitalization leads to new products and services that make heat pumps more attractive and more future proof. Compared to traditional business models, they have more responsibility for the efficiency of the IoT enabled heat pump systems.

The energy system (aggregators, suppliers, grid, etc.) has a strong need for flexibility provision to compensate for fluctuating renewable generation. Heat pumps allow for sector coupling by combining the heat and the power sector and can offer flexibility at various scales which is a valuable asset for the future.

Energy service companies (ESCO) are a rather new actor in buildings but are already established for industrial contracting. They help to spread heat pumps as their service reduces the involvement of the consumers.

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12 Factsheets

The following chapter includes in total 11[1] factsheets of projects and/or companies providing innovative business models in the context of connected heat pumps.

They are relating to the four IoT categories outlined in section 3 as follows:

- Operation optimization: three use cases from Austria, three use cases from Denmark
- Predictive maintenance: one use case from Austria, two use cases from Denmark
- Flexibility provision: one use case each from Austria, Denmark, and Switzerland
- Heat as a service: one use case from Denmark

[1] One of the factsheets relates to two use cases.

PreHEAT for Heat Pumps by Neogrid Technologies ApS

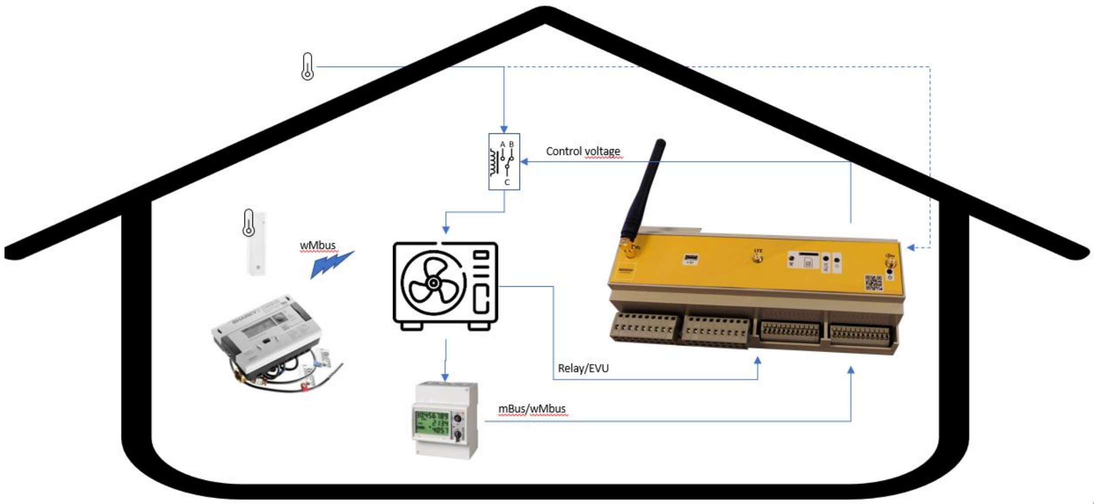

Figure 1: Hardware setup for PreHEAT Heat Pump Controller.

PreHEAT for Heat Pumps is developed by Neogrid Technologies with the purpose to save energy and reduce the cost of heat, by optimizing the heat pump operation in relation to demanded energy from the building and local electricity prices and tariffs. This enables customers to adapt to market flexibility and at the same time to save energy without compromising indoor comfort requirements.

By collecting data from the heat pump, it is possible for Neogrid to deliver three categories of services:

The **first category** are services available as soon as data is collected from the heat pump and connected meters. If external control is activated, extra services like MPC to control, can secure a lower operation cost of the heat pump. This category "only" requires a bilateral agreement with the heat pump owner and a cloud connected operator.
In **category 2** variable prices, tariffs and services to the DSO are taken into account. Variable prices and tariffs are rolled out over most of Denmark, but DSOs flexibility demand to cope with bottlenecks is still limited in Denmark.
In **category 3** specialized services to the electricity markets are delivered. This might be regulating power and frequency reserves. Those services require separate settlement of the electricity to the heat pump and an aggregator is required to pool a number of heat pumps.

From, sensor data like indoor temperature, consumed electricity and delivered heat are collected, and send to Neogrid PreHEAT Cloud.

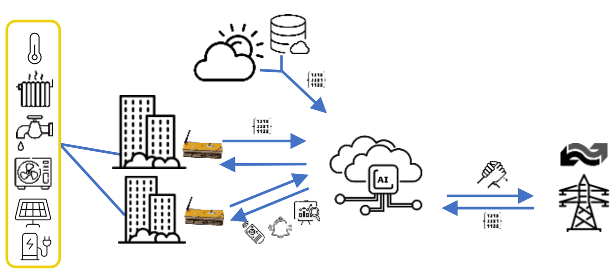

Figure 2: Neogrid PreHEAT Cloud.

In the Cloud, the data is analyzed and optimal operation schedules are send back to the pump.

Establishing connection the heat pump installation, can be implemented in different ways dependent on the type of heat pump. Older and/or simpler heat pumps requires a gateway to provide online access, and to collect all sensor and meter data. Control is established via the heat pumps relay input or by manipulating the outdoor temperature sensor.

Other heat pumps have a communication interface where data and control capabilities are available to access via a local gateway.

Modern heat pumps are "born" online and have the possibility to collect data from external sensors and meters. Here, the heat pump manufacture typically operates a cloud where all data are collected and available for a third-party actor, like Neogrid, via an API.

Neogrid Heat pump aggregator

The aggregator method provided by Neogrid, pools a number of heat pumps together and control the heat pumps as a swarm. I.e. we are allowing / blocking the individual heat pump operation to provide an overall behavior of the pool. This is done by complying with the constraints of each heat pump operation. The pool can then be adjusted according to market changes.

Figure 3 illustrates the installations as a normalized energy storage, where heat pumps are charging/ discharging the storage also fulfilling the run-time constrains of the heat pump.

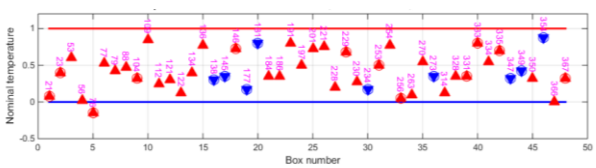

Figure 3: Swarm controller in operation.

Learnings

Heat pumps using the optimized control and flexibility service can provide costumers with energy savings without compromising indoor climate and comfort. Neogrid can optimize a heat pumps energy consumption by 5-15 %.

Multiple factors have an impact on the possible energy savings, but demonstrations have shown that value proposition for the heat pump owners are:

- Online access to key data from heat pump
- Low operation cost
- Improved comfort
- Lower energy bill
- Reduced CO2 footprint

About Neogrid Technologies

Neogrid Technologies have more than 12 years' experience in providing smart energy solutions for cloud-based heating control in buildings, as well as data collection from IoT devices and smart meters.

Neogrid have extensive knowledge within the smart grid and smart energy systems, which have been obtained by participating in a number of research- and demonstration projects both on a national and international level and by performing business development within this field.

The knowledge gained from these projects is used for commercial activities, and PreHEAT by Neogrid is operating commercially in more than 400 buildings in Denmark, with 24/7 active online control and surveillance.

FACTS ABOUT THE PROJECT

IoT Category: Optimized heat pump operation

Goal: Save energy and reduce cost of energy without compromising end user comfort. Deliver real-time monitoring of the heat pump.

Beneficiary: User, Society

Data required: Access to heat pump sensor data, energy and electricity meter and weather forecasts

Analysis method: Data analytics, model- and control engineering

Control method: MPC

Technology availability: TRL 8

Link to webpage: https://neogrid.dk/

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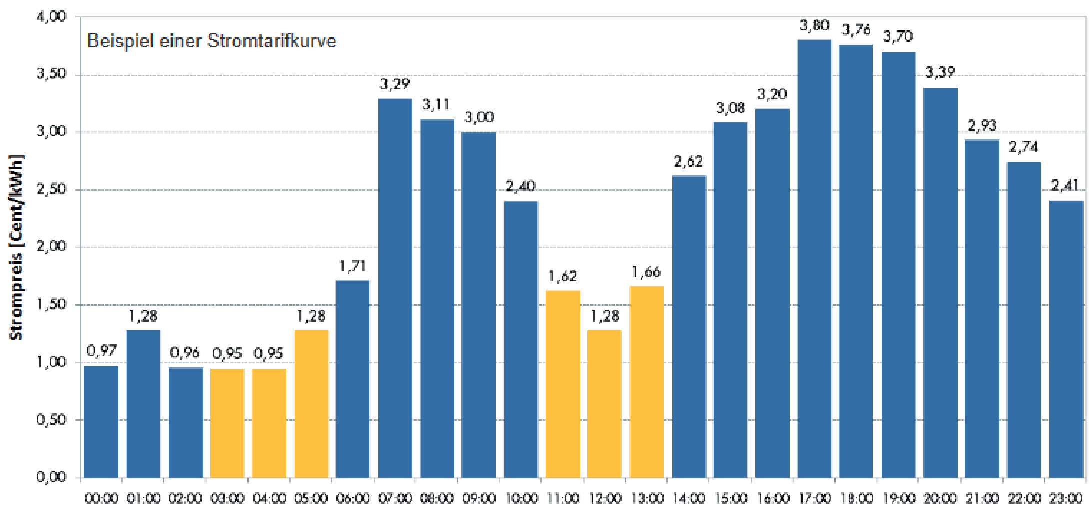

Figure 1: Variable electricity tariffs are used to optimize costs of heat pumps electricity consumption

Summary of IoT case

"iDM Energiesysteme" is an innovative Austrian heat pump manufacturer located in Eastern Tirol. Their product "myiDM +energy" aims to consume electricity preferably when electricity prices are low. Another intention is, besides the reduced costs, that the prices are mainly then lower, when a lot of cheap wind and solar production is available. This correlation is expected to enforce in the future. At the current status, the application mainly targets residential heating/end consumers.

Prerequisite for participation is an iDM heat pump with the corresponding software version, as well as a smart meter and an internet connection. Further, the consumer needs a variable electricity tariff. Currently, the system supports three Austrian electricity suppliers with flexible tariffs.

The heat pump system can use the heating buffer, the domestic hot water storage as well as thermal building masses as energy storages to shift electricity consumption in time. To optimize the electricity consumption for spatial heating, room temperature set points are tuned. For this purpose, day-ahead hourly prices are pulled from the electricity supplier. If the hourly price is lower than the day's average electricity price, then the set point is increased, if it is higher, then it is decreased. Further, domestic hot water preparation can be shifted by a certain amount of time, which can be chosen manually. If the prices at that potential time are lower than at the original time, the domestic hot water preparation is shifted. In this way, the costs for heat pump operation are reduced. The application can already be purchased and used.

In combination with a photovoltaic system, the heat pump is able to use the surplus energy for spatial and domestic hot water heating, to increase the self-consumption of the household. Using variable tariffs and photovoltaic surplus production can be also used in combination, there is no prioritization, the storages are heated whenever the described rules apply.

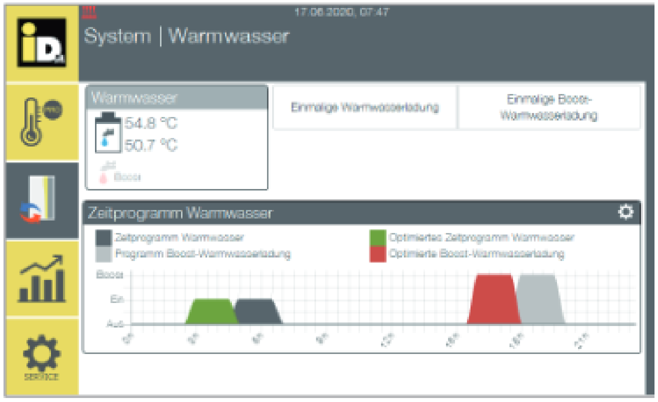

Figure 2: User interface showing potential shift of domestic hot water heating

Results

- Benefit for the user perspective: Depending on the background electricity tariff, potentially lower costs for provision of heat and hot water
- Improved system flexibility through reduced demand in peak-hours and correlation of demand and RES-supply
- Perspectives and bottlenecks: low-threshold technology, easy to deploy

FACTS ABOUT THE IOT CASE

IoT category: optimize HP operation according to prices, increase PV self-consumption

Heat supply capacity: 2 kW - 1500 kW

Heat source: air, ground, water

Data required: day-ahead variable electricity prices

Data interface: Smart meter, iDM heat pump, internet connection

Quality-of-Service: daily, online

Technology Readiness Level: TRL 9 (system works and proven in operation)

Link to webpage: https://www.idm-energie.at/myidm-energy/

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KNV S Serie

KNV / NIBE

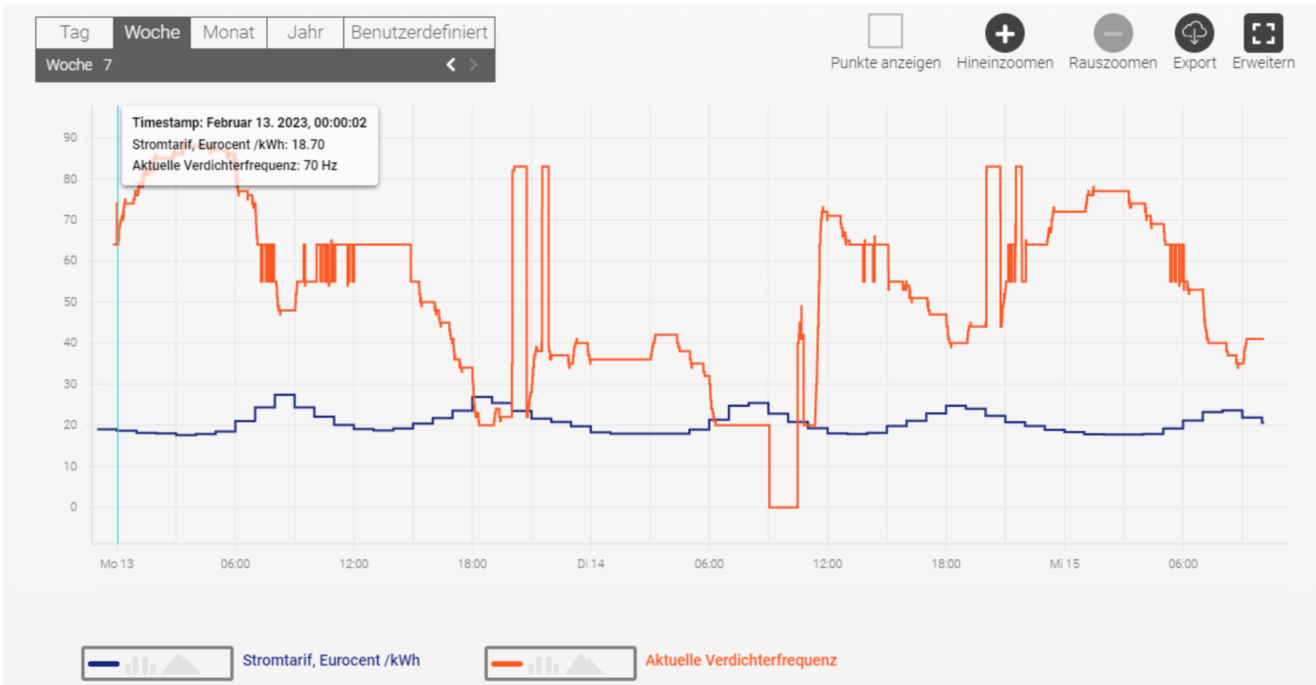

Figure 1: Adaption of heat pump operation according to price signals
(blue = electricity price, orange = current frequency of the heat pump compressor)

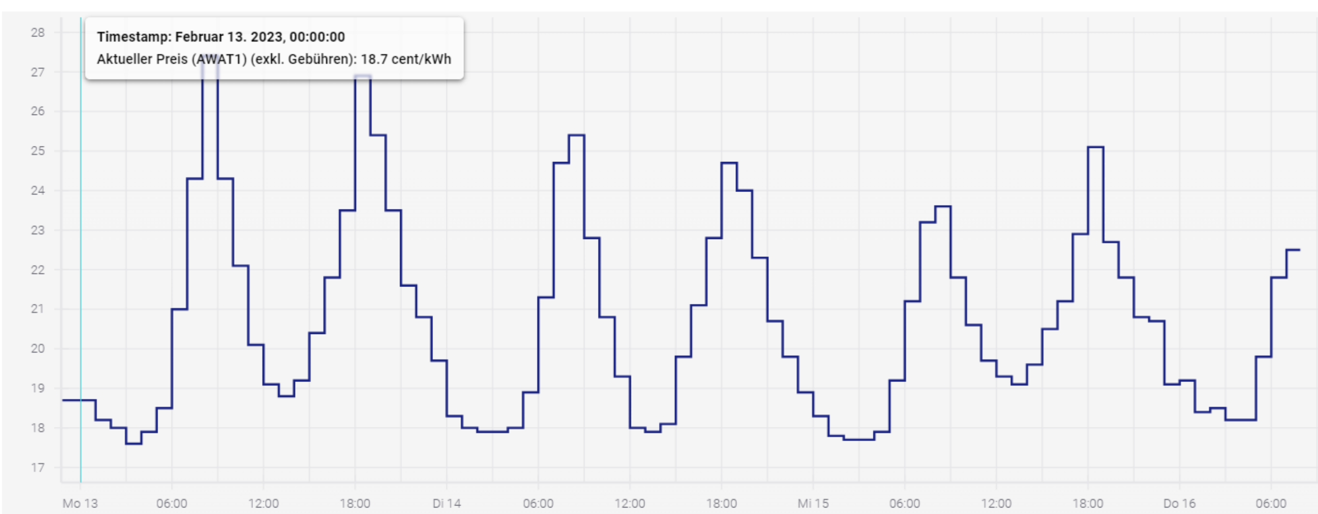

Figure 2: Realtime information on electricity prices

KNV is an Austrian heat pump manufacturer that merged with NIBE AB from Sweden in 2008. Heat pumps from KNV/NIBE have been connected to the Internet since 2012. Since then, thousands of customers have benefited from convenient operation and monitoring of their heat pump via computer, smartphone, or tablet. Further improvement was included in the new generation of heat pumps, the "S-Series".

Technology: myUplink allows for a quick overview of the status of the heat pump via the Internet. If a malfunction occurs, the user will be notified directly via push-note and e-mail. The automated logging of heat pump parameters gives full control of the heat pump, and, with the help of remote monitoring and control, heat pump operation can be optimized and possible faults can be detected or prevented. Furthermore, smart functions such as "Smart Price Adaptation" and "Weather Forecast" are possible in connection with myUplink, which saves costs for the customer and increases the system efficiency in heating and cooling operation.

IoT aspects: The main IoT aspects include a software platform with continuous maintenance, full control of the heating and heat pump system to ensure high operating and living comfort, reduction of electricity costs by intelligently shifting the operating hours during the day, increase of system efficiency by weather forecasts and early detection and elimination of possible malfunctions remotely.

Functionaliy of the platform: MyUplink is a web application. All web browsers with JavaScript support the use of myUplink. The system and home network are protected through various security measures, including encryption of network traffic and verification of the authenticity of the myUplink server to prevent data theft. The system does not allow external connections that are not initiated by the system itself, so an attacker cannot connect to the system. In addition, the system cannot be affected by malware that is typical for computers, as it does not run a normal desktop operating system. Furthermore, myUplink can be used with various smart home devices such as "Google Assistant", "Amazon Alexa" or "IFTTT".

Main features

Smart-Price-Adaption: Smart-Price-Adaption offers customers the possibility to choose a variable electricity price model. The heat pump retrieves the hourly prices for the coming 24 h via myUplink and adjusts the operating times to times with low prices, thus saving additional costs. Heating, cooling, pool heating and hot water preparation can be influenced.

Weather control: With weather control and myUplink, the heating and cooling operation of the heat pump is aligned with online weather forecasts. The smart heat pump works proactively and knows when the weather changes at the user's location. This means that weather changes can be considered even more efficiently. In anticipation of a clear frosty night, the heating output is increased in time. If a sunny day is announced, heating operation is reduced, or cooling activated.

Contact information

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📞 +43 7662 8963

FACTS ABOUT THE IoT CASE

IoT category: optimize heat pump operation

Goal: Reducing costs while increasing comfort

Heating capacity: 1,5 – 25 kW

Heat source: geothermal heat, air

Analysis method: visualization of time series

Modelling requirements: Dynamic model, black box model to log heat pump parameters Integrated in heat pump

Data required: electricity prices, weather data, operational data

Transmission protocol for data: Modbus TCP/IP

Quality-of-Service: real-time

Technology Readiness Level: 9

Link to webpage: https://www.knv.at/

MyUpway™ – Online heat pump control

METRO THERM A/S

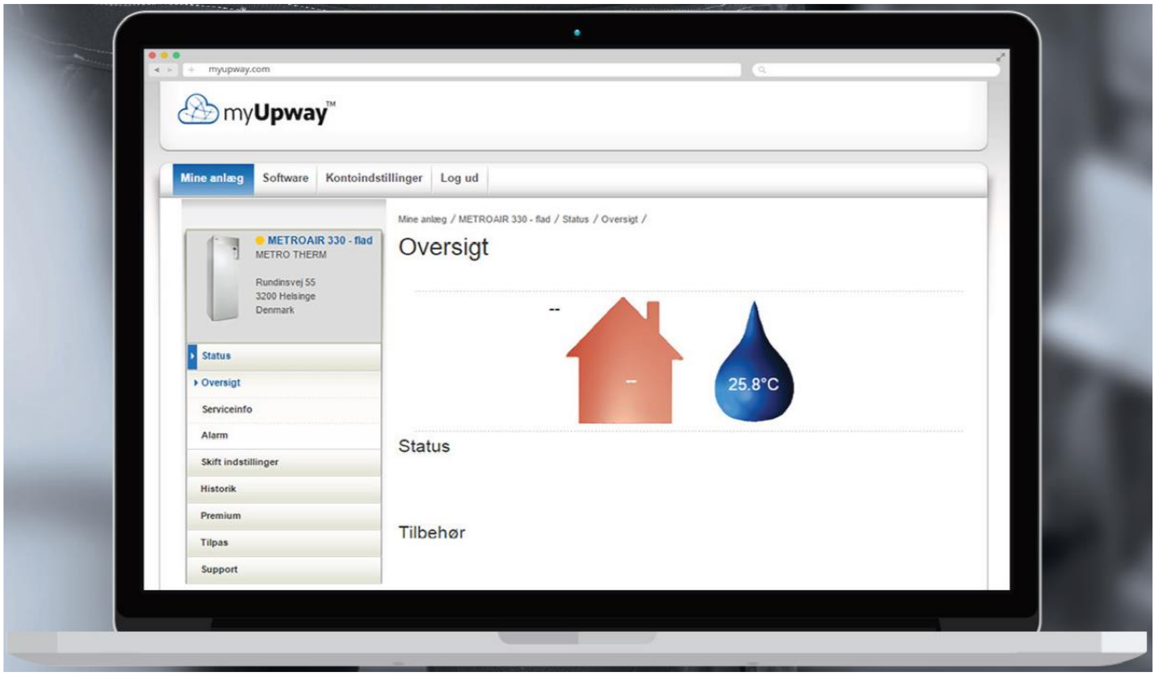

Figure 1: Homepage of the online-service myUpway™ where overall heat pump information is displayed.

Summary of IoT case

The platform myUpway™ provides online monitoring and control services, including surveillance of heat pumps energy consumption and fault alarms as well as remote control possibilities. This platform is exclusive to METRO THERM products with suitable connectivity specifications, which includes air source and ground source heat pumps.

Moreover, heat pumps integrated with myUpway™ are smart grid ready. This could be used to optimize remotely the operation of heat pumps based on information from electricity grids and users' consumption patterns to minimize operational costs of heat pumps. The current version of myUpway™ includes a feature called Smart Price Adaption, which enables the automatic adjustment of heat pump operational periods to minimize electricity consumption costs.

MyUpway™ is available in two different functional levels, namely a basic level and an advanced level. The basic level includes services such as operation monitoring, fault alarms and access to one month of historical data with a limited number of parameters. The advanced level includes the same functionalities as the basic level and the option of changing the configuration of the heat pump. Moreover, with the advanced level, users can access to historical data from more variables compared to the basic level and over the entire operational life of the heat pump. Heat pump users are able to retrieve such historical data and apply their own advanced data analysis methods (e.g. by means of machine learning), which are not included in the platform.

MyUpway™ represents METRO THERM's version of the online service platform from its parent company NIBE named NIBE Uplink™. This service has been commercially available for several years, which has enabled NIBE users to monitor and control their heat pumps to maximize thermal comfort and minimize heating-related costs.

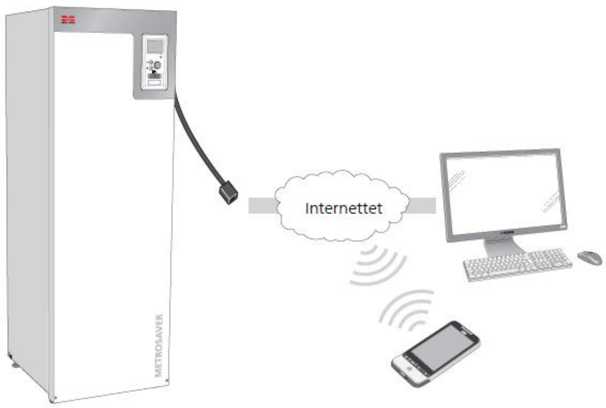

Figure 2: Representation of the interconnection between METRO THERM heat pumps and desktop through myUpway™.

Results

- Users of myUpway™ are able to receive insights about heat pump status and indoor climate, control temperatures related to space heating and domestic hot water supply, and get suitable support from service providers.
- Users can reduce their electricity bills as a result of the Smart Price Adaption feature. Here, the operation of heat pumps is automatically reduced during hours with high electricity prices, without sacrificing comfort requirements.
- Service providers connected to myUpway™ can avoid unnecessary physical assistance to heat pump users and get remote assessment of multiple units.
- The possibility of third-party remote control of heat pumps through myUpway™ may in the future increase their performance and provide ancillary services to electricity grids. However, this feature has not been applied in commercially available units yet.
- As a future possibility, the data retrieved through myUpway™ could be used for performance forecasting and advanced fault diagnosis methods.

FACTS ABOUT THE IOT CASE

IoT category: optimize HP operation and predictive maintenance

Heat supply capacity: up to 20 kW

Heat source: air and ground

Analysis method big data analysis

Modelling requirements: Data-driven

Data required: operation data

Data interface: LAN and Wireless

Transmission protocol for data: Modbus

Quality-of-Service: Real-time (online control)

Technology Readiness Level: TRL 9 (system works and proven in operation)

Link to webpage: https://www.metrotherm.dk/support/varmepumper/online-styring-af-varmepumpen

Contact information

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Energy Planning and Optimization Platform

Centrica Energy Trading

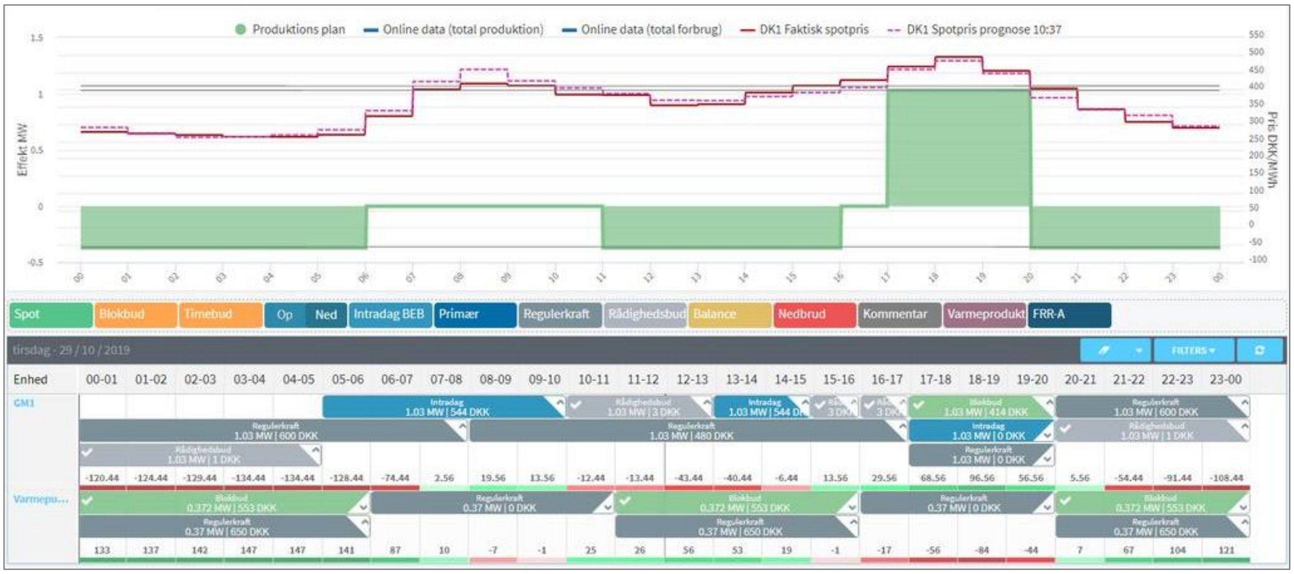

Figure 1: Interface of the energy planning and optimization platform developed by Centrica Energy Trading.

Summary of IoT case

The energy planning and optimization platform developed by Centrica Energy Trading consists of a web-based API with a data warehouse system for energy route-to-market services. The Centrica Energy Trading tool enables an optimal utilization of several asset types including heat pumps for district heating supply. This enables the optimization of energy consumption and production earnings as well as the minimization of expensive imbalances.

The platform provides an estimation of the Power consumption, heat production, and COP of the heat pump based on forecasted weather variables such as outdoor temperature, humidity, wind direction and speed. In addition, the interface includes estimation of the varying marginal prices in different electricity markets.

The services provided by the platform include coordinating heating and electricity markets, optimizing heat pumps for the provision of frequency regulation services and guaranteeing electricity prices for large-scale heat pumps and other consumption systems.

To date, several Danish district heating supply companies have adopted the Energy Planning and Optimization platform developed by Centrica. Electricity prices from the Nordic power exchange Nord Pool are analyzed in the platform, including Day ahead spot, Intraday and frequency regulation markets. The platform has enabled the correct registration at hourly level in the spot market and minimization of electricity and heat imbalances.

Figure 2: Example of the interface used by the platform from Centrica Energy Trading.

Results

Danish district heating companies have been able to maximize their profits by using the platform from Centrica Energy Trading. This was done through the optimization of the operation of heat pumps according to heating and electricity prices, as well as weather forecast indicators.

Contact information

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FACTS ABOUT THE IOT CASE

IoT category: Grid services.

Heat supply capacity: No specific requirements regarding heating capacities.

Heat source: No specific requirements regarding types of heat sources.

Analysis method: Big data analysis and market models.

Modelling requirements: Data-driven.

Data required: Weather forecast and margin prices for electricity prices markets.

Technology Readiness Level: TRL 7 (system prototype demonstration in an operational environment). TRL 9 expected in Q4-2021.

Link to webpage: www.centrica.com/our-businesses/energy-marketing-trading/

Energie Burgenland HP Neusiedl am See

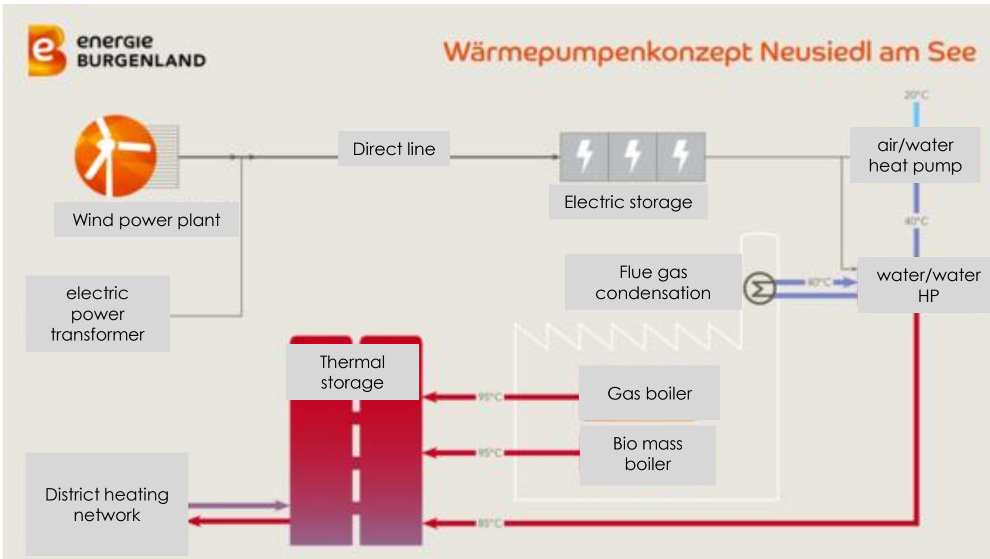


Figure 1: Heat pumps are supplied by excess wind electricity to substitute gas in the district heating network

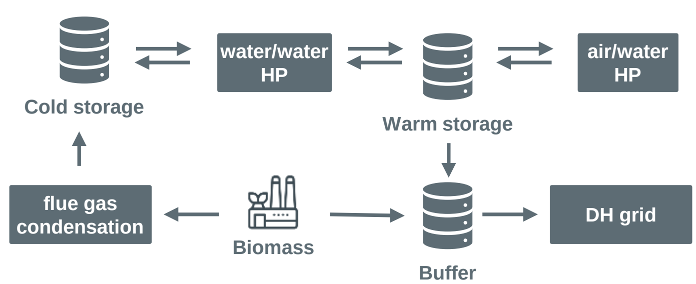
Summary of project

The project is located in Neusiedl am See, a town with increasing population size. Within this project, the existing infrastructure of a district-heating network as well as the biomass-boiler was extended by a direct line to the nearby wind park, a battery storage as well as four heat pumps.

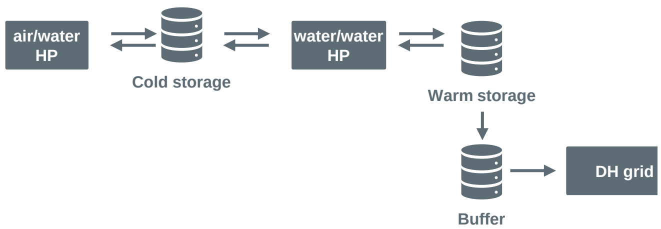
The trigger for this innovative concept was that wind capacities dropped out from the support system around 2015/2016. This provided the case to look for the most profitable use case for wind energy. Depending on the COP and the heat price, using wind electricity for heat production could provide a good upside potential.

In a first step, the wind profile was compared to the heat profile and resulted in a good fit, 80% of time where heating was on, wind was available. To cover the heat load, only a small fraction of the 32MW wind park 'Neusiedl' needs to be used. A direct electricity line of 1.5MW was built for around 2km from the transformer station to the existing biomass/gas heating plant.

In winter, the majority of the heat load is covered by biomass. When biomass is on, flue gas condensation delivers water of around 30/35°C into the cold storage. From there, 2 water-water heat pumps lift the heat level of the warm-buffer of around 60/65°C to around 65/70°C. Additionally, 2 air-water heat pumps are supplied by the warm buffer with 74°C/78°C which they lift by 4°C. Heat load in winter is between 1-4MW.



In summer, the biomass plant is not operational and the heat from flue gas condensation is replaced by air-water heat pumps which deliver heat at level of 30/35°C that was done by the flue gas condensation before. From there on, same procedure as in winter. Heat load in summer is around 0.5-1MW.



The concept ensures the use of excess electricity from the nearby wind park for heating purposes and provides therefore a unique flexibility option. This leads to significant reductions in:

- the consumption of biomass (1,200 t/a)
- natural gas (1,250 MWh/a)
- CO2 emissions by around 300 t/a
- Less transport of biomass

"This Power2Heat concept opens the door into a climate-neutral heat supply that. Such innovative concepts form the basis for decarbonization of the region."

Technical facts

- 2 water/water heat pumps, 600kW each
- 2 air/water heat pumps, 600kW each

- Cold-water storage 17m³
- Hot water storage 17m³
- Buffer storage 2x150m³

- Around 10% of heat is produced from gas, 40% from biomass and 30% from wind.

Learnings and results

The project is considered innovative as it demonstrates an integrated energy system connecting a wind park directly with heat generation through heat pumps. A challenge consists the environmental conditions regarding noise for the surrounding neighborhood.

FACTS ABOUT THE PROJECT

IoT Category: Optimize heat pump operation
Goal: Reduce costs from gas-use in heat generation and use biomass more efficiently
Beneficiary: wind park operator
Data required: wind forecasts, heat demand
Analysis method: control engineering]
Modelling requirements: N/A
Quality-of-Service: Real-time
Project participants: Energie Burgenland, Ochsner Heat Pumps, Green Energy Lab
Time schedule: 2018-2021
Technology availability: TRL 9

Contact information

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Bitzer Heat Pump Eco System

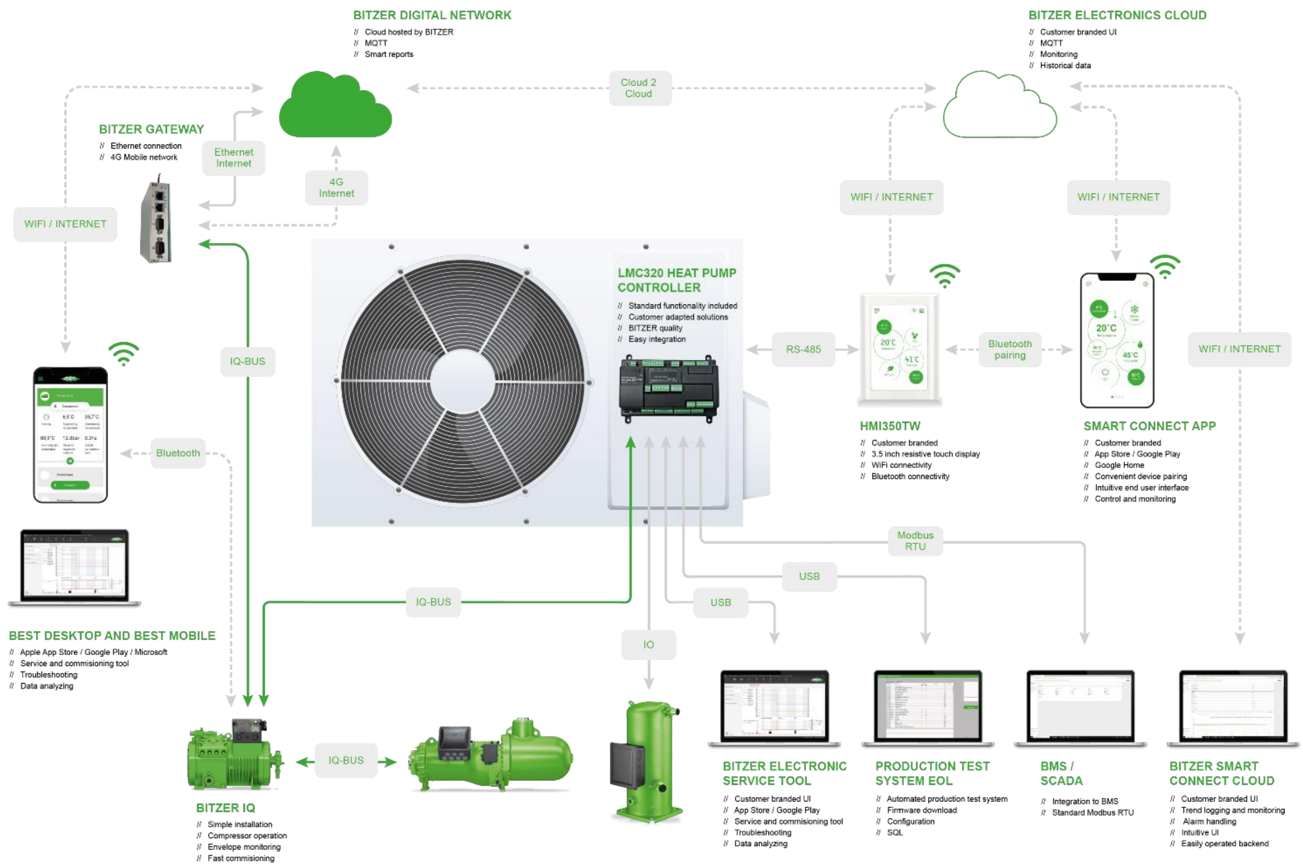

Figure 1: Overview of the Bitzer Heat Pump Ecosystem

Summary of IoT case

The Bitzer Heat Pump Ecosystem is provided by BITZER Electronics, a company in the BITZER Group. BITZER Electronics targets OEMs, installers, owners and service technicians of domestic and industrial heat pumps.

The core component is an intelligent smart grid ready system controller or intelligent compressor module. The intelligent compressor module allows connection between compressors and the heat pump control unit plus to a gateway simultaneously by using an IQ-Bus.

There are two possible use cases for the Ecosystem. The first uses the Bitzer Gateway to load data into the Cloud via WiFi or a 4G signal. The cloud is hosted by Bitzer and is fully compliant with the General Data Protection Regulation. The data stored there can be accessed via the BEST App which is available for Android, iOS and Microsoft and allows for troubleshooting and data analysis and provides multiple service and commissioning tools and apps for end-users.

The second possibility uses the heat pump controller by Bitzer which features USB, Modbus and RS-485 connectivity and a customer hosted cloud. The Smart Connect App for Android and iOS features a user interface to control and monitor the heat pump. Furthermore, it is possible to use a customer branded GUI via the Smart Connect Cloud which features alarm handling, trend logging and monitoring.

Figure 2: The Bitzer IQ Module

Contact information

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FACTS ABOUT THE IoT CASE

IoT category: optimize HP operation, predictive maintenance, performance benchmark, installation error analysis

Heating capacity: any

Heat source: any

Analysis method: depending on service, e.g. simulations, big data analysis, market models, control engineering, fault detections, energy balance calculations

Modelling requirements: No specific requirements regarding modelling.

Data required: Depending on use case. Enables access to compressor data.

Data interface: LAN, WLAN, 4G, Bluetooth, IQ-BUS, USB, RS485

Transmission protocol for data: Modbus, MQTT

Quality-of-Service: real time, depending on use case and connectivity option. Limited only by Modbus/IQ-BUS capabilities.

Technology Readiness Level: TRL 9

Link to webpage: https://www.bitzer.de/gb/en/bdn.jsp

Energy machines verification (EMV)

Energy Machines ApS

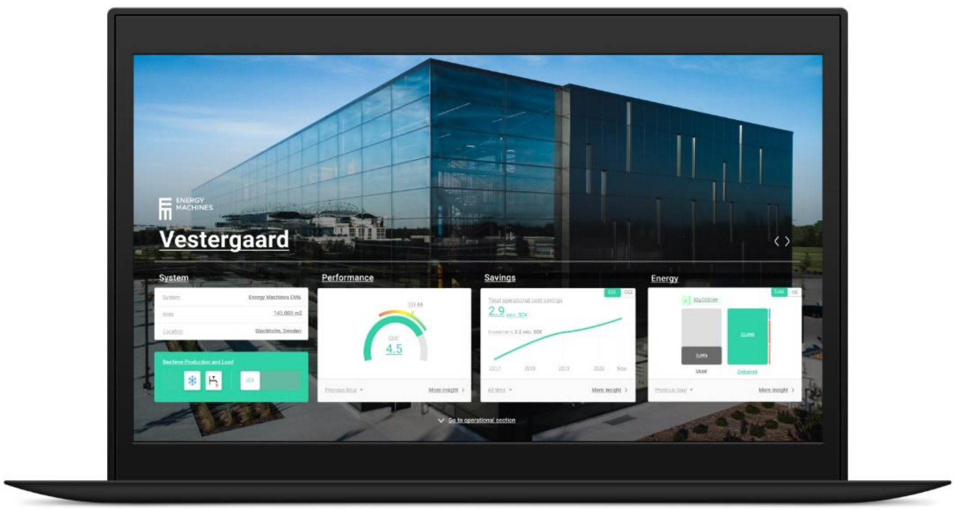

Figure 1: The energy machines dashboard including the EMV with a quick overview of current performance.

Summary of IoT case

Energy Machines™ is a leader in the design, implementation, and operation of integrated energy systems for buildings. Buildings are a growing climate problem, accounting for over 28 % of global CO_2 emissions. We are working to transform them into climate solutions.

The Energy Machines Verification tool (EMV) is a combined hardware/software solution based on physical measurements, a service REST API (REpresentational State Transfer Application Programming Interface) and thermodynamic models of the heat-pumps, in order to provide online/live transparent performance monitoring of these, as well as to provide early warning systems for predictive maintenance (to-be-implemented).

The tool is based on measurements of temperature and pressure, and enthalpy data for the refrigerant(s). It provides an alternative measurement to energy meters, but also extends beyond the limitations of these, as even more information can be extracted from the thermodynamic cycles.

Using a reliable and scalable cloud backend (Google Kubernetes Engine), it can be extended to any number of systems.

Data security is taken very seriously, and all services use encrypted protocols (TLS/HTTPS) when exchanging data from client to server. Endpoints require authentication with user permission granularity to access.

Figure 2: An Energy Machines installation. Heat pumps are located on the right. Sensors are placed inside the boxes.

The tool is functioning on most Energy Machines systems, with paying external customers in the portfolio. It is currently implemented through the ControlMachines SCADA service (https://control machines.cloud/), but the API allows flexibility in external access.

Results

Live monitoring of heat pump performance provides total transparency between supplier and customer.

A typical use-case would be if customer has been promised a heat-pump that can deliver a COP (Coefficient of performance) of 5, they can live monitor the COP and see if they are getting what they are promised. This can potentially lead to better performing heat-pumps, as suppliers can be held accountable.

As monitoring also includes the compressor efficiency, there's a potential to include early warning systems for predictive maintenance, when for example the compressor efficiencies rise above 100 %, indicating liquid refrigerants cooling the compressor outlet, which can cause breakdown and failure. Combining EMV with data-driven machine learning models, which run as digital twins, may even reveal early signs of deterioration.

FACTS ABOUT THE IOT CASE

IoT category: Online service with analysis of functionality and performance from live measurements of the heat pump COP, energy production and cycle efficiency. In addition to this, service with early warning system for predictive maintenance.

Heat supply capacity: Any.

Heat source: Air and ground.

Analysis method: Sensor measurements of pressures and temperatures are sent to a REST API. Energy balances calculate COP, compressor efficiency, and heating/cooling production, etc. The calculations are uniquely timestamped, and results are made available on demand. To reduce noise from raw measurements, know-how of the system is applied (typical time constants).

Modelling requirements: Measurements and knowledge of refrigerant and cycle.

Data required: Temperature, pressure, and compressor power.

Data interface: No specific requirements.

Transmission protocol for data: REST API

Quality-of-Service: Data measured every minute and results provided every minute (real-time).

Technology Readiness Level: TRL 9.

Link to webpage: www.energymachines.com

The latter models, can also be trained using the output from the EMV as input, when the drift over time is interesting to monitor (e.g. refrigerant loss through leakages, fouling of heat exchangers etc.). EMV is not a predictive tool and relies on sensor measurements, nevertheless EMV can also be applied on modelled sensors, and may be interesting to apply for simulations of heat production in system simulations, where multiple heat pumps are connected through a thermal grid. EMV may find usage even in optimization of heat production with respect to balancing electricity prices, demand and thermal reservoir capacity.

Contact information

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Community owned heat pump company

Nærvarmeværket a.m.b.a.

Figure 1 – Complete PVT energy system from Nærvarmeværket.

Summary of case

Nærvarmeværket is a community owed company which provides solutions for simplified heat as a service based on heat pumps for areas without district heating. The end-users can buy into a co-operative community which ensures a total-solution with installation, service and maintenance of the heat pump. A one-time fee for the installation cost is paid, together with a smaller annual payment, which ensures the cost of maintenance and a free change of the heat pump if it breaks down or needs to be changed. In this way, the community structure ensures cheap and reliable green heat for the end-user. Nærvarmeværket cooperate with several heat pump suppliers, e.g. Vailant, Pico Energy, DVI, and HS Tarm.

Results

Nærvarmeværket use digitalization as the heat pumps installed typically are connected, so they can be monitored remotely. This provides an unique opportunity for having cheaper service cost. As the heat pumps typically are installed in remote areas, e.g. on an island, where there is no access to a larger district heating network, the travel cost for a service technician can be saved if the technician knows the fault beforehand, and has the spare part available the first time the heat pump is being serviced.

FACTS ABOUT IOT CASE

Category: Heat as a service and predictive maintenance

Heat supply capacity: 3 to 249 kW

Heat source: Air/water and PVT panel.

Analysis method: Error analysis. Simple and cross platform.

Modelling requirements: n/a

Data required: Key operating data from the heat pump.

Data interface: LAN, WLAN, GSM (mobile network)

Transmission protocol: Modbus (open source)

Quality-of-Service: Real time

Technology Readiness Level: TRL 8-9.

Link to webpage: https://www.xn--nrvarmevrket-6cbh.dk/

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Virtual Energy Storage Network based on Residential Heating Systems

Tiko Energy Solutions AG

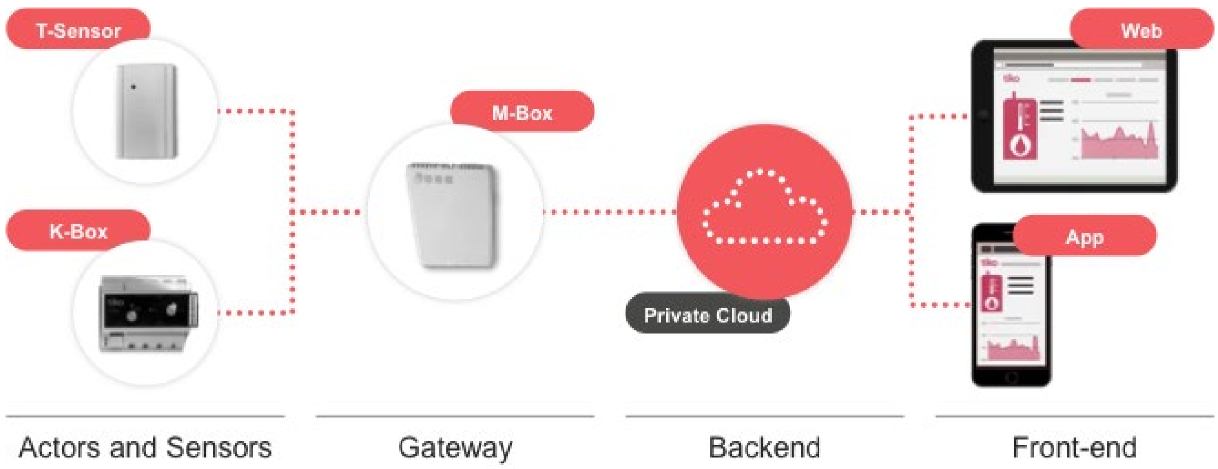

Figure 1: tiko system overview [1]

Summary of IoT case

To ensure stability of power grids, the energy supply and demand must be balanced. Traditionally, the demand for electricity was assumed to be unchangeable and production-side balancing was applied to the system. With the increase of fluctuating renewable energy sources, electricity production itself is becoming difficult to control. To enable a reliable power grid operation with fluctuating supply, flexibilization of the demand side must be achieved. Due to the high inertia of the thermal energy demand in the buildings sector, 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 been expanding 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 actors and sensors, two devices are connected directly to the heating system. The “K-box” measures the power consumption and at the same time serves as a control switch using a relay. The T-sensor is used to ensure comfort, 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 “M-box” (gateway). The “M-box” collects all data and communicates via 3G/4G network with the private cloud (backend) of tiko. All processing work is performed on the cloud server. This backend 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,

the system determines the removal or addition of the individual loads to achieve the necessary balance throughout the entire system. On the private user side, customers can monitor and manage their own energy consumption via a webpage or app (frontend). This enables them to make better use of their energy-saving potential.

Apart from comfort limits, switching limits have also been implemented. Especially for heat pumps, frequent switching on and off can lead to a performance loss and increased wear of the equipment. The switching limits were developed by tiko in cooperation with leading HP vendors. Figure 2 shows an example of an air/water heat pump being switched off for 52 minutes by the tiko system. The typical heat pump in the tiko system is switched less than five times per day on average.

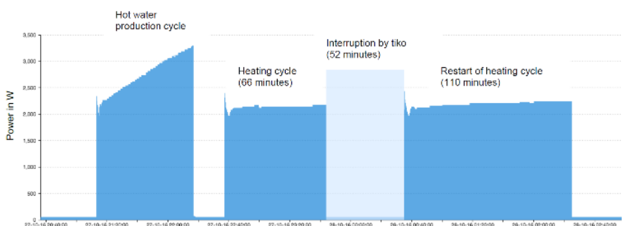

Figure 2: heat pump cycle interrupted by tiko control [1]

The market experience of tiko shows that a pooling of heat pumps and other electrical heating devices in a virtual power plant is economically viable. Due to the large number of devices connected, the on/off control system is the only economical solution. An individual control of parameters is regarded to be too expensive and complex without much increase in the benefits. Due to the high transparency provided to the private users, it was possible to identify incorrectly configured heat pumps and to improve their efficiency with new parameters set by the customer.

Result

- Ancillary services based on residential heating devices can be provided economically.
- The key elements for a successful solution are:
    - Simple and cost-efficient hardware
    - Secure and reliable communication
    - Efficient handling of big amounts of data
    - Simple and efficient control algorithms
    - Value proposition for all involved parties

FACTS ABOUT THE IOT CASE

IoT catagory: HP pooling, power grid services

Heat supply capacity: Up to 50 MW

Heat source: Multiple sources covered

Analysis method: Big data analysis, control engineering

Modelling requirements: Data driven model further detail n.A.

Data required: Power consumption, weather forecast, user behaviour, user profile, power prices, grid operator demands

Data interface: Local Power Line Communcation, GSM (3G/4G) to backend (Cloud) and frontend (App, Webpage)

Transmission protocol for data: TCP-IP, Modbus RTU, Modbus TCP, Power Line Communicaton

Quality-of-Service: Real-time (online control)

Technology Readiness Level: TRL 9

Link to webpage: www.tiko.energy

References

[1] M. Geidl, B. Arnoux, T. Plaisted, and Dufour Stéphane, “A fully operational virtual energy storage network providing flexibility for the power system,” in Proceedings of the 12th IEA Heat Pump Conference, Rotterdam, 2017.

[2] Energy Management System & Virtual Power Plant - tiko Energy, Online Available: https://tiko.energy/ (accessed: Nov. 28. 2022).

Flex+

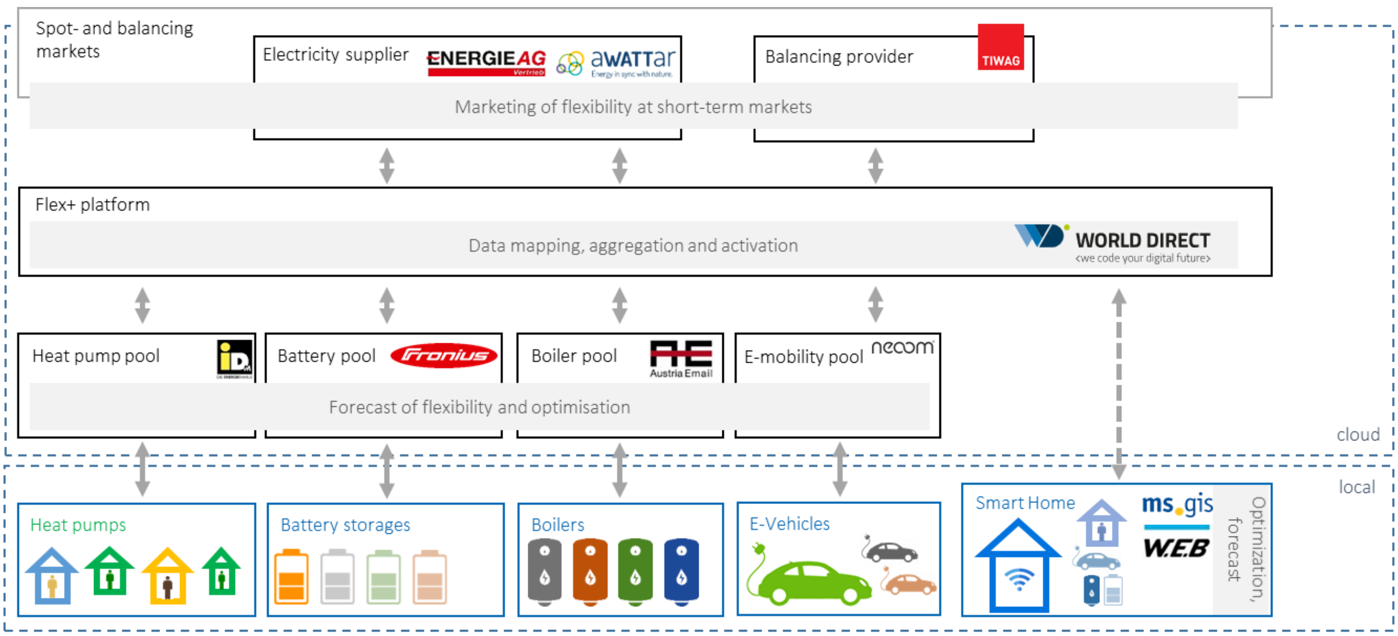

Figure 1: Project overview, interaction and data processes between stakeholders

Summary of project

The project Flex+ investigates the flexibility provision by heat pumps in the context of the provision of automatic and manual frequency restoration reserve (aFRR, mFRR). Different use cases were tested in demonstrations. A reference use case represents the conventional operating mode, where the heat pump is activated, in case the room temperature falls below a certain reference temperature. In another use case, the operating schedules are optimized based on day-ahead spot market prices. In a third use case, also free capacities for frequency restoration reserve are reserved and considered when optimizing the schedules. Since the actually consumed energy can differ from the forecasted one, the deviations can be rebought at the intraday market. For scheduling of the heat pumps, mixed integer linear programming algorithms were used. The buildings were depicted as RC models, which are thermal network models commonly used to predict building dynamics using thermal resistances and capacitance. Further, storages for domestic hot water and heating water have been used for load shifting. Measured heating curves were provided by the heat pump manufacturer and linearized.

The architecture used in the project is shown in Figure 1. Suppliers send day-ahead spot price forecasts to the Flex+ platform on the day before delivery. At the same time, the balancing provider sends price forecasts for frequency restoration reserve and the corresponding forecasts of call probabilities to the Flex+ platform. Two price positions are provided by the balancing provider. One price position with high call probability and a low price and one with low call probability and a high price.

The Flex+ platform forwards this price/call probability information to the component pools. Each component pool produces a consumption forecast and the forecast of available flexibility. Based on the predicted prices, the call probabilities, the consumption forecasts and the forecasts of the available flexibility, an optimal schedule and an optimal control energy participation is calculated for each component pool.
The balancing energy potentials of the pools are aggregated by the Flex+ platform and transmitted to the balancing provider. When an aFRR or mFRR bid is activated, the activated balancing energy is communicated to the Flex+ platform. It is distributed by the Flex+ platform among the individual component pools. Depending on the amount of activated balancing offers, the supplier will rebuy or sell energy on the intraday market if necessary, to cover the total consumption and to not violate storage or temperature limits.

For most processes that do not require real-time transfer, a REST with CSV interface was chosen. For the live interface between Flex+ Platt-form and the balancing provider, a VPN is used using the IEC 60870-5-104 transfer protocol. For the connection between the Flex+ Platform and the pools, which must be continuously available for balancing energy activation, the pools can choose between a Modbus protocol (RTU, TCP/IP) and JSON via a REST API.

Learnings and results

- Total simulated revenues for all stakeholders per year per heat pump between 8-23€ (Day-ahead-market participation) and 65-117€ (aFRR provision)
- Households can profit from reduced grid tariffs for negative balancing reserve, because in Austria balancing is partly exempt from grid tariffs
- Business case becomes more interesting, the simpler the processes and the lower the implementation costs

FACTS ABOUT THE PROJECT

IoT Category: Grid services, flexibility provision

Goal: Integration of small-scale flexibility components in to the balancing market & reduced operational cost of heat pump

Beneficiary: user, supplier, component manufacturer

Data required: forcasts for DA-prices and balancing prices, weather forecast

Analysis method: simulation, demonstration

Modelling requirements: Mixed integer linear programming

Quality-of-Service: daily close to real-time

Project participants: AIT Austrian Institute of Technology, Energie AG Oberösterreich Vertrieb GmbH , neoom group gmbh, aWATTar GmbH , Technikum Wien GmbH , World-Direct eBusiness solutions Gesellschaft m.b.H., Sonnenplatz Großschönau GmbH , Technische Universität Wien, WEB Windenergie AG., MS.GIS Informationssysteme Gesellschaft m.b.H. , TIWAG-Tiroler Wasserkraft AG, Software Competence Center Hagenberg GmbH, Fachhochschule Technikum Wien, IDM-Energiesysteme GmbH , Austria Email Aktiengesellschaft , FRONIUS INTERNATIONAL GmbH

Time schedule: 2018-2022

Technology availability: 7

Link to webpage: www.flexplus.at

- With change of aFRR and mFRR market regime (MARI/PICASSO)/ introduction of short-term balancing energy markets, also short-term offers can be made and free capacities can be offered (and no longer only day-ahead)
- There are different flexibility products and market regulations in different countries, also product specifications within Austria have changed a lot in the last years – optimization algorithms always have to be adapted to these (often rapid) changes
- Prequalification for aFRR provision of the pool is complex
- Regulatory framework in Austria suitable for market integration (which was the goal of Flex+)
- For DSO TSO interaction even more need for research
- Prediction of user behaviour is challenging (hot water, heating demand, electrical load)
- Difficulty to find the right modelling depth for technical components (duration of the solution time of the MILP (mixed integer linear programming) increases strongly with model depth)
- Demonstrations have shown that the concept is technically feasible, but to use it as "Plug and Forget", more research is needed.

Contact information

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FlexHeat – Intelligent and Fast-regulating Control

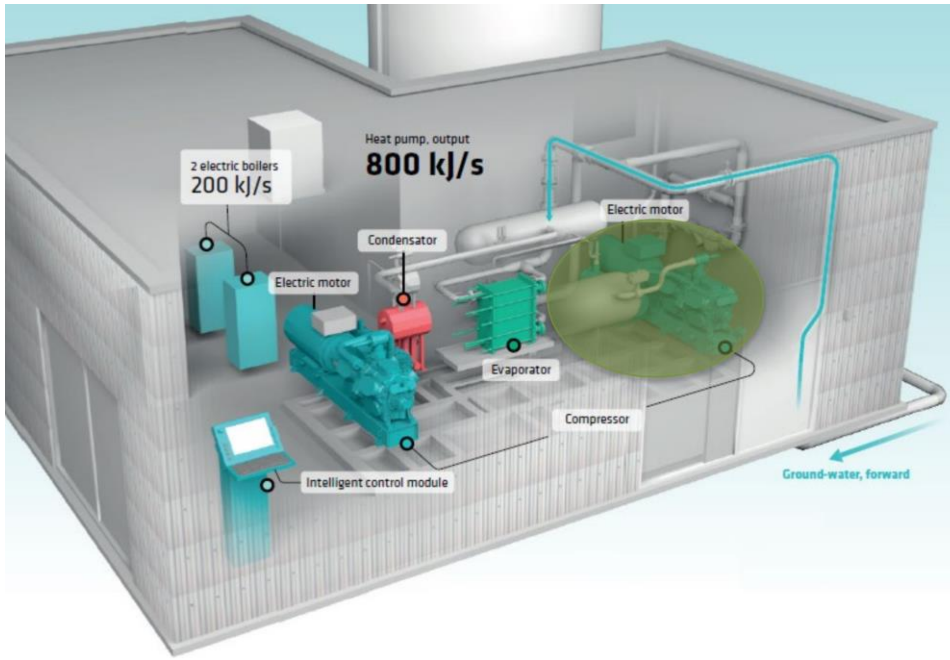

Figure 1: 3D drawing of the energy system with the most important [HOFOR, communication department, 2021]

Summary of project

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. This system delivers heat to 4 customers in an island district heating grid, which were supplied by oil-fired boilers previously.

This 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, see figure 2. The linear-optimization model includes heat forecast with inputs from weather data, complex stratified storage tank modelling, and start-up costs for the heat pump, and an electricity price forecast is supplied to find the minimum costs for the system.

On top of this, the heat pump has been modified to provide fast regulation services to the grid – here, the optimization module can additionally plan for the heat pump to deliver this service, and, still under construction, a setup is implemented to read the grid frequency and stabilize this accordingly by changing the set-points of the heat-pump.

The 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.

Learnings and results

The most important finding here is that ammonia-based heat pumps can regulate fast enough to deliver the FCR-N service (frequency stabilization service).

It was found that this would compromise the COP due to pre-heating of the suction line and compressor blocks as well as the increased overheating from the evaporator, and that a control scheme where you would only do this if you were asked to deliver a grid service would be optimal – hence, the overall COP of the facility is not compromised, unless you choose to do so, and here you could be making money delivering a grid service.

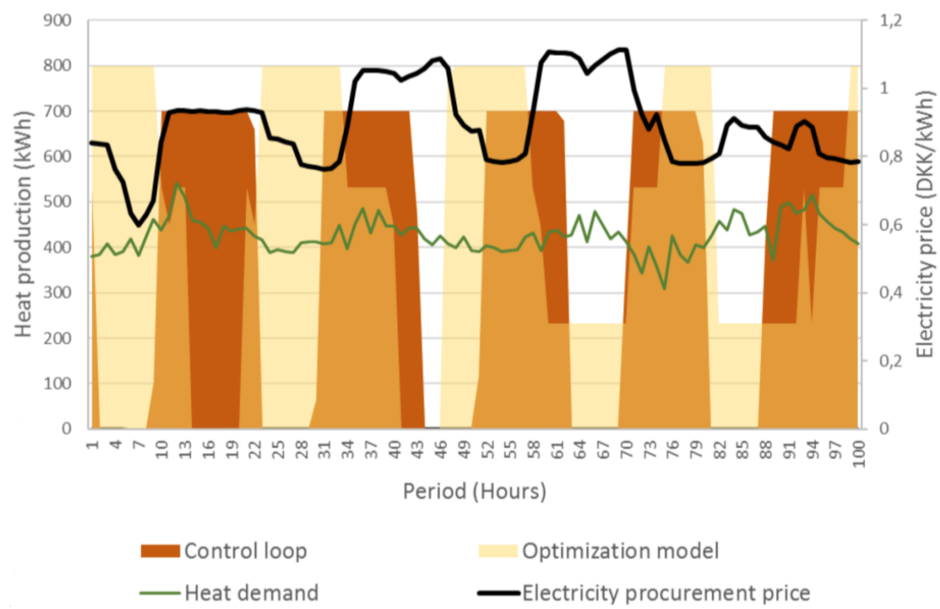

Figure 2: Flexible heat production during winter [HOFOR, 2021]

These results give an idea of asking manufacturers for a fast-regulation option in the design and control of the heat pump, the next time HOFOR build a heat pump. HOFOR have seen the feasibility of doing so, and more compressor types and refrigerants should be tested – so it is ensured, that heat pumps can help out the electricity grid now and in the future, to the benefit of the electricity system and the district heating customers.

Contact information

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FACTS ABOUT THE PROJECT

IoT Catagory: Grid services.

Goal: Reduced heat production costs for the system and ensure that heat pumps can help stabilize the current and future electricity system.

Beneficiary: User, TSO and the heat pump manufacturer.

Data required: Weather forecasts, electricity price forecasts, heat pump operation data, grid frequency measurements.

Analysis method Control engineering.

Modelling requirements: Primary model is a linear-optimization model, which has been backed up by a dynamic model to support the constraints implemented.

Quality-of-Service: Real-time control signals and 24-hour optimization schedules.

Project participants: HOFOR, DTU MEK, Johnson Controls (Factory and Enterprise), COWI

Time schedule: 2018-2020

Technology availability: TRL 7.

Link to webpage:

http://www.energylabnordhavn.com/deliverables.html (see deliverable 5.5a) www.heatpumpingtechnologies.org

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