Technology Collaboration Programme
by iea

Technology Collaboration Programme on Heat Pumping Technologies (HPT)

Annex 56

Digitalization and IoT for Heat Pumps

Executive Summary

Editor:
Veronika Wilk
(Operating Agent)

October 2023
Report no. HPT-AN56-SUM

Published by Heat Pump Centre
c/o RISE – Research Institutes of Sweden
Box 857, SE-501 15 Borås
Sweden
Phone +46 10 16 53 42

Website https://heatpumpingtechnologies.org

Legal Notice

Neither the Heat Pump Centre nor any person acting on its behalf:
(a) makes any warranty or representation, express or implied, with respect to the information contained in this report; or
(b) assumes liabilities with respect to the use of, or damages, resulting from, the use of this information.
Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement recommendation or favoring.
The views and opinions of authors expressed herein do not necessarily state or reflect those of the Heat Pump Centre, or any of its employees. The information herein is presented in the authors' own words.

Production Heat Pump Centre, Borås, Sweden

ISBN 978-91-89896-64-2
Report No. HPT-AN56-SUM

DOI: 10.23697/m9t4-v063

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.

Disclaimer

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.

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:
Heat Pump Centre
c/o RISE - Research Institutes of Sweden
Box 857, SE-501 15 BORÅS, Sweden
Phone: +46 10 516 53 42
Website: https://heatpumpingtechnologies.org

Operating Agent

Annex 56 on Digitalization and IoT for Heat Pumps is coordinated by the Operating Agent:

Veronika Wilk, veronika.wilk@ait.ac.at
AIT Austrian Institute of Technology, Center for Energy

The Annex was 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

This document is the result of a collaborative effort with contributions from various authors that are listed in the table below. It was edited by Veronika Wilk (AIT), veronika.wilk@ait.ac.at

Please cite this document as:
IEA HPT Annex 56 Digitalization and IoT for Heat Pumps, Executive Summary, 2023.
DOI: 10.23697/m9t4-v063

Tilman Barz Regina Hemm Reinhard Jentsch Philipp Ortmann Christoph Reichl Veronika Wilk Bernd Windholz Gerhard Zucker	AIT Austrian Institute of Technology	Austria
Goran Music Wolfgang Kastner Gernot Steindl	TU Wien	
Helmut Plank Roman Stelzer Christian Heschl	University of Applied Sciences Burgenland	
Felix Schaber	Austrian Academy of Sciences	
Wiebke Brix Markussen Jonas Lundsted Poulsen	Danish Technological Institute (DTI)	Denmark
Tobias Dokkedal Elmøe	Energy Machines™	
José Joaquín Aguilera Christian Ankerstjerne Thilker Wiebke Meesenburg Henrik Madsen	Technical University of Denmark (DTU)	
Odile Cauret	EDF	France
Lilli Frison Simon Gölzhäuser Danny Günther Tim Rist	Fraunhofer ISE	Germany
Sebastian Borges Stefan Goebel Tim Klebig Dirk Müller Christian Vering Fabian Wüllhorst	RWTH Aachen	
John Clauss Kristian Stenerud Skeie	SINTEF Community	Norway
Cansu Birgen	SINTEF Energy	
Markus Lindahl Tommy Walfridson Metkel Yebiyo	RISE	Sweden
Davide Rolando Yang Song	KTH	
Raphael Agner Beat Wellig	HSLU	Switzerland

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.

IEA HPT Annex 56 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.

Executive Summary

Ambitious climate, energy and environmental goals require the transition to an efficient, renewable, and low-carbon energy system. Digitalization is one of the most important factors for the transformation of energy systems, as it is expected to facilitate the matching of supply and demand in the face of increasing volatility of energy production and contribute significantly to final energy savings and CO_2 reductions. According to an IEA study, digitalization can reduce energy consumption in buildings by 10% by 2040. Heat pumps are increasingly becoming networked devices that can participate in the Internet of Things (IoT). Such heat pumps, both domestic and industrial, enable optimization of operation to reduce energy consumption, lower CO_2 emissions, achieve economic benefits and increase comfort. They also enable grid services through the targeted provision of flexibility, e.g., in a pool of small heat pumps or with large heat pumps for industrial or district heating applications.

The IEA HPT Annex 56 project analyses the opportunities and challenges of IoT-enabled heat pumps for use in buildings and industrial applications. The aim of the project is to provide a structured overview of IoT-enabled heat pumps and commercial products and services. The presented data and information were developed in an intensive exchange with experts from the participating countries (Austria, Denmark, France, Germany, Norway, Sweden, Switzerland).

The work is structured in five tasks: Task 1 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. A Zotero literature collection with more than 100 items was created. Market overview, a manufacturer survey and experts interviews on IoT and heat pumps were conducted in four countries (Denmark, France, Austria and Sweden). In total, 44 factsheets of IoT use cases and projects were created, thereof 23 from Denmark and 10 from Austria. The examples were compactly summarized in two-page factsheets, that contain information on the description of the technology used (hardware, platform, protocols), explanation of the application (background and benefits, lessons learned) and an info box (Data requirements, analysis methods, modeling requirements, maturity level, etc.).

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

Task 2 focuses on the communication infrastructure and 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. Four use cases are discussed in detail based on 10 different examples.

Task 3 gives an overview on data analysis based on examples of IoT products and services. Different targets for data analysis are derived from 32 examples, data analysis methods are categorized and assessed, ranging from visualization and manual analysis to machine-learning algorithms. 16 examples are described in detail, they are mainly research projects. Furthermore, this task provides insights in the pretreatment of data, the use of data models, meta data and BIM (building information modeling).

Task 4 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). 19 examples of implemented business models are presented.

Task 5 aims at reporting results and disseminating information developed in the Annex. Interactions and synergies with six other Annexes and Tasks in the IEA Technology Collaboration Programs that

are also working on digitalization were sought.

Highlights of the project were the Deep Dive Sessions, which took place in the context of the international expert meetings. In these sessions, different aspects of IoT enabled heat pumps are covered based on presentations of research projects presented by the participating organizations and invited external experts. The Deep Dives enable a deeper exchange on concrete questions and thus contribute significantly to the networking of the international participants and to the exchange of knowledge. Ten different Deep Dives were organized.

The results of Annex 56 are published on the website: https://heatpumpingtechnologies.org/annex56/ There, an introduction of the participants, all task reports, the final report providing a structured overview on the work and the factsheets are available. Furthermore, a webinar was carried out to promote the results and the slide deck and the recording of the webinar are provided on the website. Annex 56 yielded numerous publications: 8 presentations at conferences and workshops, 3 conference papers, 6 journal papers (thereof 3 submitted) and 1 magazine publication.

The results of Annex 56 provide a good overview of the risks and opportunities for connected heat pumps. 44 application examples were collected in the participating countries, which clearly show that IoT-enabled heat pumps and products based on them are already available on the market. Five general categories can be assigned to the application examples: Heat pump operation optimization, Predictive Maintenance, Heat pump operation commissioning, Provision of flexibility and Heat as a service. For the user, this typically means operating cost and energy savings and increased operational reliability. For the energy system, the provision of flexibility is of particular importance, as it enables better use to be made of fluctuating renewable energy generation. Exchange and use of data plays an essential role in this.

Various interfaces and protocols for communication are available for networked heat pumps. Often, the connection to the Internet is wireless via WiFi and gateways that connect to the cloud, where data analysis services can be accessed. For heat pumps integrated into building automation, BACnet and Modbus are widely used. In the Austrian survey, Modbus and KNX Fieldbus, UPC UA and BACnet were frequently mentioned. The analysis of the Danish use cases illustrates that different stakeholders need to interact (quickly) at different levels and through different interfaces, for example, API interfaces, Modbus, MQTT, end-user apps, and fog/edge-based computing facilities. The Swedish work shows that interoperability is difficult between heat pumps from different manufacturers and even within a single manufacturer's product range. However, these challenges do not apply exclusively to heat pumps, but more generally to interconnected actors in the energy system. Interoperability and data availability will play an essential role in balancing generation and consumption in the energy system.

Modeling and data analysis are key activities for IoT-enabled heat pump products and services, as they enable meaningful use of collected data to provide targeted information for desired purposes. Five data analysis objectives were collected in the analysis, to which different methods can be assigned: Fault detection, Predictive maintenance, Optimization, Control, and Comparison with other heat pumps. The data analysis methods used in the application examples are visualization and manual analysis, analysis of alarms, KPI calculation and comparison, prediction, MPC (model-based control), MILP (mixed-integer optimization), big data analysis, data model development, and machine learning. The analysis points out that the application largely determines the data analysis method.

IoT-enabled heat pumps are already part of business models and new services. The main benefits for users of IoT-enabled heat pumps are lower costs, more efficient heating systems, and higher reliability. For the heat pump value chain, i.e. component manufacturers, heat pump manufacturers, dealers, installers, digitalization leads to new products and services that make heat pumps more attractive and future-proof. Compared to traditional business models, they have more responsibility for the efficiency of IoT-enabled heat pumps. The energy system (aggregators, suppliers, power grid, etc.) requires flexibility to balance fluctuating renewable generation. Heat pumps can provide flexibility and enable sector coupling by linking the heat and power sectors, which will be particularly relevant for the future. Energy service companies (ESCO) are a new player in the building sector (heat as a service, leasing of heat pumps, heat as a service), they are already established in the industrial sector with heat pump contracting. ESCOs can support the further diffusion of heat pumps, as users in contracting models do not have to deal with the heat pump, but only purchase the heat.

The importance of digitalization for the energy transition has increased further in recent years. Intelligent, digital solutions are increasingly in demand to make efficient use of various flexibility options such as electricity-based heat generation, the use of storage or e-mobility, and to control the power grid securely. Therefore, connected heat pumps will also play an important role in the future energy system. Current efforts of the latest EU action plan to develop a sustainable, cyber-secure and competitive market for digital energy services and digital energy infrastructures underline this. Important fields of action are the definition of common standards and the improvement of the interoperability of devices in the energy system. A common European energy data space for the exchange and use of energy data, as well as a code of conduct for interoperability, are to be created. IoT-enabled heat pumps can contribute to the following EU energy policy objectives: increasing participation in demand response programs for energy-efficient appliances and increasing the cyber security and resilience of the energy system.

www.heatpumpingtechnologies.org

Heat Pump Centre
c/o RISE - Research Institutes of Sweden
PO Box 857

SE-501 15 BORÅS
Sweden
Tel: +46 10 516 53 42
E-mail: hpc@heatpumpcentre.org

www.heatpumpingtechnologies.org

Report no. HPT-AN56-1