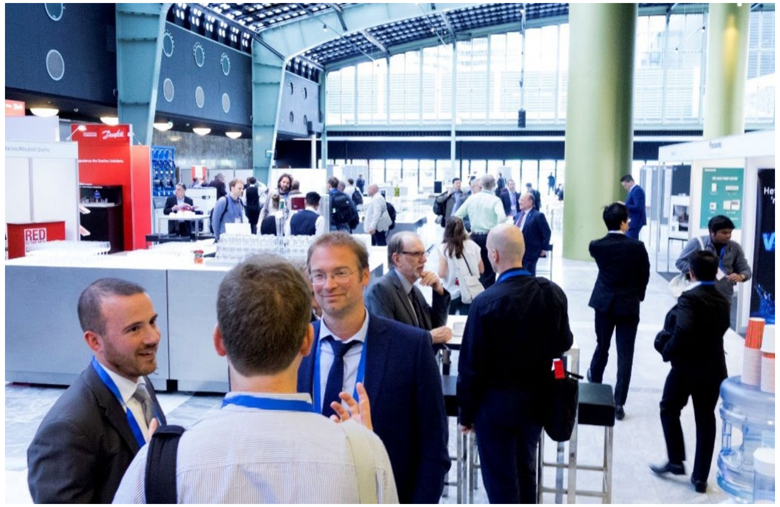
IEA Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)



Research, Development, Demonstration, and Deployment of Heat Pumping Technologies

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 organized 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.

Annex 57

- Flexibility by implementation of heat pump in multi-vector energy systems and thermal networks

Webinar 6/5-2024
Svend Pedersen Danish Technological Institute

Agenda regarding webinar: 6/5 -2024 from 13.00-15.00

Time	Subject	Presenter	
13.00	Welcoming	Svend Pedersen	(DTI)
13.05	Introduction of the IEA Heat Pumping Technology Program	Caroline Haglund Stignor	(RISE/HPC)
13.10	Presentation of Annex 57 participants, project frame and Tasks, and main results.	Svend Pedersen	(DTI)
13.20	The Energy market now and 2030-2050 trends (Task 1)	Svend Pedersen	(DTI)
13.30	Development in the Heat pump market. Future of DH and HP Trends (Task 1)	Svend Pedersen	(DTI AAU)
13.40	Presentation of flexibility, creation of flexibility in large scale heat pumps (Task 3-4)	Wiebke Meesenburg	(DTU)
14.00	Best practice examples of flexibility created with heat pumps (Task 2)	Dietrich Schmidt/Axel Oliva	(Fraunhofer)
14.20	Flexibility created by small scale heat pumps. Policy / Communicationprotocols.	Markus Lindahl	(RISE)/
		Marion Bakker	(RVO)
14.40	Existing and future business models and barriers (Task 5)	Philipp Ortmann	(AIT)
14.55	Questions		
15.15	Closing		

HPC

Caroline Haglund Stignor

Annex 57 Presentation

Svend Pedersen (DTI)

IEA HPT Annex 57 -Flexibility

Objective

Providing an overview of how HP technologies can create flexibility in the thermal network and electrical grid

Scope

Heat pump technologies in combination with District Heating **but individual heat pumps has been included.**
Markets and potential |Cases | Concepts | Assessment | Business cases| Dissemination

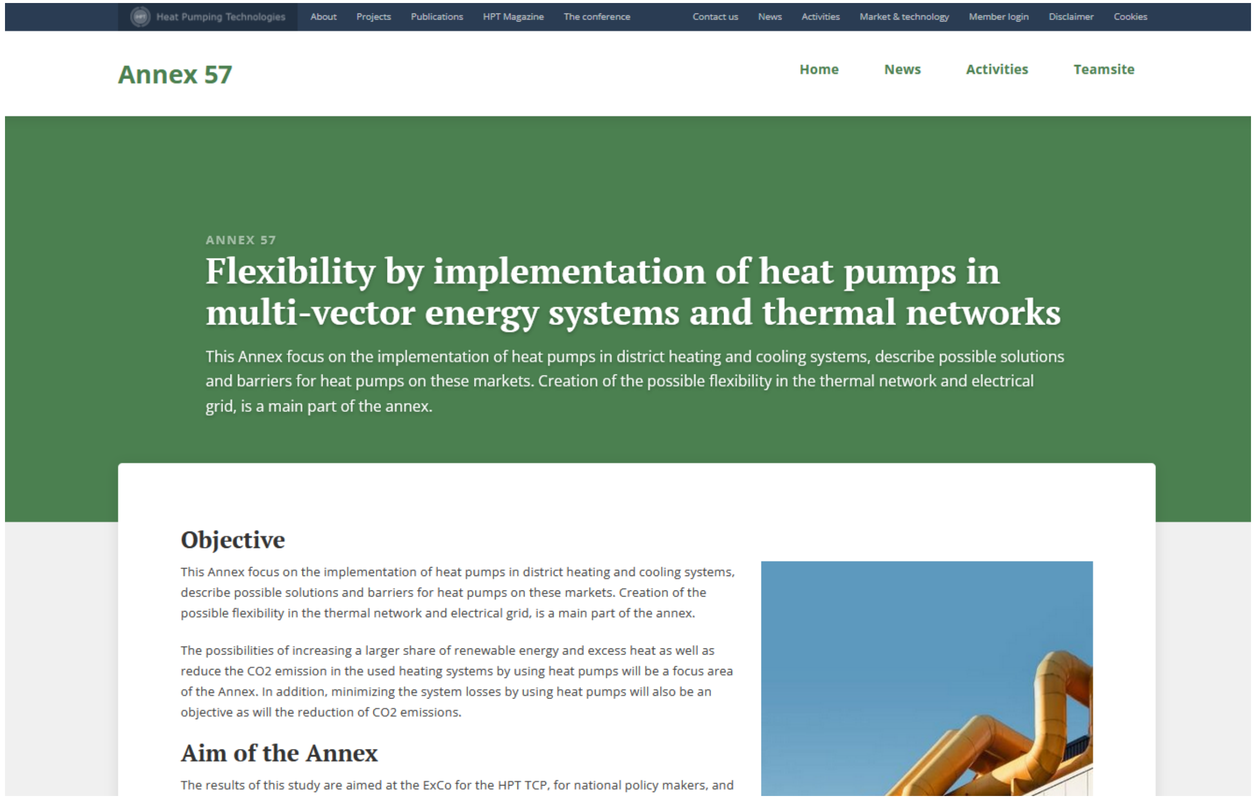
Project facts and partner group

2021 – 2023 | Annex of the IEA HPT TCP | https://heatpumpingtechnologies.org/
Austria/**Denmark (Operating Agent)**/Germany/ Netherlands/Sweden

IEA HPT Annex 57

Participating countrys:

- Austria: Austrian Institute of Technologies
  TU Wien
- Denmark: DTI, DTU, AAU,JCI, PlanEnergi, Danfoss
- Germany: Frauenhofer
- Netherlands: RVO
- Sweden: RISE, Halmstad University



Deliverables

- **Task 1: Energy market analysis**
  - National reports A,DK,SE,NL,DE
  - Report from AAU EU
  - Summary report
- **Task 2: Best practice examples – Description of existing projects with flexible solutions with heat pumps**
  - Case stories
  - Two pagers
  - Detailed description
- **Task 3: Concepts – development of representative and promising solutions**
  - Task 3 report
- **Task 4: Flexibility – Assessment and analysis of different options**
  - Task 4 report
- **Task 5: Business models – Development and evaluation of innovative concepts**
  - Task 5 report
- **Task 6: Dissemination**
  - Summary report
  - Annex webpage
  - Workshop
  - Webinars

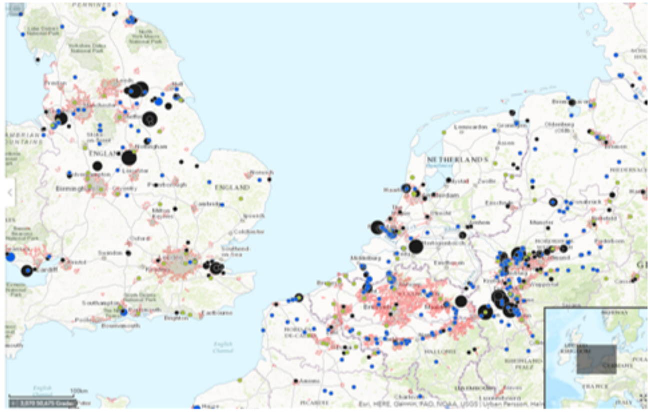
Task 1 Energy market analysis

ANNEX 57 FLEXIBILITY BY IMPLEMENTATION OF HEAT PUMPS IN MULTI VECTOR ENERGY SYSTEMS AND THERMAL NETWORKS

IEA Heat Pumping Technologies Annex 57

FLEXIBILITY BY IMPLEMENTATION OF HEAT PUMPS IN MULTI_VECTOR ENERGY SYSTEMS AND THERMAL NETWORKS

Task 1 report Netherlands:



Authors:

Marion Bakker (RVO Netherlands)

Project website:
https://heatpumpingtechnologies.org/annex57/

January 2023

Article

Heat Roadmap Europe: The increasing role of large-scale heat pumps in district heating systems

Christopher W. Wild*, Brian Vad Mathiesen

Department of Sustainability and Planning, Aalborg University, 2450 Copenhagen
* *Corresponding author. E-mail address:* cww@plan.aau.dk *(C. W. Wild)*

Abstract:
Europe's heating sector, facing an energy and climate crisis, needs a transition away from its current 75% reliance on fossil fuels. Decarbonization strategies and increased availability of renewable electricity are driving the shift toward large-scale heat pumps. Despite only a 13% district heating market share, the production from large-scale heat pumps is gaining momentum, with an anticipated short-term market expansion from 2.6 GW_{th} to 15 GW_{th}.

Commercial refrigerants are being replaced by natural alternatives e.g., ammonia (NH_3) and carbon dioxide (CO_2), due to their lower environmental impacts, accounting for two thirds of newly established systems. For future energy system scenario design, the paper presents a technology dataset for large-scale heat pumps based on cases established between 2010 and 2023. Investments ranging between 0.6 and 1.5 million € pr. MW_{th} while in recent years there has been a notable shift from high-capacity HFO based heat pumps to smaller 1-10 MW_{th} facilities. However, forthcoming plans anticipate a countertrend toward very large heat pump systems based on natural refrigerants.

The Heat Roadmap Europe and sEEnergies projects suggest district heating could meet 50% of Europe's heat demand by 2050. In this perspective, large-scale heat pump capacity may jump to 108 GW_{th} by 2050 (EU27), enhancing the utilization of untapped waste and geothermal heat. Austria, Denmark, Germany, Spain, France, Italy and Sweden could contribute with 59 GW_{th}. Heat pump operation times may be between 22% to 41% annually, contributing with 16% to 38% of the district heating supply, increasing system-level energy efficiency substantially.

Keywords: Large-scale heat pumps, district heating, buildings, smart energy systems, energy systems analyses

1. Introduction

In the context of the present energy crisis and the escalating climate crisis, diligent attention must be directed toward the heating sector. While the necessity of augmenting renewable energy sources is self-evident in the electricity sector with decreasing costs for wind power and photovoltaic, it is imperative to acknowledge that energy efficiency constitutes an option to lower the demand overall. Hot water and space heating represents about one third of the European Union´s (EU) final energy demand, 75% of this heat comes from burning fossil fuels [1]. The EU's focus on energy efficiency in buildings has been successful and these are much more efficient pr. square meter compared to 20 years ago, however there are more dwellings, appliances and larger homes, so the resulting energy demand is similar to today [2]. Also, renewable energy integration has been successful in the electricity sector but not yet in the heating sector. The EU's REPowerEU package aims to further address the heating sector as part of the proposals to be independent of natural gas imports by 2027 [3]. The REPowerEU implementation has been effective to reduce natural gas consumption and imports. However, the focus is still on the building level and not on the key strategic option to fundamentally redesign the energy system.

This paper focuses on the recent developments with large-scale heat pumps (LHP) and the future European potential for using them in district heating systems, as they constitute a crucial aspect of energy system decarbonization in smart energy systems [4]. Historically, research on heating system decarbonization has predominantly focused on buildings, either through enhancing building envelopes or replacing fossil fuel-based heating with solutions like individual household heat pumps in net-zero emission buildings [5]. This trend is also evident in the latest European Union long term scenario report "A Clean Planet for All" and the Paris Agreement aligned 1.5TECH scenario in which buildings continue to be treated in isolation from the broader energy system and where district heating as well as large-scale heat pumps are not assigned a crucial role [6].

Previous work on large-scale heat pumps has highlighted various synergies, such as within industry [7,8], with thermal

Task 2 Best Practice examples (28 cases)

Best Practice Examples

ANNEX 57 — Flexibility by implementation of heat pumps in multi-vector energy systems and thermal networks

IKEA Aalborg, Aalborg Denmark

"To have a CO_2 neutral cooling production for the warehouse and use of excess heat from the cooling production in the district heating system."

Key Facts

RD&D Status:
Large-scale demonstration

Type of heat pump:
Decentralized HP with district heating-system 1,2MW and 750 kW cooling

Building description:
Warehouse
Mix of new and existing.

Energy distribution System:
District heating / District Cooling. Electrical connected to the grid.

Energy Storage:
District heating grid

Control for the flexible heat pump operation:
Predictive control

General description:
Number of heat pumps:
1 W/W + 1 A/W
Total capacity 1.2 MW Heating and 750 kW cooling

Heat Source:
Excess heat/Ground/Air
Source temperature:
? to -2/3 °C

Summary of the project:

IKEA Aalborg and Aalborg Forsyning's CO_2 emissions will be reduced when the department store replaces its traditional cooling system with remote cooling from Aalborg Forsyning. District cooling is both cheaper and more climate-friendly than traditional cooling, and thus completely in line with IKEA's focus on sustainability.

"The climate benefits have been decisive for our choice of the new district cooling system from Aalborg Forsyning. The facility will be a step on the way to 2030, when IKEA must be a climate-positive, circular business," says the warehouse manager at IKEA Aalborg.

Expected results:

- Technical capacity of approx. 1MW with the option to expand if more customers are interested.
- The plant has a total CO2 saving of between 1120-1950 tons in the period 2022-2028.
- The excess heat from the system can annually heat up what corresponds to approx. 480 ordinary houses.

Delivered by: Team Denmark

IEA HPT Annex 57

Demo No.: D-001	**Location/City:** Neusiedl am See	**Country:** Austria
Project name: Energie Burgenland HP Neusiedl am See		
Quotation: "Use excess wind electricity for heat pumps to enable flexible operation of the district heating system"		
Schedule of the demo project (research study):		**Year of realisation:** 2021
Leader organisation (owner, constructor, solution developer, research inst., etc.): Energie Burgenland		
Participating organisations – demonstration project part (involved other organisations): Energie Burgenland, Ochsner Wärmepumpen, Hybrid DH Demo, 4Ward Energy Research, Heat Water Storage Pooling		
Budget of the demo (invest/monitoring etc.): €5m		
Summary of the project: The region Burgenland (where Neusiedl am See is located) is the region with the highest wind energy supply in Austria. Neusiedl am See is a preferred living space with increasing heat demand. The project consisted of installation of a direct electric line from a wind park, a thermal and electric storage, as well as the installation of 4 high performance heat pumps and provides therefore the unique opportunity to source heat from renewable electricity generation.		
Expected results • Gas-savings of around 1,250 GWh/a • Reduction of carbon emissions of around 300 t/a • Reduction of biomass consumption of around 1,200 t/a • Reduced transport of biomass, reducing carbon emissions in transport by 9 t/a		
Published articles (paper, article etc.) • N/A		

IEA HPT Annex 57

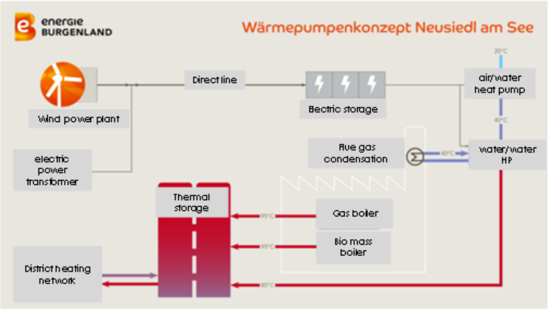


Figure 1 General layout

If available Homepage address:

Project classes:

RD&D status

Large-scale demonstration	Small-scale demonstration	Lab scale (results based on measurements)	Design study (results based on simulation)
☒	☐	☐	☐

Type of heat pump

Decentralized HP (cold district heating)	Centralized HP with a district heating system
☐	☒
Heating	Cooling
☒	☐

Task 3 Concepts for heat pump flexibility and solutions

ANNEX 57 — FLEXIBILITY BY IMPLEMENTATION OF HEAT PUMPS IN MULTI VECTOR ENERGY SYSTEMS AND THERMAL NETWORKS

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IEA Heat Pumping Technologies Annex 57

FLEXIBILITY BY IMPLEMENTATION OF HEAT PUMPS IN MULTI-VECTOR ENERGY SYSTEMS AND THERMAL NETWORKS

Task 3 report: Concepts for heat pump flexibility and promising solutions

Authors:

Philipp Mascherbauer (EEG TU Wien)
Philipp Ortmann (AIT Austrian Institute of Technology)
Axel Oliva (Fraunhofer ISE)
Dietrich Schmidt (Fraunhofer IEE)
Marion Bakker (RVO Netherlands)
Markus Lindahl (RISE Research Institutes of Sweden)
Svend Vinther Pedersen (Danish Technological Institute)
Wiebke Meesenburg (Technical University of Denmark)

Project website:
https://heatpumpingtechnologies.org/annex57/

January 2024

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY   Fraunhofer   RI. SE   DANISH TECHNOLOGICAL INSTITUTE

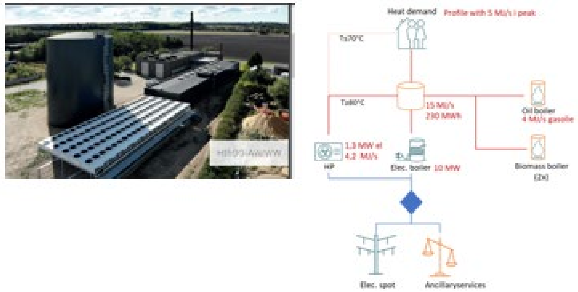


Figure 5 System plant and layout, Sdr. Felding. (Fenagy / Energinet)

Flexibility Shown

The heat pump and the electrical boiler supplement each other. When it comes to delivering ancillary services, the boiler can react very fast and adjust the electric load up and down, and it can supplement the heat pump to reach the bid limit when the plant operator puts offers into the market.

The heat pump has been tested regarding the reaction time. It has a start-up time within seven minutes, and a turn down time within four minutes as shown in figure 6. This means that it is able to act within the aFRR regime, see figure 7.

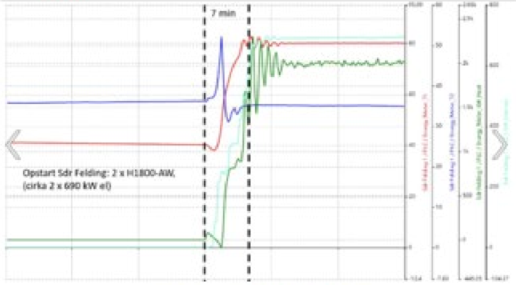
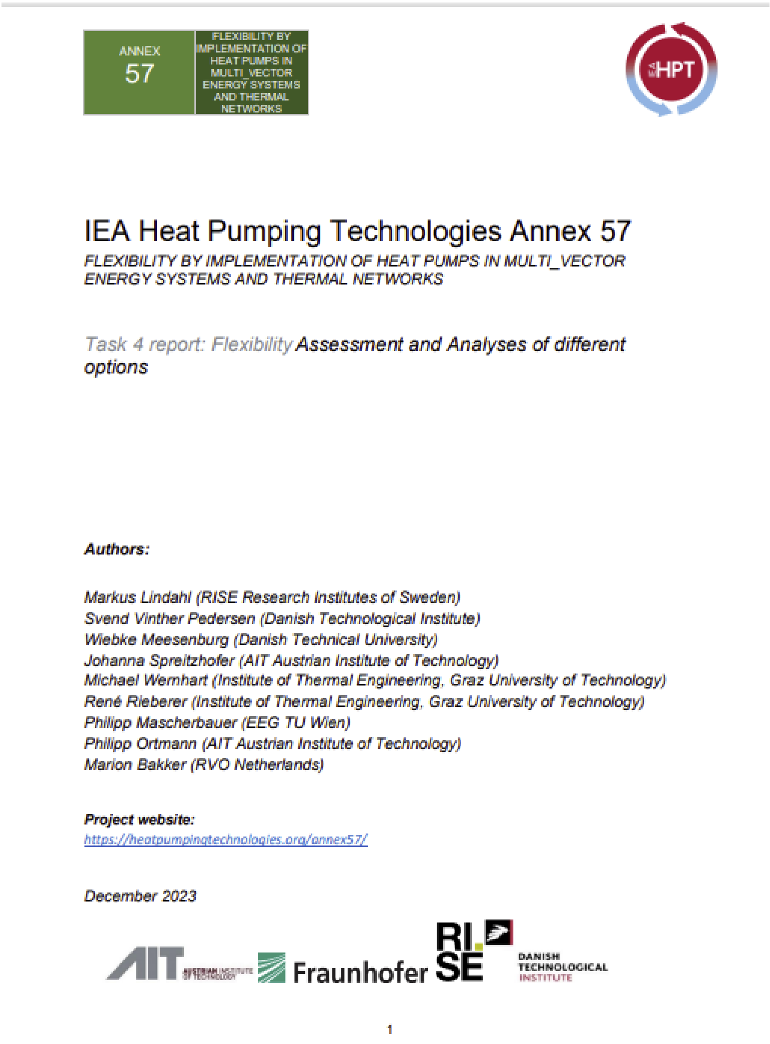


Figure 6 Startup, Sdr. Felding. (Fenagy)

Task 4 Flexibility Assesment and analysis of different options


ANNEX 57 FLEXIBILITY BY IMPLEMENTATION OF HEAT PUMPS IN MULTI_VECTOR ENERGY SYSTEMS AND THERMAL NETWORKS

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IEA Heat Pumping Technologies Annex 57

FLEXIBILITY BY IMPLEMENTATION OF HEAT PUMPS IN MULTI_VECTOR ENERGY SYSTEMS AND THERMAL NETWORKS

Task 4 report: Flexibility Assessment and Analyses of different options

Authors:

Markus Lindahl (RISE Research Institutes of Sweden)
Svend Vinther Pedersen (Danish Technological Institute)
Wiebke Meesenburg (Danish Technical University)
Johanna Spreitzhofer (AIT Austrian Institute of Technology)
Michael Wernhart (Institute of Thermal Engineering, Graz University of Technology)
René Rieberer (Institute of Thermal Engineering, Graz University of Technology)
Philipp Mascherbauer (EEG TU Wien)
Philipp Ortmann (AIT Austrian Institute of Technology)
Marion Bakker (RVO Netherlands)

Project website:
https://heatpumpingtechnologies.org/annex57/

December 2023

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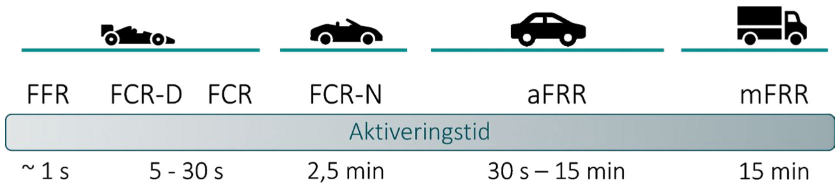

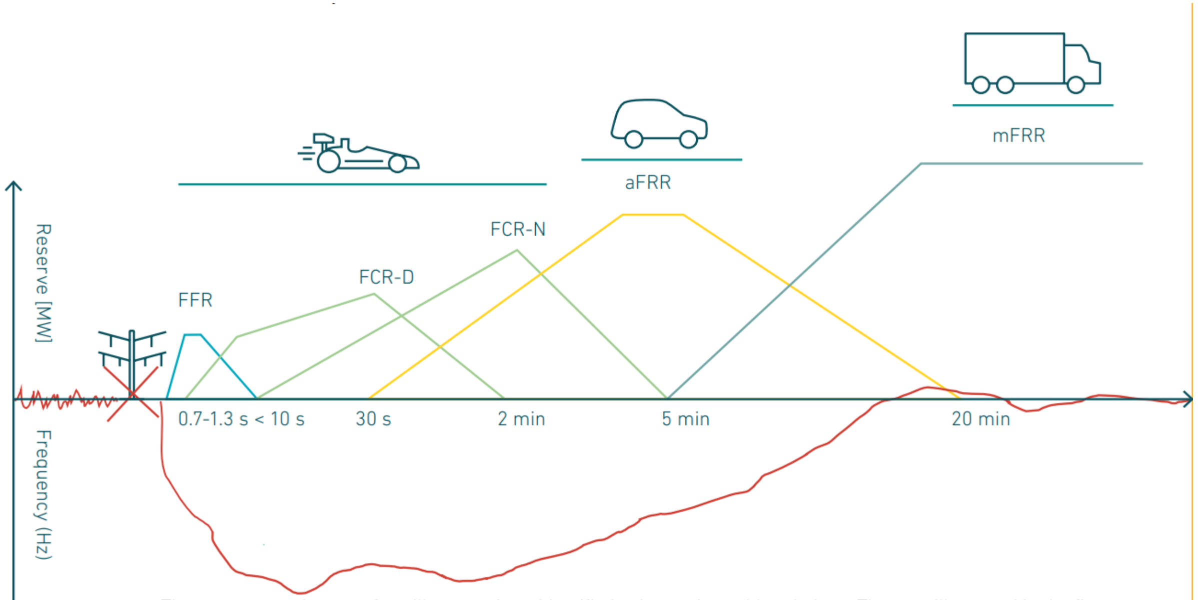

There are several types of ancillary services, identified using various abbreviations. They are illustrated in the figure above using vehicles. The racing car represents small, responsive reserves, while the truck is a bit slower, but carries more load when it starts to move. The figure shows how a frequency drop (red curve) occurs in the event of sudden imbalances or outages. Various ancillary services are then activated to restore the frequency to the 'healthy' level (50 Hz). Frequency products must quickly add power to the system to mitigate the frequency drop and prevent it from falling to a critical level. The more energy-intensive services (aFRR and mFRR) have to relieve the frequency services, so these are available again to mitigate new frequency drops and restore balance.

Task 5 Business models

ANNEX 57 FLEXIBILITY BY IMPLEMENTATION OF HEAT PUMPS IN MULTI VECTOR ENERGY SYSTEMS AND THERMAL NETWORKS

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IEA Heat Pumping Technologies Annex 57

FLEXIBILITY BY IMPLEMENTATION OF HEAT PUMPS IN MULTI-VECTOR ENERGY SYSTEMS AND THERMAL NETWORKS

Task 5 report: Business models – development and evaluation of innovative concepts

Authors:

Johanna Spreitzhofer, Philipp Ortmann, Regina Hemm (AIT Austrian Institute of Technology)
Svend Vinther Pedersen (Danish Technological Institute)
Michael Wernhart, René Rieberer (Graz University of Technology, Institute of Thermal Engineering)
Philipp Mascherbauer (EEG TU Wien)
Markus Lindahl (RISE Research Institutes of Sweden)
Marion Bakker (RVO Netherlands)
Axel Oliva (Fraunhofer ISE)

Project website:
https://heatpumpingtechnologies.org/annex57/

December 2023

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Intern gebruik

Table 5: Overview of barriers for business models.

Technical	Ramp-up times	Stand-still times	Part load behavior	Measurement/ control of electric load	Measurement of flexibility	Temperature flexibility	Fast change of source temperature
Regulatory	Unforeseeable changes in regulation	Local flex-markets still under development	Different regulations in different countries	Minimum bid size	Market entry requirements	Aggregation of small assets creates coordination problems	
Economic	Low revenues from day-ahead prices	Grid fees make up large part of electricity bill	Risk of end user intervention	Maintenance costs	Reduced efficiency and lifetime		
Other	Education of operators and installers	Cyber security / data protection	Acceptance of end users	Different electricity / heat supply mix in each country	More clear information from manufacturers	Wider digitalization measures needed	

(light yellow)	Low barrier for business model formation
(yellow)	Medium barrier for business model formation
(orange)	High barrier for business model formation

Main Results

- **The market is growing**
- It can briefly be shown by the referred demonstration cases that heat pumps are well operated within the energy trading markets of day-ahead and intraday. As large-scale thermal power plants are phasing out, the market for flexibility services is diversified and growing. Heat pumps might address this and can play a significant key role in the balancing of the market for the electrical grid. It is shown by various analyses that large heat pumps for district heating have a high economical potential to operate accordingly and act into the ancillary service market.

- **The market for heat pumps in district heating systems is growing**
- The market for district heating is growing throughout entire Europe, and scenarios show that heat pumps have a potential to cover from 16 % to 38 % of the annual production in most of the markets.

- **Heat pumps can act in the ancillary service market**
- Some of the cases show that heat pumps can act in the ancillary service market, especially if they are combined with electrical boilers and weekly storages. However, this is a new way to control heat pumps, and there are still barriers to overcome.
- Flexibility is possible to create with individual heat pumps, hybrid heat pumps, and heat pumps in district heating systems.
- The annex describes some of the barriers and business models. One of the barriers is that in people's mindset, heat pumps cannot technically create high temperatures for district heating, but the development of the heat pump technology is moving fast now, and the first district heating heat pumps which provides 90°C is starting up in Vienna in 2024.

The Energy market now and 2030-2050 trends

Svend Pedersen (DTI)

Increasing electrical demand

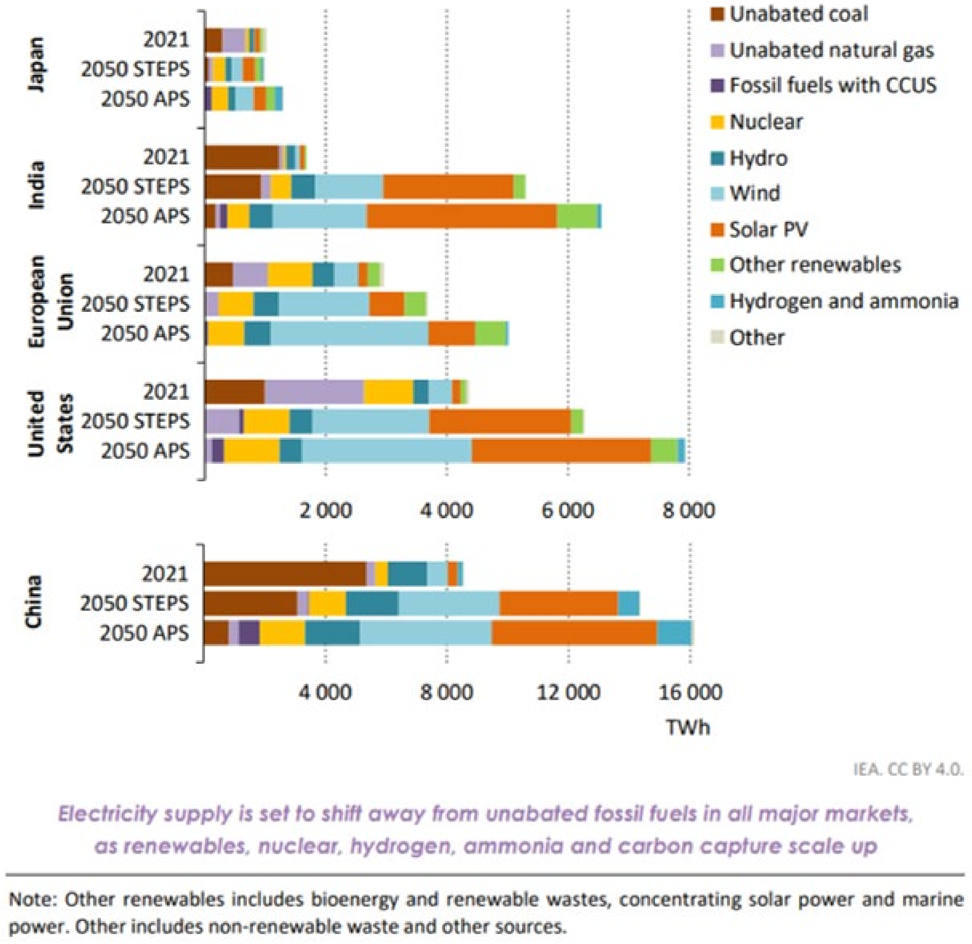


Figure 2 Electricity generation by source, key region, and scenario, 2021 and 2050. (IEA Outlook 2023)

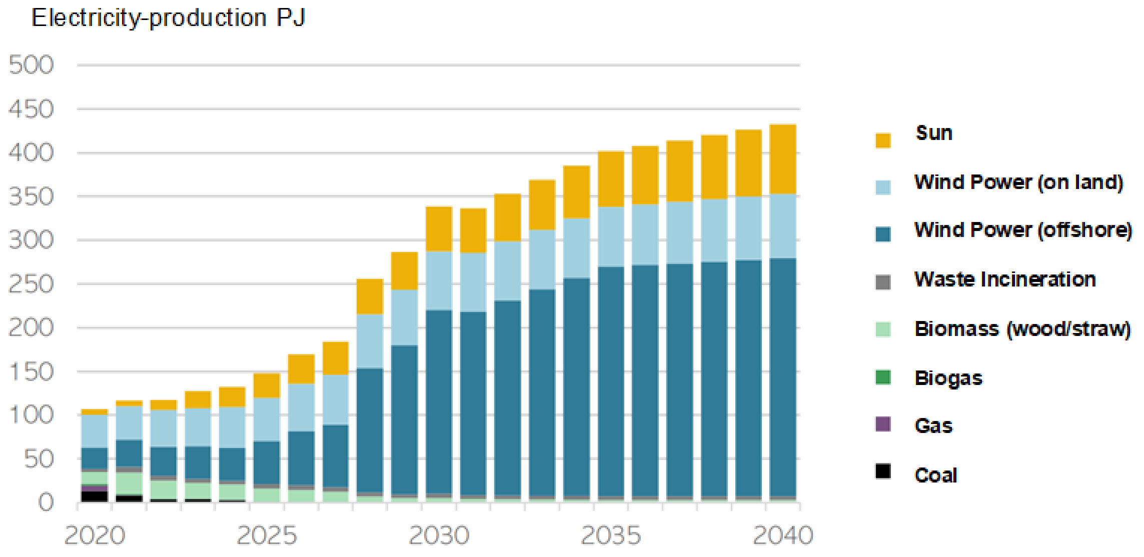


Figure 12 Scenario for the development in electricity production until 2040. (Danish District Heating Association)

Market development Increase of heat pumps

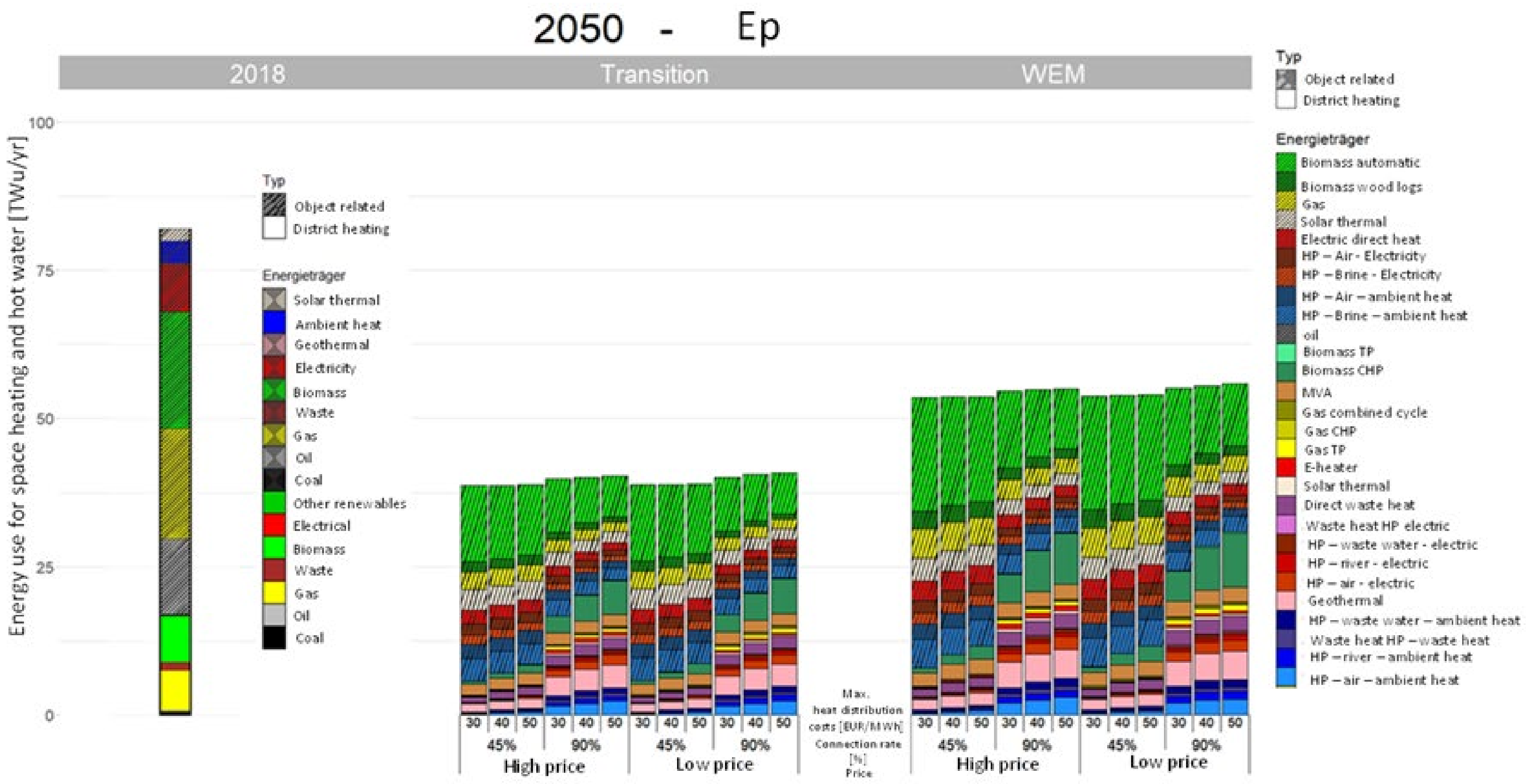
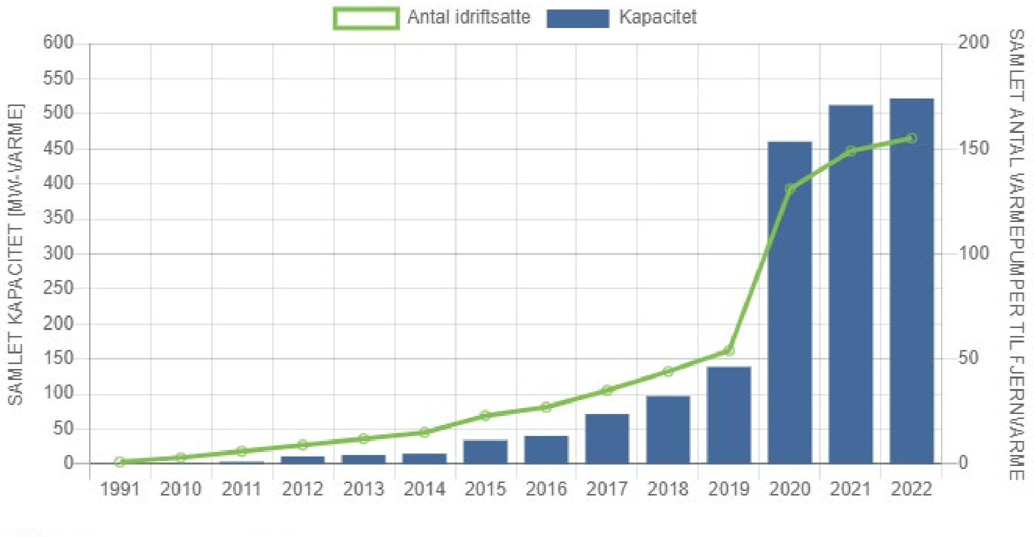


Figure 12 Use of energy sources for space heating and hot water in different scenarios in 2050 in Austria from an economic perspective. (AIT)

Market developments



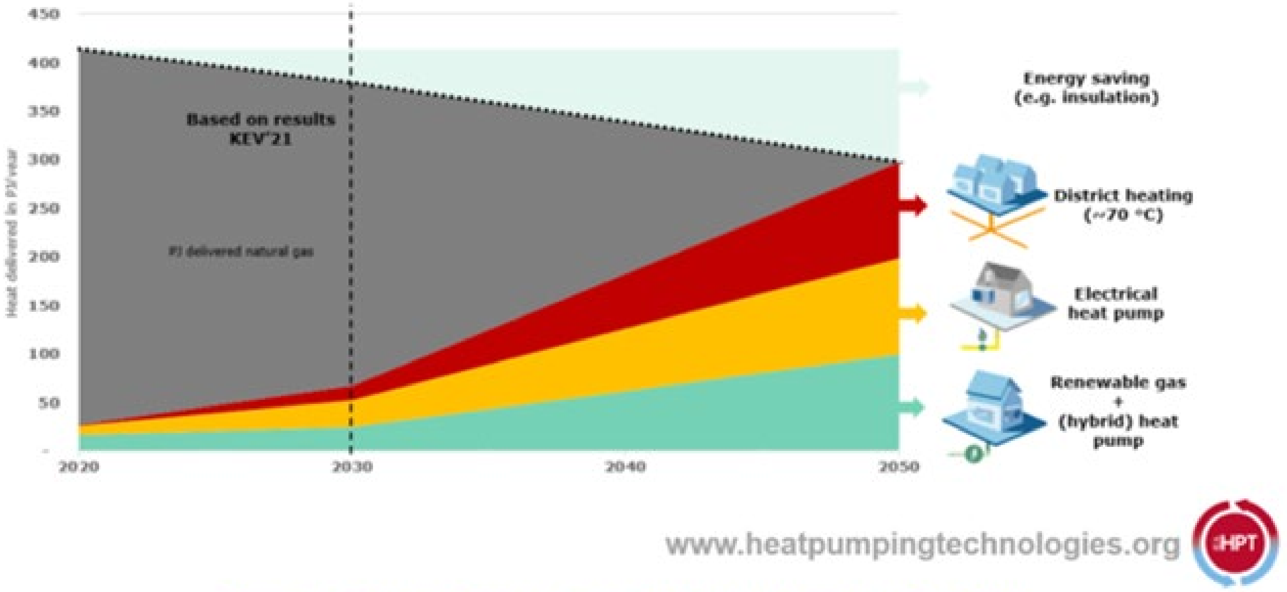
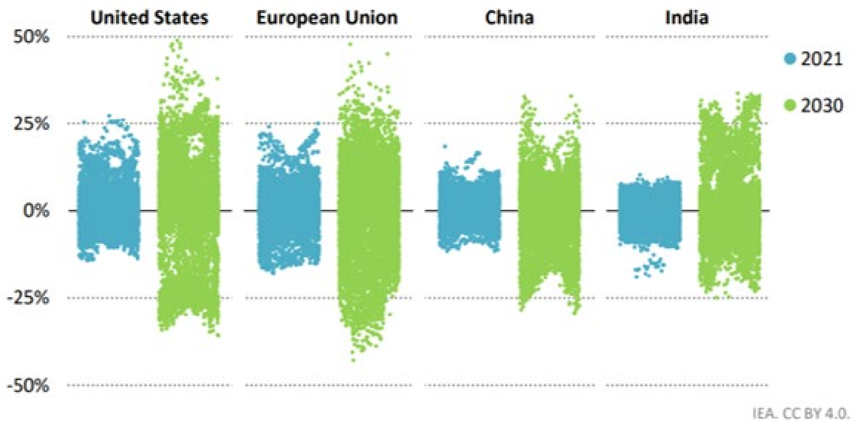


Figure 14 Policy Transition in The Netherlands (IEA 2023)

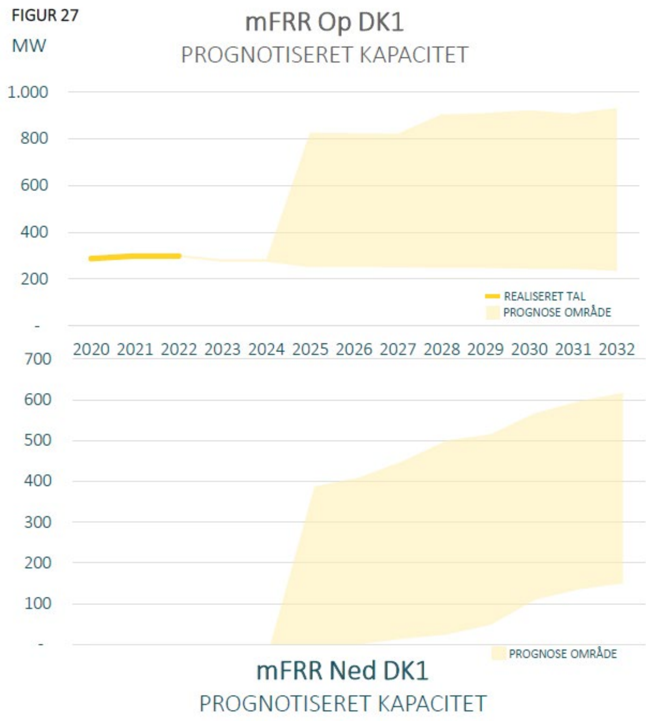
Increasing need for flexibility

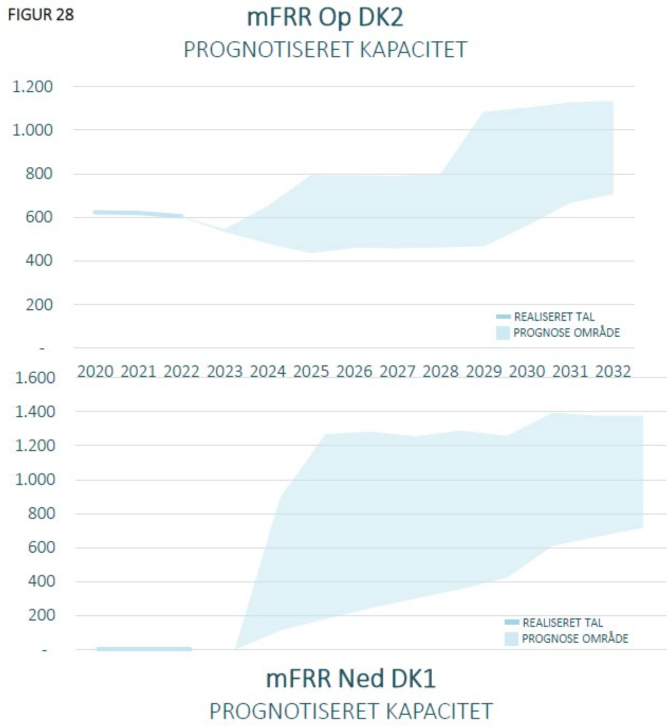


Hour-to-hour flexibility needs rise significantly by 2030 in major markets, driven by increasing shares of variable renewables and changes in demand patterns

Note: Flexibility needs are represented by the hour-to-hour ramping requirements after removing hourly wind and solar PV production from hourly electricity demand, divided by the average hourly demand for the year.

Figure 4 Hour-to-hour flexibility needs in the United States, European Union, China, and India in the APS, 2021 and 2030. (IEA Outlook 2023)





Technology mix which delivers ancillary services

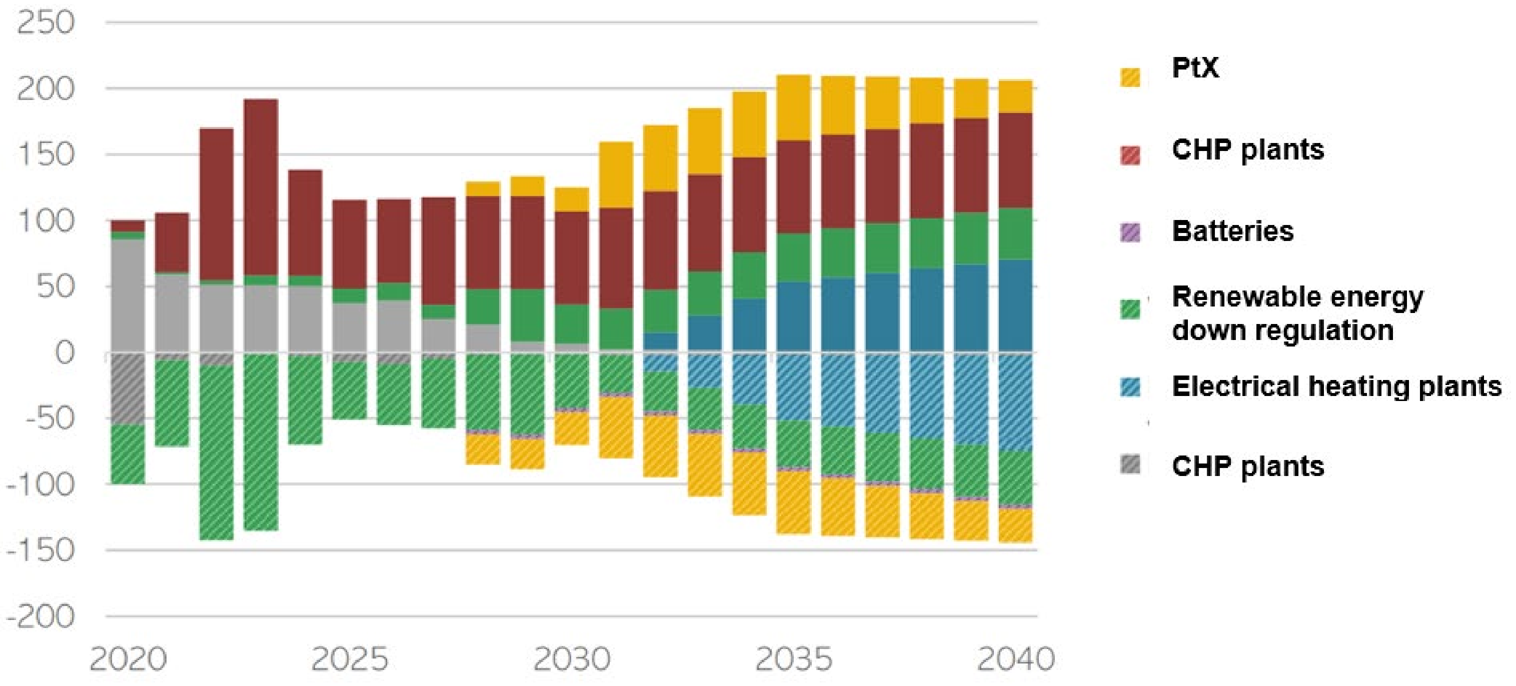


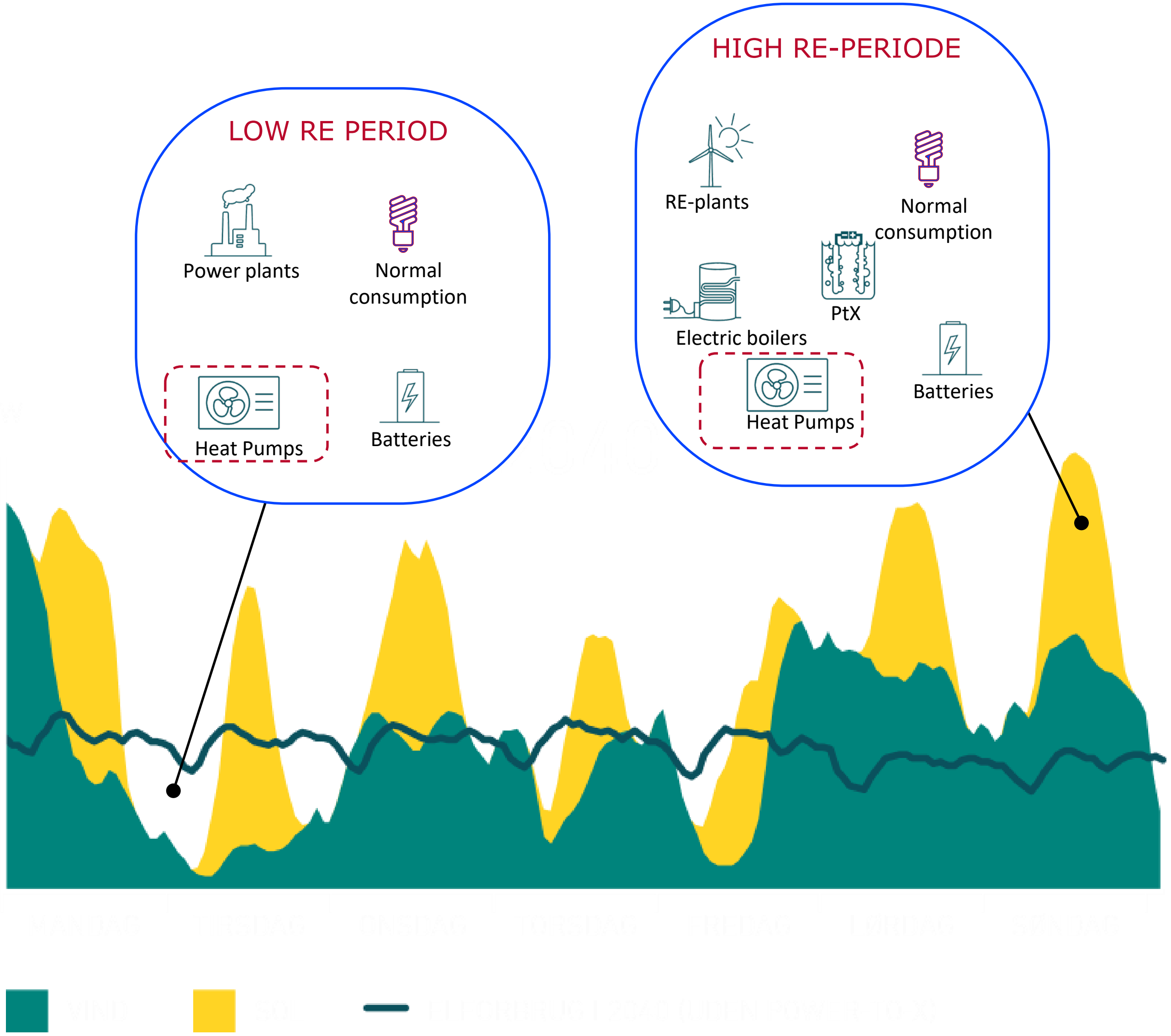
Figure 26 Technology mix which delivers to the capacity market for ancillary services. (Energinet)

DIVERSITY of Actors

The electrical grid needs a **wide** portfolio of balancing resources to secure a **high** supply security in the future.

No **heat pumps** are approved to deliver ancillary services !

… The Heat Pump in Sdr. Felding is the **first** in DK !



Barriers Energy price structures.

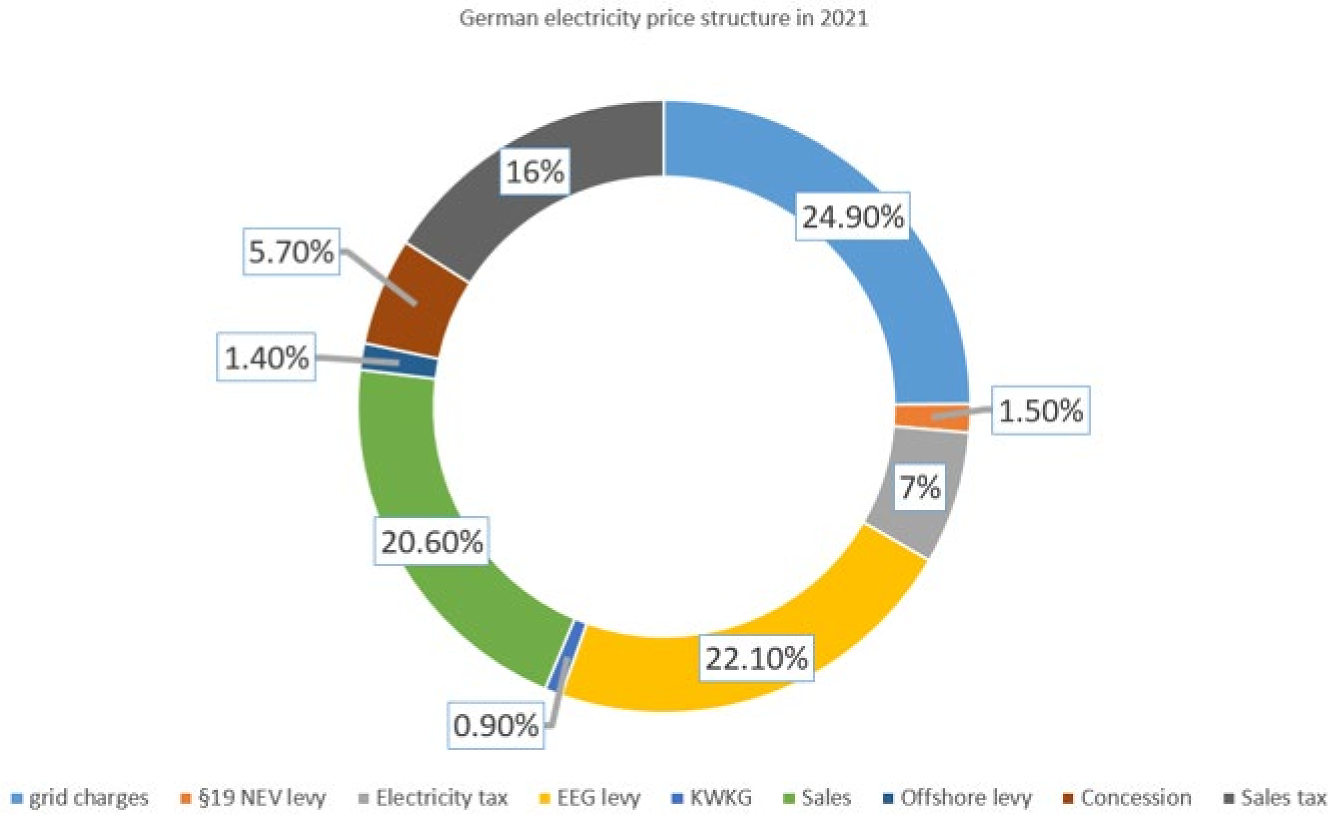


Figure 29: Structure of the German electricity price in 2021. (Verivox, 2021)

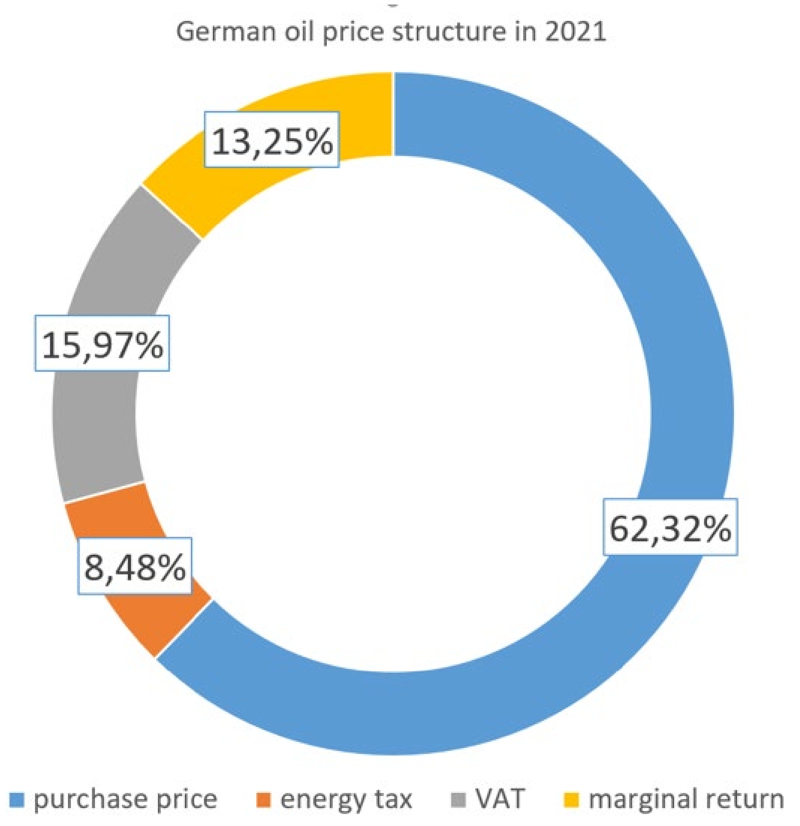


Figure 30: Structure of the German oil price in 2021. (Verivox, 2021)

Development in the Heat Pump market Future of DH and HP

Svend Pedersen (DTI)

Survey and Simulation

- Survey of installed heat pumps and market review
- Data collection with Plan Energi, Danfoss, EHPA
- Smart Energy System Modeling with EnergyPLAN

Article

Heat Roadmap Europe: The increasing role of large-scale heat pumps in district heating systems

Christopher W. Wild*, Brian Vad Mathiesen

Department of Sustainability and Planning, Aalborg University, 2450 Copenhagen
* *Corresponding author. E-mail address:* cww@plan.aau.dk (C. W. Wild)

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Keywords: Large-scale heat pumps, district heating, buildings, smart energy systems, energy systems analyses

1. Introduction

In the context of the present energy crisis and the escalating climate crisis, diligent attention must be directed toward the heating sector. While the necessity of augmenting renewable energy sources is self-evident in the electricity sector with decreasing costs for wind power and photovoltaic, it is imperative to acknowledge that energy efficiency constitutes an option to lower the demand overall. Hot water and space heating represents about one third of the European Union´s (EU) final energy demand, 75% of this heat comes from burning fossil fuels [1]. The EU's focus on energy efficiency in buildings has been successful and these are much more efficient pr. square meter compared to 20 years ago, however there are more dwellings, appliances and larger homes, so the resulting energy demand is similar to today [2]. Also, renewable energy integration has been successful in the electricity sector but not yet in the heating sector. The EU's REPowerEU package aims to further address the heating sector as part of the proposals to be independent of natural gas imports by 2027 [3]. The REPowerEU implementation has been effective to reduce natural gas consumption and imports. However, the focus is still on the building level and not on the key strategic option to fundamentally redesign the energy system.

This paper focuses on the recent developments with large-scale heat pumps (LHP) and the future European potential for using them in district heating systems, as they constitute a crucial aspect of energy system decarbonization in smart energy systems [4]. Historically, research on heating system decarbonization has predominantly focused on buildings, either through enhancing building envelopes or replacing fossil fuel-based heating with solutions like individual household heat pumps in net-zero emission buildings [5]. This trend is also evident in the latest European Union long term scenario report "A Clean Planet for All" and the Paris Agreement aligned 1.5TECH scenario in which buildings continue to be treated in isolation from the broader energy system and where district heating as well as large-scale heat pumps are not assigned a crucial role [6].

Previous work on large-scale heat pumps has highlighted various synergies, such as within industry [7,8], with thermal

District Heating levels towards 2050

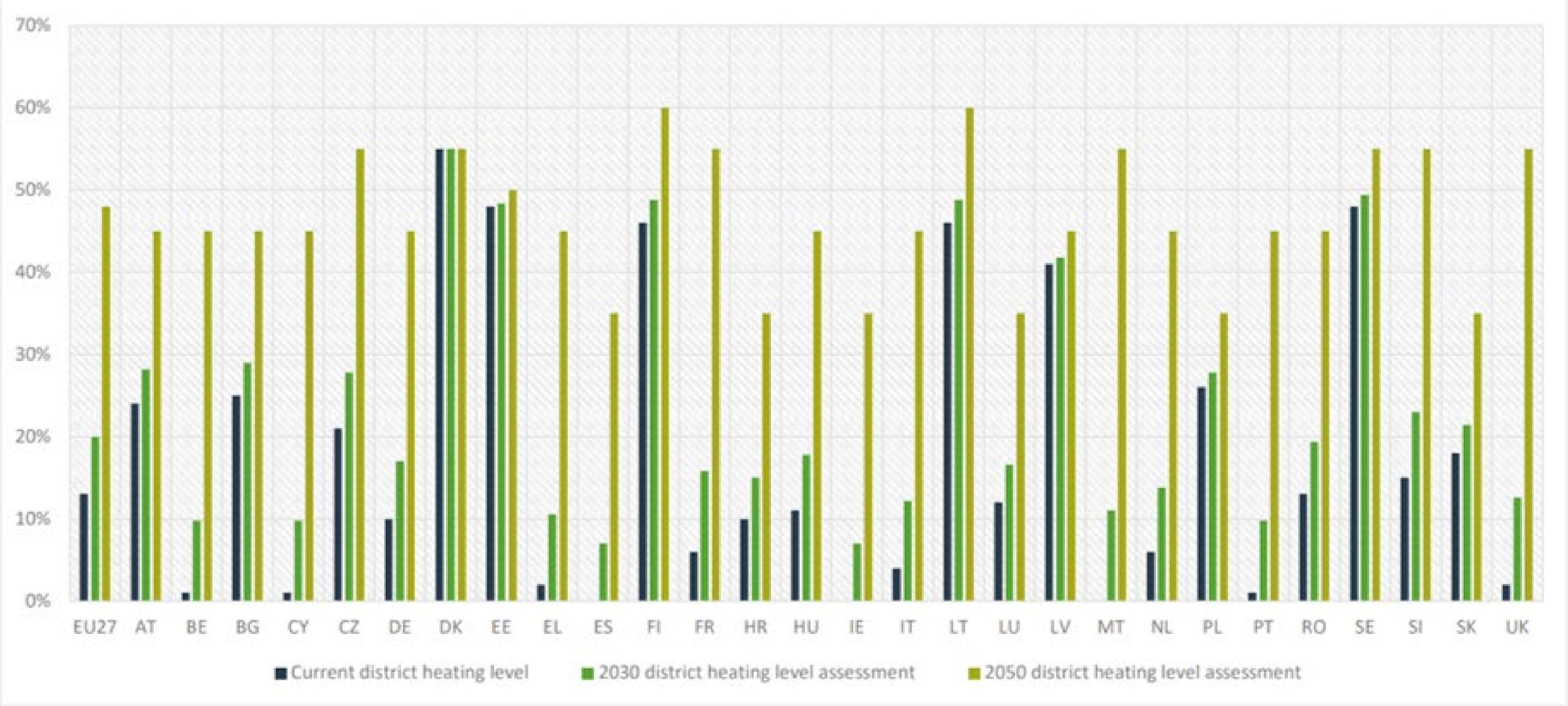

Figure 7 District heating levels towards 2023 and 2050 for heating buildings for EU27, pr. EU country and UK. (Aalborg University)

Heat Pump coverage in district heating

	unit	AT		DE		DK		ES		FR		IT		SE	
		BASE	LW	BASE	LW	BASE	LW	BASE	LW	BASE	LW	BASE	LW	BASE	LW
HP Capacity DH	MWe	450	450	3500	3500	600	600	2500	2500	3750	3750	3000	3000	900	900
HP operation	%	22%	26%	28%	34%	37%	41%	24%	28%	36%	39%	24%	26%	34%	36%
HP operation in HS	%	39%	43%	47%	54%	68%	68%	41%	45%	61%	65%	39%	49%	49%	51%
HP DH share	%	16%	19%	16%	21%	24%	27%	21%	25%	35%	38%	17%	19%	25%	27%
HP DH prod.	TWh	3.5	4.2	34.6	42.0	7.9	8.6	21.3	24.5	47.5	51.6	24.8	26.9	10.7	11.4

EU 27 DH/HP

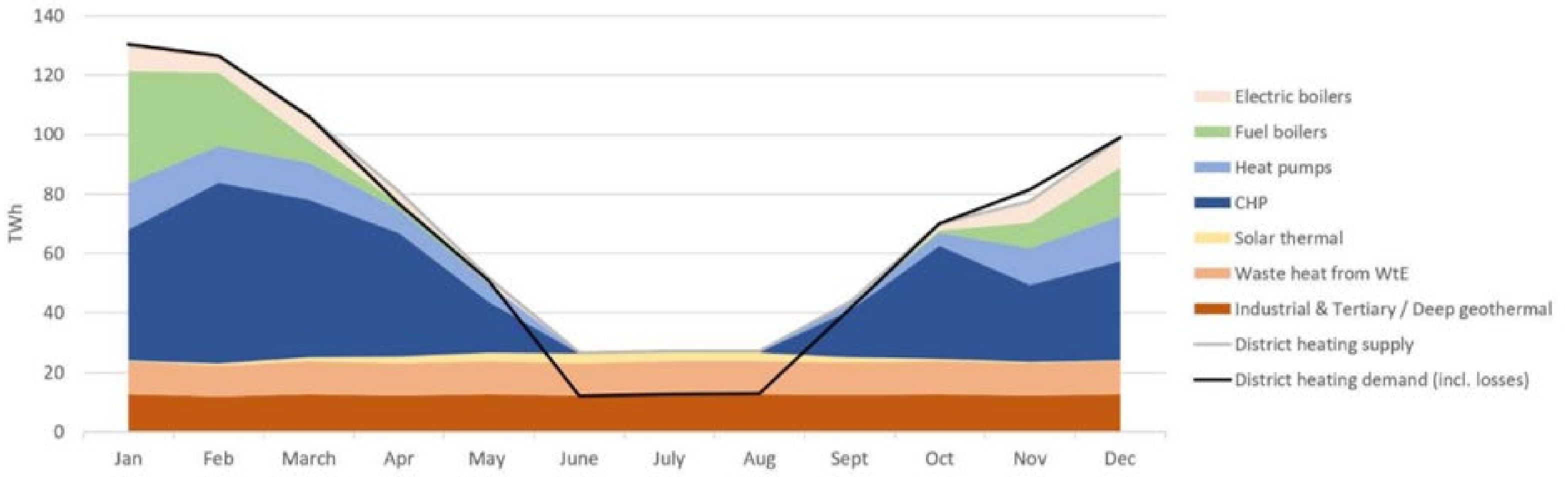

Figure 5 District heating production mix presented monthly, 2030 scenario. (Aalborg University)

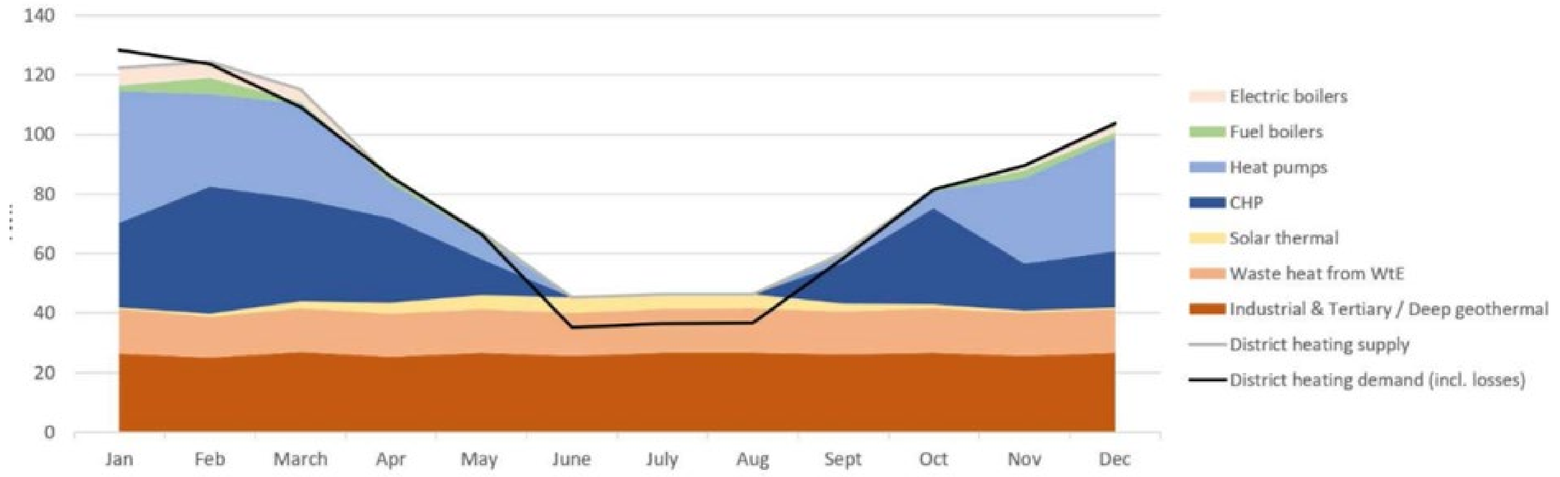

Figure 6 District heating production mix presented monthly, 2050 scenario. (Aalborg University)

Survey on technology

CO_2 Compr.-HP	2025	2030/2050
TRL level	8-9	
Thermal Capacity	1 – 25 MW_{th}	
DH temperature	80°C / 40°C	
COP at 0-7°C (Air)	2.8 - 2.9	2.9 - 3.1
COP at 5-15°C	*2.8 - 3.1	2.9 - 3.2
COP at 15-25°C	*3.1 - 3.5	3.2 - 3.7
COP at 25-35°C	typically no application	
DH temperature	70°C / 35°C	
COP at 0-7°C (Air)	3.0 - 3.2	3.1 - 3.3
COP at 5-15°C	3.0 - 3.4	3.1 - 3.6
COP at 15-25°C	3.4 - 3.8	3.6 - 4.0
COP at 25-35°C	typically no application	
Investment (mill€ / MW_{th})	0.6 - 1.5	0.5 - 1.4
Fixed Annual O&M (€ / MW_{th})	2000	2000
Variable Annual O&M (mill€ / MWh_{th})	0.6 - 1.5	0.6 - 1.5
Technical lifetime (y)	25	

NH_3 Compr.-HP	2025	2030/2050
TRL level	9	
Thermal capacity	1 – 25 MW_{th}	
DH temperature	80°C / 40°C	
COP at 0-7°C (Air)	*2.8 - 3.0	2.9 - 3.1
COP at 5-15°C	3.0 - 3.2	3.1 - 3.3
COP at 15-25°C	3.2 - 3.4	3.3 - 3.5
COP at 25-35°C	*3.4 - 3.6	3.6 - 3.8
DH temperature	70°C / 35°C	
COP at 0-7°C (Air)	*2.9 - 3.2	3.0 - 3.3
COP at 5-15°C	3.0 - 3.5	3.1 - 3.6
COP at 15-25°C	3.5 - 4.0	3.6 - 4.2
COP at 25-35°C	4.0 - 5.0	4.2 - 5.5
DH temperature	60°C / 30°C	
COP at 0-7°C (Air)	*3.2 - 3.6	3.3 - 3.7
COP at 5-15°C	3.5 - 4.0	3.6 - 4.1
COP at 15-25°C	*4.0 - 4.5	4.1 - 4.8
COP at 25-35°C	4.5 - 5.5	4.8 - 6.0
Investment (mill€ / MW_{th})	0.6 - 1.5	0.5 - 1.4
Fixed Annual O&M (€ / MW_{th})	2000	2000

THANK YOU FOR YOUR ATTENTION!