Technology Collaboration Programme on
Heat Pumping Technologies (HPT TCP)

Annex 42

Heat Pumps in Smart Grids

Executive Summary

Operating Agent: The Netherlands

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Disclaimer:
The views expressed in this report do not necessarily reflect those of the individual project participants.

1 Executive summary

Heat pumps in smart grids can contribute to solutions for several energy system-related obstacles. Within the Annex 42 working group, we distinguish five main smart heat pump contributions:

1. Keeping grid load under control while renewable energy production grows to restrict or even avoid grid capacity investments.
2. Keeping grid load under control during extreme conditions (i.e. 'coldest week'), again avoiding grid capacity investments.
3. Increase self-consumption of renewable energy sources (achieving better grid balance and higher economic end user value).
4. Selling flexibility to the grid, for the benefit of balance responsible parties, grid operators, traders, etc.
5. Allowing for a higher share of heat pumps in the energy system without risking local overload problems.

Enhancing the *realisation* of these solutions has been the basic driver for the Annex 42 participants.

It turns out that there is a real – and often pressing – benefit in implementing smart grids in all participating countries. The table below summarizes the main recommendations and actions that should be considered when trying to stimulate further development of smart grids.

Challenge domain	*Actions needed*	*Main stakeholders involved*
Sources of value	Carry out field trials that implement a 'full market model', including complete financial handling of flexibility contracts. Governments may facilitate this by authorizing dispensation for obstructing legislation where appropriate.	DSOs, Aggregators, Energy suppliers, BRPs, Policy makers
	Invest in development of new customer propositions. Possible directions are: monitoring & energy saving assistance, heating as a service, identifying alternate ('non-energy') benefits, increasing self-consumption of renewable energy.	Aggregators, Researchers
Technical barriers	Set up field trials to explicitly focus on building thermal mass. Preferably, flexibility limits should be tested *without* using any heat storage vessels at all.	Aggregators, DSOs, Researchers
	Start quantifying building thermal mass potential for groups of buildings in relation to typical building characteristics (e.g. size, materials used, building codes, occupation, etc.)	Researchers, Manufacturers
	Gain insight in end user behaviour patterns through field trials. How much demand response potential is actually available in a given end user group?	DSOs, Aggregators
Regulatory framework	Develop alternate taxation models, for instance taxing *as a percentage* of the commodity price, instead of adding a fixed tax tariff.	Policy makers, DSOs
	Increase absolute energy price levels, either directly or indirectly through a CO_2 tax.	Policy makers
	Enforce development of (open) communication standards.	Policy makers, Manufacturers, DSOs
	Appreciate negative effects of energy market unbundling and stimulate market cooperation and information exchange to counter these effects.	Policy makers, TSOs, DSOs, BRPs, energy suppliers

Challenge domain	*Actions needed*	*Main stakeholders involved*
End user behaviour	Develop simple and effective business propositions, focussing on customer engagement rather than return value maximisation.	Aggregators
	Privacy and data integrity will grow to be more important. Explicitly address these issues in new business models.	Aggregators

Structure of the Annex work

The Annex 42 work has been split into several topics:

MARKET OVERVIEW – To gain a first understanding of the present status and future changes for heat pumps in smart grids for the participating countries.

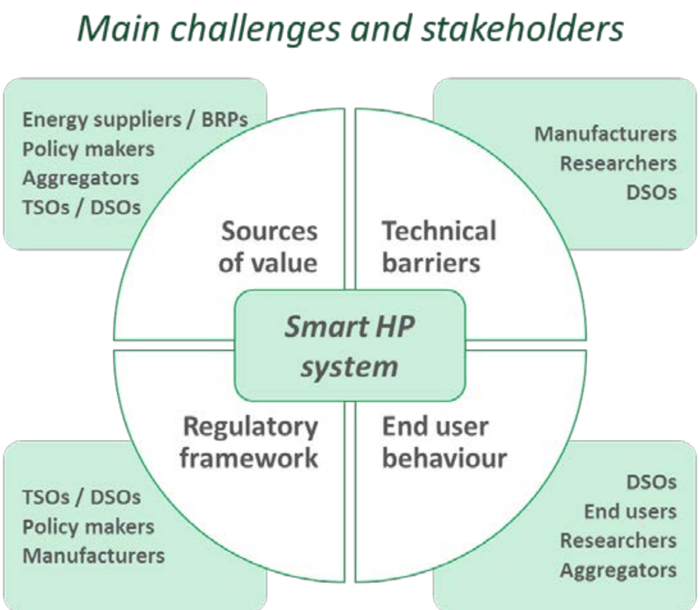
CASE SCENARIOS AND MODELLING – Through the definition of use cases for each participating country and subsequent modelling efforts, we have managed to give an overview of *sweet spots* for smart heat pumps, as well as extending our knowledge on situation-specific behaviour of heat pumps in smart grids. The commonality across all countries is the desire to explore the potential flexibility that can be provided by heat pump systems. Building on these cases, extensive modelling work has been performed by a number of participants. From these modelling studies, cross-country comparisons can be made on several distinct topics.

DEMONSTRATION PROJECTS – The Annex 42 working group has analysed the existing demonstration projects on heat pumps in smart grids in all participating countries. Together, these demonstration projects give a clear view on the feasibility of smart heat pump projects in terms of technical, regulatory and end-user issues, as well as the best ways to create value for all participants.

ROADMAP – Building on three years of Annex 42 work, a roadmap has been compiled containing (policy) recommendations for several different market stakeholders. This roadmap recommendations will now be discussed first, before giving an overview of the other parts.

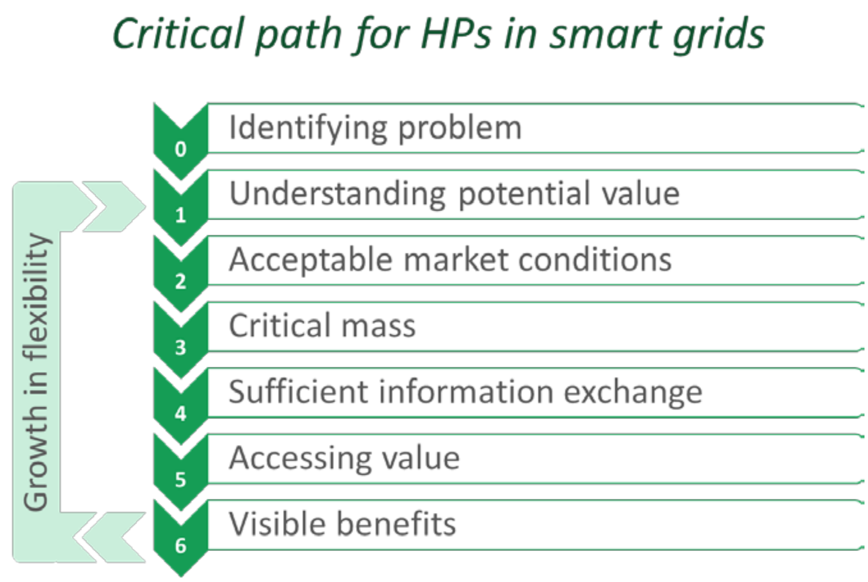
1.1 Roadmap

There are many challenges for heat pumps in smart grids, which can be split across four 'challenge domains'. For each domain, a specific set of market stakeholders is in a key position to contribute to solutions and further help the market progress of smart heat pumps.[1]



[1] BRP = Balance responsible party; TSO = Transmission system operator; DSO = Distribution system operator.

Looking at the ‘critical path’ for smart grid applications, we have found that most countries do acknowledge various (future) problems within their respective energy markets. However, by failing to quantify and understanding the potential value of flexibility to solve at least part of these problems, there is little movement towards explicitly designing or enabling flexibility-friendly market conditions. That is: most countries are ‘stuck’ on the first rung of the critical path. However, some initiatives have found ways to progress along the critical path. Several of those projects are discussed in Part V.



The actions and recommendations outlined in the table below are a concise summary of the most pressing concerns obstructing the critical path. More details on the actions and underlying analysis can be found in Part II of this document.

1.2 Market overview

For each participating country, an extensive market overview has been carried out. Metrics were drawn up to give an indication of how well suited each country is to the development of heat pumps in smart grids. These metrics are analysed in detail in chapter 9. The table below gives an overall suitability score for each country. Notably, only France and Switzerland are at this moment reasonably well prepared for (large scale) smart HP implementation.
In both countries, pressing capacity and power management challenges are expected in the near future. Heat pumps already play a major role in the Swiss domestic heating sector, making for a natural factor to consider in solving these challenges. France has much experience with smart heating appliance management and now faces the challenge to apply this experience to heat pumps.

Country	*Score*	*Market snap-shot*
AT	±	**There is a potential smart HP need expected within the coming decade.** However, uptake of HPs by households has been modest, and end-users are not used to flexible tariffs. Energy system challenges justifying smart grids are not quantified, making it **difficult to devise solid business cases**. Flexible energy tariffs are not (yet) available. The potentially flexible component in electricity prices is presently around 1/3: too little to have a serious impact on end-user behaviour.

Country	*Score*	*Market snap-shot*
CH	+	**The need for flexibility is in a 2020-2030 timeframe** in Switzerland, related to managing load on the high voltage grid. **HPs are a large potential flexible resource** – The Swiss HP market is the most mature of all participant countries, with HPs the technology of choice in single family homes and making up around 40% of annual heating installs. End-users with HPs are used to the HP being shut-down at peak times. The greatest challenge is capturing flexibility from the older buildings (making up about a third of the building stock).
DE	±	Supply/demand balancing and grid congestion are recognised as a medium-term (5-10 year) challenge for which demand side flexibility will be needed. **The typical heating solution in Germany looks stronger than other markets in terms of potential flexibility** – large storage tanks and strong share of HPs (some of which are already remotely operated at peak times). However, **energy price structures do not currently encourage market growth or give benefits for end-users** from providing flexibility – this is the biggest challenge to overcome.
DK	±	**Denmark faces challenges within the next 5 to 10 years, related to managing and balancing production and load on the high voltage grid.** District heating covers 60 % of all households, but in non-district heating areas (30-40 % of the country), electrification (HPs) is the policy direction. **There are market barriers to overcome to increase the HP market share in non-district heating areas**, the main barrier is high electricity prices and low fossil fuel and biomass prices. Furthermore, the **very high share of taxes in consumer electricity prices** in Denmark do not encourage market growth.
FR	+	In France, **capacity margins and grid congestion are already a challenge** to manage. The electric heating market is Europe's largest, and HPs are a significant part of this. As a result, **there is a large potentially flexible resource, and there is a lot of experience in controlling or influencing operating times of electric heating**. The main challenge in France is translating what has worked for electric heating to HPs, and capturing flexibility in an aging building stock.
KR	±	**South Korea faces an immediate challenge to fill a capacity margin gap** which has already resulted in black-outs. Capturing demand-side flexibility is therefore high on the political agenda. For HPs to contribute to this flexibility, **market challenges must be overcome (e.g. end-users' preference for gas, and unattractive electricity tariffs), and the thermal storage potential in floor heating and the relatively young building stock should be tapped into**.
NL	−	In the Netherlands, **the need for flexibility is recognised, particularly for managing grid congestion in the medium-term**. However, similarly to the UK, the HP market is <1% of the heating market, and there are challenges of lack of space for storage. **The flexibility potential from HPs is therefore quite low – hybrids could be key to unlocking flexibility here.**
UK	−	**The UK will need demand side flexibility in the medium term (5-10 years), particularly to manage growing distribution grid congestion.** The HP market is expected to grow quickly in the next few years, but the **flexibility potential from HPs is constrained e.g. by the old, poorly insulated buildings, lack of space for storage, an end-user preference for gas, and 'spiky' heat demand patterns**. The availability of flexible tariffs, and the growth of hybrids, could be key to unlocking more flexibility potential from HPs.

Country	*Score*	*Market snap-shot*
US	±	**Demand response has historically had far stronger drivers in the US than in Europe**, so the market is more advanced, leading to greater experience with "3rd party control" (even if the use of HPs within demand response has seen only small-scale activity so far). The total HP market is huge - **but the dominance of air/air HPs (mostly in southern regions), and lack of storage, does create a constraint on potential flexibility. An emerging ground-source HP market and a growing DHW HP market offer greater kW demand levelling opportunities**.

1.3 Case scenarios and modelling

The topic of smart grids is too broad and multifaceted to allow drawing overall and clear-cut conclusions. The picture is even more complex due to the fact that every country considers somewhat distinct aspects of the topic, addresses diverse problems and, accordingly, searches for different solutions, while defining various factors to express the results. Additionally, various models and methods are used for these purposes.
Nevertheless, some interesting findings and results are discernible from the country reports. **Overall, it is clear, that heat pump technology will play an important role in the future energy system, commonly referred to as "smart grids".**

The overarching topic, flexibility, can be divided into two sub themes: load shifting potential and length of off-blocks (times without the heat pump operation). These topics are closely connected, despite their individual specifics. Generally speaking, the flexibility describes how long a heat pump can be switched off without diminishing the comfort of the end users, or alternatively how much energy a heat pump can "absorb" from the grid, if forced to run.

The UK study underlines a **significant influence of building fabric on the amount of flexibility** that could be achieved across different building types. It was found that high levels of insulation were required to achieve more than a 1 hour DSR event in a typical UK house in a cold winter period. **Oversizing of a heat pump was the next most important factor.** In some cases, only a combination of the above increased the flexibility to 3 hour DSR events without compromising the thermal comfort of the occupants. From the other side, the current building fabric provides sufficient flexibility in combination with a 1°C internal temperature change to maintain thermal comfort during a 2 hour DSR, including during the coldest external temperatures in an average year. Thus, it may be concluded that **heat pump installations in existing buildings could provide a useful level of flexibility without additional intervention**.

The analysis from different countries indicated that a **substantial improvement of the flexibility for heat pumps in smart grids is possible through integration of thermal storages**: the operation times can be more concentrated and long off-blocks can be achieved (the average length of an off-block can be almost tripled already with the integration of a small additional storage system and a predictive control system). **However, a drawback of the additional storage** (in particular small volumes) **is a reduced heat pump efficiency**, which limits the financial benefit of the flexibility.

The Danish, Swiss and UK studies addressed the length of off-blocks. **How long a heat pump can be switched off depends predominantly on the thermal capacity of buildings**. The Danish project shows that the off time for most of the house types are above 5-6 hours at 5°C and 2-3 hours at -12°C outside temperature. The UK study shows that a standard construction with moderate levels of insulation is able to maintain thermal comfort with a 2-hour DSR event given a sufficient (4 hours) notice period and with a standard ASHP and no additional thermal storage. This comfort is maintained during an average cold winter period.
In order to maintain comfort during a 4-hour DSR event, an oversized (+50%) heat pump is required alongside an increased level of thermal storage, for example through thermal mass of the building fabric (+20%). A comparable result shows also the Austrian study, taking into account, however, a pooling aspect.

The German study underlines the conclusion - **a smart operation leads to higher overall electricity consumption,** mostly due to decreased HP efficiency and to additional storage heat losses caused by rising the operating temperatures.

The above paragraphs allow for the general conclusion, that **heat pump systems are able to provide a useful level of flexibility without significant interventions to the heating system or the building fabric**. With these additional interventions a greater level of flexibility can be achieved.[2]

1.4 Demonstration projects

The analysis of the key findings and challenges of the projects summarised by the Annex 42 participants has shown that there is one key challenge many of the projects have in common – the customer. Other recurring topics are of a more technical nature and relate mainly to a lack of standardisation and protocols for DR as well as the challenge of integrating automated- and direct control platforms with the controllers of the HPs.

Customer related challenges

Understanding the customers / participants in the trials, anticipating their behaviour and planning for its integration into the trial seems to be a key challenge for many trials.

Engagement is one key area where differences between the trials can be observed. On the one hand customers in some trials were found to have “small understanding and interest in heating technologies”, and were often found to show low levels of engagement. On the other hand, some trials report that customers “were interested in the project and gave a positive feedback”, or there was “very positive customer engagement and response as they were strongly involved in the trial”. Understanding better what differentiates these two diverging attitudes towards heating and the smart HP projects could provide important insights into if and how customer engagement with those technologies could be improved, e.g. by tailoring the message and incentives better to the target audience.

Another key area where a more in-depth comparative analysis of the different projects could provide important learnings on how to successfully implement smart grid solutions is the customer’s response to and experience to DR events and the smart technology. Here some stark differences were observed.[3]

Several trials report that:

- customers did not perceive any disruption to their comfort
- or measured success through customers not overriding the remote heating control function.

Other trials on the other hand found that their control systems were

- blamed for small comfort level violations
- did not sufficiently make clear the value from the controlled operation of the HP
- or were generally perceived as “obscure and complex”.

Understanding how to improve this perception of DR could prove to be the key to the further deployment of the technology in the residential sector.

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[2] E.g. through employing specific characteristic of a building or/and heating system, as well as additional elements, like a buffer storage.
[3] References to specific projects are given in Part V.

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