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Electrification of heat and decarbonisation of the electricity system: Sector coupling is creating opportunities for heat pumps

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Abstract

As the electricity sector decarbonises, the need for energy system flexibility is rising – and electric heating and cooling have a role to play in providing this flexibility. The flexible operation of residential electric heating and cooling products – including heat pumps – is beginning to move from trial stage to commercial reality in some European markets, potentially creating value for customers, networks and energy suppliers. Where are the opportunities today, how will these change in the future, and how can the heat pump industry be part of a future world of flexible energy? The authors present their latest research into the emerging opportunities and business models for heat pumps arising from 'sector coupling', home energy management, and demand-side response.

Keywords: heat pump; Europe; sector coupling; decarbonisation; flexibility; home energy management; demand-side response; business models; opportunities; customers; networks; energy suppliers; aggregators.

1. Introduction

As the electricity sector in Europe decarbonises, the need for energy system flexibility is rising, due to the greater share of electricity coming from intermittent renewable sources such as solar PV or wind generation (versus traditional, dispatchable fossil-fuel based generation). Smarter control of the level and timing of demand-side electrical loads (so-called demand-side response) can provide an important source of this flexibility, and one which can also generate value for a number of players in the energy system.

At the same time, the penetration of electrically-driven heating and cooling in homes and businesses in Europe is also increasing, driven by: a desire for forms of heating that are more efficient and lower carbon than traditional forms using fossil fuels; rising average summer temperatures; and increasing consumer expectations on year-round thermal comfort in buildings.

This convergence of the heating and electricity sectors in Europe (so-called 'sector coupling') – and the growing need for energy system flexibility – therefore presents an opportunity for heat pumps in Europe to become a more attractive technology to end-users, energy suppliers, aggregators, network operators, governments and other players, through their role in providing demand-side response. The flexible operation of residential electric heating and cooling products – including heat pumps – is beginning to move from trial stage to commercial reality in some European markets today.

However, as this is a space which is still in development, there are challenges associated with understanding the exact nature and timing of the opportunity, and the associated developments needed to realise it. It is therefore pertinent for those involved in the design, development, manufacture and sale of heat pumps (and related components & services) to understand where these opportunities are today in Europe, how they might change in the future, and what role heat pumps can play in a future world of flexible energy, in order to make the right strategic decisions for their businesses.

Delta-EE here presents its latest research into the emerging opportunities and business models for heat pumps arising from 'sector coupling', home energy management, and demand-side response in Europe.

2. Heat pumps and other HVAC loads represent an important potential source of flexibility

2.1 There is a growing need for energy system flexibility in Europe, leading to greater consideration of the potential for demand-side response

As the electricity sector in Europe decarbonises, the need for energy system flexibility is rising, due to the greater share of electricity coming from intermittent renewable sources such as solar PV or wind generation (versus traditional, dispatchable fossil-fuel based generation). This flexibility could be provided by various means, including additional dispatchable generation or electricity storage solutions.

Smarter control of the level and timing of demand-side electrical loads (so-called demand-side response) can also provide an important source of this flexibility, and one which can generate value for several different players in the energy system – plus end-users.

2.2 Heat pumps and other electric HVAC loads could provide many GWs of energy system flexibility – if appropriately connected

Delta-EE estimates that within Europe in 2019, the installed base of electrical heating, cooling and hot water appliances within residential properties represents over 220GW of installed capacity (table 1). We also estimate that the expected replacement of older electric HVAC appliances – or installation of new appliances – within Europe will likely represent 10's of GWs of 'new' capacity in the next five years, in the markets studied [1].

Table 1. Electrical heating, cooling and hot water loads in Europe in residential properties in 2019. An estimate of installed capacity, % of installed based with connectivity enabled, and potential for flexibility of timing of use. (Markets considered: UK, Germany, France, Italy, Norway, Sweden, Denmark and Finland).

	Space Heating	Hot Water
Capacity of installed base (GW)	110	110
% of installed base with connectivity enabled	<1%	<1%
Potential for flexibility of timing of electricity demand (qualitative)	Low to medium	Medium to high

Space heating loads – including heat pumps – offer low to medium potential to be flexible with regards to the timing of electricity demand. This can be increased by the provision of additional thermal storage, and/or smarter control regimes.

In order to be used to provide demand-side response to the wider energy system, it is necessary for an electricity-using appliance (such as a heat pump) to have the ability to receive signals from an external source which can influence the operation of the appliance (e.g. turn off, turn on, modulate power usage up or down). Delta-EE estimates that today, a very low percentage of the installed base of heat pumps in Europe (<1%) has the necessary connectivity installed - and enabled - in order to allow them to be used for demand-side response. However as new appliances are installed and sold, we expect that this percentage will rise, as it is easier for new appliances to be sold with the necessary equipment and control protocols already installed (preventing the need for costly retrofitting). We also expect to see a growing number of commercial offerings to residential customers emerging in the coming years, which will increase the user awareness and acceptance of such models.

3. How this flexibility can create value for energy system players, and end-users

3.1 There are several potential sources of value from sector coupling

Transmission system operators (TSOs), distribution system operators (DSOs) and electricity suppliers all benefit from having flexibility in the energy system. The value to these players of demand-side flexibility (demand-side response) includes the opportunity to avoid costs, or to generate revenue (figure 1).

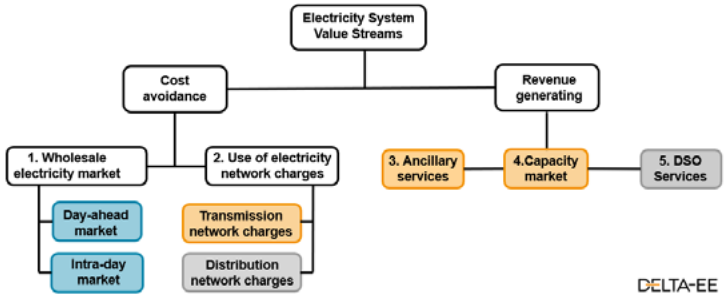

Fig. 1. Value streams typically available in European countries from demand-side response [2].

Demand-side flexibility can help market players to avoid costs by improving their trading in the wholesale electricity market, and/or avoiding charges arising from the use of the electricity networks.

- **Wholesale electricity market:** the majority of electricity on the wholesale market is traded by generators, suppliers and traders, on the day-ahead and intra-day markets. In the day-ahead market, trading takes place one day ahead of when the electricity will be delivered. The intra-day market is used by market members to fine-tune their market positions and account for any unforeseen circumstances which occurred once the day-ahead market has closed. Energy market players can choose to use demand-side flexibility to reduce the costs associated with this trading, by – for example – shifting the time of electricity use by their customers into a time period when it is cheaper for them to generate or purchase that electricity.
- **Electricity network charges**: are fees charged to network users (e.g. end customers) to recover costs associated with building, operating and maintaining the electricity transmission and distribution systems. The fees are related to the volume of electricity consumed, the connection capacity, or the timing of the electricity consumption (with higher charges often associated with periods of peak demand on the networks). Energy market players can use demand-side flexibility to reduce these charges – especially where the flexibility can be used to shift consumption into times of lower demand on the networks.

Alternatively, demand-side flexibility can be used to generate revenue from ancillary services payments, capacity market payments, or providing services to distribution system operators (DSOs).

- **Ancillary services payments:** are payments made by the Transmission System Operator to energy market players on the agreement the player provides services which maintain the proper function of the electricity system, by helping to maintain grid frequency, or enable the efficient handling of imbalances or congestion. Traditionally, these payments have been awarded to energy market players who can turn on or turn up electricity generation assets in order to provide the necessary services. However, in an increasing number of markets in Europe, these payments can now be awarded to players who can provide the necessary services via demand-side flexibility.
- **Capacity market payments**: are market subsidies paid to owners of electricity generation assets to ensure they can provide electricity generation to meet peak demands. As with ancillary services payments, an increasing number of European markets are allowing energy market players to use demand-side flexibility to bid to provide this service.
- **DSO services**: some distribution system operators (DSOs) are beginning to pay energy market players for demand-side flexibility, where this can help the DSO to avoid costs such as reinforcing their network or paying for constraint management.

Heat pumps can – in theory – be used to access all these value streams. In reality, the opportunity to access them is dependent on several factors in each European market, including:

- Minimum load size needed to access each stream (residential heat pumps will normally need to be aggregated into a larger portfolio of assets than individual appliances)
- Whether regulations permit the value stream to be accessed by residential loads in that country

- The penetration of smart meters, which are often a key enabler of residential demand-side response offerings.

In addition to the above value streams, heat pumps can also be used to provide value to end-users by optimizing heat pump operation within the building itself - e.g. by improving the self-consumption of electricity and/or integrating with other loads within a building. This can be done either using intelligence within the heat pump itself, intelligence off-site (within a cloud computing service) or intelligence within a home energy management unit – or a combination of several of these.

We have illustrated these potential uses for heat pumps (and other electrical heating and cooling loads) within a residential property in figure 2.

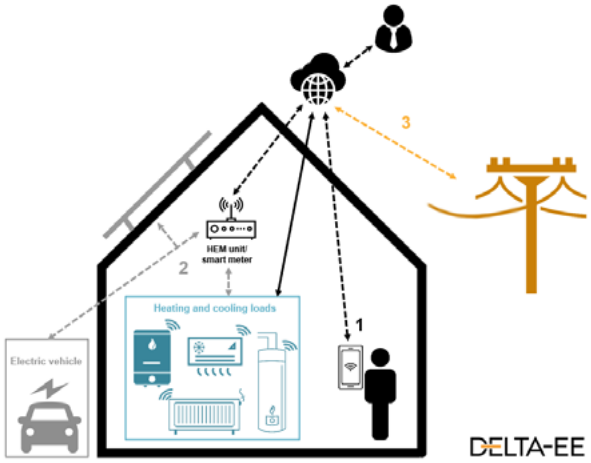

Fig. 2. Illustration of different uses for connected heat pumps (and other electrically-driven heating and cooling loads). 1: connected individual appliance providing greater control & visibility to end-user. 2: integration with other loads, at building level, for optimizing self-generated electricity. 3: providing services to the wider energy system (demand-side response).

3.2 Over time, more value streams are expected to become accessible, in more European markets

Delta-EE has surveyed a number of major European energy markets, using a mixture of desk-based research, and conversations with relevant industry experts and players. Delta-EE has found that today in Europe, the number of demand-side response value streams which are open to residential loads – including heat pumps – varies by country (table 2).

Based on our observations, and conversations with industry experts, Delta-EE expects that in the coming years, more markets within Europe will open an increasing number of value streams to residential loads, driven by increasingly favourable policy and improving regulation. This will open up a growing commercial opportunity for players in the energy market to use aggregated fleets of residential heat pumps for demand response.

Table 2. Number of demand-side response value streams which can be accessed by residential loads in selected European markets in 2019. (Excludes improved self-consumption within one residential property). [1].

	#
Finland	3 or more
France	3 or more
United Kingdom	3 or more
Germany	2
Denmark	2
Sweden	2
Norway	2
Netherlands	2
Switzerland	1

3.3 End-users can gain value from sector coupling in a number of ways

In-home optimization of the heat pump operation can bring value to the end-user (as above) via improving self-consumption of electricity, and/or integrating with other building loads. In addition to this, the end-user of a heat pump (or other HVAC appliance) can also benefit from the appliance being used for demand-side response.

Depending on the value stream(s) being accessed and the business model used, companies wishing to influence heat pump operation in order to provide demand-side response may choose to offer one or several of the following financial benefits to the heat pump end-user:

- Access to a lower-cost electricity tariff
- Access to a time-of-use electricity tariff, where the cost of electricity (price per kWh) varies by time. These can be fixed time periods within each 24yr period (static time-of-use tariff) or variable (dynamic time-of-use tariff). Time of use tariffs allow the heat pump end-user the opportunity to change their times of electricity consumption, in order to lower their electricity bills.
- Some companies offer an additional service whereby they will provide an optimization service to the end-user, automatically shifting the heat pump operating times into periods of lower cost electricity (where possible without affecting user comfort).
- A small number of companies will reward end-users with a financial payment for allowing their heat pump to be used for demand response, either in the form of a direct payment, or a discount on their energy bill.

As well as financial rewards, companies can also choose to reward the end-user of the heat pump through offering non-financial rewards, such as:

- Improved controls, such as via a smartphone app
- Improved visibility of energy usage (energy insights provision) via a smartphone app, or website
- Optimising the heat pump to run at the times of lowest electricity carbon dioxide intensity, thereby helping to reduce the end-user's 'carbon footprint'
- The positive emotional benefit from explaining that their heating appliance is helping to decarbonize Europe's electricity supply, by helping to accommodate more renewable sources of electricity.

4. Commercial examples and learnings from using heat pumps in Europe to provide demand-side response

4.1 Commercial examples already exist in Europe, and more are likely to emerge in the coming years

Our review of the European market has revealed several commercial offerings in Europe which use residential heat pumps to provide demand-side response, generating value for the company providing the offering, and also financial and/or non-financial rewards to the end-user. The key metrics are provided in table 3, and the following sections give three commercial examples available in Europe today. (Please note that the

use of these examples does not represent an advertisement for any of the companies mentioned, or show any form of endorsement).

Table 3. A summary of commercial offerings using residential heat pumps for demand response in Europe in 2019. There are numerous further projects which are in pre-commercial or trial stage; information for these is not presented here. [3].

Metric:	
Number of fully commercial offerings with heat pumps as the main asset:	7 offerings
Number of countries:	5 countries
Number of assets being steered for demand-side response (majority of which are heat pumps):	>20,000 assets
MWs of capacity provided by these assets:	>160MW

4.2 Commercial examples 1 & 2: Time of use tariff optimization in Sweden & Austria

In 2017, the Swedish government passed a law requiring energy suppliers to offer half-hourly electricity tariffs (with prices tied to market spot prices). A similar law has now been passed in Denmark. This has given rise to heat pump manufacturers such as NIBE and IVT (Bosch) introducing a service whereby the heat pump can automatically respond to price signals and generate heat to store when it is cheapest to do so. Customer savings are in the range of 5-10% on the variable part of their electricity bill. While this may have minimal impact in the Nordic countries, where wholesale prices are relatively stable, in countries such as Germany and the UK, where wholesale prices are more variable, the saving could be much greater. A dynamic time of use tariff for residential customers was recently launched in the UK, from supplier Octopus Energy.

In Austria, an energy supplier called aWATTar offers hourly time-of-use electricity tariffs to residential end-users. The company also offers end-users an additional hardware and software package which can automatically shift their heat pump operating hours into lower-priced hours, where this is possible without reducing their comfort. End-users pay a fee of around €149 for this additional package, and the company claims it will reduce the end-user's yearly energy bills by around 10%, through this load-shifting

4.3 Commercial example 3: heat pumps for ancillary services in Switzerland.

In Switzerland, company TIKO gains revenue from the ancillary services market. It controls the operation of a fleet of residential heat pumps throughout the country to provide grid balancing services to the Swiss electricity network. The offer to the end-user is reduced-price access to a smart phone app, which allows them to remotely adjust their preferred heating times, view their heat pump's energy consumption and performance, and alert them to possible faults.

5. Further development of several enabling factors would help the heat pump industry fully realise the opportunity across Europe provided by sector coupling

Our research has shown that only a small share of today's installed base of heat pumps in Europe is being used for demand-side response. There remains an - as yet - largely untapped potential for residential heat pumps to be used for sector coupling, allowing such appliances to be fully part of a future world of flexible, low carbon energy.

The further development of a number of enabling factors would help to increase the number of commercial offerings available, including (but not limited to):

- Greater wholesale & retail energy price variation
- Increased value from electricity system revenue streams, in order to mitigate the associated costs of aggregating and managing the assets
- Regulatory frameworks allowing residential assets to be (more easily and more commonly) used to provide demand-side response
- Reduced cost of associated hardware (including cost of retrofitting, where applied to an existing installed heat pump)
- Greater standardization of communications protocols among devices
- More use of real load profiles by energy suppliers to settle residential customer electricity bills

- More wide-spread use of home energy management systems, to control and optimize electricity loads within residential buildings

Creating a compelling proposition for the end-user was voted as being the most important area for development, in a poll of energy & heating industry professionals conducted by Delta-EE (figure 3).

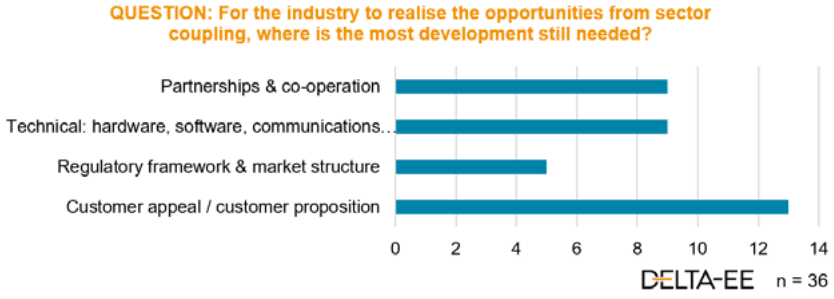

Fig. 3. Results of a poll among energy & heating industry experts by Delta-EE in September 2019. Respondents could select one of the four possible options shown.

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