‘Smart’ Heat Pumps: Enablers of a Low Carbon Future

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Delta Whitepaper, February 2011

A low carbon future brings with it many opportunities, and a few challenges, for heat pumps.

A decarbonised grid - with high penetration of inflexible wind and nuclear - means that balancing generation and demand is not as straightforward as ramping up supply to meet demand. Instead, demand may be shaped to meet available generation. On the demand side, increasing electrification of heat and transport could result in congestion on the distribution networks at peak times.

‘Smart’ operation of heat pumps - to help balance generation and demand, and to manage network congestion - represents a significant opportunity for heat pumps. In this Delta Whitepaper, we look at three case-studies from Germany, Denmark and Switzerland, where heat pumps are already being used as part of a solution to deal with the new challenges.

Heat pumps can play an important role in dealing with the challenges of a low carbon future

‘Smart’ use of heat pumps will be a key part of a low carbon future.

In markets with an increasingly high level of inflexible (renewable and nuclear) generation, having capability to control heat pumps could be a game-changer for the market. Even in markets where balancing generation and demand is not such an extreme challenge, ‘smartening’ the operation of heat pumps will still add to the heat pump value proposition.

In Germany, the utility Vattenfall Europe has launched a new control system whereby it sends daily dispatch signals to heat pumps according to the forecast day-ahead power market prices. Pilot projects in Belgium, the Netherlands and Denmark are also trialling the ‘smart’ use of heat pumps.

Reducing congestion on the grid will be critical in many growing heat pump markets. As electric vehicles are deployed in increasing numbers, the ability to ‘smarten’ the operation of heat pumps will become more valuable. Operators of electricity networks in Switzerland and Germany are already controlling the operation of heat pumps to avoid network congestion during hours of peak demand.

What does this mean for the heat pump industry?

Operating heat pumps ‘smartly’ requires:

- **Built-in or retrofitted control and communication capability** – this is standard to all heat pump installations in Switzerland, but not in all markets.
- **Heat storage capacity.** Where there is not enough inertia in the system (ie through underfloor heating or in the thermal fabric of the building), increasing heat storage capacity increases the flexibility in operating time – and therefore controllability – of the heat pumps.

HIGHLIGHTS OF 'SMART' HEAT PUMP ACTIVITY IN GERMANY, DENMARK AND SWITZERLAND

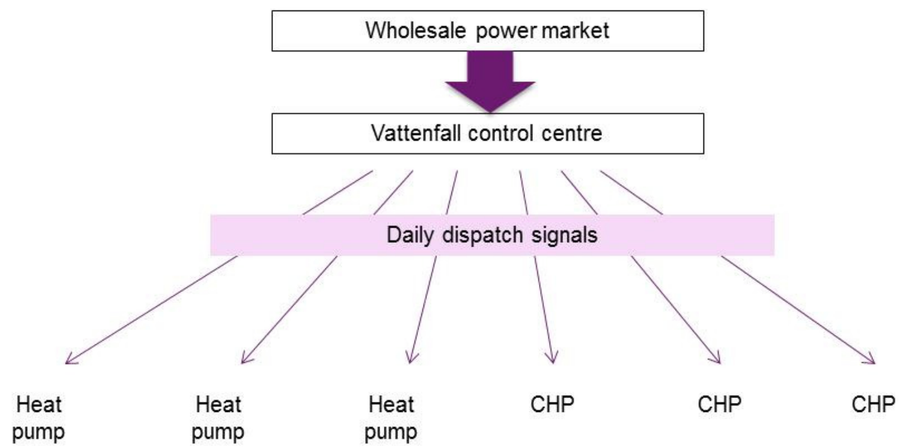
Core Driver:	**Balancing Generation & Demand**	**Balancing Generation & Demand / Reducing Congestion**	**Reducing Congestion**
Case-study:	**Vattenfall Europe – Virtual Power Plant (Germany)**	**Denmark – Smart Heat Pump Pilot Project**	**Switzerland – Heat Pump Tariffs**
Project overview	**A utility-led initiative to influence the operation of heat pumps and CHP units** according to day-ahead power prices. This is driven by the growing volatility on the German power market as a result of rapidly increasing penetration of wind in Germany and surrounding countries.	**A government-backed pilot project to test the use of 'smart' heat pumps** as mechanism to solve Denmark's growing energy challenges - the projected high penetration of wind causing generation / demand imbalances, and congestion in distribution networks.	**On-going tariffs offered by most of Switzerland's network operators,** enable them to control heat pump operating times as a means of reducing bottlenecks in distribution networks.
Key players	- Vattenfall Europe - Stiebel Eltron	- Danish Technological Institute - Danish Energy Agency - Energinet.dk	- Local network operators - Swiss Government - Swiss Heat Pump Association (FAWA)
Project timing	- Commenced in October 2010; large-scale roll-out by 2012.	- Initial data collection in winter 2010/11, with full trial in winter 2011/12. Larger-scale roll-out anticipated beyond 2012.	- Network operators began offering such tariffs in the early 90s.
Project size	- 30 heat pumps / CHP systems, collectively 30 MW. The aim is to expand to reach 500 MW by the end of 2011.	- 300-400 houses to be included in initial trial.	- Around 80% of the 900 network operators offer a tariff, and 50-90% of installed heat pumps in Switzerland are controllable in this way.
Implications	**Vattenfall's costs to run heat pumps can be reduced by influencing when they run.** As wholesale market prices become more volatile, this will substantially increase the heat pump value proposition.	If heat pump operation can be shifted for several hours, **it could have a profound impact in markets with high penetration of inflexible generation**.	Swiss network operators have a **significant controllable resource enabling them to avoid large surges in demand at peak times** – this represents an opportunity in other growing heat pump markets.

Case-study 1: Vattenfall Europe's Virtual Power Plant

Vattenfall Europe, one of Germany's big four utilities, has launched a virtual power plant to control the operation of heat pumps and CHP units according to wholesale market power prices. This is a response to a growing volatility on the German power market, driven by the rapid increase in wind generation in Germany and surrounding countries. This volatility is likely to become even more pronounced in the future. Working initially with heat pumps from Stiebel Eltron, Vattenfall is currently 'controlling' the operation of around 20 small and medium sized (<25 kWth) systems.

VATTENFALL'S VIRTUAL POWER PLANT

This project currently controls the operation of around 20 heat pumps and 10 CHP systems, which collectively serve the equivalent of 6,000 housing units or 30 MW of demand. By the end of 2011, Vattenfall hopes to increase the number of systems to an equivalent of 100,000 housing units or 500 MW of demand.



Delta Energy & Environment, 2011

Features of the Vattenfall Virtual Power Plant are as follows:

- The intelligence behind the virtual power plant is centralised in Vattenfall's control centre - based on day-ahead power prices, this control centre generates dispatch schedules for each heat pump and CHP system.
- Communication & control capability is retrofitted to each heat pump to receive these schedules and respond to them.
- The utility owns each unit, selling the heat to the customer.
- If end user comfort levels are not being met, these dispatch schedules can be overridden by customers.

While initially working with Stiebel Eltron, Vattenfall is open to working with any manufacturer. Ultimately, it would like to see heat pump manufacturers incorporating the control and communication functionality in their units.

Case-study 2: Denmark Smart Heat Pumps trials

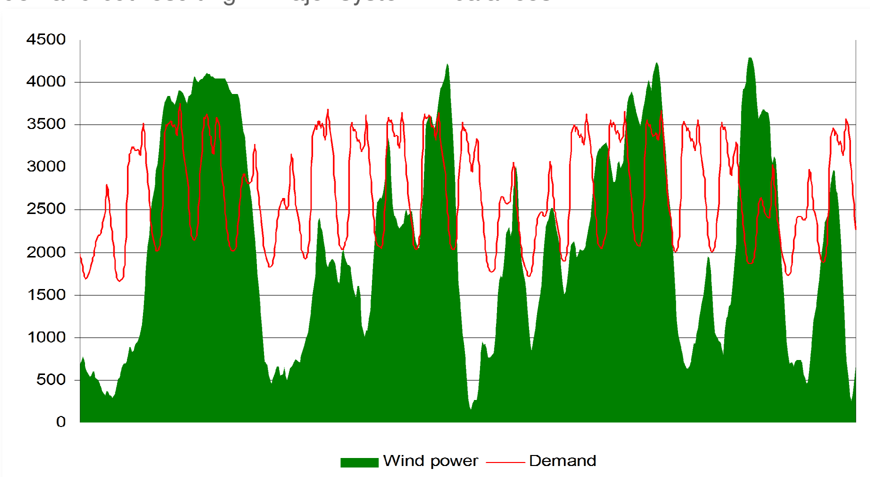
The Danish network operator Energinet.dk has launched a Smart Heat Pumps research project with the Danish Technological Institute and the Danish Energy Agency (a government body). **The project is motivated primarily by the projected mismatch between generation and demand** which will create challenges in Denmark over the next 2 decades as wind penetration increases to over 50% of electricity generation.

Two major challenges are:

- Balancing high levels of inflexible / unpredictable wind generation with demand.
- Avoiding bottlenecks in the distribution system caused by large increases in electricity consumption.

THE DANISH CHALLENGE: GENERATION / DEMAND PROJECTION FOR 2025

Wind capacity is set to grow from 3 GW today to 6 GW by 2025, meeting 50% of Danish electricity demand but resulting in major system imbalances.



Source: Energinet.dk

The Danish Government recognises that smart heat pumps can help deal with these challenges, and is pushing market growth with a boiler replacement incentive. Its target is to secure 10% of the boiler replacement market within the next few years.

The Smart Heat Pumps project is a pilot project, aiming to test the control of heat pumps as a mechanism for shaping demand to meet spiky wind generation. 300-400 homes will be used as trial sites (focusing on retrofit) and ultimately, if successful, the project will be rolled out across Denmark. Participants in the trial will receive 5-10% off their standard electricity tariff. Initial data collection began this winter but the full trial will begin in winter 2011/12.

The primary aim is to assess how the buildings and heating systems can cope with HPs being cycled on and off, and to investigate how long the units can feasibly be shut down in different types of building.

There are two major elements to the research:

- **Developing control systems:** An open-source control box is being developed which can be used with heat pumps from all participating manufacturers, to enable 2-way communication between the heat pump and the network operator. The aim is ultimately to be able to control **more than** 1000 heat pumps together, so acting as a virtual power plant**.**
- **Testing building physics and design**: This part of the project is investigating how far heat pump operation can be shifted, by assessing the thermal properties of different building types (ie for how long can the building fabric store heat), and assessing the impact of the sizes of the heat pump and the buffer/thermal store on the ability to time-shift operation.

Anticipated outcomes & implications

The trial is in its early stages, but the early indications are that the findings will include:

- **Building fabric is key:** A heavy building is likely to be able to store more than double the heat that a light building with a buffer tank and small heat pump can store.

- **Time-shifting should be possible to a few hours** (more than the 2 hour period that is common under tariffs in Switzerland and Germany) – **possibly even as much as a day** depending on the building fabric.

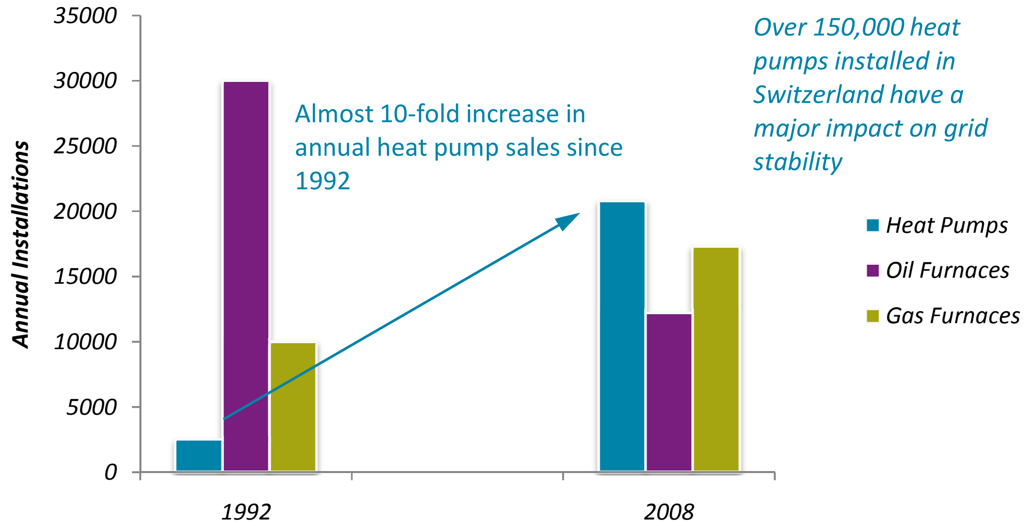
Case-study 3: Swiss heat pump tariffs

In Switzerland, network operators have been controlling heat pumps to avoid congestion in the grid since the early 1990s, an activity which has gone hand-in-hand with the growth of the heat pump market. The heat pump promotion programme (supported by government and led by the Swiss Heat Pump Association, FAWA) began in 1992, and recommendations were made at this early stage that network operators should offer tariffs enabling control of HP operation.

Around 80% of the ~900 local network operators in Switzerland now offer such a heat pump tariff. In return, the customer receives a significantly cheaper electricity rate (20-40% cheaper than the standard rate). **Between 50 and 90% of the total installed heat pumps in Switzerland (ie over 100,000 heat pumps) are now controlled by network operators via such a tariff**. This represents a significant controllable resource – especially given that an additional 400,000 heat pumps could be installed by 2020.

THE SWISS CHALLENGE: THE ELECTRIFICATION OF THE RESIDENTIAL HEATING MARKET 1992-2008

Since the early 1990s, the penetration of heat pumps has transformed the domestic heating market. Heat pumps have grown from a minor player in the early 1990s, to the heating product of choice in the late 2000s. This growth has brought with it the challenge of 000s of heat pumps putting pressure on the distribution grid. Encouraged by the Government, network operators have responded with special tariffs.



Delta Energy & Environment, 2011; data - Swiss Federal Office of Energy, 2009

Features of the Swiss approach include:

- The heat pumps can respond to utility signals, turning off at peak times and running as far as possible at off-peak times.
- Heat pumps are typically switched off for two periods of 1 hour per day (a minimum of 1 hour per day, and a maximum of 3 x 2 hours per day).
- Sophisticated 2-way communication capability is standard to all heat pump control system installations in Switzerland (this is not standard in more emerging markets, where only some heat pumps will be 'smart-ready').
- Heat storage capacity (eg through a buffer tank) is required where there is not enough inertia in the system (inertia may come from underfloor heating or heat storage in the thermal fabric of the building).

Delta's Heat Pump Research

For more information on the Delta Heat Pump Innovation Monitor or Delta's wider heat pump research, please visit www.delta-ee.com or contact Lindsay.Sugden@delta-ee.com, +44 (0)131 625 1006.

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