IEA HPP Annex 42: Heat Pumps in Smart Grids

Review of Smart Ready Products

United Kingdom

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Report compiled by:

Delta Energy & Environment

Contact: Lindsay.Sugden@delta-ee.com

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1. Executive Summary – smart heat pumps in the UK

There are few truly "smart-ready" products on the UK market

- **The most common 'smart' capability built into (or available with) heat pumps in the UK is internet connectivity** – which comes with either remote monitoring – or remote monitoring AND control capability. The latter has greatest 'smart' implications, enabling 3rd party control of heat pumps.
- **Most products commonly sold on the UK market do not have sophisticated communication of control potential.** However, we expect greater levels of activity – particularly on development of communication capabilities – in the coming years.
- **The availability of dynamic tariffs in the UK will unlock greater flexibility potential** – many manufacturers are not yet investing in R&D to develop smart capabilities unless they can see what the benefit to the customer will be.
- **Clearer standards on smart requirements could encourage greater investment from manufacturers in smart** - some manufacturers are building capabilities to the standards set for individual smart projects, but overall a lack of standardisation on what utility requirements will be is resulting in manufacturers delaying R&D investment.

There is only one active demonstration project in the UK which will control the operating times of heat pumps – but more in the pipeline

- **The Customer Led Network Revolution (CLNR) project involves 16 heat pumps** being controlled in response to utility signals.
- **Two major upcoming projects from NEDO and ETI both have ambitious plans for the involvement of heat pumps**. Demonstration results unlikely before 2016, but will be testing e.g. direct control of heat pumps, influence through price signals, business models and aggregation concepts for the use of heat pumps as tradable flexible loads.

There are two critical factors influencing the level of flexibility which may be gained for the utility, and the benefits to the customer of smart heat pumps – both of these require further research to explore their impact in the UK.

- **The exact structure of the dynamic tariffs in the UK will be important in influencing the potential savings – and flexibility potential**. Initial experiences from smart trials and simulations across Europe indicate that very simple (e.g. 2-rate) tariffs are unlikely to give much flexibility, whilst more dynamic tariffs will both unlock most flexibility and enable greatest customer savings.
- **The amount of flexibility gained for the utility is hugely dependent on how much temperature variation an end-user is willing to accept** - there is still relatively little knowledge of this. The experience from Sweden will be valuable learning for the UK.

As the market moves closer towards a standard smart home set-up, required capabilities for heat pumps to integrate into this will become clearer.

- **Heat pumps will need to interface with smart meters** to unlock value for customers or utilities from their flexibility
- **Internet connectivity likely** (through not certain) to be the communication protocol of choice in a UK smart home
- There is **growing engagement with Home Energy Management Systems** as a possible interface between the heat pump and the utility – potentially reducing the 'intelligence' which needs to be built into the heat pumps.

2. List of smart projects in the UK

2.1. Customer Led Network Revolution (CLNR)

Background & funding

CLNR is one of a suite of projects funded through Ofgem's Low Carbon Network Fund – receiving £54 million.

Aims

The overall aim is to test the network impacts and customer response to the application of a "smart distribution grid". Specific aims include:

- Testing the impact of new technologies on the grid: Electric Vehicles(EVs) solar PV, heat pumps
- Testing consumer behaviour and how far it is possible to shift or manage loads (focus on peak period between 4pm and 8pm)

Key participants

- Energy Retailer – British Gas
- Distribution Network Operator – Northern Powergrid

Scope & timeline

CLNR covers 14,000 homes & businesses in the North East and Yorkshire (rural homes + cities of Durham, Leeds, Newcastle & Sheffield). **450 heat pumps are included – though 16 (from Neura) being 'controlled' smartly.** The rest of the heat pumps are being monitored and tested with Time of Use tariffs).

The project has run since 2011 and the smart control of heat pumps is being investigated between now and the project close (late 2014).

2.2. Low Carbon London

Background & funding

Low Carbon London is another Low Carbon Network Fund Project – funded £21.7 million from the fund, topped up to ~£28 by industry partners.

Aims

The overall aim is to test the network impact of distributed generation on the distribution grid. Specific aims include:

- Testing the technical and commercial innovation required to facilitate the integration of low carbon technologies into urban and suburban networks

- Trialling dynamic Time of Use tariffs to assess potential flexibility from residential customers

Key participants

- Network Operators: Nationalgrid (TSO), UK Power Networks (DNO)
- Energy Retailer: EDF Energy

Scope & timeline

The project covers the London area and has so far involved the installation of 6,000 smart meters, alongside PV, Electric Vehicles and Heat Pumps. **The heat pump part is very small however – only three heat pumps are in the trial and they are only being monitored, not controlled.**

The project runs until 2014 – with any results from the HP monitoring (particularly in regards to response to ToU tariffs) being published late in 2014.

2.3. Energy Technologies Institute (ETI) Smart Systems & Heat

Background & funding

The **ETI is a public-private partnership** between global energy and engineering firms who invest in large-scale modelling and demonstration projects addressing ways to overcome the UK's energy system challenges and meet targets. The ETI "Smart Systems and Heat" Programme is such a modelling and demonstration project, allocated a budget of £100 million over 5 years. It was set up based on the recognition that domestic heating accounts for ~20% of UK CO_2 emissions – and that, through electric heating and heat networks, there is a strong interplay between heat and the wider energy system.

Aims

The Programme aims to **design & test innovative smart energy and heat systems which will enable the delivery of efficient heat and comfort, meeting local needs across the UK, whilst minimising CO_2 emissions**. Specific aims include:

- Understanding **consumer behaviour & requirements**
- Testing **energy services offerings & business models**
- Testing **implementation of required infrastructure for smart heat**

Participants include

- ETI
- EDF Energy
- Hitachi
- Academia – UCL, Imperial

Scope & timeline

Modelling will seek to understand the future evolution of the whole energy system to 2050, including buildings retrofits and energy distribution system choices. The programme has a **strong focus on space and water heating**, and on the **domestic retrofit market**.

- **Phase 1 (2012-2014):** Design & develop software tools for local 'smart energy systems' (working with Local Authorities)
- **Phase 2 (2014-2016):** Develop large-scale demonstration projects of these 'smart energy systems'
- **Phase 3 (2016-):** Commercialisation (post-ETI project)

2.4. New Energy Development Organization (NEDO): Smart Community Project, Greater Manchester & Wigan

Background & funding

The project is spearheaded by NEDO (an organisation funded by Japan's Ministry of Economy, Trade and Industry), and led by Hitachi.

Aims

It aims to **develop and demonstrate energy load-balancing through controlling the operating times of residential heat pumps**, and to **develop business models to aggregate and trade the flexible load on the electricity markets**.

Specific aims:

- Testing the **automated control of 200-300 heat pumps** (replacing gas boilers) in various building types, for load-management purposes
- Testing **mechanisms for aggregation** of hundreds of residential heat pump loads
- Testing **consumer pricing mechanisms** and associated customer service offerings.
- Developing **new business models for trading aggregated residential heating loads** on the power markets.

Key participants

- NEDO
- Hitachi (ICT)
- Daikin (Heat Pumps)
- Mizuho Corporate Bank & Mizuho Information & Research Institute

Scope & timeline

The project will cover the areas of Greater Manchester and Wigan, with an aim to include 200-300 homes with retrofitted heat pumps. The main focus is on ways to shift space heating demand. Time-line is as follows:

- Feasibility study: 2013
- Demonstration project: until ~2016

3. Analysis of smart-ready products

3.1. Criteria for 'Smart-Ready': Analysis of Full Range of "Smart" Capabilities

We assess ways in which a heat pump can be "smart", through analysis of several layers of functionality which could be defined as smart-ready. We will give an indication for each criterion, of its importance for peak shifting.

The characteristics of a 'smart' heat pump required by a utility versus an end-user are potentially conflicting

Ultimately, 'smart' operation of HPs, where the HP is switched off for periods of time, is may not beneficial to heat pump efficiency. The criteria for "smart" heat pumps have to be addressed, taking into account the relative importance of the utility requirements for peak shifting, and the customer requirements for comfort. The 'smartest' heat pumps could be seen as those which maximise flexibility for the utility to peak shift – while minimising the impact on the end user.

FIGURE 1: CHARACTERISTICS OF SMART OPERATION OF HEAT PUMP REQUIRED BY CUSTOMER VERSUS UTILITY

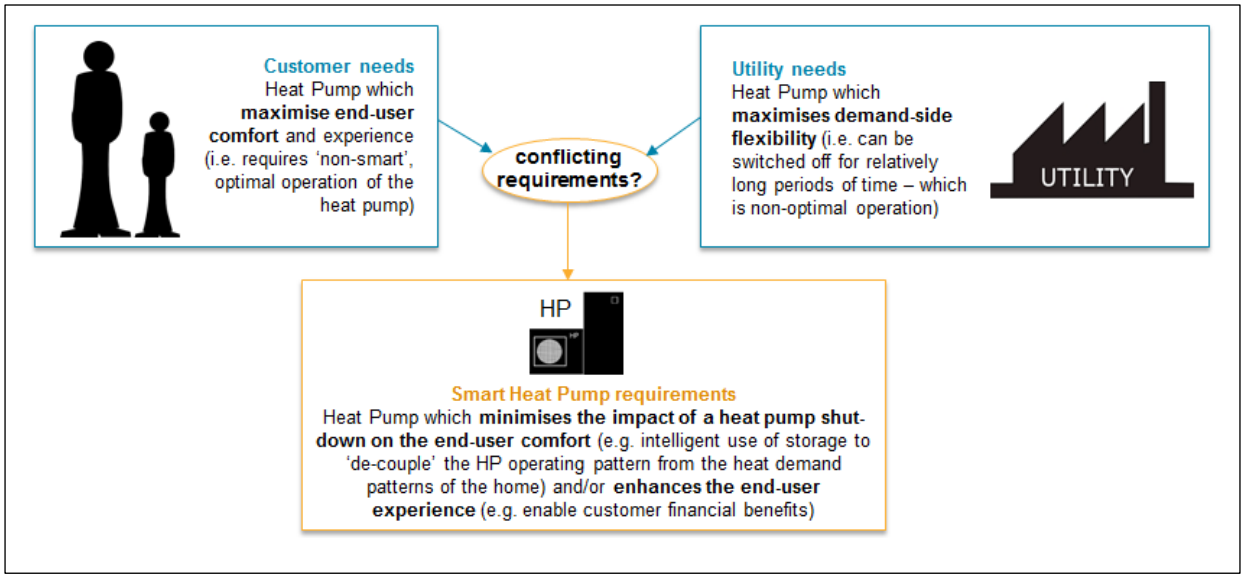


TABLE 1: ASSESSING CHARACTERISTICS OF 'SMART-READY' HEAT PUMPS

We assess different layers of functionality which could be considered 'smart', comparing the importance of the criteria to the utility for peak shifting, and the importance to the end user in maintaining comfort or providing additional benefits. We group the criteria into 9 themes:
1/ Heat pump functionality, **2 /** Connectivity, **3** / Communication capabilities, **4 /** Control Strategies, **5 /** Thermal storage, **6 /** Integration with 2nd energy source

Criteria		Importance for peak shifting	Impact on end-user experience	Maturity	Future evolution
1/Basic heat pump functionality	Inverter-driven / modulating compressor which can ramp down rather than switch off	High – maximum flexibility	Positive – modulating down rather than complete shut-down will have less impact on temperature in building – lower end-user impact	Many products available (mainly Asian) – but few which can utilise modulation in response to smart signal - at demonstration stage	HP market moving away from fixed speed. Modulation in response to smart/ dynamic signals likely to become standard
	On/off	Medium – still has value, less flexible than the above	Negative – a HP being shut down often is not at optimal efficiency - increasing electricity bills	Standard HP functionality	Few products will only have on/off capability in the future – most who do not have it today will develop it or access it via partnerships
2/ Connectivity	Internet-connected – remote monitoring capability	Low – remote monitoring does not create flexibility	Positive – enhances user experience & builds confidence if they can see how the HP is working, be alerted when there is a problem etc	Many manufacturers already offer this (either built-in or as an 'add-on' to enhance end-user & installer experience	Will be standard
	Internet-connected – remote control capability	High – remote control capability critical	Positive – ability to control HP when away from home via mobile enhances experience	Capability being added as standard by some HP manufacturers (especially in the Nordics)	Likely to be standard capability – but aimed at installers / end-users rather than utility

Criteria		Importance for peak shifting	Impact on end-user experience	Maturity	Future evolution
	Connectivity enabling remote control through another communication protocol	Medium / high – remote control capability will be critical (though likely to be internet based)	Positive – if the end user has access to HP via the chosen protocol. Internet-based protocol more likely to easily integrate in the home	Many different protocols been tested with HPs e.g. radio-based, GSM (mobile). Some within retrofitted control/ communication systems, others built-in	Connectivity will be standard – signs point towards internet-based being preferred route, but there may not be a single protocol – depends on standardisation
3a / Communication capability	1-way communication (can receive external steer signal but does not communicate back)	Medium – allows utility signals to be sent, calculation of flexibility achieved based on statistical estimate (this approach taken by e.g. SSE in UK electric heating)	Minimal impact	Many can do this – standard for HPs in e.g. Germany, Switzerland, who are on the HP tariff, but not standard for all HPs in UK	All HPs will have to have at least this capability if they are to be able to automatically respond to any kind of external steer signals ("steer" could be price signals or direct control)
	2-way communication (can receive steer signal + can communicate externally the current & historic status)	High – Communication of sufficient parameters enables the control system to 'learn' the response of the building/tank/HP – which allows estimation to be made of future flexibility potential.	Positive – if it gives customers visibility of a small number of parameters via e.g. an app	Many HPs can communicate simple info (i.e. <5 parameters to be used in smart phone app offered by several manufacturers) but few can communicate detailed information (i.e. >20 parameters which are used to define control algorithms)	Will become a standard for more advanced smart-ready heat pumps – built in (not retrofitted). The Nordics (especially Sweden) furthest ahead, with both HP and HEMS products already emerging to respond to dynamic price signals.

Criteria		Importance for peak shifting	Impact on end-user experience	Maturity	Future evolution
	2-way communication (can receive steer signal + can communicate how much flexibility is available – forward looking)	High – provides realistic data allowing aggregator / utility controller to calculate how much flexibility it has available across its assets & design control algorithms accordingly	Positive – if it gives customers visibility of parameters via e.g. an app – but the communication of future 'flexibility' does not enhance the user experience	Few HP on market can communicate flexibility – mostly R&D & demo stage, usually with retrofitted control box (though some now working with specific manufacturers to build in capabilities).	Likely to become more common (built-in, not retrofitted) but ultimately this level of intelligence may not be required within the HP – flexibility could be calculated externally via e.g. VPP controller (e.g. powermatcher software, or Homa product), or an in-house device such as HEM / home hub
3b / Communication - speed of response to utility signal	Needs advanced notice (~24 hours)	Medium – enables control of HPs in response to more predictable grid challenges	Minimal impact (though with advanced warning of a shut-down period, the HP can ensure it has enough storage to minimise end-user impact	Basic capability fairly standard in heat pumps – but few HPs with built in capability to respond to utility signal.	Will be minimum capability of heat pumps to respond to utility signals
	Can respond within <1 hour - minutes	High – fast response of HPs to utility signal enables more dynamic response & so increases flexibility (also enables utilities wishing to trade flexible capacity to play in higher value power markets)	Minimal impact on end-user unless the fast response time also enables fast response to price signals.	HPs with e.g. remote control capability can already respond very fast to signals – but regarding utility signals, this is at demonstration project stage (often with retrofitted communication equipment)	HPs will have to have built in capability to respond to utility signals – but response within minutes may not be necessary for all HPs. Ultimately this gives the HP less time to prepare for shut-down.

Criteria		Importance for peak shifting	Impact on end-user experience	Maturity	Future evolution
4a / Control strategies: response to internal building environment	'Learning' building thermal response (through monitoring of past behaviour)	Medium	Positive – supports efficient operation of the HP according to individual household characteristics	Handful of advanced systems can do this already (e.g. Neura, NIBE), some have learning capabilities for some functions (e.g. Daikin for hot water), many at R&D stage.	Will become increasingly critical – not just for smart but for end-user comfort, likely to become standard. Majority of HP manufacturers already working on some form of this.
	Algorithms to pre-heat the home / storage / heating circuit	Potentially high – extends length of switch off (though needs advanced warning)	Potentially positive – means the HP could be shut down for a longer period with less impact on the end-user – but uncertainties how end-users will respond to over-heating before shut-down	Some already testing this with storage tanks (e.g. Neura in CLNR project) - others developing advanced algorithms to make use of building thermal mass and heating circuit – modelling stage.	Several years before function will be commercial where making use of building mass. Could provide valuable additional flexibility but could be internal comfort issues.
4b / Control strategies: outside environment	Weather compensation & variable capacity	Low – does not provide flexibility	High – optimises performance in real time depending on outside temperature – enhances efficiency	Standard in most new HPs today	No fundamental changes from today
	Responding to weather forecast data	Medium – does not directly increase flexibility but could enhance HP energy market link e.g. weather forecast data including wind data could indicate expected wholesale electricity price => indicate the need for flexibility.	Positive – access to e.g. day-ahead forecasting means heat pump can prepare itself for more efficient operation – e.g. filling the tank in advance of a cold spell.	Demonstration project stage e.g. trials to be run in Denmark, some manufacturers (e.g. Neura) already claiming the capability to accept & respond to weather forecast data.	Some manufacturers likely to offer functionality depending on outcomes of demonstration and testing

Criteria		Importance for peak shifting	Impact on end-user experience	Maturity	Future evolution
4c / Control strategies: energy price	Responding to pre-set price signals (e.g. high peak price)	Medium – mechanism to respond to predictable grid congestion	Positive – can be connected to low rate HP tariff	Available from many manufacturers to varying degrees (at more advanced level see for e.g. hybrid control strategies of Daikin, Vaillant, Viessmann; or manual pre-set options functions to block hot water production in advance from e.g. Danfoss)	Ability to respond to price signals will be critical – ultimately will make leap to dynamic not pre-set signals
	Responding to dynamic (e.g. hourly) price signals	High: A mechanism to respond to unpredictable and dynamic grid volatility e.g. from wind generation	Positive – key to providing end-user savings?	Handful of manufacturers have developed control strategies (at a simple level) - little market application yet (no activity in UK)	Will emerge in each market when dynamic tariffs become a possibility – control strategies likely to become more advanced
5 / Thermal Storage	Control strategies to intelligently integrate HP with storage	High – strategies can be designed to maximise storage volume and therefore maximise flexibility	High – intelligent integration with storage (e.g. using stratification) can minimise the impact of producing large volumes of hot water on the HP efficiency.	Very little real intelligent integration between HP & storage – key barrier is lack of thermal sensors in standard tanks. Being retrofitted / built-in for demonstration projects.	Will become increasingly critical – not just for smart but for end-user comfort, likely to become standard

Criteria		Importance for peak shifting	Impact on end-user experience	Maturity	Future evolution
	Use of conventional heat storage (water tanks)	High – creates flexibility	Positive – can reduce frequent cycling – increasing efficiency. BUT if very large thermal store is installed to maximise flexibility for utility, physical footprint in the home a potential problem and potential for higher bills from large tank losses.	Common-place/standard to use water storage tanks – most manufacturers buy "off-the-shelf" products but some (e.g. NIBE, Dimplex) manufacturer their own (gives an advantage where they can build-in sufficient sensors)	Challenge of physical fit of storage tanks (particularly in UK) will create a demand for alternative storage / flexibility options. Advancements to tanks to build in e.g. more sensors for better control / integration with HP likely (sensors often retrofitted in current smart projects e.g. Linear, Belgium)
	Advanced heat storage technologies e.g. phase-change materials	High – if advanced technologies mean thermal storage provides flexibility with smaller physical footprint, or lower cost, v high value	Positive – if advanced technologies can be more easily / less intrusively integrated in buildings	Demonstrations / lab tests	Advances in R&D and testing likely over the next 5 years but few commercial solutions likely to emerge in short-term. HP manufacturers not driving this.
6 / Integration with 2nd energy source	Bivalent system with set-point control to switch from HP to other source	Low – could provide flexibility but without way to control based on external signals, flexibility cannot be accessed	Positive – some energy cost savings may be achieved by not running HP at coldest times	Available from many HPs on the market – most major manufacturers offer a common control system through which multiple systems can be controlled.	Likely to become standard for HP work in conjunction with second heat source such as boiler – market may move to more 'intelligent' hybrid operation

Criteria		Importance for peak shifting	Impact on end-user experience	Maturity	Future evolution
	Hybrid which switch between heat sources according to pre-set price signals (or CO_2 grid signals)	Medium – creates flexibility by switching away from electricity at pre-determined, predictable peak times	Positive – potential for energy cost savings by switching between gas/other fuel and electricity depending on relative prices	Hybrids available from most major boiler brands in Europe, and with increasing interest from HP players – mostly with control strategy defined by pre-set price/CO2 signals	Likely to remain an important market with new players (especially pure heat pump players) entering the market. Potential for 'smart' driving utility interest.
	Sophisticated control hybrid which can switch between sources in response to dynamic tariffs	High – creates flexibility by switching between electricity and gas/other fuel in response to dynamic signals from utility	Positive – once variable tariffs are available, a more dynamic response from the hybrid could maximise energy savings.	Hybrids being sold today do not have capabilities to respond to dynamic tariffs	The next generation of hybrids likely to have this capability built in – once dynamic tariffs are rolled out

3.2. Defining Required Capabilities for Smart-Ready Heat Pump Systems

We consider the most important elements of being "smart-ready" (for the purpose of this annex) as follows:

1. **Connectivity** – internet-based likely to become dominant.
2. **Communication to and from the HP** - ability to measure detailed information on current status and ability to communicate this externally, and the ability to accept and automatically respond to dynamic steering signals[1].
3. **Control** – sophistication of algorithms to translate communicated data into optimal heat pump performance.

Based on the above three core elements, we have identified in Figure 2, a possible framework upon which to base the analysis of smart ready products.

TABLE 2: THREE LEVELS OF SMART READY HEAT PUMP.
In the Table below we describe what each identified "Level" can potentially achieve – and what market characteristics are required to support this.

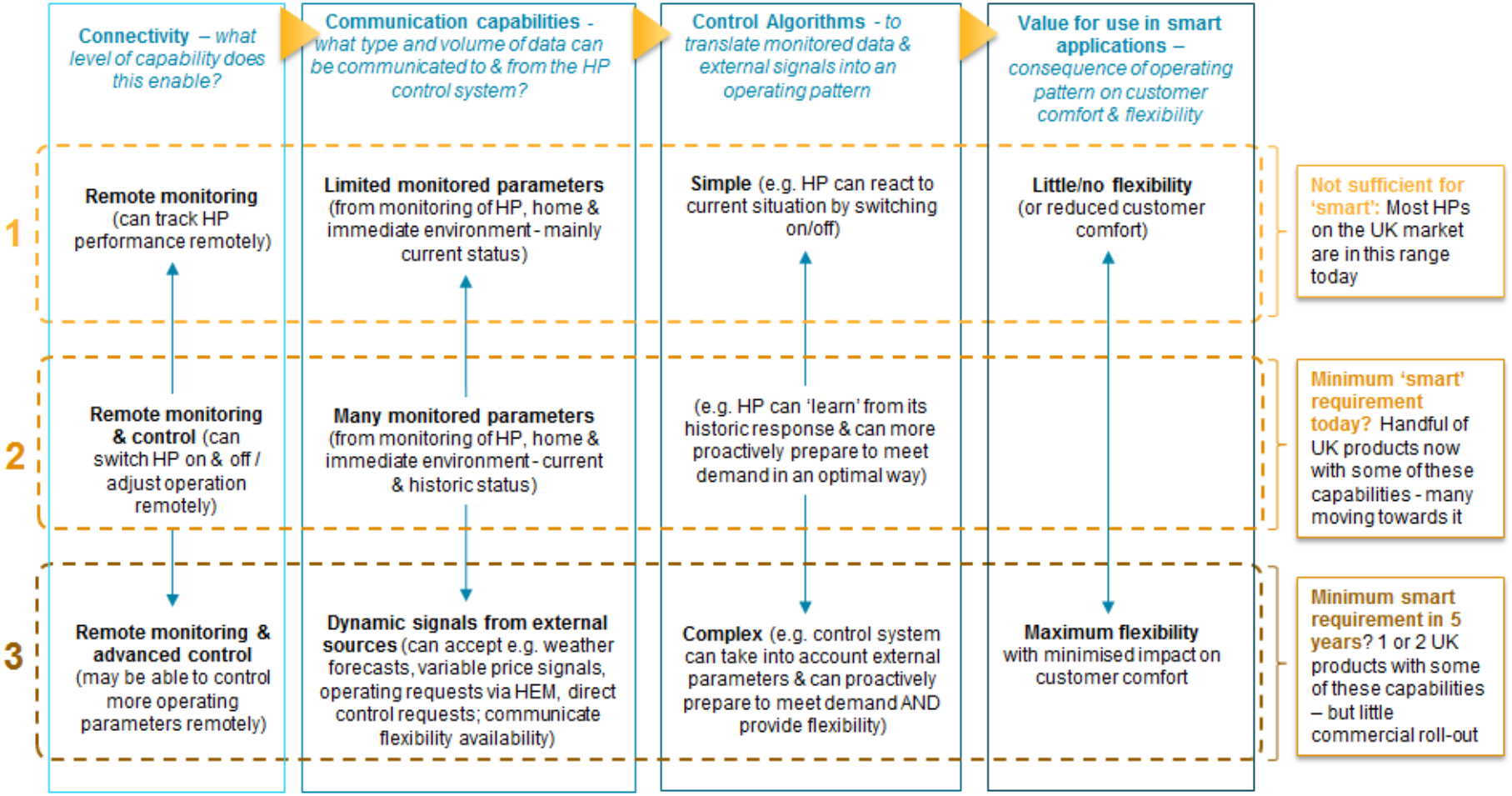
Smart Ready Level:	What type of steering does this Level of Smart Ready HP enable?	Market characteristics which are required / desired to capture the benefits of this Level of Smart Ready HP
Level 1	*Does not enable smart operation of heat pumps:* The heat pump cannot be remotely controlled, which is a minimum requirement for response to any steer signal.	▶ No specific market characteristics
Level 2	*Allows for simple remote steering in response to e.g. pre-determined / predictable signals to avoid peak periods.* Enough intelligence in the control algorithms to automatically adjust operation to maintain end-user comfort.	▶ Smart meter roll-out – enabling communication infrastructure ▶ Availability of 'static' Time of Use tariffs (i.e. pre-set blocks of time at different rates) – allows customers to access value
Level 3	*Allows for dynamic steering in response to e.g. flexible tariffs / unpredictable grid volatility* (HP could receive direct signals or communicate via e.g. HEMS or other in-home devices). Can pro-actively maximise flexibility while minimising end-user impact.	▶ Smart meter roll-out – enabling communication infrastructure ▶ Availability of 'dynamic' Time of Use tariffs (e.g. hourly pricing linked to energy markets) - allows customers to access value ▶ Regulatory structures in place to enable utilities & other electricity players (e.g. independent aggregators) to access value from Demand Response[2] e.g. through balancing services, capacity markets, energy markets

[1] By 'dynamic' steer we mean anything which could require a shut-down at unpredictable times i.e. flexible tariffs or direct utility control signals. We do not need dynamic today if we are only dealing with predictable requirements e.g. evening peaks.

[2] There are multiple potential sources of value for electricity market players – many of which are dependent on changes to regulatory structures before they will drive a strong market. For example, aggregators are already capturing value from the use of electric heating for balancing services in e.g. France and Germany. Electricity retailers can shift the purchase times of electricity to lower cost times, but there are regulatory barriers in e.g. Germany. Capacity markets do not exist yet in most markets but could offer a value to HPs for existing as an available flexible resource.

FIGURE 2: POSSIBLE FRAMEWORK FOR ANALYSIS OF SMART HEAT PUMP CAPABILITIES

We suggest three levels of smart-ready capabilities – each level reflects a relative "value for use in smart applications", determined by the extent to which the capability (1) enables flexibility for the utility/3rd part controller and (2) is designed to minimise impact on the end-user or give additional benefits. [note that products in the market do not necessarily fall fully into one single Level but may have elements if different levels].



We also identify additional capabilities which could be advantageous in smart applications (which we consider in the manufacturer analysis in 3.4):

- *Hybrid system – intelligent integration with 2nd energy source:* This could increase potential demand-side flexibility by enabling longer heat pump switch-off periods with minimal impact on end-user comfort
- *Ability to modulate heat pump output:* Modulating capacity downwards provides an alternative to full shut-down, to increases potential flexibility.
- *Ability to interface with Home Energy Management Systems (HEMS):* In the long-term, interfacing with HEMS could be critical to HPs being integrated into smart, connected homes (see 3.3).

3.3. UK Smart Home Landscape – impact on heat pumps

The UK Smart Home Landscape: Smart Meters & the Smart Home Set-Up

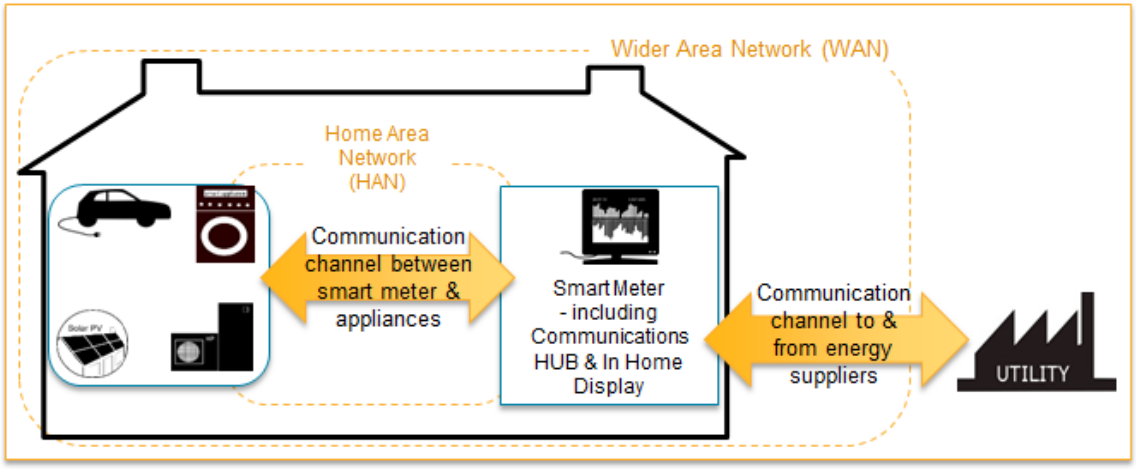
All UK homes should have a smart meter by 2020

A supplier-led smart meter roll out is due commence in 2015, to be complete by 2020 across 53 million UK homes & businesses. **Smart meters will likely be necessary for households to access flexible tariffs** (when they come in – industry insiders predict flexible tariffs will be available within 5 years in the UK) - which **is a core way through which smart heat pumps can bring value to the end-user**. This combination of smart meters & flexible tariffs being tested in the *Customer Led Network Revolution & Low Carbon London* projects currently on-going in the UK.

The UK is focusing on **wireless connectivity as the likely communication mechanism within the 'Home Energy Network'**, which will be the interface between smart meters and home appliances such as heat pumps. There are not yet clear standards for the required heat pump capabilities to enable communication with the smart meter & other smart home devices – but **there is already an indication that internet connectivity will be advantageous**.

FIGURE 3: POSSIBLE SET UP OF A UK SMART HOME

This is a possible set-up of a smart home, as currently envisioned by the UK government. It suggests a series of communication channels between different points in the Home Area Network – which is essentially the interface between smart meters and heat pumps (+other appliances). The smart meter would receive the flexible tariff data if/when available. The communication mechanisms, and the physical devices which connect the smart meter to devices is not yet clear.



The UK Smart Home Landscape: Home Energy Management Systems

Growing interest in HEMS – but the UK still in the slow lane

Home Energy Management Systems could be an important interface between heat pumps, the smart home and flexible external steer signals – **allowing heat pumps to be operated as one of a suite of electric devices in a home which could be used for load management.** Further, in some smart homes scenarios, **the main 'intelligence' which determines & optimises operating patterns of home appliances including heat pumps could be within the HEMS rather than within the heat pump** – minimising the HP's required level of intelligence.

The capabilities of UK heating controls are relatively poor relative to many other European countries – meaning heating is not used in the most optimal way. There is growing interest in developing more advanced controls – moving towards HEM type systems – although the market is still embryonic. We see three levels of activity in the UK – only one of which is already commercial:

1. **Advanced heating controls – enabling control but not system optimisation – most UK activity focused here:** Available offerings in the UK from e.g. Honeywell, British Gas, Climote. Customer-friendly interfaces and smart phone Apps enabling remote monitoring and control of customer heating systems. Similar functionality to many remote control / monitoring offerings from heat pump suppliers.
2. **HEM for heating - advanced heating controls including system optimisation – embryonic market with limited number of products:** e.g. UK-based PassivSystems one of the most advanced offerings in the UK, incorporating much of the functionality of the above category 1, but with more intelligence, aiming to optimise the system efficiency. PassivSystems is now working on a solution specifically to work with heat pumps.
3. **Wider HEMS for optimising whole home energy consumption – very few / no products in the UK**: Currently very little, if anything, available in the UK with such capabilities, though there is a lot of interest in the topic. The UK lags behind the Nordics, Germany and France in developments of such products / offerings.

What does the UK smart home landscape mean for heat pumps?

- **Heat pumps will need to interface with smart meters** to unlock value for customers or utilities from their flexibility
- **Internet connectivity likely (through not certain) to be the communication protocol of choice** in a UK smart home
- There is **growing engagement with Home Energy Management Systems** as a possible interface between the heat pump and the utility

3.4. Review of Existing Products in the UK which Meet these Smart-Ready Criteria.

Based on the three level framework discussed in 3.2 above, we compare products on the market according to the key differentiators: connectivity, communication and control. We focus on some of the most important products which are available in the UK (or will be soon).

TABLE 3: EXAMPLES OF SMART CAPABILITIES OF SELECTION OF HEAT PUMP PRODUCTS
The companies listed below are selected to give an overview of the range of smart capabilities available (or soon to be available) on the UK market. We present here examples of companies with offerings focusing around connectivity, communication and control.

Company	Main 'smart' capabilities
Neura	Can respond to direct utility steer signals - deep involvement in UK's main smart heat pump trial
NIBE	Can respond to dynamic price signals - but awaiting such tariffs in the UK before potential can be unlocked
Dimplex	2-way communication integrated into latest electric heater – but could be 5 years away for heat pumps available in the UK
Danfoss	Remote control & monitoring capability, possibility to interface with HEM, but no automated smart capability yet
Ochsner	Can respond to dynamic steer signals (but awaiting dynamic tariffs in UK) – and intelligent integration with PV
Daikin	No smart capabilities yet – but long-term potential with hybrid system with the availability of dynamic tariffs
Panasonic	Can modulate heat pump output in response to steer signals and customer comfort requirements, without the necessity for a storage/buffer tank.
Stiebel Eltron	Heat Pump remote control capabilities & electric water heaters which allow users to take advantage of off-peak electricity tariffs

Besides the offerings from the manufacturers below, several others have some smart capabilities. For example:

- **Remote monitoring / control / connectivity** e.g. Mitsubishi's "MELCloud", several companies using "intesisHome", smart phone Apps from De Dietriche, Alpha Innotec & Heliotherm, remote monitoring for fault detection from IVT/Bosch, CTC Enertech, GreenTerra AG remote control via Siemens rvs61.
- **Response to dynamic tariffs** - IVT / Bosch smart HP offering (developed for Sweden)
- **Intelligent integration with PV** – e.g. Viessmann
- **Hybrid system with intelligent integration of HP & boiler** – many products from e.g. Viessmann, Ariston, Bosch, Vaillant. The 'series' (rather than 'parallel') operation of Daikin's unit may indicate more advanced control algorithms.

TABLE 4: MANUFACTURER PROFILE - NIBE

NIBE	Can respond to dynamic price signals - but awaiting such tariffs in the UK before potential can be unlocked
'Smart' USP + key product(s)	**In-built internet connectivity in all new HPs, + ability to respond to dynamic tariffs** ▶ **Connectivity**: Internet connection built in as standard – remote monitoring and control is available via "NIBE Uplink" (available in UK). ▶ **Communication**: NIBE's core focus is on enabling steering via price signals – their heat pumps can accept and respond to dynamic prices (currently offered in Sweden because hourly prices are available there – could come to the UK quickly if & when dynamic tariffs come in). ▶ **Control**: Control algorithms strongly focused on maintaining end-user comfort, whilst enabling end-users to make financial savings through dynamic tariffs. Testing in Sweden indicates customer savings in the range 5-10% could be realistic – and potentially higher – though there are many factors influencing this and it is too early to draw clear conclusions.
Implications for peak shifting in the UK	**Flexibility**: The technological capabilities are in place for NIBE heat pumps to respond to price-based steer signals to avoid peaks. But the value of NIBE's offering for peak shaving depends on the availability of – and structure of - dynamic tariffs in the UK. The fact that the heat pumps are not designed to communicate 'available flexibility' to the utility, means that the utility may have less certainty as to how much flexibility it will get from a price signal. However, this is also potentially a lower cost and simpler way to create flexible demand. **End-user comfort / benefits**: The approach taken by NIBE to focus on the customer rather than the utility means that the impact of steering heat pumps on the customer comfort will be minimised. The potential customer savings achieved in the UK with dynamic tariffs are dependent on the structure of the tariffs and individual customer requirements for comfort. However, savings have the potential to be higher in the UK than in e.g. Sweden, because electricity price volatility is likely to be higher (Sweden's large proportion of hydro power smooths peaks).
Activities/presence in Europe	NIBE's core market is Sweden, so technology development has been driven by the market requirements there (where hourly pricing is already possible from utilities).
Activities/presence in UK	Amongst the top 5 heat pump players in the UK – remote monitoring and control available here, but awaiting dynamic tariffs before smart capability can be unlocked.

TABLE 5: MANUFACTURER PROFILE - NEURA

Neura	Can respond to direct utility steer signals - deep involvement in UK's main smart heat pump trial
'Smart' USP + key product(s)	**Built-in capability to respond to direct utility signals** • **Connectivity**: Built-in internet connectivity (UPNP router configuration which means in-coming connections are automatically allowed) • **Communication**: The USP of Neura is primarily in its communication capability– the system is based on a LINUX-driven system, which is easy to adapt and integrate into smart grid projects. It can receive & respond to direct utility requests for flexibility (could also respond to dynamic price signals), and can communicate available flexibility back, including for a 24 hour forward period. It is also possible to communicate once flexibility has been provided. It could potentially accept weather forecast data if this was available. • **Control**: Control algorithms determine operating patterns by 'learning' maximum charging time & maximum shut-down time based on the previous 24 hrs (constantly monitored & adapted every <2 minutes).
Implications for peak shifting in the UK	**Flexibility:** Neura's ability to accept utility requests and communicate back available flexibility, means that the utility can accurately calculate the total flexibility it has available, and plan how to shift the operating times across its asset base in order to avoid peaks. **End-user comfort / benefits**: Neura's approach focuses primarily on meeting utility needs – though the customer should not be affected. The application of Neura heat pumps in the CLNR project will provide some valuable first insight into how customers will respond. Unless customers are on dynamic tariffs, any additional (financial) benefit to the customer would depend on the utility sharing captured value with them.
Activities/presence in Europe	Neura is a relatively new Austrian manufacturer who has been working on 'smart-ready' heat pumps as its USP since at least five years ago. It is a small player in the European market.
Activities/presence in UK	A minor player in the UK heat pump market, but strong involvement in the Customer-Lead Network Revolution in the north of England, where Neura have the only heat pumps which are being controlled.

TABLE 6: MANUFACTURER PROFILE - DIMPLEX

Dimplex	2-way communication integrated into latest electric heater – but could be 5 years away for heat pumps available in the UK
'Smart' USP + key product(s)	**Quantum heater (not heat pump) is designed to be used with existing UK off-peak tariffs – and can accept direct utility steer.** This capability is not currently built into heat pumps, but there is potential for some of this capability to be integrated once a strong enough market requirement is recognised. ▸ **Connectivity**: The Quantum heater has built-in connectivity. *Remote control and monitoring of Dimplex heat pumps is also already possible – currently GSM based but likely to move towards internet based (this is the extent of Dimplex's 'smart' heat pump capability).* ▸ **Communication**: The Quantum hub enables 2-way communication between Quantum heaters and the utility – Quantum can receive utility signals and communicate available flexibility. Focus is on response to price signals – currently simple off-peak tariffs as are available in the UK (response to dynamic tariffs could be added "rapidly" when the market requires it according to Dimplex UK). *2-way communication not yet possible with heat pumps.* ▸ **Control**: The focus is on maintaining customer comfort through automated dynamic response to its immediate environment (via learning function) as well as maximising customer savings through response to basic 2-rate tariffs. *The control functionality in Dimplex heat pumps is comparable.* *The smart capabilities of the Quantum heater (largely around communication) cannot yet be integrated with Dimplex heat pumps. Dimplex UK (HP product manager) estimates "this is at least 5 years away" – but the time-lag determined by market need rather than technological barriers.*
Implications for peak shifting in the UK	**Flexibility for the utility:** The communication capabilities of the Quantum heater are designed to make it easy for utilities to shift electricity demand away from peak periods. The Quantum is one of the best options for utilities to gain demand side flexibility in the current UK market through the existing (limited) flexible tariffs. If they run – as claimed – 90% of the time on the off-peak rate, then they are making significant in-roads to avoiding peak time. The flexibility offered here deals with predictable demand peaks – but the system offers long-term term potential to respond to more sophisticated steering (through dynamic tariffs or direct control). *Learning experience of the use of the Quantum for flexibility in the UK will be valuable for understanding how heat pumps could be used.* **End-user comfort / benefits**: Dimplex claim that the Quantum heater can save customers as much as 27% in running costs compared to a 'static' electric heater - largely because it is designed to run on off-peak tariffs "90% of the time". More dynamic tariffs could potentially increase this saving – depending on the structure of the tariffs. *Further investigation is needed to quantify what benefits could come from operating a heat pump according to such tariffs.*
Activities/presence in Europe	Does not have high profile involvement in European smart projects – most of its experience around peak shifting is with electric heating (much of this in the UK). As a heat pump brand it is amongst the leaders in Germany.
Activities/presence in UK	Dimplex has a strong brand in the UK & Ireland based largely on electric heating, although its heat pump business is growing here. It has a long history in the use of storage heaters for 'peak shifting' (fairly simple e.g. 2 rate night/day tariffs such as Economy 7 and Economy 10 – available in the UK today).

TABLE 7: MANUFACTURER PROFILE - DANFOSS

Danfoss	Remote control & monitoring capability, possibility to interface with HEM, but no automated smart capability yet
'Smart' USP + key product(s)	**Connectivity enabling remote control & monitoring – focus on end-user and installer benefits rather than utility requirements.** Danfoss AQ is the most advanced heat pump model – though some functionality not yet available in the UK. ▸ **Connectivity:** Internet connectivity available through Danfoss-Online – not built-in but accessed via a small connection box added to the HP, which then connects to an internet router (previously used GSM but switched to internet in 2012). This enables remote monitoring & control. ▸ **Communication**: Communication capabilities not currently designed to enable response to dynamic steer signals (either dynamic prices or direct control) – but via Danfoss Online, communication capabilities to enable e.g. remote diagnostics are relatively advanced. There is also the possibility to communicate via Danfoss Link – a HEM type thermostat control which adjusts the temperature in each room based on customer pre-set levels. However, very few heat pump customers use this (possible none in the UK). ▸ **Control**: Currently limited automated response to external steer – though there is the possibility for manual response to pre-set events (e.g. set-back of HW production in advance of a known peak period). A "tariff control" function – which could potentially enable automated response to dynamic tariffs - is built in to the AQ, but so far this is not set up for any HP in UK.
Implications for peak shifting in the UK	**Flexibility:** Based on currently available functionality, limited flexibility available to utilities. Availability of connectivity means the foundations are in place – automated response would be a next step. **End-user comfort / benefits**: Danfoss-Online already brings customer (and installers) benefits – confidence and security (e.g. through Alarm function), ability to adjust remotely, and remote diagnostics. There is not yet any tangible financial benefit.
Activities/presence in Europe	Does not have high profile involvement in European smart heat pump projects. Given that the core Danfoss markets are the Nordics – where dynamic prices are already coming in ahead of the UK – this is a likely next step for Danfoss.
Activities/presence in UK	Currently no real 'smart' activities, though one UK utility is already trialling the use of Danfoss-Online with existing customers as a tool to learn about end-user behaviour, and for installer education purposes.

TABLE 8: MANUFACTURER PROFILE - DAIKIN (HYBRID)

Daikin	No smart capabilities yet – but long-term potential with hybrid system with the availability of dynamic tariffs
'Smart' USP + key product(s)	**Hybrid Altherma is Daikin's 'smartest' product, which can shift operation between the gas boiler and the heat pump dependent on gas and electricity price.** ▸ **Connectivity:** Connectivity is possible via e.g. intesisHome – also used by other manufacturers. Some control possible – but not a focus. ▸ **Communication**: Communication capabilities not currently designed to enable response to dynamic steer signals (either dynamic prices or direct control). The hybrid chooses its operating modes in response to pre-set price or CO_2 figures but as yet cannot receive dynamic signals. This capability is likely to be added in the future but Daikin need to see the market pull for this capability before they will add it. ▸ **Control**: The most sophisticated part of the hybrid is its control algorithms to switch between three modes of operation – boiler alone, heat pump alone, or "hybrid mode" where the heat pump and boiler run in series (most hybrids run in parallel rather than in series which has less flexibility). Both the heat pump and the boiler can modulate capacity according to (pre-set) price or CO_2 signals.
Implications for peak shifting in the UK	**Flexibility:** Currently the hybrid can respond only to pre-set price or CO_2 levels – gives little demand-side flexibility today, but in the long-term, once the system is enabled to respond to dynamic signals, flexibility potential is big. **End-user comfort / benefits**: Full commercialisation of the hybrid is only beginning in 2014 in the UK, but indications from Daikin's own field trials (including a site in the UK) are that the control system enables running cost savings to be made against a gas boiler (possibly up to 20% or more – but further trials by a UK energy supplier in the UK over the next months will add valuable insight). The potential benefits of this concept could be more significant with the availability of dynamic tariffs.
Activities/presence in Europe	One of Europe's biggest heat pump manufacturers, with low level involvement in some European smart heat pump projects. Daikin not positioning itself amongst the leading companies in terms of smart capabilities – but when the market pull becomes apparent they will likely move fast.
Activities/presence in UK	In the top 2 heat pump manufacturers in the UK, and with heat pumps installed as part of the CLNR project – however these are being monitored and not smartly controlled. Daikin heat pumps will be involved in the NEDO project in Greater Manchester.

TABLE 9: MANUFACTURER PROFILE - PANASONIC

Panasonic	Can modulate heat pump output in response to steer signals and customer comfort requirements, without the necessity for a storage/buffer tank.
'Smart' USP + key product(s)	**Panasonic has had a long-term focus on developing smart capabilities – sophisticated control algorithms, interface with HEMS and utilities, and involvement in major European smart project.** ▸ **Connectivity:** Connectivity is possible via e.g. intesisHome – also used by other manufacturers, enabling some remote monitoring & control. Ultimately Panasonic looking at developing more sophisticated mechanisms. ▸ **Communication:** Interfacing with utilities / smart grids has been a long-term focus for Panasonic. 2-way communication possible – heat pumps can communicate electricity consumption externally (e.g. interfacing with HEMS has been a focus). Panasonic has the capability to receive utility steer signals – preferably with advanced (~12 hr) notice of peak periods, but with the capability for response within a minute if required. ▸ **Control:** Sophisticated control algorithms which can use a combination of pre-charging hot water tank / buffer, and/or modulate heat pump output to match end-user's (pre-set) temperature requirements, whilst providing flexibility according to (usually day-ahead) utility peak shifting schedules –Panasonic currently field testing modulation in response to utility signals with a major European utility. Once challenge to optimise the algorithms for tank pre-charge, is that additional temperature sensors have to be built into the standard off-the-shelf tank to enable accurate measurements of available heat.
Implications for peak shifting in the UK	**Flexibility:** Panasonic still at relatively early stages in quantifying how much flexibility they may be able to achieve through their control algorithms. Ultimately the most flexibility will be available through e.g. pre-charge of the storage tank or buffer in advance of a peak period. However, the ability to modulate the output of the heat pump without the need for a buffer / storage could be valuable particularly in the UK where there is often little space for storage in homes. The field testing on-going with the European utility will provide valuable insight into flexibility potential of this approach. **End-user comfort / benefits:** The primary focus of Panasonic's control algorithms are to maintain end-user comfort levels through intelligent use of storage and/or heat pump output modulation. The possibility to provide flexible heat pump output and avoid the need for storage tanks is an end-user advantage in many UK homes which have little space available (although ultimately the flexibility will be more limited than with storage). There has not been significant focus on quantifying potential end-user (financial) benefits from responding to e.g. dynamic tariffs.
Activities/presence in Europe	A relatively new player in Europe for HPs, but with steadily growing reputation and presence in key markets. 'Smart' has been a key interest for Panasonic in recent years, with investment in developing sophisticated control algorithms, investigations into interfacing with e.g. HEMS, and involvement (with their HPs) in one of Europe's biggest smart projects (Smart Electric Lyon). Testing of smart heat pump with the University of Aachen and a major European utility.
Activities/presence in UK	Small market presence in the UK and no involvement in major UK smart projects.

TABLE 10: MANUFACTURER PROFILE - OCHSNER

Ochsner	Can respond to dynamic steer signals (but awaiting dynamic tariffs in UK) – and intelligent integration with PV
'Smart' USP + key product(s)	**Ochsner has connectivity & communication capabilities. A focus has been on development of sophisticated control algorithms to optimise operation according to demand. Ultimately this will enable optimisation of operation in response to steer signals, but only once flexible tariffs are in place.** ▸ **Connectivity:** Connectivity is possible, enabling remote monitoring of 10-12 parameters, & enabling remote control. ▸ **Communication**: Fitted with simple free contacts which can receive on/off signals from a third party. Heat pumps can communicate back current & historic status (i.e. monitored data) – but cannot (yet) communicate flexibility going forward. ▸ **Control**: So far Ochsner's control algorithms are designed to optimise heat pump operation according to demand rather than in response to external steer signals – they await flexible tariffs. There is a learning function which enables the heat pump to optimise operation based on the previous day's response to demand. Some Ochsner models have the possibility to modulate output in response to consumer demand – but so far they cannot modulate in response to dynamic steer signals. Ochsner has a HP/PV integrated offerings where the heat pump can automatically respond to PV by increasing the required water temperature in the tank when PV levels are high.
Implications for peak shifting in the UK	**Flexibility:** Limited flexibility available until flexible tariffs are in place – but 2-way communication in place. As Ochnser have no deep involvement in smart demonstration projects it is not yet possible to quantify possible flexibility. **End-user comfort / benefits**: Currently the main focus of Ochner's offering is on comfort provision – the next stage will be to integrate flexible steer signals into these control algorithms and learn from testing this. The HP/PV offering which is already available can enable customers to take advantage of self-consumption incentives, which already provides financial benefits to end-users in some markets
Activities/presence in Europe	One of the longest-established 'pure' heat pump players in Europe – based in Austria. Ochsner has the SG-Ready label in Germany and advertise 'Smart Grid Ready' products – though no major involvement in smart heat pump demonstration projects. The SG-Ready label however does not currently provide the level of connectivity for grid balancing.
Activities/presence in UK	Relatively small player in the UK market.

TABLE 11: MANUFACTURER PROFILE - STIEBEL ELTRON

Stiebel Eltron	Heat Pump remote control capabilities & electric water heaters which allow users to take advantage of off-peak electricity tariffs
'Smart' USP + key product(s)	Stiebel Eltron offer remote control solutions with internet connectivity which can work with their heat pumps and other systems. The most 'smart' product available in the UK is the recently launched electric water heater, which has the capability to accept flexible (dual-rate) tariffs. ▶ **Connectivity:** Remote control and monitoring of heat pumps possible via Internet Service Gateway ▶ **Communication**: Via home router ▶ **Control**: Series of control systems available with sophisticated control mechanisms – all focused on maintaining end-user comfort & responding to demand. So far no sophisticated control for heat pumps to respond to external steer signals (though it is likely to come). Automated electric water heater response to dual rate tariffs is the most immediately valuable offering.
Implications for peak shifting in the UK	**Flexibility:** The electric water heater offering can already provide flexibility from customers on dual rate tariffs by shifting operation to night time / non-peak times. Ultimately, tariff structures will be more dynamic, creating the opportunity for greater flexibility. If similar capabilities can be built into heat pumps, greater flexibility will be available to utilities. **End-user comfort / benefits**: Electric water heater offering can already provide end-user financial benefits by operating at lower rate times.
Activities/presence in Europe	Has the German "Smart Grid Ready" Label for heat pumps, and has been previously linked to work with Vattenfall on a project integrating heat pumps and CHP into a Virtual Power Plant (Vattenfall have since dropped heat pumps from the project).
Activities/presence in UK	Relatively small player in the UK but very active/visible in UK policy-lobbying.

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