VCHARGE

Smart Electric Heat:
Kickstarting a Revolution in Heat

October 2017

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Executive Summary

Decarbonising heat

The UK currently lacks a clear path to decarbonising heat, despite the sector contributing 20% of the country's carbon emissions and nearly 50% of its energy consumption.

Furthermore, domestic heating systems take a long time to replace and renew – longer than cars or even power stations. This long lead-time means that action on heat decarbonisation must take place sooner, not later.

A new solution

Smart electric heat is a no-regrets technology that provides a pathway to complete decarbonisation of the heating sector, whilst supporting the integration of renewables and alleviating fuel poverty.

Smart electric heat is an electric heating system with storage that is connected to a distributed energy management platform. This enables participation in grid balancing and smart tariffs, and provides improved user control and comfort.

The short-term: unlocking the UK's largest storage asset and improving lives

In the short term, OVO and VCharge have developed a solution for the 1.5m UK homes with electric storage heaters. Electric storage heaters can store large amounts of thermal energy and, with a combined peak capacity of 12GW, they represent the largest grid-connected storage asset in the UK.

Poor controls and restrictive tariffs leave many customers unsatisfied with heating quality and expensive fuel bills. Unfortunately, this affects some of the lowest-income households in the UK, and has been identified as a major social problem.

Using new controls, software, and a 'smart tariff,' storage heaters can be aggregated to form a virtual battery, delivering dramatically improved control, comfort, and savings for consumers. This solution brings major social benefits and can be implemented at significantly reduced costs compared to other technologies, such as district heating.

The long-term: the complete decarbonisation of the heating sector

Smart electric heating technology can be applied to any form of electric heating with storage, such as heat-pumps or hot water heaters. The growth of renewable energy in the power sector has already rendered electric heating less carbon intensive than gas central heating and, with the additional value from grid balancing, electric heating can also be cheaper. We see a pathway to complete electrification of the heating sector, following a transition similar to that forecast for the transportation sector.

Executive Summary (cont.)

Barriers

Smart electric heat technology does not require subsidies or large-scale government programmes to ensure its deployment. However, its impact could be accelerated and magnified by a small number of policy adjustments. In particular:

1. A review of the Energy Performance Certificates and their relation to the Energy Company Obligation scheme to enable inclusion of smart electric heat and other smart appliances.

2. Ensuring fair market access for smart electric heat to grid balancing services from National Grid, or during the transition to Distribution System Operators (from the existing DNO market framework).

3. Give smart electric heat a level playing field with district heating schemes, in both policy and funding.

4. A review of metering and billing requirements for smart appliances participating in smart tariffs.

5. Inclusion of smart electric heat in future energy scenario planning.

The purpose of this white paper is to raise awareness amongst policy makers and other stakeholders of this potentially ground-breaking technology.

Introduction

Britain's energy system is undergoing a period of profound change, unprecedented since the creation of a single, national AC transmission grid in the 1930s.

Rapid advances in technology and falling costs have resulted in a large volume of variable renewable capacity coming onto the grid at the same time that centralised coal and nuclear plants have come off it.

Distributed generation plays a growing role, largely in the form of wind and solar, and from smaller plant providing balancing services and on-site back-up joining the network.

Perhaps unsurprisingly in an era of massive digital and technological development, the UK's energy industry has begun to experience a boom in nimble, insurgent, technology companies bringing innovative services and new software-led solutions to the market. New markets have emerged that value on-demand capacity, inertia, localised supply and, ultimately, a more flexible grid.

For the Government, there remain three key energy challenges:

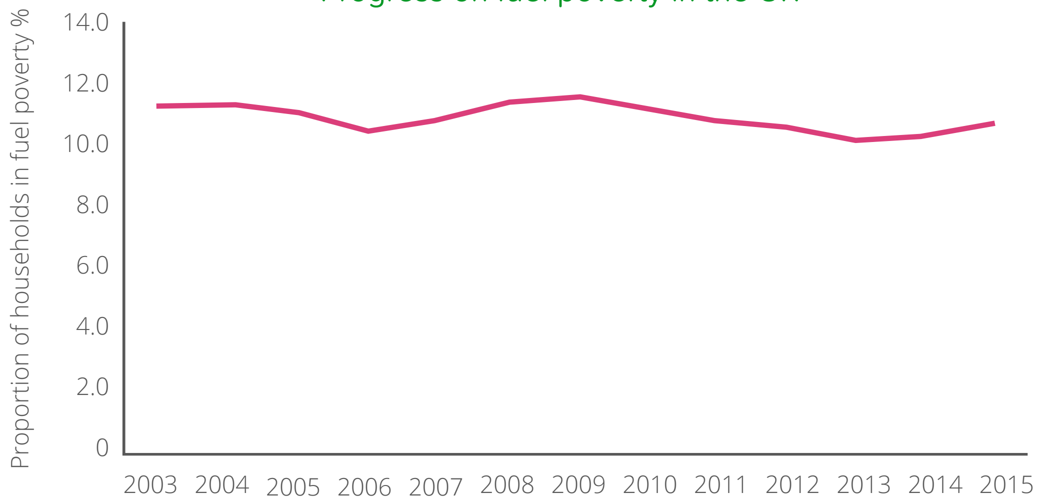
1. Cost

The cost of energy, particularly for consumers, remains high on the political agenda.

Large energy companies have used their legacy customer bases to subsidise cheap deals to attract switchers, leading to profits for the 'Big Six' built on the energy bills of some of their poorest customers. Government and the regulator have moved to intervene with price caps for vulnerable households, and now for customers on single variable tariffs. However, bills remain unacceptably high.

Fuel poverty continues to affect the vulnerable in society most of all, without a sustainable solution to the 'heat or eat' trap, or to significant winter mortality figures. Age UK estimates the cost to the NHS of cold-related illness, often caused by fuel poverty, to be in the region of £1.3billion[1] and, despite a revision to the calculation methodology and a range of policy interventions, the proportion of households stuck in fuel poverty has remained at around one in ten for well over a decade.

Progress on fuel poverty in the UK



Source: BEIS, 2017

1 http://www.ageuk.org.uk/latest-news/archive/cold-homes-cost-nhs-1-point-36-billion/

2. Decarbonisation

Progress has been made on the decarbonisation of power and energy efficiency, mainly through large-scale renewables projects and the roll-out of insulation. But longer-term carbon targets depend on reaching close-to-zero carbon from power and a gradual shift to zero-carbon in other sectors.

Growth in Electric Vehicle (EV) ownership is accelerating, driven by measures to decarbonise transport, and by improving customer economics and better products. This shift will create potentially significant demand for new generation capacity and system balancing services over the coming decades.

With good progress on power and transport, heat remains the weakest link in government's decarbonisation plans.

3. The Future Grid

The ongoing shift in generation presents an enormous challenge to the operation of the energy system. Large central plant is being replaced by intermittent generation far from centres of demand. It is less well connected to the transmission system, and so needs to be backed up by other generation, or storage, to keep the lights on when the wind isn't blowing or the sun isn't shining. Equally, the business case for intermittent renewables is not helped by oversupply at times of low demand.

The Distribution Network Operators (DNOs), which own and manage the regional grid systems in different parts of the country, have traditionally delivered power from the transmission grid to homes and businesses. That is, they moved energy in one direction from National Grid to customers. With the development of distributed generation, such as solar farms and anaerobic digestion plant, DNOs must manage a more dynamic and multi-source network. This has created the need for new interfaces with customers and new regulations to ensure secure supply and controlled costs.

The Heat Challenge

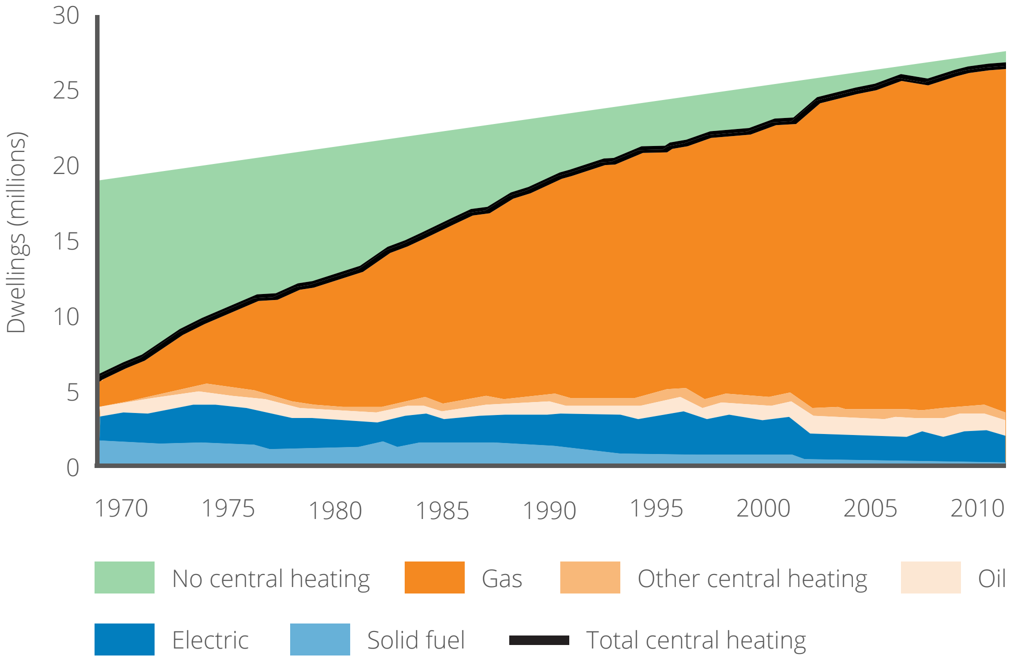
The decarbonisation of power generation has been driven by generous public subsidy, and renewables are now close to cost-parity with fossil fuel generation. Similarly, EV uptake will soon be attractive even without government support. In both cases, winners have emerged - like onshore and offshore wind, and battery-powered vehicles.

Unlike power and transport, decarbonising heat remains a considerable challenge. Despite significant subsidy over the years, no clear winners have emerged. Whilst technologies have improved, most are still far from viable without significant support. As a result, government is already falling behind its own heat targets.

However, removing carbon emissions from heat is crucial. Compared to the far higher barriers to decarbonising freight, aviation, and industrial scale agriculture, heat will have to decarbonise almost completely by 2050 if the UK is to meet its legally-binding carbon targets.

Heat systems have lower churn rates than vehicles (i.e. they are replaced less often by their users), which creates a much longer lead-in time for the heat sector to decarbonise. Indeed, it took over thirty years to install the current base of gas boilers.

Installed central heating by type, 1970-2012



Source: DECC, ECUK, 2015

Coupled with this, over 90% of the UK's 26 million homes are likely to still be in use in 2050.

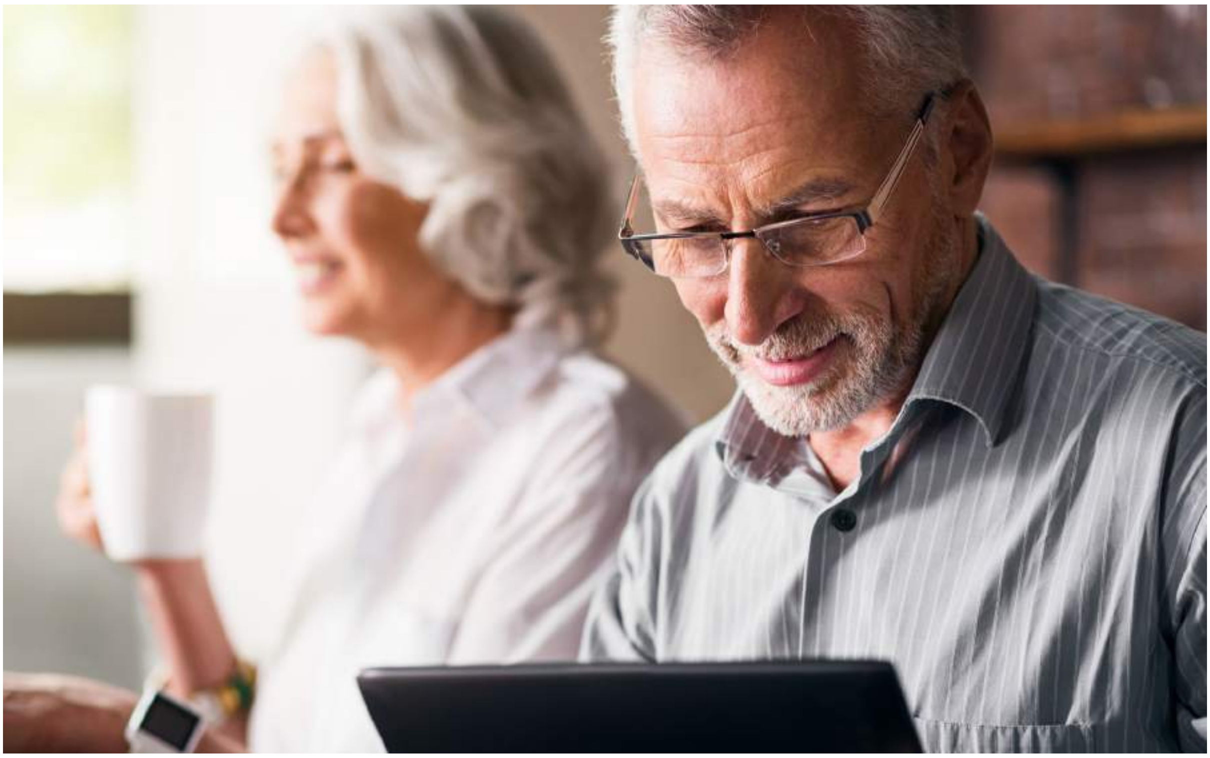
Yet they are some of the least efficient in Europe - heating them (and their hot water) creates 20% of the UK's carbon emissions. Measures to reduce these emissions are typically more cost-effective than those in power or transport.

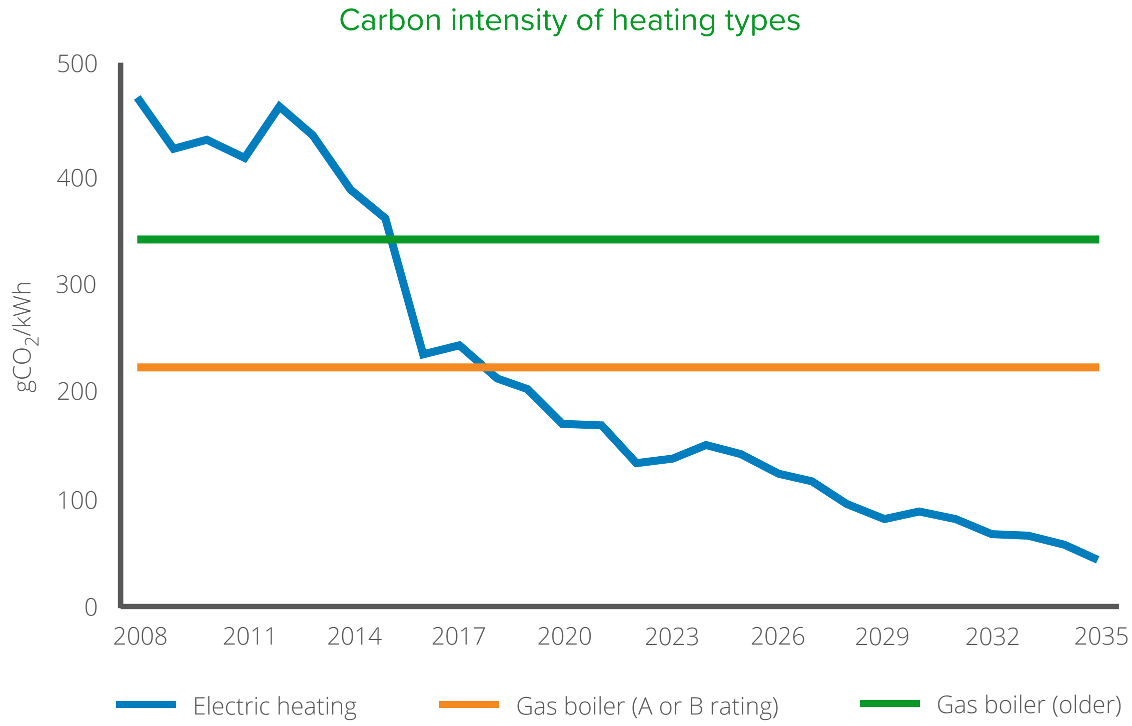
Average U values (a measure of heat efficiency) of walls, roofs, floors and windows in homes

Rank	Country	Walls	Country	Roof	Country	Floor	Country	Windows
1	Sweden	0.3	Sweden	0.2	Sweden	0.2	Finland	1.9
2	Finland	0.4	Denmark	0.3	Denmark	0.4	Austria	2.3
3	Denmark	0.5	Finland	0.3	Finland	0.4	Denmark	2.4
4	Czech Republic	0.8	Czech Republic	0.6	Germany	0.8	Sweden	2.5
5	Austria	0.9	Austria	0.6	Czech Republic	0.9	Germany	2.7
6	Germany	0.9	Ireland	0.7	Belgium	0.9	Czech Republic	2.7
7	UK	1.0	Germany	0.7	France	1.0	France	3.1
8	Netherlands	1.1	UK	1.1	Ireland	1.0	Netherlands	3.2
9	France	1.2	Netherlands	1.2	Austria	1.0	Belgium	3.8
10	Ireland	1.2	France	1.3	UK	1.2	Ireland	3.8
11	Belgium	1.5	Belgium	1.6	Netherlands	1.3	UK	3.9

Source: UKACE, 2015

However, efficiency is not the full answer to the problem. Even if progress is made on efficiency, natural gas space heating is too carbon-intensive to play a significant role in the 2050 energy mix. Electric heating must play a larger role because it is increasingly lower-carbon. It is now lower carbon intensity than gas heating, and this trend is likely to continue.





Source: BEIS, Parliamentary Office of Science and Technology, 2016

Despite this clear need, the decarbonisation of heat lags behind the decarbonisation of power, and government lacks a clear strategy.

The Renewable Heat Incentive (RHI) has supported the piecemeal deployment of new low-carbon heat technology, like heat pumps. Heat pump deployment through the RHI has fallen far behind government targets.

Fuel poverty is increasing and the UK has some of the worst levels in Europe, exacerbated by the rising cost of living and some of the poorest quality housing stock in Europe.

The failure of the Green Deal scheme to deliver the intended scale of change, and the gradual watering down of supplier obligations, has stalled progress in improving domestic energy efficiency.

Ultimately, for a systemic decarbonisation of the sector, domestic heat must transition away from natural gas heating. All of the current options available to achieve this would require a huge shift in the way the UK uses energy. There is a need for a faster route to begin the process at scale.

Smart Electric Heat

New data-led technologies in heat are an emerging part of the heat solution, making heating more controllable and more efficient, improving comfort, and reducing much of the damage caused by fuel poverty.

The UK government is already moving to take advantage of a smarter energy system. In its July 2017 white paper *Upgrading Our Energy System*, the Government explored building greater flexibility in supply and demand, improving the visibility and density of metering data, and enabling the greater use of software-controlled balancing tools.

As the electrification of heat develops, the potential for smart heat to play a key role in balancing and decarbonising the network is huge.

Technology: Storage Heaters

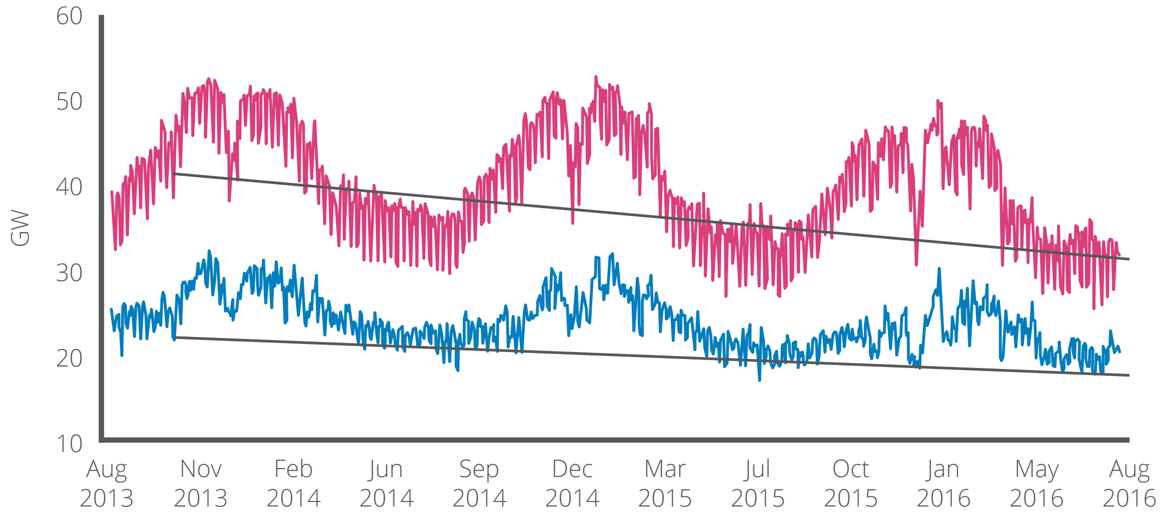
Electric heat encompasses a range of technologies, from fairly inefficient products like infra-red, bar, or convection heating to efficient underfloor heating and new high-efficiency (but high-cost) solutions like ground and air source heat pumps.

However, the easiest place to start taking advantage of smart heat is with electric heat technologies that are already in place, and at scale.

Electric storage heaters use electricity to heat a storage medium, usually a set of ceramic bricks. Historically, they heat up at night, then release heat during the day.

Storage heaters were designed to heat up when power was considerably cheaper at night, using that stored thermal energy to warm homes when power is expensive - in theory, taking advantage of the economics of the grid. But loads on the grid are changing as a result of increasing levels of variable generation, energy efficiency, and changing work patterns. The gap between peak power loads and baseload demand have narrowed visibly, even in the last three years.

Peak and minimum (night-time) electricity supply UK 2013-16



Source: National Grid Balancing Mechanism

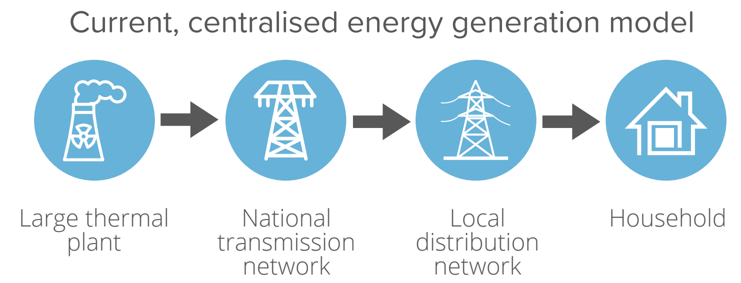
However, with intelligent controls, electric storage heaters offer huge potential to reduce consumption, improve comfort and take advantage of low-demand (and low-cost) periods throughout the day, to improve quality of life for homeowners, and to reduce bills.

Instead of being seen as a problem that needs to be replaced, retrofitted storage heaters (or new ones that already have the technology integrated) are an ideal candidate for early inclusion in the smart grid. The technology is quick and easy to install and can be readily scaled up in both the home owner and social housing markets.

How do smart grids work?

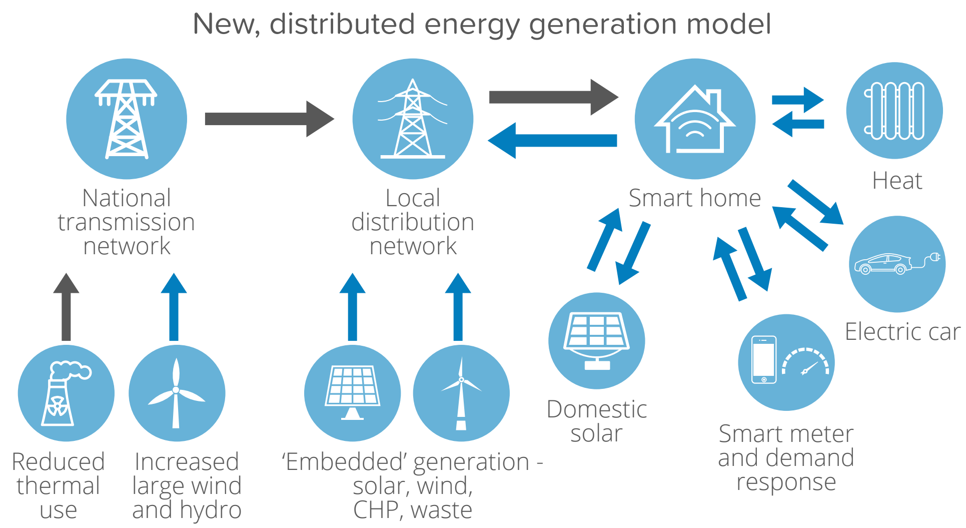
The electricity grid – the UK's network of electricity transmission lines, transformers, and substations – was built in the early 20th Century to send power from big centralised power plants to homes and business, and to bill them every month. It is split into a national grid, which deals with very high voltages, and distribution networks, which deliver power at lower voltages from the national grid to homes and businesses.

But this one-way transmission makes it hard for the grid to respond to the changing energy needs of 21st Century Britain. The growing volume of intermittent generation from renewables, coupled with increased and changing types of demand, requires a two-way exchange of energy and real-time data from users about how much power they need and when in order to balance the system.



Smart Grids provide this exchange by connecting a network of sensors, controls, computers and new technologies like electric vehicles and battery storage via the internet to make the grid more efficient, more reliable, and less carbon-intensive.

Just as services like Uber connect customers and drivers in real-time, using flexible pricing to respond to demand, Smart Grids connect energy companies and consumers, enabling the companies to anticipate changes in demand, and rewarding flexible customers with lower bills.



OVO – the UK's leader in smart electric heat

OVO's mission is to transform energy from the other end of the wire by utilising new technologies to put the needs of the customer and the planet at the heart of future energy systems.

It is about creating smart energy solutions - which can help address the complex challenge of providing reliable, affordable and renewable energy at scale. To create those solutions, OVO acquired VCharge, an energy technology company working to solve the problem of renewables intermittency in order to accelerate the transition to a zero carbon future.

VCharge has developed a ground-breaking technology solution that uses advanced algorithms to balance grid requirements with individual user requirements, through remote control of energy storage devices. The first application of VCharge's pioneering VNet technology has focused on controlling electric storage heating in social housing to better manage resident comfort and to address the issue of fuel poverty, while simultaneously supporting the widespread adoption of renewable energy by providing valuable grid balancing services.

But that's just the start. VCharge's technology has the potential to aggregate limitless numbers of storage devices - such as in-home batteries and electric vehicles - to produce a massive flexible electrical load.

The VNet platform responds in fractions of a second to strain on the grid to increase or decrease the demand side, and help to stabilise the frequency of electricity, using smart grid technology to create a 'virtual power plant'.

Essentially, VCharge intelligently controls storage devices to provide a similar frequency response service as gas turbines do by ramping up and down according to demand.

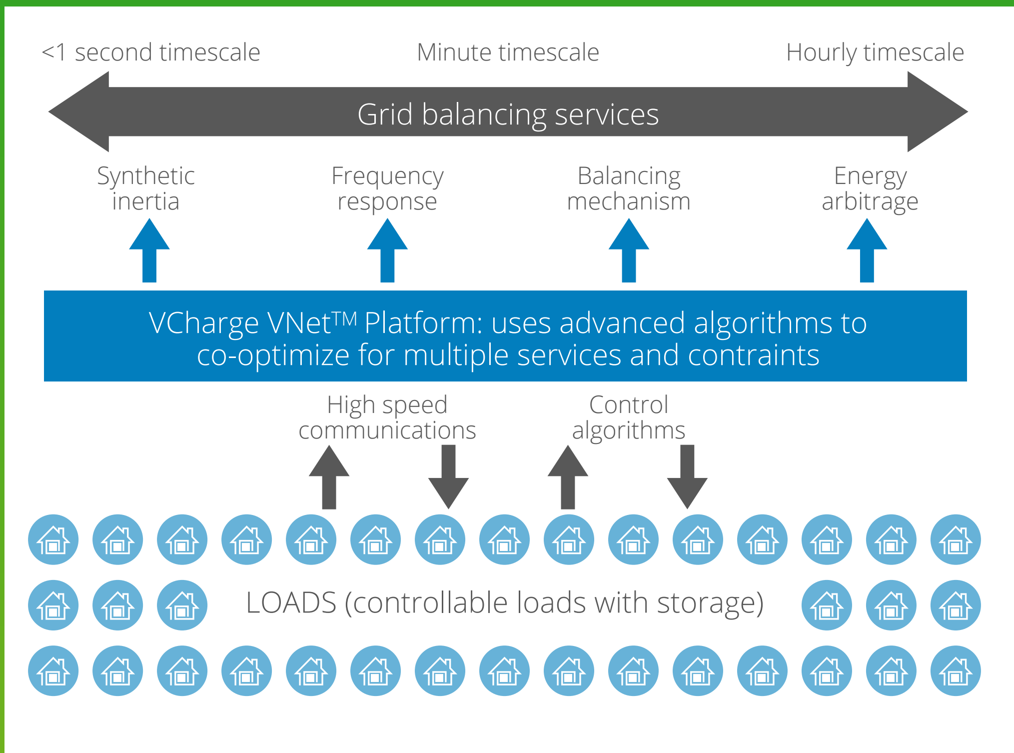
And it does this within the constraints of the customers' needs and comfort. By applying the VCharge technology at scale, OVO will be able to intelligently harness the enormous potential of energy storage in reducing dependency on fossil fuels, while helping to make energy more affordable for all.

A massive virtual battery

We tend to think of batteries in terms of the storage of chemical energy that is then released to create power. But storing thermal energy, as smart electric heat does in storage heaters, serves exactly the same purpose – capturing energy when it's cheapest or most freely available, to use when it's most needed.

From the grid's point of view, there is no difference between chemical and thermal storage. So, a network of thousands of electric storage heaters, distributed in thousands of homes across the country, acts like a single energy storage device - an enormous battery.

As the world pushes towards energy storage to smooth out the weather-dependent variability of wind and solar power, it's important to realise that thermal storage in electric storage heaters is already able to serve this purpose.



Fuel poverty and social housing

Age UK estimates that the NHS spends £1.36 billion per year treating illnesses caused and exacerbated by fuel poverty. One study[2] showed that investing £1 in improving affordable warmth delivered a 42 pence saving in health costs for the NHS alone.

According to research by the UK Health Forum[3] children of all ages living in cold, damp homes can suffer from respiratory illness and low infant weight gain. Among adults, circulatory and respiratory disease, including increased blood pressure, asthma, emphysema and bronchitis, are the most common physical health impacts. As well as physical health effects, fuel poverty also has a significant impact on residents' mental health.

Smart electric heat can play a role in addressing this because, as well as reducing costs, it gives residents more comfort and control. This reduces the stress caused by uncomfortable homes, lack of control, and social stigma, which studies show impairs mental wellbeing.

[2] http://www.energybillrevolution.org/wp-content/uploads/2014/10/Building-the-Future-The-Economic-and-Fiscal-impacts-of-making-homes-energy-efficient.pdf
[3] http://www.fph.org.uk/uploads/UKHF-HP_fuel%20poverty_report.pdf

The System Potential of Smart Electric Heat

The 1.5 million homes already using electric storage heaters manage a load equivalent to 2.5 Hinkley Point C nuclear power stations.

Even if we consider only the storage heaters that are already installed in the UK, they can clearly play a significant role in the Government's energy strategy.

As the electrification of heat accelerates, it is essential that the role of smart electric heat is understood and anticipated in regulation, allowing the full potential of the technology to be unlocked.

The potential advantages of smart electric heat at a systemic level are significant:

- It can work at scale. Electric heating is a huge untapped asset, equivalent to around 8GW of peak load. The existing households with electric storage heaters in the UK represent one of the world's largest energy storage resources.

- It reduces the burden of further subsidies on bills. By using software to control electric heating, load can be better matched to desired heating levels, giving improved control and comfort. This lowers the need for back-up power, transmission management, low-carbon subsidies, and other mechanisms paid for by consumers through their bills.

- It reduces carbon emissions from heat in the short-term. Electric heating is already less carbon-intensive than condensing gas boilers. The domestic heat sector currently accounts for 20% of UK emissions. The slow churn of domestic heating systems makes this a long-term project in which large-scale quick wins are highly valuable.

- It supports the development of more renewable energy. As well as cutting the carbon emissions of an individual home, the system underpins greater deployment of renewables. Wind often blows when demand is low and, by purchasing this power, smart electric heat systems provide revenue for renewables and support the business case for greater deployment of low-carbon technologies.

- It supports the Industrial Strategy. Smart electric heat has the potential to position the UK as a leader in energy storage technology. It also allows the market to start signalling at the domestic level (with lower bills) that electrification is attractive.

- It helps to alleviate fuel poverty. Pilot projects have demonstrated energy savings of up to 30%. Fuel poverty is a major driver of government energy policy, from the ECO scheme to the most recent debates over energy price caps. It also has a major impact on the health of the nation and the financial independence of economically vulnerable people. In both cases, alleviating fuel poverty would reduce dependence on the state.

- The financing of smart electric heat systems offers an attractive alternative to other technologies. Compared to equivalent systems, such as district heating, heat pumps and gas boilers, smart electric heat offers a major cost saving when deployed at medium scale (see table below).

Comparing options for tower blocks with storage heat

	Upfront costs (estimated cost per property)	Heating costs (cost/kWh)	Comfort	CO_2 savings	Supports grid balancing
Standard electric storage	None	6-7p off peak	poor	None	No
Gas boiler	4,000	4-5p	good	None	No
Biomass district heating	12,000	8-12p	good	40%	No
Air source heat pump district heating	13,000	8-12p	good	Up to 100%	No
Smart electric heating	less than 1,000	6-7p	good	Up to 100%	Yes

Source: VCharge analysis

Barriers to Wider Deployment

Smart electric heat can be deployed quickly and easily, its benefits to consumers are tangible and clear, it relies less on government intervention than many alternative heating systems, and it is not dependent on new large-scale infrastructure.

However, there are some policy barriers whose adjustment would allow a revolution in storage heating. All are relatively easy to address:

1. The role of smart electric heat is not recognised

- Energy Performance Certificates (EPCs) do not recognise the role of smart electric heat, and government incentive schemes are based on EPC calculations, which address the performance of properties through measures like insulation, lighting, and boiler efficiency.
- The Energy Company Obligation (ECO), an effective scheme where utility companies fund energy efficiency retrofits, does not allow for the funding of smart heat solutions.
- Outdated metering regulations restrict the development of smart tariffs for demand -side flexibility.

2. There is a focus on district heat in current government policy

- Government offers support to hydrogen and district heating projects through grants.
- District Heating, and the potential of hydrogen to replace natural gas, have been touted as front-runners in the quest to decarbonise heat; but both require significant subsidy, and cost to bill payers, whilst the lifecycle carbon impact of each is in doubt.
- The focus on district heating is using time and resource to pursue a technology that is only part of the solution. District heating projects are also removing the electric storage heaters in social housing that will enable VCharge and other smart electric heat programmes.

3. The balancing markets

- The grid is currently balanced through a range of overlapping mechanisms, markets, and charges administered by BEIS, OFGEM, and National Grid. The process of reform to streamline grid balancing services is underway, and officials and ministers in BEIS understand the huge value in creating a more resilient, flexible, and low-cost system. However, without political support, it will take time.

- Balancing is happening at distribution and transmission levels, but consumers have not yet been able, or incentivised, to participate.

- The current entry rules for the Capacity Market auctions do not allow for smart heat services to bid.

- Similarly, the rules governing grid balancing services such as Fast Frequency Response, make it difficult for residential electric heating load to participate.

Conclusions & Recommendations

The government white paper *Upgrading Our Energy System*[4] highlights the potential for smart electric heat in the future. But VCharge's technology is already in use today, with the potential to have a huge positive impact on customers' lives in the very short term. Whilst long-term thinking and ambition should be applauded, there are major steps that can be taken immediately for the fast roll-out of large-scale changes. These should not be overlooked.

Smart electric heat should be given the long-term support from government to develop and grow, and the policy barriers to that growth should be removed.

With a small number of changes, technologies like VCharge could deliver a rapid uptake of smart electric heat to some of the most vulnerable people in the country, using the heating systems already in their homes.

With no obvious drawbacks, there are numerous political, environmental, and consumer benefits to increasing support for smart heat today, including carbon abatement, comfort, the ability for the grid to absorb more intermittent renewables, as well as reduced energy bills.

To achieve fast, no-regrets growth in smart electric heat, the barriers to growth mentioned above should be addressed. These are small adjustments that have significant potential.

[4] https://www.gov.uk/government/uploads/system/uploads/attachment_data file/633442/upgrading-our-energy-system-july-2017.pdf

Policy asks

1. A review of Energy Performance Certificates (EPCs) and their relation to the Energy Company Obligation (ECO) scheme to enable inclusion of Smart Electric Heat and other smart appliances. This would allow energy suppliers to offer Smart Electric Heat to vulnerable customers as a recognised way to mitigate fuel poverty, helping further deployment.

2. In the transition from a system of Distribution Network Operators to a system of Distribution System Operators, tariffs and markets are being restructured. It is important that the tariffs that currently allow smart electric heat to operate commercially are not removed - either intentionally, or as an accidental by-product of the process.

3. The market framework for smart appliances participating in smart tariffs should be standardised through a review of compliance, technology and billing requirements. This market is advancing and diversifying quickly; regulation must keep pace in order to allow consumers access to the broadest range of technologies whilst helping grid operators to manage a stable energy supply.

4. Smart electric heat should be included in future energy scenario projections. Currently, organisations such as the Committee on Climate Change and National Grid produce models for projecting the impact of different technology mixes on the UK's carbon emissions. Given the large potential scale of smart electric heat and the ease with which it can be deployed rapidly, such projections should include smart electric heat. This will allow an evidence base for public policy, underpinning its use.

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