

An Electric Heat Pathway: Looking Beyond Heatpumps



Scottish & Southern
Electricity Networks

Grid Edge Policy

Regulation · Energy · Consumers



An Introduction from Andrew Roper at SSEN

It is clear that if the UK is to achieve its carbon target by 2050 a major element will need to be the decarbonisation of our heat pathways. In addition to improving the thermal efficiency of our homes we need to accelerate the installation of low carbon technologies that reduce our reliance on fossil fuels. There are lots of opportunities to make changes to the way we heat our homes - more than 23 million homes will need to install new low-carbon heating solutions by 2050 – however this rollout needs to consider regional differences such as existing infrastructure, geography and existing housing stock. In the current debate there has been a presumption of any electrified heat pathway being based around the use of heat pumps, however they are not the only solution, and SSEN is aware they might not be suitable for many of our most vulnerable customers for a range of reasons. A sound and structured look at some of the other possible heat pathways is long overdue and SSEN is delighted to present this independent report by Maxine Frerk, a widely regarded industry expert. This timely study uses industry and SSEN expertise to examine the opportunities presented by the control, operation and use of domestic electric storage heating as a viable alternative to heat pump technology and as a valuable tool to help achieve the UK's carbon target.



Andrew Roper - Distribution System Operations Director

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Maxine Frerk – Director at Grid Edge Policy

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Executive Summary

De-carbonising heat from our homes is one of the major challenges facing the UK in its transition to net zero greenhouse gas emissions. While different pathways are currently being debated and explored, the “electrification pathway” is always treated as synonymous with the use of heat pumps and there is little or no consideration of the role that new forms of thermal storage heating or direct electric heating might play – nor of the issues around hot water provision.

Currently around 2.2 million homes across GB are electrically heated, of which around 1.4 million have storage heaters. While these are technically less efficient forms of electric heating than heat pumps (which use the electricity to draw heat from surrounding ground or air) there are very significant numbers of homes for which heat pumps are not a practical solution. This can be either because of a lack of space or because in homes with a low energy demand the upfront costs of a heat pump may not be justified, despite having lower running costs.

Today’s homes with storage heaters risk being put to the back of the queue as hard to upgrade and therefore “hard to de-carbonise”. However, these properties are overwhelmingly lived in by more vulnerable households on lower incomes who can be pushed into fuel poverty by the higher running costs of existing legacy electric heating systems. Developing a clear vision for this segment of households and the housing stock should be a priority given the often-voiced commitment to “no-one left behind” in the move to net zero.

The other strong reason why storage heating ought to be given more serious consideration is that discussion around the energy transition places a strong emphasis on the growing value of flexibility as far more intermittent generation comes onto the system. Smart storage heating and hot water could potentially provide this flexibility more readily than a heat-pump.

Historically storage heating was “leaky” and had only crude controls, delivering a poor customer experience. However, the next generation of smart storage heaters are less leaky and provide far more sophisticated controls. Evidence from a range of trials show that these can save customers money (compared to traditional storage heating) and deliver much improved comfort. Even fitting smart controls to existing storage heating has been shown to improve comfort.

A major challenge with existing storage heating is that it requires both special metering arrangements and appropriate tariffs to enable customers to benefit from the use of electricity at off peak rates (typically overnight). In some cases these legacy arrangements are quite complex and customers struggle to understand them. They can also make it hard to switch supplier.

The rollout of smart meters was always expected to help address these issues by providing an interoperable meter that could be used across all suppliers and an improved consumer interface through the in-home display (IHD). However, because of the complexity and range of meter types, customers with storage heating are among the last to benefit from smart metering. What is deemed to be a suitable meter ‘variant’ is expected late this year but care will be needed to ensure that this critical group of customers are dealt with appropriately and that installers have the requisite skills to deal with these more complex arrangements. Customers will also need continued access to suitable off-peak tariffs.

Ofgem and BEIS should work with Energy UK and the industry to ensure that this sensitive phase of the rollout is carefully handled and the opportunity taken to help customers understand how their heating systems work as part of the energy efficiency advice suppliers are required to give during the installation visit.

One feature of these more complex arrangements is that they enable the distribution network to determine the timing schedules for storage heaters in constrained areas that would otherwise need costly reinforcement. These messages are currently sent over what is known as the Radio-Teleswitch System (RTS) using the long wave radio infrastructure provided by the BBC. However this is shortly due to be de-commissioned.

With the smart meter rollout as currently envisaged, the Distribution Network Operators (DNOs) will no longer have a direct ability to control local heating loads and so new arrangements need to be put in place to ensure that SSEN can maintain local-level security of supply without needing to make significant infrastructure

investments. While the direction of travel for flexibility services is for these to be provided on a competitive basis, the domestic Demand Side Response (DSR) market is still nascent. Network requirements are likely to be very localised and time specific (reflecting a need to cope with night time peak heating loads in certain constrained network areas). SSEN will need to work with suppliers including OVO (who have taken on the SSE retail customers) and with housing associations to find solutions. If SSEN do move to a more commercial basis for flexibility services to avoid this network reinforcement (a service which they currently get 'for free' from certain storage heater customers) it would add to the costs for customers at large – but that may ultimately be a fairer solution.

It is critical to address the many legacy problems for existing storage heater customers. These customers represent many of the most vulnerable in society. Moreover, finding an enduring solution that works for them should also help provide a way for electric storage heating and hot water to play a valuable role in providing flexibility in future.

Aside from these arrangements, there are a range of other policy decisions and practicalities that are critical to get right if smart storage heating is to play a more credible role in a flexible, de-carbonised energy future. These include building and appliance standards (MHCLG and BEIS), network charging arrangements (Ofgem), up-front funding for the heaters for those in fuel poverty (BEIS and Scottish government), tailored customer information and ongoing support (various including consumer bodies), and addressing the current regulatory incentives in network price-controls that continue to drive gas replacing electric heating (Ofgem). Given the wide range of practical factors that impact on the relative attractiveness of different heating options and choices there is a need for some co-ordinated thinking and oversight – especially for those who lack true choice.

While BEIS has yet to confirm what it sees as appropriate options and pathways for heat decarbonisation, there would seem to be strong arguments for smart electric storage heating being a part of the solution for 2050. Hot water tanks are also likely to be needed in many electrically-heated homes. BEIS and Ofgem should ensure that their short-term policy decisions help keep these options open and BEIS should give proper consideration to them as a part of its forthcoming heat de-carbonisation roadmap.

Sending a clear signal that smart storage heating has a part to play in a de-carbonised future would send a valuable signal to the supply chain and to housing associations and others who are grappling with what to do with their properties in the short term as they strive to deliver against SAP targets.

In summary the key requirements highlighted by this report are:

Future thinking

- Smart storage heating to be given proper consideration in thinking about heat de-carbonisation;
- Government policy (MHCLG, BEIS, Ofgem) to ensure policies they enact do not inadvertently act as barriers to smart storage heating playing a role;
- **Today's storage heater households**
- In the near term Ofgem and BEI to ensure a strong focus on the replacement of restricted meters in the smart meter rollout and that customers in homes with electric storage heaters receive the necessary advice and support;
- More broadly, to establish routes to independent customer advice and support to help customers make appropriate choices on low carbon heat solutions;
- SSEN to work to develop commercial arrangements to properly reward the provision of flexibility and diversity that is currently provided by storage heating through the RTS arrangements.

Introduction

This report has been funded by SSEN as part of its Network Innovation Allowance (NIA) to help inform thinking about future trends impacting the distribution network as a part of the energy transition.

It was agreed that the output of the project would be a report setting out the benefits of and barriers to electric storage heating (and hot water tanks) playing a part in the overall heat de-carbonisation strategy together with options for commercial models for how this could be taken forward.

The purpose of this report is therefore threefold:

- to stimulate public debate on an important but neglected element of energy policy;
- to understand the opportunities and benefits of flexible heating demand, and how best to implement them;
- to provide insights to SSEN on how to tackle the immediate issues relating to RTS de-commissioning (in terms of alternative commercial / regulatory models).

The report starts (section 1) with an overview of the current position of electric storage heating including some of the factors that contribute to a poor customer experience today and a strong association with fuel poverty. It then considers (section 2) how modern smart storage heating has the potential to address at least some of these concerns based on a number of recent trials.

The next three sections then look to the future and how storage heating could and should play a role in the de-carbonisation of heat which is one of the biggest challenges in meeting our net zero commitment. In particular it looks at (section 3) the limited role envisaged for storage heating in current projections and why this should be extended. More detail is then given (section 4) on the sorts of properties in which smart electric storage is likely to be most suitable, making the point that these are typically low-income homes and hence should be an early focus – not left until last. The following section (section 5) reinforces the importance of this in the context of the DSO transition and the increased need for flexibility.

The report then turns to what is needed to make this happen. This covers (section 6) the many policy and regulatory barriers that need to be addressed to support smart storage heating playing its part in the future – from network charging to building regulations and customer information and advice. It then explores (section 7) some of the immediate challenges for SSEN around the de-commissioning of the RTS and the rollout of smart metering, which are also important in establishing a viable model for the longer term. The report concludes (section 8) with a summary of recommendations to policy makers and to SSEN.

The report is based on a literature review, personal knowledge of the regulatory framework and interviews with key players including SSEN themselves. The conclusions were tested at two expert roundtables – one in Edinburgh (hosted by Citizens Advice Scotland¹) and one in London (hosted by National Energy Action²). I am very grateful to these organisations for hosting and to those who have given their time to input in this way.

Finally, Judith Ward of Sustainability First has provided valuable expert challenge and peer review throughout. However, any errors remain the responsibility of the author.

¹ 14 February 2020

² 17 February 2020

1 Storage Heaters Today

- A small but significant number of homes have storage heating today
- Storage heating is strongly associated with fuel poverty
- Consumer experience of current storage heating is acknowledged to be poor
- Poor understanding of controls and tariffs is a key issue
- The metering and tariff arrangements are complex creating added risks
- Hot water provision creates further complexity
- Direct electric heating in the ascendancy
- Why this matters

Storage heaters operate by storing heat produced through electrical heating during periods when electricity is cheapest, traditionally during Economy 7 hours (midnight to 7am). The heat, which is stored in bricks inside the heater, is then released gradually over the following day. Some systems also provide for an additional input boost in the afternoon.

Night storage heaters were first introduced in the 1960s to take advantage of what was then a significant baseload of generation from nuclear power. In Scotland this was aligned with a major programme of social housing development by the Scottish Special Housing Authority. The result of such a high uptake of storage heaters was that by the 1980s some areas ended up with the peak load being at night. The Radio Tele-switch System (RTS), which uses BBC long-wave radio signals, was introduced to address this and to allow scheduling of these heating loads to be spread to avoid the need for costly network reinforcement.

A small but significant number of homes have storage heating today

According to the Ofgem 2015 Insights Paper³ on homes with electric and other non-gas heating there were around 1.8m electric heating households in England (8%) at that time, with a higher proportion in Scotland, 0.3m (13%), and lower proportions in Wales, under 0.1m (5%).

Of the total 2.2 million electric heating households, at that time the majority (1.7m) used heating systems with the capability to store heat.

Since that paper was produced (using data from 2013), the number of homes with storage heating has fallen, driven in part by action to tackle fuel poverty. Based on the latest (2017-18) English and Scottish House Condition Surveys, around 2.2 million homes across GB are electrically heated, of which around 1.4 million have storage heaters.

Thus, while the number of electrically heated homes has remained constant, a higher proportion of them use direct electric heating rather than storage heating than was the case in 2013. Direct electric heating is cheaper for landlords and developers to install who may not be concerned about the running costs for residents.

The English Housing Survey 2017-2018 shows this is part of a longer-term decline since 1996, when 8% had storage heating falling to 6.1% in 2013 and 5.1% in 2017.

The higher prevalence in Scotland reflects the fact that more properties there are off the gas grid and also a higher proportion are flats where storage heating is more common, as discussed further in section 4.

Storage heating is strongly associated with fuel poverty

Households using electricity as their main fuel for heating are twice as likely to be in fuel poverty compared to gas heated households:

- In England 20.4% of electrically heated homes are in fuel poverty compared to 10.1% using gas;
- 26.5% of all Scots are in fuel poverty, but the figure among electricity users is 51%. The figure for gas users is 23%.

³ <https://www.ofgem.gov.uk/publications-and-updates/insights-paper-households-electric-and-other-non-gas-heating>

This reflects a number of factors:

- A higher proportion of **low-income** households use electric heating than use gas
- A higher proportion of properties that use electricity as their main fuel for heating are in the lowest **energy efficiency** bands. Specifically, properties in Band F/G account for 0.8 per cent of properties using gas, but 22.9 per cent of properties using electricity as a main fuel. In part this is a definitional problem (i.e. electricity use for heating lowers the SAP-rating). However, it is likely that the properties themselves – particularly in the private rented sector - will be less thermally efficient. The NEA projects summarised in Annex 1 generally highlight problems with insulation and draft-proofing that contribute to difficulties achieving adequate warmth with storage heaters.
- The higher **cost of electricity** compared to gas, exacerbated by the fact that social and environmental policy costs are very largely recovered through electricity bills. As the “What is Fair?” report⁴ by Sustainability First highlights, policy costs account for 20.4% of electricity bills but only 1.6% of gas bills. Users of electric heating are therefore paying a disproportionate share of these policy costs.

While storage heating is generally more efficient than direct electric heating because it allows for use of cheaper off peak / “low” rate electricity, the above factors still lead to a strong correlation between homes with storage heating and fuel poverty.

Customers with pre-payment meters and storage heating will pay higher rates again.

Consumer experience of current storage heating is acknowledged to be poor. Citizens Advice Scotland (CAS) have recently highlighted⁵ the experience gap; with 85 per cent of households with mains gas central heating being fairly or extremely satisfied with their heating system, compared to just 42 per cent for those with electric storage heating.

Cost, comfort and control are the key issues.

In response to the Scottish Housing Survey question “does your heating keep you warm enough in winter?” those answering “no never / only sometimes” accounted for 15% for gas, but 33% for electric heating. However, looking at the reasons given, this is again a mix of the heating system itself, the cost of running it and the draughtiness of the property.

Most legacy storage heaters have fairly crude customer controls governing the rate of input or charging of the heaters and the rate at which heat is then discharged through the day.

The storage heaters, particularly older models, start to release their heat as they charge. They will then continue to release heat throughout the day until all heat is expended. Residents find that they are too hot in the mornings and that they are too cold in the afternoons and evenings as the storage heaters do not retain enough heat for use during this time. Residents often have to resort to expensive on-peak direct-acting heating in addition to provide adequate comfort.

The extent to which this is an issue will depend in part on the lifestyle of the residents and there is anecdotal evidence that elderly people are happier with storage heating, in part because they are more familiar with it but also because they are at home all day and hence benefit from the gradual leaking of heat.

Also, as discussed below some of the tariffs that are offered allow for an afternoon boost which significantly helps.

For tenants in rented accommodation there is an additional layer of dis-satisfaction that comes from feeling that they have no choice about their heating system. They are also more likely not to understand how to use the system.

⁴ <https://www.sustainabilityfirst.org.uk/other-publications/what-is-fair>

⁵ <https://www.cas.org.uk/news/satisfaction-gap-between-electricity-and-gas-exposed>

Poor understanding of controls and tariffs is a key issue

The NEA projects summarised in Annex 1 highlight that storage heating is generally not well-understood, with some residents assuming heaters did not work because they didn't heat up as soon as they were turned on – and so were using alternative on-peak electric heating instead.

More generally there is poor understanding of controls and of Economy 7 / 10 tariffs, as reflected in the Citizens Advice "False Economy" report (Sept 2018) on legacy time of use tariffs (which built on their earlier report "From Devotees to Disengaged" (2012)). The primary issues faced by Legacy Time of Use (LToU) customers are inadequate information provision and difficulty in switching suppliers. In a survey of 500 LToU customers, around a quarter were unsure of the hours when the cheaper off-peak rates were available. This could result in consumers inadvertently increasing their costs when changing their usage patterns in an effort to save money.

The report recommends that energy suppliers regularly inform their customers about the hours for which the peak and off-peak rates apply, and what these rates are. They should also provide guidance on how a ToU tariff may or may not fit the customer's lifestyle. The report notes, however, that some energy suppliers do not have detailed information about the meter and its settings for each of their customers. They recommend that this is remedied during routine meter reading visits. However, this does not currently happen and mechanical time-switches that have got out of synch are never identified and can be several hours adrift, resulting in customers paying peak rates for that usage.

In September 2018, Citizens Advice concluded on legacy time of use tariffs that if the long-standing problems of these tariffs were not fixed at that point, then new time of use customers would experience the same frustrations in the future, stating that 'suppliers and regulators need to act now'. 18-months on, research for this paper reinforces that this remains a 'critical gap' in terms of policy and regulatory consideration.

The metering and tariff arrangements are complex creating added risks

When most original storage heaters were installed the industry was still in public ownership and vertically integrated. Arrangements were put in place to enable the distribution networks to schedule the timing of loads to minimise the potential network impacts. Different systems installed at different times often had bespoke arrangements. With the introduction of supply competition, the legacy supplier in each geographic DNO area continued to retain a particular role in controlling the timing schedules. Other suppliers can take on these customers but may struggle to accommodate the various different metering types in their customer service systems. The type of meter that is installed will determine the types of tariffs that can be offered.

Enabling the customer to access cheaper night-time or off-peak electricity requires both a suitable metering arrangement and an appropriate tariff. There are a variety of different metering arrangements still in existence, many with only small numbers of customers. The CMA looked at this as part of its review of the retail market and defined "restricted meters" as "*(a) one Electricity Meter whereby electricity consumption in two or more Consumption Windows is separately recorded on two or more registers; or (b) two or more Electricity Meters (each with one or more registers) installed in the same premises whereby electricity consumption for distinct purposes is separately recorded on such Electricity Meters*".

Thus, in broad terms the meters (and associated tariffs) can be grouped into categories as:

- **Economy 7 meters** – a single meter but with two registers which records the units used separately for day and night rates, with the tariff allowing 7 hours of cheaper night rate charging. In this case the switching of the heating system will typically be done by a separate manual clock and all the customers off peak usage is charged at the lower rate (what is sometimes called "whole house switching"). **Economy 10** meters are similar but the tariffs provide for 10 hours of cheaper rate usage often including an afternoon boost. Some suppliers say that Economy 10 is not suitable for storage heating⁶ while others recommend it⁷;

⁶ <https://sse.co.uk/help/electric-heating/economy-10>

⁷ <https://www.ovoenergy.com/guides/energy-guides/economy-10.html>

- **Two meters working in combination** – one linked to a separate circuit for heating / hot water (at night / off peak times) and one to a circuit for other uses (which can be a single rate meter or can be again Economy 7). In this case the switching of the heating load can be either manual or managed through the meter.

- **More complex arrangements involving RTS** – which can include separate meters with separate Meter Point Administration Numbers (MPANs) and/or three tariff rates (peak, off-peak and heat). This includes the SSE Total Heat Total Control arrangement⁸, where in addition to the storage heaters being charged at times set by the supplier (taking account of the weather), there is provision for cheap rate heat for panel heaters, towel rails etc. However other electricity use is more expensive than standard rates. Scottish Power have a similar arrangement known as Comfort Plus Control⁹. These more complex arrangements rely on messages being sent over the RTS network to the meter to control when the heating / hot water is switched on and off. Having two meters can result in customers paying two standing charges.

Where a meter has more than one register, there needs to be a way of controlling when units are recorded on the different registers. Similarly, where a restricted meter only operates at certain times of the day, the electricity supplied through that meter must be switched on and off. This switching process might be controlled remotely by radio signal (ie tele-switched) or locally (mechanically or electronically) through a separate time-switch.

Tele-switching itself can be either dynamic, semi-static or static. With dynamically tele-switched (DTS) meters, the operational times and charge duration can be changed – on the instructions of the original host supplier. With semi-static tele-switching, operational times change periodically but infrequently, e.g. when the clocks change. With static tele-switching the times do not change but the RTS is simply used to ensure the timeclock maintains an accurate time.

The extent of usage of the RTS today remains somewhat unclear. According to figures from the ENA¹⁰ there are 190k used dynamically, 105k used in a semi-static mode and 1.36 million meters that use RTS statically. Ofgem figures reproduced in Annex 2 suggest 330k DTS.

The complexity of these arrangements mean that customers do not generally understand them. In particular they often do not understand how to use the heating controls nor how these relate to their tariffs. Moreover, they are at risk of significant detriment if meters or appliances, have incorrectly set time clocks, are wrongly wired or if they move onto an inappropriate tariff. Citizens Advice have published a Good Practice Guide¹¹ aimed at encouraging suppliers to provide better support to customers on these more complex arrangements.

There are some informative self-help forums online¹² dealing with the complexities of tariffs and different wiring arrangements, but these nonetheless largely serve to highlight the complexities and different set-ups involved. They are also aimed at those who are already pretty engaged and informed consumers looking for more information.

Customers with restricted meters also face barriers to switching suppliers and to switching tariff type. The Competition and Market Authority's (CMA) 2016 investigation into the energy market highlighted the problems customers with restricted meters face engaging in the market¹³. Following their report, energy suppliers are obliged to offer a standard rate tariff to customers with restricted meters and to provide a

⁸ <https://sse.co.uk/help/energy/meters/types-of-meter>

⁹ <https://www.scottishpower.co.uk/energy-efficiency/energy-efficiency-toolkit/electric-heating/>

¹⁰ <https://www.energynetworks.org/assets/files/news/consultation-responses/Consultation%20responses%202016/Consultation%20on%20RTS%20Access%20provision%20from%201%20January%202018.pdf>

¹¹ <https://www.citizensadvice.org.uk/about-us/policy/policy-research-topics/energy-policy-research-and-consultation-responses/energy-policy-research/good-practice-guide-supporting-customers-with-restricted-meters/>

¹² <https://www.diynot.com/diy/threads/timer-for-economy-7-storage-heater.532309/>

¹³ https://assets.publishing.service.gov.uk/media/56ebdec8ed915d117a000000/Appendix_3.1_-_Restricted_meters.pdf

standard meter to assist switching. However, they are not required to offer the same off-peak tariff or the same metering arrangements as the customer had previously.

Hot water provision creates further complexity

Most homes with storage heating will also have immersion tanks for hot water that can also be heated at off peak rates. However, this adds a further layer of complexity.

Arrangements vary as to whether the hot water is included on the heating circuit or wired as part of the main circuit with the off-peak rate applied based on a separate timer being used. If customers manually adjust the timer for hot water provision (or if the timer gets out of synch) they can end up paying much higher peak rates.

Moreover customers on off-peak rates who have a hot water tank over-sized for their needs (if, for example, they have an electric shower and do not take baths) will be paying to heat hot water they do not use. This is compounded by the fact that most wet appliances are cold-fill these days. Some consumers are aware of this and will only switch on their hot water every 3-4 days.

Direct electric heating in the ascendancy

As noted above while the number of homes with storage heating has been falling the number using direct-acting electric heating (e.g. panel heaters, oil-filled radiators) has been rising. The reasons for this include:

- The lower purchase and install costs make them more attractive to private landlords and developers who may disregard the running costs for residents (and compared to gas heating they are a “fit and forget” solution for landlords with no requirements for maintenance or gas safety checks);
- Within the home owner market there are some providers who position them as a replacement for storage heaters and it can be hard for consumers to navigate through the different options. One company in particular has had 11 Advertising Standards Association (ASA) complaints upheld over a period of 5 years¹⁴ and fuel poverty organisations have talked about the increased bills customers have seen and instances where they have had to go in and remove what are effectively new heaters that have been mis-sold.

While direct-acting heating can be problematic in these scenarios, it can also have a valuable role either as a supplemental source of heat alongside storage heating (eg in less frequently used rooms) or in small, very well insulated homes as the primary form of heating.

Why this matters

With the imperative to de-carbonise heat and the growing emphasis on system flexibility, smart storage heaters and hot water could and should form a part of the landscape going forward (as set out in section 3). It is also critical to ensuring “no-one is left behind” in the transition to net zero, given the demographics of those with storage heaters today (as explored further in section 4). Getting things right for today’s storage heating consumers is essential to protect some of the most vulnerable in society, who already face some of the highest charges for their energy and are often least able to participate in the market. But getting things right for storage heater customers is also vital in paving the way for an alternative form of electric heating that helps fill an important, and not insignificant, space in the heat-de-carbonisation landscape.

¹⁴ <https://www.asa.org.uk/rulings/fischer-future-heat-uk-ltd-A19-1033945.html>

2 Developments in Smart Storage Heating and Hot Water

- New technology storage heating – smart and less leaky
- Retrofit of smart technology can add some value
- Combinations of technology could be interesting
- In all projects the people dimension proved critical
- And hot water tanks are getting smarter too
- EU standards demand smarter heating technology
- Smart controls are developing more widely

While the previous section set out the issues with legacy storage heating, modern smart storage heaters are now available which deliver a much improved consumer experience and lower cost. A number of pilot projects have been carried out using these new appliances, including the RealValue Horizon2020 project, NINES in Shetland and a large number of smaller projects led by National Energy Action. These various projects are summarised in Appendix 1 and key lessons drawn out below.

New technology storage heating – smart and less leaky

The latest Dimplex Quantum heaters retain the heat much more effectively and are recognised in the government's SAP scheme as a 'High Heat Retention Storage Heater', offering reduced running costs and improved energy efficiency ratings.

The Quantum heaters also have smart controls that allow households to programme the required temperatures for different rooms at different times up to a week ahead. This includes some standard settings such as "away from home". The system then uses this information, together with external temperature projections and information on the previous day's usage, to determine how much to charge the heaters and when to release the heat.

Glen Dimplex claim that these two improvements (smart and less leaky) can provide savings of 27% compared to traditional storage heat.

All the projects carried out confirmed that customers generally experienced improved comfort and control and were satisfied with the new arrangements. The case studies include some very positive statements showing the impacts of being able to heat more rooms, including the wider benefits to health and wellbeing. Aesthetically they were seen as more attractive.

However, in most cases steps were not taken to collect information on previous bills, which made any comparison of the cost savings difficult. That said, the general assumption is that the more modern heating systems will be cheaper to run but that in some cases households will have taken this benefit in improved comfort.

Similar anecdotal feedback has been received from a number of housing associations who have been installing high heat retention storage heaters as part of their SAP driven retrofit programmes.

Retrofit of smart technology can add some value

Another option available from Connected Response (co-founded by Kenny Cameron ex Vcharge) is to utilise smart technology to improve the operation of existing storage heaters – a more affordable option for local authorities than replacing the heaters themselves. Again, the technology uses weather forecasts, internal temperature and resident comfort requirements to calculate the level of input and output required (rather than customers having to set this themselves). The system can also set charging to start later in the night, rather than the default charging to start at the beginning of the Economy 7 period (typically around midnight), which reduces potential heat-leakage. Timings can also be optimised taking account of wholesale energy prices to enable the supplier to reduce their costs of providing the service and also provides the potential for a day-time boost.

The conclusion from the trials discussed in Annex 1 is that retrofit of smart technology can have significant impact on comfort levels just through improved control – but with more limited scope for actual cost saving

without improved thermal insulation of the heaters themselves (i.e. replacement with high heat retention storage heaters).

The Connected Response retrofit arrangement was pioneered by Westminster City Council and Energy Assets in 2015 and the technology is now part of the Connected Response range with interest from other councils with blocks of flats that they are looking at updating.

Combinations of technology could be interesting

One project being led by Warm Works in Scotland is using storage heating with batteries together with the Octopus Agile tariff in 150 housing association homes. The battery stores electricity when it is cheapest and then uses it to charge the storage heater as required. This is seen as a way to enable top-ups of heat during the day. While the project has not yet been evaluated, one early benefit was during Storm Chiara when the network was down but these homes retained power (as an islanding capability had been built in with the batteries)

In all projects the people dimension proved critical

The Real Value project concluded that in the interests of customers and for projects to succeed it was about:

- Comfort – maintaining warmth
- Cost – and availability of suitable tariffs
- Control – to balance cost and comfort
- Care – additional advice and support
- Connectivity

All the pilots of smart storage heating have involved a degree of hand-holding of customers that wouldn't normally feature – and in all cases that was seen as crucial to ensuring that customers make proper use of technology to deliver the cost and comfort they desire.

While installers (and possibly manufacturers) can play an important role up front, there is a real question about where the ongoing support that is really needed should best come from. In Scotland, Home Energy Scotland plays this sort of role but there was a strong sense from those working on the ground that a central repository of information is needed to enable frontline advisers to be effective in what is a complex area.

CSE in their “Smart and Snug” project have been looking at how granular usage data can be used to indicate how the heating system is being used and enable advisers to see what is happening and explain it to customers.¹⁵

There has been a lot of discussion around the potential for heat as a service¹⁶ and how such a model would provide a clear service contract by which the customer could raise any issues, whilst also framing the proposition in terms that customers can understand regarding the heat level they require.

As well as the issues with the controls on the heaters, it is also important that customers are on the right tariff i.e. Economy 7 / 10 (or some other suitable time of use tariff). As highlighted above customers, currently have a low awareness of how these tariffs work. Citizens Advice and Sustainability First continue to press for Economy 7 etc to be used to test what good engagement and “treating customers fairly” looks like in the context of ambitious plans for DSR and more sophisticated TOU tariffs.

This tariff issue and the provision of better advice and support urgently needs to be addressed for existing storage heater customers. It is picked up again in section 8 in the context of the RTS de-commissioning and the smart meter rollout.

And hot water tanks are getting smarter too

Very limited research has been done to date on hot water tanks and there have been limited technological improvements beyond insulation. However this is starting to change.

¹⁵ <https://www.cse.org.uk/projects/view/1333>

¹⁶ <https://es.catapult.org.uk/news/ssh2-introduction-to-heat-as-a-service/>

Research by Oxford led to the spin-off of a new boiler design by Mixergy (which British Gas has invested in) which allows:

- you to heat the amount of water you need (rather than progressively heating the whole tank);
- you to see how much hot water there is;
- more hot water to be provided from the same size tank;
- fortnightly sterilisation to be carried out by full heating (as required by HSE);
- user control via an IoT and smartphone app.

As highlighted in Annex 1 there are a number of other projects looking at the use of hot water tanks for providing demand side response, funded by BEIS.

There is also some renewed interest in the potential for electric hot water tanks with a brick core to be used to provide heating through existing wet radiators which might provide a less disruptive solution for some households.

Finally, there are also other innovations around thermal storage such as the SunAmp heat battery which, through the use of phase-change material (like that used in hand warmers), can provide a supply of hot water but with a smaller demand on space than a hot water tank.

EU standards demand smarter heating technology

Lot 20 of the EU Eco-Design Directive Electric covers heating systems apart from electric boilers (which are covered separately). This came into force on 1 January 2018 setting minimum standards for new heating systems. Given these requirements are now in UK legislation it is to be expected that they will continue post Brexit.

In addition to improved efficiency requirements, there are several 'smart' control features which must be present on local electric space heaters. Lot 20 specifies that these should use existing, non-proprietary technologies and should therefore not increase the combined costs of purchasing and operating the systems.

All heaters falling within the scope of Lot 20 must now include all of the following features:

- Electronic room thermostat
- 24/7 programmable timing control
- Labelling specifying the power consumption for heating and for auxiliary systems (i.e. fans and controls)

Storage heaters must include all of the following features:

- Electronic heat charge control reacting to either the room or outdoor temperature
- Electronic room temperature control and 24/7 programmable timing control
- Fan assisted output.

In addition, all direct-acting heaters must include at least one of the following features:

- Open window sensing to cause the product to shut down if a sudden temperature reduction is measured
- Adaptive start control to initiate heating at the appropriate time to reach the desired set point at the desired time without overheating or reaching the set point too early
- Distance control to allow remote system interaction, e.g. via an app

Infrared heaters have three additional options for fulfilling this requirement:

- Presence detection to cause the product to shut down if no one is present in the room
- Black bulb sensor to measure the air and radiant temperatures
- Working time limitation to automatically shut down the product after a set time

This framework can be expected to lead to progressive improvements in the standards of electric heating of all forms and a significant step change from the legacy storage heaters of old. All new heaters will have to be smarter.

That said there are also some concerns voiced by storage heater manufacturers about the unintended consequences of Lot 20 rules which would merit further consideration by BEIS. In particular:

- there is a risk that these new rules add significant costs to storage heating which then push people into taking up the less efficient direct heating options;
- for example, the requirements for improved insulation in the heater mean that the heat from storage heaters is no longer simply diffused heat but needs to be produced using a fan adding cost (and potentially also noise);
- the more complex controls can be more than is required in some settings (eg for student accommodation where most of the control might be managed centrally, or for heat as a service) or to make the interface more consumer friendly (perhaps for older customers);
- even with this prescribed smartness the heaters do not have to be externally controllable in the way that would be needed to provide flexibility services to the grid.

Smart controls are developing more widely

The sorts of smart controls now being offered by, for example OVO on its storage heating app, are in line with the trends for more use of smart thermostats across all forms of heating. Indeed, the provision of room by room temperature choices arguably goes further than many smart thermostats today.

While app-based interfaces may not work for all customers – and some will still not want to adjust settings – they are valuable in allowing people to feel that they do have control and can use it easily if needed.

Given the importance of controls, developing a good user interface is critical and storage heating should benefit from wider developments and learning in this space.

3 Heat de-carbonisation – looking to the future

- Heat de-carbonisation is a major challenge as we move to net zero
- Current heat de-carbonisation pathways largely ignore storage heating
- Similarly, little attention is paid to hot water
- All the major studies assume high levels of flexibility and thermal storage – which storage heating could provide
- Studies that do look at storage heating identify a niche role it can play
- The scope for heat pumps as a source of flexibility has not been fully explored
- This is not to suggest electric storage is a universal solution
- Although in any scenario the role of hot water needs more attention

Heat de-carbonisation is a major challenge as we move to net zero

One of the major challenges facing the UK in its aim of meeting a commitment to net zero greenhouse gas emissions by 2050 (and 2045 in Scotland) is how to de-carbonise heat. Emissions from domestic heating account for 14% of UK carbon emissions and the winter peak presents a particular problem as shown in Figure 1 below. Given that 84% of homes currently use gas for heating, to decarbonise heat entirely through electrification would involve around a six-fold increase in the electricity capacity to cope with that peak alone and there are additional challenges created by the sharp ramp-up in the morning, when gas heating systems kick in (which are currently handled by the gas stored as line pack in the pipes).

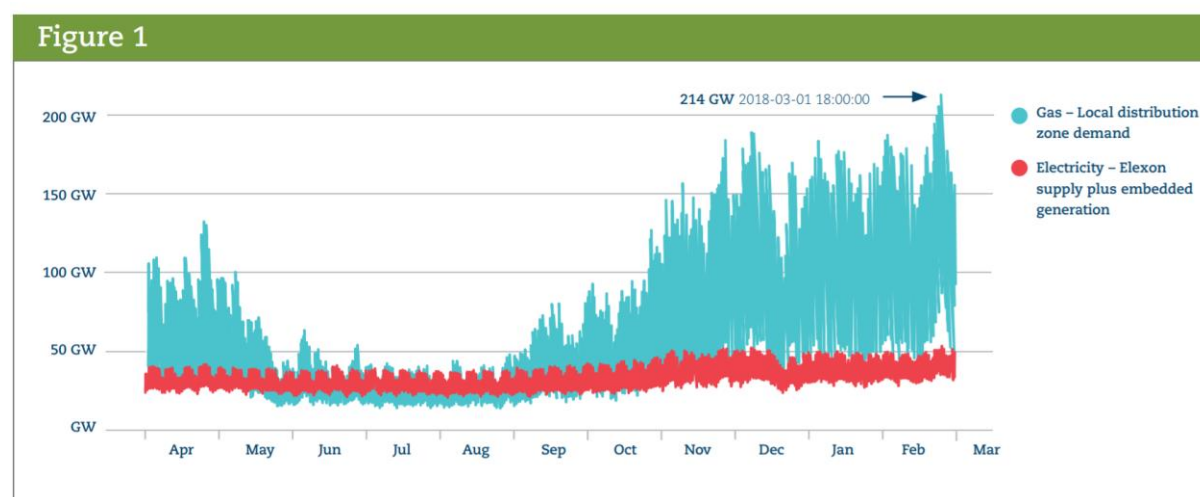


Figure 1: Britain's hourly local gas demand and electrical system supply, 2nd April 2017 - 6th March 2018.

Heat de-carbonisation is also particularly challenging because it involves people in their homes potentially having to undertake costly and disruptive work and because people with gas boilers have got very used to the instant heat that they provide. While there is growing support for action to tackle climate change there is very little awareness of the need for and options around heat de-carbonisation. As Carbon Connect said in its report *Uncomfortable Home Truths*¹⁷, “Heat is also an area of climate change policy which may require contentious decisions that involve changes to people’s homes. There is not currently a strategy for understanding and integrating public attitudes into policy around low carbon heat to ensure these decisions have public consent”.

¹⁷

https://www.policyconnect.org.uk/cc/sites/site_cc/files/report/730/fieldreportdownload/uncomfortablehome truthsfuturegasseriespart3.pdf

At present there are essentially two options for de-carbonisation of heat: either electrification (which is taken as meaning heat pumps) or converting the gas grid to hydrogen – or a combination using hybrid heat pumps (with gas used for peaks). There is also some interest in the role district heating could play, particularly in high heat density urban areas. BEIS have committed to taking a policy decision on the heat de-carbonisation pathway in the early 2020s and are currently supporting innovation and pilot projects to build the evidence base to inform that decision. In the meantime off gas-grid properties are seen as a priority for low regrets action given that hydrogen is not an option for them.

In terms of the costs of the different options, the Committee on Climate Change cite the finding in the report Imperial prepared for them that overall system costs are similar regardless of the heat decarbonisation pathway. This is in contrast to previous findings in a [2016 KPMG report](#) (funded by the gas networks and which concluded that repurposing the gas grid was cheaper) but is in line with more recent work by [Element Energy and E4Tech](#) for the National Infrastructure Commission.

Given there is no clear winner in terms of technology, the growing consensus is that the eventual solution will be a mix, with the appropriate technology varying depending on geography, housing type, local energy resources, household choice etc. This view is espoused by the Energy Systems Catapult, who have placed an emphasis on Local Area Energy Planning¹⁸ including pilot studies in three areas looking at the appropriate technology at a local level and bringing in a whole systems perspective. Ofgem have reinforced this message in their guidance on business planning for RIIO2. Similarly, Element Energy and E4Tech for the National Infrastructure Commission (2018) Cost analysis of future heat infrastructure¹⁹ note that it is highly likely that a mix of heat decarbonisation options will occur across different regions and building types. Finally, a recent report by Navigant²⁰ for the ENA talked about a balanced scenario and drew out the potential for hydrogen clusters with domestic hydrogen building out from industrial clusters in locations suitable for hydrogen production and carbon storage.

Current heat de-carbonisation scenarios largely ignore storage heating

While there remains considerable uncertainty around the future of heat, one common feature of all the studies that have been done is that they largely ignore the potential role of electric storage heating when considering an electrification pathway:

- The Committee on Climate Change CCC- Net Zero Report²¹ includes only a single, very brief reference to storage heating.
- The National Grid Future Energy Scenarios (FES) for 2019 all show electric storage heating flat or declining.
- The BEIS evidence report includes only a few peripheral mentions of storage heating.

The only serious consideration of electric storage heating is the CCC work (discussed more fully below) on hard to de-carbonise homes.

Similarly, little attention is paid to hot water requirements

In the BEIS report pulling together the evidence on heat decarbonisation²² the department acknowledges that “relatively little is known about the need for hot water storage in UK households”.

Other reports, such as Element Energy and E4Tech for the National Infrastructure Commission (2018) Cost Analysis of Future Heat Infrastructure²³ frequently mention “space heating and hot water” – but no separate drivers are discussed and the issue of hot water tanks is not mentioned.

¹⁸ <https://es.catapult.org.uk/news/ssh1-local-area-energy-planning/>

¹⁹ <https://www.nic.org.uk/publications/cost-analysis-of-future-heat-infrastructure/>

²⁰ <http://www.energynetworks.org/assets/files/gas/Navigant%20Pathways%20to%20Net-Zero.pdf>

²¹ <https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf>

²² <https://www.gov.uk/government/publications/heat-decarbonisation-overview-of-current-evidence-base>

²³ <https://www.nic.org.uk/publications/cost-analysis-of-future-heat-infrastructure/>

All the major studies assume high levels of flexibility and thermal storage. In the National Grid 2019 Future Energy Scenarios (FES) they have assumed 25 per cent of homes have some form of thermal storage (equivalent to the current proportion with hot water tanks) and that legislation and technology will develop from the mid-2020s so that this heat storage starts to be used to reduce heat demand at peak. However, they acknowledge that the speed at which residential flexibility grows will depend on a number of factors including the number of heat storage systems in homes, such as hot water tanks.

In the faster decarbonising scenarios, they assume that by 2040, homes with heat storage do not use any electricity for heating over peak periods, instead drawing all heat from storage systems.

The report by Imperial which underpins the costs used by the CCC²⁴ notes that:

“.. if heat demand is supplied by electric heating, reducing the peak of heat demand by preheating or using thermal storage can reduce the required firm generation capacity... The ability to shift thermal load provides significant benefits through reducing system peak capacity requirement and the associated costs ... The modelling results demonstrate that in the absence of thermal storage and other flexibility sources, there would be a need for more than 55 GW of new electricity storage as well as substantial additional power system capacity in the Electric scenario”

Similarly, the Energy Systems Catapult note that *“Thermal storage in homes could help manage the demand placed on energy networks and reduce peaks by providing greater flexibility when energy is supplied and used in the home. However, the thermal storage capacity required is typically larger than could be provided by the space available for hot water storage in most homes.”*

Invariably the assumption is that the thermal storage would be provided by hot water tanks (or buffer tanks) rather than electric storage heaters. While clearly hot water tanks offer a year-round source of flexibility, storage heaters could still provide a valuable source of flexibility to help manage the winter peak.

Of course, thermal storage can be provided by the building itself if it is sufficiently well insulated and highlights why improving energy efficiency should be a priority in the UK when our housing stock is so poor.

Studies that do look at storage heating identify a niche role it can play

A report by Element Energy and UCL²⁵ for the CCC's net zero study looked at various categories of “hard to de-carbonise” properties including those that are space constrained (ca. 13% of the housing stock) and Heritage properties (listed buildings and those in conservation areas). These properties were not suitable for individual heat pumps. The report concluded that in the “speculative” scenario, electric storage heating was a suitable solution for 70-80% of these properties (with communal heating systems using air source heat pumps accounting for most of the rest).

They describe “speculative” as options that currently have very low levels of technology readiness, very high costs, or significant barriers to public acceptability. While this is not what the authors intended, to put electric storage heaters in this category would be somewhat perverse – and would mean that they would not be rolled out until 2045.

Overall they envisage a total of 1.6 million homes using electric storage heating, but with over a million falling in the “speculative” category because of the high carbon abatement cost.

Given that an urgent question is what to do about the 1.4 million homes with storage heating currently it would be helpful if future work in this area could clarify whether upgrades of these would be an acceptable low carbon option (entailing much less disruption).

The report finds that the most costly 10% of homes to de-carbonise (with an average cost of abatement of above £418/tCO₂e) are primarily small or medium properties, with insulated walls and roofs. Homes with

²⁴ <https://www.theccc.org.uk/publication/analysis-of-alternative-uk-heat-decarbonisation-pathways/>

²⁵ <https://www.theccc.org.uk/publication/analysis-on-abating-direct-emissions-from-hard-to-decarbonise-homes-element-energy-ucl/>

small heat demand have a smaller potential for carbon abatement than homes with larger heat demand. Moreover, the capital cost of the installed heating system per unit of heat delivered is assumed to be higher for homes with a small heat demand than it is for homes with a high heat demand. Whether this is the case in practice will depend on the level of fixed costs and how the system is configured. It will also depend on the value assumed for flexibility in future and this is an angle that Element Energy will be exploring further in an updated report for the CCC work on the 6th carbon budget.

The report assumes high fixed costs for electric storage heating associated with metering and internal wiring and appears to assume one heater per room although in small properties that may not actually be necessary. Intuitively direct electric heating or storage heating should be more scalable and hence more suitable for smaller properties than a central boiler or heat pump.

This was the conclusion of the NEA report²⁶ “Heat Decarbonisation: Impacts on Social Equity and Fuel Poverty”, which looked separately at installation, system and running costs for different heating solutions and found that electric storage heating (which has lower up-front costs but higher running costs than a heat pump) was particularly suited to small modern flats with a heat load below 7.5 MWh as shown in Figure 2 below:

A CCC blog²⁷ in 2018 reiterated this message (although it does not seem to be reflected in their main reports):

“In some smaller or very efficient flats, new generation storage heaters offer a highly flexible and low-cost solution for meeting small space heating loads”.

Similarly, the ESC Local Area Energy Systems report finds nearly 10% of homes with a surface area under 50m² would be best served by electric storage heating in their Newcastle study.

The Element Energy report recommended further research to better understand the physical and consumer preference factors contributing to space constraints, to better characterise this segment of the stock and what solutions will be required to address this issue. We would reinforce this message.

The BEIS summary of evidence on heat gave this work a brief mention:

“Direct electric heating systems, such as storage heaters, can also be used to convert electricity to heat. As referenced in Element Energy & E4Tech’s work for the National Infrastructure Commission, whilst they are less efficient than heat pumps, they can be applied across most of the UK’s building stock without the need for the energy efficiency upgrades which may be required with heat pumps.” Clearly energy efficiency upgrades should be a priority in all properties to reduce costs and system demands – the point here is that without them heat pumps cannot provide adequate comfort. Direct electric can but would be very costly.

BEIS also commissioned Element Energy²⁸ to review the electric heating options (excluding heat pumps) for off gas grid areas. This showed that of the available direct electric heating options storage heaters were the most efficient – and indeed for larger homes this saving was greater. This is a result of being able to access an off peak (Economy 7) tariff.

The scope for heat pumps as a source of flexibility has not been fully explored. As discussed above, in most reports it is simply assumed that adequate thermal storage will be available to provide the necessary system flexibility alongside heat pumps.

²⁶ <https://www.nea.org.uk/resources/publications-and-resources/heat-decarbonisation-potential-impacts-social-equity-fuel-poverty/>

²⁷ <https://www.theccc.org.uk/2018/09/10/cleaning-up-the-uks-heating-systems-new-insights-on-low-carbon-heat/>

²⁸ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/831079/Electric_heating_options_in_off-gas_grid_homes.pdf

One study that explores this more fully is the Energy System Catapult study²⁹ of 5 typical houses. This does not mention storage heaters but talks about the value in load shifting (while noting the risks of creating new peaks). More critically it notes that heat pumps are not inherently flexible:

“Heat pumps operate more efficiently over sustained periods, rather than frequent on/off cycles and power modulation, particularly if a continuous low base-load strategy encourages installation of smaller capacity heat pumps. Hence it is recommended that the heat pump is operated at fixed output as much as possible, switching off or reducing power during peak times, and using thermal storage to buffer the output and match it to household heat demand.”

The report is also quite realistic about the levels of thermal storage that would be required and the challenges this presents:

“Reducing or entirely eliminating power draw from the heat pump during the evening peak demand period is possible with technically feasible quantities of storage of approximately 20 kWh. This will require a hot water cylinder of around 9 kWh, 2-3 times larger than the one familiar to householders if sized for the coldest days in winter”.

One reason that hybrid heat pumps have been seen by many as a positive development is that they offer a way to allow more flexibility by switching to gas at times of stress on the electricity system.

The potential flexibility that can be provided with heat pumps will probably be rather different to that available from storage heating (which in turn may well be different from what storage heating has historically provided). More work is needed to understand what flexibility services each could offer.

This is not to suggest electric storage heating is a universal solution

One of the reasons that electric storage heating is often dismissed in the de-carbonisation debate is that studies modelling single technology pathways reach the unsurprising conclusion that if all homes were on electric storage heating then the peak would shift to night time and additional network infrastructure costs would be required.

For example the National Infrastructure Commission (NIC) argue:

“In some of the scenarios set out here, a very large uptake of electric heating is modelled, leading to an additional electrical load (at whatever time of day heating is carried out) of the 10s of GWs. This would quickly saturate the benefits of peak avoidance – for example, an additional 30 GW of electricity demand at night would be likely to lead, hypothetically, to a new peak during the night. In this case, any electricity pricing differentials would adapt accordingly with the objective of redistributing demand. Thus, in these scenarios the impact on the electricity distribution, transmission and generation system due to peak demand increase is found to be a significant challenge”.

Another line is that the acknowledged higher efficiency of heat pumps means that a full reliance on electric storage heating would place much greater demands on the system. For example, the Imperial study notes that

“Heat pumps cost more but are more efficient than resistive heating (an average of 270% efficient compared to 100% for resistive heating); therefore, the model is used to determine the optimal portfolio of investments in heat pumps and resistive heating. Generally, heat pumps are used to supply ‘baseload’ heat while high temperature heat demand (e.g. hot water) is supplied by resistive heating, as this portfolio of heat devices minimises the overall system investment and operating costs.”

Similarly, the NIC report concludes that

“Storage heating is an alternative electrification option to heat pumps, with a quite different cost profile. While the capital cost of the installation is substantially lower, the ongoing electricity cost is much larger due to the lower efficiency. The lower efficiency also means that this option requires greater investment in electrical grid

²⁹ <https://es.catapult.org.uk/news/pathways-to-low-carbon-heating-dynamic-modelling-of-five-uk-homes/?download=true>

reinforcement and electrical generation than the heat pump option, and also that a lower level of decarbonisation is reached for the same level of deployment”

And the BEIS evidence report, argues similarly:

“Direct electric heating systems such as storage heaters are typically much less expensive to buy and install than heat pumps. However, they consume considerably more electricity, with potential impacts on peak electricity demand...”

However, the fact that storage heating does not make sense as a universal solution does not mean that it cannot have an important role to play as a more flexible electric heating solution (for example in geographies where that is important to manage network constraints) or as a more cost-effective solution for smaller properties.

As noted above, most commentators now accept that the appropriate heating solution will vary by geography. Taking this one step further, the ESC 5 homes report argues that: “The transformation of domestic heat will not be achieved with a one-size-fits-all solution for every UK dwelling. Each home has a unique combination of building type, size and fabric, householders, neighbouring properties and space, location, and other factors which present different requirements and constraints and on the design of any changes necessary to reach satisfying, low carbon provision of heating”

Furthermore, earlier work by the Energy Systems Catapult³⁰ highlights the very different behaviour patterns of consumers in terms of hours that they heat their home, the proportion of rooms they heat, the temperature that they prefer and the level of control they want. The cost effectiveness of different solutions will vary depending on these factors as well as the building properties.

While it does not make sense for households to regularly change their heating system, helping consumers identify the system that is most likely to deliver what they want and is most suitable for their property is likely to be crucial in the difficult challenge of engaging consumers in de-carbonising heat.

In any scenario the role of hot water needs more attention

As discussed above, hot water tanks are seen as important alongside any electric heat solution (including hybrid heat pumps) to provide a source of hot water and essential system flexibility.

The current trend towards removal of hot water tanks noted below only makes the de-carbonisation of heat more challenging and hence there is an urgent need to reverse this trend.

In the Clean Growth Strategy, the government committed to consulting on introducing measures for new homes which would make it easier to install low carbon heating in future such as making provision in terms of space for hot water storage. However, in the current consultation on a Future Homes Standard³¹ for new homes MHCLG seek views on requiring low temperature emitters (i.e. radiators) as a way of future proofing homes but do not propose anything on hot water storage. Indeed, the proposed regulations actually penalise any form of thermal storage. While in many (small) new homes, with showers not baths, instantaneous hot water may be sufficient. However, in larger properties, without a hot-water tank, one would be forgoing an extra source of flexibility – and making it harder to shift to a heat pump in future given the assumptions set out above around the need for thermal storage to help cope with the additional demands on the electricity system.

³⁰ <https://es.catapult.org.uk/news/smart-energy-services-for-low-carbon-heat/?download=true>

³¹

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/852605/Future_Homes_Standard_2019_Consultation.pdf

4 The GB Housing Stock and Future Heat Choices

- Size (and space) matters – will heat pumps fit?
- Size (and energy efficiency) matters – what's most cost effective?
- Significant numbers of (mainly smaller) properties currently rely on storage heating
- Because they are smaller they use less energy
- There is scope with more energy efficient housing for more use to be made of storage heating
- The social dimension means the issue cannot be ignored
- Hot water tanks are an endangered species that needs protecting
- More thought needed on institutional residential properties

As discussed above, the idea that the approach to heat de-carbonisation will involve a mix of technologies is starting to be accepted, but to date there has been limited work looking at the sorts of properties that are best suited to different solutions. Although often dismissed as simply a part of the wider implementation challenge, it is important to acknowledge the practical requirements for heat pumps to be an effective solution for a particular property.

In looking at the potential role of heat pumps, the size and space in the property (internal and external) is a key consideration. It matters both in terms of the physical practicality of installing a heat pump and also the cost structure in terms of the balance of upfront and running costs. While some small, energy efficient homes have been identified by the CCC as “hard to de-carbonise”, using heat pumps the range of properties where storage heaters (or even direct electric heating) could be more efficient is potentially somewhat wider – especially if insulation is improved as is likely to be necessary anyway for a heat pump to provide adequate comfort.

Size (and space) matters – will heat pumps fit?

On the physical space requirements, the BEIS evidence report says: *“Heat pumps typically transport heat through a lower temperature distribution system than gas fired systems. They may therefore require larger emitters (such as radiators or underfloor heating), and good levels of insulation, to operate efficiently and provide adequate thermal comfort. They may also involve a number of other practical requirements, for example space for the outdoor and indoor unit, and hot water storage. Ground source heat pumps require a suitable area of ground to either dig trenches or drill a borehole (between 15 and 100 meters deep).”*

Similarly the Greater Manchester Smart Community Demonstration Project³² also highlighted the unsuitability of heat pumps for heating “hard-to-treat” properties. For example, the demonstration project found that where properties lacked the space for installation works, or were poorly insulated, they could not install heat pumps, as was the case for 19.5% of the properties in the project. In these cases they concluded that other electric heating systems such as high-temperature heat pumps, hybrid heat pumps or storage heaters might deliver the heating service required whilst avoiding potentially disruptive or difficult ancillary works.

In the Element Energy Hard-to-Decarbonise study they developed a representation of space constraints based on the metric of ‘available dwelling floor area per habitable room’. In the absence of better data addressing the prevalence of space constraints, this metric was deemed to be a useful identifier of homes most likely to value the available space in the home. The metric was deemed a better single identifier than simply total floor area as Element Energy considered it better represented the available space per occupant and therefore better reflected the space constraints occupants are likely to experience (assuming the number of habitable

³² The Carbon Trust and Rawlings Support Services (2016) Evidence gathering – Low Carbon Heating Technologies: Domestic High Temperature, Hybrid and Gas Driven Heat Pumps
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/565248/Heat_Pumps_Combined_Summary_report_-_FINAL.pdf

rooms would correlate with the number of occupants). While there is some logic in this it is far from clear that every habitable room will be occupied (given levels of under-occupancy) and the heat pump or water tank is a shared resource so the more rooms there are in the property the easier it will be to accommodate. Even where theoretically there is space for a heat pump, customers in smaller properties are likely to be particularly concerned by the loss of space (and visual impact).

For this reason, the analysis carried out later in this report looks at overall floor space whilst acknowledging the insights provided by the Element work.

In their modelling, the threshold for a building to be considered space constrained was set at 16 m²/room, chosen to capture the 20% 'most space constrained' homes in the stock by this metric. As noted above these homes were identified as more suitable for storage heating but with a high cost to de-carbonise (meaning this was viewed as a "speculative" solution).

The Element Energy report argues that there is a need for innovation funding to support the development of space saving technologies such as thin internal solid wall insulation, low temperature heat batteries, low carbon heating systems with innovative space saving designs, small area emitters and other approaches to address this constraint. While clearly there is a need for innovation in this space (in particular around insulation) it would also seem sensible to look at how other electric heat solutions could be used rather than just chasing after a way to make heat pumps work in these properties.

Similar considerations apply in terms of space requirements for hot water tanks. Most households are familiar with domestic hot water (DHW) cylinders, which typically store around 10 kWh of heat and are approximately 0.6m in diameter and 1.5m in height. However, as set out in the ESC 5 homes study referenced above, a larger water tank is required to store water at the lower temperatures produced by heat pumps and for effective demand management, requiring greater space per kWh stored. Again this is likely to be difficult in smaller properties.

Size (and energy efficiency) matters – what's most cost effective?

As well as these practical challenges, as noted above electric storage heating will also be more cost effective in smaller, well insulated properties because of the lower upfront costs (offset by higher per unit running costs).

As referenced in Element Energy & E4Tech's work for the National Infrastructure Commission, whilst they are technically less efficient than heat pumps, storage heaters can be applied across most of the UK's building stock without the need for the energy efficiency upgrades which may be required with heat pumps. As the NIC report says:

"Direct electric heating represents an option used by a large number of buildings today, and unlike heat pumps is assumed to be suitable across the stock without energy efficiency upgrades. Although this pathway results in significantly higher fuel consumption than the heat pumps case, these costs are offset by the lower capital costs of the equipment at the building level"

The NEA report looks to give a ballpark quantification of this effect. Figure 2 below shows the relative annual costs – with upfront costs spread over 20 years - of different solutions at varying consumption levels compared to the current costs of gas heating. From this analysis it would appear that with an annual consumption of under around 7.5 MWh electric storage heating would be more cost effective overall than a heat pump taking account of the upfront costs and the ongoing running costs.

Horses for courses: relative costs vary dependent on energy usage



Source: Grid Edge Policy and Provident Policy report for NEA

These figures should only be seen as indicative. For example, these calculations are based on conventional storage heating while analysis by GNV KEMA for Glen Dimplex³³ suggests that smart storage heaters have the potential to be more cost effective again – 27% cheaper than conventional storage.

It is also worth noting that these figures were based on the KPMG report, which as highlighted above was particularly favourable to hydrogen, whereas more recent reports have tended to conclude that on average costs for hydrogen and electrification are comparable.

Finally, relative values will vary depending on the value attributed to flexibility and any changes in the structure of electricity charges.

However, what the NEA report does uniquely is show how the overall costs vary across consumption levels given the different composition in terms of capital and running costs – attempting to quantify the point made by several commentators about direct electric heating being more suitable for smaller more energy efficient properties.

Recognising that there is a high level of uncertainty in all of these forecasts, not least in terms of the future structure of network charges and the balance of peak and off-peak prices which is a critical factor, this report uses the 7.5 MWh break point from the chart as an indicative figure when looking at the range of housing for which storage heating could be more cost effective than a heat pump.

What the chart also highlights is that, at the very lowest consumption level (below around 5 MWh), direct electric heating may be more cost effective than storage heating. In the smallest, most energy efficient homes (eg those meeting a new Future Homes Standard) hot water will account for a larger share of the overall consumption and even using storage heaters unnecessary and too costly in terms of the upfront cost.

One twist on this is that from a fuel poverty perspective what matters is the running cost. There was a suggestion from a fuel poverty charity that in comparing options that should be the focus with the assumption that the upfront costs would be covered by someone else (which might point to more use of heat pumps). However, others took the view that it was still right to look at what was most cost effective from a societal

³³ https://www.dimplex.co.uk/sites/default/files/Running_Cost_Report_2014.pdf

perspective with support on running costs being provided separately if necessary. That is the approach taken in this report.

Significant numbers of (mainly smaller) properties currently rely on storage heating

There is a risk that policy makers enthuse about the role of heat pumps based on their own perception of a typical home. The ESC 5 homes study looks at 5 “typical homes” but they are all 2-4 bed houses despite the fact that according to the English Housing Survey 20% of dwellings are actually flats, and in Scotland the figure is even higher at 36%.

Tenure is also important as it may be feasible for social landlords to convert blocks of flats to communal heating (which is acknowledged as being a good solution in heat-dense areas). However, this would not work so readily in the private rented sector (or owner occupied) where the challenge of mandating connection to heat networks is hard to address and where converted flats are more prevalent. Electric storage heating has the benefit of being an individual, scalable solution that can be installed in conjunction with other refurbishment work for example.

As shown in the table below, storage heating is more prevalent in the rented sector where properties also tend to be smaller and are more likely to be flats. Fixed electric heaters are used particularly in the private rented sector where their cheaper up-front costs appeal to landlords who are less concerned about the higher running costs faced by their tenants.

	Owner occupied	Private Rented	Social rented	All
Total % dwellings	63%	20%	17%	100%
Breakdown by type (%):				
Houses / bungalows	92	63	55	80
Conversions	2	11	4	4
Low rise flat	6	22	37	14
High rise flat	1	4	4	2
Average floor area m2	107	77	66	92
% with storage heaters	3.5%	8.7%	6.7%	5.1%
% with fixed electric heaters	2.2%	6.5%	1.5%	3.0%

Source: 2017-18 English Housing Survey³⁴.

In total, of the 1.2 million homes in England in 2017 with storage heaters, 0.53 million are owner occupied, 0.42 million are private rented and 0.27 million are social rented.

In Scotland the 2018 House Condition Survey³⁵ shows 10% of homes (0.25m) are electrically heated.

Because they are smaller they use less energy

The latest Typical Domestic Consumption Value report from Ofgem³⁶ shows that the energy consumed by homes with electric heating (profile class 2) is much less than the energy consumed by gas heated homes. In particular it is worth noting that even the upper quartile “high” energy consumption (including all other electricity uses) is below the 7.5 MWh cut-off point at which the NEA report’s analysis suggests storage heating is the next best solution after gas. Thus, while they are high electricity users, they are not high energy users.

³⁴ <https://www.gov.uk/government/statistics/english-housing-survey-2017-to-2018-headline-report>

³⁵ <https://www.gov.scot/publications/scottish-house-condition-survey-2018-key-findings/pages/4/>

³⁶ https://www.ofgem.gov.uk/system/files/docs/2020/01/tdcvs_2020_decision_letter_0.pdf

One important caveat that should be attached to this is that it is widely acknowledged that there are many homes that have Economy 7 heating but do not have storage heating. As the figures in Annex 2 show there are over 4 million homes with some form of restricted meters – meaning that only around 40% of them actually have storage heating. More analysis (and better data) is needed to distinguish those who actually have storage heating and to understand their usage as between heating and other usage. Similarly, more work is needed to understand profiles for those with two separate meters.

		KWh
Gas Consumption	Low	8000
	Medium	12000
	High	17000
Electricity Profile Class 1	Low	1800
	Medium	2900
	High	4300
Electricity Profile Class 2 (Economy 7 and other restricted meters)	Low	2400
	Medium	4200
	High	7100

Source: Ofgem TDCV analysis

However even allowing for that it would appear that electric heated homes use significantly less energy overall than gas heated homes, which may in part reflect levels of underheating which BEIS research³⁷ (comparing actual and theoretical energy consumption) showed is more prevalent among lower income households (and is likely to be exacerbated by the higher price of electric heating). However, it also aligns with the evidence on types of properties that currently use storage heating which tend to be smaller and are more likely to be flats (which are inherently more energy efficient than houses).

While the Ofgem numbers are believed to be robust (and are derived from the BEIS sub-national energy consumption data), other data sources present a different picture and gaining a consistent view of the current position is clearly important for policy making going forward. For example, the FES assumes that an average home (EPC band C) in 2018, with electric heating (such as storage heaters), used around 11.8MWh of electricity a year for appliances, lighting, heating, etc. This seems very high.

As Ofgem set out (and confirmed by DUKES – see Annex 2), in 2019, 80% of domestic electricity consumption was on profile class 1 (single rate) and 20% was on profile class 2 (multi-rate) although only 14% of meters are profile class 2. The fact that these customers account for such a significant portion of domestic electricity consumption (much, but by no means all, off-peak) is a further reason for a focus on their future needs.

With more energy efficient housing there is scope for more use to be made of storage heating

The BEIS NEED database provides information on gas consumption by property type, including age and tenure. The following tables summarise this information and colour code consumption levels with green as the lowest consumption. Apart from the oldest properties, flats and properties with a floor area of less than 50m² have a consumption level that suggests storage heating could be the most suitable form of electric heating.

³⁷

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/791293/Energy_Trends_March_2019.pdf

	Detached	Semi detached	End terrace	Mid terrace	Bungalow	Converted flat	Purpose built flat
Pre 1919	23,000	17,400	14,700	12,100	14,700	9,400	9,400
1919-44	22,400	14,500	12,900	11,300	14,700	8,400	8,500
1945-64	19,500	12,800	11,500	10,800	12,900	8,100	7,500
1965-82	16,500	12,100	10,900	9,700	11,800	7,100	6,500
1983-92	15,400	9,700	8,900	7,900	11,100	6,900	5,800
1993-99	15,300	9,500	9,300	8,300	10,900	6,600	6,000
Post 1999	15,000	9,600	9,700	9,300	10,300	6,500	5,600

Floor Area (metres-squared)					
	50 or less	51 to 100	101 to 150	151 to 200	Over 200
Pre 1919	8,000	11,100	15,500	22,400	29,700
1919-44	7,900	12,400	16,700	24,000	31,000
1945-64	7,100	11,400	14,900	22,400	28,500
1965-82	6,000	10,500	14,500	20,800	26,800
1983-92	5,600	9,400	14,800	19,000	25,100
1993-99	5,700	9,200	14,400	18,600	24,900
Post 1999	5,200	8,100	12,100	16,500	22,400

Given that 20% of properties are flats (36% in Scotland) and in England 9.5% of all properties have a floor area of under 50m² there would seem to be scope for more use to be made of storage heating or direct electric heating on the basis of cost efficiency than is currently assumed in the various scenarios for de-carbonisation.

Moreover, building standards have continued to improve since 1999 and hence, for the newest properties as well as for those built in future, it is reasonable to assume that energy consumption levels could justify using storage heating in larger properties as well. In the smallest new build properties with high energy efficiency it may well be that, as noted above, direct electric heating would be sufficient as heating requirements should be minimal and the majority of costs will be for hot water. The fact that panel heaters are more slimline than storage heaters is another reason they may be preferred in the smallest properties.

The social dimension means the issue cannot be ignored

Unsurprisingly, those on lower income tend to live in smaller (and less energy efficient) homes and are more likely to live in flats. As such, finding the most suitable solution for these properties – and one that is affordable – should be a priority.

In England over 30% of households in the bottom income quintile live in 1-bedroom properties. The proportion is slightly lower in Scotland, but in both England and Scotland over 60% live in 1- or 2-bedroom properties. This highlights the importance of identifying an appropriate affordable solution for this type of property for those on the lowest incomes.

Hot water tanks - an endangered species that needs protecting

As acknowledged by BEIS “relatively little is known about the need for hot water storage in UK households. The number of homes without hot water tanks has risen substantially with the introduction of combi-boilers. In 1996 12% of households were without hot water tanks, rising to 54% in 2016.”

This reflects the growing use of gas combi boilers that operate without a tank – and a desire for more storage space in the home. The growth of electric showers (which provide instant hot water) and more generally the switch from baths to showers reinforces the trend even in all-electric homes.

Nevertheless, it is assumed that removal of hot water tanks is less common in many of today's electrically heated homes as the existence of an immersion heater allows overnight heating of hot water at off peak rates.

More thought needed on residential institutions

Another sector that does not seem to have been considered in the context of heat de-carbonisation but is potentially important, both in terms of volumes and in terms of its symbolism and awareness raising, is student accommodation. Purpose built student accommodation provided by private developers now accounts for over half of all student bed spaces. In discussion with Glen Dimplex it was suggested that although the rooms were small, this sector was not suitable for storage heating because of students' lifestyle patterns – with little time spent in the room direct electric heating (with smart controls to avoid heating being left on when absent) was more likely to be suitable. In some cases, universities are installing district heating systems, which could be an effective option, but with increasing private sector provision of student accommodation there will be a desire to keep costs to a minimum.

Other types of institutions that raise similar issues (but with the inhabitants having rather different lifestyles!) might be care homes, possibly prisons and hotels. That said care homes (and hospitals) have limits on the surface temperature of heaters which tend to preclude direct electric heating and storage heaters.

In all these cases there is an argument for the individual occupant having a level of control over their own heating – in much the same way as one would want to in one's own home - but within bounds set by the institution.

In principle, effecting change at an institutional level should be easier than encouraging individual domestic customers to make changes to their homes – provided the business case exists – and aggregated loads of this sort are also likely to be more valuable in terms of flexibility. However, a key factor here is Energy Performance Certificates (EPCs). Domestic properties and institutions will have different measures and targets for refurbishment and so will likely follow different technology pathways.

5 Flexibility and the DSO Transition

- Flexibility is key to the energy transition
- Questions remain about the commercial framework for flexibility
- Ofgem undecided whether DNOs should have any rights to effect control

Flexibility is key to the energy transition

The availability of flexibility, through thermal storage, is seen as a pre-requisite for the cost-efficient electrification of heat, as the quotes in section 3 illustrate.

This is part of a wider emphasis on the role of flexibility in a net-zero electricity system and being able to cope with the integration costs of more intermittent generation. In the technical annex of their May 2019 net-zero report, the CCC note that variable renewable resources provided a 22% share of UK electricity in 2018, with the potential to rise to some 50-65% by 2030 and greater still by 2050³⁸. Two big challenges going forwards will therefore be the need to soak up large amounts of excess / low-priced wind at night (especially in winter) and also to manage network constraints as the system strives to cope with the bulk-transport of transmission-connected renewables, with new electric loads and more distributed generation. Even today, wind is being 'constrained-off' at night and at weekends – either because of network bottle-necks or because there is insufficient load at the right times to use it. January and February 2020 have already seen fifteen half-hour periods with 'negative' wholesale prices i.e. the energy had negative value due to insufficient demand on the system.³⁹

Goran Strbac of Imperial University has estimated⁴⁰ that in a system with deep de-carbonisation (50g/kWh in 2030) the total value of flexibility to the system would be £7.1-8.1bn pa – a figure which is widely cited elsewhere, for example by the National Infrastructure Commission in their 2016 report Smart Power⁴¹. This was also the basis for an updated report by the Carbon Trust and Imperial⁴², which quoted a net value of £17-40bn by 2050. This is the figure quoted by BEIS / Ofgem in their Smart Systems and Flexibility Plan⁴³. The importance of flexibility was reiterated by Ofgem in its latest De-Carbonisation Action Plan⁴⁴ that included a theme around promoting electricity system flexibility.

In particular there is a strong emphasis in policy thinking around the potential for DNOs to make more use of flexibility to help in managing constraints on their systems, rather than investing in traditional reinforcement. This together with more active management of the network is core to what is being described as the creation of a Distribution System Operator role.

In its latest position paper on Distribution System Operation (DSO)⁴⁵, Ofgem makes clear that it has not yet decided whether in the longer-term various DSO functions should be carried out by a DNO or by third- parties

³⁸ <https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-Technical-Annex-Integrating-variable-renewables.pdf>

³⁹

<https://www.current-news.co.uk/news/negative-pricing-will-be-a-big-feature-as-high-winds-get-the-uk-network-off-to-a-strong-start>.

⁴⁰ https://www.theccc.org.uk/wp-content/uploads/2015/10/CCC_Externalities_report_Imperial_Final_21Oct20151.pdf

⁴¹ <https://www.nic.org.uk/our-work/smart-power/>

⁴²

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/568982/An_analysis_of_electricity_flexibility_for_Great_Britain.pdf

⁴³ https://www.ofgem.gov.uk/system/files/docs/2017/07/upgrading_our_energy_system_-_smart_systems_and_flexibility_plan.pdf

⁴⁴ https://www.ofgem.gov.uk/system/files/docs/2020/02/ofg1190_decarbonisation_action_plan_web_0.pdf

⁴⁵

https://www.ofgem.gov.uk/system/files/docs/2019/08/position_paper_on_distribution_system_operation.pdf

but in the meantime it is pressing DNOs to build their capabilities to support flexibility. This work is being supported by the Open Networks project led by the ENA.

This stress on the importance of electricity system flexibility reinforces the intuitive point that smart storage heating and hot water should have a role in a de-carbonised energy system. While energy stored as heat cannot readily be converted back into electricity, it can still play a part when viewed from a whole system perspective. As a demand-side asset-class, storage heaters and stored hot-water could provide future flexibility services with differing characteristics and which could therefore offer value, in principle, to networks, to wholesale and capacity markets and to the system operator. This includes services which might be peak-related (turn-down, turn-up); dynamic (price- or system-stress led; fault-led); and, potentially, certain balancing services (e.g. frequency response).

The NINES project in Shetland (discussed in Annex 1) demonstrated that electric storage heating loads could be used effectively as part of a demand side management system in an island context. BEIS has since awarded grant-funding of £8.57 m to thirteen domestic demand-side response projects to complete by the end of 2020. Six of these reference water-heaters, albeit only one seems to involve storage heaters.⁴⁶

Questions remain about the commercial framework for flexibility

One strand of work on the DSO role is that DNOs are now using the Piclo platform to invite tenders for the provision of flexibility services where they have constraints on their network and are considering reinforcement. Given the size of loads that need to be offered up for flexibility the focus currently is on industrial and commercial loads. However, SSEN are also working with NEA to make use of Social Constraint Managed Zones where solutions to reduce or shift domestic load can bid in – and hopefully also help tackle fuel poverty.

Connected Response have identified an opportunity in social housing where landlords could deliver aggregated storage heating (and hot water) loads, especially where heat with rent arrangements apply.

Ofgem are still exploring the extent to which such contractual arrangements are the best way of engaging flexibility or whether direct price signals (e.g. through dynamic time of use network charges) would be the best way forward. This is being considered as part of the Access and Forward-Looking Charges Review⁴⁷.

In their summer working paper on this project they included a section on the implications for procurement of flexibility⁴⁸. In it they explored the advantages and disadvantages of using contractual arrangements (including access charges and procurement of flexibility services) or price signals (network charges) to signal the need for flexibility, against various criteria. Although the paper did not reach an overall conclusion, it noted that contractual arrangements were better able to provide local and real-time signals, to support competition and to provide certainty of response. Price signals were seen as potentially easier for customers to understand.

In my report for Oxford University on network charging⁴⁹ I argued that contracts were likely to make more sense where a way to deal with highly localised or time specific constraints was needed, noting in particular the risk of price signals being blunted by how suppliers choose to pass the charges on. The supplier dimension was also highlighted in the Sustainability First report “What is Fair?”⁵⁰, which notes that Ofgem research showed that most suppliers would not expect to reflect changes in the structure of network charges in their tariffs to end customers.

⁴⁶

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/783338/BEIS_innovative_domestic_demand-side_response-competition_phase_2.pdf

⁴⁷ <https://www.ofgem.gov.uk/publications-and-updates/access-and-forward-looking-charges-significant-code-review-summer-2019-working-paper>

⁴⁸ https://www.ofgem.gov.uk/system/files/docs/2019/09/summer_2019_-_working_paper_-_links_with_procurement_of_flex_note_final_nd.pdf

⁴⁹ <https://www.renewableenergy.ox.ac.uk/wp-content/uploads/oxford-network-charging-190818.pdf>

⁵⁰ <https://www.sustainabilityfirst.org.uk/other-publications/what-is-fair>

Ofgem undecided whether DNOs should have any rights to effect control

A bi-lateral contractual arrangement can provide the ability for the network operator to directly control the load when faced with a fault situation, for example. As Ofgem acknowledge, this certainty of response can be important to the networks.

Whether this ability to directly control load more widely is a right the DNO should have to ensure network resilience is an issue that has been discussed in the context of electric vehicles. Through an SEC modification (SEC 0046) SSEN have proposed that they should have the ability to be able to intervene to interrupt EV charging in critical situations by sending load control messages through the DCC.

In their DSO Position Paper, Ofgem said (a propos this modification) that they will need to consider: *“whether DNOs should have the capability to modulate EV chargers to resolve network and system needs that could also be met through market mechanisms”*. This reflects Ofgem’s general preference for market solutions.

The modification report highlights the highly locational nature of network issues, their relatively rare occurrence, the need for rapid response, and the fact that properties are served by multiple suppliers as adding complexity and justifying them having the right to apply direct load control (rather than having to procure ancillary services to deal with the risk of such events occurring).

The significant power-outage of 9 August 2019 is a reminder that in extremis, to protect the system, DNOs have the right (and indeed an obligation) to shed load. What such backstop arrangements look like in a smart world is something that Ofgem will need to consider in deciding on this modification.

SSEN also has an ‘interim solution’ for EVs where they will fit a device to local substations as part of a network innovation (NIA) project Smart EV. The device will measure demand on the cable in real-time, assessing whether a managed EV charging event is needed. If a managed charging event is required, then the substation device will communicate with a device (fitted by SSEN) at the customer’s property. This device at the property will then delay or curtail EV charging rates. This is considered as an interim solution, requiring agreement with the individual customer and activation through the customer’s own systems.

While this debate is taking place in the context of EV charging, the question is how does this compare with the issues around electric storage heating? Currently under the RTS (described in more detail below) the DNO has the ability to over-ride supplier schedules in designated Load Managed Areas to avoid or defer the need for reinforcement or extension. This can be done on either a programmed basis (for example day ahead) or an immediate basis (to shed load within 12 seconds). This latter facility has been only used very rarely but is a key resilience tool.

Section 7 sets out some of the steps SSEN have already taken or are taking to tackle the diversity of load issue with the loss of RTS but there has been no discussion to date about the existing backstop ability to shed (or boost) load.

While Ofgem is right to look to market solutions to deliver flexibility cost effectively, the question does remain of what backstop provisions should be in place. SSEN should continue to focus on trying to think how a market solution for storage heating might work – which will then also help clarify the gap that any backstop needs to fill. They should also continue to consider and draw analogies with the debate around EV charging.

Citizens Advice have highlighted the importance of customers being able to override any action, with customers having control seen as key to customer acceptability of any intervention by the networks. Again, however, there is a case for distinguishing between “normal” operation and emergency situations where the alternative may be more widespread disruption.

6 Looking to the future: Barriers and Policy Changes Required

The barriers or drivers that can be expected to impact on take-up of alternative forms of electric heating and of thermal storage going forwards can be grouped under a number of headings:

- appliance and building standards;
- price signals;
- commercial models;
- consumer information;
- the Fuel Poor Network Extension Scheme;
- wider regulatory restrictions (including the future of RTS considered further in Section 7);
- funding support for future storage heating.

While many of the points have been raised earlier in this report, they are brought together here as an agenda for policy makers to consider and to highlight the diverse range of elements that need to be addressed by a range of policy makers (BEIS, MHCLG, devolved governments and Ofgem) in order to make progress on heat de-carbonisation. Given the very wide range of factors that can impact on the relative attractiveness of different low carbon heat solutions there is a need for a co-ordinated approach across policy makers.

Appliance and building standards

In terms of the appliances themselves **Lot 20** in the Eco-Design standards is driving use of smart heat solutions as set out above. Provided these remain in place post Brexit any new heaters installed will have to be smart but, as set out in section 3, not necessarily “connected” to ensure of value to the grid.

However, **building standards** (Part L and Future Homes standards) for new builds risk holding developments back by:

- Actively discouraging any form of thermal storage
- Ignoring the potential for electric heating other than heat pumps
- Ignoring the point that the appropriate solution will vary by property type
- Underplaying the continued importance of energy efficiency.

The proposals have been subject to consultation by MHCLG and a range of stakeholders are known to have responded raising these concerns.

The BRE Standard Assessment Process (**SAP**) is used to assess the dwelling emissions rate and fabric energy efficiency for new build properties. A simpler version RdSAP (reduced data SAP) is used for existing properties. In each case the EPC (Energy Performance Certificate) for the property comprises an energy efficiency rating which takes account of prices and shows how much it would cost to heat the property, and an environmental impact (CO₂) rating which shows the emissions. The EPC (primarily the energy efficiency element) then underpins Minimum Energy Efficiency Rental standards and fuel poverty targets and drives choices by landlords and homeowners.

Historically the SAP framework has penalised electric heating on the basis that it was higher carbon than gas. This is now being addressed, recognising electricity is now more de-carbonised but initially will only apply in new build assessments. The level of carbon emissions related to electric heating is due to be lowered in 2019/20 as SAP 10 is incorporated into building regulations from 0.519 kgCO₂/kWh to 0.233 kgCO₂/kWh, which is comparable to the figure of 0.210 kgCO₂/kWh for gas. This will have an impact on the environmental credentials of electric heaters – and hence that aspect of the SAP rating - but not on the cost of running those heaters (and hence the energy efficiency element of EPC). There could be arguments for setting the carbon intensity on a forward-looking basis (given the life of heating systems) and hence the EPC arguably still penalise electricity. Moreover, it will be some time before RdSAP is updated to reflect these new figures in the EPCs for existing properties.

Price signals

As noted above **electric** heating is consistently more expensive than **gas**. This reflects the fact that social and environmental policy costs are primarily recovered through electricity bills and that there is no carbon cost in the price of domestic gas.

The Committee on Climate Change have identified tackling this distortion as a near-term priority for heat-decarbonisation⁵¹, noting the need to “tackle the current balance of tax and regulatory costs across fuels, which currently weaken the private economic case for electrification”.

The relative costs of **peak** versus **off peak** electricity is also a critical factor in whether storage heating is a cost-effective solution. The relative costs will be affected by differences in the wholesale energy price and can also be radically affected by changes to industry rules around network charging. For example a report for the Smart Fintry community energy project⁵² highlighted that SHEPD’s DUOS charges changed from being 8.7p/kWh in the red (peak) period and 0.7p.kWh in the green (off peak) in 2017/18 to 7.6p/kWh and 1.6p/kWh in 2018/19 as a result of charging modification DCP228 (which changed the allocation of the residual from being a % uplift to a flat rate). This represents a significant shift in the peak to off peak ratio in the network charge component (from 13:1 to 5:1) which will inevitably have fed through into retail prices and adversely impacted those on electric storage heating.

Future changes driven by current policy debates around Ofgem’s Targeted Charging Review (TCR) look set to further reduce the differential and diminish the incentives for demand side response, although their Review of Access and Forward-Looking Charges could potentially increase the strength of the price signal.

In contrast a move to put more emphasis on **fixed** charges rather than **volume related** charges would have the effect of making direct electric heating a relatively more attractive solution.

While Ofgem’s aim is to move to more cost reflective pricing this is a difficult area – particularly as one tries to anticipate what might be the longer-term pressures and constraints on the system. It is not clear that Ofgem have thought about how their decisions on network charging in the round could impact on the viability of different options for electric heating – and whether they understand enough about **the effects of different heating types on network costs** to be confident that the signals being sent are the right ones.

While specific changes that would have penalised storage heating (i.e. a higher standing charge for Economy 7 customers) have now been dropped from the TCR, this is an angle that Ofgem needs to keep in its sights given its focus on vulnerable customers. A move to **capacity-based charges**, while fairer in many ways, would need careful thought in the context of electric heating. Increased standing charges could particularly hurt those with complex metering arrangements involving two meters.

Finally, the debates around **access arrangements** are also relevant here as one potential model would be for there to be different levels of access that, for example, may or may not be interruptible. At present this is largely being debated in the context of generation connections and larger demand customers but there is an analogy with the DTS arrangements in Scotland.

While debates on charging tend to look in isolation at the structure of network charges, it is **what suppliers do in terms of passing on price signals** that matters to end customers⁵³. Ofgem have committed to monitor how far suppliers reflect network charges in their end tariffs. It is important that as a part of this Ofgem look at how customers with electric heating are being impacted. For example, stakeholders at the roundtables for this report felt that the Octopus Agile tariff, while sending sharp time-of-use signals, would not be suitable for most storage heat customers who would be concerned at the potential for extremely high prices at certain times.

Also, as a part of the proposals to move to **half-hourly settlement** there is a suggestion that Elexon would move away from having a separate profile class for Economy 7 customers (to be used in the event that the

⁵¹ <https://www.theccc.org.uk/wp-content/uploads/2019/02/UK-housing-Fit-for-the-future-CCC-2019.pdf>

⁵² <http://smartfintry.org.uk/about-smart-fintry/resources/>

⁵³ <https://sustainabilityfirst.org.uk/other-publications/what-is-fair>

customer did not want to share their half-hourly data for settlement purposes). Ofgem needs to be satisfied that this will not result in higher costs to serve for those customers on Economy 7 who have higher than average electricity consumption but with the majority at off peak times.

Commercial models and smart metering

As discussed above one of the factors that will affect whether storage heaters are able to participate in demand side response and support the DSO is whether or not DNOs will have the continued **ability for direct control of the load** - be that directly via the DCC and the smart meter - or via another route - to deal with short term constraints or faults on the system. This is a question both of principle and practice.

DNOs also need to find a way to ensure **diversity** of storage heating loads, at least in Load Managed Areas. This should be possible working with aggregators or suppliers (and OVO's acquisition of SSE's retail customer base may be helpful in this regard).

Aggregators currently face the same challenges as DNOs in not being able to send direct load control messages via the DCC to the smart meter. Presently, this is restricted to licensed suppliers,

Independent aggregators have yet to emerge in the domestic sector but the market is likely to evolve. In particular if more reliance is placed on contractual approaches to procuring or providing flexibility services (rather than direct price signals into the market) this will open the way for aggregators. BEIS and Ofgem clearly anticipate this in their review of the retail market⁵⁴ where they discuss the need for stronger regulation of aggregators to provide customer protection.

As noted in the section on flexibility, aggregators (or suppliers) could combine the household storage heater and hot-water 'value-stack' to support both the DNO plus other parts of the market with a mix of different flexibility services, including enabling access to cheap energy. The ability to access this **stack of benefits** would help make storage heating (and electric water heating) a more economic proposition for customers.

In the EV market we have seen Octopus offering its Agile tariff, allowing people to charge their vehicles when electricity is cheap – and indeed, at one point last year customers were paid to charge their vehicles as wholesale prices had gone negative. It is hoped that some of the thinking that has been and is being done on smart **EV charging** will be able to **read across** into smart storage heating.

Also having a clearer view of the market requirements around flexibility would enable storage heater manufacturers to start to develop **new heater models** with physical properties and controls that could address those requirements – for example to be able to take advantage of short bursts of cheap / surplus electricity.

Consumer information

As noted by a number of commentators including the Committee on Climate Change and Carbon Connect in its report Uncomfortable Home Truths⁵⁵, there is **low awareness** among customers **about the need to de-carbonise heat** and hence how their choices could impact on climate change – something that consumers do see as an increasingly important issue.

There is also an issue as noted in section 1 about **the poor reputation of traditional storage heaters** and of electric heating more generally. If storage heating is to play a part in the future of heat de-carbonisation then a total re-set is needed. This is a big task if consumers and householders, their landlords, energy sector actors, policy makers and even equipment manufacturers are to 'buy into' a future where storage heaters become a solution of choice. First, concerted effort is needed to address the many legacy problems. Second, far more could be done to communicate the lessons from trials such as those highlighted in the last section where consumers seem much happier with modern storage heating. Third, recognition is needed that storage heaters are a positive, green solution and will be increasingly so as electricity is further de-carbonised.

⁵⁴ <https://www.ofgem.gov.uk/publications-and-updates/flexible-and-responsive-energy-retail-markets>

⁵⁵ <https://www.policyconnect.org.uk/cc/news/mps-call-green-heat-roadmap-2020-olympic-style-delivery-body-tackle-uks-27m-%E2%80%98uncomfortable-home>

There is very little in terms of **independent advice** on the best heating solution for different sorts of homes – and significant misinformation. Bodies like the EST provide generic advice on their website (including advice to replace storage heaters with gas heating). It can often be hard for customers to distinguish genuinely independent advice from what can appear independent but is promoted by manufacturers of particular types of equipment. BEIS and the devolved governments should consider how consumers can best be supported in making choices around low-carbon heating technology and sizing of their requirements.

Accreditation of installers is also important – and does apply currently where government funding is involved. A specific requirement on installers to highlight the need for the customer to talk to their supplier to check their tariff is still suitable would be a helpful step.

As highlighted in all the trials, there is also a vital need for active ‘after-care’ plus **ongoing support** and advice for some customers on both how to use the controls to achieve comfort and to manage bills, recognising that life-stage changes or simply changes in tenant can mean that advice needs to be refreshed. It is unclear where responsibility for support of this kind should sit, for those customers who need extra help, but it is likely to be an issue for all new forms of low carbon heating. Ensuring those with smart storage heating (or indeed any new form of heating) get the best experience possible will be vital in building the reputation of these technologies. In Scotland the Home Energy Scotland service effectively performs this role, with NEST carrying out a similar role in Wales, but there is no equivalent in England.

Manufacturers have a role to play here including ensuring that clear operating instructions (road tested with users) are available in hard copy and on-line, including You-Tube advice. Equipment retailers, landlords and installers also have a part to play.

Finally, it is **essential that customers are on a suitable tariff** for their heating systems. While suppliers may not have full visibility of the current heating system used, they do have a responsibility under Ofgem’s treating customers fairly requirements to ensure that customers can make informed tariff and consumption choices⁵⁶. Citizens Advice have highlighted that many legacy time of use customers do not understand the tariffs they are on and the times when different rates apply. Ofgem should proactively monitor and enforce these requirements. Having a route to get **redress** where problems arise (and where responsibility among different parties may be unclear) is also important.

The Fuel Poor Network Extension Scheme

As part of the RIIO price control framework for gas distribution the gas networks have an obligation - the **Fuel Poor Network Extension Scheme (FPNES)** - to connect a certain number of fuel poor households to the gas network with the costs of the network connection being funded by customers at large. The costs of the in-house works (i.e. the installation of the boiler and radiators) are typically covered by government schemes such as the Energy Company Obligation (ECO) or the Warmer Homes Scotland scheme.

For RIIO GD1 the requirement was for 91,000 new fuel poor gas connections over the 8-year period across the four companies. While in some cases this might be replacing other forms of heating such as oil, many are converting from electricity.

For RIIO GD2 there has been some discussion around the case for continuing the FPNES in the light of the heat de-carbonisation challenge. However, Ofgem has decided to maintain the obligation given the important role it plays in tackling fuel poverty. The expectation is that the obligation will be set at a similar level to GD1 or perhaps a bit lower (on an annual basis), with the potential for review in the light of policy decisions from BEIS on the use of gas for heating.

⁵⁶ https://www.ofgem.gov.uk/system/files/docs/2018/12/final_decision_-_customer_communications_rule_changes.pdf

While the Ofgem scheme does not give flexibility for networks to provide **alternative solutions**, it would clearly be desirable for them to consider how far insulation measures or upgraded storage heating systems⁵⁷ might provide an equally effective but more sustainable solution. The networks currently have an obligation to ensure the partners they work with check that a gas connection is the best solution to meet the needs of a household, including whether there are other fuel options that would be more appropriate. Moving forward there is an argument that this should look beyond simply the short-term running cost impacts.

Some GDNs have addressed this tension in their business plans. SGN has committed to providing 18,000 new fuel poor connections over the period but has also committed to exploring with stakeholders the complex challenge of how to balance the need to tackle fuel poverty with the de-carbonisation challenge. Cadent has proposed a lower connections target but a much more extensive (and costly) programme of whole house refurbishments. How Ofgem responds as it finalises RIIO2 and the detailed guidance will be key.

National governments also have an influential role here in the type of in-house measures that they choose to fund. FPNES can only be delivered if there is **funding for the in-home work** in terms of a first-time central heating system. If new gas heating systems cease to be funded then Ofgem will need to revisit the FPNES.

Other regulatory barriers

Another regulatory barrier is the obligation on GDNs to **provide and maintain gas connections** on request within 23 metres of their network. In some cases, GDNs might want to take gas out of blocks of flats, for example, to avoid costly maintenance of risers. Electric heating would be an obvious alternative in these cases but GDNs may not always be able to persuade people to change, even where they provide compensation.

As discussed above, the availability of suitable **smart meter variants** – together with suitable solutions for blocks of flats (alt-HAN) and adequate DCC coverage – is necessary to enable the provision of more sophisticated flexibility solutions (and to support existing customers with more complex arrangements).

The arrangements - set out in the **Smart Energy Code** - around which parties have access to and an ability to send messages relating to different elements of the smart meter system (from calendars, through levels of randomisation and load control) will also impact on how commercial services develop.

Funding support for future storage heating

Carrying out a major upgrade of existing storage heating or installing it as a replacement for other fuels will involve a significant cost. When combined with energy efficiency measures, such upgrades can help with both de-carbonisation and tackling fuel poverty and it is important that sources of funding in terms of **up-front grants (or low interest loans)** are available for those who cannot afford to pay.

The Energy Company Obligation (**ECO3**) – which places an obligation on suppliers to install a certain level of energy efficiency measures in the homes of those on low incomes – does cover electric storage heating alongside other measures. However, storage heaters can only be replaced under ECO if all heaters are not working – and, as stakeholders noted, storage heaters rarely actually break. There is also scope under ECO to replace less efficient direct electric heating panels with storage heaters if combined with efficiency measures at the same time. According to Ofgem, in the period to the end of December 2019 1,922 storage heaters were installed under ECO3, equivalent to perhaps 550 homes, significantly lower than the number of boiler replacements (at 29,942). ECO runs until 2022 and the design of any successor scheme – along with the **successor to the Renewable Heat Incentive (RHI) will obviously be extremely important in shaping the uptake of different low carbon heat solutions.**

The Conservative party manifesto pledged to invest £9.2bn on improving energy efficiency in domestic and public buildings; including £3.8bn on a Social Housing Decarbonisation Fund and £2.5bn on **a new Home**

⁵⁷ 63% of storage heating systems are over 12 years old compared to more like a quarter for other solutions – and new models are generally more efficient

Upgrade Grant Scheme (HUGs) in fuel poor homes⁵⁸. These aims were reaffirmed in the Queen’s Speech on the 19th December 2019. Ensuring that this help is appropriately targeted, can support a suitably broad set of measures and can work alongside other schemes, are all important considerations.

In **Scotland interest-free loans** are available to cover the costs of heating and energy efficiency measures including up to £5000 for high heat retention electric storage heaters.

VAT is levied at 20% on smart high heat retention storage heaters whereas the installation of heat pumps can attract a reduced 5% rate as they are counted as energy saving materials.

As part of **RIIO** network companies will be funded through totex (their total expenditure allowance) for flexibility solutions as alternatives for reinforcement and also, depending on Ofgem’s policy decisions, may continue to have incentives around support for vulnerable customers. The ability to combine this funding with, for example, funding from government schemes could be key in providing sufficient funding for the necessary upgrades to smart storage heating.

Significant **innovation funding** is being made available to test and ultimately deliver large scale pilots of alternative heating solutions (hydrogen, district heating and heat pumps). While there are a wide number of smaller scale innovation projects looking at heat and flexibility described in Annex 2, there would seem merit in providing for a large-scale pilot in this area to demonstrate the potential value of the flexibility provided and to focus on how practical innovations (institutional, advice, controls) could help upgrade storage heaters and provide a more effective heating solution for many **vulnerable** households.

⁵⁸ Source: NEA briefing

7 RTS Specific challenges – a step on the road

- How RTS works today – a prototype for flexibility services?
- Understanding time of use profiles
- Problems with DTS from a consumer perspective
- The future of RTS and its funding
- Smart metering as a building block
- The mechanics of effecting load control
- DNO Requirements of an RTS replacement
- Steps to maintain diversity in a smart meter world
- Putting the costs in the right place
- Protecting consumers in the short term as smart meters are rolled out
- Longer term lessons for flexibility

How RTS works today – a prototype for flexibility services?

As set out in section 1, the Radio Tele-switch System (RTS) was established in the 1980s as a way to enable suppliers (in the then vertically integrated energy system) to control the loads on electric storage and water heating that otherwise risked creating a night-time peak that would have caused problems for the distribution networks in certain areas.

Ofgem's report on the 'The State of the Market for Consumers with Dynamically Tele-switched (DTS) meters' in 2013, explains how the RTS meters allow suppliers to set timing schedules for the storage heating (and potentially hot water) circuits in customers' homes. The signal is sent over the long-wave radio infrastructure also used for Radio 4 as part of a common industry arrangement. In many cases these schedules are left unchanged (static) or just respond to clock changes (semi-static), but Ofgem estimated at the time that there were over 500,000 customers whose Dynamically Tele-switched (DTS) meters had the potential for the timings to be changed from day to day (allowing charging at times of low demand or excess nuclear generation at night and accounting for weather variations). However even then only a proportion were actively used in this way, primarily in the North of Scotland (i.e. in SSEN's area where the network issues are most acute).

According to the recent Ofgem decision on Modification DCP204 there are currently an estimated 5.6 million customers who rely on RTS to switch tariff registers of which 1.6 million are in active use for switching electric heating or immersion heaters⁵⁹. These numbers seem higher than those from other sources such as the latest TDCV consultation from Ofgem cited in Annex 2 which showed a total of 4 million meter points on restricted meters of which 330k were on RTS / DTS. However even these figures clearly include many who do not have storage heaters.

Customers on RTS will typically be entitled to a certain number of hours of charging their storage heaters – a main charge overnight but in some cases with a boost in the afternoon. As noted above the DNO has the ability, in Load Managed Areas, to update the schedule to help in managing their system. In particular they can use this to ensure there is a diversity of loads on their networks (whereas conventional Economy 7 would always start charging at midnight for example). They also have the ability to issue immediate instructions to interrupt the charging in an emergency (which has been used on a few occasions – on Orkney and on the island of Unst – as described by EA Technology in their paper to support the change report on DC326⁶⁰)

⁵⁹ <https://www.ofgem.gov.uk/ofgem-publications/99208>

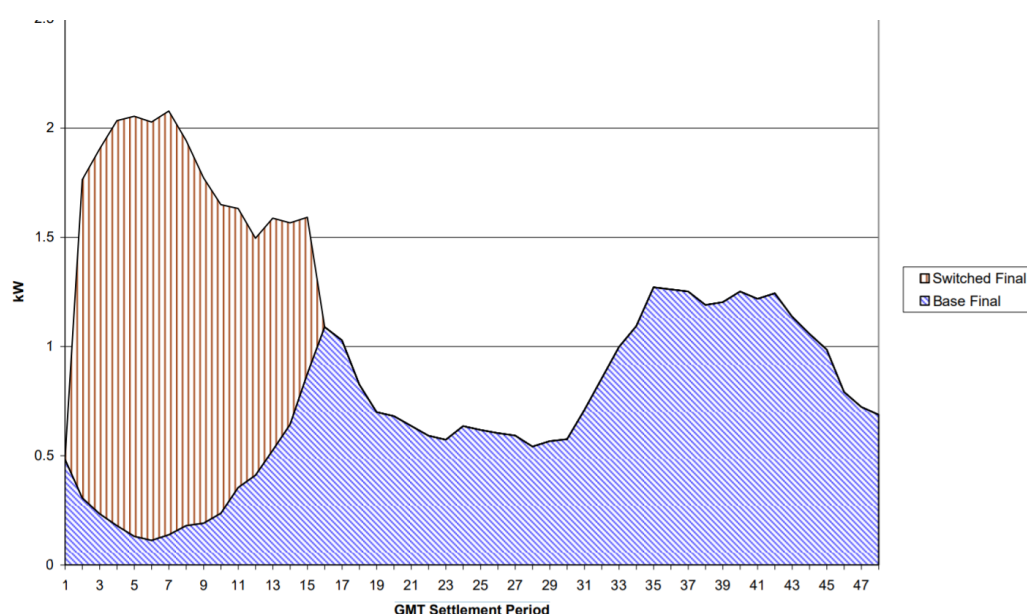
⁶⁰ <https://www.dcsa.co.uk/group/dcp-326-working-group/>

While flexibility in the domestic sector is still seen as some way off, the existence of Economy 7 heating and in particular the Radio Tele-switch System (RTS) can be seen as an early prototype that might provide some learning. However, there is also a need to work out how to fill the gap that will be left when the RTS is de-commissioned in the near future.

SSEN have estimated that being able to control the loads in this way through the RTS system has allowed them to avoid reinforcement costs of £718m⁶¹ – hence their concern about how it might be replaced.

Understanding time of use profiles

Elexon guidance notes⁶² explain how the Economy 7 profiles (for domestic and non-domestic customers) are split into switched load and base load, using sample customer information on storage and immersion heater ownership and information on customer switching regimes (the times that the customer's low Meter register is active). The Figure below (taken from that guidance) depicts a typical switched load/ base load split. This shows how the switched load kicks in at 12.30 am and then drops off from around 3.30 am as the storage heaters become fully charged, finally switching off around 7.30am.



In contrast to general electricity use, where analysis by Grid Edge Policy⁶³ found that there were very significant differences in the profiles of usage across all demographics, the pattern of the off peak load for Economy 7 customers is highly predictable being controlled as it is by a time switch. This absence of “diversity” creates problems for the networks which can otherwise rely on not everyone turning on load at the same time to allow them to configure their networks to cope with a lower “after diversity” maximum load. This is one of the problems that RTS was looking to address, by setting different charging times for different groups of meters.

In Ofgem’s TDCV open letter they state, based on Elexon data, that the proportion of off-peak usage by Economy 7 customers is 59% with 41% peak usage. This is based on standard Economy 7 and similar meters and excludes more complex meter types where Ofgem does not have the data. It also includes a large number of Economy 7 customers who do not have storage heating

Problems with DTS from a consumer perspective

The Ofgem report on DTS customers also sets out the problems it creates in the market as the technical arrangements limit the number of different schedules and hence leave control of the schedule in the hands of

⁶¹ AE Technology paper 3 supporting the DCP 326 modification

⁶² <https://www.elexon.co.uk/documents/training-guidance/bsc-guidance-notes/load-profiles/>

⁶³ www.gridedgepolicy.com - [here](#)

the original PES-supplier in an area. If the customer changes supplier the new supplier may not have visibility of the schedule (to help in managing their balancing risk) and no ability to control it. There are therefore limited opportunities for DTS customers to switch – an issue also identified by the CMA who introduced new requirements around restricted meters (that suppliers must at least offer standard tariffs on them without requiring a meter change).

Ofgem also carried out research with DTS customers which highlighted both the lack of engagement in the market but also the risks of detriment to some of these customers in terms of thermal comfort relating to:

- Inefficient use leading to heaters being charged for longer than needed;
- Increased use of potentially inefficient or expensive secondary heating;
- Where understanding / control was very low some consumers had turned off the storage heating and were only using secondary heating.

In this research the problems seemed to be more about the impact on bills or a lack of understanding – there seemed to be fewer concerns raised about the storage heaters not providing enough heat per se, perhaps because of the afternoon boost provided under DTS.

DTS was seen by customers as inherently more complex than other forms of metering / tariffs. Many customers had inherited the arrangements which had never been properly explained. Moreover, DTS customers were more likely to be elderly, less affluent and less well educated and hence often struggled to understand the complexities of the arrangements.

The 2013 report also cites usage levels for DTS customers that were markedly higher than for Economy 7. This is not explored but may reflect the fact that there is an additional charging period – which should result in homes being warmer but more expensive to heat (and with seemingly less control). However, it could also reflect the fact that many Economy 7 customers do not actually use electric heating and hence the average figures quoted understate usage for those with electric heating.

The future of RTS and its funding

It has long been known that the RTS would eventually be de-commissioned when BBC long-wave radio is turned off. However, given the slow progress in developing a replacement solution for RTS, Elexon last year put in place arrangements to ensure continued funding of the RTS⁶⁴.

The Elexon decision notes that there is a need to extend and utilise RTS to ensure that customers on Load Switching devices can continue to be supported, until a smart metering solution, or alternative proposals, are available to replace this type of metering. Customers with tele-switch metering arrangements can be gained by any supplier. In the event of the RTS arrangements not continuing, where there are meters that require switching by the service, there will be an impact on settlement calculations. As such, it was decided that the Balancing and Settlement Code (BSC) was an appropriate vehicle through which to consider the arrangements for cost-recovery. Suppliers will pay for the RTS in proportion to the number of RTS customers they have.

The BBC have stated that they plan to cease long-wave radio transmission after 2021 and that if the service is required for RTS after that, industry will need to pay the whole costs of the infrastructure. The estimated charges to be levied by the BBC after 1st April this year go from under £1m, to over £1.5m and will increase again on 1st April 2021. The BBC have suggested they can keep transmission going until 31st March 2023 but after that, a complete overhaul will be needed.

In a February 2020 update from Energy-UK⁶⁵ it was confirmed that suppliers recognise they need the current RTS arrangements in place until 31st March 2022 and this has been communicated to the ENA who have negotiated a contract extension with the BBC accordingly. Replacement meters should be available later this year (see below) which means suppliers will have approximately 18 months to replace circa 1.5m legacy RTS meters with smart equivalents.

⁶⁴ <https://www.elexon.co.uk/smg-issue/issue-84/>

⁶⁵ <https://www.energy-uk.org.uk/files/docs/Policies/Smart%20Meters/TheFutureofRTSFebruary2020.pdf>

Smart metering as a building block

In developing the smart metering (SMETS) specification it was always acknowledged that there would be a need for meter variants to deal with Economy 7 and RTS.

All SMETS meters have the ability to handle time-of-use tariffs and could in principle offer two-tier Economy 7 style tariffs. If the heaters were controlled through some other communications channel then this would be adequate. It clearly works if the customer does not have storage heating or an immersion heater but still wants Economy 7. However, a SMETS variant that can handle separate circuits for heating and other loads and includes an Auxiliary Load Control switch (allowing the timing of when the heater is charged up to be controlled through effectively an on/off switch on that circuit) is needed to offer the service in the way it is currently provided in many cases. These 5 terminal / twin-element meters would also allow different tariffs to be applied to the different circuits and hence provide the ability to offer the sort of “heating tariff” that is sometimes offered with RTS (where the afternoon boost is charged at the heating off-peak rate).

Despite the variants being defined in SMETS back in 2012⁶⁶, there has been slow progress in developing and testing them for use in the market. Economy 7 customers are not yet generally getting smart meters, although the meter variant discussed above is expected to be available later this year.

There is also a question around DCC coverage and whether it will reach the more remote areas of Scotland, where many of these meters are located. If it has not already been done, an exercise to map the location of RTS meters against the DCC postcode checker would provide insights as to whether there is likely to be an enduring issue. It is also worth noting that RTS has proven a highly reliable communications infrastructure where the DCC has experienced some hitches.

Another complication is that in blocks of flats (where storage heaters are more prevalent) the meter can be located some distance from the property. A particular solution (Alt-HAN) is being developed to deal with this. It is expected that this will start rolling out in 2020/21.

The mechanics of effecting load control

These arrangements for an Economy 7 meter effectively look to duplicate the existing arrangements where what is provided is a binary on/off signal applied to all the heaters – with input and output on individual heaters controlled by the customer.

With the move to smart storage heating discussed in section 2, the expectation is that controls will become more sophisticated, including having different timing schedules and arrangements for different rooms. In this world it is far less clear that the current simple on/off load control arrangement is appropriate.

BEIS have produced a leaflet⁶⁷ that sets out the different routes that can be used to deliver demand side response with smart meters. These are:

- the use of time of use tariffs sent to a Consumer Access Device which will then control the different smart appliances in the home (taking account of other user input such as when the washing needs to be done by);
- an Auxiliary Load Control (ALC) that sends an on/off signal directly to particular circuits and would be the route to delivering traditional storage heating control – but requires a specific meter variant;
- a HAN Controlled Auxiliary Load Control that sends an on/off signal over the Home Area Network to a separate switch – this is envisaged by BEIS as a potential route for EV charging;
- consumer behaviour in response to time of use tariffs.

⁶⁶

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/42953/6129-consultation-second-version-smets.pdf

⁶⁷

[https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/579774/291116 - Smart meters Demand Side Response leaflet - DR - FINAL.PDF](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/579774/291116_-_Smart_meters_Demand_Side_Response_leaflet_-_DR_-_FINAL.PDF)

Implementing smart storage heating could involve any or all of these routes, in part depending on whether the flexibility market develops through price signals or contractual arrangements. Price signals could feed into the algorithms used by the smart storage system to determine the schedules for each heater. Equally a load control signal – including the new proportional load control – could be used to provide ancillary services – subject to adequate comfort being maintained or with customer over-ride.

One of the common challenges encountered by the various pilot projects around smart electric storage heating discussed below was communication with the heaters. In some cases, the customers' broadband was used but not all customers have broadband (in particular in this demographic) and in any event it is not seen as a reliable way to control an essential service. In other projects a tailor-made broadband solution was used and, in some cases, other technologies such as long-range radio. It was not possible to use the smart metering infrastructure because of the stage of the rollout but also because of restrictions on what messages DNOs can send. That said, even with access to the smart meter infrastructure smart storage heaters are likely to still require an additional two-way communication channel to enable room-by-room heating schedules to be set, taking account of a range of information, including weather forecasts and information fed back from temperature monitors in the property.

Even if the flexibility is procured through the market there is still a question as to how the DNO would call that load. Arguably it is more reliable if the DNO can trigger this itself rather than having to go via suppliers given the geographically narrow area that might be impacted and the need for speedy response.

The enduring solution being considered by SSEN for EVs (SEC 0046 discussed above) would effect load control by using Home Area Network (HAN) Connected Auxiliary Load Control Switches (HCALCS). The HCALCS will be connected to domestic EV chargers, and the SEC modification seeks to allow Electricity Distributors the ability to send the relevant Service Request via the Data Communication Company (DCC). This would result in altering the load on an EV charger in the event that the Electricity Distributor detects a potential risk of overloading on a low voltage network. Suppliers currently have the ability to manage load via HCALCS and this modification would extend these capabilities as well as the capability to install HCALCS to the Electricity Distributors. This would be defined in the SEC and require changes to the DCC Systems.

These same arrangements could be used to communicate with smart storage systems in future, though it should be noted that HCALCS are not yet generally available.

At present only suppliers can issue load control messages. This acts as a barrier to the involvement of third-party aggregators unless they use their own communication channels which, in the context of EV charging, BEIS did not want to see develop, preferring smart meters to be used as the platform.

Reflecting this, in August 2019 BEIS published a response⁶⁸ on the government's proposal to add proportional load control functionality to the Smart Metering System. This relatively small and incremental change will build on existing Auxiliary Load Control Switch (ALCS) and Home Area Network (HAN) Connected Auxiliary Load Control Switch (HCALCS) functionality to enable more precision and flexibility in the control of load on behalf of consumers than is currently possible. The consultation includes proposed drafting changes to the SMETS2 Technical Specification to deliver this outcome. The consultation said the technology is intended for use in effective management of significant loads such as electric heating systems and the smart charging of batteries and electric vehicles. In the detailed use cases that are discussed BEIS argues that hot water and storage heaters can be controlled by a simple on/off function and do not need this proportional control. This would seem to be based on a backward-looking view of how storage heating has worked historically rather than trying to envisage what might be valuable in a smart electric heat future. However, the drafting is intended to cover a range of potential uses so could be adopted for smart storage heating technology in the future.

The other change proposed as part of this BEIS consultation is around third-party load control. The aim is to future-proof devices so that third parties would be able to issue commands rather than having to go via suppliers. Allowing third parties to exercise load control would require a further formal decision by BEIS but

⁶⁸ <https://smartenergycodecompany.co.uk/latest-news/beis-response-to-consultation-on-proportional-load-control-and-associated-smets-drafting-new-consultation-on-gbcs-and-chts-drafting/>

the aim was to ensure the technology would allow it (given the likely lives of these assets). Having third parties able to provide flexibility services in this way would probably be of benefit to the DNOs as aggregators may be better able to recruit local heating loads.

DNO Requirements of an RTS replacement

In order to explore what else is needed in terms of an RTS replacement, it is worth being clear on what specific forms of DSR response the DNO needs and how these are best delivered.

Simply thinking about replacing RTS to deal with the problems the RTS was designed to deal with originally is missing the point as the network challenges can be expected to change over time anyway. This points to the need to go back to first principles in terms of what is needed. The list below gives examples of what are understood to be the primary requirements as a structure for SSEN to think further through what they will need over time – and hence to enable them to articulate these requirements in any commercial negotiation / tender.

Encouraging load to shift to off-peak times

This is about managing the overall network capacity at peak times and is the traditional benefit of Economy 7. This can be expected to still be relevant (and could be signalled through network charges).

Handling more local variation in when off peak is

With the increased uptake of DER and EVs the timing of the peak can be expected to vary between local areas. This could be reflected in a move to having differential network charges by Grid Supply Point for example but the risk is that suppliers will not want that additional complexity and will not reflect these differences in their end user tariffs (and GSPs may still be too broad an area). As indicated above this may therefore point to the use of contractual solutions to deal with very local issues.

Handling more dynamic variation in network utilisation patterns – and managing incidents

More use of DERs with different drivers will lead to more variability in network utilisation patterns across seasons and even from day to day (e.g. dependent on weather and indeed on pricing signals themselves including wholesale price). Seasonal variations may be manageable through network charging (subject to the conclusion of Ofgem's Forward Looking Charges SCR which is considering the issue). However other more dynamic changes may be best dealt with through contractual arrangements.

Ensuring diversity

From SSEN's perspective ensuring diversity is the biggest challenge. Where RTS adds value over traditional Economy 7 is by having a number of different switching schedules that are used in a local area to diversify the load.

SMETS includes randomisation (e.g. +/- 10 minutes) to avoid surges in load when prices change. However, this is not the same as ensuring a spread of load across a longer off peak period, for example. The same requirement is likely to arise in relation to smart EV charging.

In principle it should be possible to specify this in a contract with an aggregator/supplier, provided they have sufficient contracts within a limited geography. An obvious opportunity is social housing where there are likely to be clusters of premises with storage heating and a single contact point (especially in those cases where heat is included in rent). As noted above a significant proportion of storage heating today is in social housing and the Connected Response retrofit solution discussed above targets blocks of flats where there is a significant overall load.

In the short term SSEN should be able to convince Ofgem that this sort of negotiated arrangement – talking to specific parties to find a way to address a specific and very local system issue – is acceptable and that the overhead of requiring an open tender would be disproportionate. Ofgem has signalled that it recognises the need for transitional arrangements until the market for domestic DSR becomes more developed.

Steps to maintain diversity in a smart meter world

Currently, Load Managed Areas are handled through the use of numerous Standard Settlement Classes (SSCs) to ensure switched load – such as night storage heaters and water heating – does not occur simultaneously, thereby reducing the risk of overloading on the network.

These arrangements are set out in Schedule 8 of DCUSA (along with the wider arrangements for ensuring security of supply) and are the focus of efforts to evolve the arrangements in the light of the smart meter rollout and RTS de-commissioning. In 2016 Ofgem approved⁶⁹ modification DCP204 to update the arrangements in the light of smart metering and in particular to provide for randomisation of any load control signals (by at least 10 minutes) to avoid large spikes in loads occurring at the same time, creating problems for the system.

Subsequently in 2019 Ofgem approved SECMP0025, which gives the DNOs visibility of any instructions sent by suppliers in relation to load control, including updates to load switching schedules. Having visibility of what is happening is a minimum requirement to enable the DNOs to efficiently manage their network.

Also, in 2019, Ofgem approved DCUSA modification DCP326⁷⁰ on the Introduction of load diversification identifiers in Load Managed Areas. This put in place arrangements through industry processes around Line Loss Classes for DNOs to have visibility of and influence the load switching schedules in designated Load Managed Areas (where there are particular constraints). In approving the modification Ofgem again signalled its preference for market solutions but acknowledged that this was not practical at present. In particular Ofgem said *“Whilst we continue to encourage DNOs to look at more innovative ways to provide network resilience without reinforcement for example through flexibility, and treat these options on a level playing field, we acknowledge that domestic level flexibility is nascent, and this is difficult in some LMAs in rural and remote locations. We recognise the need for DNOs to have sight of the LMAs to allow a safe and reliable service to be provided to customers, and that this change would allow this to continue.”*

Putting the costs in the right place

There is an important question here about the appropriate baseline for RIIO revenues if new commercial arrangements have to be put in place. As noted above the legacy arrangements have enabled SSEN to avoid significant levels of reinforcement historically. While it may well be able to procure suitable flexibility services to avoid the need for investment, this will come at an incremental cost for SSEN where previously it was effectively getting this benefit for free. The reason for this is that many of these heating systems were put in place at a time when the industry was still vertically integrated. However, the position now can be seen as one where SSE (now OVO) as supplier is forced to maintain what are potentially unattractive tariffs for them (as they do not benefit from lower DUOS charges or ancillary payments for supporting the DNO). This almost certainly exacerbates the issues around competition for these customers and results in suppliers trying to move them onto more standard tariffs which may be detrimental to the customer.

If this was a new constraint that SSEN had identified it would tender for DSR as an alternative to reinforcement (through for example its Constraint Managed Zones). The costs of the tender would be part of totex and recovered from customers at large.

To untangle the current situation and move to what Ofgem may wish to see in terms of a market-based solution for RTS, will cost SSEN more and would need to be reflected in its RIIO allowance.

However, regularising the position in this way would mean suppliers / aggregators who are providing a service would then be rewarded and could properly pass those benefits on to the end customer. The higher costs faced by SSEN would be borne by customers at large – in the same way they would be for any reinforcement or flexibility services. This should rightly and properly help those with storage heaters who have for a long time been supporting the system without recognition.

⁶⁹ <https://www.ofgem.gov.uk/ofgem-publications/99208>

⁷⁰ <https://www.dcusa.co.uk/event/dcp-326-authority-decision/>

In carrying out such flexibility tenders to deal with the legacy issues – or indeed new ones – it may well be that by reflecting the true value of the flexibility in particular locations the payments would be sufficient to enable upgraded smart storage heating to be installed – or at least a contribution made towards that. This is similar to the Social Constraint Managed Zones that SSEN have been running where they have contributed to the cost of energy efficiency measures to reduce peak load. It is important that Ofgem are open to these arrangements and that they can be combined with other sources of funding if necessary.

Protecting consumers in the short term as smart meters are rolled-out

Given the complexity involved in these restricted metering arrangements there are clearly additional risks associated with this phase of the smart meter rollout – which BEIS and Ofgem should pay particular attention to given that the customers involved are more likely to be vulnerable. The risks which are identified earlier in this report relate to potential problems with wiring, time switches and alignment with tariffs.

For customers who do accept a smart meter and are moved onto an inappropriate tariff for charging their storage heaters and hot water, they cannot move back if they then find this is much more expensive. The legacy heating tariffs are not open for new customers (even previous customers) to sign on to.

Another consideration is what happens if customers refuse a smart meter – which they may do if they are set to lose access to particular tariffs (or indeed for a range of other reasons).

The Energy-UK update notes the growing problem of customers with faulty RTS meters where no replacements are available. The paper highlights options of using a SMETS1 variant meter that is available or using an ordinary smart meter with a separate contactor (switch) to control the heating load. The paper notes that this would require additional skills and reinforces the point that dealing with these more complex meter types will require installers to have additional training.

Given the complexities involved and the real risk of consumer detriment, there is a need for a strong focus from Ofgem and industry on managing this changeout process carefully – and a route for customers to get additional support if needed.

A first important step will be for suppliers, together with DNOs, to identify and map which customers are reliant on legacy off-peak tariffs for which the schedule for electrical charging is controlled via the RTS.

Suppliers and DNOs should consider next steps, including ensuring that installing a smart meter will allow continued satisfactory operation of a customer's storage heaters and off-peak hot-water. For some customer groups, installing a smart meter might create a knock-on set of problems (e.g. tariff-related, wiring-related, a need for smart controls to replace RTS functionality). Ultimately, informed advice will be essential dependent on the particular circumstance of these customers, as to how far they may benefit from a smart meter installation – or not. Suppliers will need to ensure that smart meter installers have appropriate training to deal with these more complex arrangements.

From a customer standpoint, it is also very important to be clear what happens if the RTS signal is lost without a suitable smart meter being installed to replace it. It seems that the schedule will cease to be updated and will either just continue at the timings last programmed or will revert to a pre-set “fallback” schedule (depending on meter age and type). However the precise impact is likely to vary in unpredictable ways as demonstrated by the responses to the ENA consultation on the RTS closure⁷¹ and it is has not been possible to rule out the risk that some customers might lose their heating entirely. Suppliers and DNOs need to satisfy themselves which customers are at risk of significant detriment – and potentially how - from loss of the RTS signal.

Longer term lessons for flexibility

In the long term, as the DSR market develops (in particular domestic DSR given the location of the constraints), it may be possible for SSEN to tender for solutions on a more technology neutral basis, which would be more in line with the Ofgem philosophy. This means thinking about the interactions of storage heating with EV

⁷¹ <https://www.energynetworks.org/assets/files/news/consultation-responses/ENA%20Response%20to%20Consultation%20on%20RTS%20Future-with%20Appendix1.pdf>

charging and batteries and where the solutions might be interchangeable – or where the distinct customer requirements and the nature of the technology mean that they are not interchangeable as resources. For example:

- how long it takes to charge a storage heater compared to an EV;
- heating is seasonally variable where other solutions – including hot water - are not (or at least not to the same degree);
- EV charging may actually be more important to do overnight (when the car is less likely to be in use) whereas storage heating and hot water could more readily be charged in the daytime (if new daytime off-peak periods develop);
- the geographies where different solutions will be prevalent are likely to be different (eg social housing is likely to have lower EV take-up but more storage heating);
- stored heat cannot be converted back into electricity whereas vehicle-to-grid services are likely to develop.

There would be value in further work to compare usage profiles for smart storage heating and EV users as a first step in looking at the potential combined impacts (which may not be in the same household but could be on the same feeder).

At this stage it remains unclear whether smart storage heating would be of more or less value in a system with significant EV uptake but also one with significant excess wind at night and with increasing network constraints. However, in this uncertain future there would seem to be real value in retaining the option of storage heaters and hot water as an additional source of demand side response.

8 Recommendations

Recommendations to Policy Makers

Short term

Ofgem's RIIO incentives to remove storage heating systems (and replace with gas) should be re-examined and alternatives considered (including storage heater upgrades and whole-house insulation).

As part of its work on distributional impacts **Ofgem** should consider the effects of its charging and wider reforms on those with storage heating.

Ofgem should monitor supplier communications around legacy time-of-use tariffs to build learning and best practice for a move to more widespread use of TOU.

Ofgem should ensure that its monitoring includes regular updates on the numbers of different meter types and off-peak tariff arrangements. Better data on household usage at different times / rates would allow **Ofgem** to better understand the impacts of their policy decisions on this critical group of customers.

To avoid significant consumer detriment, an active programme of oversight and support from **BEIS and Ofgem** is essential as smart meters are rolled out to around 2 million Economy 7 customers and other households with complex meter types.

Ofgem should clarify that for customers with storage heating, the smart meter installation should be used to explain to customers how to use their heating cost effectively (as part of the SMICOP required advice).

Ofgem should clarify that **suppliers** are responsible for ensuring that customers are on a tariff that is suitable for their needs including their heating arrangements.

BEIS should establish arrangements to ensure independent advice is available to consumers about low carbon heat solutions.

MHCLG should ensure that building standards do not over-look the value of household thermal stores (heat, hot-water) as part of future proofing for net-zero and should not preclude particular heating technologies at this stage.

2050 vision - **BEIS**

Electric storage heating (and even direct-acting electric heating) should be recognised among future policy-options for heat-de-carbonisation, together with whole-house approaches to thermal insulation.

Policy-thinking on de-carbonised heat needs active signalling to the supply-chain so that the market can respond and consumers and households are able to make informed choices.

There should be acknowledgment that future heaters may not look like current storage heaters and the model for their use may require different and more sophisticated demand side functionality more akin to that being considered for smart EV charging.

More attention should be paid to the role of hot water tanks in all heat electrification scenarios. This includes the disbenefits of removing today's water tanks.

Recommendations to SSEN and wider industry

SSEN needs to be clear where DTS meters are located on its system and in particular any clusters in Load Managed Areas. Linking this to PSR data could also highlight risks from a customer perspective.

SSEN also needs to be clear what proportion of these customers will fall within DCC coverage and whether there are significant clusters of DTS customers that will not be able to switch to suitable variant smart meters.

Energy UK to work with suppliers on a solution for DTS customers where there is no DCC coverage.

SSEN should open a dialogue with suppliers and with housing associations to develop a market-solution, which could comprise:

- rewarding the supplier (for example through discounted DUOS charges) for managing schedules that provide a diversity of switching patterns;
- putting out to tender requirements for rapid response load management solutions (which could be met through switching off storage heaters as now – though perhaps with a consumer over-ride – but could also be met in other ways);
- building on this evidence to continue discussions with Ofgem around local resilience arrangements and whether more sophisticated load shedding arrangements should be considered going forwards.

SSEN should also explore RIIO funding arrangements with Ofgem if it is to pay going forwards for load-management services that were previously provided ‘free’.

Suppliers should work with SSEN and relevant local authorities to consider the potential for area-based rollouts of smart meters (following the Derby pilot) to help deal with clusters of more complex installations requiring more specialist skills.

Annex 1: Summary of electric heating research projects

Real Value

This project was funded by Horizon2020 and involved the installation of smart storage heaters across Ireland, Germany and Latvia. The project was a collaborative effort by a number of partners including Glen Dimplex and the University of Oxford. In total 736 Smart Electric Thermal Storage (SETS) were installed of which 534 in Ireland. In Germany this included a number of retrofits. The project explored both the consumer experience and the network benefits of demand side response.

The research showed how customer outcomes were related to contributory factors such as a good experience at installation, technological reliability, support and advice from others (supplier, heating engineer, housing manager or neighbours - what they term "middle actors"), metering arrangements and tariffs, the homes themselves with their unique combinations of people, appliances, preferences and activities.

The control architecture allowed control to be shared between customers and aggregators. A boost button was provided for manual over-ride but the DNO also has the ability to schedule the charging of the heaters, taking account of consumer preferences. In Germany the scheduling also took account of weather forecasts.

Overall 74% of those surveyed were positive or very positive about their new heating system – with a strong sense from those who previously had traditional storage heating that this was much better. The positive comments given focussed on the improved comfort and warmth.

The project tested in depth how well customers understood the controls. While most customers said they understood them, when asked for example to demonstrate how they worked many struggled. This highlighted the need for significant effort to be put into explanation (or even just encouraging people to play with the controls). Support could come from a range of sources but was critical to households using the system effectively.

The project did not manage to gather previous information on customer bills so no formal comparison was possible on cost savings. When asked most customers tended to believe their bills had stayed the same or increased but it was clear that there was little awareness of the actual impact. While cost was important it had to be balanced with comfort and health.

Connectivity (between the appliances and the system) was invisible to and not always understood by customers who did not always realise the need to keep their equipment switch on at all times to provide 24x7 demand side response. Conceptually though there was a lot of support for the idea of demand side management.

NINES⁷²

A Demand Side Management system was successfully implemented in Shetland within the SSEN NINES project which had the wider objective of how to balance demand and renewable energy supply on an island, not connected to the main GB network. Quantum smart storage heaters and hot water tanks were installed in 229 social housing properties. DSM then allowed the network operator to balance demand with intermittent generation by controlling the charging of smart these domestic space heaters and hot water tanks. The heaters can be switched on and off at varying power levels every 15 minutes, according to a target schedule transmitted from the network control centre; they also estimate their next day's energy requirement and transmit this back to the centre for scheduling.

The evaluation report based on surveys and monitoring of the properties found the heaters delivered much improved levels of comfort (as a result of their better thermal insulation).

Like many of the projects they experienced problems with communications in several of the properties which meant that they had to revert to stand-alone operation. In some cases where unusual results were picked up

⁷² <https://www.ninessmartgrid.co.uk/library/1a-nines-dsm-customer-impact-report-2/>

this reflected either technical communications problems or issues with consumer understanding (eg switching things off). The close monitoring through this project meant those issues could be detected but highlights the need for an ongoing support role.

While meter readings were not collected to allow costs to be properly assessed the modelling carried out suggests cost savings from the improved thermal insulation on the storage heaters. On hot water the report concludes that costs may have increased as the DSM led to higher levels of hot water being provided.

The report concludes that “the NINES DSM technology is best suited to large, poorly insulated houses, which need a lot of energy to maintain comfortable temperatures. The technology is inherently a poor fit in modern, well insulated houses requiring little heating, often less than the uncontrolled output of storage heaters. Even if heater insulation were to improve radically, the contribution of such houses to controllable power and storage would be very small relative to the overhead”. This was interesting and somewhat counter to the messages in section 4 above.

The point here is that the DSM equipment itself was costly to provide and maintain and hence could not be justified for smaller loads. Clearly if smart meters are already being installed in such properties and provide the functionality required then that would change the economics and even if the loads were small there could then be scope for an aggregator to offer more useful loads to the DNO.

The other point about small properties needing less than the uncontrolled output of storage heaters is another reason why direct electric heating may be a better solution where the heat load is minimal. The report also suggests that there is a much stronger case for storage heaters to be used in the living room and potentially hall areas where there is more heat demand – but not in bedrooms. In many cases the heaters installed were over-sized (or under-sized) as the previous heaters were essentially replaced on a like for like basis. This reinforces the importance of having proper independent advice up front that takes account of customers’ real-world use of the system.

Access Mull

This project was funded by Local Energy Scotland and used VCharge technology to control new and existing storage heaters on the Island of Mull in order to try to balance the system which is heavily dependent on hydro. The report⁷³ does not comment on the customer experience or comfort levels but concludes that the use of DSR in this way can be effective in tracking generation load and that the DNO should have confidence in the use of the “flexible connections” approach as a way to connect more community generation.

Scottish Government Low Carbon Infrastructure Transition Programme (LCITP)

This project was funded 50:50 by Scottish Government and VCharge (OVO) and project managed by Keepmoat Regeneration (Engie). The participating landlord was Glasgow Housing Association (Wheatley Group). Around 300 homes were installed with smart controls on each storage heater, and each home had a SMETS1 meter installed. Heater charging was based on a combination of local weather forecast, actual in-flat temperature and resident self-specified comfort needs (both time and temperature). Residents voluntarily participated by switching from the incumbent supplier, Scottish Power, to the new entrant supplier, Our Power (ceased trading 2019).

Around 300 customers participated and reported the benefit of improved storage heating, elimination of supplementary heating and reduced electricity bills. The 300 were spread across 8 Glasgow tower blocks, representing around 35% of the block population. The initial business model of VCharge was to fund projects like this via grid revenues but there proved to be a gap between National Grid revenues and installation costs, resulting in early termination against the original Scottish Government plans to install in 5,600 flats across 65 tower blocks.

⁷³ <https://www.localenergy.scot/media/110697/the-access-project-final-report.pdf>

Westminster City Council

Westminster City Council, previously City West Homes, has operated a Heat-with-Rent scheme on its storage heating and hot water in over 900 flats across 8 tower blocks. This was originally managed on the London Electricity Cyclo system that sent switching signals via the 11kV network and was switched off in 2015. From 2015, Energy Assets collaborated with Westminster to develop an aggregated half hourly metering system to create a single MPAN for each block and then from 2017 a smart switching system set-up to deliver three charging periods for both heating and hot water, by night, afternoon and evening. This has significantly enhanced resident comfort and produced significant savings that have been passed onto residents. The technology involved was subject to a legal transfer in 2018 to Connected Response, co-founded by former VCharge and Energy Assets employees to develop this solution for the wider market. The next major project in a London tower block is scheduled for April 2020 with a different landlord and will involve optimisation services being provided by a major energy supplier.

NEA – Technical Innovation Fund⁷⁴

The NEA through its Technical Innovation Fund has provided support to a range of projects aimed at building understanding around emerging technologies and how they can be used to help those in fuel poverty.

A number of these projects have involved smart storage heating or hot water systems and they provide significant evidence on the customer experience both through surveys and monitoring of the properties. There is an issue that many of the projects were quite small scale and hence the results are not statistically robust. Moreover in many cases there was no baselining of performance before the measures were installed making comparisons difficult.

However aside from those concerns the projects provide valuable insights and in particular apply a robust methodology for taking account of different outdoor temperatures when comparing energy use. An external temperature of 15.5°C is accepted by energy professionals as that below which heating is normally required, and above which no heating is needed. Degree days (DD) are the heating need i.e. the number of degrees below 15.5°C that the average temperature falls, for each day. Degree days are added together to give a total in the relevant period, enabling different periods to be compared for their energy consumption.

Common messages from across the projects were:

- It is important to ensure that residents are given support on how to use their heating systems most efficiently post install. This requires provision of on-site advice, materials such as manuals and follow-up visits. New tenants need to be provided with comprehensive information and thought is needed as to how best to support those with learning difficulties etc.
- Support is also needed to ensure residents are on an appropriate tariff.
- There are very significant differences in how people choose to heat their homes and what their need are which need to be taken into account in determining the appropriate solution and setting it up.
- Modern storage heating is generally more cost effective than direct heating (because of the ability to use off-peak rates).

Nottingham Community Housing Association (CP1022)

In this project old storage heaters were replaced with 4 different types of modern electric heating systems (3 on-peak heat, one storage heater). Rointe, Osily and Fischer systems all use 'on-peak' electricity while Dimplex Quantum storage heaters uses 'off-peak' electricity. The project was limited in terms of sample size (total of 8 properties).

⁷⁴ <https://www.nea.org.uk/hip/projects/?s=&hipprogramme=technical-innovation&hiparea=&sortBy=>

Overall the on-peak heating systems provided residents with more control over when they wanted to be warm and provided them with heat at those times. However, this was compromised by the annual energy costs that were required to achieve the higher temperatures. This issue was compounded by a lack of understanding over how best to use the heating systems.

On-peak electric heating may be more appropriate in smaller-sized properties such as bedsits or places where an ASHP or gas connection are not possible. They are not suited to larger properties where residents occupy the property for longer periods.

The most significant improvement noted was the increased control residents felt that they had over the heating system, with all the systems they were better able to set temperatures and heating periods.

All the properties had solar hot water systems which should provide up to 50% of hot water demand per annum and more in the summer. However, an immersion heater is still required to provide hot water when the availability of solar hot water is low. Previously residents were able to automatically heat water during E7 hours. When moving away E7 to a single-rate tariff, the cost of hot water will rise and extra care is needed to only heat as much as is needed.

Walsall Housing Group

This project installed and compared 2 different electric heating solutions in 2 bed flats in a tower block in a deprived community with no mains gas. One group of 10 flats received novel “lower energy” on-peak electric Enviroheat HET EconoRad heaters and replacement EconoCylinder immersion tanks, combined with Switchchee smart thermostats – which learns residents’ occupancy patterns, to adaptively control heating even if the householders don’t interact with it. The other 10 flats received new Elnur storage heaters (not high heat retention models) also coupled with Switchchee smart thermostats and the VCharge controller with weather correction, using OVO’s Economy 10 tariff and a smart meter. Five control properties were also monitored.

Households using Enviroheat heaters (Tempergreen group) attained cooler temperatures on average than VCharge. They may have either restricted heating to ensure affordability, or be used to using only spot-heating. VCharge group properties used more energy but at lower cost, due to the majority being on the lower cost off-peak rate.

Installation of both new heating systems helped improve comfort, with around half in each case saying they could now heat and / or comfortably use more of the flat (where previously they may have only been heating one room for example). Significant cost savings could not be calculated for either group in this study, given changes in the level of heating and because some properties were wrongly wired previously and hence not paying for their heating. In each case there was less use of supplementary heating. Even where households did not make a saving, satisfaction with heating generally improved: homes were warmer and more comfortable, and the temperature was felt to be easier to control in Tempergreen group flats.

The combination of the Elnur, Switchchee and VCharge technologies was more complicated than the old storage heaters. Moreover VCharge control was via a website: a few householders were not online, and others had trouble finding or logging into this, which limited desired control

Therefore, the report concluded that neither solution could be wholly recommended. A simpler-to-control off-peak system would be better, giving both the ease of use of the Enviroheat heaters, but with lower cost off-peak electricity costs. This must be combined with clear instructions for use, given regularly, and to new tenants. Enviroheat heaters may have a place in well-insulated properties which do require little heat, but cannot be recommended as the main heating in social housing with low income residents, where their extra cost may lead to under-heating of homes.

Other benefits noted were that 5 of both groups stated that the new heaters were much nicer to look at than the old storage heaters, and 1 of each group said the new heaters were cooler to the touch and hence more child-friendly. One in the VCharge group felt that old storage heaters gave out a dry heat which affected a resident’s breathing, but that the new storage heaters were better.

There were quite a few technical issues around the installation, including the requirement for separate wiring for heating (which had previously been done incorrectly) and poor mobile coverage causing problems for the Switcher control system. Switcher is fitted with both GSM (mobile phone) and Wi-Fi connectivity (Wi-Fi was originally planned to be installed as part of this project but could not be for logistical reasons) to help prevent connectivity problems in those who do not have broadband, or who turn it off overnight / when out.

Your Homes Newcastle

This project retrofitted existing night storage heaters with VCharge Dynamos in a tower block situated in the west end of Newcastle Upon Tyne. The VCharge Dynamo aims to increase comfort and reduce energy use by charging the storage heaters taking into account the household's preferences, internal temperature, previous consumption patterns and external temperatures to determine how much charge is required. A total of 26 properties received VCharge Dynamos and of these 14 were monitored (with temperature and humidity loggers and smart meters to record electricity usage).

The original ambition was for over 100 homes to be fitted. The block is in the top 1% of most deprived areas and is aimed at over 55s.

After the installation of the VCharge most residents stated that their homes were warmer and more comfortable. There was a significant reduction in residents using expensive supplementary heating in their properties. Residents found the system easy to use but this did not translate into an improvement in the amount of control that the residents felt they had over the system.

There was considerable variability in the annual heating costs experienced by the residents, this issue was further compounded by initial householders signing up to the project on a flat rate tariff with the original supplier partner Future Energy. Subsequent customers were signed onto OVO's Economy 10 tariff which was more suitable.

Previously room temperatures were set based on the level the input control was set at and were not altered regularly by residents. The VCharge system enabled them to specify a temperature and specific heating periods. One drawback was that they had to contact VCharge if they wanted to alter the temperatures or specified heating periods.

One lesson is that in setting up the system careful consideration should be given to the number of rooms heated, how long they are heated for and to what temperature they are heated to. Some residents experienced artificially inflated bills because of unnecessary temperatures in lesser used rooms. Not all residents wanted heating in their bedrooms as their preference was for a cold bedroom. One did not have the bedroom storage heater on yet still achieved average temperatures between 18°C–19°C. The hall heater was used and likely provided some of the warmth that heated the bedroom.

As with other NEA studies customers were asked when in the day it was most important for them to feel warm. In contrast to other studies there was a sizeable proportion here concerned about being warm during the day – reflecting the fact that many were retired – and reinforcing the point about usage patterns being key.

Overall 12 of the 13 residents noted an improvement in the warmth and comfort of their home and 6 of those residents also stated that there had been a subsequent improvement in the quality of their homes. 2 of the residents noted improvements to their health, making reference to reduction in discomfort related to their arthritis. One stated that they found it easier to get up and out of bed in the morning. This reinforces the importance of effective heating to health and wellbeing.

Several of the residents did not use their immersion heaters as they had electric showers and would fill up their kettle to wash their dishes. Not using the immersion heater reduces the annual electricity cost.

Aspire Housing Newcastle-under-Lyme – Quantum smart storage heating

In this project 20-year old storage heaters were replaced with Dimplex Quantum high heat-retention (HHR) electric storage heaters, and the domestic hot water (DHW) tanks with integral immersion heaters were replaced with Dimplex unvented cylinders, with immersion heating.

These have improved insulation over older heaters – so minimising heat loss when it is not required - and a controller which allows the resident to set a 7-day timed heating-period profile, and which has a self-learning algorithm allowing it to match to residents' lifestyle and climatic conditions. Participants also received a replacement electric immersion tank, a 150L Dimplex ECSd150-580 hot water cylinder.

The properties covered were 1 and 2 bed flats – typically they received 3 heaters (hall, living room and bedroom). Measures were installed in 32 properties but only 6 were monitored with some additional surveys sent out.

After installation of the new heating measures, the majority of householders (7 of 9 who responded) felt their home was warmer and more comfortable, and that it warmed up faster. 6 felt the heating was easier to use, and 5 said they had more control over it. 4 also felt their energy bills had reduced, but fewer (3) felt they were saving energy in the home.

Apart from one flat which appeared not to have been adequately heated previously (where costs and energy use went up), all other properties made savings after correction for outdoor temperature. Energy use reduced from 4.85 to 4.11 kWh per DD, a saving of $14.5\% \pm 7.1\%$ when averaged across properties for which both before and after data was available. Across the whole group, the average electricity need would be 7,635 kWh per year after the measures

The report concluded that provided residents, particularly those who are most vulnerable, are supported with information, advice and assistance, Dimplex Quantum storage heaters appear to reduce heating energy use, costs and improve controllability compared to older types of storage heaters

Ensuring hot water tanks are suitably sized both for the space available, and the items installed in the property which use mains hot water, is essential. For example, if no bath is fitted but only an electric shower, in a flat with 1-2 residents, it is highly unlikely that 150L of domestic hot water would be required per day, and an over-sized tank could increase costs if more water were being heated than previously. Ensuring domestic hot water tanks are not over-sized for residents' needs will further reduce energy need – and therefore costs – in fuel-poor households.

Nottingham Community Housing Greenvision – Dimplex Quantum Heaters

Dimplex Quantum Heaters were installed in 61 properties, 11 of which were monitored.

There are indications that lower bills prior to the installation of the Dimplex Quantum heaters were due to the households not using the old system as often as they would like. This is due to factors including perceived expense, unreliability, uncontrollability and thermal comfort. Many reported they chose to have the old heaters off and wear extra clothes rather than turn the heating on and be uncomfortably hot as well as worrying about how much the heating would cost them. The Dimplex Quantum storage heater was effective at improving overall heating standards for the majority of households however some residents still felt they could not adequately heat their homes

Most residents found the Quantum controls harder to use and the report concluded that more time needs to be spent explaining the controls at installation.

Alternative Heating Systems Wakefield WDH

A comparative trial involving small numbers of different heating technologies (upto 6 of each) including ASHP with solar thermal, gas boilers and hybrid boiler, infrared electric heating and Dimplex smart storage heating.

Replacing a range of previous solutions (from coal to old night storage heaters) in a variety of property sizes – making strict comparison more difficult.

One of the benefits of infrared heating cited by Logisor is that objects within the room such as the sofa and person sitting on it are heated rather than the air. This should mean that heat is almost instantaneous, and energy is not wasted heating the remainder of the room. The main method of controlling the temperature of the infrared system is through a thermostat which will turn off when the set temperature is reached. This thermostat will respond to the air temperature within the room therefore, the infrared panels are still required to heat the air even if it is indirectly.

Infrared heating resulted in a marked increase in costs compared to the old storage heaters that it replaced. The in-line hot water system (replacing an immersion heater) had a number of performance issues.

Ongo Homes North Lincolnshire

A comparative trial involving hybrid heat pumps, infrared heaters and Sunamp thermal storage.

Although they gave better controllability, 4 out of 6 of the infrared heating systems were more expensive than the heating systems they replaced (primarily electric storage heating).

Sunamp thermal storage used with a heat pump where cheaper to run than existing heating where used with an Economy 7/ 10 tariff. They were popular with customers – primarily replacing solid fuel systems as they require a level of internal space for the heat battery.

Innovation competitions

BEIS has funded a number of projects which are still in train but where the conclusions will be worth watching out for. In particular this includes projects specifically around heating but also some larger scale projects on domestic DSR which include the use of smart hot water tanks.

BEIS Low Carbon Heating Innovation Fund

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/825616/BEIS_Low_Carbon_Heating_Technology_Innovation_Fund_summary_project_details.pdf

Competition run in 2018. Reports not yet available but include:

- OVO and Sunamp will come together to develop a mass-market smart electric heat product, that can be deployed at scale by 2022. The proposed system uses the heat battery mentioned above to store heat generated from cheap, renewable electricity either via a heat pump or direct electric heater. A drop-in replacement for central heating, the system will be controlled by energy management software that ensures power is only drawn when it is being generated renewably, as well as enabling revenue to be earned from various grid support services, such as frequency response and energy arbitrage.
- BMSHome Ltd and GSPK design - The Thermionix system (similar to VCharge discussed above) matches the Time of Use of energy consumption with generation. The Thermionix Internet Of Things (IOT) Smart Controllers can be retro-fitted to existing electric storage heaters to turn them into smart devices. These Smart Heaters are then remotely instructed to use electricity to store heat when low carbon green energy is available for use, thereby maximising the benefits of renewable energy sources. The Thermionix Smart Controllers also improve the efficiency of the heaters, so they use less energy, keeping customers warmer for less.

BEIS Innovative Domestic DSR – Phase 2

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/783338/BEIS_innovative_domestic_demand-side_response-competition_phase_2.pdf

Competition run in two phases looking at innovations to support domestic scale DSR. Projects which made it through to the second phase with more substantial funding include:

- Voltalis – Aggregation platform looking to combine loads including storage and direct electric heating (with the Electric Heating Company) and to provide DSR services including to the grid. Delta EE providing support.
- Levelise – using AI in hot water tanks to create flexible loads
- Mixergy – using smart hot water tanks as flexible loads
- Powervault – looking to control hot water loads
- GEO Core4Grid – looking at providing DSR signal including a grid signal module to enable provision of balancing services
- GLA Home response – controlling batteries and hot water systems, working with UKPN

Other Ongoing Projects

SMILE (Smart Islands Energy System)⁷⁵ – Funded by Horizon 2020 and led by Kaluza this project looks at the potential to make use of DSR (of electric heating and EV charging) to support three island communities where there are system constraints. One project is based in Orkney – building on the Real Heat Orkney project – looking at using DSR to avoid having to constrain wind generation on the island using hot water cylinders and Sunamp thermal batteries as DSR.

⁷⁵ <https://www.h2020smile.eu/the-islands/the-orkneys-united-kingdom/>

Annex 2: Extracts from key data sources on meter numbers

Ofgem TDCV Open Letter describing different meter types

https://www.ofgem.gov.uk/system/files/docs/2019/10/tdcvs_2019_open_letter_0.pdf

Further insight: Economy 7, White Meter / Economy 8, Economy 10 and other

meter types

Restricted meters within profile class 2 vary across supplier, region and can be bespoke to a few households across GB. There are approximately 500 different SSCs in profile class 2 alone. The most common restricted meters are Economy 7, White Meters and Economy 10 that combined cover around 90% of the meter points in profile class 2. Despite the large variety of restricted meter types, many suppliers bill consumers on an Economy 7 or generic 'two rate' tariff arrangement irrespective of the exact configuration of their meter.

We have considered consumption on different types of metering arrangements, not billing arrangements.

Economy 7 metering arrangements are more prominent in the East of England, East Midlands and the South East, accounting for 59% of all Economy 7 meters installed.

White Meter / Economy 8 metering arrangements provide cheaper electricity for 8 or 8.5 hours during the night and electricity that is more expensive during the day. Similar to Economy 7, the majority of off-peak periods are set at the same time every day (although the exact hours can vary by region). White Meter / Economy 8 metering arrangements are most prominent in Southern Scotland, accounting for 75% of all White Meter / Economy 8 meters installed.

Economy 10 meters provide cheaper electricity for 10 hours during the night (and in some cases during parts of the afternoon) and electricity that is more expensive during the day. Economy 10 metering arrangements are more prominent in the East of England, East Midlands, Northern Scotland and Southern England, accounting for around 69% of all customers on Economy 10 meters.

DTS meters are designed for electric heating customers, most often with no access to mains gas, allowing remote control of the heating load by suppliers. Unlike with standard Economy 7, White Meter / Economy 8 and Economy 10 meters, heating loads can be activated at different times every day, typically depending on weather conditions. DTS meters are mainly located in Scotland.

Using the same approach set out in above, our classification of Economy 7 meters includes meters with an 8 or 8.5 hour off-peak (White Meter / Economy 8), and Economy 7 meters that are teleswitched. Our classification of teleswitched meters includes any meter that is teleswitched and which is not categorised as Economy 7 or Economy 10. This category includes DTS, heating and off-peak metering arrangements. Off-peak meters include those with a single Time Pattern Regime (TPR).

The below table shows our estimates of the number of meter points per category of restricted meter in each regional distribution area. The GB total includes meter points connected with independent distribution networks, which are not shown here.

Meter point counts,	Economy 7 / white meter	Economy 10	Teleswitched (including DTS offpeak and heating)	Other
East England	822,358	48,113	13,537	1,932
East Midlands	756,107	14,187	13,321	1,520
Northern Scotland	45,805	14,980	80,635	-
London	152,765	1,889	5,592	6,631
North Wales	83,372	1,401	3,459	2,752
Midlands	263,792	2,872	7,468	1,006

North East	79,013	1,333	13,207	590
North West	166,082	5,362	3,532	12
South East	405,356	2,916	22,655	15,074
Southern	237,225	12,789	46,529	793
Southern Scotland	152,285	8,230	101,636	145
South Wales	47,990	3,012	690	89
South West	196,265	4,284	12,025	3,384
Yorkshire	119,750	2,186	6,296	606
Total GB	3,547,081	131,337	330,732	34,835

While our TDCVs for profile class 2 electricity customers show the median consumption across all customers with restricted meters, the consumption patterns of customers with different metering arrangements varies within this. The table below provides estimates of mean annual consumption values by meter type. It is based on Elexon settlement data showing total estimated annual consumption for Profile Class 1, Economy 7 and Economy 10 meters as of June 2019, split by region. From our data, we are not able to calculate the consumption for the heating aspect of DTS meters, therefore we cannot accurately estimate the mean consumption for this meter type.

Because we use aggregated data, we are unable to break down consumption to meter point level, and so to derive the median consumption level, or to understand the distribution of consumption among customers with these different meter types. Nevertheless, these averages illustrate the consumption patterns that we observe between different groups of restricted meter customers.

Profile Class 1 3,421

Economy 7 / White Meter 5,177

Economy 10 6,819

Please note that the values are calculated per meter and not per household. In some cases, there will be two meters within a property, recording electricity consumption at different times (or being used for different purposes). As a result, the averages presented above may underestimate the annual consumption of customers on restricted meters, as the true consumption of the household will be split across two meters. This also provides another reason why, wherever possible, we would encourage customers to use actual energy consumption.

DUKES Data

Table 5.2 in DUKES attributes household final consumption to 'standard' and 'Econ 7'. For 2018, the numbers look like this.

2018 – TWh. Domestic final consumption – 103.4 TWh (278 TWh total) – of which Industrial = 83TWh, 'Other' = 87 TWh, Agric – 4 TWh		
Meter type	TWh	%
Standard	70	68
Standard Econ 7	16.5	16
Standard Pre-Pay	13.3	13
Econ 7 Pre-pay	3.4	3
TOTAL Standard TWh	83.3	81
TOTAL Econ 7 TWh	20	19

Extract from CMA Appendix on restricted meters

Table 1 provides information on the numbers of restricted meters including Economy 7. We found that around 17% of customers have restricted meters including Economy 7. We also found that roughly 86% of these restricted meters are Economy 7 meters. There are roughly 700,000 restricted meters that do not belong to the Economy 7 category.

Table 1: Analysis of the number of restricted meters (June 2015)

Total number of accounts (2015) 24,600,000

of which:

Number of restricted meters (inc Economy 7) 4,300,000

As a proportion of all accounts 17%

Split by meter type:

	Number of meters	% of all restricted meters	% of all accounts
Economy 7	3,700,000	86%	15%
Economy 10	100,000	2%	0%
Other	600,000	14%	2%

Source: CMA analysis of data from the Six Large Energy Firms and mid-tier suppliers.