An ETI Insights report

DOMESTIC ENERGY SERVICES

Delivered by:
CATAPULT Energy Systems

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Our homes are becoming **smarter and even more connected** and the new level of data and control created by technology is likely to lead to a **profound change** in energy retail.

Commercial, policy and regulatory opportunities need to converge, which will take time as the possibilities are different to the traditional concept of "utilities".

DOMESTIC ENERGY SERVICES

To move consumers to low-carbon heat we need to rethink the consumer proposition. The emergence of the "connected home" allows us to look at heat and comfort as a packaged service not simply the purchase of units of fuel.

The ETI commissioned the **Energy Systems Catapult** to deliver its **Home Energy Management Systems** project to explore the potential of the "connected home" of the 2020s.

The **Energy Systems Catapult** is building on the learnings from the ETI project to establish a **"living lab"** of c100 homes which will be available to innovators from 2018 onwards.

There is the potential for new business opportunities to capture new value beyond the meter – by using a new dialogue and new datasets to **help people obtain the heating experience they want.**

This opens up new ways to decarbonise heat by enabling service providers to design, market and **deliver appealing low-carbon solutions.**

EXECUTIVE SUMMARY

Our homes are becoming smarter and ever more connected, through technology from a wide range of innovative vendors. The new level of data and control created by technology is likely to lead to a profound change in energy retail. Over time, the possibility of retailing service experiences people value is likely to open up in place of being limited to the retail of units of energy which people simply don't understand.

While this may well happen anyway over time, it is unlikely to happen naturally at sufficient pace to establish the conditions to decarbonise heat; specifically, having the means to design, target and deliver near-zero carbon solutions people want to buy. Commercial, policy and regulatory opportunities need to converge, which will take time as the possibilities are alien compared to the traditional concept of 'utilities'.

The Energy Technologies Institute (ETI) commissioned its Home Energy Management Systems project from the Energy Systems Catapult (ESC) as part of its Smart Systems and Heat programme to understand how our homes might be in the 2020s; to explore opportunities for a profound change in energy retail provision and how it might open new possibilities for the decarbonisation of domestic heat.

The project is still under way, analysing the huge volume of data gathered during a trial undertaken over the winter of 2016/17. However, there are some key insights starting to emerge:

- People seem to be more engaged and express their real needs when the dialogue is about the services they experience, in a language they can relate to, rather than technical units of energy.
- As found in other sectors, when it is clear how data is used to the customer's benefit, their anxieties about sharing data diminish.
- There are substantial new business opportunities, such as:
  - To help people become more comfortable at home, and to make guarantees on the performance of service offerings;
  - To design better low carbon products and services that people want to buy using revealed consumer preferences;
  - To enable advanced quality management for installation, maintenance, support and insurance by comparing estimated performance to actual measured performance;
  - To drive infrastructure investment choices to maximise consumer value and willingness to pay, as opposed to just minimise costs; and
  - To differentiate retail offerings in a highly competitive market and reduce customer support and energy costs.
- And there are new policy and regulatory needs, such as:
  - People can become more discerning when the dialogue is about service experiences they value, so prescriptive retail licences fixed by regulation may no longer be appropriate;
  - With the ability to measure actual performance comes the possibility for policies based on delivery of results for decarbonising heat and tackling fuel poverty; and
  - There is a risk consumers will not be able to use their data to drive an open market of services if their data becomes locked within proprietary domains of different vendors.
- Technology firms can deliver more value if they focus on how their products and analytical tools enable others to deliver new services.

The ESC is now taking this forward supported by the Department for Business, Energy and Industrial Strategy. The Catapult is building on the learnings from the ETI project and the wider Smart Systems and Heat programme to establish a 'living lab' in ~100 homes over the winter of 2017/18. The data from this 'living lab' will be used to enable businesses, policy makers and regulators to develop new business models, products, policy options and regulatory frameworks. They will be able to test solutions with this panel of ~100 homes participating in the 'living lab' from 2018 onward.

CONTEXT

Although we spend most of our time at home, the pace of innovation in the automotive industry has brought us a far more comfortable experience in our cars

We spend the majority of our life (67%[1], on average) at home, but the experience of thermal comfort in our cars, where we spend very little of our life, has seen a far more rapid pace of innovation. Air conditioning, multi-zone climate control, heated seats, air filtration and so on are now very normal features in our cars. But consumers never asked for these things; they only realised how valuable they were once the industry had *offered* better experiences. And industry only *offered* these things because they could see *how* to make people's lives better and profit from it.

Our recent Consumer Insights[2] report highlighted significant latent dissatisfaction with the experiences of comfort at home; issues people find hard to articulate and industry finds hard to see. In other words, there are significant opportunities for innovative service businesses to *offer* better experiences as long as they can see *how* to do so commercially. Of course, this is not easy but the smart homes of the 2020s appear likely to make it possible.

It is important to recognise that comfort is complex. It involves physical, physiological and psychological elements. Physical elements are:

- Air temperatures
- Air humidity
- Radiant heat of surfaces or sun
- Air flows, such as draughts
- Clothing

There is a trade-off between these elements. For example, cool air may feel more comfortable in the sun and less comfortable in a breeze. Micro-environments within the home, such as a draughty porch or a sunlit conservatory, changes the required balance between elements for people to feel comfortable.

The physiology of how the body regulates temperature includes:

- Activity: exercise warms us up
- Sleep: falling temperatures can help people get to sleep
- Age: thermal regulation is lower in babies and the elderly
- Some are more sensitive to heat than others and the process is affected by illness, medicine and hormones

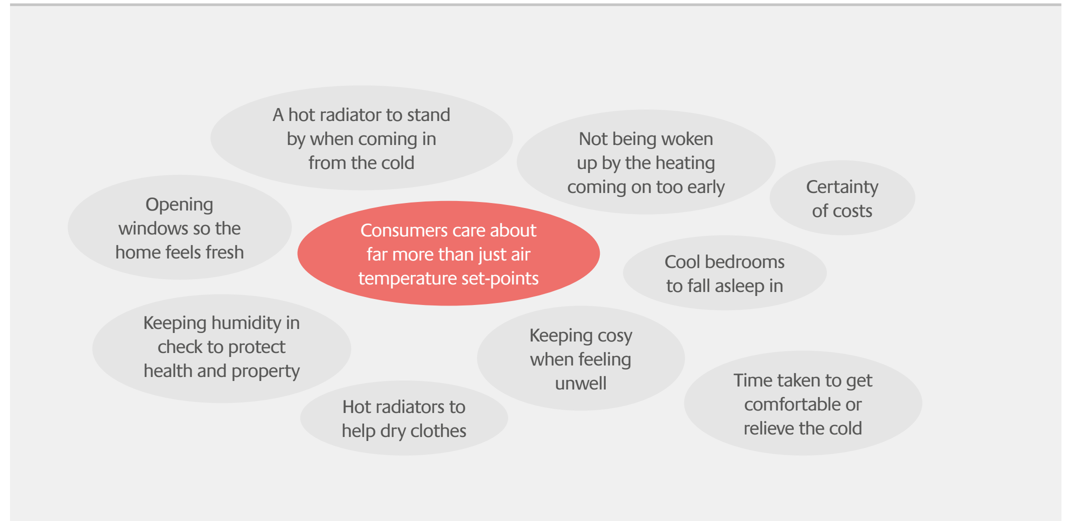
Psychologically some prefer to be warmer than others but the reasons people use heat are influenced by many indirect factors; for example:

- Anxiety about costs can cause people to turn heat down
- Desire to be a good host can mean increased heat for guests
- People may prefer higher temperatures on cold days
- Windows may be opened to make the home feel fresh
- Rooms may be kept warm just in case they are needed

1 Energy Systems Catapult analysis of the National Travel Survey; Department for Transport; https://www.gov.uk/government/statistics/national-travel-survey-2016

2 An ETI Insights Report: How can people get the heat they want at home, without the carbon? www.eti.co.uk/insights

Figure 1



Many companies are developing connected home devices that provide the data and control for improving experiences; the appliances people buy such as boilers, electric vehicles, fridges, etc are also becoming connected, and smart meters are bringing data on actual energy use. Much of this is emerging for customer benefits not related to energy at all: improved security, health services, greater convenience and so on. In combination, this rapidly emerging landscape has the potential to enable a profound change in energy retail services. However, very few of these devices are as yet connected beyond the commercial domains of their individual vendors; in other words, they are *connected* but not *available* to energy service innovators. Furthermore, as analysis by Delta-ee shows (next page), most of these devices are not yet integrated beyond individual home controls; few in Europe are as yet providing service optimisation products.

CONTEXT

Continued ›

A profound change in energy retail is almost certain to happen at some point, but not fast enough to establish the conditions required to decarbonise heat

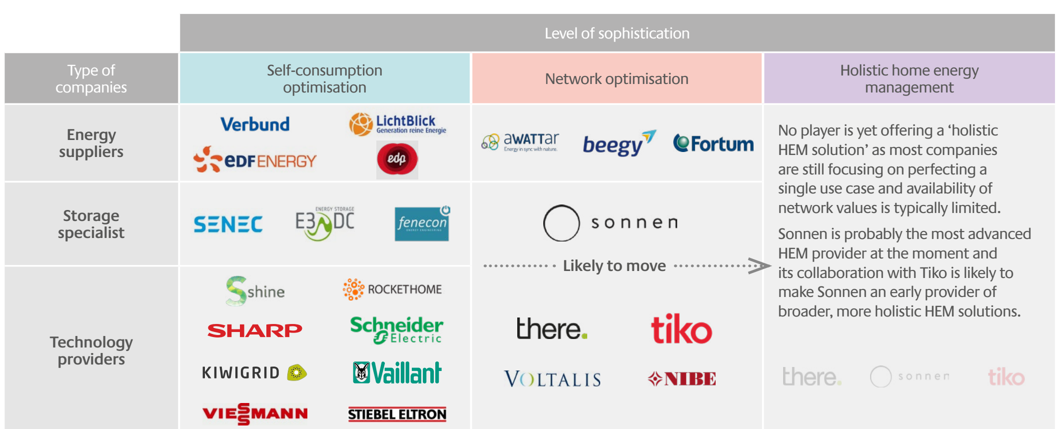
It is almost inevitable that a profound change in energy retail services will happen at some point in time, bringing energy retail into line with other consumer services. However, when the challenge of decarbonising domestic energy is considered, it becomes evident that this change is required far more urgently than it might otherwise happen. If we are to achieve the UK's energy and climate change goals, it will mean almost every home becoming close to zero carbon by 2050; conversion at a pace of a million homes each year is required by 2025, from almost none today.

The need to accelerate this change is why the ETI launched the Home Energy Management Systems project. This research project has established the data and control capabilities that might be possible in the connected homes of the 2020s. This has enabled exploration of the energy service opportunities that might be made possible and the new options this might open up to decarbonise domestic heat.

The devices acquired off the shelf and installed in 30 homes for a trial over the winter of 2016/17 included individual wireless temperature and humidity sensors for each room, individual wireless radiator controls, utility meter readers, water pipe temperature sensors and boiler controls. The participants were selected to be a diverse sample of mainstream owner-occupiers living in a mix of house types.[4]

Figure 2

Companies providing home energy management offerings in Europe (companies listed on the graphic are representative but are not a comprehensive listing, based on research conducted in 2017).[3]



3 Delta Energy & Environment Ltd, Connected Home Research Service, July 2017; https://www.delta-ee.com/CHS

4 The selection criteria were designed to screen out unusually pro-environmental consumers or those with a particular propensity to be the earliest adopters of new technology. Beyond this, a broad range of houses and households were selected, subject to technical compatibility criteria (e.g. all homes had to have a combi gas boiler), safety criteria (e.g. the boiler had to have been serviced in the last two years, the electrical consumer unit needed to be of the more modern variety with circuit breakers, etc), vulnerability criteria (e.g. no one in the house suffering from an illness that could be made worse by heating issues, no one with very young children or very elderly people in the house, not a home classified as 'fuel poor', etc) and ability to use controls (e.g. familiar with touch screen devices, etc).

Considering the wide range of potential technical solutions, as illustrated by Figure 2 on the previous page, the optimal path to decarbonisation is almost certain to involve different combinations of integrated components in different geographies and different buildings. The scale of transformation required is vast: almost no building and no part of the energy infrastructure will be left untouched.

The drivers for a particular solution in a given geography include technical factors (such as headroom in existing networks), commercial factors (such as an existing network against which to offset take-up risk) and social factors (such as level of community cohesion).

The drivers for a particular solution in a given home include technical factors (such as the condition of the fabric), commercial factors (such as split incentives between owners and occupiers) and consumer factors (such as aesthetics, use of space within the building, willingness / ability to invest capital, symbolic value of the home, etc).

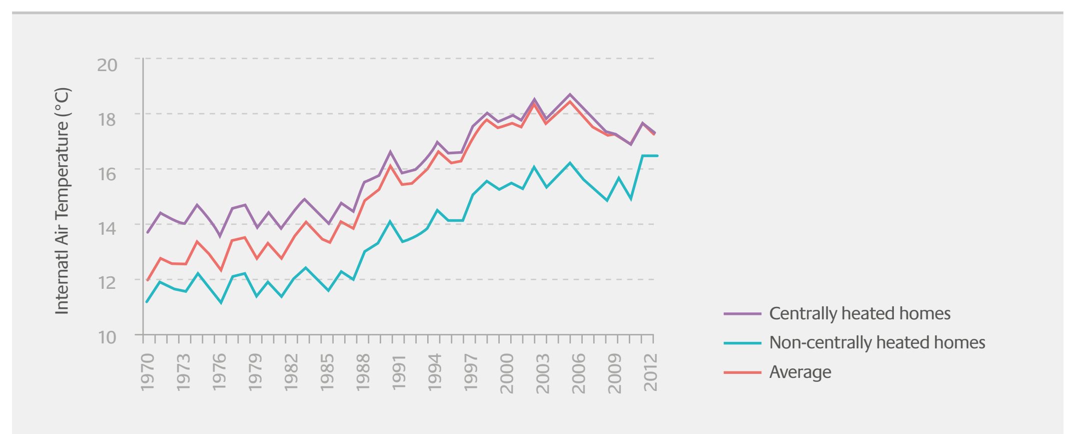
Furthermore, the world is highly uncertain. Technology performance and cost can change drastically, as we have seen with Solar PV and batteries. Consumer preferences can evolve rapidly, as we are starting to see with attitudes toward plug-in vehicles; and indeed, as has happened with heat over the last half century as illustrated in the chart below. Understanding of interdependencies between different parts of the economy will continue to identify new issues to resolve and opportunities to realise.

It is inconceivable these drivers of diversity could be understood, let alone appropriate solutions tailored and delivered, by any form of 'central authority', especially given the need for agility in the face of huge uncertainty. There can be no route to design, sell or optimise low carbon heat without businesses that deeply understand their customers' diverse and complex needs, and have the capabilities to integrate the required components within the customers' homes to deliver on their promises to meet those needs. A profound change in energy retail services is therefore both critical and urgent.

It will be much easier to achieve the decarbonisation of domestic heat if consumers want to buy low carbon products and services, as is starting to happen with plug-in vehicles.

Figure 3

Internal air temperatures[5]

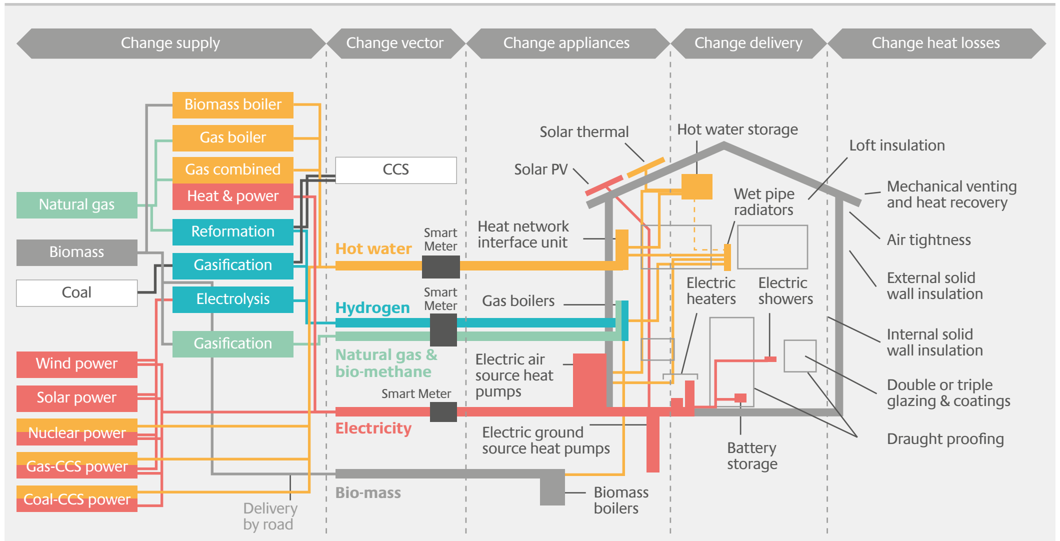


5 Energy Consumption in the UK; Office for National Statistics; 2017; https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/633193/ECUK_Tables_2017.xlsx

CONTEXT

Continued ›

Figure 4
Illustration of the complex system of systems for low carbon heat. The selection of components, which will differ by both geography and home, needs optimising in investment and operational timeframes.



Central to a profound change in domestic energy retail will be the emergence of a service language with which customers and suppliers can align expectations

It is currently challenging to design, target and deliver low carbon heat solutions people will buy. Different people have different needs and preferences. If energy retailers are to create new business models that seek to overcome this, they need to be able to *understand* what service experience a given customer is trying to achieve from their use of energy in order to delight that customer with future low carbon heat solutions.

As a comparison, the automotive sector has made enormous progress in recent years with low carbon vehicles. It has used deep insight on why people buy cars, what they *intend* to do with them and how they *actually* use them to design and promote low carbon cars people want to buy and enjoy using. Using the same deep insight to enable the provision of low carbon heat that people will find appealing and so want to pay (and vote for), has so far been elusive.

Heating solutions – low carbon heat especially – also have constraints on what can be achieved due to power, thermal mass, heat flows and so on. This creates trade-offs, so retailers need to be able to *shape* customer expectations on the relationships between: (1) what is physically possible and how this is affected by building fabric and heating solutions; and (2) different levels of service and the associated costs.

The profound change discussed above represents a new class of business model, in which the retailer takes the risk of service outcomes not being delivered or costing more to deliver than budgeted for; the consumer no longer pays for units of commodity input (kWh), a thing which few can relate in any way to service experience.
The consumer may change their usage after the risk has been taken on by someone else, so if these energy retailers are to price risk *affordably*, they need to be able to *limit* their customer's expectations in some way to manage costs; for example, not leaving the windows open all the time while the heating is on.

This language will of course emerge over an extended period of time, but there are key issues retailers, consumer advocacy groups and regulators will need to explore. A unique energy sector challenge is the role of regulation, as consumers have traditionally been protected up to the meter with prescriptive retail licensing based on selling units of commodity input. This approach may well be incompatible with consumer-centric services.

And underpinning such a profound change in energy retail services will be the emergence of open data frameworks and advanced machine learning

The *ability* of a given home and its heating system to achieve a particular set of service expectations is heavily dependent on the equipment installed, how it is configured, the efficiency of the building and how it is used. Buildings, and how they are used, vary enormously, even between those of similar type, age and size. Retailers will need data with which to be confident that promises are physically viable, so as to price in the risk of having significant customer service or compensation costs from failing to deliver.

Likewise, the cost to serve a given set of expectations is equally affected by the above factors. Demographics and building archetypes do not provide enough data to *price risk affordably,* so it will be critical that a data pack can be provided by connected home devices with which energy retailers can price risk. Such a data pack would need to include insight on efficiency of the fabric of the home, performance of major appliances such as boilers, how window use affects energy consumption, etc. However, the trade-off between data privacy (highly aggregated data) vs. minimising the price of risk (highly granular data) is a complex social issue that needs to be understood. This issue is common with other new services, so expectations will be formed by interaction with social media, search engines, smart phones, etc, not by the energy industry.

There is also a trade-off in enabling competing energy retailers to *price risk competitively.* The trade-off is between ensuring there is incentive for retailers to invest in their customer relationships and service development (reserving data to the incumbent so they can price risk favourably) vs. ensuring a competitive market focused on driving cost out (opening data to any retailer so they can price risk equally). This is a complex commercial and consumer issue that needs to be understood, linked to a wider debate on data use by organisations across the internet.

How data might be used to enable advanced energy services is a key question for retailers, technology companies, consumer advocacy groups and regulators to explore.

Of course, as noted earlier, many of the drivers for the connected home are customer benefits not related to energy at all; services such as security and health. For many people, simply being able to see and control their domestic environment has significant value. These services may be a stronger driver for the emergence of data and control than energy, so energy businesses will need to build their understanding of this wider context.

THE STORY SO FAR...

A carefully designed user experience can help people become discerning customers, discovering what they value and expressing their expectations to retailers

The heart of the user experience is the concept of 'discomfort feedback', which is triggered when someone within the home is unhappy about something. This may be because it is too cold in a particular room, too hot in another room, there is anxiety about the potential bill, etc. These are experiential; things that can only really be explained when they occur. The user experience also needs to elicit instrumental objectives, such as needing extra heat to be seen as a good host.

The 'discomfort feedback' should lead advanced controls to seek to resolve the discomfort to the extent possible within the limitations of the physical heating system, and learn what, if anything, to do differently in future.

Interfaces should be designed to help build shared understanding between customers and retailers. For example:

- How heat choices in one room may limit choices available in another room due to heat flows
- How system components, such as radiator size, limit achievable service performance levels
- What the optimal balance is between 'scheduled' use, which is regular enough that it can be planned for, and 'on-demand' use, which is less regular
- The reason 'on-demand' heat use is needed, to distinguish between a need for higher air temperatures or radiant heat
- The cost for 'on-demand' heat use relative to 'scheduled' use
- Evolving the mental model of control from time the heating system is switched on to time an outcome is achieved, such as a space being warm or a radiator being hot to dry towels

The data gathered from the user interfaces can be correlated with the context, such as weather, historic activity patterns, etc to enable effective learning and service delivery.

The person an adjustment is being made for is also important. Personal user accounts enable understanding of individual preferences and relationships, and relative priorities.

The user interfaces on the next page are examples from follow-on work the Energy Systems Catapult is doing funded by the Department for Business, Energy and Industrial Strategy. They have been developed with learning from the ETI project. This is described in more detail in the Enabling a New Market chapter.

Figure 5
Example interfaces to help elicit a user's needs[6]

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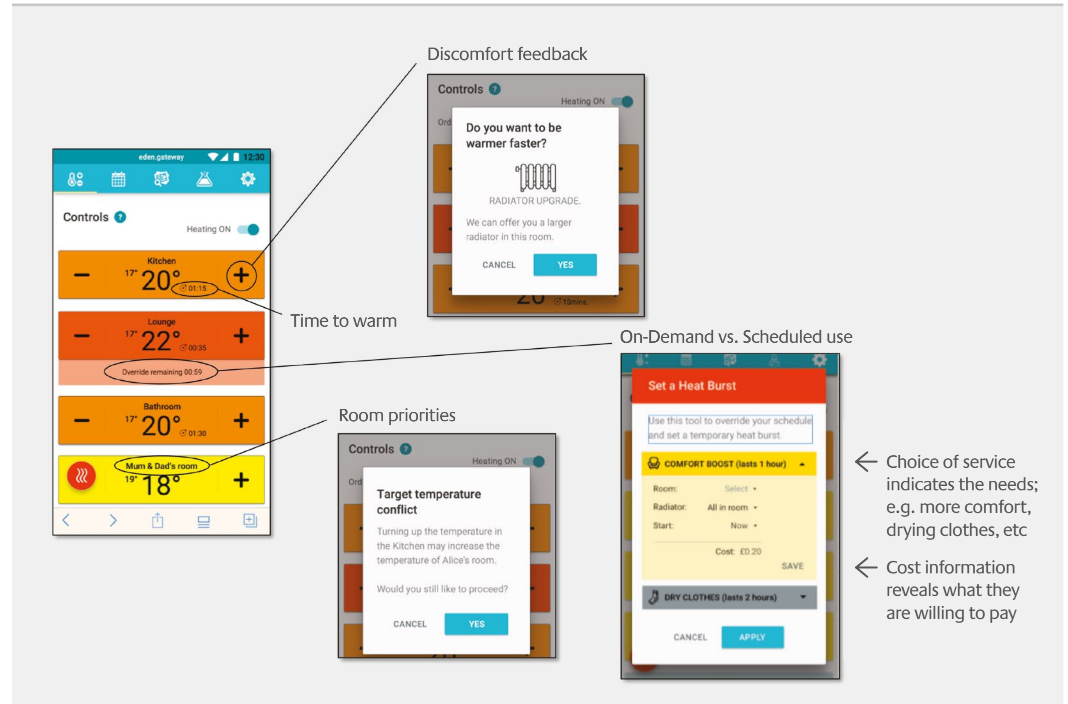


Over the winter 2016/17 trial, we were able to have increasingly sophisticated conversations with the participants as their experience with advanced controls made them increasingly 'discerning' heat users. For example:

- Discerning customers value radiant heat (for example a hot radiator to stand by) at least as much as air temperature, which has important implications for design of low carbon systems where heat pumps might need to be combined thoughtfully with radiant heat provision (such as already often occurs in non-domestic environments)
- Discerning customers need their controls and services to provide for multiple uses, such as to dry clothes or to warm up after a long walk in the cold
- The time a radiator 'turns on' is important, as it may wake people too early; turning on the radiator early enough to hit an air temperature target on time may not, in fact, be considered good service if it leads to sleep disturbance
- Responsiveness for on-demand heat use is important, but the time to relieve the discomfort of feeling cold may matter more as warming up may be part of the valued experience

6 Smart Systems and Heat Phase 2 announcement; 2017; https://es.catapult.org.uk/news/success-leads-phase-two-smart-systems-heat-programme-catapult/

THE STORY SO FAR...

Continued ›

- Feedback on temperatures in each room seemed to improve people's ability to articulate what they found comfortable
- Draughts and cold spaces are important to people's comfort, but are difficult to detect with current room sensor products
- Some people may need advice, derived from occupancy data, to help them know how and when a particular space is used
- Discerning customers prioritise spaces, such as a cooler lounge, to avoid heat transfer making bedrooms too warm to sleep in

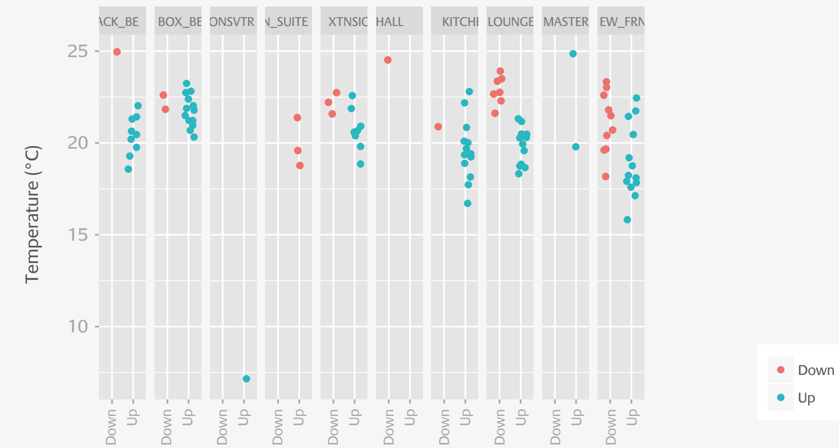
'Discomfort feedback' yields hugely valuable data on what comfort means to different households and the importance of different relationships within a home

Comparing the discomfort feedback from the homes involved in the trial conducted over the winter of 2016/17, we can see from the example charts below how different they are. But we also see that the needs within each home are very complex. For example:

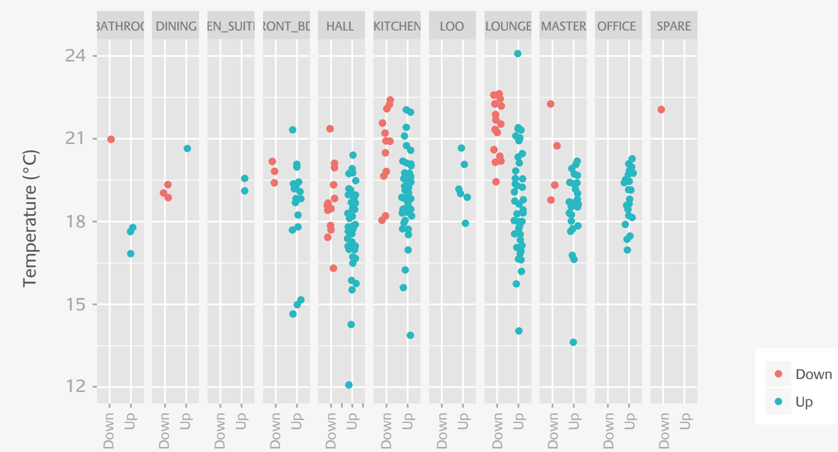
- Different people in the home have different preferences
- People want warmth when ill
- Individual people have different thermal preferences at different times of day and with different outside weather
- Radiant heat may be wanted to feel warm after coming in from the cold, but the (earlier version) of controls couldn't distinguish this need properly
- Radiant heat may explicitly not be wanted if someone is close to a radiator causing discomfort even if the air is still cool
- Different spaces within a home have different uses, so require different thermal conditions
- A particular space may have multiple uses, so different thermal conditions are needed at different times of the day

Figure 6
Two examples from the winter 2016/17 trial showing the temperatures in a given room at the points when requests to be warmer or cooler were made

House 1



House 2



THE STORY SO FAR...

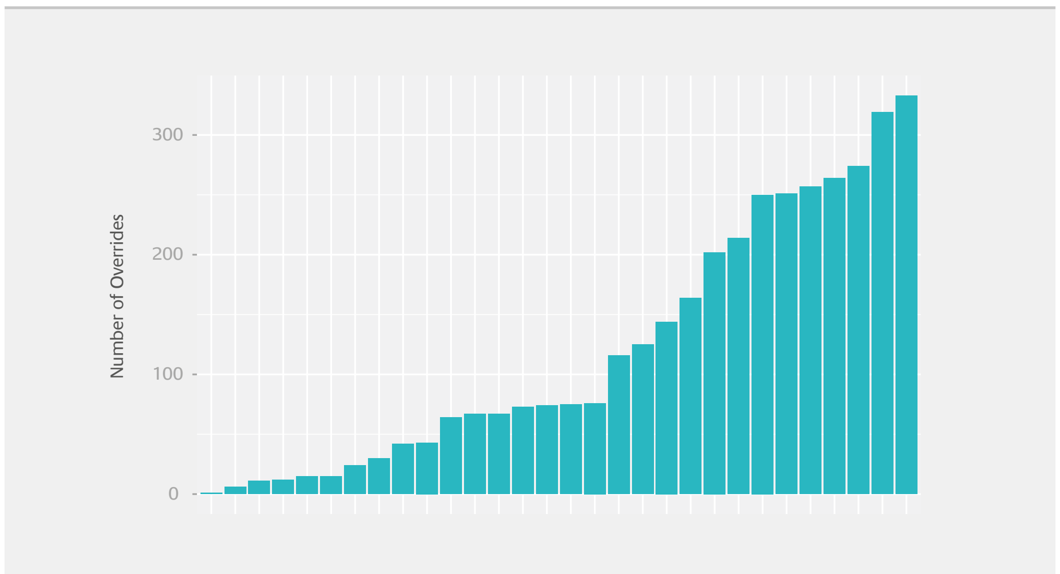
Continued ›

The data also reveals huge variance in the level of active control people need. Some of the participants in the trial over the winter of 2016/17 hardly touched the controls while others were providing 'discomfort feedback' multiple times a day. The reasons behind this are complex, including: the fact it takes time for machine learning algorithms to become effective; the reality that there is uncertainty in occupancy and heat needs so no algorithm can predict and plan perfectly; and the nature of some people is that they naturally want more hands-on control. For example:

- The occupancy pattern may be highly unpredictable, so there is a natural tendency toward 'on-demand' energy use
- Some people prefer to plan, whereas others simply prefer to react and adjust as needed
- Schedules may not plan specific uses, such as for drying clothes
- One or more component may not be performing adequately, such as an under-sized radiator
- Different people in the home may have mismatched thermal preferences, or different views on the use of time and money
- There is a paradox of control that may lead to overrides, as the ability to ensure a target is met on time inadvertently takes away the ability to ensure the boiler (or radiator) is on (or off) at a specific time
- Some homes and household needs are more complex than others, so machine learning algorithms can take longer to become effective

There are significant opportunities for machine learning to use such complex data sets to enable retailers to design, target and deliver services that help their customers get a better thermal experience at home. However, the user experience design is critical to eliciting the most insightful data within the maximum time a user wishes to interact with it.

Figure 7
Level of user interaction during the winter 2016/17 trial by participants



Reports help reinforce the user's mental model of how heat use, comfort and energy bills relate to one another; and Suggestions enable proactive services

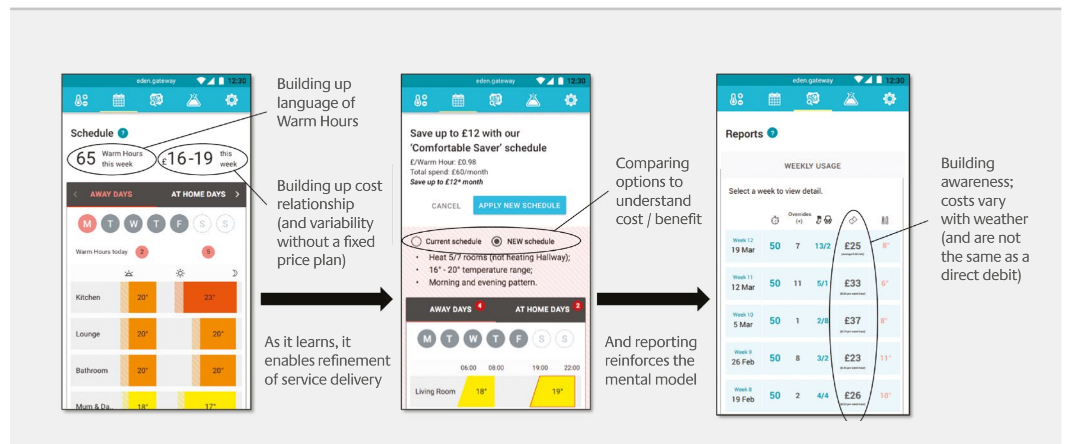
Few people today understand how their comfort, heat use and energy bill relate to one another. The cost information for 'on-demand' heat use presented in the user interfaces outlined in the previous section was insightful, as it revealed most users are willing (and able) to pay for on-demand heat use; of course, this will not come as any surprise to on-demand entertainment providers!

A more complex picture emerges when exploring alternative options via a supplementary tool (a 'What If Portal') and one-to-one interviews. This indicates that:

- It is possible for people to build a good mental model relating comfort levels and their costs
- The reference point (average days, warm weeks, cold months, etc) is an issue since the weather is so variable
- Trial participants used this emerging mental model in different ways; some to reduce cost, some to increase comfort and some for conversations with family members to make pragmatic compromises
- Forming this mental model is important in enabling people to feel they haven't lost control through HEMS automation, similar to the way modern navigation apps give options

The user interfaces below are examples from follow-on work the Energy Systems Catapult is doing financed by the Department for Business, Energy and Industrial Strategy. They have been developed with learning from the ETI project. This is described in more detail in the Enabling a New Market chapter.

Figure 8
Example Interfaces to relate heat use, comfort and energy bills[7]



7 The influence of occupants' behaviour on energy consumption investigated in 290 identical dwellings and in 35 apartments; Rune Andersen; Technical University of Denmark

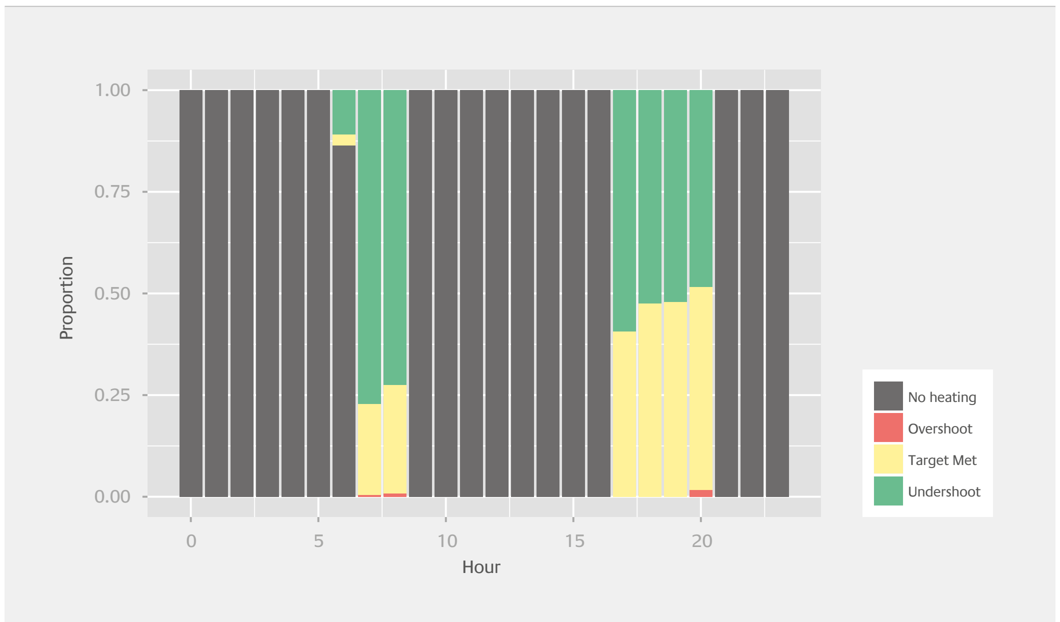
THE STORY SO FAR...

Continued ›

Most participants in the trial over the winter of 2016/17 were interested in a discussion which analysed how their home comfort experience could be improved, but would prefer to receive alerts to specific issues rather than having to 'go looking'. For example, analysis showing when targets had been met, undershoot or overshoot was used in one-to-one interviews. The discussion helped people to identify specific actions they could take. In the example below, the bedroom temperature was regularly undershot as the radiator was blocked by the bed being too close.

Figure 9

Proportion of time targets met, overshot or undershoot for a single room in a single house within the winter 2016/17 trial



Data analytics reveal opportunities for helping customers to achieve better comfort experiences and to determine how best to deliver low carbon solutions

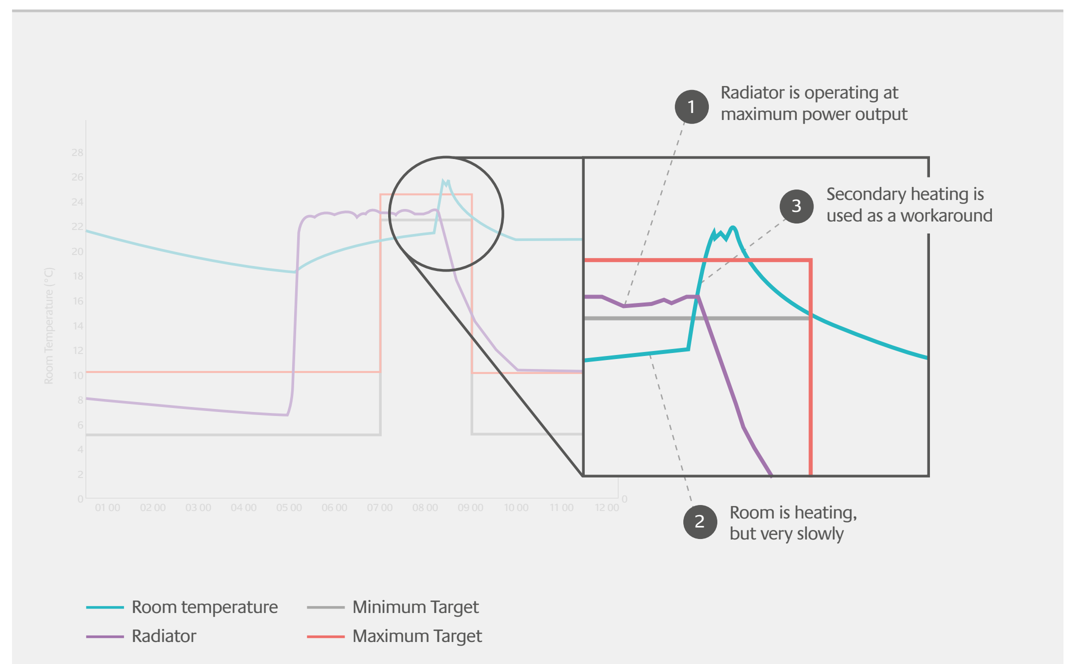
It is evident that many customers don't realise that their comfort experience is not as good as it could be. In part, this is simply a case of people accepting the status quo, but also a case of having found tolerable workarounds to issues.

While it may be considered a challenge to decarbonisation if people become more aware of these issues, in reality it should be seen as positive. There are opportunities for low carbon solutions to delight people by fixing issues they might not even have realised the value of until resolved; a positive market feedback. However, the opportunity may easily be lost if new service businesses are not incentivised by policy to reduce carbon emissions, as they may simply help people fix these issues with a high carbon solution. There are also threats to low carbon solutions if workarounds are inadvertently removed; a negative market feedback.

As an example (below), one of the homes in the trial was using a secondary heater to compensate for an underpowered radiator in a particular room. Conversion from a gas boiler to a heat pump and disconnection from the gas grid may make the problem worse (by further reducing the power output of the radiator) and remove the workaround (the secondary heater).

Figure 10

Example data from the winter 2016/17 trial showing improvement potential



Such in-depth data on the real-world performance opens up opportunities to identify issues:

- In combination with insight gathered via the Interfaces, opportunities to improve the service experience can be identified as exemplified above
- Helping people to gain benefits they didn't even realise they could have is an opportunity for a very high value service
- Using data to guarantee performance of any solution would build much greater customer confidence and trust
- This could enable energy retailers to become an effective route to market for low carbon products such as building fabric efficiency improvements, heat pumps, heat storage, etc

Access to a large anonymised dataset which integrates occupants needs, building characteristics and heating system dynamics also opens up opportunities to improve product design, equipment installation, maintenance and customer support operations; and to develop better business strategies, policies and regulations. Some of these opportunities are further enhanced by access to data linked to specific homes.

- Tools can be developed to use the data to help installation and maintenance teams diagnose issues quickly and cheaply
- Tools can be developed to help a customer diagnose issues they might resolve easily without an expensive call-out
- Comparison of estimated vs. actual performance enables advanced quality management to identify and rectify business issues in design and installation
- Performance of component products can be measured in a real-world context as part of an integrated system, to inform product development
- Pre-emptive maintenance may become possible, to resolve problems before symptoms are obvious, adding customer value and improving management of maintenance team logistics

There are substantial opportunities for advanced machine learning to analyse such complex data sets to realise these opportunities and for developers to create tools to help installation, maintenance and customer support teams. Further, as the market scales there are substantial opportunities for big data analytics to optimise targeting of efforts across a portfolio. While this may seem a distant prospect, the pace of change in other sectors suggests this may be very close.

HEAT AS A SERVICE

Innovative future services could focus on selling the experiences people value that use of energy affords, instead of the commodity inputs they can't relate to

One possible way of delivering a future energy service, based around the concept of a 'warm hour', has been developed as part of the HEMS project. This is only one of many approaches that could be adopted for future energy services and was used to explore the issues.

It was developed via participatory design with some of those involved in the trial during the winter of 2016/17, which indicates that:

- Those involved in the trial could understand the concept easily, and could see how it could be delivered given the arising data
- Participants found it easier to relate to the service experiences they value than kWhs, engaging enthusiastically in exploring the cost-benefit of different service levels
- It was easy for participants to specify what they needed, as use of the controls had enabled them to articulate their needs
- Most of the participants would trust recommendations made based on analysis of data to optimise their service choices; many felt they could use heat better and welcomed advice
- Although people were offered different prices for a 'warm hour', using data for *their* home, it was not seen as a concern or unreasonable; they expected a 'warm hour' would cost more for an older house or for being warmer (of course, this is not to say they were not concerned about fairness more generally)
- Initial 'add-on' ideas such as winter cover (a guarantee of service performance regardless of how extreme the winter turns out to be) were explored, but participants found these difficult to relate to or value so further work is required on how best to explain such concepts

The concept was also tested with around a hundred people who hadn't been involved in the trial. It was challenging to get past the first step of explaining the concept with this group, due to the leap required to how such *future* services could be enabled by *future* connected homes. This is unsurprising, of course, since people can't talk about things they have no experience of; a major limitation of traditional consumer surveys and focus groups. Participants in such a trial environment are therefore a valuable resource with whom to test ideas. Formalising this into a 'living lab' with ~100 homes in the winter of 2017/18 is hence a key aim of follow-on work the Energy Systems Catapult is doing financed by the Department for Business, Energy and Industrial Strategy.

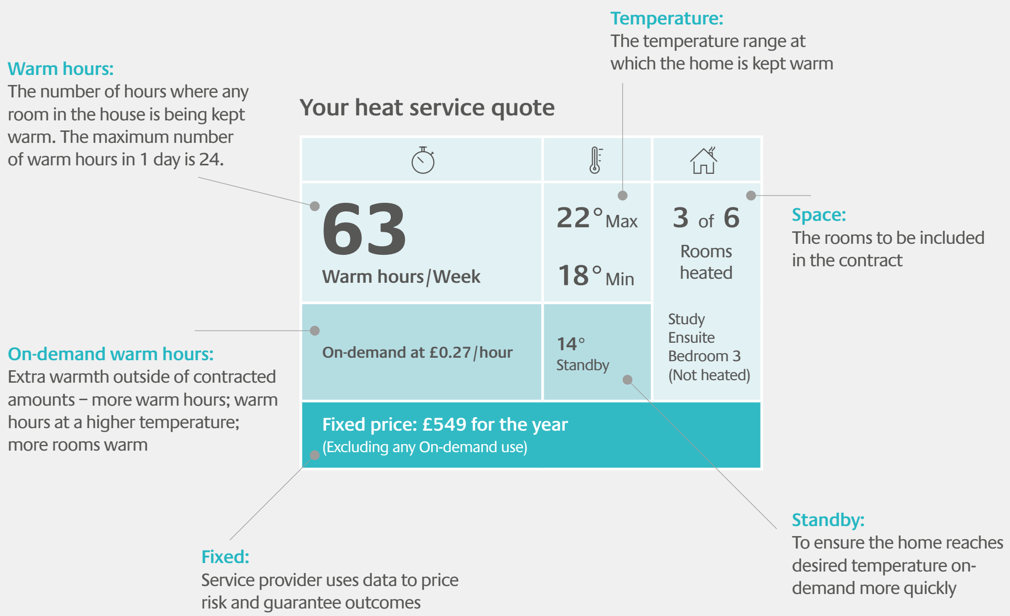
The potential for new services people can relate more closely to the experiences they value is likely to open a range of interdependent commercial opportunities, policy options and regulatory needs. The 'living lab' is an environment for many organisations to explore their own opportunities as quickly, cheaply and robustly as possible.

HEAT AS A SERVICE

Continued ›

Figure 11

Example concept for one of many different types of potential future service



Data enables 'warm hours' to be priced like insurance offerings, given the inherent uncertainties due to the fabric of the home, how it is used and energy costs

The cost to heat a given home is heavily dependent on the efficiency of the building, the characteristics of the appliances, the way windows are used, the time of day when heat is needed most, etc. For example:

- The energy consumed for identical homes can be up to a twenty-fold difference purely due to how the home is used[8]
- Making a home warm in the morning can be more costly, as the home has cooled overnight and has not yet received any sun
- Most UK housing is old and has been extensively adapted over the years, so it is difficult to cheaply ascertain its efficiency from simple surveys
- Even for new build homes, there is often a gap between design and actual performance

This creates an obvious challenge for pricing the risk in delivering an energy retail service where the outcome is guaranteed regardless of the amount of energy needed. However, there is also opportunity in that the value a given customer attaches to a 'warm hour' may remain constant but the cost for delivering it may in fact be cheaper than the value. For example:

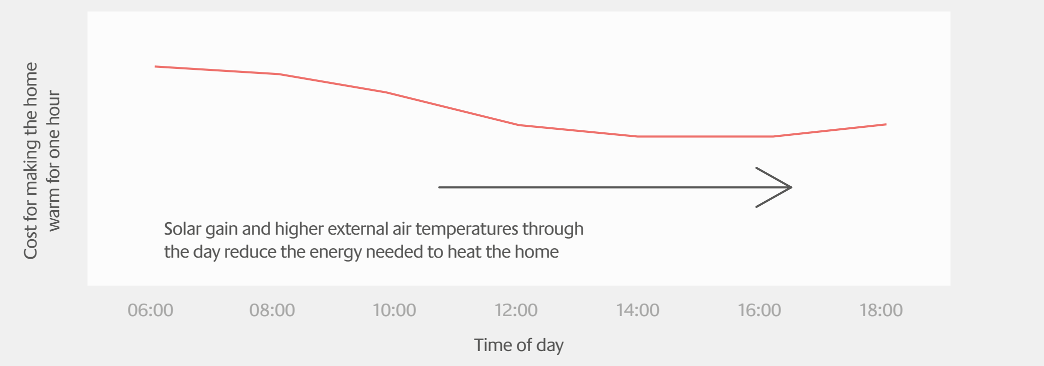
- Extending a heating period, when the building fabric has already heated up, may actually be quite cheap to deliver
- Heating extra spaces may not add much cost if the internal heat flows are already heating that space to some extent

This suggests there is opportunity to help customers achieve better comfort experiences where it costs less than the value perceived by the customer.

Of course, there are also risks of the most attractive customers being 'cherry picked'; risks which regulators will need to ensure they properly understand and manage to ensure fair treatment of everyone.

Figure 12

Modelled cost of making a home warm at different points in the day



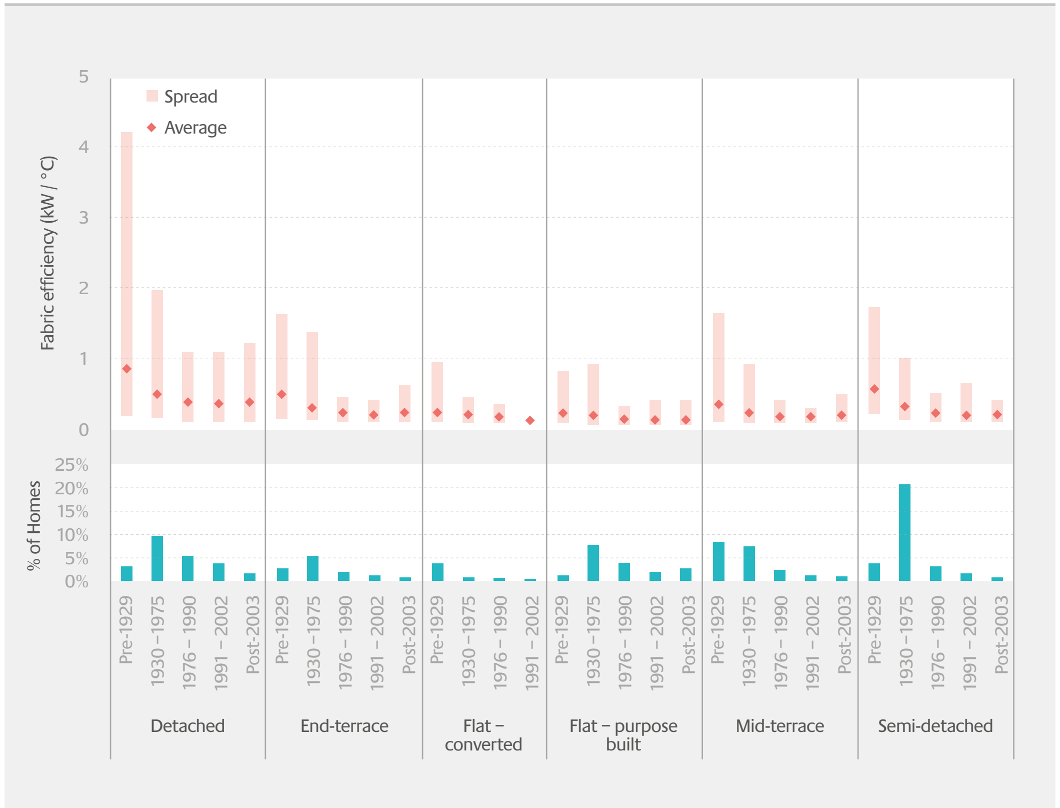
8 Derived from data contained in the Cambridge Housing Model; Department for Business, Energy and Industrial Strategy; https://www.gov.uk/government/publications/cambridge-housing-model-and-user-guide

HEAT AS A SERVICE

Continued ›

Figure 13

Proportion of existing homes in each archetype and their efficiencies[9]

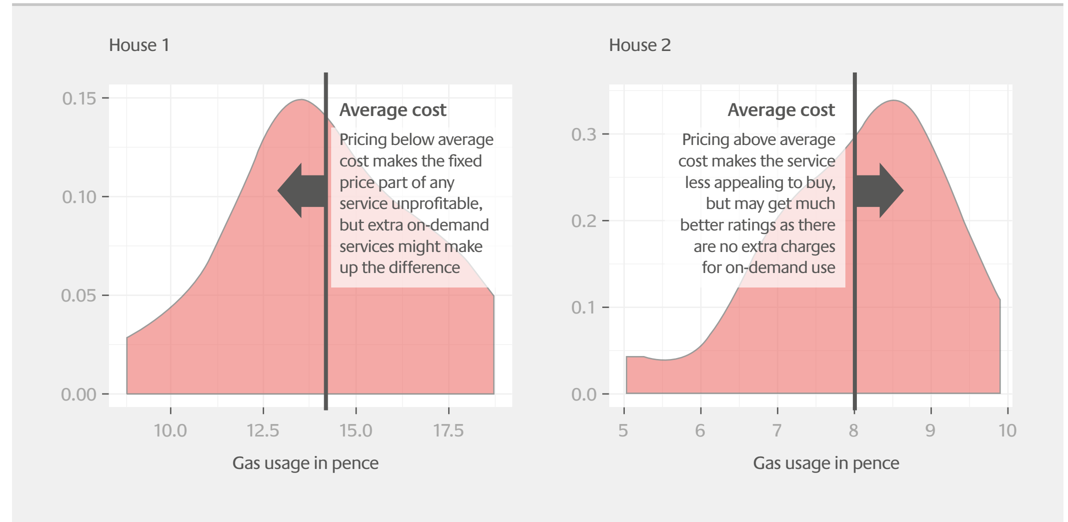


Examination of the data arising from the trial over the winter of 2016/17 shows it is possible to determine a probability distribution for cost to deliver a 'warm hour'. This shows how different the costs can be from one home to the next, but also how variable it can be from one time to another. Hence, it is necessary to think of new energy retail models that guarantee a service experience regardless of the energy required more like insurance products than commodity retail. In this sense, they would be priced using data specific to a given customer, and positioned to make a profit from the overall portfolio not individual customers.

9 Systems Architecture Methodology; Energy Systems Catapult for the Energy Technologies Institute; 2017; ### insert link when published ###

Figure 14

Probability distributions for the cost to heat two different homes in winter



There is considerable opportunity for machine learning and big data analytics to analyse such datasets and optimise offerings, such as:

- Tailoring what is offered in the scheduled 'warm hours' vs. the on-demand 'warm hours'
- Charging less than the average cost for scheduled use, expecting to make up the shortfall from on-demand use

These opportunities are likely to grow as the energy system is decarbonised. The homes involved in the trial over the winter of 2016/17 were all heated by gas, which has a simple underlying cost structure which is mostly usage related rather than capacity related.

Electrification is one of the key means for decarbonising heat, alongside the repurposing of gas grids to carry hydrogen and heat networks. Electricity, especially if it is low carbon, has a more complex cost structure with significantly higher capacity related costs and lower usage costs *on average.*

The peak period of greatest concern is when heat demand is high and renewable energy supply is low, which can't be known sufficiently far in advance for traditional on/off-peak tariffs with fixed time windows to effectively reduce peak demand. Furthermore, while tariffs with varying time windows might be more effective, they shift the uncertainty and risk exposure to individual consumers. Retail models that guarantee service outcomes open the ability for a provider to decide how and when they use energy to deliver those outcomes; for example:

- Switching to the gas boiler in a hybrid heating system to avoid the need for peak electricity generation during periods of extreme cold and low wind
- Use of heat stored in the thermal fabric of the building to reduce the need for peak generation over several hours
- Storing heat in hot water tanks using low marginal cost energy

HEAT AS A SERVICE

Continued ›

There is considerable complexity and uncertainty to be managed in the transition towards low carbon. This is likely to be best managed by retailers using their proximity to customers, enabled by connected homes, competing to improve customer satisfaction and reduce carbon, as opposed to individual consumers being compelled to deal with this on their own or the state mandating standard solutions.

Conceivably, the kinds of tariffs we see in the mobile telecoms market which permit practically unlimited service use, since the costs are primarily related to peak capacity, may become possible with low carbon solutions too. The analogy can only be taken so far though, since certain comfort levels need to be maintained. However, to exploit this would require:

- The ability to sell the outcomes people care about, leaving the retailer free to manage the way capacity is used to deliver them
- Even more advanced big data analytics to optimise the overall portfolio within the capacity constraints of their resources
- A very different set of market arrangements, so retailers can reduce their cost to serve by reducing the peak capacity used for *their* customers; as many of the capacity related costs are effectively socialised within the current market, so savings can't be captured by individual retailers[10]

But there are many consumer issues the industry and government will need to tackle if innovative energy retail services are to become widespread

Involvement in the trial enabled the participants to engage in highly constructive discussions about the benefits, but also the issues that need to be addressed and their potential resolutions. This is of course unsurprising; most people are now very familiar with the concept of an app store, for example, not many years ago few could even relate to the concept let alone identify benefits and issues. People involved in such trials should be considered a valuable group for industry, policy makers and regulators to test solutions with.

Most of the participants found the concept of 'warm hours' intuitive and didn't have concerns about the fact that a 'warm hour' costs more in an older home and/or for being warmer. In other words, their mental model of the relationship between comfort, heat use and energy costs was more aligned with the physical realities. However, they did all raise concerns that will need to be addressed regardless of what concept future energy retail services are based on; for example:

- What happens when going outside contracted allowances needs to be clear; high roaming charges in the past for mobile telecoms is a helpful analogy
- Outcomes need articulating with a language that reflects the potential need for cooling, or at least no heat, in summer
- What is included in the terms of service needs to be clear, for example whether 'warm hours' are consumed while the house is heating up (they wouldn't be)
- Terms for contract change need to be fair, as life changes; gym membership is an analogy where regulators imposed rules
- People still want to compare offers, but the emergence of appropriate terminology is an important part of the innovation process and will inevitably emerge over time

This highlights the importance to both industry and consumers of shared good practice, such as basic principles all retailers work to, and converging towards common terminology for similar aspects of their services as they emerge.

Figure 15
Overview of questions raised during a participatory design exercise

What happens if they go 'out of contract?'

What happens if I go over my contracted warm hours? Will my heating run out like old metered heating? Will I get stung for huge charges?

What if I want a higher temperature than my contract allows?

Getting 'locked in' to a contract

What happens if I underestimate what I need? Can I change my contract or am I locked in?

Can I still use comparison engines to find the best deal?

What about unused hours?

Do I lose them? Will they 'roll over' to the next month?

I have an unpredictable schedule but don't want an 'unlimited' contract
It's wasteful; would this system still work for me?

What about change of season?

What happens in Summer? Is it cheaper when I use less?

What if it's colder and takes my house longer to warm up? Does that use up my warmer hours faster?

Can I adjust the warm hours I need depending on if it's warmer or cooler?

10 Salford Energy House; http://www.salford.ac.uk/research/best/research-groups/applied-buildings-and-energy/accordion/energy-house

ENABLING A NEW MARKET

The ESC is now establishing a 'living lab' where industry and government can work on opportunities for accelerating a profound change in energy retail

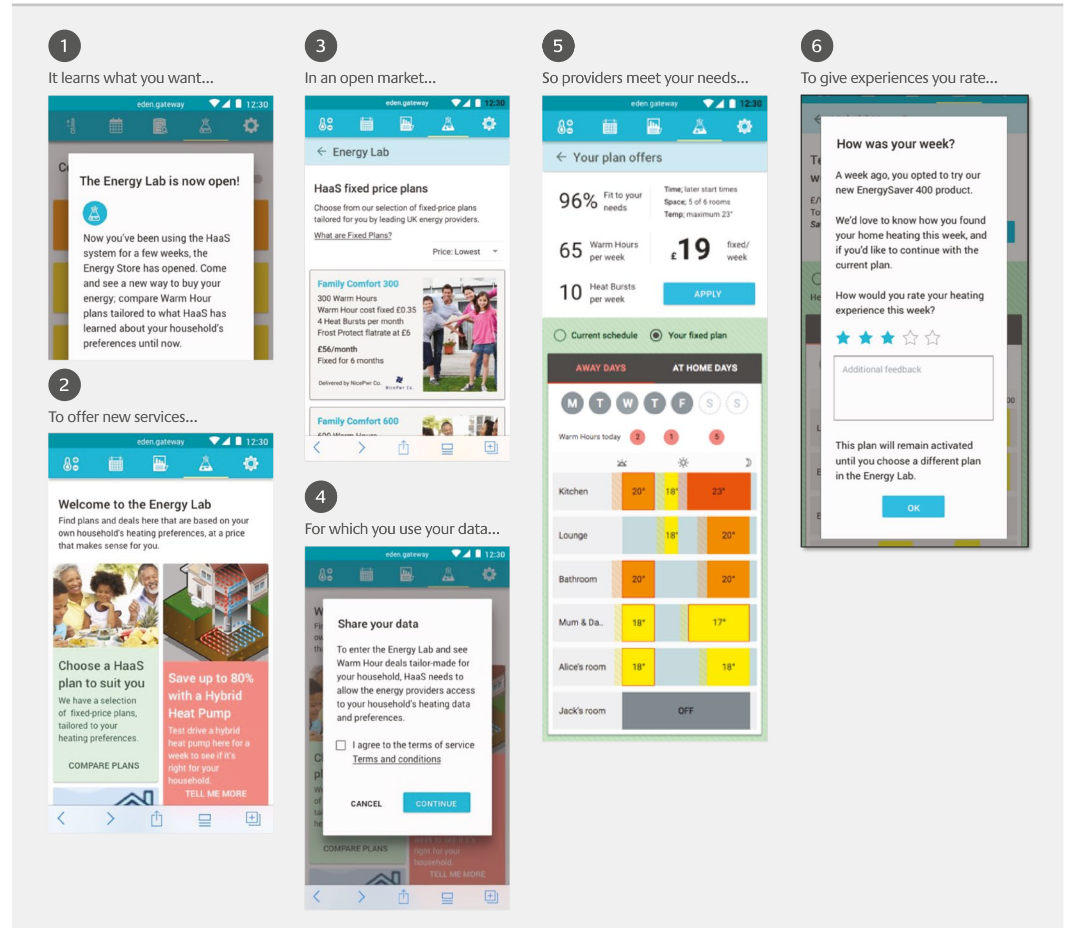
The foundations established through delivering the Home Energy Management Systems project to the ETI are being taken forward by the ESC with support from the Department for Business, Energy and Industrial Strategy (BEIS).
This follow-on work is:

- Refining the user experience and user interfaces to reflect the substantial learning to date
- Developing an additional part of the user experience, where service offers can be presented to trial participants
- Adding additional sensors to enable hot water to be included as an integral service element
- Improving algorithms to process data into information, businesses need to design, target and deliver products and services that better meet the needs of discerning heat users
- Gathering an initial dataset from a trial over the winter of 2017/18 in ~100 homes, which can be used to help businesses design new products and services; policy makers and regulators to explore new issues and solutions
- Establishing an initial 'living lab' with these ~100 homes, with whom industry and government can test their ideas faster and more cheaply than would otherwise be possible
- Establishing the supporting capabilities to help businesses trial the delivery of their services with those participants that choose to take up one of their offerings quickly, cheaply but robustly

The user interfaces below outline the concept of the user experience that enables different service offers to be tested with participants.

- Individual participants can choose how to use their data
- Choices of services to adopt, or express an interest in, will reveal insight on how different types and levels of service are valued by different people
- How the services people adopt are then used will reveal insight on how services perform and which features are most valued
- Comparison of both buying and usage enables understanding of the difference between how people *intend* to use and how they *actually* use a service
- People can provide feedback on performance, giving insight on how to improve the experience

Figure 16
Work in progress interfaces to illustrate how service concepts can be tested[11]



11 The Energy Systems Catapult is delivering a separate project to the Energy Technologies Institute: Integrated Electric Heat. The design tool built for the project is expected to evolve into a general design tool for low carbon heat.

ENABLING A NEW MARKET
Continued ›

There are potential market failures that could be avoided by thoughtful early design to ensure device vendors can capture a share of value from services

The connected home is gradually emerging and, currently, there are many companies establishing proprietary device domain ecosystems. This has implications for consumers and service innovators. For consumers, they risk their home energy systems being fragmented and poorly optimised, and being limited in how they can use data to get energy retailers to compete. For service innovators, it means they may struggle to obtain sufficient breadth and depth of data or control at home level to enable them to deliver high value services.

Regulators may consider trying to impose open standards, but it will be almost impossible to know in advance what to regulate, especially where control by a third party creates potential warranty risks.

An alternative approach is to architect the market for advanced energy services in a way that enables device vendors to capture an appropriate share of the new value associated with energy services that their devices have, at least in part, enabled.

The ESC is also working on alternative architectures for the future energy system.[12]

One of the key ideas arising from this work is the opportunity to establish a Home Energy Services Gateway; an intermediary business model, to help *any Householder* find an energy service from *any Provider;* and for any Provider to deliver that service using devices from *any Device Vendor's ecosystem.* Of course, such an intermediary should ideally be owned, financed and governed in the collective interest to enable market-led innovation. It enables creation of a range of standard device class Service Level Agreements, and governance to modify, add or retire a device class. Those SLAs define device performance, permitted usage and fees payable. A Services Provider or a Device Vendor can raise a request to add or modify a device class, enabling ongoing innovation driven by emergent discoveries of new value. A device is not necessarily physical; it may be an analytical capability to process data into more valuable insight.

The ESC is uniquely placed to facilitate the emergence of such intermediaries, since it has no vested interests; its business motive is uniquely to help others grow their businesses, and is constituted not to compete.

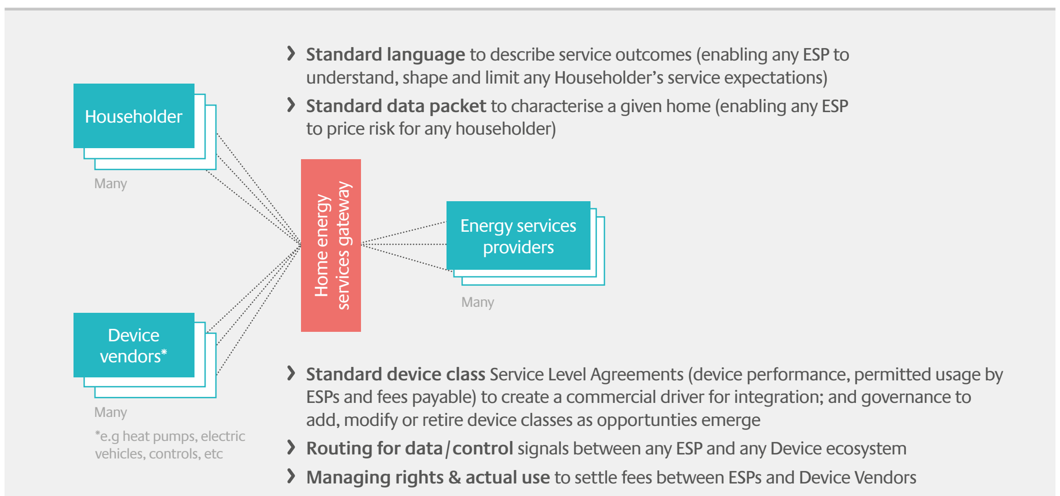
The importance of industry using comparable terminology for similar aspects of service offerings was evident in the participatory design exercise (as outlined in the Heat as a Service section). It is also evident people value the ability to compare alternative offerings, as is now commonplace with many products. However, in practice, such terminology can only emerge over time as part of an ongoing competitive process of innovation.

A profound change in energy retail will open new opportunities for comparison websites, but to enable this will require comparable terminology and access to structured data on different companies' offerings.

It would be beneficial if such companies can work together with service innovators to ensure effectiveness of market competition is considered from the outset.

An illustration of a hypothetical comparison site for energy retail services based on the 'warm hours' concept is presented below, but it should be noted that 'warm hours' is just one of many concepts that future energy retail services could be based on.

Figure 17
Overview of a Home Energy Services Gateway as a market enabler[12]



12 Annual Fuel Poverty Statistics Report; 2017; https://www.gov.uk/government/statistics/annual-fuel-poverty-statistics-report-2017

Figure 18
Hypothetical illustration of what a comparison table might look like for a market of competing retailers providing 'warm hour' type contracts

Currently GreenCo Inc.	Multi-Flex Bonus	£110	21 of 24 months	100%	220 / 50 month	£0.60	+70 boosts +Boiler cover	Extreme winter cover	£49.99 Exit fee
Heat level limit 22°c		Heat accuracy +/− 1°c			Time to heat 30mins			Include equipment	
Provider	**Product**	**Monthly cost £**	**Term**	**Fit**	**Planned/ Unplanned**	**On demand £/hour**	**Add-ons**	**Exclusions**	**TRY / BUY**
Eenergie Co.	Cost saver Max	**£89.99**	36 months	**96%**	200 / 50 month	**£0.30**	+80 Boosts +Boiler cover	Extreme winter cover	TRY BUY
MegaPwr Co.	No limit Spring offer	**£149**	12 months	**92%**	Unlimited / Unlimited	**£–**	+200 Boosts ++Boiler cover	Extreme winter cover	TRY BUY
Cleanpwr Inc.	Wind only megasaver	**£100**	1 month	**90%**	200 / 50 month	**£0.40**	+60 Boosts +Boiler cover +Extreme winter	None	TRY BUY
Gust co.	Offshore bundle	**£70**	24 months	**87%**	150 / 25 month	**£0.55**	+80 Boosts +Boiler cover	Extreme winter cover	TRY BUY
NicePwr Co.	Early saver	**£55**	12 months	**83%**	150 / 20 month	**£1.15**	+40 Boosts	Extreme winter Boiler cover	TRY BUY
Don't forget to read the terms									

ENABLING A NEW MARKET

Continued ›

There are significant opportunities to better integrate low carbon heat components and improve the quality of connected home devices for the mass market

Low carbon heating devices typically have different characteristics to the existing gas combi-boilers that dominate the UK domestic heating market today. For example, the cost of a high power boiler is not significantly more than a lower powered one and doesn't take up much more space, whereas a high power heat pump is significantly more expensive and takes up considerably more space, so is inherently less responsive to on-demand heat requests.

If looked at as a system, instead of individual components, it is more likely that an overall low carbon experience can be designed that people will find appealing, want to buy and will vote for. For example, responsiveness to on-demand heat requests could be improved by sharing storage between hot water and space heat; or by managing heat stored in the building fabric; or by having a gas boiler in hybrid combination with a heat pump; etc.

It is clear that advanced controls can enable such integration, if the devices are designed to work within an open architecture as discussed in the previous section. It is also possible that the data arising from advanced controls could be used to support lab testing, for example in the Salford Energy House; a unique UK test facility with a full sized two-bedroom house built inside an environmental test chamber[13].

Figure 19
Salford Energy House

A potential use of data arising from real-world trials is to create 'usage cycles' (i.e. how people use their home and its appliances) and 'customer scorecards' (i.e. what is a good overall system experience) for modelling and/or lab testing, which would enable multiple organisations to work on developing components within an open architecture in a repeatable way.

- The data on how people use their home and its appliances could be used to derive real-world repeatable 'usage cycles'
- The data on the experiences people value could be post-processed into a customer satisfaction 'score card' against which the experience of a whole heating system, as opposed to just technical performance, can be assessed
- Initial options for open architectures to integrate heat components could be explored in an open industry dialogue supported by modelling tools

There are many opportunities to develop connected home products that enable new services and give better customer experiences. A 'living lab' creates an opportunity to continue to identify opportunities and test potential solutions.

For example:

- Wireless radiator valves can create noise that propagates through the heating system and disturbs people's sleep
- Room environment sensors, radiator temperature sensors and radiator controls could be integrated into a single package
- Battery management at the component level is carefully optimised, but it may become less effective when integrated into a system to deliver services
- There are opportunities for devices to capture data at a more granular level and/or to issue updates more regularly, with significant value to gain in terms of enabling new services
- Devices could provide diagnostic reporting that would reduce the cost for a service provider due to people having to call the helpdesk
- There are many different types of radiator valve in people's homes today, and it is not possible to find a wireless mechanism in the market today to fit all of them, especially for small radiators and towel rails
- Secondary heating appliances are often an integral part of the heat experience, so should ideally be able to be managed as part of an integrated system

13 Committee on Fuel Poverty – A Report on Initial Positions; September 2016; https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/553931/CFP_report_-final.pdf

ENABLING A NEW MARKET

Continued ›

Installation and maintenance teams are critical in a customer's journey towards connected homes and advanced energy services, but they need to prepare

We were fortunate to have the expertise of a highly professional installation and maintenance organisation for this project who did an excellent job from initial training through to decommissioning. Even so, they needed to give their teams specific training for the challenges of advanced controls. A number of key issues arose, such as:

- Occupiers may not be in at the time of install to receive any guidance or to be involved in the set-up
- Installers need to be trained to provide advice on where to locate sensors and how to set up and use advanced controls
- Installers also provide opportunity to explain how a system should work, including setting expectations that machine learning algorithms may change the way the system behaves over time
- When installing controls, the boiler may be deemed unsafe; frustrating for someone not planning on a replacement cost
- Advanced controls need to provide for 'stress tests' at the end of an install, as the level of integration established by advanced controls can create emergent performance issues that didn't occur before
- There may be opportunity for installers to use data from advanced controls to help customers see the value of improvements while on site, such as cooling for a kitchen overheated by use of a cooker

Significant resource is deployed to help the most vulnerable in society; connected homes could enable richer relationships to improve targeting and delivery

There are currently 2.5 million households in fuel poverty in England. The UK currently has schemes worth approximately £3 billion per year to help eliminate this inequity; to ensure everyone in society can protect their health and well-being. In terms easier to relate to, it could be approximated at around £1,200 per year per household in fuel poverty. And yet, despite this financial resource, the number of homes in fuel poverty, about 11%, has hardly changed over the last decade.

There are significant effectiveness challenges that sit under this. Effectiveness in this sense is the number of people lifted out of fuel poverty for each pound spent.

- It is difficult to target financial resource to those who need it partly because many under-heat homes so energy bills and income are weak indicators and partly because those who need it don't fit neatly into standard classifications; so little finds its way to those it intended to help
- It is very difficult to ensure the interventions actually achieve desired impacts, for example: insulation may lead to damp build up and consequent health risks, low energy lighting may not materially reduce bills, etc
- Interventions tend toward subsidies for discrete one-off activities such as installing a new boiler, so there is little incentive to build deep customer relationships with those in fuel poverty to continuously help them protect their health and well-being

Connected homes may open new opportunities for addressing the productivity challenges. Advanced controls could empower people by putting them in control of their finances, to make decisions knowing how much different levels of heat use will cost. It may be worth policy makers considering options for financial support that ensure this benefit quickly reaches those that most need it.

Targeting of any financial support for advanced controls will of course suffer from the same challenges as above. However, this may well be more than offset by the power of the arising data, if available within an open architecture, to improve productivity for much more costly interventions to tackle fuel poverty; for example:

- Data could enable significantly improved targeting of interventions such as fabric efficiency improvement
- Data could enable tailoring of interventions, to significantly reduce the cost of expensive 'one size fits all' solutions that only partially meet a particular customer's needs
- Actual performance could be measured to enable 'payment on results' type business models to be introduced, to incentivise productivity and quality improvement, and to reward long-term investment in relationships with vulnerable consumers to continuously adapt services as needs change

Significant effort will be required to unlock such opportunities. Companies and Non-Government Organisations that could provide new services enabled by connected homes will need to work with policy makers and regulators to converge on commercial and policy solutions.

But the potential prize is enormous. Policy makers would benefit from the ability to ensure the vulnerable in society are protected. Industry would benefit from far less need for frequent regulatory interventions.

CONCLUSION

Society is progressing toward connected homes, which is likely to enable a profound change in the way people buy energy; away from input commodities people can't understand toward service outcomes people value. It is much the same as has happened in other parts of the economy in recent years.

Such a profound change is so far from the traditional 'utilities' model of energy retail that it is hard to imagine just how transformative it could be. The Energy Systems Catapult, supported by the Department for Business, Energy and Industrial Strategy, is enabling industry, policy makers and regulators to accelerate this profound change with lower risk by taking forward learning from the Energy Technologies Institute HEMS project.

A 'living lab' is being established in ~100 homes over the winter of 2017/18, seeded with an initial set of off-the-shelf devices. The arising data will enable better solutions to be developed, and the panel of homes will enable solutions to be tested and improved in rapid cycles of iterative development.

Accelerating such a profound change could have significant benefits:

- **Consumers** benefit from an industry increasingly focused on helping them achieve the service experiences they value
- **Retailers** benefit from differentiating themselves in a crowded market on high value services people want to pay for and stay with
- **Policy makers** benefit from retailers being able to play an active role in decarbonising domestic energy, using deep insight on their customers' needs to design and deliver services to delight people within carbon limits
- **Infrastructure investment** benefits from data on revealed consumer preferences to optimise against value and not just to minimise cost
- **Society** benefits from reduced 'friction' in the process of decarbonising domestic energy and increased system productivity to keep costs down
- **The UK economy** benefits from being a world leader in domestic energy services and connected home technologies, with global export potential

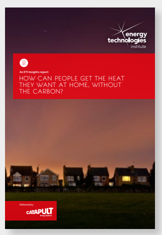
A 'living lab' is being established in ~100 homes over the winter of 2017/18, seeded with an initial set of off-the-shelf devices.

FURTHER READING

Decarbonising heat for UK homes

Consumer challenges for low carbon heat

Housing retrofits – a new start



How can people get the heat they want at home, without the carbon?

All of these reports are available via the dedicated insights report page of the ETI website – www.eti.co.uk/insights

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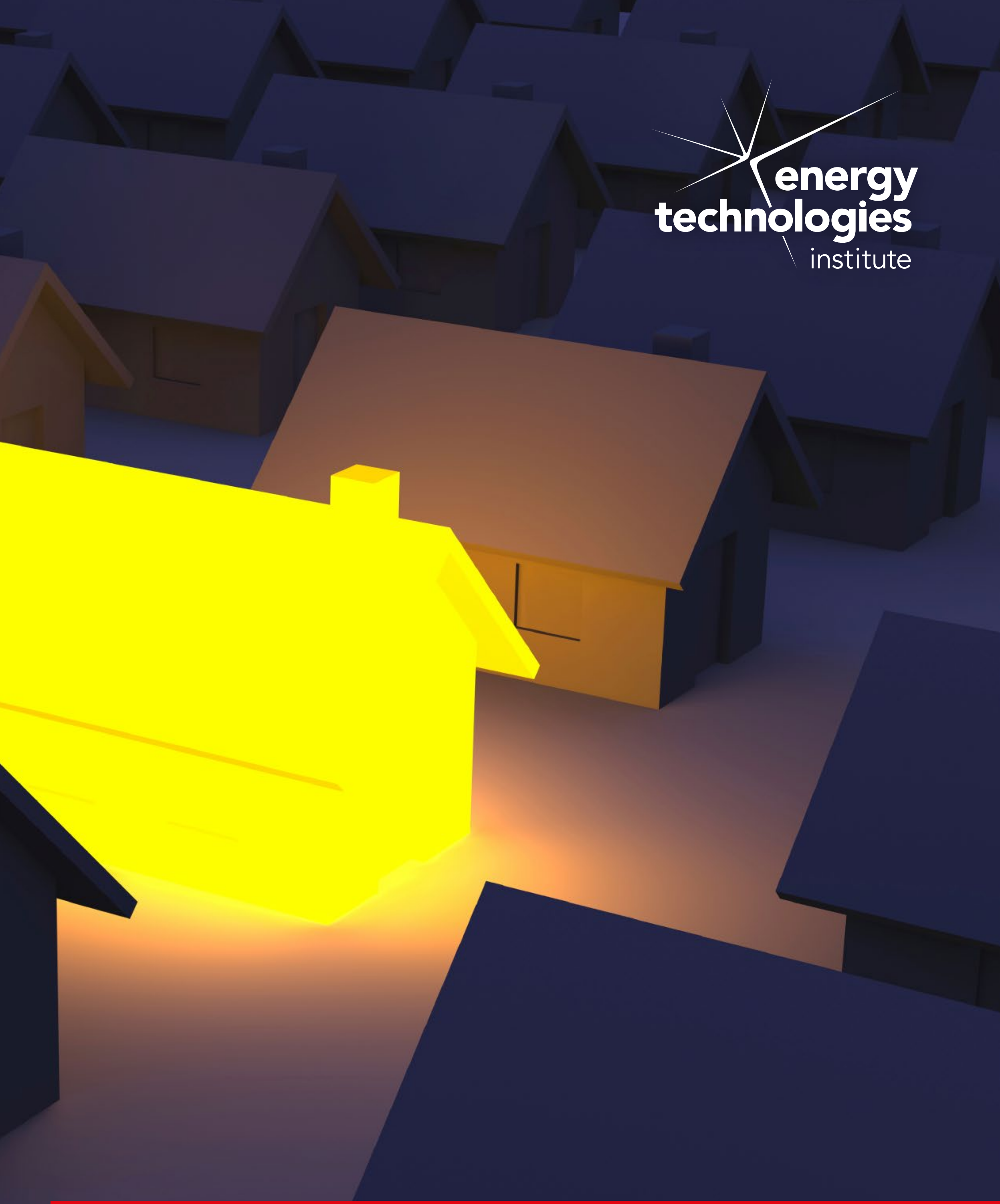
The Energy Technologies Institute (ETI) commissioned its Smart Systems and Heat programme in 2012 with the objective of creating future-proof and economic local heating solutions for the UK. In 2015 the ETI's Smart Systems and Heat team transferred to the Energy Systems Catapult (ESC) to become delivery partners for the first phase of the programme. The ESC will take forward phases two and three of the programme independent of the ETI to demonstrate at scale the methodologies and technologies developed in phase one of the programme.



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