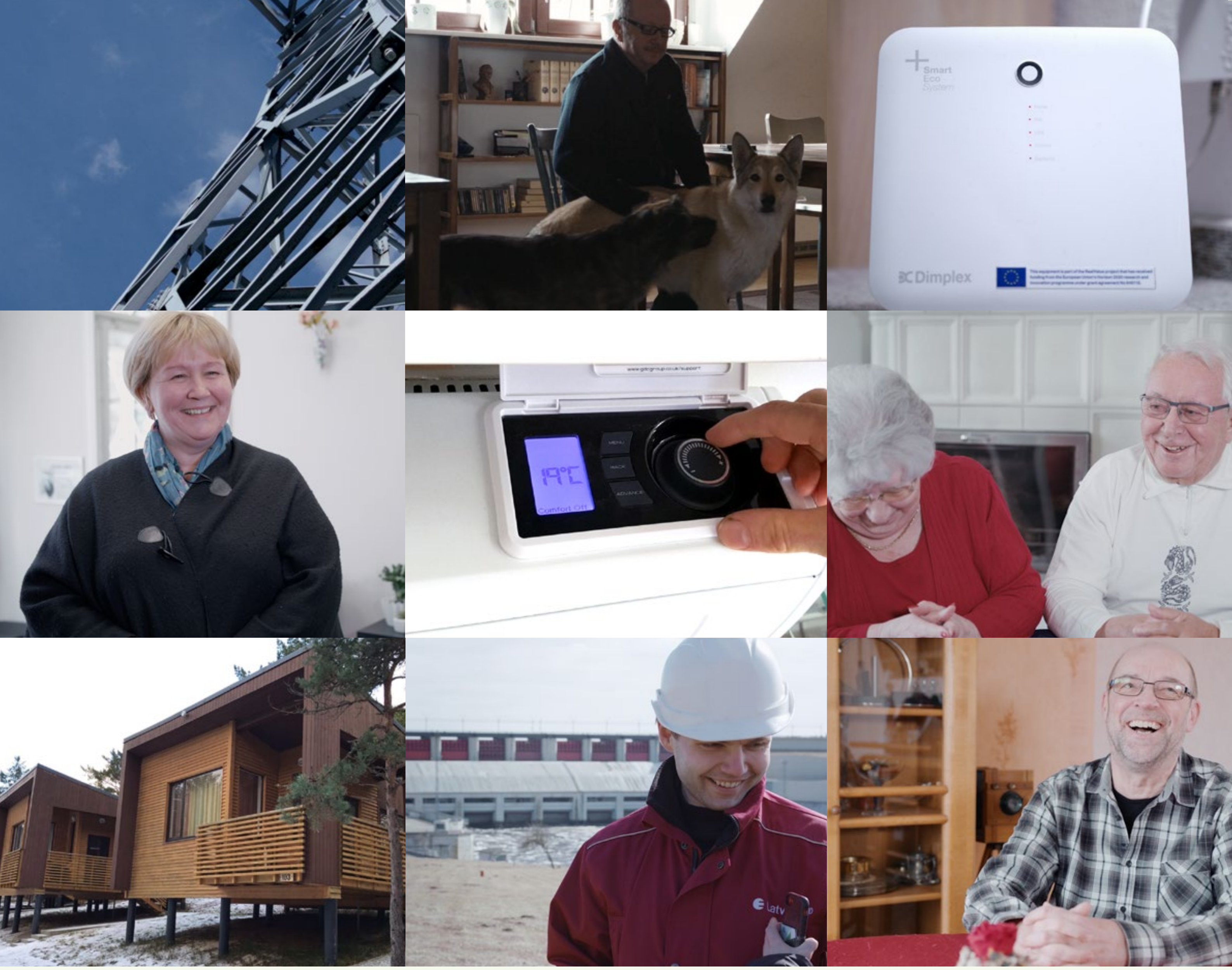


Getting the balance right:

Can smart electric thermal storage work for both customers and grids?

Consumer Impact Study
RealValue Project Horizon 2020

Environmental *Change* Institute

eci

UNIVERSITY OF OXFORD

Real Value

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646116

— Acknowledgements

The European Commission made this work possible by funding RealValue as one of the 'Smart Grids and Energy Storage' projects in the Horizon 2020 programme (Grant Agreement 646116). The project was developed in response to the call for research into local/small-scale storage (LCE-8)

Many people have contributed to this report. Our thanks go to all the project participants and partners who responded to surveys and agreed to be interviewed or to contribute to focus groups; to the Project Management Office staff at Glen Dimplex Ireland; industrial and commercial partners Glen Dimplex Heating and Ventilation Ireland, Glen Dimplex Deutschland, MVV Energie, Scottish and Southern Energy Airtricity, ESB Networks, Eirgrid plc, Intel, Beegy GmbH and Logica; and to our academic partners in the German Institut for Economic Research (DiW Berlin), Riga Technical University, the Electricity Research Centre at University College Dublin and the VTT Technical Research Centre of Finland. Scott Macdonald and Laura Brinker of the ECI helped with online surveys, interviews and focus groups; Yevgenijs Kozadajevs and Dmitrijs Antonovs carried out surveys and interviews with the Latvian households. We are grateful to Caitlin McMullin and her Transcription Centre colleagues for assistance with transcription and to Kerstin Leder Mackley for translation. Mark Sheehan and Camillia Kong of the Ethox Centre, University of Oxford, monitored and gave guidance on ethical issues.

All the above helped with their experience, insights and skills, and many partners also contributed to reviewing the report. Any remaining errors and omissions are those of the authors.

— The authors

Sarah Darby is acting leader of the Energy Programme and an Associate Professor at the University of Oxford Environmental Change Institute, where she researches social dimensions of energy systems and the implications of smart technology for energy services and environmental impact.

Sarah Higginson is an interdisciplinary researcher focusing on energy use in the home, with a particular interest in how social practices influence that energy use. She has a background in designing processes that facilitate dialogue between stakeholders in sustainability issues.

Marina Topouzi is an interdisciplinary researcher in building energy use and demand, focussing on how social, technical and non-technical factors affect users' interaction with smart low-carbon technologies.

Julie Goodhew is an environmental psychologist with research interests in interventions that promote heat conservation and in how householders conceptualise the behaviour of heat in their homes.

Stefanie Reiss is a sustainability engineer with research interest in evaluating the sustainability of technical options, providing decision support for industrial implementation.

Contents

Introduction

This report forms Deliverable 5.3 – the Consumer Impact Study – of the RealValue project. RealValue is a €15.5m (€12M European Commission-funded) project within Horizon 2020, the largest-ever EU Research and Innovation programme.

"Physical trials, involving real people, in three Member States."

— Running from June 2015 to May 2018, RealValue involved demonstrations of Smart Electric Thermal Storage (SETS) space - and water-heating systems in approximately 800 properties (domestic and non-domestic) in trial sites in Ireland, Germany and Latvia; also legacy storage heaters retrofitted with gateways to enable smart control in Germany. Project partners were not only testing single items such as heating appliances, smart meters or mobile phone apps, but combinations needed for quite complex processes. The tests were carried out in real-life conditions with customers who needed reliable heating, billing and maintenance services. This report stems from our research into customer experiences of participating in the project.

The level of ambition yielded valuable lessons about adopting ICT-enabled technology and developing distributed DSM.

The project relied on a combination of technological innovation with human knowledge, understanding, practical know-how and goodwill. Our research into customers' experiences with their storage devices showed how outcomes (in terms of satisfaction and readiness for DSM) were related to contributory factors such as a good experience at installation; technological reliability; support and advice from others such as a supplier, heating engineer, housing manager or neighbours; the electricity system to which they were connected, with its supply and demand patterns, metering arrangements and tariff possibilities; and the homes in which customers lived, with their unique combinations of people, appliances, preferences and activities.

Our research questions included

- Who adopted SETS and why did they do so?
- Did they prefer the SETS to their previous heating arrangements and if so, why?
- What were their views on demand-side management (DSM)?
- How significant were technical, market and cultural differences in influencing project outcomes in the three countries?

We then looked for some general lessons for development of distributed thermal storage and smart grids.

This introduction outlines some issues relating to heating and thermal storage, along with an explanation of DSM. It is followed by an account of project design and research methods. The central sections of the report summarise our findings on customer experiences and how these relate to comfort, control, cost, care, and connectivity.

These come from

- customers themselves;
- 'top actors' in the project who planned and directed the work;
- 'middle actors'. These were project partners or associates who were in direct touch with customers and had expert knowledge or practical know-how relevant to heating and DSM. Middle actors carried out surveys, installed and maintained equipment, and provided advice and guidance to customers. Some also coordinated operational activities and liaised with senior project partners.

The report ends with a discussion of the findings, some recommendations for policy and future research, and a summary.

The future of heating

Heating buildings and maintaining a supply of hot water is costly in terms of fuel, infrastructure and environmental impact. The 2016 EU strategy on heating and cooling begins with the statement that these two end-uses 'consume half of the EU's energy and much of it is wasted. Developing a strategy to make heating and cooling more efficient and sustainable is a priority for the Energy Union. It should help to reduce energy imports and dependency, to cut costs for households and businesses, and to deliver the EU's greenhouse gas emission reduction goal and meet its commitment under the climate agreement reached at the COP21 climate conference in Paris.' The strategy focuses on stopping energy leakage from buildings, maximising the efficiency and sustainability of heating and cooling systems, supporting efficiency in industry and reaping the benefits of integrating heating and cooling into the electricity system.[1] Many European policy scenarios involve electrifying heating, using renewable sources of power.[2]

Electrifying heating increases demand for electricity, though. There is also the question of timing: people are likely to want heating at times when power systems may already be struggling, for example in winter mornings when millions of people are waking, showering and making hot drinks[3], and in winter evenings as they return home and the system has to supply enough for household activities while industry, commerce and the public sector are still operating. Storage, and the ability to shift electricity consumption to times when demand is low, are going to be crucial for low-carbon, renewables-based electricity systems.

Storing energy as heat

Energy can be stored in many ways: as fuel (oil, coal, gas and food); through dedicated electricity-in/electricity out arrangements (batteries, compressed air, pumped hydro) and as heat in materials such as walls, floors and water. In the middle of the twentieth century, engineers started to use cheap night-time electricity to heat bricks to high temperatures inside an insulated casing, so that the warmth could be released gradually over the course of the day. Hot water tanks are also a useful and familiar way of storing heat.

Storage heaters and domestic hot-water cylinders may be small items, but there are millions across Europe and in some countries they make a substantial contribution to storage capacity. For example, in 2012 roughly a fifth of UK electricity to homes was supplied during seven night-time hours, much of it for storage heating and water heating.[4] There are similar figures for Germany, with around 25% of residential usage occurring between 9pm and 6am[5].

This capacity could be increased if the heaters were able to charge up at any time when electricity is abundant, not just overnight. This is increasingly important as we rely more on sun and wind generation for supply.

1 https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v14.pdf

2 Robinson (2017) https://www.oxfordenergy.org/wpcms/wp-content/uploads/2017/09/Fiscal-policy-for-decarbonization-of-energy-in-Europe-EL-25.pdf

3 Hanmer et al., (2018) How household thermal routines shape UK home heating demand patterns. Energy Efficiency

4 BEIS (2016) Energy Consumption in the UK. National Statistics. https://www.gov.uk/government/statistics/energy-consumptionin-the-uk Table 3.16; Sustainability First (2014). The Household Electricity Demand Side & Participation in the GB Electricity Markets. High level overview. Paper 12 in series 'GB Electricity Demand – realising the resource'. Sustainability First, London.

5 https://de.wikipedia.org/wiki/Standardlastprofil#/media/File:Lastprofil_VDEW_H0_Winter.png

A study commissioned by the heating appliance manufacturers Glen Dimplex estimated that if all suitable domestic storage heaters and cylinders in the EU-27 were replaced by smart-enabled equipment for 'any time' charging and customer comfort, the storage potential would be almost four times that in existing large-scale storage capacity, mostly in reservoirs that hold water pumped uphill by electricity generated at times of low demand. The combined storage capacity of storage heaters and electrically-heated water tanks in EU-27 was estimated in 2013 as being 55 gigawatts, equivalent to peak electricity demand for the UK.[6]

Unlike electricity from batteries, thermal storage cannot be converted back to electricity cost-effectively, but it is highly competitive with batteries as a mode of storage at the time of writing.

EU policy is to cut overall heating demand by over 40% and to decarbonise the remainder.[7] A central aspect of the RealValue project was to assess, through modelling and demonstration, the potential role for well-insulated and ICT-enabled storage heaters that are easier to control than the old models, offering a better service to customers and to grid and network operators[8]. A guiding concept was that Glen Dimplex Quantum SETS space- and water- heating devices, and retrofitted legacy storage heaters, can be aggregated to realise additional value for the electricity system in several ways:

- using electricity at times when it is relatively cheap to generate – for example, when the wind is blowing, the sun shining, and/or demand is low– and avoiding demand at peak times, when generation is more expensive and often more polluting;
- offering 'system services' to grid operators by switching on and off for very short periods to balance supply and demand in real time;
- avoiding or postponing the need to reinforce local networks, by enabling smart control of domestic electrical loads;
- avoiding investment in new generating capacity to meet high levels of peak demand.

Storing energy as heat: The customer offer

Customers encountered the SETS technology through two types of heater, designed to run on electricity at times of plentiful supply and low cost, with 'boost' facilities that can be activated manually at any time:

– **Quantum room storage heaters.** Depending on size, these can absorb 1.1- 3.3kW of charge (as deployed in Ireland and Latvia) and 2 - 7kW (Germany) to heat a high-density, highly-insulated core. The Irish models store 7.7 -23.1kWh and the German models 16-54kWh. Thus a two-bedroom apartment might contain one large and two small heaters with a combined storage capacity of ~ 50kWh and a four-bedroomed house more than twice that. The stored heat is normally discharged into the building over the course of a day, in accordance with pre-set programmes and (if necessary) manual adjustments. The heaters used in Ireland and Latvia had a 'boost' element, drawing 0.63-1.3kW depending on heater size, which can be used to provide additional heating rapidly but expensively, if used during peak demand hours. The discharge rate (and potential need for boosting) will depend on the energy efficiency of the buildings (the rate at which heat is lost to the surroundings) and on the temperature settings chosen by customers. Quantum room heaters offer a range of 14 - 26°C. Technical surveys of participants' homes assessed the number and size of heaters that would be suitable for each property.

Retail costs for these heaters at the time of writing were from ~€575-920 in 2017 in Ireland[9],~ €865-1793 in Germany[10]. By comparison, a 2kW electric panel heater can cost ~ €250.[11] But while the upfront costs of non-storage heaters are attractive, they are much more expensive to run, as they are unable to store energy from offpeak electricity. In Ireland, approximate costs of a unit of night- or day-time electricity at the time of the project were 9 and 18 cents respectively, depending on customer contracts while the daytime price was 18c. In Germany, comparable prices are ~21c and 29c.

- **Quantum water cylinders** of 125-300 litres capacity, which can absorb up to 6kW of charge and store 7.1-18.4kWh.[12] Retail costs are from ~€1045-1260[13]; these costs compare with ~€750 for a 150 litre direct fill cylinder[14], or ~€910 for a 150 litre 'preplumb unvented indirect single zone cylinder'[15]. (Installation of cylinders is likely to cost an additional ~€250.) The Quantum cylinders are advertised as long-life and low-maintenance.

- **Gateways retrofitted to legacy storage heaters, along with high-resolution smart meters, to enable flexible charging and DSM.**

Both space and water heaters use the same control architecture, allowing control to be shared between customers and demand aggregators. The aggregators can switch the heaters on or off (depending on network and market conditions) once customer requirements for temperature and timing have been met.

6 DNV KEMA (2013) Energy & Sustainability. Potential for smart electric thermal storage. Contributing to a low carbon electricity system. Report for Glen Dimplex and SSE plc by Raadschelders, J., Sikkema, F. and in t'Groen, B. http://www.dimplexrenewables.com/uploads/Kema%20report_LO%20RES.pdf

7 https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_autre_document_travail_service_part1_v6_0.pdf

8 We use the term 'grid' to refer to transmission or high-voltage electricity grids. 'Network' refers to more local, medium- or low-voltage networks.

9 According to a Consumer Association (UK) report (2017), http://www.which.co.uk/reviews/home-heating-systems/article/home-heating-systems/storage-heaters

10 Glen Dimplex Deutschland, pers. Comm.

11 https://www.dimplex.co.uk/product/plxe-200kw-panel-heater

12 http://www.dimplex.co.uk/assets/kb/brochure/0/Quantum_Cylinder_Brochure.pdf

13 http://www.electricpoint.com/heating/water-heating/quantum-water-cylinders.html

14 https://www.bhl.co.uk/dimplex-ecsd150-580-150-litre-direct-cylinder.html

15 http://www.screwfix.com/c/heating-plumbing/hot-water-cylinders/cat830956#category=-cat830982

The table below shows how better control and improved comfort are part of the Quantum customer offer. If smart meters and 'dynamic' tariffs (depending on time of use) are added, there is also the possibility of some financial benefits to customers from providing DSM services to electricity network operators.

Table 1: Some aspects of traditional storage heating and Quantum Smart Electric Thermal Storage (SETS) space heaters

	Traditional storage heating*	Quantum SETS space heaters
Timing	Charging during fixed hours of the day with manual 'boost' possible at other (high-cost/peak) times.	Programmed charging at times to suit customer preferences and grid conditions; manual boost function also available.
Thermal storage and uncontrolled heat loss	Heaters likely to lose stored heat within ~24 hours, even without setting controls for output (i.e., uncontrolled loss).	With better insulation, uncontrolled losses reduced to 120-240w (Clarke et al., 2013): more heat still available by evening.
Metering and tariffing	Separate meter used for offpeak (night-time) consumption, charged on a special tariff	May be charged in traditional manner with fixed tariffs or, with smart meter and dynamic tariffs, charged at any time in line with real-time cost of supplying electricity.
Design	Bulky; relatively poor insulation.	Slimmer, better insulation.
Controllability	Basic input and output control; slow response. In Germany, charging based on current outdoor temperature.	More sophisticated, with seven-day programming for temperature and timing of heat release. Smart energy calculation, fan-assisted output, can be controlled by phone app. In Germany, charging is based on weather forecast.

*NB: retrofitting traditional storage heaters with gateways and smart meters enables them for flexible DSM.

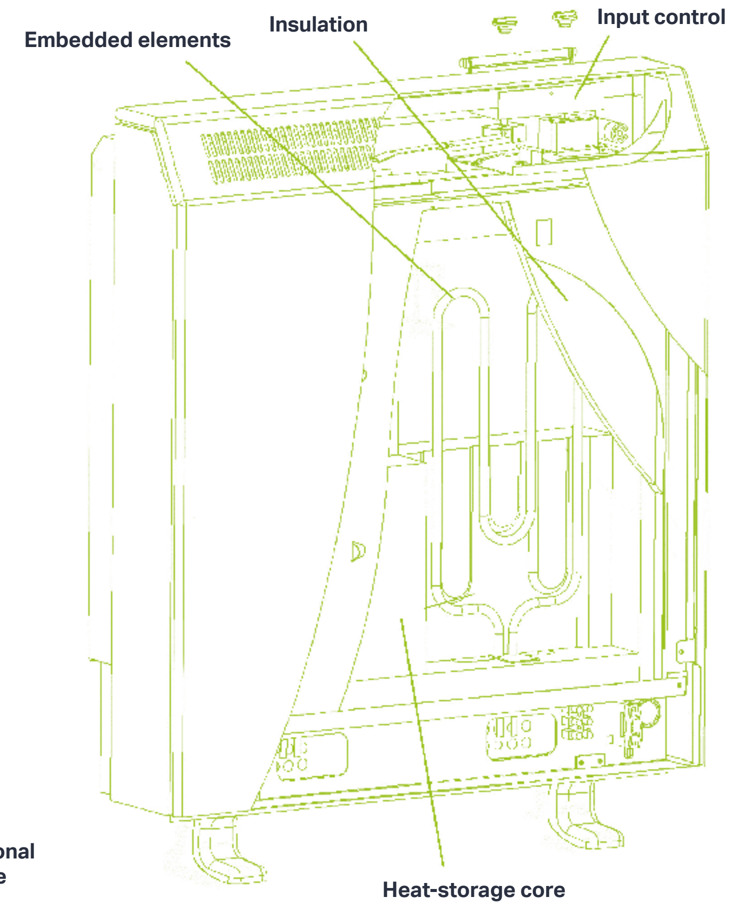
Controlling storage heating: The customer experience

Traditional storage heating has not offered the off/on, rapid-response control that is possible with central heating radiators, gas fires or simple electric resistance heaters. People with storage heaters have typically had three control options:

(a) set an input control on each heater each evening - that is, a few hours before it is due to start charging), based on an estimate of how much heat they would want the following day;

(b) adjust an output control to govern the speed at which heat is released over the following day;

(c) use a 'boost' control for extra heat, which may come either from accelerated release of stored heat, with the aid of a small fan or (if the stored heat has been used up), from additional resistance heating that will be charged at peak-time rates and will contribute to system difficulties with meeting demand.



Traditional storage heater

Analogue controls on a traditional heater


Quantum heater 'onboard' digital control panel (Ireland, Latvia)

16 see https://www.cse.org.uk/advice/advice-and-support/night-storage-heaters for simple guidance, much-consulted.

Customers have often found these controls hard to operate effectively and somewhat inconvenient [16]. The type of housing has also influenced customer experience: for example, people in poorly-insulated homes who spend most of their time at home in the late afternoon and evening may have struggled to achieve affordable warmth if relying on storage heating (Bouzarovski and Petrova 2015; Ofgem 2015).

The Quantum heaters are much better insulated and have controls that allow customers to set precise temperatures for specific times of day (below). Note that the Quantum heaters used in Germany for the trial differed slightly form those deployed in Ireland and Latvia: for example, the German heaters had an automated link between the weather forecast and the input setting.


Quantum heater, Germany

Gateway, Germany


Quantum control dial, Germany

Demand-side management

Electricity systems only work when supply and demand balance each other in real time. In the past, this balancing work has been done by the supply side: when a new device (load) is switched on, the generator supplies more power. This is quite easy to do with generating plants that burn gas, coal or other forms of fuel; less easy when generators are relying on wind or sunlight that are not always available. So demand increasingly needs to respond to supply, rather than the other way around.

> Demand-Side Management (DSM) '*refers to all changes that originate from the demand-side of the market in order to achieve large-scale [system-level] energy efficiency improvements through deployment of improved technologies or changes in end-user behaviour and practices. The market organisation of a country impacts the changes and the actors involved. In many cases, the energy sector plays an active role.*'[17]

DSM in a commercial context can be arranged in many ways. For example, some industries have 'interruptible contracts' with their supplier that give them cheaper electricity in return for switching off their processes when demand is exceptionally high. Supermarkets may set up contracts to alter their freezer settings in response to grid conditions. On a much smaller scale, householders may be on tariffs that encourage them to use appliances such as washing machines at times of day when supply is plentiful. Such demand-shifting can be done manually or automatically.

ICT now allows customers, network operators or other parties such as utilities and aggregators to control selected appliances remotely. There is some evidence that customers can be willing in principle to hand over some control of their space- and water-heating loads to a supplier/aggregator via an automated system, in order to take part in DSM and receive some benefit from dynamic pricing, provided they retain the power to override the automated setting and provided room temperatures will not fluctuate beyond certain limits[18].

There is also some evidence of remote control of water heating working well for customers in practice.[19]

The size of any demand response achieved through DSM can be shown in terms of a 3-D space or box, as shown below. The dimensions are:

- *Technologies* used for the response (devices, switches/controls, infrastructure);
- Users' *service expectations*, such as the number of hours of heating per day they want and the temperatures they prefer.
- Users' *activities*, e.g. altering the controls of a heater, setting a washing machine to operate only at off-peak times of day or ironing clothes at times of peak demand.

For all or most of the potential to be realised, the technology needs to work well, customers need to understand and be able to manage the controls, and they need to have service expectations that are flexible enough to allow some of their demand to be shifted. It will not be enough simply to develop new technical capacity: new skills will also be needed and also new expectations and norms.[20]

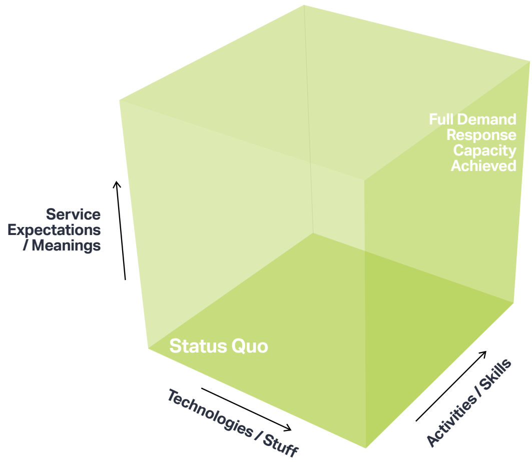


Figure 1: The 'demand response box': the greatest response comes from a combination of technology, the services a customer wants and the activities and skills that influence.[21]

17 http://www.ieadsm.org/wp/files/Strategy-Oct2015.pdf

18 Fell et al., (2015) Public acceptability of domestic demand-side response in Great Britain: the role of automation and direct load control. Energy Research & Social Science 9. 72-84. Note that many of the survey respondents did not have electric heating and were asked to imagine that their heating, in a DSM scenario, 'works exactly as it does except that it runs on electricity'.

19 E.g. Saele, H. and Grande, O.H. (2011) Demand response from household customers: experiences from a pilot study in Norway. IEEE Transactions on Smart Grid 2 (1), 90-97

20 Grunewald, P. and Diakonova, M. (2018) Flexibility, dynamism and diversity in energy supply and demand: a critical review. Energy Research and Social Science 38, 38-66

21 McKenna, E., Higginson, S., Grünewald, P. and Darby, S.J. (2017) Simulating residential demand response: Improving socio-technical assumptions in activity-based models of energy demand. Energy Efficiency DOI 10.1007/s12053-017-9525-4

Customer participation in DSM

Thermal storage can help electricity system operators to balance supply and demand in real time. It is unusual as a network resource because the system operators who stand to benefit from it do not usually invest in the heaters themselves: they are owned either by the people who use them, or (if they rent their homes) by their landlords. However, day to day management of the heaters is shared between customers (who programme their preferences for temperature and timing) and whoever controls the charging.

Customer consent, understanding and cooperation are therefore essential to using storage heating effectively for DSM and, as this report shows, they are also needed in order to use the heating effectively for everyday comfort. From our analysis, the factors that lead to good or bad customer experiences will strongly influence the potential for using storage heating for DSM.

RV trial site in Latvia (Holiday Homes)

RV trial site in Ireland

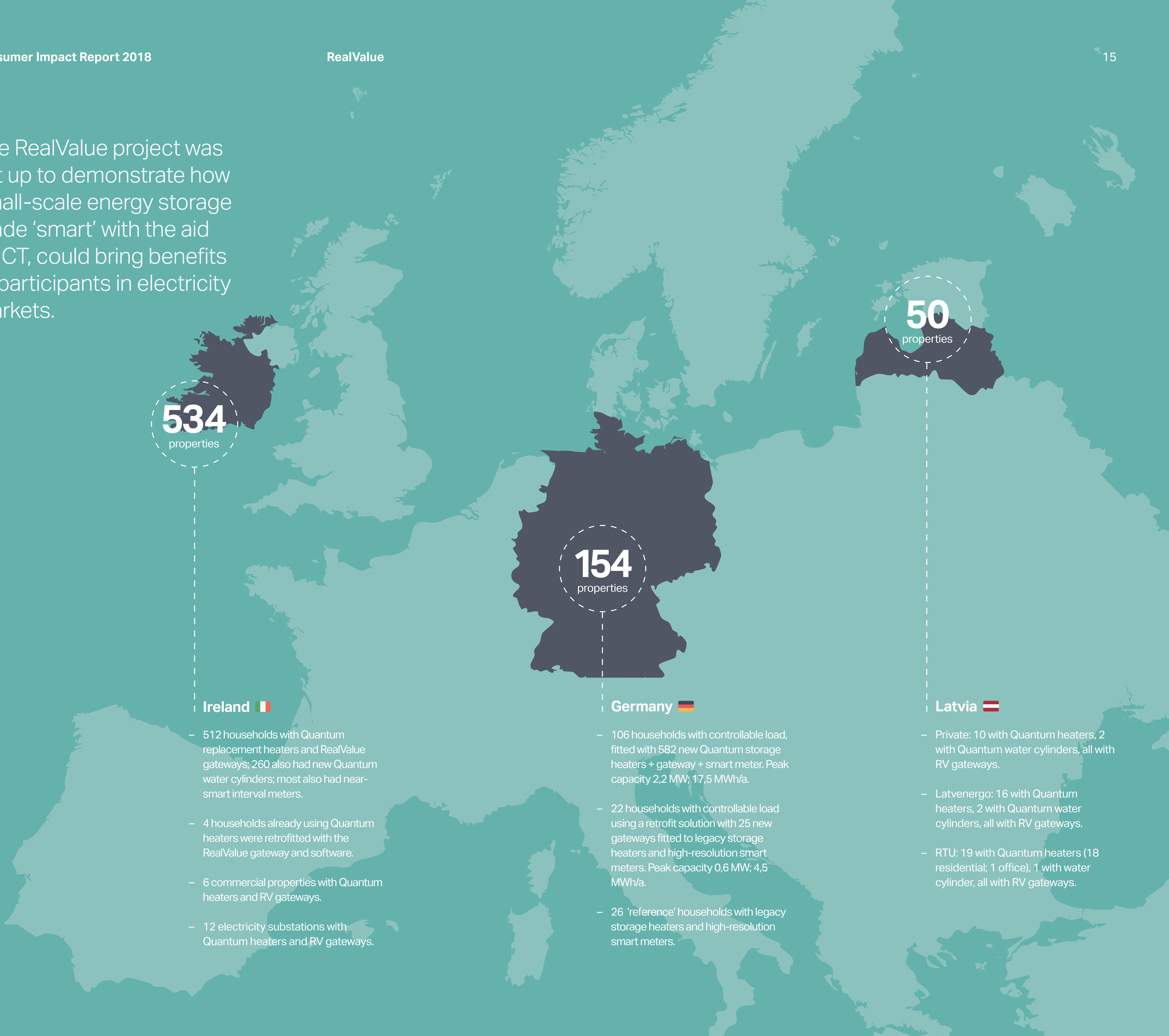
RV trial site in Germany

Project Design

The RealValue project was set up to demonstrate how small-scale energy storage made ‘smart’ with the aid of ICT, could bring benefits to participants in electricity markets.

— Crucially, smart electric thermal storage (SETS) had to work well for the customers who used it in their daily lives in homes and workplaces. And it had to work in homes and business premises in three contrasting EU countries. The project also looked at, to give an indication of how viable it might be as replacement for, or enhancement of (by retrofit), the 55GW of storage in room heaters and water tanks already installed across the EU and, beyond that, as well as a further 93GW of resistance electric heaters with no storage capability.

RealValue has complemented smaller-scale trials using SETS in Scotland and Ireland[22]. Installations took place as shown on the map.



Ireland

- 512 households with Quantum replacement heaters and RealValue gateways; 260 also had new Quantum water cylinders; most also had near-smart interval meters.
- 4 households already using Quantum heaters were retrofitted with the RealValue gateway and software.
- 6 commercial properties with Quantum heaters and RV gateways.
- 12 electricity substations with Quantum heaters and RV gateways.

Germany

- 106 households with controllable load, fitted with 582 new Quantum storage heaters + gateway + smart meter. Peak capacity 2,2 MW; 17,5 MWh/a.
- 22 households with controllable load using a retrofit solution with 25 new gateways fitted to legacy storage heaters and high-resolution smart meters. Peak capacity 0,6 MW; 4,5 MWh/a.
- 26 ‘reference’ households with legacy storage heaters and high-resolution smart meters.

Latvia

- Private: 10 with Quantum heaters, 2 with Quantum water cylinders, all with RV gateways.
- Latvenergo: 16 with Quantum heaters, 2 with Quantum water cylinders, all with RV gateways.
- RTU: 19 with Quantum heaters (18 residential; 1 office), 1 with water cylinder, all with RV gateways.

22 See http://www.realvalueproject.com/related-projects

SSE promotional material in second phase of recruitment

Engagement

Customer engagement was an important element in the project. The related research aimed to find out about

- Customers' experiences with their new heaters and with others taking part in a research and innovation project.
- Ways in which engagement could inform the project as it went along, through feedback from customers and project personnel, so that experience could be shared between partners.
- Ways in which engagement research findings could be used to build an appraisal of distributed thermal storage, for use by the European Commission and other interested parties such as policy makers, technology manufacturers and actors in the electricity supply chain.

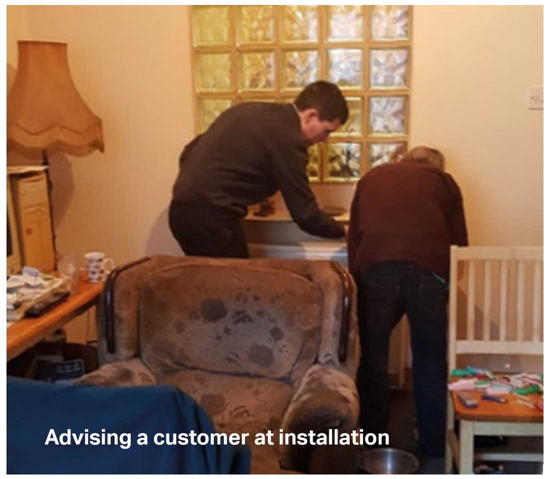
Customer recruitment

First, the project had to interest customers in signing up to take part, offering them new heating equipment and (in some locations), the possibility of taking up time-of-use tariffs. This was done through a combination of written information (all partners), social media[23], door-to-door recruitment of new customers by the electricity supplier (Ireland), and of existing customers (Germany and Ireland), and a combination of, press releases and events (Latvia).

Equipment installation

This involved engagement between suppliers, customers, landlords, supply chain stakeholders and installers AND between customers and their new appliances and communication devices. It was an intensive period of engagement, including

- Training installers to install the equipment correctly and explain it to the customers. Due to the novel nature of the ICT components, this was a first-of-a-kind installation.
- Carrying out the installation professionally and in a friendly manner.
- Giving customers written and verbal instructions on how to operate the controls.
- Making sure customers had information about who to contact if they had any difficulties;


Advising a customer at installation

23 E.g. https://www.youtube.com/watch?v=pQfQYbVwZrQ

Follow-up engagement

After installation, engagement continued throughout the project. The mix varied between countries, but all the following played a part:

- follow-up checks by project engineers;
- customers experimenting with their heaters, adjusting controls to get the levels of comfort they wanted, viewing online information about their energy use and trying out phone apps;
- 'troubleshooting' visits by suppliers, landlords and project staff to address particular issues;
- queries to the suppliers about any difficulties with the SETS, which could then be channelled to the person or organisation able to address the problem;
- customers talking informally with family, friends and neighbours about their heaters and the project;
- community events and workshops at which the SETS and the concept of DSM could be explained further and queries could be dealt with locally, in person. About 25 events were held in all;
- surveys, interviews and focus groups through which customers could feed back and discuss their perceptions and experiences of SETS & DSM;
- newletters and emails to keep customers informed;
- a dedicated service phone and e-mail address (e.g. realvalue@rtu.lv, realvalue@mvv.de) were created for communication with all trial candidates and participants.

How RV objectives were met through the engagement programme

- Levels of customer satisfaction with their new heating and with the research project were related to their interactions with project personnel before, during and after installation: the engagement was worthwhile as part of the energy service.
- Findings from customer engagement were fed into the project at regular intervals, during and between project meetings. This helped with 'project learning', for example making it possible to offer more effective advice to customers on how to operate their heaters, and to improve the mobile phone app.
- Findings from the engagement activities were invaluable when it was time to carry out an overall analysis of customer experience, as set out in the Findings on the next page.

— Do

- Teilen Sie uns mit,
- wenn ihre Hezizungsanlage erweitert wird.
- ween beil ihnen ein Mieterwechsel / Eigentümerwechsel ansteht.
- Heizen Sie ganz normal wie davor.
- Geben Sie uns gerne Feedback.
- Nehmen Sie bitter an unseren Befragungen teil.
- Halten Sie Ihr Internetverbindung immer aufrecht.

— Don't

- Schrauben Sie nicht an den Geräten.
- Deaktivieren Sie nicht Ihre Sicherungen.
- Trennen Sie nicht Ihre Internetverbindung.
- Schalten Sie Ihren Internetrouter nicht aus.
- Zeihen Sie nicht den Stecker der Zentraleinheit heraus.

Advice on adapting to the new Quantum heaters

Country Comparisons

Given the diversity of countries in the EU, it was important to deploy the SETS in different contexts.

The table below shows some of the ways in which the three countries differed from one another.

Table 2: Some characteristics of the three RealValue demonstration countries

	Germany	Ireland	Latvia
Climate	Cold winters, warm/hot summers.	Mild/cool all year round, with fairly consistent temperatures day to day.	Severe winters, mild summers; temperatures can fluctuate a lot day to day.§
Electricity System	Highly interconnected with neighbouring countries, which lessens challenges as solar+ wind generation increases and nuclear plants are retired.	Islanded apart from two interconnectors with Great Britain. Some of the highest penetration of wind generation in the EU on a synchronous system.	Highly dependent on hydro power; linked to, Nordic and Baltic systems and (until 2025, provisionally[24]) to the Russian grid.
Citizens views of energy system	Wide popular support. built up since 1970s, for energy transition (Energiewende) based on efficiency and renewables.	Energy not a usual topic of conversation or debate. Fuel poverty a serious concern.	Widespread support for Latvian energy independence.
Electricity market	Diverse, liberalised, deregulated. Four large suppliers + many local utilities.	Liberalised market, on the way to deregulation.	Recently liberalised market with several suppliers, but little diversification of electricity retailers in household sector. Single TSO; one main DSO, covering 99% of the country. Regulated distribution and transmission tariffs.[25]
Electricity tariffs	Day/night tariffs available; other time-of-use tariffs being introduced by some suppliers. All RV customers on same tariff.	Two-tier tariffs with cheap night-time electricity for customers with storage; no other time-of use tariffs yet.	Various: fixed price (most popular), dynamic (hourly), and static time-of-use (day/night). Some participants chose dynamic pricing.
Billing and metering	Monthly down payment based on estimated consumption Yearly billing based on meters reading once a year. Smart meters being introduced slowly.	Billing periods usually bimonthly. Meters read once a year by ESBN though customers can send in their own readings. Near-smart interval meters being introduced for ESBN. A minority of RealValue customers on prepayment meters.	Meters read each month or once a year depending on retailer and customer preferences. Customers may phone in readings. Payments are correspondingly either different each month or evenly balanced throughout the year. Smart meters are being introduced; rollout expected to be complete by 2023.[26]
Electric heating	~1.4m households electrically heated (storage or direct resistance heating); 5.4% of all apartments. Heating accounts for 7% of total household electricity consumption.[27] District heating common in cities, also gas central heating; solid fuel in rural areas.	~140,000 homes electrically heated; most people rely on gas or oil central heating as primary heating.	Most homes heated by district heating in cities, solid fuel in countryside.
Electric water heating	Uncommon in Germany; no Quantum cylinders installed.	Quite common.	District water heating is the most common option.
Buildings in the trial with storage heating	Mostly owner-occupied family homes, well insulated.	Mostly social housing, apartments, variable amounts of insulation.	Mostly rented apartments or vacation homes; also Latvenergo industrial buildings and Riga Technical University properties.
Participants' recent home heating history	Old and inefficient storage heaters.	Old and inefficient storage heaters.	Gas central heating and/or electric heaters; one solid fuel stove.

24 http://europa.eu/rapid/press-release_STATEMENT-18-2142_en.htm
25 https://www.sadalestikls.lv/en/customers/electricity-market/electricity-market-households/electricity-traders-households/
26 http://www.baltic-course.com/eng/energy/?doc=128414
27 http://www.nymoen-strategieberatung.de/uploads/tx_cedownload/nsb_ifeu_Analysepapier_PtH_im_privaten_Heizungsmarkt.pdf

— **In addition to differences between countries, there were differences between the ways in which the technologies were set up in each and what functions they offered customers and the system:**

28 http://www.baltic-course.com/eng/energy/?doc=128414

Table 3: Storage heater functionalities in the three countries

	Weather prediction	Appliance charging/input	Temperature control	Customer information
*	Combines weather forecast from Internet (digital control) with actual external temperature (hardwire analogue control) to control charging/input for the next day.	Charge controller: central signal tells device what level it should be charged to. It responds if allowed to by the price/ time signal. Central signal must work for heating to work. Two systems: analogue (hardwire with central control) and digital (Wi-Fi controlled by gateway – more precise and faster). SETS communication module enables Internet access No boost function	Every room has a thermostat that communicates with a central controller.	Monthly billing based on estimated consumption; meters only read once a year. Smart meters being introduced slowly. Online 'energy cockpit' shows total power consumption; YouTube video shows how to operate heaters. Phone app can control heating if logged into supplier network. Newsletters, email, social media. Dedicated call centre service.
	Not available	Charging in response to electromechanical or radio signal, based on forecast energy demand; boost button.	Heaters have thermostat on bottom corner to control room temperature. Programmer offers a range of 14-26°C	Billing periods usually bimonthly. The Irish regulator requires that meters be read by ESBN at least twice a year, though they try to do so at least four times a year and customers can send in their own readings whenever they like. Near-smart interval meters being introduced for ESBN. A minority of RealValue custom-ers on prepayment meters. Phone app can control heating from anywhere with Internet connectivity. Call centre, dedicated helpdesk. Leaflets, email, social media, newsletters.
	Not available. Causing difficulties because temperature fluctuations can be significant.	As Ireland	As Ireland	Meters are read each month/ once a year. Smart meter rollout expected to be complete by 2023.[28] Special service phone line and e-mail address (created to communicate with participants. Technical support service wasprovided by RTU staff. Participants were kept up to date by RTU articles in an energy magazine as well as brief updates during surveying and interviews.

*** (Quantum heaters and retrofitted legacy heaters)**

Technologies

Quantum storage heaters were installed as shown in Figure 2. All properties had an Internet connection installed if one was not already there, and a gateway device. Some also had smart plugs, sensors and smart meters. The gateway linked the heating appliances to an aggregation platform at Cloud level, sending data from each appliance so that the platform could interpret their availability to provide DSM at any time. This information was transmitted to a Cloud-based optimisation engine that allowed aggregators to see current and future wholesale prices and any network constraints. An optimised charging schedule for each appliance could then be calculated and passed through the gateway to be activated. Software and security updates could be 'pushed' to the gateways. The diagram on the following two pages gives an overview of social and technical interactions in the project.

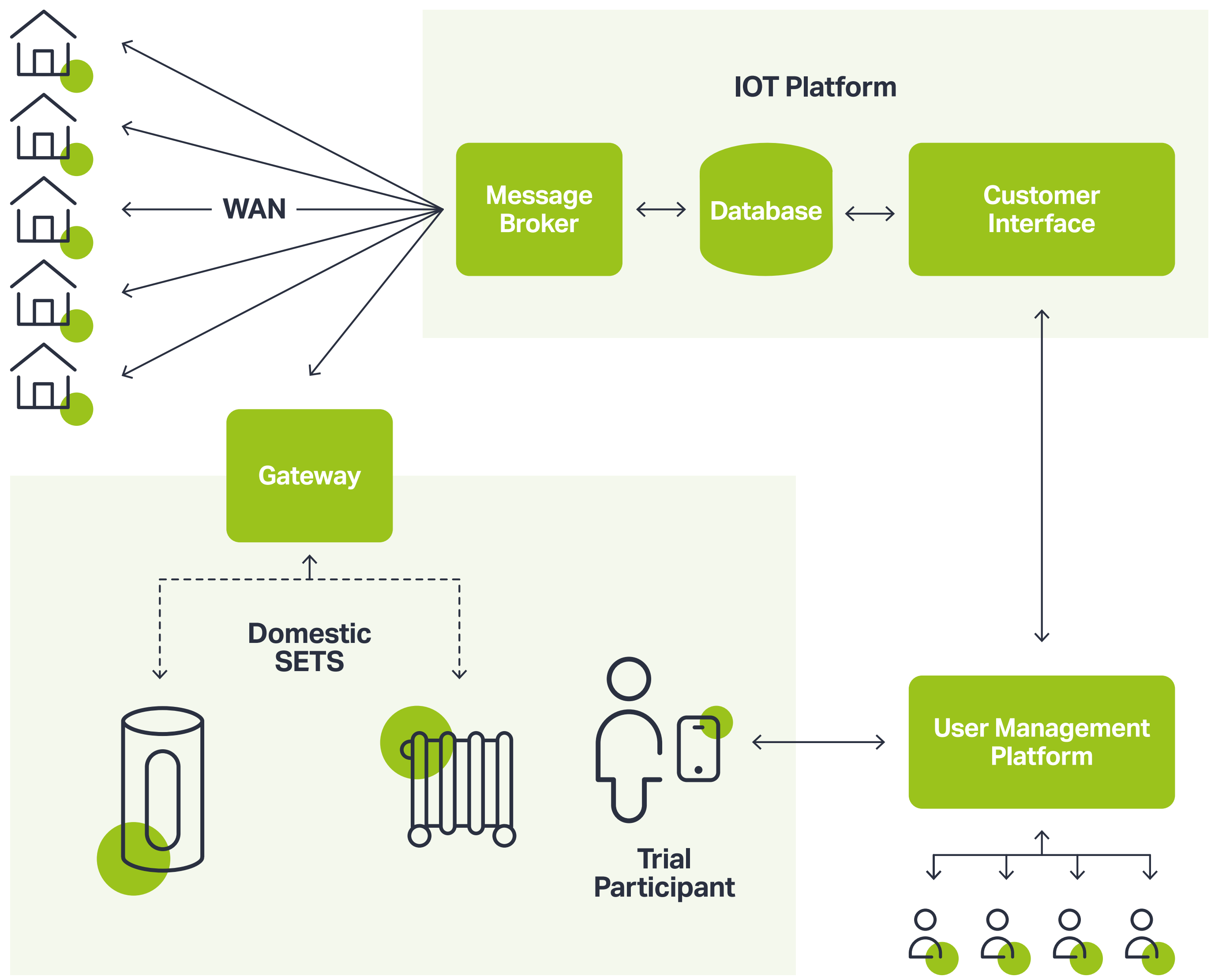
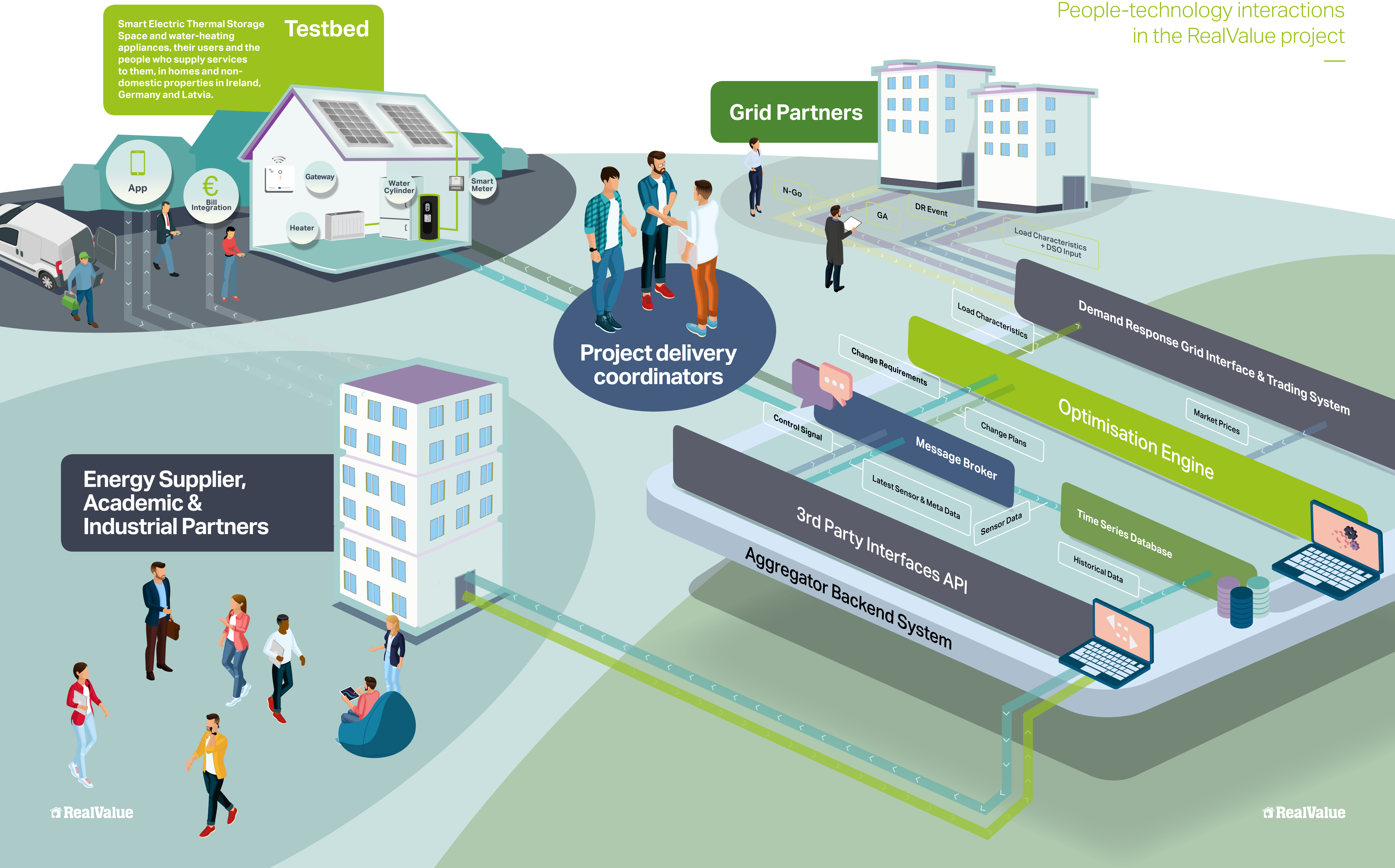


Figure 2: Diagram outlining the sub-system integration and data flows behind the RealValue user interface application. (WAN=Wireless Area Network) (Source: GDHV)

People-technology interactions in the RealValue project



Research methods

Our aim was to analyse customer experience in the three countries and what lay behind it. With the aid of project partners, translators and transcribers, we carried out a programme of surveys.

- A sign-up survey[29] before the new appliances or retrofit gateways were installed. The aim was to collect baseline information on topics including demographics, household occupancy (including pets), the fabric of the home, heating history, sense of comfort, expenditure on electricity, how much control people felt they had over their heating and whether they were aware of time-of-use tariffs.
- A post-installation survey. Within two months of installation, this was to check whether the process had gone well, pick up any early problems with the technology and assess customers' satisfaction with their ability to control their appliances and the level of support received.
- A final survey, as close to the end of the project as possible, to access general satisfaction levels, what advice had been most helpful, confidence in controlling heaters and cylinders, perceived changes in behaviour, electricity bills and comfort levels; and thoughts about DSM, variable tariffs, the phone app and engagement during the project.

Table 4: Customer survey schedule

	Ireland 1st phase	Ireland 2nd phase	Germany	Latvia
Sign-up survey	Face-to face with supplier sales representative, recorded on paper	Face-to face with supplier sales representative, recorded online	All surveys filled in by RealValue customers, online.	Face-to-face with RTU researcher, recorded on paper.
Technical survey	In-home, conducted by installer	In-home, conducted by installer	In-home, conducted by installer	In-home, conducted by installer
Post-installation survey	By phone, with SSE customer services staff, recorded on paper			Face-to-face with RTU researcher
Final survey	By phone, conducted by SSE customer services staff, recorded online	By phone, conducted by external agency staff, recorded online	Online	By phone, conducted by RTU researcher, recorded online

Table 5: Number of households surveyed

	Ireland (Tranche 1)	Ireland (Tranche 2)	Latvia	Germany
No. of households[30]	533		10	106
Sign-up	179	338	10	
Post-installation	80		9	76
Final survey	72	51	9	53
Customers completing at least 2 surveys*	106		9	46

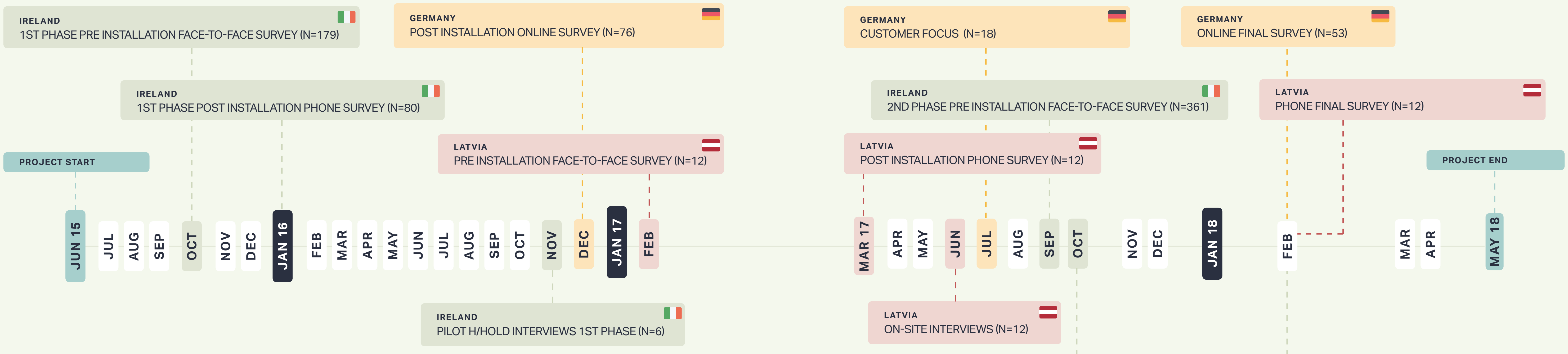
***Note:** This report is based on customer feedback data from households who responded to surveys/interviews. We only analysed customers who had completed at least two surveys (the shaded row at the bottom).'

- **Interviews** with customers at different stages of the project (nine households in Latvia and 44 in Ireland in customers' homes; 17 in Germany at MVV), to explore their experiences and views in more depth and to observe how they were using their new equipment. The German and Latvian interviews and focus groups were undertaken by project partners in MVV and RTU, then translated and transcribed.
- **Observation** during installations and at community events, to understand customer interactions with others.
- **Focus groups** of customers and installers (Germany).
- **Participation** in project consortium meetings, approximately every six months, plus visits and regular phonecalls with partners, to discuss developments in the project, issues arising and how these were being addressed
- **Interviews** with four of the lead partners in the project, to draw out general lessons for SETS and related technologies.
- **Interviews** with 'middle actors' who dealt directly with customers, to find out how the SETS equipment was introduced to customers and how any difficulties were handled
- We also had access to a small amount of usable **quantitative data** on energy consumption and costs, temperatures and timings.

29 There was also a technical survey just after sign up but prior to installation, carried out by engineers, to assess whether a property was suitable for the project and capture information about the fabric of the building, type, size and location of dwelling.

30 The study used data from customers who responded to surveys and/or interviews, somewhat fewer than the total number of properties as (a) not all customers responded and (b) some properties did not have a corresponding 'user', e.g. electricity substations.

Audio recorder and customer information and consent form, ready for an interview



The timeline shows when the various customer surveys, interviews and focus groups were carried out.

Data analysis

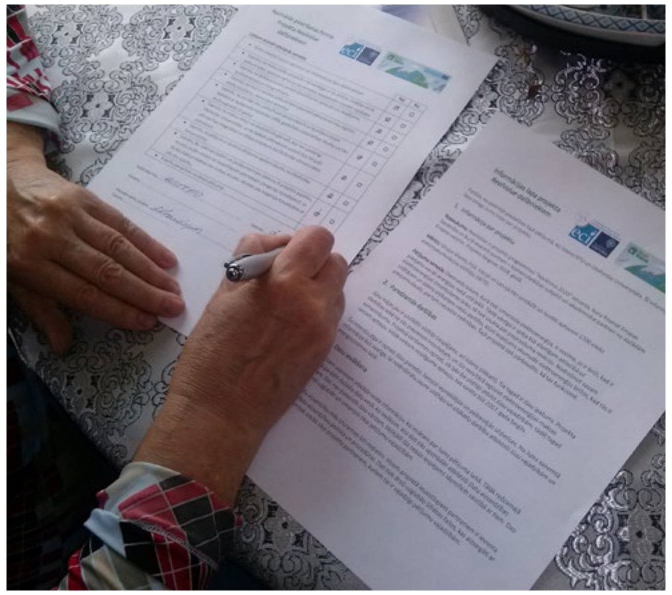
With the help of a NVivo software package, we

- organised, in one place, the survey data, interview and focus group audio records and transcripts, photos and observation data;
- made comparisons between countries;
- identified themes emerging from the qualitative data and use them to build up a picture of customer experiences as a whole;
- cross-checked between different data sources.

Microsoft Excel, SPSS and JMP were used to analyse quantitative data, e.g. for country comparisons and correlations between variables.

Consent, privacy and confidentiality

All customers were given an information sheet about the project before signing up to it; they also signed a consent form in which they agreed to let us use their anonymised data. Project partners who were interviewed are quoted in this report with their permission.



31 Where meter data was concerned, this was due to the challenge of setting up a clean set of consumption data when participants were on different billing cycles, and privacy considerations regarding data sharing.

Strengths and limitations

The range of methods helped in building up a 'thick' picture of customer experience and what lay behind it. We gathered information 'horizontally' across the three countries and 'vertically' at three different levels of activity that we labelled 'bottom up' (customers), 'top down' (project leaders) and 'middle out' (those in touch with both customers and project leaders).

The interviews and observations with customers and installers proved invaluable, offering a far more realistic and in-depth picture of technology adoption and everyday experience than would have been available from the surveys alone.

End-of-project interviews with country leaders and middle actors also added depth to the analysis, as each could offer reflections from their standpoint on a process they had been immersed in for nearly three years.

There are of course limitations to what we can learn from the RealValue social research. Not all participants were willing to fill in a survey or take part in an interview, while not all surveys were applicable to all types of participant. The surveys were carried out by different people in the three countries, with varying levels of training and experience, and this may affect consistency.

While there was extensive telemetry and meter data, most was not in a suitable form to complement our qualitative findings on comfort and consumption.[31] The data also had to be interpreted in the light of how it had been gathered. For example, two distinct groups of customers were recruited in Ireland, in 2015 and 2017, and they answered slightly different sets of questions during their sign-up surveys. Post-installation and final surveys were designed to be harmonised between all three countries, but even then some questions had to be adapted slightly to meet the needs of project partners.

Overall, though, our flexible approach and methods allowed us to make the most of opportunities as they arose and to build a dataset that offers valuable insights into customer experience, technology adoption and commercial possibilities. While customers were our main concern, we did our best to take account of all aspects of the project and to reflect them in the Findings that follow.

Findings

The findings cover general information about RealValue participants, the project-related technology and the various actors in the project.

**A short section on overall customer satisfaction leads into an analysis of satisfaction in terms of five 'Cs': comfort, control, cost, care and connectivity.
The Findings end with reflections on customer engagement and DSM from project partners who were in leading positions and those who worked directly with customers, the 'middle actors'.**

Demographics

Our analysis is based on the sample of customers, who completed at least two surveys: 46 in Germany, 106 in Ireland and 9 in Latvia, that is a total of 161 domestic customers. Roughly a third of respondents in all three countries were over the age of 65 – slightly higher than in the European population[32].

Survey respondents were mostly male in Germany (37/46) and Latvia (6/9); in Ireland, the gender balance was more equal with 52 female and 45 male respondents. Most households were small, with roughly 40% having only one occupant and almost as many having two (Figure 3). The Irish sample averaged 1.8 occupants per household, Germany 2.1 and Latvia 2.9.

32 EU average is 19.5% of population aged 65 and over. Source: http://ec.europa.eu/eurostat/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=tps00010&language=en

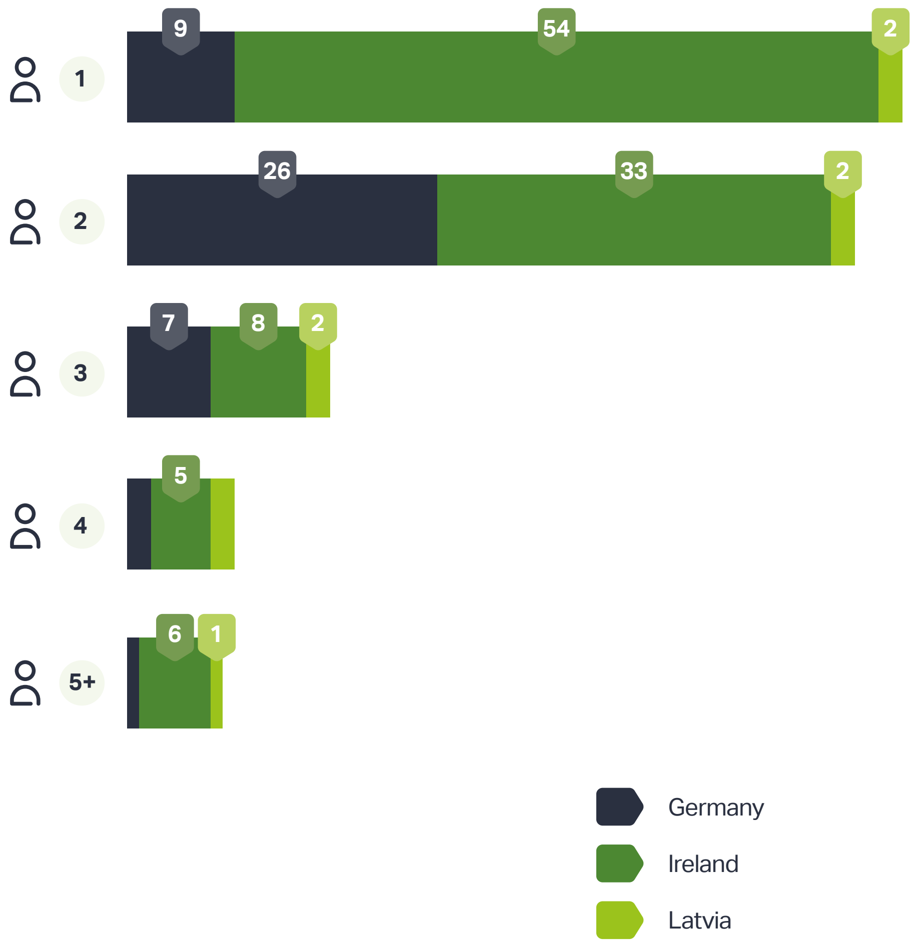


Figure 3: Number of occupants per household (installation survey)

Another significant influence on energy use is the fabric of the building. We were not able to gather much detail on this but, of 126 customers who answered the question, 55 (44%) said that they had wall insulation and 37 (29%) draughtproofing. Three had solar hot water or photovoltaic (PV) panels. Irish customers in social or owner-occupied housing were more likely to say they had energy-saving measures than those in private rented accommodation.

Figure 4 shows occupations. Some 43% were in full or part time work, with 43% retired and nearly 9% unemployed. These figures compare with EU average unemployment of 7.6% in 2017[33] and 29%, 20% and 30% of the population retired in Germany, Ireland and Latvia respectively[34].

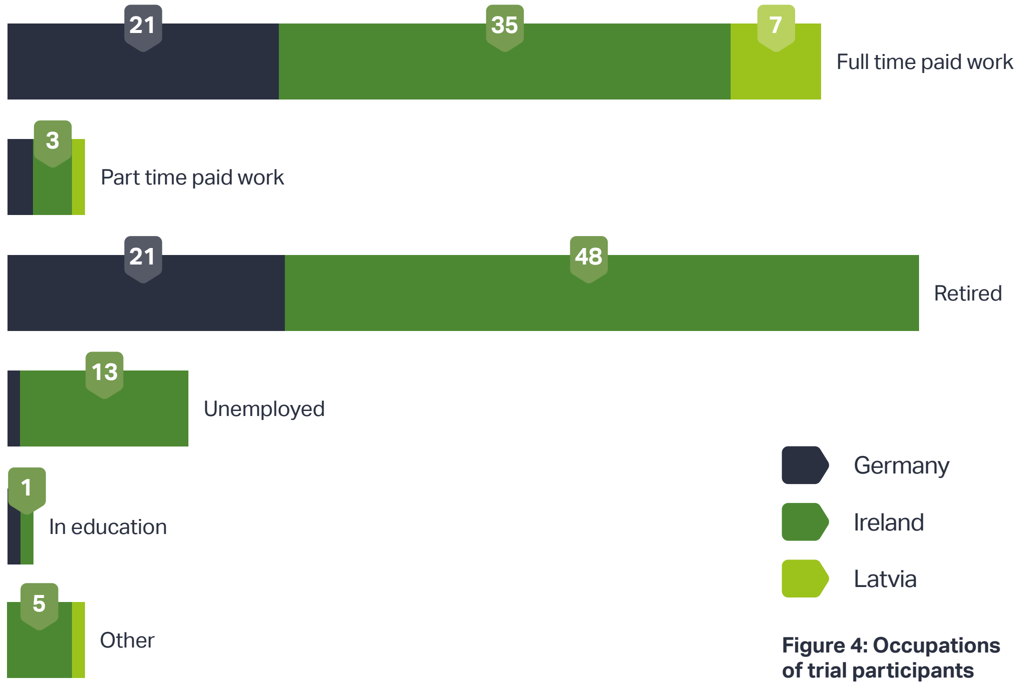


Figure 4: Occupations of trial participants

33 Eurostats http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tps00203&plugin=1

34 Source: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=spr_pns_ben&lang=en and http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tps00001&plugin=1

35 The 'at risk of poverty threshold (annual income) for a single person (in Euro's 2014 and 2015) are Ireland (9,598€), Latvia (4,855€) and Germany (12,219€). (http://ec.europa.eu/eurostat/statisticsexplained/index.php/People_at_risk_of_poverty_or_social_exclusion#Income_poverty:_17.3.C2.A0.25_of_the_population_in_the_EU-28_facing_risk_of_poverty)

In Ireland 77 customers responded to the question on tenure. Of these, 35 (45%) were in social housing, nine (12%) were in private rented accommodation, and 33 (43%) owned their homes.
In Germany and Latvia, a higher proportion were homeowners: 72% in Germany (33/46) and seven of the nine respondents in Latvia.

Income levels varied, with 8% of survey respondents reporting income levels below, or on, the 'at risk of poverty threshold'[35] for their country (Table 6). Home visit observations suggest that numbers in Ireland on low incomes were higher than the figures below suggest. Note that many customers (61%) did not report their incomes.

Table 6: Reported monthly household incomes in the three countries (installation survey)

Monthly household income after tax (€)	Germany	Ireland	Latvia
Under 900	2	10	1
901 – 1,500	4	1	3
1,501 – 2,500	10	1	3
2,501 – 3.500	6	3	
3,501 – 4,500	9	1	
4,501 – 5,500	2		
5,501+	5	1	
N/A	2	38	2
Rather not say	6	51	
Total	**46**	**106**	**9**

Climate

Customer experience was influenced by weather conditions, which differed markedly between the three countries, and the ability of the storage heaters to adapt to them. At one end of the spectrum was Ireland, with relatively predictable mild weather; at the other, Latvia, where

"The charging algorithm of the heater cannot predict the outside temperature, and … the temperature can drop dramatically within one day. As a result, comfort level cannot be achieved and additional costs appear… There have been several cases when the temperature in an office was about 9°C after the weekend, and [the heater] could not raise the temperature … in accordance with the setting. "

Project delivery coordinator, Latvia

In and around Mannheim, with a climate somewhere between that of Ireland and Latvia, heaters were charged using an algorithm that combined the weather forecast with current outdoor temperatures. This worked well.

Recruitment

In all three countries, customers were visited several times to determine whether their properties were suitable for the trial. In Latvia, where storage heaters or water cylinders were being installed for the first time in a small sample of 50 properties, this was relatively straightforward. Partners at the Riga Technical University (RTU) selected a mix of households, small businesses, holiday homes, electricity substations, a workshop, security guardhouse, storehouse and locker room. Surveys and interviews were carried out with nine customers living in the permanently-occupied buildings.

" Energiewende, it's a very big picture. … the motivation here in Germany was that they get a new storage heating system for free. … some of them… are motivated because they want to be part of this Energiewende and so on."

Project delivery coordinator, Germany

In Ireland, a large part of the funding a large part of the funding for the capital cost and cost of installation came from the Better Energy Communities programme, administered by the Sustainable Energy Authority of Ireland (SEAI). In the first phase of recruitment, SSE Airtricity focused on customers in social housing with storage heaters needing replacement. Some participants came from their existing customer base; others (the majority during the first phase of the project) were recruited through contacts with housing associations and doorstep sales, supported by a campaign using leaflets and social media. These customers typically received two replacement storage heaters, in their living room and hallway. A significant number[36], mostly in the first wave of recruitment, had no Internet connection and this increased installation complexity. These customers had a fixed line broadband line installed with a modem. In the last phase of the demonstrations, SSE offered heavily subsidised heaters and cylinders, again with funding support from the SEAI, to a broader range of their customers. This phase included homeowners, businesses and or community organisations. This recruitment exercise was very effective in achieving participation in the project.

36 The project delivery coordinator estimated that over a third were without broadband access.

Heaters were also installed in some ESBN electricity substations and, toward the end of the project, Quantum heaters belonging to four existing SSE domestic customers were retrofitted with gateways to enable them to participate in the project.

In Germany, MVV recruited participants from their customer base who had a suitable wiring system and no asbestos in their old heaters, an Internet connection and, ideally, some computer literacy.

Customers joined the project for a variety of reasons. The hope of reduced bills was the most significant of these, but there was also an interest in new technology, greater energy independence and environmental gains.

"We are still connected to the Russian network; they are controlling our frequency. But we are going to reconnect our power network to the west European. … separation from the Russian network will be in … 2019 … People, I think, mostly do like to have this energy independence, but there is a big But. All the time when I am talking to our customers, the first place is money saving."

Project delivery coordinator, Latvia

'Become part of the Energy Turnaround' from German marketing materials

People: bottom, top and middle actors

"RealValue is one of the Horizon 2020 smart grid projects with the most demonstration participants… My understanding is that none of the participants, or close to none, have ever been part of such a trial before and have no, or extremely limited experience of, the smart grid, demand side management etc. So, our project has attracted a lot of attention from stakeholders including the EC, in the area of consumer engagement."

Rowena McCappin,
Project Director, Glen Dimplex Heating and Ventilation

In what follows, we have divided the many people who took part in RealValue into three groups.

- **Bottom-up actors:** the customers who adopted and operated the SETS technology, contributing 'upwards' to the system, but were not involved in project decision-making. Note that 'bottom' does not mean 'least': indeed, MVV described their customers as 'top' or 'central'.
- **Top-down actors:** leading project partners in each country who planned and coordinated the work.
- **Middle actors:** these were mostly professionals who were in contact with the 'bottom' and 'top' actors and responsible for putting plans into action, seeing that the work was done effectively, and that customers received good service and understood how to get the most out of their new equipment. We have also used the term to cover those people who gave informal support and advice to customers.

Put another way, top-down actors had a great deal of capacity to make things happen in the project but were not in a position to carry out DSM actions themselves, while the reverse was true for bottom-up actors. Middle actors, as will be seen, were crucial in bridging the gap between top and bottom and preparing the way for DSM. But we start with the bottom-up actors, the customers.

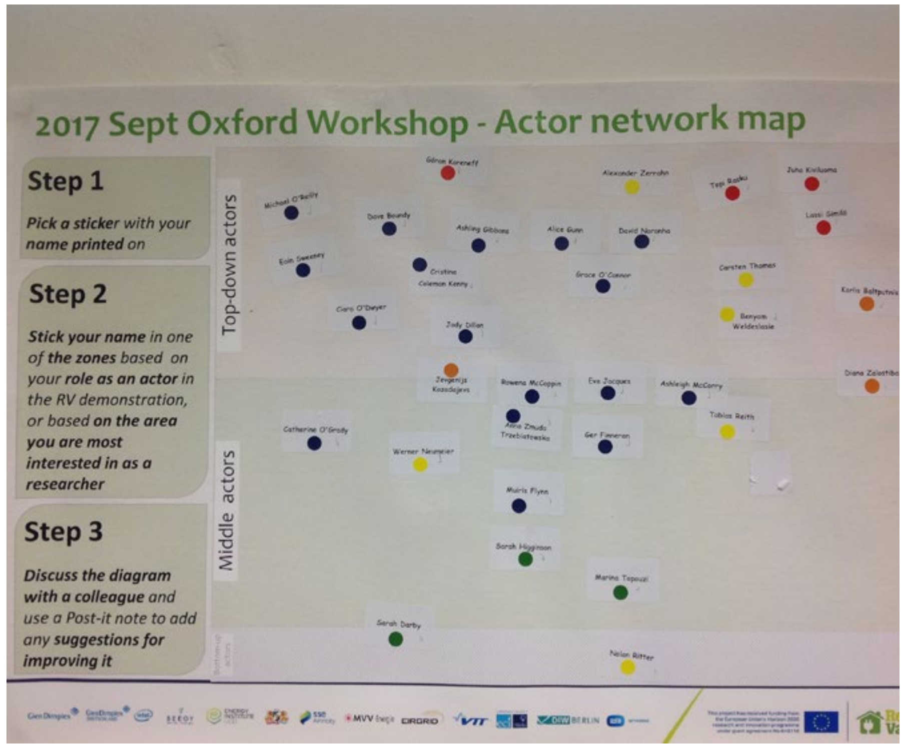


Figure 5: An Actor Network Map in preparation – project partners placed themselves on the map

Bottom actors – customer experience and perceptions

This section tracks customers' experiences of the RealValue technologies. We start by reporting overall customer satisfaction with the new heating devices, prior to flexible charging, and then introduce Five Cs: Comfort, Control, Cost, Care and Connectivity, which we use to frame the customer experience and assess the implications for SETS and DSM.

Overall expectations and satisfaction

FINDING: The majority of customers were satisfied overall with the new heaters and cylinders in terms of comfort, control and aesthetics. However, there were instances where expectations were not met.

The initial surveys show that customers' main expectation on joining the project was that that they would save on their energy costs. Additional expectations were improved heating and better control of heating. At the end of the project, out of our sample of 161 customers across all countries, 119 (74%) were 'satisfied' or 'very satisfied' (Figure 6) with their new system and 113 (70%) thought their new heating system was 'better' or 'much better' than their old system (Figure 7).

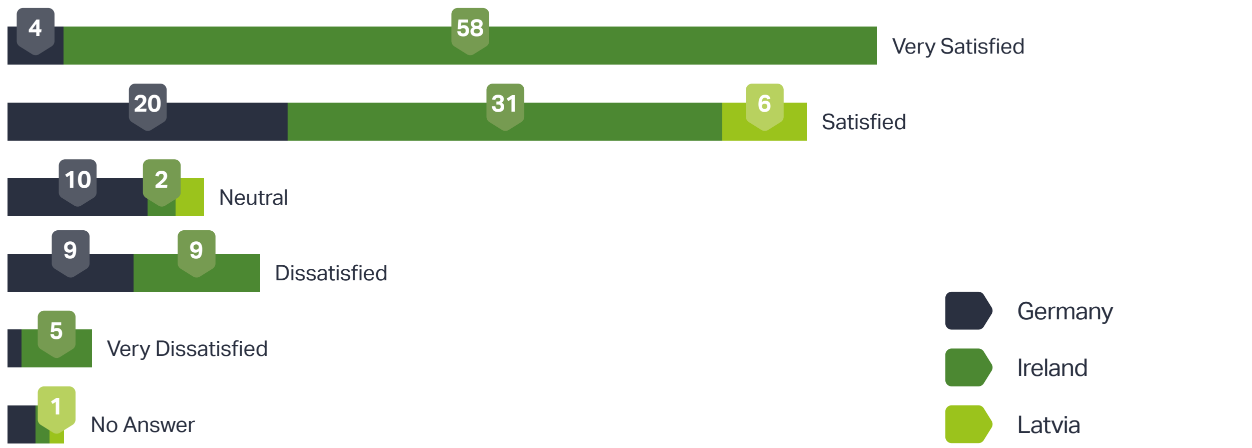


Figure 6: Responses to survey question: How satisfied are you with the new electric storage heaters?

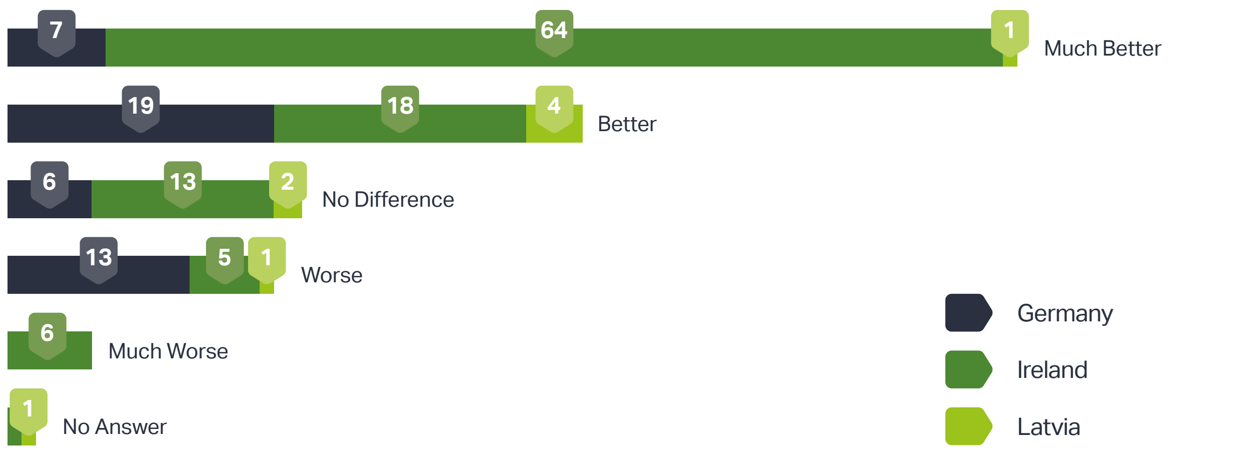


Figure 7: Responses to survey question: How do you rate your new heating system in general, compared with your old system?

In the final survey, across all three countries, positive comments centred on the heaters themselves, typically focusing on how they looked and the improved warmth they provided:

"The heater is a lot better at providing heat and looks better."
Irish customer interview [37]

"When this came in, it just changed our winters for us, really, because we could feel warm… It's brought cosiness into our lives."
Irish Customer

"Regarding (the) warmth of the heaters … the heating power has always been sufficient for me. However, I generally prefer it not too warm."
German customer focus group

Negative comments were more distributed, being about heaters, problems caused by software updates in Germany and Ireland at the point when preparations were being made for 24-hour DSM, problems with control, and cost-saving expectations not being met. Table 7 summarises both positive and negative reactions.

Table 7: Customer comments in response to question about satisfaction with heating appliances and controls, final surveys

Positive Comments ☺	Negative Comments ☹
Warmer, sufficient/ more/ more continuous heat (48)	Some problems reported regarding the heaters, e.g. noisy (fans), not warm enough, ran out of heat in the night, could be better insulated (23)
Good/ better control (22)	Unhappiness with recent software update which had caused problems in controlling and regulating the heaters (17 comments) and lack of communication about this (4)
Look better/ modern (10)	Problems with controls and/or app (12)
Cheaper and efficient (10)	High consumption and lack of electricity savings (12)
	Expensive (9)

Some customers with lower satisfaction ratings towards the end of the project had reported satisfaction earlier on. This phenomenon has been reported in post-occupancy evaluations for 'green buildings', as customers become used to new living conditions[38,39]. A drop in satisfaction levels in the final survey could also have been caused by the impact of a software update[40] that had occurred just beforehand:

"Until the software update of the central unit in December 2017, we were very satisfied, except for a few small aspects. After the update we are pretty annoyed".
German final survey

What contributed to a good customer experience? We conducted a thematic analysis of interview transcripts and identified five themes from interview transcripts and from the surveys. These are presented as the 'five Cs': **Comfort, Control, Cost, Care and Connectivity**.

37 Unless otherwise noted, quotations come from interviews.

38 Altomonte et al, (2017). Indoor environmental quality and occupant satisfaction in green-certified buildings. Building Research & Information, 1-20.

39 Leaman et al., (2010) Building evaluation: practice and principles, Building Research & Information, 38:5, 564-577

40 See section on 'Connectivity' for more context on this software update

41 The World Health Organisation(2007) has recommended 21°C for living rooms and 18°C for other occupied rooms.

Comfort

Comfort, in this report, refers to customers' sense of being at ease in their home or business: in particular, whether they are warm enough.

FINDING: Comfort improved. Customers had to invest some effort in learning how to achieve it, and there may also have been a financial cost.

The most obvious impact on customers from participating in this project was on their comfort, based on survey and interview responses. At its most basic, this meant getting and keeping warm. This required a certain level of understanding of how the appliances worked, which was sometimes challenging.

Achieving comfort in the broad sense – being at ease – meant that customers

- had learned to use their new heating equipment and controls to their satisfaction (not always straightforward);
- were not anxious about cost;
- did not have to spend much time or effort on making themselves comfortable.

Achieving warmth

In other words, comfort was connected to control, cost, care and connectivity but the Cs are separated out here to help with analysis and to give pointers to future priorities in customer engagement.

Across all countries, customers reported that their new storage heaters delivered a better heating service than what had gone before. In Latvia, all nine of the households surveyed reported being comfortable. In Ireland, 67 of 106 customers who completed two post-installation surveys said they felt warm (63%), with only eight reporting not being warm enough. 28 of the 46 German customers surveyed (61%) reported being warm shortly after the installation and this figure increased over time.

Observations, focus group reports and home visits revealed that, in Latvia, temperature set points ranged from 16-24°C, with the most common setting being 20°C. In Germany, temperature set points were 21-23°C. In Ireland, the average recorded set point temperature for 220 dwellings was 21°C but, during 44 household visits in October/November, it was observed that 26 customers had setpoints over 24°C, with eight showing the maximum setting of 26°C (Figure 8).[41] High temperatures imply high costs.

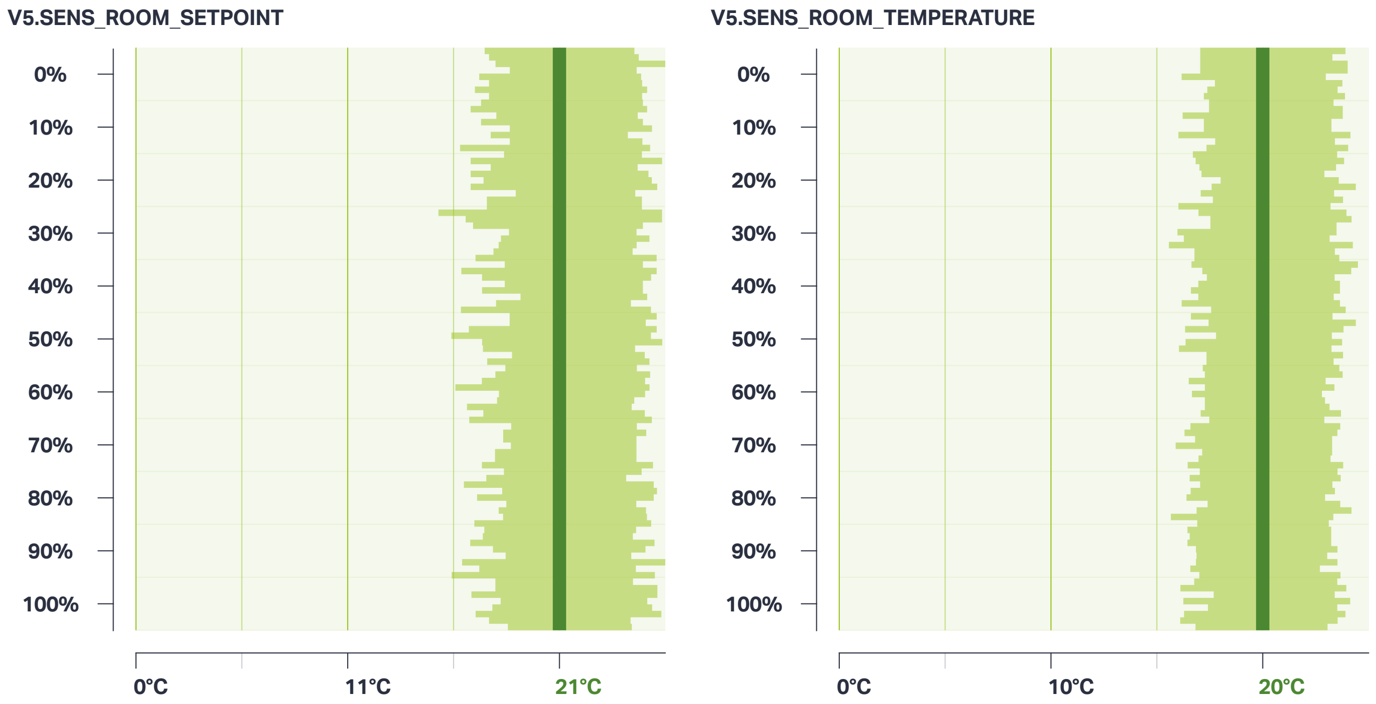
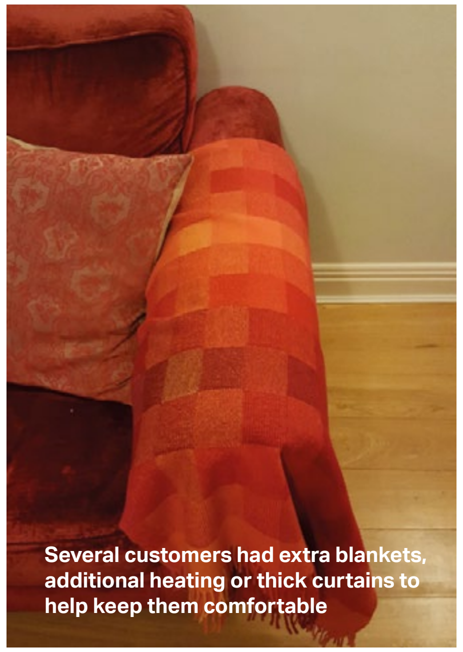


Figure 8: set points and room temperatures from 220 project homes in Ireland. The average set point temperature was 21°C (green line). The average room temperature was 20°C (Source: RealValue telemetry data).

Comfort for the whole household



Several customers had extra blankets, additional heating or thick curtains to help keep them comfortable

The German customers, as noted above, were mostly satisfied with the warmth offered by the new heaters but there were some comments indicating that quite high indoor temperatures were considered normal:

> "(The) operation (is) unsatisfactory unless the system is operated according to Glen Dimplex specifications (20°C!). This does not correspond to the usual feel-good temperature in Germany."
> **German final survey**

RealValue participants who had previously used traditional storage heaters were particularly satisfied with the comfort provided by the new heaters. An Irish customer commented:

> "I have always had [to wear] a dressing gown until they installed this [Quantum]. Now in the mornings I don't have to worry ... it makes a big, big difference. Our [patio door] glass is not really one of the best so if you feel the heating in the room it is really, really, good. Before, I had to have to put on the oven, just to get some heat in the room. Whereas with this, it's really, really, great, …. mine is set on 21/22[oC]. When [my young son] is at home it's 22 so that he doesn't have to be dressed up when he plays, but … it heats up straighta-way and the room keeps the heat. … I have to say that heater saves me a lot of money with … the tumble dryer, because I used to use it a lot during the night, so I could dry my clothes. Since the heater is installed I don't need to use it at all."

Another described how she had been through a process of learning how to achieve warmth, and how the installers and some written information had helped her:

> **I: How easy was it getting to know how to use this new one?**
>
> R: Fairly easy, I mean the guys [installers], he had a printout and it told you. And then the guys would show you when they were here. I mean I found it relatively easy… not too hard at all.
>
> **I: About how long do you think it took to settle into a pattern with the new heater?**
>
> R: Very quickly... it was too hot initially which was incredible for this building. Having spent all that time freezing, to suddenly be com-plaining, "I'm too hot!" That's how effective they are, we were too hot, about a week or so maybe two weeks. ...I used to have the [old] ones...on all day, home all day because [my husband] had a transplant and he needed a lot of heat. So, we had it at that we were here all day. But now I've put it back to just the morning and the evening which so far… is sufficient.

The combination of written information, face-to-face guidance from the installers and experimenta-tion had clearly been effective and the first two of these had helped give the customer confidence to experiment with different control settings.

Understanding the technology

Despite instruction, many customers did not understand how their heaters worked and were worried about the cost of comfort, which sometimes had perverse effects. For example, one Irish customer kept her temperature settings low, intending to save money, and then used the 'boost' function when she was cold – in fact a very expensive way to heat her home because she was then charging the heater during the day when the electricity price was relatively high.

There were some legacy issues for customers converting to the new heaters from old-style storage heaters. For example, they were cooler to the touch than the old ones because they were better insulated. As a consequence, some customers thought they were not working and had to be reassured:

> "A few customers will be saying that the heater's not working properly but again, you need to give them a heads-up[42] that it won't be as hot to touch externally."
> **Irish installer**

A heater is only part of the story of comfort in a home. During the home visits in Ireland and Latvia it became clear that some customers were keeping warm by using blankets and alternative sources of heating, sometimes instead of their storage heaters. Heavy curtains and warm clothing were also in evidence, not because of any failing on the part of the new heaters but as part of normal home-making routines.

Table 8: Customer views on new Quantum hot water cylinders

	Ireland (n=106)	Latvia (n=9)
Number who received a new hot water cylinder	49	2
Number 'satisfied or very satisfied' with it	35	2 (though ambivalent – see bottom row)
Number who rated it 'better or much better' than the previous system	34	
Number of households who thought the settings worked with their lifestyles	42	
How often do you change the control settings for your cylinder / heater (s)?		Never = 1 Monthly = 1
Number of households who had a criticism		2 Reason = 135L too small

Comfort and water heating

As indicated in the tables below, customers with Quantum hot water cylinders were broadly satisfied or very satisfied with them. In Latvia, although both participants with cylinders would have preferred larger versions, , they saw an improvement in service:

> "Before, I had centralized water supply, which I decided to refuse due to a sharp decrease in water temperature at night [and] rusty hot water from the tap due to the wear of the hot water pipes… What are my benefits from installing the boiler? Hot water at any time of day and night in any quantity; by means of the filters, the water is cleaned from impurities (my child is allergic to hard water)."
> **Final customer survey**

In Ireland, the visits provided evidence that tanks had not been sized correctly in some homes: for example, apartments with electric showers did not need a 135L tank, while those without electric showers might prefer a larger tank if more than one person took a shower during the day. Nevertheless, customers' views were strikingly positive (Table 8). In response to an open question about their satisfaction with their hot water cylinders, 25 Irish customers commented very favourably, while 9 reported some issues (Table 9).

Table 9: Customer comments in response to question about satisfaction with heating appliances and controls, final surveys

Positive Comments ☺	Negative Comments ☹
Hot water always available and stays hot in the tank (13)	Worried about using a lot of electricity (3)
Excellent/Great/Satisfied (10)	Sometimes not enough hot water (2)
No need to change the settings (2)	Hot water takes longer to come through the pipes (2)
Cheaper and efficient (10)	Wasn't working properly initially (2)
	Expensive (9)
	Don't use it (2)

42 Hint, expectation.

Control

Control was the ability to alter settings on the appliances (directly or remotely), to keep costs within acceptable limits, and to manage conditions in the home or building as a whole.

FINDING: Control improved. Customers felt fairly confident about control but they could not always demonstrate how to operate the heaters.

Customers mostly found control of their new appliances more satisfactory than with the old-style heaters but many were still often confused. For this reason, we explored some of the factors that seemed to influence control and present some of them here. The phone app is also considered in this section

Across the three countries, 42% (68/161) of customers surveyed thought the new Quantums gave them better control than their old heating systems and 76% reported some confidence in controlling them (Figure 9).

"Well, they're effective... and it is easier to control the temperature and see the temperature and all of that and 'on all day' or 'off all day', whatever. What is it? 'Comfort on' and 'comfort off' is the term they use. It's much easier to use."
Irish customer

"The control of the radiators is quite easily performed. At the beginning, I had to practice a little on my own, using the instructions; now, everything seems clear and simple. Maybe I will forget something till the next heating season; then I will have to use the instructions to refresh my memory."
Latvian customer

Customers' perceptions of being in control varied considerably. For example, in Ireland one customer used an in-home electricity display unit (right) to tell her exactly how much using the 'boost' function on her heater was costing her, and had an excellent sense of control; another took the extreme – and expensive – step of installing an oil fired boiler after an attempt to change the controls had misfired and resulted in an unacceptably high bill.

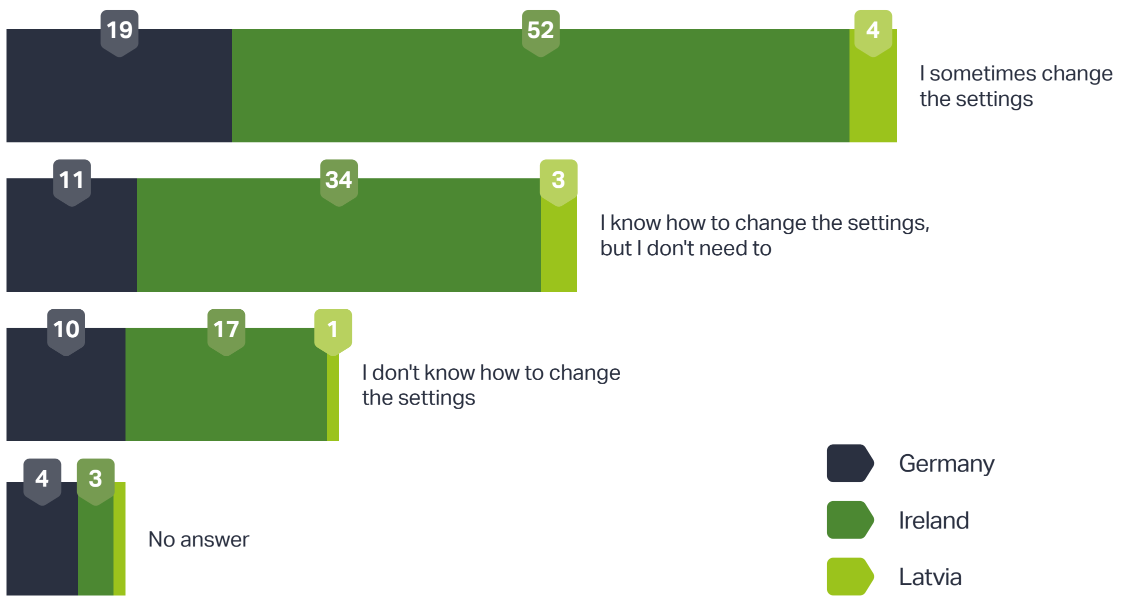
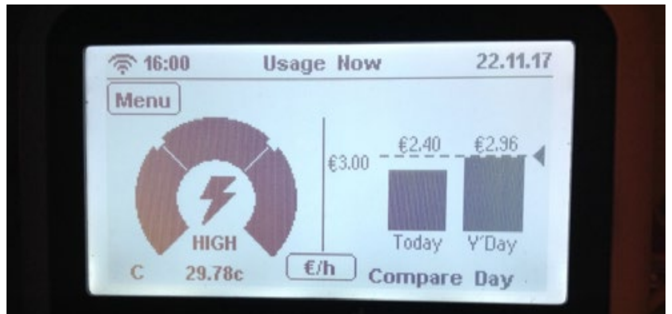


Figure 9: Comparison of confidence in controls of new heaters, by country (n= 161)



In-home display showing real-time and historical information on electricity costs

Some customers were not clear about how the smartness of the settings and how their interaction with the technology affected the charging of the heater. It was not uncommon for the researchers to have this type of conversation during the Irish interviews:

> R: I'm kind of experimenting at the moment. I felt 18 degrees was probably a good balance, but if the weather is not too cold, then I'll keep it at 16 and then I'm kind of, do I leave it at 16, even when I'm going out or do I wait and turn it up when I come in if it's cooler? I don't really know which is more economical but I'm sure as I go along I will.
>
> **I: The way the heaters work, basically what happens is that you set it to a temperature and some times that you want it to come on, and it charges overnight… it takes a couple of days to get it to that temperature because what it's doing is it's working out, okay, in this …room, it's working out whether it gets to 18 degrees. When it gets to 18 degrees in this room, how long it needs to charge up.**
>
> R: I understand.
>
> **I: If you're changing the temperature a lot, then potentially that can disrupt how it charges up because it just won't understand.**
>
> R: That's what I wasn't actually sure of.

Of those who reported feeling confident controlling their Quantums, previous experience of storage heaters correlated with being more 'adventurous' with the controls. With one exception, Irish customers who were new to storage heaters reported changing only the 'temperature' and 'timing' settings, whereas customers who had used storage heaters before reported using the 'boost' and 'advance' functions as well. There was a substantial minority of customers who rarely if ever seemed to change their settings, because they had a 'good enough' arrangement and/or because they were afraid of disrupting their heating.

The home visits in Ireland revealed that customers' apparent confidence could be misplaced. When asked to demonstrate the controls, it became clear that many were not sure how to use them:

> **I: "Could you maybe please show us the timer settings that you have just on a general day?"**
>
> R: "Let's see now. [Working the menu on the timer settings] That's 'Home All Day', I don't want that one. ... Now, how do I get back into them settings again? No, that's just the date, is it?"

In Ireland, age was a factor in how confident customers felt about changing their heater settings. In the final survey, significantly more customers over 55 reported that they "did not know how to change the settings". An analysis of all RealValue participants with previous experience of storage heaters showed a significant relationship between age and lack of confidence: of 18 who said they were 'not confident' with controls, four were under 55 and 14 were 55 or over. Interestingly, confidence with the controls could have a downside for the project: in Germany, installers complained that they sometimes had to fix things for the younger customers who (over-) experimented with their controls.

There was a core of customers who never changed the settings after installation and were fearful of doing so.

> **I: "Have you ever tried to adjust anything on them?"**
>
> R: "No."
>
> **I: "If you wanted to adjust something, what would you do – if you decided it was too hot or too cold…?"**
>
> R: "Well, I'd just leave it."
>
> **I: "You'd just put on a jumper or open a window?"**
>
> R: "Yeah." (Irish customer)

A feeling of lack of control was correlated with a perceived increase in bills. In Ireland, of the 16 customers who did not know how to change the settings of their heaters, 12 (75%) thought their bills had increased. In contrast, of the 86 who reported some control of their settings, only 22 (26%) thought their bills had increased – a statistically significant difference. While we are talking about perceptions rather than actual costs here, this shows how customers who are more confident about controlling their heating are more likely to think that their bills are stable or reducing.

A number of customers did not understand how storage heaters work in terms of charging at one time and releasing heat at another, and charging only as much as necessary to provide a required temperature for a required period. The 'smartness' of the new appliances could make it more difficult to understand how the technology worked:

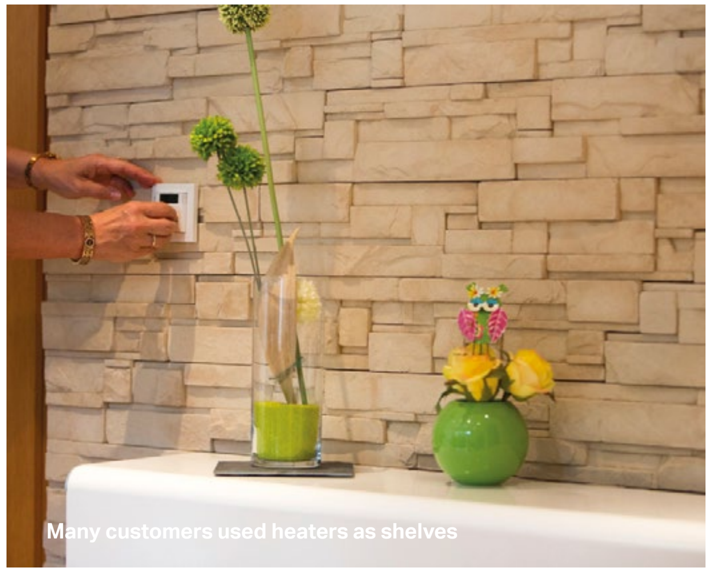
> R: "The only problem I find is (that) it's coming on for nine hours. I think that's a long time to be taking (the) heat in.… I would love to be able to knock [switch] it off at the wall but I don't want to do that…. because it would probably upset everything…."
>
> **I: "The aim though is that it will only take in as much heat as it needs for what you've said you want during the day…. It'll stop when it's got enough charge, yeah?"**
>
> R: "I would rather it be set (for) say seven hours and that's it, you know?" (Irish customer)

Misunderstandings such as these led to some customers taking control by switching their appliances off at the wall, even when aware that they were not supposed to do so:

> "The first thing I found when we went on holiday is that … you have to set the temperature while you're on holiday which makes you think, if that temperature is actually going to be consuming energy, whatever temperature you choose.… I hated it because I wasn't sure if we could actually plug the switch off from the wall, right? … We shouldn't really do it, but I did it anyway."
> **(Irish customer)**

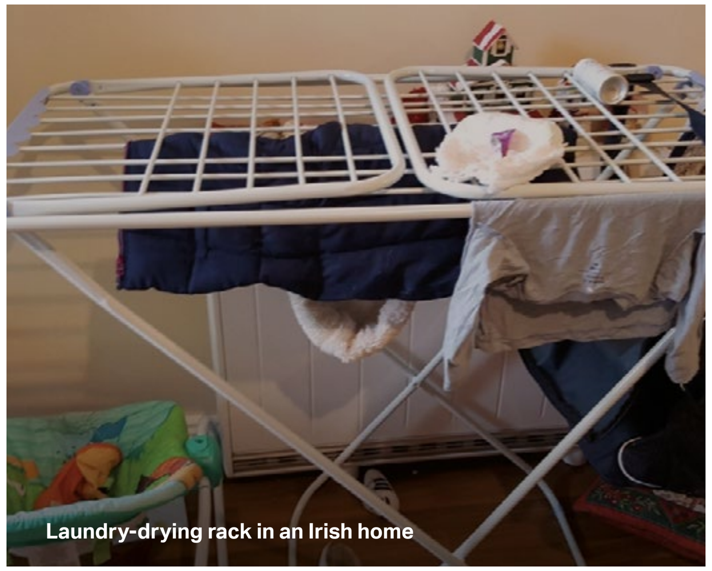
We also observed heaters being switched off as part of a general habit of switching off appliances when not immediately needed. As will be seen later, having the heaters switched off, or not communicating with the cloud because of connectivity issues, meant that the appliances were 'invisible' to the project and not available for DSM.

Household routines are a powerful influence on technology adoption and should not be under estimated. During home visits, we saw furniture so close to the heaters that it blocked the circulation of warm air, heaters covered with grilles to conceal them and with laundry (and cats), and heaters used as shelves - even as a whiteboard in one home! In some cases, this affected their operation – an inadvertent type of control. For example, placing furniture very close to the heaters meant that air in the restricted area warmed up quickly, causing the heater sensors to record the set point temperature. This made the heater output switch off before the room as a whole was warm enough and also (via the charging algorithm) led it to charge insufficiently the following night.



Many customers used heaters as shelves

Heaters blocked by furniture or covers were quite common



Laundry-drying rack in an Irish home

Controlling Quantum hot water cylinders

Customers were broadly satisfied with control although there was some evidence of similar issues to those seen with the heaters, such as turning cylinders off at the wall to save energy and not entirely understanding how they worked. Some Irish customers had initial problems in getting enough hot water when they needed it. An example relates to confusion about whether and how to heat the whole tank rather than just the top third, and when to use the 'boost' button:

> R1: [When we want hot water] We don't know how to kind of heat the tank full ….
>
> **I: You think it's not warming up the whole tank…?**
>
> R1: That's the perception we have because when you push the 'boost' button, then we have two long showers, at the end of the second one, it's kind of running out and that led us to think that the little thing on the top is the one that is containing a smaller portion of water and that's what you boost, that's what we think.
>
> **I: There's something wrong then, because pressing the 'boost' button is the worst way to do it because it's going to be expensive.**
>
> R2: One of the switches is turned off, one of the switches on the wall.
>
> **I: That'll be the problem; one of the switches is turned off.**
>
> R 2: The bottom one is switched off.
>
> **I: Okay, that's why you're only getting a third of the tank heating up.**
>
> R2: I switched that on, on the wall, the light hasn't come on, on the switch.
>
> **I: Yes… if you only have the one switch switched on, it only heats the top one-third and that probably then mixes eventually with the other colder water that's in the tank and so that's why the temperature would be going down.… So that should be much more efficient now and it'll be heating at night when it's cheap, so you don't have to use the expensive 'boost' button … If that doesn't improve things, you should definitely call customer services …**
>
> R 2: The switch we probably overlooked."

Once they had gained some confidence with the controls, reactions from the Irish customers were broadly positive:

> "I think it's easier to use than the old timer things you had. … it always has hot water, which is a great thing, and then when you run out you can always stick the boost on, and it boosts very quickly, so there's no part of the day when you're waiting on the heater to turn on so you have hot water. It's just constant hot water."

Gaining confidence takes time. MVV found that it took at least one year with stable system settings for their customers to get familiar with their heating systems. A trial with one year of installation, one year of testing the basic system and one year of flexible charging is therefore not a long time in terms of evaluating customer impact.

The app

Two apps were developed for control of the heaters and water cylinders: one for Ireland and Latvia, and one for Germany.

In Germany the app had phone and computer interfaces, and was the main method for controlling heaters. It could be used within the home but not (unlike the Irish/Latvian app) remotely. 83% of customers who responded to the final survey were using it (38/46) and only 17% had found it complicated (8/46). Customers who used the app reported that they liked being able to set the time and day for heater to come on, though they would have preferred it to be faster to load and for the user interface to be more intuitive. Some would also have liked to see weekly billing and be able to delete settings from the app. However, it was well received overall:

> "What I like with the app …you can actually see how the heater gets charged, how much is left in the heater, what the heater still needs. That is actually interesting. Before, I had the heating set to three[43] and let it charge. Now I see that it is only 68% charged, it doesn't need much more until it is full."
> **German customer focus group**
>
> "I am excited about the opportunities which the app offers, because you can set it in a very detailed way, so that it is optimal for the rooms, that you don't store too much, but neither too little and once you have set it correctly and use the automatic mode, then you can basically forget that you have a heater altogether…. At 15 degrees outside it heats up, therefore the thoughts whether or not to store in autumn can be omitted. This automatic mode absolutely convinces me."
> **German customer focus group**

43 The German settings were from 1 to 5, rather than oC.

"Previously we switched the fan in a specific room on and off when we needed it. Now we can define this with a profile. And we only need to take manual action to divert from the profile."
German customer focus group

An early version of the app was tested in Irish and German homes early in the project; Latvian and most Irish customers received their apps at a later stage. Comments on the German app were mixed, with some customers liking it and others having reservations about style and function. Several participants in a Mannheim focus group were unclear about what value it added and the older customers, in particular, wanted guidance on how to use it. Several used it mainly as a monitoring device.

Most Latvian and some Irish customers had stated their enthusiasm at the prospect of an app and 13 out of the 44 Irish householders interviewed said they would like to use one.

"They told me that there was an app and that there was that degree of control. The things I have are quite old and I thought that this would be a good opportunity."
Irish customer

However, uptake in Ireland was relatively low – 50 out of 513 residential customers at peak and 43 by mid-April 2018. This may be partly due to the fact that, by that time, customers were already accustomed to the standalone /'onboard' heater controls. Use of the app meant that standalone controls could not be used at the same time. Of the 10 householders who reported using it the app in the final Irish survey, three had found it complicated or very complicated; only one person reported it to be easy to use. Low uptake was due to a variety of reasons, including lack on Internet access, customers who refused the gateway or broadband, and software issues (Table10).

Table 10: Reasons customers did not use the app, across all three countries (final survey)

Reason for not using the mobile phone app	Responses (all countries)
Too complicated (don't know how to install it/ how to use it)	30
Don't need it (use manual control /home all day)	28
Availability (Don't know it was available/Don't know how to get it)	14
Connectivity (No smartphone/not compatible with smartphone/no Internet)	10
App not available in Latvia at the time of survey (was available soon afterwards)	9
Other	7

In summary, the idea of the app was popular, particularly among younger customers, but developing a workable app proved more challenging than expected. Questions of where an app can be used (in-house and/or remotely), how complex it is and whether there is easy switching between app and onboard controls arose from the customer experiences.

44 e.g. a study showing that Quantum heaters were up to 22% more efficient than traditional heaters

45 Moore (2012) Definitions of fuel poverty: implications for policy. Energy Policy 49, 19-26

46 NB: these questions were asked using slightly different scales in the different countries. Note also that not all customers responded to this question.

Cost

Cost refers to electricity bills. Assessing cost in the project was not straightforward, not least because we had to rely largely on perceptions of cost rather than on billing data, which was surprisingly hard to obtain.

FINDING: Saving money was the main reason customers joined the RealValue project, but they valued cost and comfort more or less equally.

In all three countries, the new heaters and cylinders as well as the retrofit gateways were fully or partly subsidised. Irish participants had €10 automatically deducted from their bill each month and were given evidence that their costs could reduce[44]. Customer hopes or expectations that their electricity costs would reduce were a considerable motivation for them to take part, as indicated in the sign-up survey responses.

In Germany, in some cases lower bills were observed by the supplier when people operated the heaters "right", i.e. using the fan and setting suitable temperature profiles. However, higher bills were observed in some cases, mainly due to software problems that led to overcharging. The potential advantages of new storage heaters with respect to lower bills could not become visible for many of the customers, because of issues with software. The influence of flexible charging on the bill is still under evaluation.

Figure 10 shows customer responses (prior to the project) to a survey question about their concern over the affordability of electricity.

Responses are likely to be influenced by three factors: unit energy costs, household income and the energy efficiency of the property.[45]

Participants were asked about electricity costs in the initial and final surveys and about whether and how their bills had changed over the course of the project in the final surve. Most respondents thought their bills had increased or stayed the same, as seen in Figure 11. However, perceptions could be muddled. For example, we have data on perceived annual electricity costs and perceptions of how bills had changed during the project from 88 comparable German and Irish survey respondents: all had storage heaters as their main form of heating and had had storage heating prior to RealValue.

44% showed an inconsistency between their perception of changes in their bills and their reported electricity costs before and during the project – for example, some customers reported that bills had gone up during the project but also reported that they were in the same cost band as they had reported in the initial survey, or lower. For others (fewer), it was the other way round.

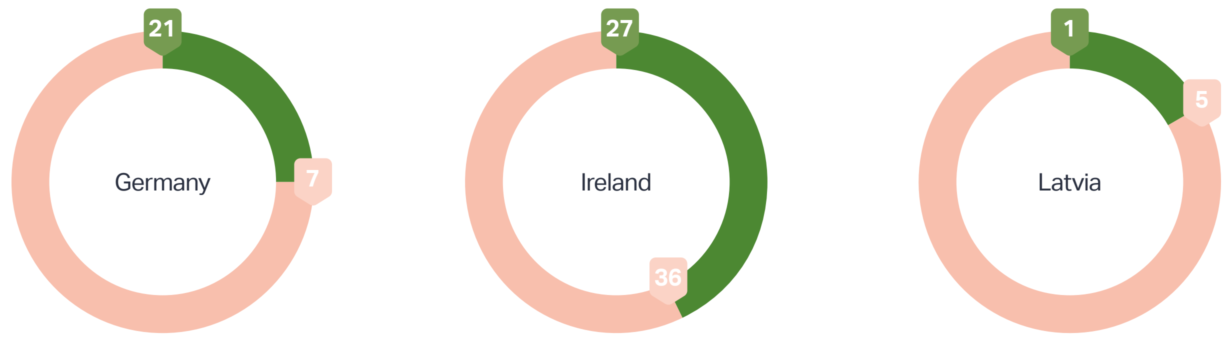


Figure 10: Customer perceptions of affordability of electricity costs at project beginning, by country (numbers of survey respondents) [46]

Comfortable with electricity bills

Concerend about affordability of electricity bills

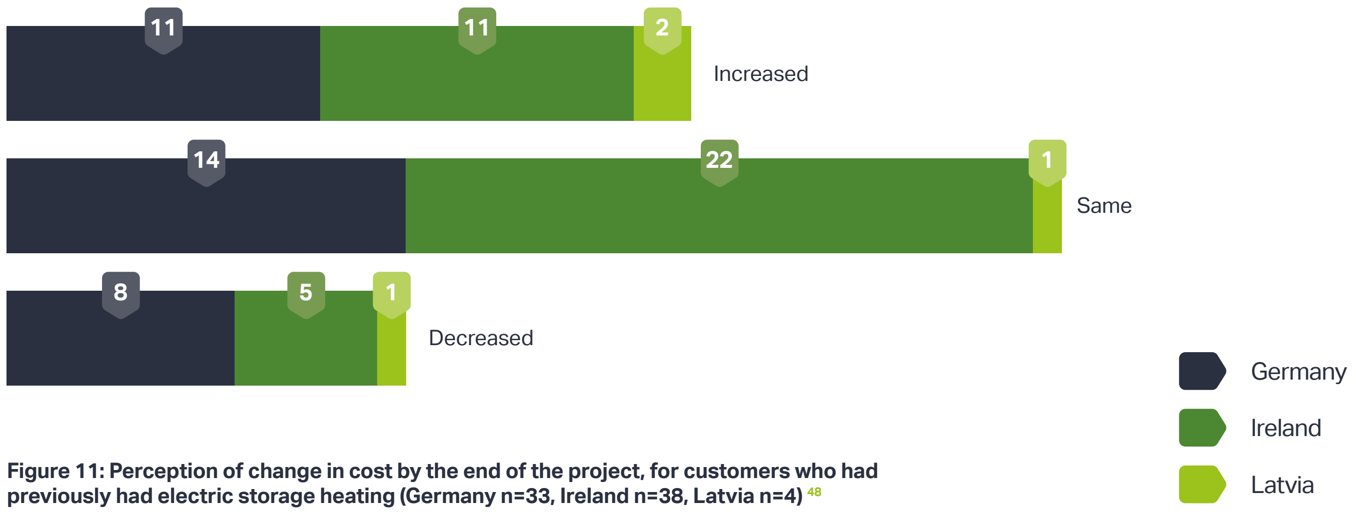
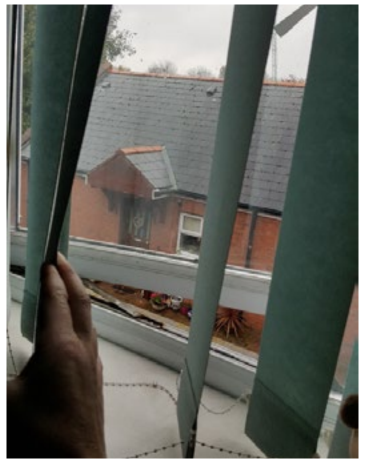


Figure 11: Perception of change in cost by the end of the project, for customers who had previously had electric storage heating (Germany n=33, Ireland n=38, Latvia n=4) [48]



Even though they were concerned about cost, some customers opened windows to control temperature or ventilate room.

In the absence of usable billing data over the project period[47], we cannot say with any confidence what happened to most RealValue customer bills in the course of the project; only that perceptions varied and that they tended towards a belief that bills had stayed the same or increased.

There were anxieties about affordability, predictability and potential loss of control; also some misunderstanding about how the charging worked:

> "Some people find that they… prefer (a prepayment plan) because then they know what they're paying as they're going along. They don't get a fright when the bill comes."
> **Irish customer**

> "I turned off the heating. Always [before] when I haven't used the heating, I've turned it off…. I thought I had a hidden mousetrap somewhere that uses electricity. (There was an) increase from €300 to €500, I had to swallow that."
> **German customer focus group**

> "If I had gas heating I wouldn't have it on for nine hours [the period during which charging may take place for a Quantum in traditional night/day mode]. I don't think anyone would have it on for nine hours. If you're too warm, you know."
> **Irish customer**

Balancing cost against other factors

Despite concerns about cost, survey respondents gave cost and comfort roughly equal importance when asked at the start of the project which mattered most to them, as seen in Figure 12.

Household routines were not just carried out with cost in mind.

For example, one customer opened windows because there was mould in the apartment and he was concerned about his child's health. An MVV customer refused to use the fan in her heater in order to avoid stirring up dust; this meant higher charging levels and higher bills for the same level of comfort.

Convenience, too, could be a factor:

> "I don't want to be going to the controls all the time, so to get something that's even keel and kind of economical as well, but I do trust that they're economical, I hope! I haven't had a bill yet."
> **Irish customer**

Although cost was important to the RealValue customers, cost was balanced against other considerations such as comfort, convenience and health.

In addition, perceptions about cost were sometimes muddled. This is not surprising, as attributing cost to single changes can be complicated: electricity price increases, shifts in the weather, changes to the fabric of the home and to the number of people in it or the amount of time they spend there might all influence expenditure on electricity as much as a new heating or hot water system, or even more so. In addition, feedback to customers on cost is often far from ideal, especially if bills are based on estimates.[49]

Customers have to make a conscious effort to record their electricity consumption and bills. Some RealValue participants did, but they were in a minority.

47 See note 31 on the challenge of achieving this.

48 In part, concern with cost reflected customers' previous heating systems, particularly where these had been old-style electric storage heaters. Most customers in Ireland and Germany fell into this category. There were also some customers who switched fuel type during the project (e.g. from oil, coal, gas, wood, etc.), particularly in Latvia where the new heaters were used in addition to other modes, mostly electric resistance heating and gas central heating. As electricity costs for these customers would be very likely to increase and the comparison between their old and new systems on cost alone would be invalid, they were excluded from the analysis in Figure x

49 Fischer (2008) Feedback on household electricity consumption: a tool for saving energy? Energy Efficiency 1 (1), 79-104

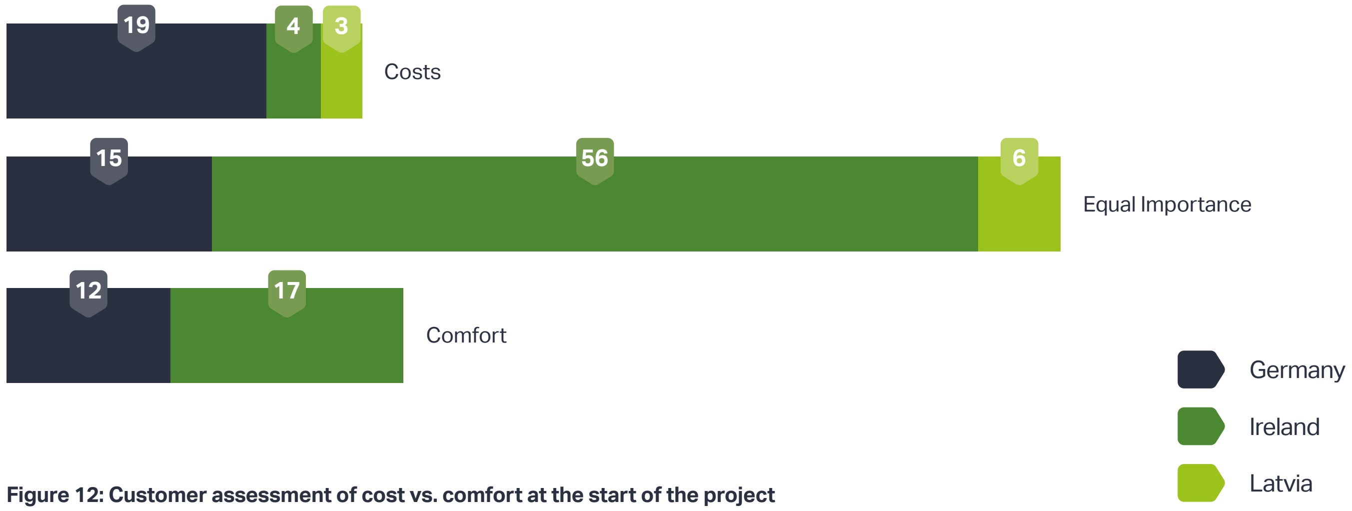


Figure 12: Customer assessment of cost vs. comfort at the start of the project

Care

Care refers to people-to-people assistance for customers.

FINDING: Installers and 'local champions' emerged as key sources of care.

There were three distinct phases of people-to-people (project partner-to-participant) interaction during the project:

- recruitment and sign up;
- assessment and instruction at installation;
- aftercare support.

Recruitment is described above, in the introductory section of the Findings. Here, we focus on installation and aftercare, both of which influenced customer satisfaction.

Installation

The main sources of care during the project were the installers and project delivery coordinators – 'middle actors', some of whose reflections on the project are presented in the Middle Actors section of the Findings. In Latvia, customer care was done by the research team. In Ireland and Germany, customers were assisted by a combination of installers, electricity suppliers and others. Customers first met the installers when their properties were being assessed for the project and then during the installation. Whilst at the beginning of the project there were a few complaints about the installations in Ireland, an overwhelming majority of customers in all countries were 'satisfied' or 'very satisfied' (Figure 13).

Towards the end of the project, personal advice from the installers was mentioned favourably by most survey respondents.

> "The installers again were brilliant and explained the operations."
> **Irish customer, final survey**

Customers were shown how to use the equipment and were left with information at the time of the installation but needed time and guidance to learn how to operate it effectively. A distinct advantage of the installer's role was that they could demonstrate how to use the equipment and see if the customer had any difficulty with it (see 'Middle Actors' section below for more on this relationship). According to the installer in Latvia, customers with additional heating sources felt freer to experiment than those without, as they knew they would still be warm even if they made a mistake with the storage heater controls.

The opportunity to talk with installers was very important. In Germany, 36 of 46 respondents (78%) stated that they had asked questions of the installer and three quarters of them said they had received a satisfactory answer. In Latvia, six of the nine customers asked questions. In Ireland, customers who were 'very satisfied' with their installation, according to the post installation survey, were those who had also asked many questions of the installer, particularly when installers were in an area for a few days and customers could refer back to them several times over this period. Being able to ask repeated questions at different times was valuable:

> "(The) first few days (of having the appliances) it was difficult…. I think it was two weeks I was asking for help. I was asking to show this, to show this. But now it's okay. For me it takes maybe a week or two"
> **Irish customer interviews**

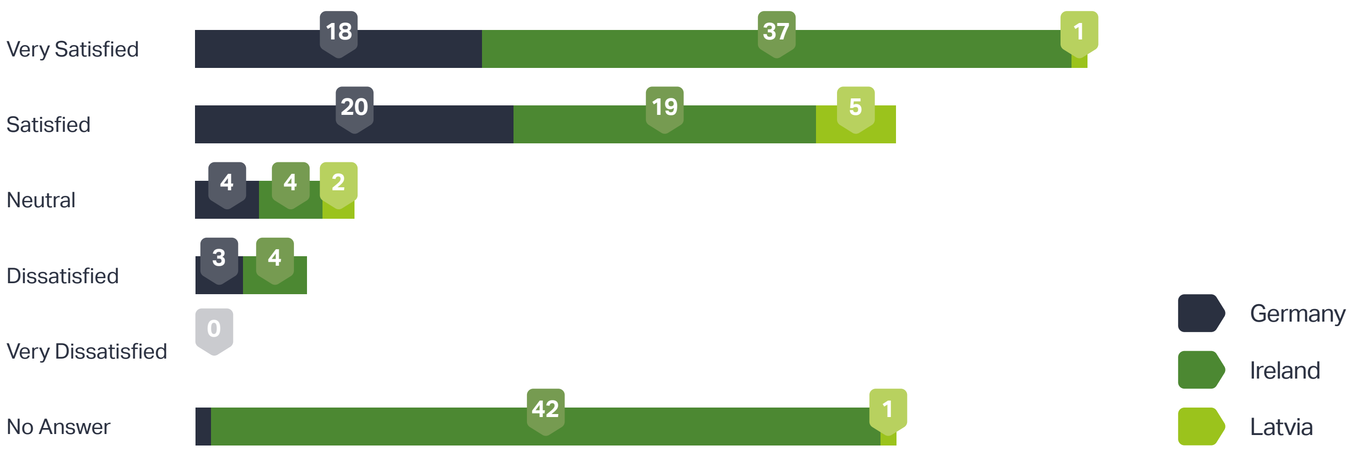


Figure 13: Customer satisfaction with installation process

Written and video information

Customers in all countries were left with a RealValue pack, which contained information on how to operate the appliances and access help. The Irish manual, for example, included FAQs, quick-start guides and 'how to…' guides. The packs were adapted over the course of the project to be more user friendly (there was some evidence of learning between countries here). Of those who used a manual (Table 9), the majority were happy and found it clear and instructive.

However, a significant number found it difficult to understand. Perhaps for this reason, only nine customers in Ireland and five in Germany mentioned written information as the 'most helpful' source of help in the final survey. The manual's most important function seems to have been as a backup to verbal advice and a resource to turn to if heating requirements were to change:

"The short demonstration given by the installer. Even if that was only superficial, it certainly helped to become familiar with the heating system. The manual was also very helpful. After I had read it I felt more confident."(German customer final survey)

> **I: "So, you've got it on "Out All Day" and…**
>
> R: Have I? I don't know anything about that. He (the installer) probably asked me certain things … I don't even know what "Out All Day" means… supposing we had (to change the settings) a really cold Christmas, well then, I'd have to go to the manual and try and understand what all this is. All this I'm sure is in the manual, is it?" (Irish customer)

Customer responses to written information are summarised in Table 11.

Both MVV and SSE produced YouTube videos in the course of the project to assist with customer understanding.

Table 11: Customer feedback on the written material left by the project

	Germany	Ireland	Latvia
Very good and instructive/ Info all there / clear / easy to use	7	13	1
Fine	6	7	0
Too technical/difficult to understand / still not sure of some controls	0	0	3
Instructions for app not sufficient	2	0	NA
Used it and caused an error in control	0	1	0
Would have preferred a second demo	0	2	0

50 *Report to consortium meeting, April 2018*

51 *See Goodhew et al., (2017) Mental models: exploring how people think about heat flows in the home. Energy Research &Social Science 31, 145-157*

Written and video information

Time spent explaining the operation of the equipment to customers was likely to pay off in more satisfied customers, reducing the number of calls to the helpline. For example, Glen Dimplex technicians visited Irish participants during the winter of 2016 to check whether they were satisfied with settings, and to show how to use the equipment again if necessary; the following autumn, one Irish housing association held a community event with SSE and GD staff to address customer queries, and there were further visits to some customers.

Using the supplier's customer helpline was less favoured than face-to-face contact, although sometimes it proved effective, especially for relatively straightforward issues:

> "Brief and clear information which was very helpful."
> **German customer survey**

> "Only had 1 issue with heater not working for 3 days & was advised [by supplier helpline] to use boost option to resolve problem".
> **Irish customer survey**

We found evidence that some customers found it difficult to articulate their problem, especially over the phone, or were reluctant to contact their supplier if in arrears with their bills. It might also be hard for agents on a helpline to understand what the customer meant, particularly if they lacked the necessary technical knowledge, which sometimes seems to have been the case:

> "I had to help myself. Several bits of advice that were given by telephone were certainly not correct!!"
> **German customer**

As a result, calls to the helpline could be escalated, which could be frustrating for customers.

However, strenuous efforts were made to streamline the customer experience. One method used in Ireland was to identify 'touch points' such as issues with billing, broadband, plumbing, gateway or cylinders, and set out a clear process for referrals to specialist help. Suppliers learned that it would be best to offer customers just one point of contact, to avoid customers getting confused.

In Germany, where over 200 substantive complaints were recorded over two years of the project (in relation to over- and under- heating, connectivity, the app and invalid outdoor temperature calculations), MVV opened their call centre for longer hours in the evening. This allowed customers to call if they came home from work, found a problem with their heaters and needed immediate assistance. They also developed a daily preventative four-stage process to make sure that customers' appliances were working properly:

- Check the 'energy cockpit' (website) remotely. If heaters were charging, no further action was needed.
- If there was no charge and no data then check the 'state of charge' room temperature.
- If that was not satisfactory, they called the customer and asked them to reboot the system
- If this did not work then BEEGY charged the appliance for them.
- If the connection to the gateway was lost and there was no charge, an installer would attend the property to install emergency heating

MVV produced regular newsletters with advice and help for customers, held two customer focus group sessions and produced YouTube videos about the app so that customers could review the instructions as often as necessary in their own time. MVV also set up a 'consultation hour' where participants could meet project management on request; one-fifth of participants took up this offer. MVV noted that personal conversations were a more effective way of addressing questions and complaints than more remoted interactions.[50]

MVV found that their colleagues on the customer hotline needed more information and digital tools to respond to customer problems than had been expected. Ideally, the resources available to specialist second or third-level support should also be accessible to the hotline staff.

The project itself could be a source of aftercare, as when project partners called to check on how well the appliances were performing for customers:

> **Survey question:** *During the project, different methods were used to stay in contact with you. Please name the methods you can remember*

> R: In person from Oxford and Glen [Dimplex].

Care Champions

Once installation was complete, valuable face-to-face help could come from 'care champions': people who were relatively well informed, trusted and willing to help others, either as friends and neighbours or in a professional capacity. In Latvia, the small group of customers had their own RTU engineer 'on call'; in both Germany and Ireland, partners noted and appreciated the contribution that could be offered informally 'on the ground'. For example, a manager in an Irish social housing complex explained how she helped one vulnerable customer who did not understand her system over a period of time until they got it working well:

> "We had one person last year who was complaining about her bill. She had her heater set at 14 or 15 but she was putting on the boost every evening and I said, 'That's why your bill is high'. She wouldn't let me put up the temperature, but then she got the higher bill, and I said, 'Look, that is why'… But it was because she was putting on the boost herself. .. maybe for four hours at night [i.e., in the evening]. Her bills were... You know? They were serious now".

She had developed her ability to give effective advice through talking with the project staff overseeing installations:

> "They were instructing me from the day they came on site, I was being told, "This is how it works". And then I suppose when different problems would come up, you would [them]. And they'd be saying… if it's this, if it's that, you could do this, you could do that. Do you know? That's the kind of a way I would have learned it, really."

Two Irish customers comment here on their 'local expert', a fellow resident:

> R: "It (the heater) did take a bit of getting used to and I have to admit that the lad next door ('John')... once he showed me it was fairly... He said if you get cold, you can just go on to boost and it gives you a good blow out of air. I don't need the place too warm."

> **I: And this chap who showed you. We've heard about him from a lot of customers. So he's like the local expert?**

> R: John, yeah. He be sharp enough now on that... on the computers."

> R: " (I) found it a bit hard in the beginning, to understand it and one of the men, 'John' … came up and he done it all for us. Put the heating on here for me now. And in the bedroom, he fixed it that it comes on at four hours in the evening and then four hours in the daytime."

Useful as professional advice can be, sometimes professionals and laypeople use different concepts and vocabularies when trying to communicate about heating.[51] Local champions had the advantage of being on the spot, able to see heater settings and communicate effectively with people whose way of life they understood. Some of those we observed during the trial also had technical expertise which they put at the service of relatives, friends and vulnerable people in the neighbourhood.

Other forms of care

Apart from these sources of care relating to installation, instruction and aftercare:

- RealValue partners in all three countries reached out via community events that gave an opportunity for people not only to listen to advice but to discuss it with experts
  and with their neighbours: several customers mentioned these as being useful and project staff also gained feedback from them.
- Some use was made of the remote diagnostic capability of the new appliances, which allowed engineers to avoid having to travel to the customer.
- In Ireland, pens and USBs left with customers to remind them of where they could get assistance were well-received.

When asked about future contact methods (Figure 14), customers preferred phone calls (43%), followed by email (27%) and personal visits (9%). Only 6% of customers reported 'post' [mail] as their preferred method. Answers to this question may have reflected the previous contact methods used by partners. Irish and Latvian customers who had been contacted frequently by phone said they would prefer this for the future, whereas German customers, who had been used to email, preferred this method.

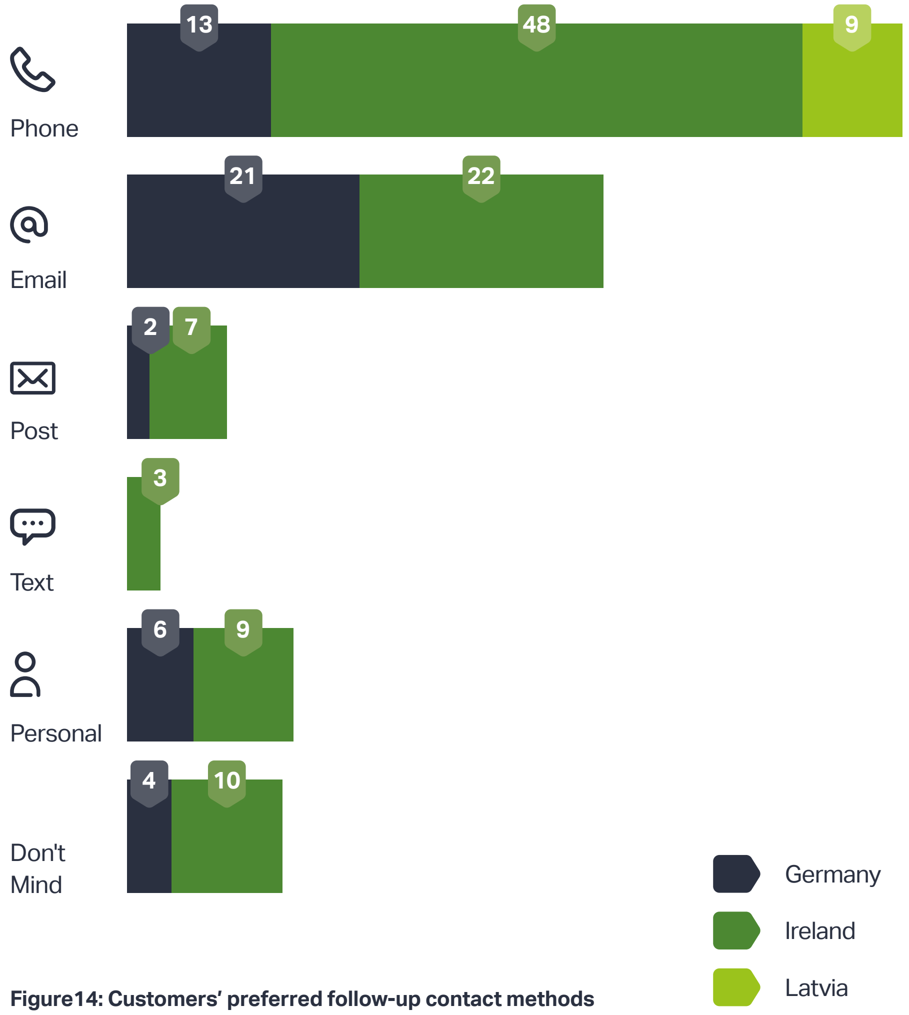


Figure14: Customers' preferred follow-up contact methods

Connectivity

Reliable connectivity between technologies was vital for the feasibility of DSM using SETS. We concentrate here on connectivity and readiness for DSM from the customer's perspective.

Finding: connectivity between appliances and the system was largely invisible to the customers, who did not always realise the need to keep their equipment switched on at all times in order to allow for 24-hour DSM. Software upgrades at one point disrupted comfort. However, customers were generally positive about the concept of DSM at the end of the project, as long as it delivered cost savings and did not affect reliability and comfort.

RealValue was a project to test the potential of using SETS for DSM, something that would not be possible if customers rejected it. This section focuses first on connectivity between the different technologies, including the app, and then the customer's understanding and acceptance of the concept of DSM.

Technology

Connectivity, from a customer standpoint, was neither highly complex nor entirely straightforward. For example, Figure 2 above illustrates the subsystem linking customers with the aggregator and to the electricity system as a whole. Customer registration, data reading and writing through this subsystem were each five-stage technical processes (invisible to the customer). The large diagram on pages XX indicates the number of actors, devices and operations involved. Again, much of this would be invisible to customers.

To project partners, though, it was clearer that deploying different types of technology with different interfaces into a 'real world' context, in collaboration with many different stakeholders, was complex.

> Given IOT [Internet of Things] is in the news… clean technology, all these buzzwords are always being used, but yet, when it comes to the practicalities of doing a project with [hundreds of] houses, it was incredibly difficult… It was simply difficult in all those other technology categories, I would say."
> **Project delivery coordinator**

Hence the value of a demonstration project in which difficulties with communications and software updates could be identified, addressed and learned from. Timing was an issue and the need to keep the project moving had to be balanced against the need to develop connectivity at a pace that allowed for learning and minimised any inconvenience to customers.

In the Irish trials, the appliances were not fully funded by the project and the external support, while of immense help, meant that partners had to comply with another set of criteria and schedules. In the early stages of the project, this meant rapid installations of novel combinations of technology in homes that did not necessarily have Internet connectivity. The resulting complications involved partners in spending a good deal of time and resource troubleshooting, which had an impact on further recruitment, customer satisfaction during the first phase, and learning (DSM was delayed and some data was unreliable until well into the third and final heating season).

In both Ireland and Germany, a software update for the Quantum heaters in the final heating season caused problems for customers who were fully-connected for DSM at the time. Heating is a fundamental energy service and people expect it to work, so the impact of a failure, even if only for a short time, can be substantial. The final surveys contained 90 positive comments about the trials and 77 negatives. Of these, 21 related to the software upgrades.

> "In the beginning I was very enthusiastic about the heaters. This has however been increasingly diminished, when weaknesses in the control became apparent due to the control software."
> **German final survey**

An Irish customer had to stop using the app temporarily during a period of cold weather and go back to 'onboard'/standalone controls following the software upgrade, in order for her heaters to charge:

> "(I) experienced the worst failure with the bad weather and had to remove the appliance [app] as this was the only way to get control of the heating…. terrible and frustrating and it was the only way to get control of the heating again manually."
> **Irish final survey**

Customers were compensated for loss of connectivity, and these problems were sorted out, but experiences such as this demonstrate how connectivity that had been working well initially was vulnerable to upgrade errors. Dealing with such issues required coordinated effort from project partners.

Original marketing leaflet in Ireland and Latvia

Connectivity also required customers to have a basic understanding of how their communications technology worked and what to do with it – for example, that DSM would not be possible unless they left their appliances and gateways switched on, able to transmit and receive data. This was not always the case.

At the start of the project, attempts were made to educate customers in Ireland and Latvia about DSM using a recruitment leaflet that used yoga imagery as a metaphor for balance and flexibility on the grid, and comfort and calm in the home. After the first phase of recruitment, however, market research consultants concluded that it did not help customers understand the central offer of the project. The leaflet was therefore changed to reflect the fact that 'cost', 'comfort' and 'control' would be enhanced with the installation of these heaters. Only a brief mention was made of DSM and interested customers were referred to a web link. Most were unfamiliar with the concept when asked about it during in-home interviews.

In Latvia, technical challenges included having to establish connectivity when organisational firewalls stood in the way, changing protocols, power failures and blocked DNO servers. Even after a trip to Latvia that resolved these issues in all but one case, communications were offline again within weeks in several properties. One impact of this was that customers expecting to benefit from greater control by using the app, and from improved prices through DSM, were disappointed. Three out of the nine customers interviewed said that the project had not met their expectations because the aggregation and app did not work at the time[52]:

> "First and foremost, we would like to point out that the promised functions, such as aggregation and control by means of smartphone, are not working yet, which worsens the overall impression from the project."
> **Latvian customer**

Reactions to flexible DSM in operation

Flexible charging of up to 70 homes was in live operation in Germany for 11 weeks from late February until the end of April, 2018. First responses to this seemed to be positive, which was seen as very encouraging by the German partners. (A final survey is underway at the time of writing.) Seven customers reported under-heating during that period and the aggregator then initiated ad-hoc individual charging. The main causes were identified as problems with the gateways and/or connectivity issues. [53]

In Latvia, flexible DSM was under way from December 2017 and here also there were initial problems with connectivity and with under-heating in some properties. Participants were able to call the RTU engineer for assistance. [54]

52 It should be noted that by the end of the project the phone app was working for Latvian customers.

53 Beegy, pers. comm.

54 RTU, pers. comm.

56 For example, the Irish customers surveyed were responding to the explanation in the previous footnote, followed by this question: What do you think about your electricity supplier being able to control the charging of your storage heaters to support the power grid?

Customer understanding and acceptance of DSM

Many customers may not have had much understanding of DSM, at least during the earlier stages of the project, as noted above. However, when DSM was explained to them[55], the majority response was positive and it remained that way. In general, people liked the idea of using up renewable energy that would otherwise be wasted:

> **I: "What do you think about this intelligent connection of your heating system with the electricity grid?**
>
> R: "For me it is the case, that the heaters are a logical consequence if you want to move away from fossil fuels. Because we burn nothing, we don't blow any CO2 into the air and if you really want to move away from fossil fuels, you need to heat with electricity at some point. The electricity needs to come from renewable energy."
> **German customer focus group**

> "It was great getting the heaters in and now that they're working I'm delighted. And, it is a bit exciting thinking they could be charged in a different way using more, different ways of getting your electricity, or when there's excess, so that's good ."
> **Irish customer**

> **Survey question: "What do you think about your storage heating system being specifically charged from outside to support the operation of the power grid?"**
>
> R: "The approach is good. Instead of wasting energy, it can rather be used for heating. This concept convinced me to participate in the project."
> **German customer**

However, they had certain conditions, namely that their comfort, costs and control should not be affected, and that they could choose to override remote control if they so wished:

> "I just had a doubt in my mind, would they interfere with the temperature settings or anything like that, you know? …. I mean, I doubt (it'll) happen, but they're issues that we need to be clear on."
> **Irish customer**

> On the whole, we feel positively about the project. We feel positively about the remote control of the radiators (demand response). The main thing is that it should be of some use and, of course, that it should result in diminished electricity bills."
> **Latvian Customer**

> "They [the supplier/aggregator] decide when we charge, it's not our choice, but I'd like to have an input on that … Can I understand what you're doing, maybe and I can tell you, 'oka'… by default this is a good option, but in this particular circumstance we have to override'. I'd like to have an input on that."
> **Irish customer**

Customers were also asked how they felt about DSM in an open-ended question in the final survey. [56] The response across all three countries was upbeat. The answers from surveys and interviews were clustered, showing that two-thirds of respondents felt positive in principle or under certain conditions (Figure 15, Table 11). Many customers made positive comments: 'Brilliant', 'Feel great about it', Great idea', 'Sounds logical', 'No problem at all', 'It just makes sense.' (Table 11)

Those customers who were accustomed to storage heaters had already been taking part in a basic form of DSM. In Ireland, for example, 64 of 106 Irish survey respondents knew that they had cheaper electricity at night and 42 said that they did some load-shifting with their laundry, tumble-drying and/or dishwashing (some of which can be noisy and therefore constrained in small homes or apartment blocks).

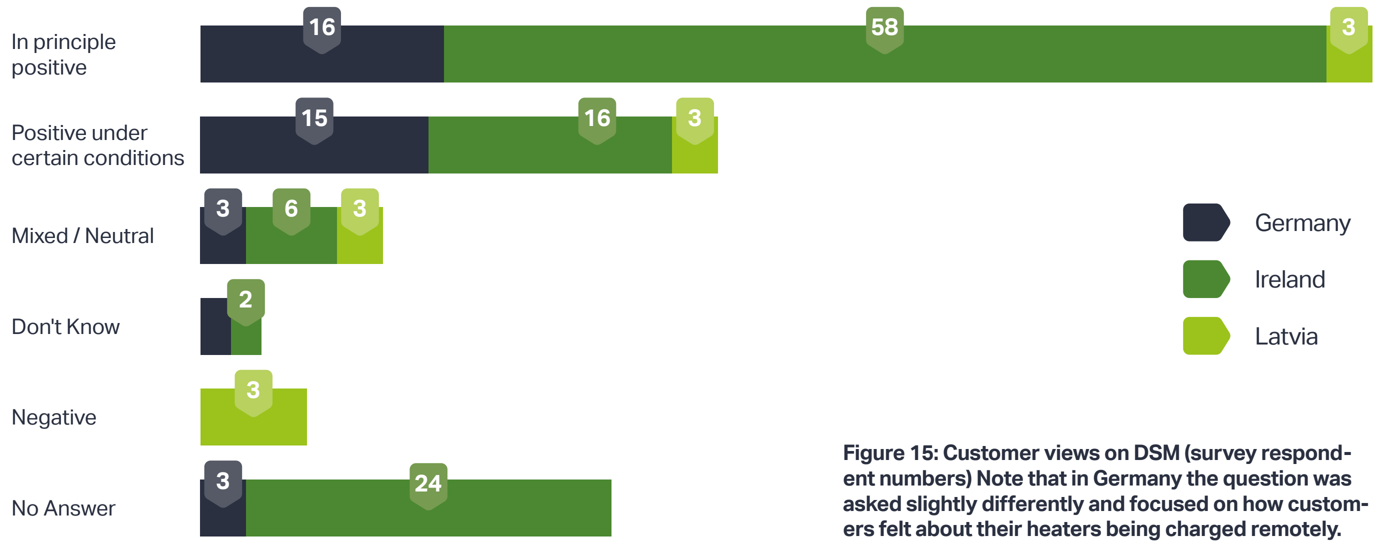


Figure 15: Customer views on DSM (survey respondent numbers) Note that in Germany the question was asked slightly differently and focused on how customers felt about their heaters being charged remotely.

57 These answers partly reflect problems that some customers had after a recent software update, which hugely affected customers' ability to control their heaters and accordingly impacted on their comfort levels.

Table 12: Breakdown of customer views (all countries) on DSM

Positive Comments ☺	Negative Comments ☹
Great idea / it's the future (70)	Not happy with it (5)
If I save money (21)	System is not yet ready (3)
If it works properly (9)	Worried about hacking and security (1)
If I am warm (6)	Will only benefit electricity companies (1)

Indifferent / don't know / happy with old system (8)

In Latvia, where storage heaters were new to the market, customers were more circumspect about helping the grid. Four out of the nine domestic customers surveyed thought the idea was good but qualified their responses in ways that would probably be important to most customers: that comfort should not be affected, that costs should decrease, that control should not be taken away completely, and that there should be some way of monitoring what was going on:

> "As regards the control from the outside, my attitude is rather negative. If the system were perfect then I would feel positively about it; yet to perform reasonable control from the outside is a very complicated task and I do not believe in its successful implementation: in the end, the user's comfort is going to be affected."
> **Latvian Customer**

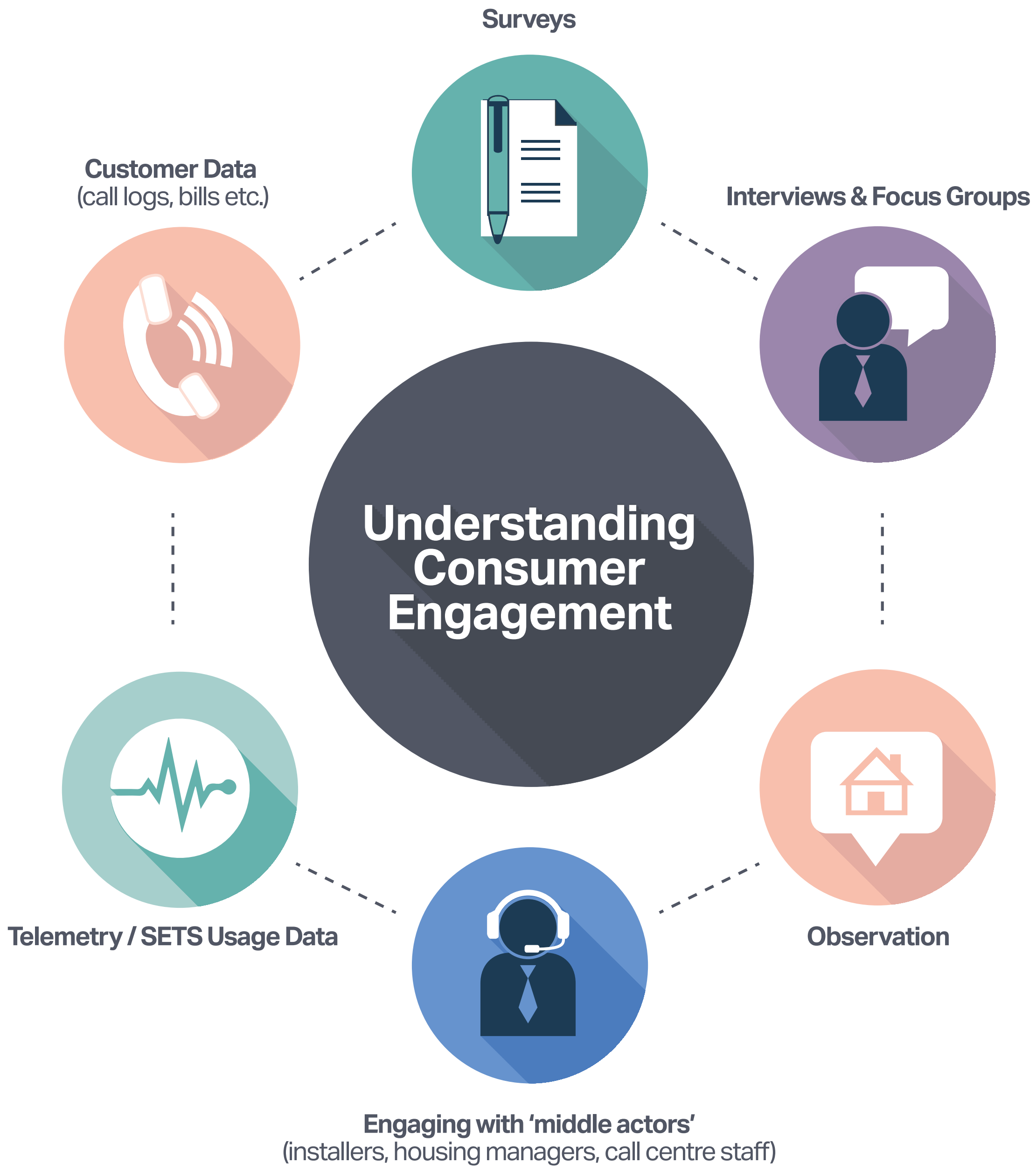
> "As regards control from the outside, I am sceptical: how can it be guaranteed that they will not cheat me and my bills will not increase?"
> **Latvian Customer**

In Germany, customers were generally open minded towards having their heaters charged from outside, as long as the system was working properly (11 comments) and their comfort was not affected (6) [57].

Some expected cost savings (4); some also mentioned that they would not accept price increases (8). There was a (perhaps surprising) lack of concern about hacking/ data security.

To set these responses in context, note that these were customers who had signed up to participate in a DSM project and had remained with it: they had shown commitment. The DSM proposition was presented in a positive light but some of the participants had also seen that everything did not always run smoothly; nonetheless, responses remained largely positive. It seems that customers can be very supportive of concepts such as DSM.

In summary, the project offered a vital opportunity to test connectivity in real-life conditions with several hundred customers. The need to connect and coordinate several technical components means there is a risk of a 'domino effect', where one failure can trigger others. The section above focuses mainly on the technical difficulties because these are important learning points. It also shows, however, that a majority of customers who responded to the final survey and answered the open question about DSM remained favourable to the idea, provided that participation would benefit them financially and not cause discomfort.



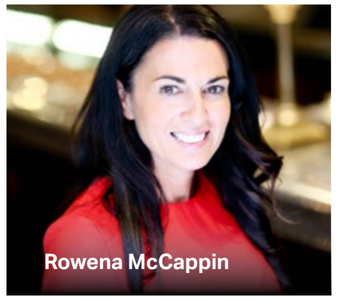
The 5Cs

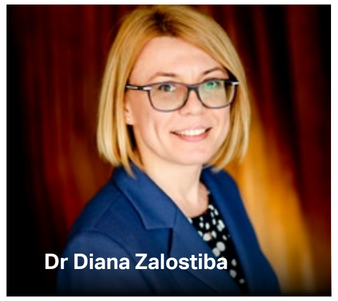
Key contributing factors to end-user experience

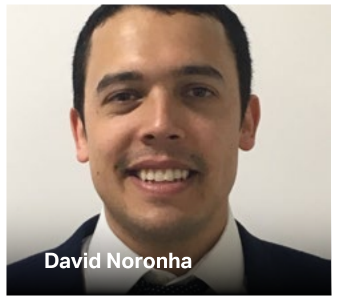
Comfort
Cost
Control
Care
Connectivity

Top-down actors

Towards the end of the project, we asked four of the leading partners for their reflections on RealValue, and on the customer engagement in particular.


Rowena McCappin


Dr Diana Zalostiba


David Noronha


Doris Wittneben

— They were Rowena McCappin, the Project Director, Glen Dimplex Heating and Ventilation; Dr Diana Zalostiba from the Faculty of Power and Electrical Engineering at Riga Technical University, Latvia; David Noronha, Strategy Programme Manager at SSE Airtricity in Ireland; and Dr Doris Wittneben of MVV Energie in Mannheim, Germany.

Their responses reflected the hard work needed to bring together a diverse group of partners in order to carry out an unusually large demonstration project, and also the value that had come from this level of ambition.

> "RealValue is one of the Horizon smart grid projects with the most demonstration participants… My understanding is that none of the participants, or close to none, have ever been part of such a trial before and have no, or extremely limited experience, of the smart grid, demand side management etc. So, our project has attracted a lot of attention from stakeholders including the EC, in the area of consumer engagement."
> **Rowena McCappin, GDHV**

All agreed that the effort and time needed to integrate people, technologies and processes had been greater than they expecte, but much of the value had come from this integrating and communicating effort. The technologies had been tested in real-life conditions with customers who were going about their daily lives and who were, mostly, non-experts when it came to managing their heating. And the project partners had learned a great deal about customer engagement in the process:

> "… with any large technology deployment there are bound to be some technology hiccups … we have learnt a lot as customers experienced some of these . .. we came across technical issues that we didn't envisage … I guess that's what makes RealValue so valuable, you can learn a great deal from how customers react to technology in a real home environment"
> **David Noronha, SSE Airticity**

> "… sometimes … negative things are more interesting than the positive …. it's very interesting these behavioural things because sometimes, as a technician, I am very oriented on the technical part, on the calculation,… and not take into account what people think and that we need maybe another approach … to involve the people to our project…. It's a good experience".
> **Diana Zalostiba, RTU**

> "What we've improved within the project…was the customer contact. We've really had discussions about how to contact the customers, via email, via letters … maybe, we will use social media more than before. And so, this is sort of an invisible outcome. And another … with this complex situation… distribution network, billing, sales and the legal department, communications and metering… we have established a new network so that we can establish new products more easily and the understanding of all the issues by every department has grown immensely, I would say."
> **Doris Wittneben, MVV**

The project had showed some of the complexities of setting up distributed thermal storage and using it for DSM. But the project leaders also saw possibilities opening up and continued to recognise a role for residential DSM as part of a mix of measures for operating the electricity networks of the future.

> "We're … very aware that … the whole connected appliances piece is there today and will gain more ground. Hence why we're … developing our own IOT platform… We do see that there is a potential opportunity for Glen Dimplex to move … away from just being a product developer and manufacturer to, then, being able to … offer value in terms of services…How much are people willing to pay for that? But we do see the area of [residential] demand-side management as a massive opportunity for us…" **RM**

> "…the network has a diverse mix of load and I think the advantage that residential load brings … is the ability to provide smarter services. For example, as distributed generation and storage becomes more prevalent, a smart connection in the home enables us to offer a lot more services for customers and the network operators alike…" **DN**

Partners' reflections on how to deal with this in the future included innovations and improvements such as:

- developing a retrofit solution that would involve only having to add a gateway to a pre-existing heater or cylinder to allow DSM without having to install new appliances (this was actually tried in Germany);
- developing their own platforms to reduce the number of stakeholders involved in offering DSM and so simplify some of the interface issues described here;
- finding ways to simplify and manage the amount of data being communicated so as to be able to use it effectively;
- developing analytic capabilities of the system so that other smart home services could be offered to customers, including remote assistance;
- ensuring backup systems were more robust before testing upgrades; and
- making sure future technologies were more mature before installing them in homes.

These 'top down' actors saw lessons for Europe and for energy research funders, in general.

As the 2017 Clean Energy Package (the 'Winter Package') emphasises customer control and participation in energy markets, this implies 'even more focus on research into customer engagement'. There are also implications for long-term transformative programmes or movements such as the German Energiewende:

> "It's a complex thing but I think it's one point, customer engagement, to manage this Energiewende here in Germany… to get a more sustainable [system], this is very important…. In former times, customer engagement was funded zero. I remember in 2006, when I proposed that we should do focus groups within [a project on stationary fuel cells], everybody was laughing. But at the end of the project in 2015, the people said the most important outcome … was the customer engagement results … and the results were what we founded our business models on… I would say 30% of the funding should go to customer engagement." **DW**

Middle actors

While customers and their activities were central to the demonstration project and project leaders were responsible throughout for strategy and delivery, middle actors were in charge of operations. For that reason, they have the last word in the Findings.

— A middle actor in the RealValue project was someone who worked directly with customers on behalf of product manufacturers or commercial stakeholders in the energy system. The idea of 'middle-out' action can be seen as an alternative and complement to 'bottom-up' and 'top-down' change strategies: middle actors may influence processes in three directions – upwards, downwards and sideways[58]. Where heating is concerned, their understandings of their professional role and relationship with householders[59] , and their roles in supply chains[60], can be crucial factors in the selection and installation of products.

Middle actors operate as a result of their 'agency' (the ability to make choices) and 'capacity' (the ability to perform these choices)[61]. Agency and capacity also allow middle actors to innovate and learn over time[62]. Here, we report on what these crucial actors had to say about their interactions with people and technology in the course of the project.

In RealValue there were several kinds of middle actor:

– installers (who put the equipment into people's homes and made sure that it was functioning correctly);
– project delivery coordinators (who managed the project on the ground;
– customer support services (who handled queries over the phone);
– housing support (Councils, Trusts and so on);
– technology developers.

This section will deal with installers and project delivery coordinators, the most obvious middle actors in the project and, to a lesser extent, with technology developers. The findings described here stem from interviews with them in all three countries, as well as from what customers said about them. In Latvia, the installer and project delivery coordinator were the same person. In Ireland and Germany, with many more customers involved, a team of third-party installers was recruited and trained to work on the installations, while the project delivery coordinators in these countries were employed by Glen Dimplex and MVV Energy respectively and were active throughout the project. In all three countries, the middle actors very much involved in project activity and became the faces of the project on the ground.

58 Janda, K.B. and Parag, Y. (2013) A middle-out approach for improving energy performance in buildings, Building Research & Information, 41:1, 39-50

59 Wade, F. Hitchings, R. Shipworth, M. (2016) Understanding the missing middlemen of domestic heating: Installers as a community of professional practice in the United Kingdom, Energy Research & Social Science 19, 39–47

60 Wade, F. Shipworth, M. Hitchings, R. (2016) Influencing the central heating technologies installed in homes: The role of social capital in supply chain networks, Energy Policy 95, 52–60

61 Parag, Y. Janda, K.B. (2014) More than Filler: Middle Actors and Socio Technical Change in the Energy System from the "Middle-Out", Energy Research & Social Science 3, 102–112.

62 Janda, K.B. Killip, G. and Fawcett, T. (2014) Reducing Carbon from the "Middle-Out": The Role of Builders in Domestic Refurbishment, Buildings 2014, 4, 911-936

"My interaction with the customers has been everything from phone calls, face-to-face visits, WhatsApp messages. Speaking directly to the customers, speaking through interpreters to the customers, speaking through caretakers to the customers … quite a bit of a crossover between my role there in some instances and the … call centre."
Project delivery coordinator, Ireland

Skills and training

Being a middle actor requires a range of skills. Installers have to be adept problem solvers, able to design workarounds in situ. For instance, in Latvia, there were difficulties fixing the heaters to the wall because the heaters are relatively high. In Ireland, we observed installers struggling to fit cylinders into built-in cupboards and dealing with antiquated plumbing, requiring carpenters and plumbers to be called. The legacy of the old heaters created challenges, too.

Fitting a cylinder in an awkward cupboard space

For instance, the old heaters had shelves to push warm air out into the room and avoid blackening the wall above them, and some customers wanted to keep these shelves. In one home, this meant the control panel for the heater could not be opened because it was too close to a shelf that could itself not be moved because of the positioning of plugs high on the wall to suit the needs of a disabled customer. . In Germany, old wiring and lack of space also caused problems at times; also the need for an external antenna in some properties (needing a hole drilled through the wall), to connect smart meters to the database via GSM.

Challenges like these slowed down installations and required installers to adapt and work with other trades.

Consequently, on-the-job training and support from project partners was much appreciated, as were the tips they shared on how to handle installations. Although the installation process was understood by all involved as mostly technical in nature, it was clear from interviews with middle actors and customers alike that there was much more to it than that. In preparation, training was conducted on how to install and operate the heaters, health and safety and, in some cases, data security. Installers were very aware of the need to keep customers happy and considered that this involved being quick, tidy, clean, quiet and showing respect. These skills were not taught but expected as a matter of 'common sense', according to one installer. Feedback was good:

"I'd go out the door, come back and the place would be spotless. They were very, very good now."
Irish customer

However, installers were sometimes put into awkward positions when customers disagreed with them Patience and good humour could prevail but installers would sometimes back down rather than offend a customer:

"You tell them to leave [the switches for the heaters] on all the time, they then turn round to you and say, '…If I know that switch … is turned off, it's not going to cost anything'.… And what can you say to a customer?"
Irish installer

In fact, almost a quarter of the 44 customers interviewed in Ireland had turned the heaters off at the walls, which meant they were unavailable to the project for DSM or data-gathering purposes.

Installation

Establishing procedures was a priority in the early stages of the project. Technical surveys and installation of the equipment could take a number of visits, ideally in a logical sequence.

For the first installations in Ireland, it was difficult to coordinate the arrival of different items, which had knock-on effects. For example, installing appliances and gateways without an Internet connection meant that the barcode scanner, which verified connections and pushed through software updates, was unusable in some properties.

This in turn meant that a confusion with some customer ID numbers went undetected until later, a problem that led to some data invalidation. The first round of installations in Ireland had to be completed very rapidly, which paradoxically increased the number of times that customers were visited in order to have all the equipment in place and connected.

Most customers were tolerant about this but a few refused access after the Quantum installation was complete, so that their properties could not be connected with gateways and were no longer useful for the trial.


Installers during their focus group session, Manheim

Installers were expected to cover a number of functions: doing the installation work; representing the company and project; explaining how the technology worked; identifying and addressing errors; helping set the controls to suit customer lifestyles and, perhaps most difficult, answering questions about energy consumption and cost:

"There was a claim that [the electricity price] should be up to half compared to the normal tariff… That was almost always the question, but we couldn't make a statement, because no data exists yet on which these prices could be based, and also we don't make the prices."
German middle actor

Installations required space and time. In addition to removing the old heater (not trivial in an upstairs apartment as these devices are heavy) and installing the new one, it was necessary to set up the software, programme the device and make sure it was communicating with the outside world:

"Initially (I) thought equipment installation (would be the) most effort, but in fact all the rest is more time-consuming. (You have to) ensure that control equipment is working (and the) temperature sensors are integrated. Generally it took one person the same time to do all the programming as the other to do the installations."
German installer

It also took time to explain to the customer how the new heater worked:

"How long were these conversations?" "About one hour, up to one and a half, after the programming … And I would say, that is quite short (because) the app is quite complex – many said that – (plus) the manual and instructions…. I think for those customers it would be good to have some training, instead of us."
German installer

There were significant problems getting the different technologies to communicate with each other, especially in Ireland and Latvia. Later, as already noted, software updates to allow for 24-hour DSM caused over- and under-heating in Germany and Ireland. In a research and innovation project, it would be remarkable if there were no such challenges but the number did come as something of a surprise.

"I felt given the amount of hype around this area at the moment, that things would be much more developed and there would be a lot more off-the-shelf solutions available. And that things would fit seamlessly together and just work… (but) it was incredibly difficult."
Project delivery coordinator, Ireland

"All ideas about the remote control have the same difficulty. The communication problem. So, all these ideas for smart: city, smart homes, and so on, have (as) the weakest point the communication.… to make this control we need this communication."
Middle actor, Germany

Interaction with customers

As shown elsewhere[63], the installation process was a crucial influence on whether the technology adoption proved successful for customers. In Latvia, customers had no previous experience of electric storage heaters and had to learn about them from first principles. In Germany and Ireland, most customers had experience of using old-style storage heaters (43 of 46 who responded to the survey in Germany and 70 of 106 in Ireland), but the new heaters were different in several ways, mostly to do with the controls. Installers had to train customers in what to expect from their heaters, how to use them, and how to participate in the project.

It became clear that one session was often not enough and the transfer of information could be frustrating for both parties.

'If I get myself … an electric car, everything is explained to me. I haven't yet seen a sales person who's thrown a key at me and said 'drive'. That's how it felt to me.'
German customer

"Many would have preferred us to come back the next day and explain everything again. (Agreement from installers).Because hat is part of the problem, that it is relatively complex."
German installer

"[Customers] appreciate [the opportunity to ask further questions on another day], because they're trying to remember so much today and then I might come down tomorrow and just give a little thing on that again, give five or 10 minutes explaining it again, and more of it will sink in. You don't want to overload them too much in the beginning."
Irish Installer

To address this difficulty, some project partners decided that they needed to provide additional resources that customers could access later.

"… if the customers are provided with the information only once, that's not sufficient. And also the instructions aren't enough. Therefore, we will now provide video tutorials, where the customers can follow the tasks step by step. I mean, if a new task is explained to me only once, I may not be able to understand it either but, with a video, I can watch it 500 times and maybe then I will understand it. That's what we have learned."
Middle actor, Germany

Despite this, it was clear that the installers carried a great deal of authority in the eyes of customers, who were often loath to change the initial settings.

"The man said I shouldn't touch anything."
Irish customer

As long as the heaters had been set up in a way that fitted with their lifestyles, this could work well, but it did not allow for any adjustment to changes in circumstances. There were examples of customers who were living with settings that did not suit them, some of which appear in the 'Control' section above:

"Typically they were quiet, and sometimes I knew that something happened only from historical data. Not from call or email…So, sometimes they were too quiet, I'd say."
Project delivery coordinator

"When used right, the appliance has the capabilities to really deliver savings, as well as deliver on comfort, but I felt that maybe some customers didn't either have the confidence or the understanding to make the most of it."
Project delivery coordinator

There were also examples of customers whose attempts to change the settings had gone badly wrong. As mentioned earlier, a local housing support officer was able to help a customer reset her heater to avoid expensive peaktime 'boosts': this sort of on-site help can be, literally, very valuable.

Difficulties with controls could come either as a result of avoiding them or of over-using them. In Ireland, installers thought older people were more liable

63 E.g. Darby, S.J. and Liddell, C. (2015) Communicating 'smart-ness': smart meter installers in UK homes. Paper 9-050-15, European Council for an Energy-Efficient Economy summer study, Hyères, June 1-5, 2015. pp 1991-2001;

Wade, F. Hitchings, R. Shipworth, M. (2016) Understanding the missing middlemen of domestic heating: Installers as a community of professional practice in the United Kingdom, Energy Research & Social Science 19, 39–47 to misunderstandings and mishaps with the controls, while in Germany their counterparts claimed that younger customers caused most problems: “those that like to play.” (Installer)

Where available, ‘local champions’, including friends, family, neighbours and housing managers, were an invaluable source of support for customers getting to know their new heaters. Where possible, installers trained these people so that they could help with trouble-shooting. As one customer had said to an installer:

> “Don’t tell me, we’ll organise tomorrow when you’re next door, then my daughter and my son will come along and you can show them… and they’ll look after it.”
> **Irish Installer**

Sometimes this went wrong. In one instance, a retired engineer who obviously did not fully understand his heaters had convinced tenants in his apartment block that they did not work, and there were other examples of misdirection by well-meaning amateurs. However, in most cases, local informal support was helpful and much appreciated by installers.

Middle actors made numerous comments about elderly and/or vulnerable customers’ ability to understand technology, deal with problems and make use of the app. They saw them as easily confused, liable to forget and to be technically illiterate:

> “They won’t remember, like we’ll explain it to them but… it’s the age group you’re dealing with.”
> **Irish Installer**

They adopted strategies for dealing with these customers that mostly involved showing them how things worked fairly quickly and then setting up the technology for them and encouraging them not to touch it. In some cases, customers were satisfied with this but not always, as indicated above.

Overall, installers concluded that hard work and humour go a long way to establishing rapport with the customer:

> **I: “They appreciate the conversation with you? That you are present?”**
>
> R: “Sure, we are friendly and good looking. [Laughing] So they are happy.”
> **German installer focus group**

Relationships between industry actors

Project delivery coordinators’ ability to connect top and bottom actors and to coordinate activities between other middle actors (sometimes across countries) was essential.[64] In practical terms, they were the main ‘resource’ for additional visits to properties to sort out problems. These visits were opportunities to engage with customers, remind them how their heaters worked, leave them with information and collect data. The coordinators provided insights into how customers were living with the technology, some of which are outlined above under the ‘Five Cs’ section. They also allowed lessons to be learned for customer recruitment later in the project.

Suppliers had a responsibility to make sure that customers’ problems were resolved in an apparently seamless manner, which could be quite complex. The supplier/retailer support service might have to refer a problem to one or more other partners in the system before it could be resolved. From a business case point of view, the proposition in this project differs from the normal experience customers might have of their heating system.

For starters, their normal point of contact to resolve any issues was their energy company rather than, say, the installer or product manufacturer. In addition, understanding what was wrong with the system was not straightforward, particularly for customers, who often struggled to explain their problems.

Fortunately, the diagnostic functionality of the technology was such that, if the appliance was connected, it was often possible to pinpoint problems by examining the data, a definite advantage of this system, particularly for people managing housing. However, it was clear, speaking to project partners,that this delivery mechanism would need to be streamlined were such a product to be delivered under market conditions:

> “I’d look at for future projects to have a more standardised process that’s efficient and fair for both sides.”
> **Middle actor**

Reflecting on the technology

In general, the project partners considered RealValue to be a technology project, so we asked our middle actor interviewees to reflect on the technology. The point was made that it was useful as a bridge between past and future, using a familiar form of heating in a new way:

> “I think the technology is good, because it’s very future orientated. So… we transform a very old technology, the storage heating, into a new technology, with the connection to the Internet? …I think we use something we have a lot of experience with, and make this new also… that’s why the project is there, to improve.”’
> **Middle actor, Germany**

This familiarity could be a problem or ‘legacy issue’, however, and middle actors talked about the difficulty of getting customers to move from familiar storage heaters and hot water cylinders to their new and more efficient appliances. First, it might be necessary to explain that the new heaters would be cooler to the touch because they were better insulated and that this was not a problem.

Second, they commented on how customers worried about their energy bills tended to turn their appliances off at the wall, making them unusable for DSM and ‘invisible’ to the project. It also meant they would take a couple of days to charge correctly when switched back on.

> “If they’ve had them off all summer and they turn them on, it takes a few days to (charge up correctly), and they ring you straight away, and are like, ‘There’s no heat coming out.’ ‘Well, it’s because you’ve had it off’ [switched off at the wall].”
> **Middle actor**

There were also more subtle issues to do with how the heaters worked. In Ireland and Latvia, the heaters ‘learned’ how much they had to charge from how long it had taken to reach and maintain the set point temperature for the required period the previous day. In Latvia, where the outdoor temperature might fluctuate considerably from day to day, this caused problems. In Ireland, if customers had supplementary heating, messages from the temperature sensors might lead the storage heater to charge up less than it should, leading into a negative spiral of more supplementary and less storage heating.

Making DSM happen

The RealValue project is based on the idea that decentralised, small-scale, smart thermal storage can be of value to customers and to electricity systems, by offering affordable comfort and DSM service. Moreover, it offers value to a particular set of customers, many of whom may not fall into classic ‘early adopter’ or ‘smart’ demographic groups:

> “I see [SETS] as a means for the ordinary person to participate in the evolving energy system. Not everybody’s going to have the money to invest in a Tesla battery, or an electric car, or to put a wind turbine, or PV on their roof, but lots of people have hot water cylinders and lots of people have storage heaters heating their buildings, consuming a large amount of energy. I see them as being a means for those people to be active and important cogs in the evolving energy system in the European Union”.
> **Middle actor, Ireland**

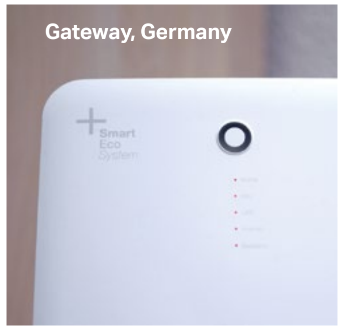
As the diagram on pp 13 shows, a number of devices and items of software needed to be in place before fully-flexible DSM could be attempted. When 24-hour DSM was set in motion,as noted above, it largely proceeded smoothly. However, in both Germany and Ireland, when a software caused customers to lose control of their heaters, there were concerns about what this could do to customer relations:

> “The lowest low for me … where an update went out to some gateways, which caused some heaters to not take charge one night… Customers (were) ringing in, something’s not right … A really avoidable (situation), and one that affected a number of people as well. … To be trying my best to manage those relationships and keep the project in good light in these customers’ minds, to be sideswiped by an event like that was quite a low for me.”
> **Middle actor, Ireland**

Despite this, middle actors judged that customers were generally positive about DSM, aware that it would involve some change, and willing to participate provided they had a basic understanding of the general principle and their comfort was not seriously disrupted:

> “Well, in general we mentioned to every customer during the first visit that the goal of this project is that the heater will charge when a surplus of electricity is available. And that the static charging cycle between 9pm and morning will not continue.” “And how was the reaction to that?” “Mainly positive, right?” [Installers agree].
> **German installer focus group**

> “I tried to explain it in a bigger picture so that if there is sun, then there is a lot of energy and with the new technology you can use it. … But I’m not sure if the people are so interested in it, how it works … It’s a low involvement product, I think…. I mean, for them it’s important that it’s warm and they have electricity and not how it works”
> **Middle actor, Germany**


Gateway, Germany

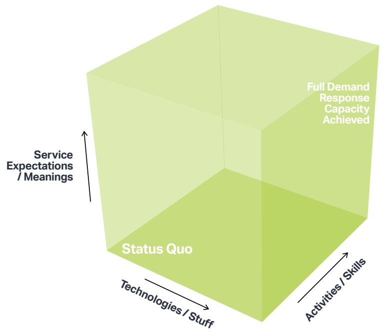

Quantum control dial, Germany

64 For a general discussion of this type of role, see Wade et al., (2016) Influencing the central heating technologies installed in homes: The role of social capital in supply chain networks, Energy Policy 95, 52–60

Discussion

— Demand-side management / demand response[65] is part of the logic of decarbonising electricity systems. It is beginning to be implemented within member states of the EU, where there are strong policy reasons for supporting it[66]. The introduction to the Clean Energy Package of 2016 states that:

> **The regulatory changes introduced by the current package and the shift from centralised conventional generation to decentralised, smart and interconnected markets will also make it easier for consumers to generate their own energy, store it, share it, consume it or sell it back to the market – directly or as energy cooperatives. Consumers will be able to offer demand response directly or through energy aggregators. New smart technologies will make it possible for consumers – if they choose to do so – to control and actively manage their energy consumption while improving their comfort.** [67]



This project has been a testbed for smart technologies in order to establish how they can 'make it possible' for consumers to manage their consumption, improve their comfort and offer demand response through aggregators. What are the conditions for effective DSM and satisfied customers?

National context matters. A recent paper from the European Commission Joint Research Centre notes how member states are at differing stages of readiness for demand response. In 2017, for example, the Baltic States had not yet altered their regulatory structure to enable it or prepared for all the technical modalities. Ireland, along with Belgium, France and the UK, was in a position to enable demand response and independent aggregation though still not fully ready for DSM to participate in markets.

Germany was in a middle position, where demand response could be enabled through retailers, and was about to conduct a regulatory review. The three countries selected to demonstrate SETS therefore covered a range of DSM-readiness at the time.[68]

The amount of customer demand response from SETS that can be used for DSM will depend on the technology being connected correctly, on customers' service expectations (e.g. temperature settings, technical support) and on their knowledge and activities (e.g. ability to control their heating, being in or out of the home or business).

Because demand response has these three dimensions, customers' characteristics, expectations, knowledge and actions will always produce varying outcomes for themselves and for the system. For example, the RealValue demonstration showed how older customers were less likely to use digital controls confidently than younger ones; how an interest in moving to renewable energy supply helped motivate them to take part in the trial, and how some might offer more flexible demand than others because of the amount of time they spent at home and the temperatures they required. It also showed some of the types and amounts of information and guidance (care) needed before they were confident with their new appliances and with using them for DSM.

Customer journeys and learning stories

The idea of a 'customer journey' is commonplace in consumer studies and becoming more widely recognised in energy studies[69]. The RealValue project has been something from which partners and participants learned, at individual, household and organisational levels, so it is reasonable to think of it in terms of a 'project journey' or a 'learning story': one 'where things are not quite as simple as they first seemed… [and] … protagonists are normal people who need to overcome a challenge '.[70] Here, we discuss how our findings about customer experiences and interaction contribute to the project's learning story and offer some answers to research questions posed at the end of the Introduction.

Who adopted SETS and why did they do so?

Most participants already had storage heaters when recruited to RealValue. This meant that they were already familiar with the basic idea of heat storage in the home and had connections ready for the new heaters. As replacement of legacy storage heaters by SETS was the basis for the project, these customers were well-suited to the trial. Participants who had never had storage heating before were also of interest, because they had to take an extra few steps on the customer journey, learning how to control heaters that did not have a simple on/off switch mechanism in order to achieve warmth when they wanted it.

The highly-discounted Quantum heaters and hot water cylinders were a powerful incentive to take part in the project. Thus in Germany, where most participants were homeowners, recruitment was easy for the first cohort of customers, who were offered free replacements for their ageing storage heaters, but take-up was far less for a second cohort of 'reference' customers, who were simply offered smart meters. [71] In Ireland, most of the participants were tenants in social housing (only in the second phase of recruitment were they joined by some homeowners) and it was their landlords – Councils and housing associations – who were offered discounted heaters to replace ageing appliances. An interview with a Dublin housing manager showed how the social landlord saw the prospect of more satisfied tenants as an incentive, over and above the free heaters. For the tenants, there was the attraction of having their existing storage heating replaced by something that would be more effective for heating throughout the day, and more affordable. A lesson from this seems to be there seems to be scope for standard offers to both homeowners and landlords to replace legacy storage heating and water cylinders with SETS.

Strikingly, comfort and cost were given equal weight by almost 60% of customers who responded to a survey question at the start of the project about what improvements they hoped for. The remaining 40% were almost equally divided as to whether cost or comfort was the more important consideration. The combination of comfort, control and cost seemed to be a powerful one for recruitment – as shown by the success of SSE's second recruitment leaflet offering "More comfort. More control. Less cost', and our findings show how it continued to shape customer experiences after installation. The SSE offer involved a substantial discount on the capital cost of the heaters and it is an open question as to how much incentive future customers (homeowners or landlords) might need to persuade them to invest in new appliances. Doing so could not only give them improved devices, enabling better comfort and control, but additional benefits such as access to DSM, better feedback on consumption and preferential tariffs when these become available.

An argument for adopting SETS is that it provides an entry to the world of smart grids and a means of benefiting from a new source of value: flexible demand. This applies particularly to customers who already have electric thermal storage in the shape of storage heaters or electrically-heated water: if the smart storage works as intended, customers' DSM capability will be extended and their comfort improved. For customers with direct resistance heating and no storage, the case could be even more compelling, depending on the options open to them. RealValue findings show that customers who had been particularly concerned about their energy bills were as satisfied with their new heating as the rest towards the end of the project; there seems no reason in principle why customers on low incomes should not benefit from DSM, provided the tariffs are fair to them and they have the necessary information and support.

Did they prefer the SETS to their previous heating arrangements and if so, why?

A large majority of customers surveyed and interviewed for the project made it clear that they found their new Quantum heaters a considerable improvement on previous heaters. Comfort, control, cost, care and connectivity were all interconnected factors contributing to customer satisfaction and readiness for DSM (Figure 13). Customers appreciated the 'package' that included care when the technology malfunctioned or they needed assistance. The implication of this for business plans for SETS is that the service needs to include engagement and support costs before, during and after installation.

What were their views on demand-side management (DSM)?

Customer views on the principle of DSM were broadly positive; the only serious difficulty arose when software was updated in Ireland and Germany, causing under- or over-heating in connected homes. So long as they do not lose out financially or in terms of comfort, our findings suggest that most customers will be content with DSM. At the time of writing, early indications were that the MVV customers had a positive

65 There are several definitions of each term and no agreed usage as yet. For many purposes, including this discussion, they can be seen as interchangeable.

66 Zancanella et al. (2017) Why is demand response not implemented in the EU? Status of demand response and recommendations to allow demand response to be fully integrated in energy markets. ECEEE Proceedings, Paper 2-278-17

67 http://eur-lex.europa.eu/resource.html?uri=cellar:fa6e-a15b-b7b0-11e6-9e3c-01aa75ed71a1.0001.02/DOC_1&format=PDF

68 Zancanella et al., op.cit.

69 E.g. Darby et al., (2015) Smart Metering Early Learning Project Synthesis Report; several reports by the Vaasa Energy Think Tank

70 Page 516 of Janda and Topouzi (2015) Telling tales: using stories to remake energy policy. Building Research and Information 43 (4), 516-513

71 Interim project data, April 2017

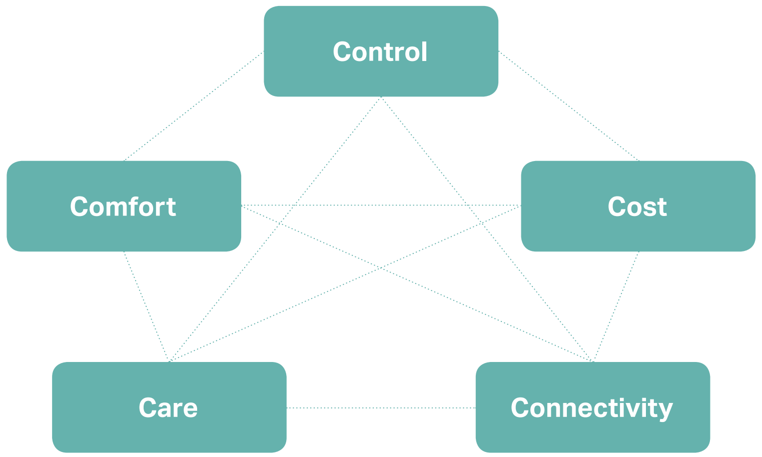


Figure 16: five factors contributing to a good customer experience of SETS

response to flexible charging for DSM.

However, until flexible charging has been in use for a more extended period, with dynamic tariffs, it is not possible to evaluate its impact on customers fully.

DSM is an appealing concept: it avoids waste, can operate in the background of daily life, and can help with system management at both local and grid level. Only a series of bad experiences seem likely to make it unpopular. But it does require shifts in thinking from all stakeholders, given that it involves whole-system changes. When 10 out of 44 customers visited in one round of interviews towards the end of the project had their gateway and/or heater switched off at the wall, in order to save money, they were not yet thinking in ways that are helpful for DSM. Gateways could also be offline due to technical issues (e.g. firewalls). Connectivity needed addressing in both social and technical terms in order for customers to take part in DSM and form a positive view of it.

How significant were technical, market and cultural differences in influencing project outcomes in the three countries?

Differences between the three countries affected outcomes less than might have been expected. There was a shared project ethos and similar technologies were used in each country. A more extreme climate, unfamiliarity with storage heating, and specific local difficulties with connectivity, were issues for SETS customers in Latvia. Irish customers, mostly tenants, were the most likely to be pleased with their replacement heaters. However, differences between countries were not a big feature of the project. Post-RealValue, however, differences in regulatory environments, market conditions and the availability of smart metering and dynamic tariffs will be significant in terms of readiness for DSM.

What were the general lessons for development of distributed thermal storage and smart systems?

The RealValue Market Design and Business Models Report, available via the project website,[72] models and analyses potential business models in some detail. It points to considerable barriers to participation in ancillary service and balancing markets in many European countries: in regulatory terms, few are ready for any substantial participation by demand aggregators. The business model report therefore concludes that, for the foreseeable future, the main opportunities for SETS lie with wholesale electricity markets. That is, the value of SETS to the system will largely come from extending the service that storage heating has traditionally provided: reducing peak load and soaking up generation when this is greater than demand. As more renewable supply comes on stream and as demand patterns change, we can expect more value from being available for charging at any time, not only overnight.

At this point it is worth mentioning the 'backroom actors' who designed and developed equipment and processes. Given the scale of R&D effort that goes into designing and developing smart grids with connected appliances, the number of operational challenges in this and similar projects is perhaps surprising. It is hard to avoid the conclusion that research effort is often unbalanced, with attention focused on 'pure' mathematical, economic, machine learning and engineering challenges at the expense of operational and organisational issuesThe RealValue experience argues for moderate expectations from complex ICT-enabled systems and for the need to monitor adoption of ICT by customers carefully over time: products can be too complex for the people they are intended to serve.

72 http://www.realvalueproject.com/images/uploads/documents/RealValue_Deliverable_6.3_-_website_version.pdf

73 e.g. Takayama et al. (2012) Making technology homey: finding sources of satisfaction and meaning in home automation. Proceedings, UbiComp '12, Sep 5-Sep 8, 2012, Pittsburgh, USA; ; Nyborg and Røpke (2013) Constructing users in the smart grid - insights from the Danish eFlex project. Energy Efficiency 6, 655-670

74 E.g. Faruqui and Sergici (2010) Household response to dynamic pricing of electricity: a survey of 15 experiments. Journal of Regulatory Economics, 38 (2010), pp. 193-225; Darby and McKenna (2012) Social implications of residential demand response in cool temperate climates. Energy Policy 49, 759-769

Some customers would seem to be better prospects for DSM than others, because of the way in which their daily routines and preferences translate into load profiles. The project has also shown how appliances are not always connected to the aggregator via a functioning gateway. An aggregator is likely to need a good range of load profiles, and many more devices than their contracted flexible capacity, in order to be confident of delivering DSM when needed. This points to the need for continued careful monitoring and evaluation as DSM capacity is built up.

Utility costs to recruit and serve 'flexible' customers will include costs for sales/recruitment, marketing campaigns, additional staff in call centres and for technical support, installation and the hardware and software for connected appliances. As RealValue has shown, these are all important factors for effectiveness; they are also serious considerations when drawing up business models. This was a demonstration project and, as such, required a high level of customer support. We might expect that this level of support would become less necessary over time as all those involved in DSM became more experienced and initial technical difficulties are overcome. However, it seems unrealistic to imagine that the need for customer care will vanish. Customers and system operators are continually dealing with new circumstances: new homes and appliances, weather events, new software, new business configurations, etc. It is hard to see any realistic scenario in which middle actors, including 'local champions', will not be needed to negotiate these challenges, coordinate activity, diagnose, advise and set things right.

The current and expected value of different types of flexibility to the system are going to be central to the prospects for SETS. However, there is a separate case for adopting smart storage heaters (even if not using them for 24-hour DSM at first) based on their customer appeal and ability to operate in night/day mode, especially in countries such as the UK where this is still economically favourable as a way of shifting load from regular peak demand times during the day. Replacing storage heating with direct resistance heating, which can and does happen, would seem to offer the worst deal for both customers and grid.

The value of SETS to customers will partly come from any financial benefit that is passed on to them for contributing to system flexibility, via favourable tariffs or subsidies for adopting the appliances. But as we have seen, cost is only one of the considerations that mattered to customers, even those on low incomes. Our findings illustrate how customers see comfort, care and confidence in controlling their appliances as important elements in the energy service they receive. These factors will matter in putting together packages that appeal not only to customers who both own and use SETS-enabled appliances but landlords who make the initial investment in them and have to judge what will work best for their tenants and their housing management.

Value to the customer will also be related to their understanding of matters such as

- the relationship between heating temperatures and size of energy bills (we found some customers who did not realise that increasing their room temperatures would mean their bills would increase, other things being equal);
- basic principles of storage, charging and grid management with renewable supply;
- smart metering, privacy and data security issues;
- controls and programming devices.

There is a school of thought that energy users can somehow be 'edited out' of smart systems by automation, in order to produce optimal outcomes for the system. In practice, though, customers 'domesticate' technology to suit themselves and will inevitably produce a range of outcomes, some unforeseen and even perverse from a systems point of view.[73] System managers and researchers have to decide whether to treat this as a problem, or as an opportunity to work with customers rather than around them. There is evidence from DSM programmes elsewhere that system outcomes improve when customer education and feedback are factored in[74] and that is supported by the evidence of this project: that the best outcomes for both customer and grid have come from a combination of reasonable expectations, reliable technology and a range of types of customer engagement: listening, information, user-friendly product design, interactive advice, feedback and community events. As one of the partners, a 'middle actor', reflected:

> "I would say that communication has been the most important thing for the success of this project and time. … Communication and time are the two most important things, I think, [is] what I would say to the funders"

Recommendations

RealValue clearly demonstrated how communications are central to the effective adoption of new technology and novel processes such as DSM.

— Feedback loops between participants and project partners were extremely helpful in promoting learning throughout the project, and they should be built into future trials and rollouts as a normal feature. Allocating around a third of R&D funds to engagement and associated research is reasonable, given what is at stake in terms of outcomes for technology users, system operators and environment.

Testing out heating controls in real-life conditions continues to be essential for effectiveness. There will be a trade-off between sophistication and usability and there is a case for 'good enough' rather than 'optimised' controls.

While there is scope for streamlining processes, the experience from this trial strongly suggests customer advice and support will continue to be needed. The technology transfer had limited effectiveness, at best, without some careful listening to customers and teaching new knowledge and skills. This is also an important consideration when properties change hands to new owners or tenants, and knowledge and skills have to be developed again.

'Fit-and-forget' is not a viable option for technologies that are a constant part of people's daily lives and essential for their comfort. In order to work for both customer and system, there needs to be realistic provision for customer support: transmitting knowledge and skill, troubleshooting and providing general guidance as DSM and associated activities evolve. In particular, installers and other middle actors should be recruited and trained on the basis that their communication skills will be as important as their technical abilities in many situations. They played a crucial role in RealValue.

There is a case for developing full-spectrum customer support, from written information and technical help via a call centre to in-home advice from an engineer, housing officer or knowledgeable member of the community. Basic training of trusted 'lay' people – local champions – who would be able to deal with common problems could be a worthwhile investment in addressing concerns and in improving customer satisfaction and DSM capability, as it takes time to develop customer confidence in their new equipment.

Summary

— This report has described and analysed domestic customers' experiences of taking part in the RealValue project to demonstrate how aggregated smart electric thermal storage (SETS) may be used for electricity demand side management (DSM). It is based on interviews, surveys, focus groups and observation with the customers themselves, with project partners who worked directly with them, and with project leaders.

The RealValue project introduced new technology to a large number of households in three countries. A good deal of care was taken to see that customers were satisfied with it, and their feedback offered valuable lessons. Two of the work packages were dedicated to customer engagement and to assessing what customer experiences with smart electric thermal storage systems (SETS) mean for developing demand side management (DSM). The research was carried out either directly with customers, via surveys, interviews, observation and focus groups; or indirectly, through focus groups and interviews with 'middle actors' who had direct contact with both customers and project leaders in each of the three countries.

The research presented here has taken shape from our particular interest in smart grid implementation and the way in which actors and technologies might influence the success of a DSM programme. Customers' experiences, and those of project partners, have demonstrated how technology adoption is a social as well as a technical process. The middle actors were largely responsible for effective implementation of the DSM programme; the middle level was where detailed planning, surveying, installation, customer-supplier interactions, troubleshooting and maintenance took place.

Our findings show how different modes of customer support were needed in order to make SETS work effectively. They show how five 'C's – comfort, control, cost, care and connectivity – contributed to bring about good outcomes for customers and pave the way for DSM. It is unrealistic to expect that any smart home system can be entirely 'plug and play', particularly if it is to contribute to an energy future where charging has to be adjusted to flexible renewable supply.

Each participating household or business had its own combination of technologies, service expectations and activities; and its own outcomes in terms of the amount of electricity used, when it was used, and how much it cost; consequently its own experience of the new heating arrangements. Some were better prospects for DSM than others.

In broad terms, RealValue participants were satisfied with the new heaters and cylinders in terms of comfort, control and aesthetics. Overall satisfaction levels were high, with 70% of final survey respondents in the three countries saying that they were satisfied (31%) or very satisfied (39%). Only 15% expressed dissatisfaction. Almost all project participants who had lived with old-style storage heaters for many years were pleased with their new and more efficient heaters. These were free or heavily discounted, came with enhanced support, looked better and provided improved comfort and control, as long as provided the customers were able to use the digital controls effectively. Customers with SETS water cylinders were also largely content with them. Customers who had not used storage heating before joining the project had to make some adjustment to this mode of heating and how to control it. None of the Latvian customers had experienced storage heating before and some found the SETS did not match their expectations.

Customers' overall satisfaction with their heating service came from the combined effects of housing + heating equipment + electricity supply + tariff + customer support + feedback arrangements. A change in any one of these can affect DSM outcomes.

The engagement activities led to helpful feedback flowing through the project in all directions, allowing project partners to develop their understanding of what is involved in developing distributed DSM.

Control improved, relative to previous storage heaters and most customers said they felt fairly confident about controlling their heaters and water cylinders but could not always demonstrate how to operate the heaters. Whilst the legacy system of charging heaters by night and discharging by day had not necessarily been good from a comfort-and-control point of view, especially in poorly-insulated buildings, it was simple and robust. The new system came with digital controls and a gateway to enable DSM. These added to complexity and the potential for misunderstanding and malfunctions. If the new heating controls were seen as complicated, this lessened the chances of satisfactory outcomes for customers and added to the cost to serve. Project participants had to invest some effort in understanding their new equipment and DSM in order to benefit fully. Software upgrades at one point disrupted comfort in households that were connected for DSM at the time.

Saving money was the main reason customers joined the RealValue project, but they valued cost and comfort more or less equally. A substantial number estimated that their bills had increased over the period of the trial. Almost all RV participants joined the project expecting an improvement in their heating costs. In the absence of usable billing data for the trial period with flexible charging, it is not possible to say accurately what happened to their electricity costs, only to report on perceptions. Of the customers who gave a view on change in their electricity costs and had had old-style heaters replaced, half reported that their bills had stayed the same, a third that they had risen and a sixth that they had gone down. Improvements in comfort seem to have made up a large part of the perceived value of the Quantum heaters and this may help to account for perceived change: there was evidence of some high temperature settings.

In Germany, in some cases, lower bills were observed by the supplier when people operated the heaters "right", i.e. using the fan and setting suitable temperature profiles. However, higher bills were observed in other cases, mainly due to software problems that led to overcharging. The potential advantages of new storage heaters with respect to lower bills did not become visible for many of the customers, because of issues with software. The influence of flexible charging on the bill is still under evaluation.[75]

Installers and 'local champions' emerged as key sources of care. Partners' engagement efforts involved listening as well as informing, advising and developing customer packages to make smart thermal storage an attractive proposition. Customers found installers and supplier call centre staff to be helpful and courteous, but some had not felt entirely confident with their new digital heating controls and settled for something 'just good enough'. Local champions can improve such a situation.

Two-thirds of participants surveyed at the end of the project were positive about the concept of fully-flexible DSM, in principle and/or as long as it delivered cost savings and did not affect reliability and comfort.

Communications were a crucial aspect of the project took three forms:

- **Tech/ tech, or connectivity:** getting the devices to 'play' with each other while ensuring data security and privacy requirements were met. Connectivity posed the greatest single challenge in the course of the project, sometimes affecting customer comfort. Connectivity between appliances and system was largely invisible to customers, who did not always realise the need to keep their equipment switched on at all times in order to allow for 24-hour DSM.

- **Tech/ people:** devices and controls needed to be straightforward to understand and operate. Advice at installation, leaflets/manuals, newsletters and videos were all used to assist customers. Visits from RealValue personnel in the weeks and months after installation were valuable in identifying and correcting technical glitches and misunderstandings. In-home visits were the only way to sort out some customer difficulties with the SETS technology.

- **People/ people:** professionals and laypeople can have different vocabularies and understandings of technologies and concepts. For SETS to produce satisfactory outcomes for customers, some post-installation follow-up was often needed from a trusted, knowledgeable and communicative person. This could be a heating engineer, housing officer, supplier staff member, community volunteer or neighbour. They needed to act as individuals but also to communicate within and between organisations.

Addressing these communication / engagement challenges led to some of the most valuable learning from the project. Time was needed for customers and other actors to absorb new information, learn new skills and adapt to new technologies and processes. A trial with one year of installation, one year of testing the basic system and one year of flexible charging is therefore not a long time in terms of developing confidence and evaluating impact.

Introducing the SETS technology involved a range of actors, from designers and manufacturers through to customers. They came from many backgrounds and needed to develop some shared understanding of the project. We identified three levels:

- **Bottom-up** – the customers whose participation would be essential for DSM

- **Top-down** – the senior personnel who formulate strategy and investment priorities

- **Middle-out** – the installers, advisers and other people who, formally or informally, try to make the programme work effectively and are in a strong position to help customers and to pass feedback 'upwards' on how to improve it.

The significance of the roles played by middle actors was a central finding. They played a crucial part in paving the way for DSM and contributing to customer satisfaction through their expertise with the technology, communication skills and ability to develop workarounds in particular situations and to spread learning among project partners.

The ethics of DSM are also important to consider. All electricity users have an interest in a well-functioning system. The costs and effort involved in achieving this via DSM need to be spread fairly, especially where the customers providing it are on low incomes and may be vulnerable in some way; such customers may well need additional support if they are to benefit. Participants in RealValue were safeguarded against financial loss from taking part in the project and had unusual levels of customer support. Mainstream, commercial DSM will however need to address, as a matter of normal practice, issues of consent (to adopt technologies and allow some measure of remote control), equity, information, support and responsibility for any failures in service provision.

In conclusion …

'Can smart electric thermal storage work for customers and the grid?' An answer, based on RealValue findings, is 'Yes, provided certain conditions are met'. Some of these conditions will be regulatory and some will relate to grid and local network conditions. Several relate directly to the customers who rely on the storage devices for warmth and hot water. At the end of what has been a complex demonstration project, offering many new and valuable insights, the best outcomes for customers have come from a combination of reasonable expectations, reliable technology, skilled middle actors and well-planned, diverse forms of engagement with technology and with people.

75 MVV, pers. comm.

References

Altomonte, S., Schiavon, S., Kent, M. G. & Brager, G. (2017). Indoor environmental quality and occupant satisfaction in green-certified buildings. *Building Research & Information, 1-20.*

Bouzarovski, S. and Petrova, S. (2015) A global perspective on domestic energy deprivation: Overcoming the energy poverty–fuel poverty binary. *Energy Research and Social Science 10, pp. 31-40*

BEIS (2016) Energy Consumption in the UK. National Statistics. https://www.gov.uk/government/statistics/energy-consumptionin-the-uk Table 3.16

Clarke, J., Hand, J., Kim, J-M., Samuel, A. and Svehla, K. (2013) *Electricity storage within the domestic sector as a means to enable renewable energy integration within existing electricity networks.* Proceedings, BS2013:13th Conference of International Building Performance Simulation Association, Chambéry, France, August 26-28

Darby, S.J. (2018) Smart electric storage heating and potential for residential demand response. *Energy Efficiency* 11(1), 67-77

Darby, S.J. and Liddell, C. (2015) *Communicating 'smartness': smart meter installers in UK homes.* Paper 9-050-15, European Council for an Energy-Efficient Economy summer study, Hyères, June 1-5, 2015. pp 1991-2001

Darby, S.J., Liddell, C., Hills, D. and Drabble, D. (2015) Smart Metering Early Learning Project: synthesis report. For the Department of Energy and Climate Change, London https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/407568/8_Synthesis_FINAL_25feb15.pdf

Darby, S.J. and McKenna, E. (2012) Social implications of residential demand response in cool temperate climates. *Energy Policy* 49, 759-769

DNV KEMA (2013) *Energy & Sustainability. Potential for smart electric thermal storage.* Contributing to a low carbon electricity system. Report for Glen Dimplex and SSE plc by Raadschelders, J., Sikkema, F. and in t'Groen, B. http://www.dimplexrenewables.com/uploads/Kema%20report_LO%20RES.pdf

Faruqui , A. and Sergici, S. (2010) Household response to dynamic pricing of electricity: a survey of 15 experiments. Journal of Regulatory Economics, 38 (2010), pp. 193-225

Fell, M.J., Shipworth, D., Huebner, G.M. and Elwell, C.A. (2015) Public acceptability of domestic demand-side response in Great Britain: the role of automation and direct load control. *Energy Research & Social Science* 9, 72-84

Fischer (2008) Feedback on household electricity consumption: a tool for saving energy? Energy Efficiency 1 (1), 79-104

Goodhew, J., Pahl, S., Goodhew, S. and Boomsma, C. (2017) Mental models: exploring how people think about heat flows in the home. *Energy Research & Social Science* 31, 145-157

Grunewald, P. and Diakonova, M. (2018) Flexibility, dynamism and diversity in energy supply and demand: a critical review. *Energy Research and Social Science* 38, 38-66

Hanmer, C., Shipworth, M., Shipworth, D. and Carter, D. (2018) How household thermal routines shape UK home heating demand patterns. *Energy Efficiency* https://doi.org/10.1007/s12053-018-9632-x

Janda, K.B. and Parag, Y. (2013) A middle-out approach for improving energy performance in buildings, Building Research & Information, 41:1, 39-50, DOI: 10.1080/09613218.2013.743396

Janda, K.B. Killip, G. and Fawcett, T. (2014) Reducing Carbon from the "Middle-Out": The Role of Builders in Domestic Refurbishment, Buildings 2014, 4, 911-936; doi:10.3390/buildings4040911

Janda, K.B. and Topouzi, M. (2015) Telling tales: using stories to remake energy policy. *Building Research and Information* 43 940, 516-533

Leaman ,A., Stevenson, F. and Bordass, B. (2010) Building evaluation: practice and principles, Building Research & Information, 38:5, 564-577

McKenna, E., Higginson, S., Grunewald, P. and Darby, S.J. (2017) Simulating residential demand response: Improving socio-technical assumptions in activity-based models of energy demand. *Energy Efficiency* 10(44), 1-15

Moore (2012) Definitions of fuel poverty: implications for policy. *Energy Policy* 49, 19-26

Nyborg and Røpke (2013) Constructing users in the smart grid - insights from the Danish eFlex project. *Energy Efficiency* 6, 655-670

Ofgem (2015) *Insights paper on households with electric and other non-gas heating.* Office of Gas and Electricity Markets, London

Robinson, D. (2017) Fiscal policy for decarbonisation of energy in Europe. Oxford Institute for Energy Studies

Parag, Y. Janda, K.B. (2014) More than Filler: Middle Actors and Socio Technical Change in the Energy System from the "Middle-Out", Energy Research & Social Science 3, 102–112.

Sustainability First (2014). *The Household Electricity Demand Side & Participation in the GB Electricity Markets.* High level overview. Paper 12 in series 'GB Electricity Demand – realising the resource'. Sustainability First, London.

Takayama et al. (2012) *Making technology homey: finding sources of satisfaction and meaning in home automation.* Proceedings, UbiComp '12, Sep 5-Sep 8, 2012, Pittsburgh, USA

VaasaETT (2017) Assessing the Potential of Home Automation in Norway. A report commissioned by NVE. Norwegian Water Resources and Energy Directorate. http://publikasjoner.nve.no/rapport/2017/rapport2017_34.pdf

Wade, F. Hitchings, R. Shipworth, M. (2016) Understanding the missing middlemen of domestic heating: Installers as a community of professional practice in the United Kingdom, Energy Research & Social Science 19, 39–47

Wade, F. Shipworth, M. Hitchings, R. (2016) Influencing the central heating technologies installed in homes: The role of social capital in supply chain networks, Energy Policy 95, 52–60

Zancanella, P., Bertoldi, P. and Boza-Kiss, B. (2017) *Why is demand response not implemented in the EU? Status of demand response and recommendations to allow demand response to be fully integrated in energy markets.* ECEEE Summer Study Proceedings, Paper 2-278-17

Glossary

ESBN – (Irish) Electricity Supply Board Networks

Gateway – a data communication device linking a local network (e.g. a Home Area Network) with a host network.

ICT – Information and Communication Technology – technology that provides information through telecommunications.

DR – Demand Response: changes in electricity usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time.

Demand Side Management (DSM) - the management of demand response to maintain a balanced electricity system, either locally or on the high-voltage transmission grid

Middle actor – a project partner or associate who was in direct touch with customers and had expert knowledge or practical know-how relevant to heating and DSM. Middle actors carried out surveys, installed and maintained equipment, and provided advice and guidance to customers. Some also coordinated operational activities and liaised with senior project partners.

MVV – Mannheimer Versorgungs- und Verkehrsgesellschaft Energie(Mannheim-based energy supplier)

RTU – Riga Technical University

SEAI – Sustainable Energy Authority of Ireland

SSE – Scottish and Southern Energy (operating in Ireland as SSE Airtricity)

Further reading and access to data

This report is one of many from the RealValue project. Others, relating to technical and economic aspects of the work and to extensive modelling exercises, may be found in the project library at **http://www.realvalueproject.com/library**

Data from the RealValue consumer impact study

Most of the anonymised data on which this report is based is held in the Environmental Change Institute, University of Oxford. The H2020 programme encourages project partners to make their data available for research purposes, and anyone wishing to access it, or to find out more about the data gathering and analysis behind this report, should contact Sarah Darby (**sarah.darby@eci.ox.ac.uk**) .

For more on the experience of being a RealValue participant, check out the 'Real People – RealValue Perspectives' video on the RealValue Youtube Channel.

—

This testimonial video clip features a range of project participants from Ireland, Germany and Latvia who had the RealValue Smart Electric Thermal Storage system installed in their properties. It captures their experiences and offers a 'snapshot' of end-user perceptions of the RealValue technology.

youtube.com/watch?v=d2G882wONO0


Participant filming in Mannheim, Germany


Filming in Mannheim, Germany


Participant filming in Latvia


Setting up filming equipment in Latvia

Participant filming in Ireland


Participant filming in Latvia

Real Value

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646116

Glen Dimplex Heating & Ventilation Ireland · Glen Dimplex Deutschland · intel · beegy · erc electricity research centre · MW · Environmental Change Institute eci University of Oxford · EirGrid · sse Airtricity · Riga Technical University · DIW Berlin · ESB Networks · VTT