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Communicating innovations: examples from smart technology retrofits

S J Darby

Energy Programme, Environmental Change Institute, University of Oxford, OUCE, South Parks Road, OXFORD OX3 7LW. E-mail: sarah.darby@eci.ox.ac.uk

Abstract. The importance of effective feedback loops during and after building retrofits is well-established. Good communications between designers, practitioners and building users typically lead to better outcomes for users and can allow designers, investors and builders to learn from experience.

Where ‘smart’ retrofits are concerned – that is, introduction of ICT for more sophisticated control and new functions such as demand response – it can seem as though the aim is a friction-free transfer of activity and learning from humans to machines. In such a scenario, the complexities of real-life routines and activities are typically minimised or ignored, along with the need for time and effort to put into sense-making and adaptation. The paper argues that this is unhelpful at best. Drawing on the author’s involvement in evaluating three contrasting programmes, it illustrates how smart refurbishment is an exercise in which ‘smartness’ is distributed between technologies and humans; one in which we can expect some emergent (i.e. unpredictable) outcomes. The three case studies, at different scales, are:

- the rollout of smart meters in Great Britain, a large-scale infrastructure refurbishment;
- ‘smartening’ domestic storage heaters and water heaters, a retrofit exercise in homes;
- ‘smartening’ electricity demand in a community – small-scale system upgrade.

These programmes show the significance of different types of communication in sociotechnical systems as they incorporate smart technologies. Thematic analysis indicates three ways of categorising communication during these processes: between technologies (connectivity), between technologies and people (controls), and between people (care). As buildings become more closely integrated into energy systems, for example via on-site generation, demand response and heat networks, these categories can be useful when designing, implementing and evaluating smart refurbishment.

1. Retrofits and feedback loops

Buildings do not have the environmental impacts their designers intended; the sheer variety and number of possible human/building and human/technology interactions makes this almost impossible, and new or refurbished buildings typically perform less well than anticipated [3,14]. In order to improve the outcomes from retrofit, a wealth of research now shows the value of developing a ‘culture of feedback’ that involves designers, practitioners and building users, and more involvement from suppliers in learning how buildings perform in real life [3].

Neither of these pathways seems out of reach, given will and modest resources, yet they have rarely been followed: the structure and practices of the construction industry militate against them [13]. When we live in exceptionally data-rich times and (as explained below), electricity system operators have a direct interest in managing demand, it seems there could be a prospect of improved feedback loops and also of a bringing-together of energy suppliers, at least, with building owners and



users. There is a good deal of optimism around the spread and potential of smart (ICT-enabled) technology; yet much of it comes from calculations and marketers rather than from lived experience [4]. This paper argues that we can learn useful lessons from introducing smart technology into the built environment and energy systems and from analysing how this is done. It offers three case studies, involving domestic and small-scale customers with different technologies at different scales.

2. Smart retrofit – the building as part of the grid/network

As electricity comes increasingly from distributed renewable sources, electricity systems need to perform more functions than in the past [10] and they rely on a far greater number of actors in order to perform reliably. Crucially, these actors include electricity users ‘beyond the meter’ whose demand, storage and small-scale generation must be balanced continually in real time. This has to be achieved not only at the level of a national/ transmission grid but within more local distribution networks. The latter is often more difficult, as new supply or demand technologies such as solar photovoltaics (PV), electric vehicles and heat pumps are likely to be clustered in particular neighbourhoods and this clustering can put considerable strain on local networks that were designed to accommodate demand only up to a certain level and were not designed for two-way flows of electricity.

Traditional systems have offered flexible power supply to meet demand and customers in the more industrialised or post-industrial economies have come to rely on their demands being met as a matter of course: if demand increases, a new generator is simply brought into action. They are also insulated from the operational realities of generation, typically to paying a flat rate for each unit regardless of how much it costs to provide it at a given time with a specific generating mix. Now customers, along with the supply industry, face a paradigm shift in which they will be called on to provide more flexible demand – demand response (DR) – to match available supply.

A corollary of this is that buildings, traditionally seen simply as ‘load’, are now being viewed in the electricity industry as potential sites for demand response in order to serve the smooth operation of distribution networks and high-voltage transmission grids. In order to do this to a significant degree, they will need information and communication technology (ICT) networks to link appliances with the electricity network, as in this definition of smart buildings:

Smart buildings are flexibly connected and interacting with the energy system, being able to produce, store and/or consume energy efficiently (Building Performance Institute Europe, 2017)

The BPiE report offers as an example a dozen Belgian houses of varying ages that contain a mix of technologies to allow for load-shifting in order to balance the neighbourhood network: PV, solar thermal capture, heat pumps, and fuel cells or batteries. A monitoring and control system is also part of the smart set-up. Another example includes homes with electric vehicles as devices that can be set to charge at off-peak times and store rooftop solar generation, avoiding the need to export it to the grid.

While it is debateable whether smart buildings will inevitably produce, store or consume energy ‘efficiently’ [4], the main point is that they have a new dimension: a communications network to link appliances or subsystems with each other that enables remote access and control. That is, the level of connectedness goes well beyond the use of ICT in smart metering, or remote control of a TV from the sofa. Smart buildings host demand-side assets such as electric water heaters and vehicles, laundry appliance, batteries and other devices. And, of course, they are homes for the occupants themselves, typically people who are not energy or IT professionals. The potential of these buildings for DR will depend on how and when their occupants choose to access the electrically-powered services they want and on how able and willing they are to adjust these services in response to system needs, either by switching manually, setting a programmer or agreeing to pass control to a third party such as a demand aggregator who will trade their flexibility, along with that of many others, into the electricity market.

In short, a building that can provide services to both occupants and system is one that will need occupants to cooperate at some level, even if that is only to the extent of consenting to particular forms of remote control for some devices [6,9]. It is also one that requires effective feedback loops and other forms of communication. Despite a great deal of research literature implying that a smart building offers

seamless services and effortless convenience, the much smaller volume of actual evaluations indicates that demand response does in fact require effort and adjustment and it takes time and skill to learn to live in a smart building, with energy and environmental outcomes by no means guaranteed [4, 11].

3. Smart retrofit – communicating the innovation

Effective smart energy retrofits therefore involve training and learning. At a minimum, designers and developers will need to learn the skills needed for effective, while those who are directly involved in operating devices and systems will have to have a basic understanding of how they work. There is also the need to exchange knowledge between specialists and non-specialists, so that building occupants can build some understanding of how their new technology might work for them and, no less importantly, professionals can learn how it is used in different real-life circumstances. An effective smart system therefore requires both human and machine intelligence; communication within and between the human and machine domains. The examples below illustrate a number of issues raised by smart retrofit, at different scales, and how they may be addressed.

3.1. Rolling out smart meters in Great Britain – a large-scale infrastructure refurbishment

Metering of some sort is a standard element in most electricity and gas systems, a link between user and supplier. A traditional or ‘dumb’ meter simply records cumulative consumption as a basis for billing while a smart meter will be considerably more complex. Smart meters all provide two-way communications between user and supplier, allowing for remote meter reading. They also measure consumption at regular, short intervals in order to allow for time-of-use tariffs that can charge the customer more at times of high demand/ short supply. Beyond that, detailed smart meter functions may be specified in many different ways. They may, for example, record microgeneration, offer remote control of appliances and supply near-real-time usage feedback to customers.

Smart metering therefore does not just involve retrofitting buildings with new meters. It is a process of retrofitting the entire power infrastructure. But if, as argued here, effective smart retrofit is a process of transferring not just technology but the knowledge and practical know-how to operate it, then it is not sufficient simply to replace one meter by another. The British smart meter rollout to homes and small businesses illustrates what can be achieved if a broader view is taken. The rollout, to all domestic and small non-domestic customers, has been undertaken on a voluntary basis and by the end of March 2019, over a quarter of all domestic and over a third of all non-domestic electricity and gas meters (approximately 17m in all) were operating in smart mode or with advanced functionality¹. Customers are offered not only a meter but an in-home display to show their consumption and costs and act, if they wish, as a tool for budgeting. All smart meter installers are required by the Smart Metering Code of Practice to train in communication skills so that they can explain to customers the purpose of their new meter and how they might benefit from the in-home display, and can offer basic energy advice. They also occupy a useful intermediary role in the process, being able to pass feedback to suppliers on how the rollout is proceeding and how customers are responding [5].

This combination of ‘smart meter + in-home display + trained installer’ is unusual and probably unique, in national rollouts. While the British smart meter rollout has been marred by a number of technical and infrastructural shortcomings, customer satisfaction levels have been high² and there is evidence of sustained reductions in demand of around 3% on average, compared with legacy- metered customers [7, 12]. This is, as far as the research literature shows, the only rollout in the world to combine the three elements of smart meter, customer interface (the in-home display) and guidance before, during and after installation. It is significant and interesting because it demonstrates the value of offering a clear,

¹https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/804767/2019_Q1_Smart_Meters_Report.pdf

²https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/650970/Post-install_key_findings_report_FINAL_05102017_PUBLICATION.pdf;
<https://www.statista.com/topics/4923/smart-meters-in-the-united-kingdom-uk/>

accessible in-home display to all customers as part of the metering package, and offering guidance to customers on what meter and display are for and how they can be used to understand and manage energy use. The British experience also points to the risk of ‘false economies’ if customer service is reduced: for example, if pressure to roll out the meters rapidly means that installers no longer have time for conversation with customers and a chance to answer their questions [7,12].

Smart metering is introduced primarily as a technology to improve data flows in electricity, gas and water systems. During implementation, the focus is normally on connecting up the various physical elements of the system: connectivity. Relatively little attention has been paid to ‘control’ – the interface between meters and the people who use them – or to ‘care’ – the person-to-person interactions that can build understanding and keep a socio-technical system functioning effectively. The British smart metering experience to date has some useful lessons to offer on the macro-scale and, as I argue below, control and care also contribute to effective retrofitting of particular technologies, or when adapting electricity systems in order to develop community energy markets.

3.2. *Retrofit with smart electric storage heaters and water heaters*

Credible financial offers to customers are an important factor in a move towards smarter power networks, to persuade people to take part in providing flexible demand and to keep them doing so. As electric vehicles and heat pumps become more commonplace, we can expect an increase in flexible tariffs. However, residential DR with dynamic tariffs is still in its infancy. In the UK, for example, there is only one ‘agile’ tariff (from Octopus Energy) at the time of writing, plus the familiar two-band Economy-7 type tariff, typically used by customers with night storage heating. Night storage heating and water heating, charged with cheap off-peak electricity for use later in the day, offers an interesting basis for more ambitious ‘smart’ thermal storage, in which heaters and water cylinders may be charged up at any time when power is abundant. A ‘smart’ storage heater is one that is connected via broadband or a modem to the Internet and that can be controlled by the customer (who chooses temperatures and heating times) AND by an actor such as a demand aggregator (who chooses when to charge up the heater or to cease charging, according to grid/network conditions at a given time).

A recent trial of smart storage heating involved roughly 800 customers in three EU countries (Ireland, Germany and Latvia) who made their new smart-enabled heaters available for charging according to grid and network conditions, provided they also met customers’ preferences for warmth at different times of day [8]. Customer experience during these trials was a crucial element of the project, as without willing and satisfied customers, there would be no demand response and no business case for smart thermal storage. Accordingly, customer experiences were monitored through surveys, interviews, and focus groups.

From 161 customers in the three countries who completed at least two surveys during the project, and from interviews with 70 of them, five themes emerged as contributory factors to a good customer experience. They were:

- *Comfort*, the single most important consideration when customers were asked about their new and more efficient smart-enabled heaters and their experiences of taking part in fully-flexible demand response. For the most part, they were more comfortable with their new heaters than they had been with the old ones.
- *Cost*. Although cost is often seen as the main consideration when planning or modelling demand response (sometimes the only one), the trial customers, many on low incomes, thought of it as roughly equal with comfort.

The other three themes all involve communicating and are specially interesting with regard to smart retrofit as each relates to a different type of connection or dialogue. They were:

- *Connectivity* (between technologies). This turned out to be the most problematic single operational issue for the project. Although the components of the DR system had been market-ready, it took a lot of effort to get them to connect effectively with each others. Connectivity multiplies the possibilities for system failure, e.g. when software is upgraded or a component

manufacturer goes out of business, and both network operators and customers needed reliably flexible heating. As one of the project co-ordinators ruefully acknowledged towards the end of the trials, *“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.”* [8, p.61].

A German installer took a similar view of the complexity of connecting the equipment: *“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.”* [8, p.60]

- *Control* (the link between people and technologies). Customers needed to be able to alter their appliance settings, directly or remotely, to manage comfort and costs. The move to ‘smart’ entailed a change from analogue to more sophisticated digital controls. This was not a problem for some participants but caused difficulties for others. Although they had been offered professional advice and written information during installation and sometimes afterwards, some householders were not able to demonstrate how they altered their heater settings when interviewed towards the end of the project. Interestingly, a sense of lack of control was correlated with a perceived increase in bills. In Ireland, 12 out of 16 customers who did not know how to change the settings of their heaters (75%) thought their bills had increased. In contrast, of the 86 who reported that they had some control of their settings, only 22 (26%) thought their bills had increased [8, p.39]. While these were perceptions that could not be tested, due to lack of billing data, they clearly relate to customer satisfaction.
- *Care* (thoughtful communication between people). Installers, utility call centre staff and locally-based people such as housing managers or knowledgeable neighbours turned out to be important for achieving affordable comfort and demand response: people who could advise on how best to programme the heaters in normal circumstances and before going away on holiday, or who could troubleshoot if the devices malfunctioned.

The clear need for different types of communication and feedback raised the question: *who* is needed for well-functioning retrofits? The researchers identified a surprisingly long list from their customer surveys and interviews, and from interviews with project personnel [8]. These included:

- Customers – using the heaters, programming and switching;
- Installers for the heaters, water cylinders, sensors and smart meters – installing, explaining, advising, maintaining and repairing;
- Neighbours – advising and passing on practical tips;
- Housing managers – advising, checking welfare, liaising with professionals;
- Supplier call centre staff – advising, referring problems if necessary to other professionals;
- Project coordinators, who played a central role, orchestrating and explaining activity, resolving misunderstandings and troubleshooting;
- Designers and manufacturers of devices, controls, apps and software –acting on feedback to develop products and services further;
- Demand aggregators – recruiting, planning, coordinating and building a market for DR;
- Network operators – evaluating viability and value of DR in their area, giving or withholding permission to carry out DR;
- Grid operators – monitoring system conditions, planning future supply and estimating DR requirements.

The length of this list and the variety of items listed contradict any notion that smart systems offer a rapid, seamless route to uncomplicated, controlled comfort and low-carbon outcomes. But the

experience of the smart heating trials did demonstrate how, with the help of three types of communication and a range of actors, it was possible to achieve more flexible demand while maintaining or improving comfort. The communication enabled the retrofit innovation and formed part of it.

3.3. *Smart retrofit in a community/neighbourhood setting*

Community energy trials offer a good opportunity to observe situated, social learning. This section briefly describes the trial of a business model and technologies that had been designed for groups of customers sharing the same segment of a local electricity low-voltage distribution network with some form of low-carbon generation, e.g. solar PV, micro-hydro, wind turbines or a combined heat and power plant. This particular trial took place between 2015-17 and involved 48 homes in three neighbouring English villages, 14 of which had rooftop solar photovoltaics (PV). It is documented in two papers by Boait and colleagues [1,2]. The business model took into account technological innovations and also the new actors and activities needed for participants to benefit by:

- shifting demand to use or store locally-generated electricity where possible, avoiding the need to export it to the grid at a relatively low price if the 14 PV-equipped households could not use it at the time of generation;
- avoiding import of non-locally-generated electricity at peak times (when, under cost-reflective pricing, the price would be high); and
- reducing their overall consumption.

This model allowed participants to form a co-operative and to use the profits from local electricity generation and management for community benefit. It can be seen as a ‘community retrofit’ of sorts, involving not only (minor) changes to participants’ homes and workplaces but to their electricity-using practices and interactions with the supplier/retailer and network operator.

Retrofitted hardware included storage heaters and batteries, plus technology to schedule loads in such a way that customers could benefit from the time-of-use tariff while respecting their preferences (for example, for timing their laundry or dishwashing, or for indoor temperatures). There was also a time-of-use tariff with a day-ahead adjustment based on the weather forecast, to reflect the amount of locally-generated electricity that could be expected. The trial participants each had a web-based display of their current tariff and usage, and were given regular feedback on the individual and collective savings resulting from their DR. In addition, the project benefited from well-informed, communicative installers and a member of the project team who was available for a day each week for engagement activities, including occasional social events. These proved very effective at developing and maintaining interest, and for gaining useful feedback.

The results of the trial were highly encouraging. For example, during the year of full operation, over 40% of the electricity generated by PV in 14 homes was used by the householders, while almost all the remainder was available to share with other participants. Financial savings varied between £5 and £12.50 per month on average, being highest in the summer when the solar PV was most productive. The 27 (out of 48) customers who were interviewed by phone reported positive experiences, with most claiming some change in their day-to-day electricity-using habits. For example, one participant had put their electric towel rail on a timer plug to avoid peak-time heating; 17 of the 21 interviewed customers who said they had load-shifted during the trial intended to continue doing so, and there were strong indications of the value of an integrated community approach that allowed people to learn in different ways and at their own pace. As one interviewee commented:

“When you have the reports that came through and here you have the cheque for your money and your report on your energy use, you could practically see how it all fitted together”. [2, p. 10].

The success of the trial has led to a commercial implementation of the business model in a Welsh community and it is being tested in around 12 locations elsewhere at the time of writing.

4. Summary

Balancing a low-carbon electricity system with the aid of demand response is likely to involve millions of small- scale generation, investment, storage and demand response decisions and actions, often on short timescales. Transforming the built environment also involves millions of decisions and actions, usually on longer timescales. Both can be seen as forms of retrofitting. Both call for competences, accountability and qualified trust, along with reliable technologies and finances. Through qualitative research into smart technology retrofit, we are learning about actors and processes that are relevant to the built environment as a whole, especially as ICT percolates further into energy systems. The three categories of technical connectivity, human-technical interaction in controls, and human-human conversations for support and sensemaking were all shown to be essential ingredients in gaining environmentally and socially positive outcomes from smart technology retrofit.

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