Article

Environment and Planning A

Environment and Planning A
2016, Vol. 48(10) 2006–2025

DOI: 10.1177/0308518X16653403
epn.sagepub.com
SAGE

Decarbonisation at home: The contingent politics of experimental domestic energy technologies

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Abstract

Policy efforts to reduce the carbon intensity of domestic energy consumption have, over the last three decades, been dominated by an almost dichotomous reading of the relationship between technology and social change. On the one hand, there is a conception of personal responsibility that constructs domestic energy users as key actors in the adoption and (appropriate) use of low carbon energy technologies; from this perspective, environmental change becomes a matter of mobilising personal capacities such that individuals make better choices. On the other hand, decarbonising homes is conceived to be an outcome of top-down infrastructural interventions, with householders (or end users) positioned as relatively passive agents who will respond to engineered efficiency in linear and predictable ways. In practice, both positions have been found wanting in terms of accounting for how (and why) change happens and in turn delivering on ambitious policy goals. The argument we develop in this article goes beyond critiquing these problematic framings of technology and the locus of agency. Drawing on three contrasting low carbon energy technology projects in the UK, we present an alternative perspective which foregrounds a more experimental, ad hoc and ultimately provisional mode of governing with domestic energy technologies. We reflect on the meaning and political implications of this experimental turn in transforming (and decarbonising) domestic energy practices.

Keywords

Decarbonising homes, experimental politics, low carbon energy technologies

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Introduction

In the UK, the consumption of energy within domestic housing accounts for roughly one third of the country's annual carbon dioxide emissions (Palmer and Cooper, 2011). As such, homes – the people who reside in them and the infrastructure/devices that constitute them – have been positioned by a range of stakeholders, from energy companies to governments and campaigning groups, as critical in reducing energy use and, more particularly, meeting national climate change-related policy goals. In broad terms, two overarching approaches to conceptualising, and achieving, transformation in the energy (and carbon) intensity of domestic life – in relation to the adoption, diffusion and use of low carbon energy technologies (LCETs) – can be identified; strategies that carry rather different assumptions about the social and technological constitution of agency and why and how change in everyday energy-consuming practices occurs.

First, a *human-centred* (Orlikowski, 2007) approach to decarbonising energy systems, in which the adoption and use of technology is understood to be a function of personal attitudes, values and choices. From this position, economically rational actors, equipped with the necessary technical information, will consistently act more responsibly through their personal consumption choices (Blake, 1999; Guy, 2006; Owens, 2000). It is an individualistic model of agency and social change that has dominated social science research on energy demand reduction and policy formulation in the UK for over three decades (Defra, 2008; Jackson, 2005). Shove (2010) and others (Benton and Redclift, 1994; Guy, 2006; Hinchliffe, 1996; Hobson, 2006; Spaargaren, 2011) have critiqued this Attitude-Behaviour-Choice (ABC) model for being too narrowly framed around individual choice, thereby discounting the socio-cultural and structural contexts that people routinely negotiate in organising domestic life. Indeed, raising individual awareness in this way has proven a very weak predictor of performed environmental behaviours (Kollmuss and Agyeman, 2002; Spaargaren, 2011), with concerns raised about the political subjectivities produced – associated with feelings of alienation, apathy and inadequacy (Shove, 2010; Spaargaren, 2011). In this policy paradigm, the nature and capacities of technology, and how devices might have effects (above and beyond those anticipated) on what people do and why, is minimised.

The second, *technocentric*, perspective on demand reduction, by contrast, rests on the capacities of technologies to leverage human action. It assumes that technology is exogenous, homogeneous, predictable and stable, performing as intended and designed across time and place (Orlikowski, 2007; Strengers, 2013). It is a model of domestic energy transformation, which is founded on human passivity, with technologies acting on behalf of people. Change, from this perspective, depends upon the material capacities of the technology itself to engineer appropriate modifications in the detail of daily life. For instance, the UK government's Framework for Pro-Environmental Behaviours (Defra, 2008) sought to influence energy (and other) behaviours through the installation of particular technologies, and, more recently (between 2012 and 2015), the Green Deal and ECO (Energy Companies Obligation) distributed energy efficiency technologies via the private sector in tandem with novel financing mechanisms. This technocentrism is also clear in the government's interest in smart grid technologies, with the mandatory national roll out of smart meters to all homes in England and Wales by 2020, as well as political enthusiasm for intelligent heating controls (Department of Energy and Climate Change (DECC), 2012, 2014b). It also runs through the sorts of libertarian (or soft paternalist) strategies advocated by behavioural economists Thaler and Sunstein (2008), in their influential book '*Nudge*'. Whilst the authors recognise the need to enable (appropriate) human choices, the role of technology and engineered environments is pivotal – expressed

through the material configuration of choice architectures (cf. Whitehead et al., 2011). There are now a great variety of strategies to decarbonise homes that seek to reconfigure consumption practices through the investment of technologies, products and domestic settings with normative capacities – to enable people to be good 'environmental citizens' (Cabinet Office & Behavioural Insights Team (BIT), 2011; Marres, 2013). Thaler and Sunstein (2008) offer a range of illustrations relating to energy policy, including the *Ambient Orb*, a feedback device offered to customers by an energy company in Southern California. They argue that the Orb, which glowed red when homeowners were using a lot of energy, and green when they were using very little, had a dramatic effect on consumption: within a few weeks, users had reduced their peak energy consumption by 40%. In a similar way, Keirstead and Boardman (2005) point to the role of displays (conveying information about electricity generation) in nudging an energy conserving behavioural effect in PV generating households. However, there is reason to be cautious about the potential of such technology-led choice engineering, framed in terms of behaviour change; for instance, home energy monitors, which provide direct feedback on electrical or other energy use, have been disappointing in terms of occupant engagement and changing behaviours (Darby, 2010; Hargreaves et al., 2010; Strengers, 2011, 2013). There is also an established and growing body of evidence that shows a performance gap between design (for efficiency) and outcomes in terms of energy use. This gap has been linked to a mismatch between the normative visions for the technology of producers and potential users (Darby, 2010; Munton et al., 2014; NHBC, 2012; Shipworth et al., 2010). Ozaki and Shaw (2014), for instance, note how the social housing sector's efforts to implement environmental policy through a technology-driven approach created a tension between strategies to influence energy consumption and the ways residents actually incorporated sustainable technologies into everyday practices.

In practice, then, these two readings of the political agencies of LCETs, and the sorts of governance strategies they enable and sustain, have fallen short of expectations in terms of reducing the energy intensity of everyday life. In their place, we suggest that a third mode of intervention is increasingly apparent, which is more provisional in its approach to decarbonisation and the powers invested in material devices. This more avowedly experimental mode of conceptualising social change can be traced in the practices of the growing number of grassroots organisations concerned with providing and using energy at the community or neighbourhood scale. Recent government estimates suggest that there are over 5000 such groups now in the UK (DECC, 2014a) taking different kinds of organisational structure (Seyfang et al., 2013). Interventions take various forms, from 'draught busting' training to curtain-making workshops, the collective installation of PV panels through mutual corporations to the use of energy monitors and devices to make energy visible and sharing knowledge about how/in what ways they changed aspects of daily life. Such interventions are also being conducted though research organisations, including Universities but also other forms of intermediary, including think tanks, consultancies, utilities and local authorities (Hargreaves et al., 2013) interested in establishing the nature and implications of different kinds of design, technologies and practices for decarbonisation at home. Our aim here is to consider the meaning and political significance of this experimental turn in strategies to decarbonise homes. To do so, we draw on three rather different small-scale projects in the UK that represent, in different ways, the deployment of LCETs as experimental objects – seeking to disrupt and intervene in routine domestic practices, but with rather tentative ideas about how these devices matter politically. The first case study is concerned with a series of LCETs, designed to 'nudge' expectations around comfort, developed and trialled by an

interdisciplinary research team; the second a Registered Social Landlord (RSL) led energy efficiency retrofit, which included a switch from electric to gas central heating (GCH); and, third, two projects (one utility-led and one initiated by the Mayor of London) seeking to establish low carbon communities through a range of technological and social innovations, but with a particular focus on the distribution of solar PV units and energy monitors. In the next section, we reflect on a developing body of work that directs attention to the politics of experimental interventions, and consider the implications for a critical engagement with questions of domestic decarbonisation, political agency and social change. This contextualises our account of fieldwork undertaken to study a range of LCET projects.

Experimental politics and LCETs

Within the energy demand literature, the dominant framing of experimental design is, as Hodson and Marvin (2007; also Evans and Karvonen, 2011) suggest, the testing or 'dropping in' of technical and economic projects, to establish performance in relation to certain anticipated outcomes. From a process-oriented perspective, authors such as Michael (2012) and Wilkie et al. (2015) have explored (and argued for) more open and speculative energy demand-related design experiments in transforming the meaning and experience of energy, producing deliberately playful energy objects that are oblique in their purposes – enabling people to re-imagine relations to energy rather than seeking to effect a specific instrumental change in terms of energy consumption behaviour. However, the central interests of this work rest with the ethos and practice of speculative design and action research rather than the political relationalities that such experimentation might give rise to – in other words, the consequences in terms of energy demand and its governance. Recent accounts of urban climate governance offer a more explicitly political interpretation of experimentation (e.g. Bulkeley and Castán Broto, 2012; Evans, 2011; Hoffman, 2011). Bulkeley and Castán Broto (2012: 363), for instance, distinguish their reading of experiment from the formal scientific sense of the term (apparent in Hodson and Marvin's characterisation); instead, they point to the often tentative nature of intervention, and of testing or establishing (best) practice through innovation and experience. At the same time, and in contrast to Michael's speculative experimentalism, they are clear on the purposive nature of urban climate governance experiments – to achieve particular ends and further specific interests. In this respect, Bulkeley and Castán Broto (2012: 367) stress the need to understand the political economies of experimentation, by whom and on whose behalf they are enacted, through which modes of governance and to what ends. However, work on the organisation and practice of climate governance experiments has attended rather less to the capacities and effects of material artefacts, and how such empirical issues matter in the constitution of the political realm.

Marres' (2013) work on sustainable living experiments and eco-show homes is pertinent here; developing an active reading of the politics of technology through a theorisation of material participation and what she refers to as experimental ontology. Marres (2012) uses the term 'sustainable living experiments' to capture the ways in which domestic decarbonisation projects are increasingly oriented to testing forms of material disruption in everyday ways of doing things, often seeking to render explicit aspects of social life that are not usually considered noteworthy. In this regard, empirical instruments – such as sensors and smart meters – play a key role in engaging residents in the proposition and practice of sustainable living. For Marres (2013), an experimental ontology shifts attention away from politics read purely through an epistemic or discursive lens, towards the purposeful design of politics and morality into material objects, devices and settings.

The ways in which things and their deployment affect the very specification of politics and democracy is integral to Marres' notion of an experimental ontology. It is an approach to material politics that explicitly recognises the political capacities of non-humans, that what tends to be considered as human action in practice depends on associations of humans and non-humans acting in concert. As such, and in contrast to an instrumental reading of governance through LCETs which seeks to design material norms into being, an experimental perspective sees the role of material things in the enactment of politics and democracy as inevitably uncertain and contingent; the empirical and normative effects of technology could always be otherwise – there is no pre-defined order to the process of social change, no fixed way in which ideas, materials, actors and so on are to be combined and no natural end-point. The mattering of objects in particular settings and situations is dynamic: smart meters do not just provide information about consumption, 'but enable people to become affected by material and physical things in their capacity of embodied beings' (Marres, 2012: 112). Hobson's (2006) account of how people engage with objects in sustainable living projects draws a similar conclusion. Her study of the Sydney-based sustainable living programme, 'Green Home', reveals the unexpected ways in which interaction with eco-efficient domestic objects (shower timers, recycling bins and so forth) engendered relations of responsibility; with these devices described as 'moralising' machines that physically disrupted familiar ways of being, effecting greater reflection on norms and practices.

Woolgar and Neyland (2013) specifically address the political ramifications of systems of governance and accountability that are organised around everyday pervasive objects (such as recycling boxes and speed cameras). Like Marres, their theorisation of 'mundane governance' critiques the tendency of policy to presume the singularity of the technical capacities of objects, when in fact this ordinary stuff is treated differently in different circumstances. As they demonstrate entities are not given, but rather offer a reference point for temporary attributions of morality or accountability (Woolgar and Neyland, 2013: 51). The authors, for instance, analyse media reporting of an incident in which a woman was fined by her local council for (allegedly) using the 'wrong' kind of black plastic sack for her rubbish (Woolgar and Neyland, 2013: 50). They show how the ontological singularity of this object, as obvious and mundane, is discursively achieved and how 'the blatant ordinariness of a *mere* bin bag' was central to the radical (and scandalous) difference that ensued with regards to in/appropriate behaviour (Woolgar and Lezaun, 2013: 336). Mundane governance, then, sees material things as more explicitly instruments of prevailing social and political forces. Braun (2014: 55) drawing on Foucault's idea of *dispositif*, develops a number of related points about the material politics of urban climate governance, emphasising that government does not proceed the deployment of technologies developed to achieve its goals 'but rather the opposite: technologies present themselves as potent sites for introducing [...] ''administration'' into everyday life' (Braun, 2014: 42). The result is a government dispositif characterised by ad hoc, diverse and loosely connected efforts to introduce 'economy' into existing relations in response to a perceived (climatic) crisis.

Drawing on concepts from this existing research corpus, there are two central meanings of 'experiment' that we pursue in this article. First, the purposive but simultaneously ad hoc, often tentative, nature of interventions aimed at dealing with the climate problematic to which Bulkeley and Castán Broto (2012) refer (also Braun, 2014). Second, we seek to relate our empirical findings to what are essentially ontological questions about the status of experimental (LCET) objects and their relationship to politics (Braun, 2014; Marres, 2012, 2013; Woolgar and Neyland, 2013). To explore these two facets of thinking

domestic energy technologies experimentally, we draw on three low carbon projects, which reflect differences in governance actors involved, the objects and devices being deployed and the normative expectations embedded in their material design.

Experimenting with LCETs

The research on which this article reports draws on three case studies, all interventions that involve mundane household objects (such as feedback devices, heating systems) in efforts to 'test' their capacities to transform domestic energy-consuming practices. The projects can also be read as more provisional endeavours, in terms of the capacities inscribed in objects, the social and institutional contexts of deployment and in the specification of project aims and outcomes. In all three cases, householders were monitored by researchers through qualitative interviews (detailed below) and quantitative measures of internal environmental parameters and energy consumption (see Tweed et al., 2014) to establish the efficacy of LCET installation.

Case study 1 – Merthyr Tydfil (South Wales)

The study was part of a multi-disciplinary project which trialled novel domestic heating control technologies designed to meet comfort expectations as well as achieve substantial reductions in overall energy consumption. The project involved seven households, all renting from a RSL, in a series of three interviews to develop an understanding of social relations, expectations and material artefacts that sustained, disrupted and reconfigured comfort practices at the household level (and over time) (cf. Gram-Hanssen, 2010; Shove et al., 2012). These insights informed the development of prototype comfort feedback devices for testing in domestic settings to establish their empirical performance. Although the overall project was underpinned by certain instrumental goals (focused on achieving substantial emission reductions), the prototypes and their normative capacities can be described in speculative terms; they sought to disrupt routine ways of engaging with energy but the practical consequences, in terms of demand reduction, were distinctly uncertain (Gabrys, 2014; Michael, 2012). A separate prototype heating automation device, developed external to the research process, was also trialled. One prototype was 'installed' per household. A final interview was only conducted at the end of the trial period, which lasted between 6 and 12 months, depending on the device. The two categories of LCETs were:

(1) Thermal feedback devices[1]: Two prototypes were developed that followed from a series of observations emerging from early interviews with householders about their experience of comfort, specifically the finding that ambient light (e.g. electrical fire lights) was an important aspect of 'cosiness' (see also Devine-Wright et al., 2014). Two table lamp devices linked a desirable 'warm' orange glow to a (new) 'normal' (Walker et al., 2015) temperature of 18–21°C: a reduction in lighting or a change in colour signalled a shift in ambient temperature away from this norm (see Figure 1). As such, the lamps were designed to recalibrate everyday domestic spaces (Jones et al., 2011), to prompt a different pattern of low carbon conduct (i.e. to encourage a lower background temperature, and for this to become the default). A further feedback device indicated the temperature of a radiator; a white LED on the radiator indicated the radiator was warm, an orange light that it was hot, and a flashing red light that it was hot and a window was simultaneously open. In this sense, the flashing red light of the radiator

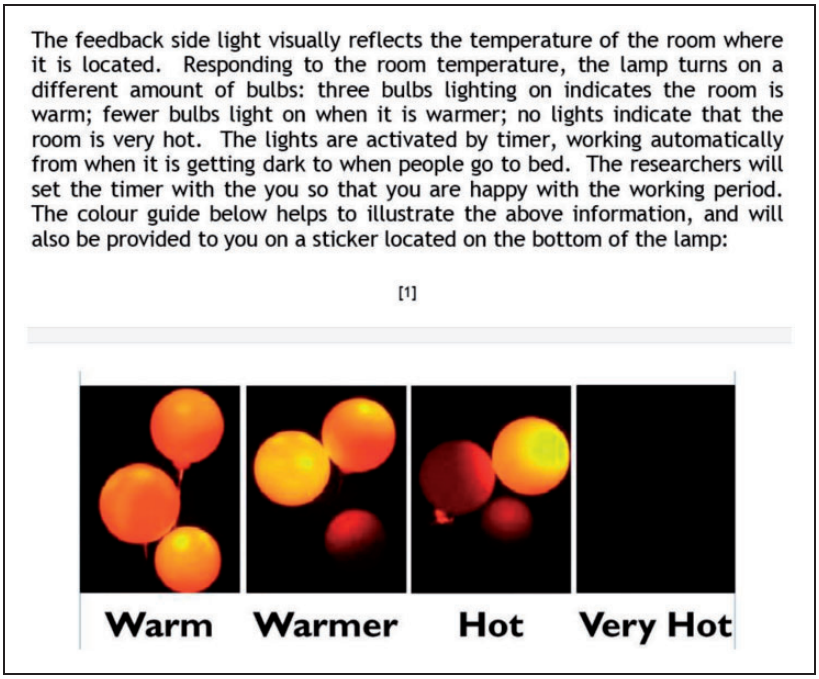

Figure 1. An extract from the guidance information provided to participants – Feedback Lamp 1. © Loughborough Design School.

prototype was invested with certain punitive powers of engagement (Hobson, 2006; Marres, 2013) – the capacity to detect and make visible so-called bad practices.

(2) The Wattbox[2] heating control system is a device for automating a (gas central) heating system, bearing some similarities to the traditional programmer or timer and thermostat. The Wattbox controls central and water heating on the basis of monitoring (and learning) household patterns, derived from electricity consumption and temperature preference data, it aligns with a distinct, and increasingly prominent, strand of government rhetoric and policy centred around 'smart' or automated heating controls. Developed by a team at DeMontfort University prior to commencement of the project, but not widely trialled, the Wattbox is unambiguously deterministic; the design intention being to increase efficiency through materially constraining scope for manual (or human) control of the home heating system. In these terms, it was very much an experimental design, with a great deal of uncertainty exhibited around householder engagement and likely consequences for demand reduction.

Case study 2 – London

Participants, five in total (all owner occupiers), had been involved with one of two London-based experiments in decarbonising communities – the Mayor's Low Carbon Zone scheme and British Gas's Green Streets project. Both schemes sought to promote emission reductions through an emphasis on the diffusion of two types of devices: (a) microgeneration (specifically solar PV) and (b) energy efficiency devices (eco-kettles,

draught-proofing, low energy light bulbs and energy feedback devices). The schemes used an eclectic mix of strategies to prompt uptake, including financial incentives and street champions – the latter, a libertarian paternalist strategy of mobilising intermediaries to effect peer-to-peer pressure (Jones et al., 2011). Providing access to energy monitors can be read in similar terms, a calculative device to nudge or rationalise decision-making by quantifying (the costs of) energy in real-time. Single interviews were conducted with householders some time after their involvement with these schemes and the take-up of devices (April–August 2011).

Case study 3 – Pontypridd (South Wales)

Two households living in the same block of flats, both renting from the same RSL were (along with others in the block) provided with a refurbishment to improve the energy performance of their home – to include replacement of electric space and water heating with GCH (installed in August 2010), external solid wall insulation (installed between November 2010–February 2011) and replacement double-glazed windows (installed January 2011). This formed part of a whole-block retrofit and as such was a decision taken by the RSL rather than the householder. The material changes are not in themselves particularly novel but the delivery of efficiency measures through RSLs and the focus on the universal deployment of prescribed material and system-level changes raises questions about institutional expectations (cf. Ozaki and Shaw, 2014), and, in this case, the constitution of GCH as a technology for demand reduction. Householders were interviewed twice – once immediately after the installation of the new heating system, and again 15 months later (December 2011).

Fifteen households (comprising one or more individuals) were interviewed across these three projects, an evaluative and reflective process aimed at exploring the multiple effects of these material interventions. In terms of the conduct of fieldwork, in all cases, in-depth interviews were undertaken with participants – an approach that offers insight into what people (generally) do, as well as how they themselves narrate normal life – why they do things as they do and what significance they attach to doing things in that way (Butler et al., 2014; Hitchings, 2012). It is also a methodology, particularly when used on a repeat basis, that enables the researcher to locate normal practices historically and thereby develop a more dynamic picture of how (when and where) change happens. In what follows, we explore householder engagements with these LCETs and their politically constructed capabilities.

The contingency of domestic energy experiments

Our account of householder engagements with LCETs from the varied case studies is organised around two key concerns: the *reordering of control*, which addresses how devices intervened in everyday domesticities and accountability relations, relative to their design expectations; and *the ambiguity of design*, which directs attention at the moral-political implications of these mundane devices, which extend beyond their immediate empirical effects at the level of energy-consuming practices.

Reordering control: The limits of instrumental designs

As noted above, the LCETs trialled in case study 1 were designed to prompt reductions in consumption of energy for heat. The smart heating control system (the Wattbox) was engineered to ensure an optimum level of comfort and economy from the heating system

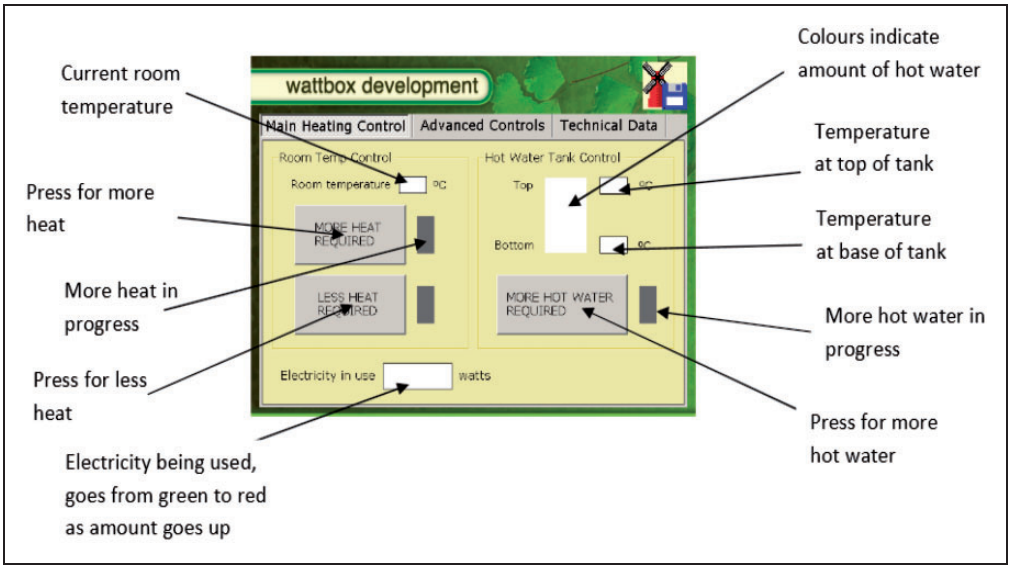

Figure 2. The Wattbox interface. © Institute of Energy and Sustainable Development (IESD), DeMontfort University.

based on patterns of use for electricity and hot water and by minimising user input. The technology offered some facility for householders to adjust settings using a touch screen to indicate more (or less) heat and more (or less) hot water (Figure 2), but such modifications were discouraged to maximise performance.

In practice, it was clear that this optimal material performance had not been achieved. The two households involved in the trial described how they felt the Wattbox had *forced* them into greater inefficiencies, and that the heating was on far more than if manually controlled. Louise preferred manual control of the GCH system and was critical of the Wattbox's engineered capabilities – particularly to recognise and deliver *her* thermal comfort requirements, and as a result, it was removed early on in the trial. In both trial cases, this rigid and technocentric reallocation of control upwards to 'the system' precipitated a reading of the Wattbox as dysfunctional: Julie, for instance, referred to persistent 'breakdowns' and of constantly being 'locked out' of the heating system. Ultimately, these responses chime with what is known about the insertion, into domestic spaces, of deterministic devices that render householders passive consumers. As others have noted (e.g. Cooper, 1998; Crosbie and Baker, 2010; Rubens and Knowles, 2013), technically rational designs for heat management are not straightforwardly accommodated by householders who tend to express a desire for greater (inter)active control.

The social housing retrofit switch to GCH (case study 3) similarly reflects a form of intervention focused on the roll-out of more energy efficiency technologies. In one sense, the new GCH system imposed certain constraints in terms of 'control' for comfort but, by and large, it required and enabled more user input. From the perspective of the three social housing tenants – Kath, John and Peter[3] – this reordering of control was central in their accounts of what amounted to a transformative shift in their experience of comfort. All expressed a view that the switch had freed them from an inflexible system associated with feelings of powerlessness and a sense of being trapped and unable to 'risk' turning the heaters off for much of the year. Components of the GCH system (thermostat, boiler

controls, TRVs) enabled a range of (new) inter-active comfort practices; as Peter commented, 'all the radiators have thermostatic valves on them, you know, so you can control the actual individual radiators'. These co-constituted capacities were articulated in terms of enabling personal control over comfort – rather than the political ideal of efficiency that underpinned the Pontypridd project. However, the devices and their role in normal comfort management, and as such outcomes at the level of energy consumption, diverged considerably. For John, the new GCH system was integrally bound up with new comfort practices that were articulated in terms of an embodied sense of control, and also a marked increase in the 'normal' temperature of his home (i.e. the rebound effect). He talked about wearing 'normal' clothes rather than using multiple layers; and he no longer wore hats, coats and gloves indoors. For Kath, the responsiveness of the GCH was liberating – she could turn off the heating without fearing the consequences of a decline in external temperature. It is of note that our participants did not utilise these material capabilities to their full – John and Kath didn't use the TRVs and not one of the householders showed interest in the programming functions of their new heating system. For these three householders, then, the GCH offered opportunities to extend and expand choice. Outcomes, as a result, were variable – in all cases, domestic comfort increased, but certainly energy efficiency was not particularly salient in the way they talked about the system-change and where recognised was focused on cost reduction.

The comfort feedback devices offered rather different opportunities for user engagement and choice that were oblique in their links to efficiency and demand reduction, although nudging changes through the provision of real-time information was explicit in the design of these prototypes. Perhaps not surprisingly given the critique of policies oriented to raising individual awareness (e.g. Shove, 2010), the post-trial interviews made clear that any interest participants had initially held for these devices diminished over time (cf. Hargreaves et al., 2010) and people did not, on the whole, recognise any changes in comfort and energy consumption routines associated with the LCETs. Overall, they were seen as an irrelevance or, where engaged with, they alerted people to practices which, for a variety of reasons, they felt unable to change (see also Strengers, 2011). As Hannah commented in response to being asked about the signals conveyed by the radiator feedback device 'Yeah, it is nice information, but it doesn't mean that it would change you; because I just think if you're cold you put the heating on'.

Four households had elected to have solar water heating or PV electric units installed (at no or lower personal cost),[4] linked to schemes that sought to reduce domestic carbon emissions through a supply rather than demand based technology. The existing and small body of research on post-installation responses to microgeneration offers not only some compelling evidence of impacts in terms of reducing energy demand but also more critical and ambivalent findings (Dobbyn and Thomas, 2005; Keirstead, 2007), with misuse, disappointment and rebound effects also reported. All of our participants reported changes following installation, revealing a range of dynamic responses to generation infrastructure that went beyond a switch in sourcing electricity. Participants talked about putting appliances (dishwasher, washing machine, etc) on during the day if the weather was sunny, so that they could use the electricity that they were producing. Fiona no longer used the washing machine or the dishwasher in the evening. She and her husband had made a deliberate effort, initially for economic reasons, to follow the rhythms of PV generation and 'use appliances when they're actually generating. It seems to make sense'. As with the use of energy monitors (case study 2), the capacity to quantify energy generated or consumed (through different calculative frames) was key to enabling these kinds of adjustments. Other studies point to similar shifts in practices – using electricity during the daytime,

using appliances sequentially and turning off appliances at the wall (Good Energy, 2011; see also Bulkeley et al., 2014; Dobbyn and Thomas, 2005). A survey of 479 Feed-in Tariff customers and prospective generators by Good Energy (2011) found that 65% of generators had changed their consumption pattern to match their generation (cf. Keirstead, 2007). Our participants described these shifts in explicitly interactive terms, as 'fitting in', or 'learning to live' with the system. Jenny, for instance, spoke of adjustments in the timing of her hot water use (particularly for bathing) following the installation of a solar hot water unit [she had expressed interest in having the unit fitted for primarily economic reasons]; the intermittent nature of solar-generated hot water had effected a shift in her expectations: 'you learn to, [...] know when you've got water. But this time of year I don't expect [continuous] hot water'.

Across the board, the LCETs included in our case studies can be read as reproducing and reworking an array of political logics – informing consumers, nudging human behaviour and/or imposing new socio-technical norms and practices – although devices were not (always) engaged with as per these instrumental expectations. What stands out is not the relationship between certain logics and empirical change but rather how the interactive socio-material capacities of objects to do work (above and beyond what they had been designed to do) matters. So, for instance, the way in which a switch from an electric to a GCH system co-constituted 'new norms' around comfort for some, and for others offered a means of enhanced personal control. At the same time, the findings underline that attempts to fix the material capacities of things in terms of narrowly delimited feedback devices and system-level changes that lock-out householders are likely to be ignored, resisted or rejected. These observations point to critical questions about the contingency and openness of (some) LCETs, and how (and why) the constitution of low carbon objects is of consequence in terms of re-imagining the governance of domestic energy.

Ambiguous designs: Enabling an experimental politics?

Across our research sites, several households had installed solar water heating or solar PV electric units, and it was particularly in relation to these devices that we saw sustained changes not only in the configuration and rhythm of everyday practices but also, and crucially, in the moral-political conception of energy as a concrete and variable entity. Whilst such impacts have been observed elsewhere (Bulkeley et al., 2014; Dobbyn and Thomas, 2005; Strengers and Maller, 2012; Strengers, 2013), existing studies tend to focus on the qualities and capacities of particular devices (e.g. Strengers, 2013), tracing empirical effects but not necessarily addressing the political significance of technological designs and interventions (though Marres' related work on eco-showhomes is a notable exception). To explore some of these questions about the role of LCET experiments in shaping and sustaining certain political and democratic arrangements, we discuss the calculative and affective capacities of LCET's – two very prominent aspects of how people engaged with devices across our interviews.

First, the calculative registers of many LCETs were of significance in rendering energy in meaningful and concrete ways. Several participants talked about how capacities to produce and quantify in situ electricity generation, particularly through monitoring devices, were critical in the evolution and stabilising of more frugal domestic practices (cf. Marres, 2011) – signals that register, as Braun (2014: 54) comments in relation to a petrol consumption gauge, 'at a preindividual, affective level, such that the responses of the individual increasingly approximate the ''automatic'' responses of a machine'. Sarah, for instance, spoke of a shift in the way her husband thought about electricity and its

conservation, following installation of PV panels and the capacity, in some sense, to make tangible, spatially and temporally, its production. In a similar way, Linda talked at length about her use of an energy monitor (a device that she had been able to access through the London-based Low Carbon Zone initiative). As a device, an energy monitor can render visible electricity flows in different ways – as a commodity (price), a resource (kilowhatt hour) or impact (greenhouse gas emissions) (see e.g. Strengers, 2013). Linda was particularly interested in identifying the financial costs of energy intensive practices and, to this end, put a lot of time into programming the monitor to generate a form of information that was useful to, and usable by, the family. She used bills to set up a daily financial target because 'I felt people weren't really interested in anything else'. Through a prolonged interaction with the device, the family had come to reimagine household practices through their energy intensity – as expressed through costs and in relation to daily targets. This rationalising of energy consumption had become woven into the socio-material fabric of domestic life: an automatic if occasional 'check' – to keep track of what activities or appliances made it [the monitor] go 'off the scale'. Linda was enthusiastic about the interactive capacities of the monitor, offering demonstrations to family and friends (as well as to us).

> Interviewer: So, does that ever get old? Do you think, I know how much this is going to use now, or do you still have a little bit of a look anyway?
> Linda: I still have a little bit of a look. I think we all do. I mean it may wear off but I think it's kind of, I think now that the behaviour's changed – you want to know. [...] I think it has definitely changed our behaviour, definitely.

This presencing of energy reflected not only the design of the monitor but also the adaptive nature of the scheme itself – which used Street Champions and tailored home surveys to connect householders to LCETs. In Linda's case, there were many interventions she didn't want (or felt were not relevant) 'I think I had about half of the light bulbs for energy saving, [and the energy surveyor] left me a letterbox cover and the monitor. [...] he left me a package of goodies to implement'. With a note of surprise, Linda described the energy monitor as 'one of the best things actually'. Yet, as Marres (2012) points out, the normative charge of objects varies – such effects are not (and were not) the case for all participants who had access to or used an energy monitor (Hargreave et al.'s 2010 work underlines this).

A second aspect of LCET design that featured across the case studies and accounts of change (or not), centred on the physical presence of devices and their aesthetics – their capacities to captivate and affect, to make energies in a more pluralistic sense (see Marres, 2012; Pierce and Paulos, 2010; Strengers and Maller, 2012; Strengers, 2013). Solar energies, in particular, revealed a capacity to affect – emotionally and ethically – so-called producer-consumers or prosumers above and beyond a rational quantification of production (e.g. discussion in Strengers, 2013). Bahaj and James (2006) have also talked of the visibility of solar PV systems in making the technology one of the best in terms of raising understanding of energy use. In a similar way, our participants pointed out how the physical presence and aesthetics of PV panels had politicising effects on immediate neighbours, with people seeking out technical information and, in the case below, one of the 'street champions' organising a neighbourhood workshop to encourage and facilitate participation:

> Paul: So most of them [neighbours] know that I have got the solar panels, because they're fairly obvious on the roof. So, a couple of people have come up to me and said, oh I've . . . I saw them

> installing it. The chap opposite said, oh, it's really exciting, isn't it? So he . . . so they're interested and quite keen. And we're having a solar panel workshop in the library.

For Sarah and her husband, this direct and proximate relationship with systems of production made a particular form of energy that was both present and scarce, that engendered a form of care, with consequences for the reconfiguration and demise of certain practices. Indeed, Sarah drew a direct analogy with farming (see also Pierce and Paulos, 2010) – and the way a farmer relates to crops: 'you don't waste what you produce'. Dobbyn and Thomas (2005) similarly describe how some householders talked about the sheer pleasure of creation and of self-sufficiency. Strengers (2013: 146) refers to how energy making practices, such as chopping wood for a fire or using a microgeneration unit, give different energies specific meanings and values: 'energy is repositioned as something that is made locally in a limited amount, rendering it more visible material and imbued with meanings of scarcity'. Linda's purposing of the energy monitor makes precisely the same point about re-constituting energy as a scare resource (through the setting of daily targets). It shifted the family's way of conceiving of energy and in particular the relationship between energy and certain routine practices. Linda talked, for instance, about how her teenage son had used the energy monitor to locate (financially) the costs associated with a whole range of everyday practices within the household – including use of his Xbox (a video game console) – and that this economic presencing of energy (consumption) had more deeply affected the way he related to energy (conservation), as well as impinging on some of his routine (energy consuming) practices.

> Linda: Initially they weren't really interested until [my son] saw the machine working in the kitchen and he got very excited, particularly when it proved that his Xbox was quite low energy use. And then he spent the next week running up and down telling me every time it had gone up when dad was using the shower, [my daughter] had left her television on or something. So, he was trying to score bonus points all the time, and it's worked with him. He's actually quite good, and then he put in the E.ON [standby] plug[5] himself and set it, I didn't have to set it up, he set it up in his bedroom. [. . .] [It] was just something that got him hooked.

To a degree, discussion of the thermal feedback devices touched on their affective force. So, whilst Gemma did not recognise any direct changes in household comfort routines during the period of the radiator feedback trial she did reflect, almost with surprise, on how: 'I now stop and think before I put the heating on'. Hannah talked about how the light signals of the radiator device had made tangible a particular kind of energy wastage which had affected, if only momentarily, the family:

> Hannah: My son-in-law would open the window and shout out to somebody and you could see the colour changes straightaway; and then when you shut it, it clicked back on to a different heat. It does make you more aware of the temperature in the room like. Yeah [. . .] well, you can see the difference when you opened the window how your energy is flying out of the window.

In such accounts, everyday activities like using an Xbox, showering, using a washing machine or opening a window resonate with other matters – financial efficiency, scarcity and in some cases wider concerns about resource consumption (cf. Marres, 2013). More commonly the comfort feedback prototypes, and the oblique links made between ambient comfort and demand reduction, failed to achieve their normative intents – eliciting feelings of confusion and annoyance. In the example below, Gemma talks about her experience of

the radiator device, and how a change in colour (from orange to white, from hot to warm), contrary to the designers intentions, often served to remind her that the radiators were cooling and in turn prompted her to turn up the thermostat.

> Gemma: Now, sometimes I notice, we'll be sitting here and I think: oh, the white light is on there. And for some reason the radiator was going off. So, it was good because otherwise perhaps you wouldn't notice. And then you think: oh, I don't feel so warm now and the heating's on. [...] I'd turn up the thermostat for a bit. And when I see it come back then onto the orange then I'd know it's okay now.

For the most part, these LCETs did not resonate with people's experience of comfort, the visual ambience of the lamps did not appear to convey comfort and warmth once abstracted from the symbolic and material context of an electric fire (see discussion of case study 1). Jenny, in fact, disliked the table lamp as a feedback device (a response that members of the team had certainly not anticipated); it conflicted with her conception of what such a LCET should look like and how it should perform. Crucially, she could not accept this alternative constitution of a table lamp and the political work it might do (cf. Woolgar and Neyland, 2013). 'It's pleasing to the eye, but I couldn't, as a gadget I couldn't fall in love with it [it failed to] trigger in me that it was anything to do with heat' (Jenny, feedback light).

Finally, it is important to note how our participants who had moved from electric heating to a new GCH system showed no changes in terms of their understanding of, and relations to, energy and its wider socio-technical production. Although the shift in heating infrastructure was described as life-changing, energy remained a distant and invisible resource. The system components and purposes were accepted as a given, and as such the switch in infrastructure did not disrupt established ways of thinking about and locating energy.

Our intention in this section has been to explore how the physical attributes of LCETs mattered politically, with some notable examples of devices disrupting established conceptions and practices around energy, and of these devices affecting and captivating those who interacted with them. Here we have emphasised how the interactive capacities to measure and make tangible energy (through indicators of costs, consumption or comfort) constitute forms of political engagement with energy demand – engagements that in many cases operated on normative planes that exceeded and/or problematised the instrumental goals set by those doing the experimenting (whether policy actors, RSLs or researchers).

Conclusions

In this article, we have explored the findings from qualitative research that followed three UK home decarbonisation experiments, to explore how LCETs impinged on everyday practices and what such interventions mean in the context of governing domestic energy. From this perspective, our analysis offers some points of critical engagement with models of 'behaviour change' rooted in human and/or technological determinism that have tended to dominate policy and academic analysis. All LCETs discussed had specific purposes invested in their design and functioning, aimed at informing, nudging or steering, through material means, human participation in the project of decarbonising homes. There are a number of observations that arise from the empirical findings of this article. It was clear that where feedback devices offered little scope for user interaction, responses were marked by resistance, alienation or outright rejection. Where LCET's were more mutable in terms of their normative constitution (e.g. PV panels), we saw (often unanticipated) socio-material

practices evolving that not only reflected change in the temporality of consumption but also shifts in conceptions of energy and what energy is for (Shove and Walker, 2014).

Furthermore, whilst we can certainly identify findings that suggest feedback devices (notably energy monitors) may prompt new patterns of conduct around energy use and demand, in line with Thaler and Sunstein's (2008) behavioural nudge, we argue that the capacities of these objects were far more variable and, in this sense, the power of devices resided, to some degree, in their performative range rather than in delivering on prescribed political functions. Here, then, it is important to recognise that even the more deterministic devices accommodated a range of meanings and normative functions (cf. Marres, 2013); for instance, the Wattbox was constructed both as a device of efficiency and a technology of discipline that excluded and disempowered.

This brings us to the challenging question of what sort of politics these experimental endeavours, individually and collectively, sustain or bring into being. The three studies broadly sit within a technocratic policy context of delivering large scale transformation in consumption through the diffusion of efficiency and smart devices and by incentivising and nudging take-up (see, for instance, Cabinet Office & BIT, 2011). DECC's 'Smarter heating controls research program', for instance, is oriented to concretely establishing 'if improving heating controls reduces the energy consumed by householders and why' (DECC, 2014b) – reflecting a conception of technologies' capacities as singular and fixed. Political responsibilities are also increasingly distributed across governance actors – including energy companies, utilities, local authorities and community organisations – exemplified by the unpopular 'Green Deal' (e.g. Vaughan and Collinson, 2014) with its emphasis on the take up of LCETs and the expanded role of the private sector. In this regard, the rather ad hoc and uncoordinated mobilisation of LCETs in governing domestic energy reflects certain neoliberal tendencies 'in which government seeks not to punish, nor to prevent or discipline, but increasingly to modulate 'natural processes' in the context of an impending environmental crisis, sustaining an 'enduring fiction that very little needs to change at all' (Braun, 2014: 61–62). And to a degree, our findings support Braun's analysis of urban climate governance through smart technologies – the aspirations of projects fall well short of radical change and, empirically, the experiments offer little direct evidence of wide-ranging transformations in householder expectations, norms and practices.

However, there is a more optimistic reading to flow from our account. In this article, we have pointed to ways in which certain LCETs functioned to presence energies and in many cases to affect participants – bodily, morally and politically (cf. Gabrys, 2014; Hobson, 2006) – extending beyond prescribed instrumental agendas. The findings from those with solar PV units, and to some extent feedback devices, contrasted markedly with traditional centralised forms of generation and supply, characterised by the dislocation of (inside) energy consumption from (outside) production, rendering energy as an abstract force entering the home (Burgess and Nye, 2008; Dobbyn and Thomas, 2005; Hargreaves et al., 2010; Hinchliffe, 1997; Strengers, 2013). So, for instance, whilst PV is not conventionally framed as a device for demand reduction, its sheer physical presence, the capacity to monitor production and the immediacy of the base resource (sunshine) served to transform 'solar' into a tangible resource – connecting 'invisible' energy use to 'a more considered frame of consciousness' (Burgess and Nye, 2008: 4458; cf. Strengers and Maller, 2012). Solar energies became a resource with a distinct spatio-temporal rhythm that could be wasted – a re-imagining of energy that had the power to make users 'think, feel, and hesitate' (Stengers, 2010: 14; cf. Gabrys, 2014). As such, the consequences of PV extended beyond a temporal shifting of consumption practices to include more embedded and embodied changes consistent with reducing energy demand. In some cases,

householders-and-their-panels were co-constituted as political actors in recruiting and facilitating wider neighbourhood participation. Here, it is useful to briefly reflect on related observations from Aylett (2013) on neighbourhood adoption of solar energy in Portland, OR, and the central importance he attaches to social ties in building demand for technological change. Whilst offering a rich and insightful account of socio-technical transformation at the community scale, the account rests entirely on social actors and capacities with no sustained engagement with how PV technologies mattered in this transition. Our own observations point to the political possibilities of the diverse capacities of PV infrastructures – how the ability to monitor and presence energies problematised extant domestic energy relations and the normative logics to which LCETs are typically mobilised (cf. Braun, 2014).

For energy demand research, then, there is a clear opportunity to move away from the dichotomies of technological or human agency to more fully scrutinise and better understand the political capacities of experimental objects. How do particular devices come to matter to people and what sorts of normative capacities co-evolve? How do these socio-material affordances disrupt established practices and with what empirical and political consequences? How are the capacities of LCET devices being (or how could they be) mobilised, and stabilised, in the enactment of energy demand politics? Here, then, we can identify a critical role for research that takes up the challenges of co-design and speculative design laid down by authors, such as Michael (2012) – to rethink the stuff of energy as well as the role of technology in delivering lower carbon homes. In Michael's (2012) work, participants were asked to document on a map the aesthetics of energy in different parts of their home as a way of inviting them to engage not with the closed problem of reducing energy demand (how to change energy consumption behaviour) but with the open prospect of reimagining their relation to energy. From this, Michael argues for forms of de-designing technologies – producing artefacts that are deliberately ambiguous and opaque, but which in prompting unexpected relationalities can undermine and reframe standard perspectives on demand reduction. For our purposes, however, Michael's account does not fully address how such relationalities might reformulate questions and political strategies around demand reduction. An experimental ethos, as we have discussed here, problematises the dualisms of technological versus human determinism and can, in this regard, suggest policy interventions that are more responsive to the variable political constitution of LCETs. PV is a useful example to expand this point; the temporal reordering of some electricity consuming practices that we (and others) have observed is partly set within a structural tariff framework which values total generated electricity. Whilst there are issues with the feed-in-tariff and the economic signals it sends, it has, along with the PV infrastructure, undoubtedly played a role in stabilising practices around measuring, sensing and visualising dynamic energies discussed in this article – practices which interrupted norms and reframed demand in unexpected ways. Such shifts were not necessarily anticipated by actors leading the relevant schemes; in this regard, a richer, exploratory understanding of the everyday constitution of PV designs (including monitoring equipment) in-use could inspire more targeted interventions and strategies that prompt and reflect re-imaginings of solar energies. The mass roll-out of smart meters in the UK, bound up with normative thinking about how people will respond to real-time information on energy use, similarly provides an example of where a much greater openness to the varied capacities of LCETs as well as to principles of co-design and de-designing would likely offer new ways of thinking about feedback information and automation, and negate certain resistances to what Walker et al. (2015) have referred to as 'new normals' – in their case, built forms and social practices centred around zero-Carbon living. Finally, whilst some of the more explicitly

'experimental' devices we trialled – notably the comfort feedback devices – had an undoubted affective force, it is important to remark how the general disengagement of participants from these devices might reflect the externally defined visual cues and thermal norms built into their form, arguably underlining people's exclusion from the experiment. In this sense, we return to Bulkeley and Castán Broto's (2012) call for research to be more alert to the political economy and ethics of an experimental politics; so any exploration of participatory methods of speculative design must be matched by an equally close scrutiny of accountability relations surrounding the political implications and applications of experimental devices.

Acknowledgements

Our thanks to the anonymous referees for their insightful and constructive comments. We also owe a debt of gratitude to the people that we interviewed who were kind enough to share their knowledge, experiences, and opinions. The usual disclaimers apply.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The research on which this paper is based was funded by a grant from EON/EPSRC (EP/G000395/1).

Notes

1. Developed by the Loughborough Design School.
2. Developed by a team at DeMontfort University prior to commencement of the project and, in 2011, bought by the Smart Home technology company AlertMe.
3. In all cases, pseudonyms have been used.
4. Either no cost through an RSL or no/low cost through a local scheme open to private householders.
5. E.ON is a UK Energy Supplier. The standby plug is a device that turns appliances plugged into it off rather than allowing them to remain in standby mode.

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