Title: People and energy use in the indoor and built environment

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The increasing potential for dramatic climatic changes, the need to protect the future of our energy supply and rising fuel prices, mean that there is an urgent need to reduce energy consumption. This Special Issue of Indoor and Built Environment on '*People and energy use in the indoor and built environment*' recognises that while buildings account for 32% of total global final energy use[1], the role of people in buildings' energy use is often overlooked, despite the fact that '*buildings don't use energy: people do'* [2].

The papers in this Special Issue demonstrate a broadening of the social science contribution to understanding energy use in the indoor and built environment. As well as focusing on 'routine actions' (or behaviours) *using* technologies and buildings, many papers presented here focus on 'one-off actions' to *change* technologies or buildings. Several papers go beyond a focus on individual building *occupants,* to include *chains of actors* or intermediaries (e.g. landlords) that influence the choice and/or use of technologies or buildings. These papers often also address the *processes or chains of actions* entailed in introducing new technology or buildings – such as service design or the communication process. Many papers explore the social, economic or technical *context for actors and their actions.* Most papers explore *motivations for actions.* Indeed, for many authors in this Special Issue, context *is* motivation and, combined with existing technologies and buildings, it creates the conditions that virtually *require* the routine actions that are observed. A few papers report on experiments with relatively 'deep' interdisciplinarity; approaches that might help the social and technical sciences learn from *each other*, and so improve our understanding of people and energy use in the indoor and built environment.

Three papers focus on the ***use of technology***. Moore at al. note that the installation of heat pumps into homes has traditionally been seen as a purely technical matter, but if heat pumps are not used effectively, they won't save energy. Examining the installation of domestic heat pumps in UK social housing, they focus on the design of the service to support the user experience of this new technology. Landlords and installers thought heat pumps were too complicated for users and more complicated than necessary. Tenants felt they were given insufficient information on how to use their heat pump, and many lacked confidence using heat pump controls, resulting in feelings of frustration and dependence. However, the authors' prototype leaflet on using the heat pump controls was not favourably evaluated by users and tenants wanted a personal follow-up visit from the landlord or installer to answer any questions. Belatedly trying to explain how to use a too-complicated technology seems a less-promising approach than developing a technology and its control interface to suit its users. Dimitrokali et al. also examine the use of technology – smart home heating controls. Participants were customers of a UK utility company who volunteered to take part; nearly all were men who felt they had a good understanding of the purpose of smart home heating controls. Participants felt the trial positively changed their heating behaviour, but wanted better capacity to control

schedules when away from home and personalised tips on how to control their heating.

The use of technology is also explored by Watson, focusing on a recently built UK 'passive design' office development, featuring a range of natural ventilation technologies and newly inhabited by a tenant organisation. The building was using significantly more energy than predicted, even after a post-occupancy evaluation helped fine-tune the technologies. The author uses social practice theory to understand this 'performance gap'. Although the material element (technologies) of social practice theory was eventually functioning correctly, this was not the case for the three other elements of the practices framework: embodied habits, engagement (developing shared meaning) and institutionalised knowledge. The habits of building users were deeply embedded after years of using mechanically-cooled buildings, placing windows in the unusual position of being a contextually 'new technology'. Due to the invisibility of the natural ventilation technologies, users did not regularly open windows. ***Intermediaries*** such as the engineering contractor, facilities manager and officer manager had different views on the level of detail users needed and how best to provide it. There was no established mechanism to create a coherent and motivational institutionalised knowledge; each intermediary assumed that his/her own perceptions of what was useful ~~was~~ were 'correct'. The outcome was a lack of suitable institutionalised knowledge or shifting of embedded habits. This highlights the importance of addressing the ***communication process*** across different intermediaries.

Moore et al. also include ***the role of other actors / intermediaries*** in their investigation of the ***design of the service*** to support the user experience of the new heat pump technology being installed in social housing. They studied service recipients *and* service providers, realising quickly that heat pump *installers* also played an important role in service delivery, providing users with information on what to expect with the installation, as well as advice on how to use the heat pump. Consequently, installers were included in later stages of the study. Owen & Mitchell also found energy technology installers and advisers to be very influential in decisions over whether or not to retrofit new energy technologies into the home. How well installers handled the highly disruptive process of installation had a large impact on householder views of the new technology and even their view of how effective it was. They note that technical, commercial and social networks influenced intermediaries' ability and willingness to deliver energy retrofit measures, but that there is little systematic study of these networks.

The role of actors other than building occupants is also examined by Ambrose, who studies the role of landlords in private rented housing in England, where tenants cannot directly influence the energy efficiency of their homes. Although landlords were very aware of the energy performance of their properties, they were still very unlikely to improve them. As expected, one reason for this was the principal-agent problem - the mismatch between who pays for energy efficiency measures and who benefits from them. In addition, Ambrose found that the ***context*** of the housing market matters. At this lower end of the rental market, landlords had little equity in the homes, and a fairly low ceiling on the rent that could be charged. They were not willing to invest more than the housing value could support. The landlords prioritised functional or cosmetic improvements rather than energy efficiency, because they felt tenants rarely ask about energy costs or energy efficiency. Moreover, landlords felt that poorly performing properties were the norm in the case study area.

Skjølsvold & Ryghaug also highlight the importance of the context – in this case the social and material context of a new technology. They examine four Norwegian smart grid demonstration projects using a science and technology studies framework. This framework emphasises that, for a new technology to work, it needs to become embedded into a pre-existing social and technical context. For instance, a washing machine cannot work without physical and social infrastructure such as water pipes, electricity wires and utility billing regimes.[3] The social and the technical are seen as so deeply shaped by the other, that the term sociotechnical systems is often used.[4] Skjølsvold & Ryghaug point out that the sociotechnical context for smart grids varies by location, as does the specific set of actors involved in embedding the new technology (for instance policy makers, electricity grid companies, building industry, users).The same technology can mean different things to different actors and in different locations, so the potential of smart grid technologies varies by location. This can result in different choices being made in different locations; smart grid technologies that were initially the same may evolve to look quite different and perform different roles in different locations. In one demonstration project, smart grids were seen as an opportunity to deliver cost-effective healthcare and simplicity to elderly and disabled householders. In another, the existence of many second homes in the municipality, already equipped with monitoring technology, was seen as an opportunity for the smart grid to build on. The quite different smart grid systems developed in the demonstration projects show that smart grids need not be homogenous, and are more successful when pre-existing local social and technical arrangements are understood and taken into account, adapting smart grid technology to the local situation.

Watson, Gabriel and Rooney provide fascinating details of a contextually sensitive community-based approach to working with a disadvantaged community to improve the energy efficiency of their homes. The program employed intermediaries in the shape of a community development officer and local residents as energy champions. The energy champions received training in home energy efficiency and communications, as well as a home energy audit and upgrade. The community development officer and champions designed a program to educate and up-skill residents in energy saving in their homes, tailoring the program to make it highly relevant to the local community, using very creative approaches. This ***participatory*** program reached new audiences but was time and resource-intensive.

The importance of participatory approaches is also emphasised by Endrejat et al.. They review the main psychological models for understanding behaviour and behaviour change, including the psychological theories behind information campaigns rarely changing behaviour, the power of habits, and the rebound effect. They outline the psychological differences between domestic and non-domestic energy conservation - highlighting the role of organisational culture in influencing social norms that then impact on behaviour. The authors then outline the psychology behind the reasons why top-down approaches to energy conservation in the workplace are likely to fail, but participatory approaches are likely to succeed. This is partly because participatory approaches develop the new social norms required for the new behaviours. The authors then argue that 'motivational interviewing techniques' could be a promising participatory approach to use in the workplace, since it should stimulate employees' motivation to take energy saving behaviours.

The dominant 'physical technical economic modelling' (PTEM) approach outlined by Lutzenhiser over two decades ago[5], ignored contributions from psychology for many years.[6] More recently psychology is being used by policy makers to supplement the 'PTEM' approach[7]. In contrast to

the position of psychology, some social science contributions cannot *supplement* the dominant PTEM approach because their worldview, conceptual tools and language are so different from the dominant approach and indeed often challenge the foundations of the PTEM approach. Consequently, their radical insights are not readily understood, or welcomed, by many of those working with a PTEM framework. The following contributions all seek to make these ***'radical social science' insights more accessible*** to a PTEM audience.

Unusually, Torriti et al. employ a social practice framework for re-interpreting *quantitative* data. Their analysis of UK time use data estimates potential *flexibility* in residential peak electricity demand. Inflexible electricity demand was defined as those times when social practices were undertaken in the company of others, or entailed high spatial mobility, or energy-consuming home activities, or many activities taking place within a time period. This analysis can help identify households, locations and times of day where practices are most and least flexible, helping electricity network operators to identify options for peak load shifting. They find morning peak loads exhibit the least flexibility. Households with children are more synchronised in their practices, thus less flexible in their residential peak electricity demand. A related finding was that areas with households with similar characteristics are more likely to have synchronised peak electricity demand, creating local challenges for electricity network operators.

Higginson et al. seek ***common ground*** between a social practice framework and quantitative/engineering modelling approaches by developing a novel way to represent social practices with structured network graphs. This approach is scalable and could work with 'big data'. Further development of the approach seems likely to provide insights into how flexible or entrenched different practices are, and could also suggest new pathways for interventions. This was a highly unusual instance of social scientists leading the generation of new engineering models based on cutting-edge social theory. It proved challenging for the engineers on the project. Instead of running new input data through existing energy demand models, they had to engage with new understandings of sociotechnical change and develop a new approach to modelling. The project also meant new ways of working for the social scientists. Instead of undertaking in-depth case studies that they then reported using narrative, they had to engage in new ways of visualising and communicating ideas.

Love & Cooper seek more than common ground, arguing for ***an integrative approach***. They point out that very few domestic energy use studies to date have properly integrated social and technical theory, measurement and analysis. They discuss a small technical study that included some comparative social data. This comparative data revealed apparently contradictory findings between ostensibly similar technical and social measures of dwelling temperature. Further analysis of the contradiction revealed the incommensurability between the technical measure 'mean internal dwelling temperature' and the social measure of 'occupant perception of temperature'. They make the point that occupant *perception* can provoke interaction with a heating system, so is at least as important as the technical measure. Analysing the contradiction between the two variables suggested a new idea for a *socio-technical* variable 'person space-time mean internal temperature', a hint of the productive potential of attempting to integrate incommensurable approaches. Love & Cooper also emphasise the lack of studies informed by adequate theories which are *really* socio-technical in a deeply integrated way.

The papers in this Special Issue demonstrate that the different perspectives and contexts of individuals and groups, as well as how they interact, has a large impact on the choice of building

technology, as well as on how it is used, consequently impacting on energy use in the indoor and built environment. The impact of people on energy use in non-domestic buildings is still relatively under-studied, however. A few papers in this Special Issue report on moves towards genuinely interdisciplinary collaborations, where both social and technical scientists strongly shape the specification of the research question and design. As a recent UKERC report noted, these interdisciplinary ventures are fraught with "*epistemological and ontological divides,* [but] *successful interdisciplinary research involves recognising these barriers, and explicitly taking them into account throughout the research cycle*". [8] Although some collaborations may produce a unified approach, as Shove points out, different ways of thinking about energy use are sometimes incommensurable, but this need not be problematic.[9] Radical ideas are needed if we are to radically reduce energy use in the indoor and built environment, and radical ideas may generate disagreement and even controversy en route to innovation.

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