Shopping for Success: Numbers, Knowledge, Time & Energy[1]

Kathryn B Janda[2], David Wallom, Ramon Granell, Russell Layberry University of Oxford

ABSTRACT

Working with Infrastructure Creation of Knowledge and Energy strategy Development (WICKED) is a UK-based research project seeking energy solutions for different retail market segments. Stakeholders include landlords, tenants, and owner-occupiers. Through cooperative research, WICKED investigates clusters of technical, legal, and organizational challenges faced by retail organizations, including those with smart meters and energy managers (the "data rich") and those without (the "data poor"). This paper provides a snapshot of the existing energy data and analytics practices of six WICKED partners. Partners include four retail tenants (a multi-national, full-service department store; a home improvement chain; a café chain; and an electronics retailer) and two landlords/managing agents (a property owner of UK community shopping centers, and a managing agent for a budget shopping center). Using quantitative data from partners, it provides a glimpse of current energy analytics within organizations. Using interviews with staff, it provides new information on the organizational context of energy management according to a 4C's "concern", "capacity" and "conditions" within a "communities" framework. These cases show that the data rich and poor will need different energy management solutions to maximize their energy efficiency and behavioral opportunities. The data rich may hire third-party experts to turn numbers into knowledge, and then discover the need for further communications strategies to engage staff. The data poor, on the other hand, have fewer opportunities to engage staff with empirical evidence. Further investigation is needed into how organizational cultures frame employee duties, behaviors, and expectations, particularly with regard to data and analytics.

Introduction

Energy use in existing buildings is a major source of greenhouse gas (GHG) emissions and there is significant potential for energy savings in retrofitting existing buildings (Ürge-Vorsatz et al. 2012). Approximately 18% of UK green house gas (GHG) emissions come from energy use in non-domestic buildings (CSE & ECI 2012). By one estimate, this rises to 34% if both operational and "capital" GHG emissions (direct and indirect emissions from construction works, services, materials, transport, and products) are included (The Green Construction Board 2013). Yet research in non-domestic buildings accounts for less than 10% of the end use energy demand research portfolio in the UK (LCICG 2012). Broadening the understanding of the socio-technical processes and constraints that affect the dynamics of change in non-domestic buildings is of critical national and global importance (Biggart & Lutzenhiser 2007).

This paper comes from a project designed to bolster research into energy management in non-domestic buildings, funded in 2014 by the UK Engineering and Physical Sciences Research Council (EPSRC). The project is called WICKED (Working with Infrastructure, Creation of Knowledge, and Energy strategy Development). The acronym WICKED draws on Rittel and

---

[1] An earlier version of the paper was presented at the 2016 Improving Energy Efficiency in Commercial Buildings conference.

[2] Authorship for this paper is based on contributions to the analysis and interpretation of these particular cases. The project overall is a joint effort which includes the work of other colleagues at Oxford University including Peter Grindrod (Maths), Malcolm McCulloch (Engineering), Susan Bright (Law), and Julia Patrick (ECI).

Webber's (1973) conceptualization of complex problems that defy simplistic or straightforward planning responses as 'wicked', or tricky.   This is particularly true in the retail sector.

The retail sector is vital to the economy, diverse, and facing a number of challenges. Retailers range from multinational corporations to small independent stores, selling everything from antiques to frozen yoghurt. Stakeholders include landlords, tenants, and owner-occupiers. Because of this diversity, retail energy management creates a "wicked" problem, where solutions to challenges are contentious and multi-faceted, both within companies and across the sector. In partnership with energy suppliers, retailers, and landlords, WICKED seeks actionable energy and business insights by combining (1) top-down big data analytics, (2) middle-out organizational research, and (3) new bottom-up data.

The paper begins by describing WICKED's novel socio-technical and interdisciplinary approach to the problem of energy management in the retail sector and non-domestic organizations. Within this context, this paper provides a snapshot of the existing energy data and analytics practices of six different partners: four retail tenants and two landlords/managing agents. Using interviews with staff, it provides new information on the organizational context of energy management according to a 4Cs framework, which addresses concern", "capacity" and "conditions" within "communities of practice". Combined with quantitative data from 5 partners, the interviews provide a glimpse of current and varied energy analytics practices within the case studies. These cases show that the data rich and poor will need different energy management solutions to maximize their energy efficiency and behavioral opportunities. The data rich may hire third-party experts to turn numbers into knowledge, and then discover the need for further communications strategies to engage staff. The data poor, on the other hand, can engage staff through a program of participatory monitoring and evaluation, using interactive handheld information and communication technologies (eg smartphones). The paper concludes that further investigation is needed into how organizational cultures frame employee duties, behaviors, and expectations, particularly with regard to data and analytics.

A WICKED Approach

This section describes (1) the sociotechnical segmentation model used to characterize different stakeholders and participants in the retail market and (2) the energy behavior change model used in the research to frame why and how these participants are (dis)engaged in energy strategy development.

Socio-technical segmentation

WICKED introduces a segmented socio-technical approach to work with and learn from different configurations of building energy data and ownership in the existing UK non-domestic stock (Janda, Bottrill & Layberry 2014). This segmentation model (see Table 1) uses the concepts of "data rich" and "data poor" to identify and map energy-related infrastructure, as well as barriers to and opportunities for change.

We define "data rich" as an ideal archetype: an organization that is able to gather, analyze, and use energy data to manage its premises in perfect harmony with its core strategy and central concerns. The reality is somewhat messier and inexact. Real organizations fitting this category will have lots of data—generally achieved through automatic meter reading (AMR)—

and an energy manager of some description. In contrast, a "data poor" organization is one without access to real-time data and lacking the in-house analytical capacity to measure, map, and understand energy issues.

This typology is a heuristic model designed to help define and categorize research assumptions about the nature and distribution of firms and organizations with respect to energy issues. Three vertical categories recognize that there are (at least) three kinds of ownership types in the market: owner-occupiers, landlords, and tenants, each of which is subject to a different kind of legal infrastructure. The horizontal categories split these three ownership types into data rich and data poor bins, resulting in a typology of six different firm types. This typology is shown in Table 1

Table 1: Overlay of Case Studies and Socio-Technical Model

Segmentation of the UK Non-Domestic Market	Owner Occupied	Leased Space	
		Landlords	Tenants
Data Rich (e.g., an organization with AMR and an energy manager)	A	B Case 5	C Cases 1, 2, 3
Data Poor (e.g., an organization with legacy meters and no energy analysis)	D	E Case 4	F Case 6

Janda, Bottrill and Layberry (2014) used this approach to focus on "data poor" tenants and owner-occupiers (Types D & F). The current research aims to "fill in" the table further by concentrating on "data rich" tenants and landlords (Types B & C) and "data poor" landlords (Types E & F). It also goes beyond the survey methods used in Janda, Bottrill and Layberry (2014) to incorporate interview data and quantitative data (where available). The cases are described in further detail in the methods section below.

Organizational Potential

In addition to the infrastructural variation noted above, organizations also vary in the extent to which they are willing and able to engage in energy management practices at different levels within and across the organization.

Previous research (Lutzenhiser et al. 2002; Janda et al. 2002) has recognized that different organizations engage in the same types of energy efficiency practices, whereas similar organizations may do different things. Based on these findings, the researchers developed a "3Cs" framework that suggests that energy efficiency and conservation actions in organizations depend on the level of "concern" within the organization about efficiency relative to other business goals; the "capacity" of the organization to take action; and the real-world physical and technical "conditions" of the premises that are to be acted upon. The presence or absence of these three variables can be used to recognize variation within organizations and potentially map different policy approaches to encourage energy efficiency or conservation. This characterization also suggests that there is not one kind of firm; there may be at least eight different kinds.

Janda (2014) augmented the 3Cs framework by adding a fourth "C"— building communities—based on (Axon et al. 2012). Axon et al.'s concept of a "building community" is built around the idea of "communities of practice" (CoP). A CoP is a system of relationships between people, activities and their outside world developing over time and interconnected with other CoPs, which themselves can be found within businesses, across businesses and other organizational and professional structures (Cushman et al. 2002; Ruikar, Koskela & Sexton 2009). Such communities can be either geographically coherent and organizationally diverse (e.g., a multi-tenanted office building or shopping mall); or organizationally coherent and geographically diverse (e.g., a fleet of Marks & Spencer stores).

One benefit of a "building communities" frame is that it moves beyond the usual levels of analysis that tend to take account of either "organizations" or "users." It recognizes that employees are both a part of and apart from the organization in which they work. Employees have to do their jobs, but in many organizational contexts, they have some agency over their actions that their employers do not completely control. Organizations govern some, but not all, of the actions their employees take, and even though inductions and protocols can help frame expectations that employees have about their work practices, employees can still disagree with corporate policies, particularly in their own areas of expertise. Similarly, organizations are a part of and apart from a larger market and social context for the goods and services they are providing. This kind of multilevel analysis is inspired by and reflective of other forms of multi-level research, including transitions theory (Geels 2002) and recent work on construction and innovation in the management literature. Hoffman and Henn (2008), for instance, identify social and psychological barriers to green buildings at three levels: individual, organizational, and institutional. The 4C's framework illuminates the presence and importance of multi-level influences, reflecting previous research that organizational change and innovation can occur from the top-down (Gouldson & Sullivan 2014), bottom-up (Thomas 1994), or middle-out (Parag & Janda 2014; Goulden & Spence 2015). Moreover, such changes are likely to be more successful if the organization recognizes the need to integrate these levels (Christina et al. 2015).

Methods

WICKED collected quantitative and qualitative data from stakeholders engaged in the UK retail sector. This paper focuses mainly on cases where both quantitative and qualitative data are available, framing these using the 4C framework presented above. This section describes the case studies (summarized in Table 2 below) and related biases.

Case Studies

Quantitative data of various shapes and sizes has been obtained from six partners. This gives us a snapshot of the raw data, metadata, analytical processes, and issues that different market participants are currently working with. In addition some fine-grained quantitative data has been collected for two additional partners sampled at shorter intervals (1 or 5 seconds) than utility meters provide (typically 15 or 30-minute intervals). This gives us an opportunity to examine whether the data that "smart" utility meters provide is at a sufficient level of detail for all energy management decisions.

In addition to the case studies represented below, qualitative data have been gathered through interviews with 33 representatives of 23 different organizations, including property owners, retailers, letting and property management companies, energy management companies, law firms and legal experts, and industry intermediaries and associations. The interviews are supplemented by document analysis of company strategy reports and reviews of policy documents and industry reports.

Table 2: Case Study Description

Case	Company Description	Quantitative Data Gathered	Qualitative Data Gathered
1	European electronics company with a work force of 40,000 employees in 3,000 stores spanning 11 countries	30 minute readings of the electricity consumed by 663 British shops during April 2013 to October 2014. Meta-data includes store type and postcode, but not floor area.	Interview with energy manager; review of external strategy documents and website.
2	Full-line food and clothing retailer, with approximately 800 stores throughout the UK and another 300 stores in 40 overseas locations.	Hourly readings of electricity from 526 British stores from 1 July, 2014 to 30 June, 2015. Meta-data includes floor area, opening hours, occupancy and temperature.	Multiple interviews with energy management team, head of property; review of internal and external strategy documents.
3	A UK high street and online retailer with over 130 million customers and a network of 740 stores.	30-minute readings of the electricity consumed by 59 British stores from 31 March, 2012 to 31 March, 2014. A second batch of 30 minute resolution gas readings for 264 stores during 5 years from 31/08/2010 to 31/08/2015.	Interview with energy manager; review of external strategy documents and website.
4	Two-storey shopping center opened in 1965 containing 91 units. Owned by a UK real-estate investment trust and managed by a national property management company.	No digital data available. High-resolution data collection discussed, but monitoring devices could not be indemnified sufficiently to be installed on the premises.	Two interviews with store managers (the first left and was replaced by a second); site visit; review of external strategy documents and website.
5	3-storey shopping mall opened in 1976, with 101 stores. Owned by UK community-focused retail property company.	30 minute readings of the electricity consumed by 1 shopping center over 5 years (10-6-2011 to 8-6-2015). No meta-data available.	Interviews with energy management team; onsite visit to gather high-resolution data; review of external strategy documents
6	Chain of cafes owned by a larger hospitality company. One café addressed in context of a landlord/ managing agent for a large London shopping center.	No utility metered data given to project. 1-second high resolution data collected by 3rd party WICKED affiliate.	Interview with energy manager of hospitality company; interviews with local café manager, shopping center manager, and managing agent.

Biases and Research Challenges

We report only on the data our partners shared and what our partners told us they were doing with their data. Therefore, this paper provides a somewhat grainy snapshot of the challenges and activities ongoing in our partners' companies. They (or their 3rd party affiliates) may be engaged in or in the process of pursuing other analyses that they did not discuss with us.

In all cases, the quantitative data that we have been given is incomplete in various ways. We asked for data from across their entire portfolios, but we received a subset of these data. Interviews across a larger number of partners indicate that "getting" and "sharing" data is easier in some stores within a portfolio than in others for a variety of reasons. Partners are starting to digitize their portfolios, but getting store information (both metadata and energy data) online and keeping it up to date across hundreds of properties is difficult. Local store managers may have the ability to make changes to the premises without reporting these changes to the energy team. Further, meters and monitors fail. Across 100s of stores, at any given time there are missing data, broken meters, and anomalies to correct.

Finally, we partnered with companies, we did not audit them. We asked for information that was easy for partners to share. If a company keeps electricity and gas records in separate databases, for instance, or if one source is digitized and the other is not, we might have received only part of the data that are available in-house. Data we received from some partners extended over multiple years and covered both electricity and gas. Data from other companies was more limited, but this may be an indicator of the company's willingness or ability to share, rather than their absolute knowledge of their own stock.

The qualitative and quantitative data in this study were gathered in an iterative fashion by two different teams. Sometimes the interviews preceded data collection, sometimes vice versa. Although both the quantitative and qualitative teams shared information with each other, different questions evolved which required further discussion with partners. As further questions evolved from the combined analysis, we treated each evolution as an opportunity for further study only if the topic was of interest to the partner.

Additional bias exists because of the small sample size, and its reliance on a convenience sample. Our findings are, therefore, not representative of the entire sector. Most of our interviews have been with larger retail organizations, which our interviews show prefer to be tenants rather than owner-occupiers. Their business model focuses on their core business—selling food and consumer goods—rather than upkeeping the physical properties that contain their businesses. These organizations mainly (but not exclusively) pair with large property landlords.

Results

We present the results of the research in three sections—concern, capacity, and conditions— according to the 4C's organizational potential model previously introduced. In keeping with (Janda 2014) and (Deline 2015), we focus on multi-level elements of organizational research. Even though the organizations we interviewed are coherent legal entities – a building "community" with a brand identity, unified on one level by name and purpose—our results show that companies operate across a diverse portfolio of properties, and there are significant variations both within companies (e.g., board room vs. energy team vs. store managers vs. employees) and across them.

Variation in Concern

The idea of energy management was not new to any of our interviewees or case studies. However, each of the 6 organizations in our cases engaged in this topic in a different ways. This section describes first the various energy topics that our partners address in their portfolios, then the ways in which these topics manifest in practice.

Different Energy Topics. At the organizational level, all of the cases had some form of sustainability statement on their website. This reflects the general external pressure for organizations of all kinds, not just retailers, to participate in corporate social responsibility activities (McWilliams 2015). The extent to which energy management plays a role in this set of concerns, however, varied. Energy management can mean many things, and each of our partners participated in a unique subset of the possible topics that "energy management" denotes. All partners were interested in reducing "out of hours" energy consumption, looking to minimize energy use in the hours their stores are not in service. Beyond this, organizations were (un)concerned about a variety of other energy aspects. For example, only one of our four retailers we talked to was interested in engaging their landlords through the mechanism of green leases. This retailer, M&S, has made a particular point of adding green leases to their sustainability toolkit. Research has shown that green leases are generally led by landlords and particularly popular in office buildings (Janda et al. 2016), but the landlords in the retail sector are not pushing this particular form of inter-organizational governance. Only one of our partners (Case 2) was considering innovative forms of energy supply, in this case, biofuels. None of the cases were seriously considering rolling out demand response strategies, although one interviewee mentioned an early stage pilot project.

Heterogeneous Practices. In terms of taking action on expressed concerns, there is a long distance between stating a corporate policy and enacting it. Across our cases, we found a number of instances where organizational infrastructures did not necessarily match the high level concerns. For example, several energy managers expressed frustration with the ways in which internal accounting mechanisms and pre-set thresholds for capital projects did not allow for upgrades that would otherwise seem reasonable. One interviewee told us that his company had a 12-month payback period, so he could not implement an improved lighting roll-out that would have had a 14-month payback. Another energy manager from a different company described how his company's capital expenditure spreadsheet did not account for increases or volatility in energy prices.

Variation in capacity

Capacity in the 4C's framework refers to the human and organizational effort allocated to the problem of energy efficiency. This effort can be allocated internally (e.g., staff members with time dedicated to these issues) or externally (e.g., 3rd parties hired in for specific expertise). On one level, the capacity of the retail sector is very coherent. In all cases, energy management is understaffed relative to the scale of the problem. For example, a recent Major Energy Users Council (MEUC) survey (MEUC & Power Efficiency 2013) found that 75% of respondents said they have at least one staff member responsible for energy, but the rest have not allocated staff time to manage energy concerns. 62% of respondents had a clearly defined energy reduction strategy for their business, but the remainder did not. These results indicate gaps in organizational capacity to manage energy, even amongst self-defined major energy users.

Internal capacity. All of the organizations we interviewed, as well as our case studies, showed varying levels of effort devoted to the task of improving energy management. Most, but not all, of our cases had an energy manager. This energy manager is typically responsible for overseeing the entire portfolio of stores, which represents hundreds of stores. In case 6, for instance, the staff member responsible for energy is also responsible for water and waste in over 1000 premises. In all cases, the "energy manager" operated in a "1-to-many" context, rather than a "1-to-1" relationship, like a store manager. While this slightly distant relationship provides the ability to learn from multiple cases, it does not enhance the ability to understand what is happening "on the ground". The energy manager can usually only see what the data tell him or her.

In a few cases (notably Cases 2 & 3), the energy manager also had direct contact and ongoing contact with the store managers. In both these cases, the organizations had hired in third-party software providers to help push energy information to the store managers. The energy manager for Case 3, for example, together with a 3rd party software provider, designed special portals for store managers to be able to see the feedback for their stores on a tablet. Case 2 (also in combination with a 3rd party) took feedback even further: store managers could see the feedback, and there was also an advertising campaign to increase energy awareness amongst store employees, as well as encouragement to exchange energy and environmental topics between employees on a special social media platform designed for the retailer.

For most cases, however, the energy information stayed with the energy manager. The premises in case 6, for instance, have "smart" meters but the meters send their data to a central location and are not pushed back out to the stores. As a part of a pilot test of new monitoring equipment in a shopping center, a WICKED affiliate working provided auxiliary metering on top of the smart meter in one of these stores to extract the information from the meters locally, upload it to a server, and display it back to the shopping center managers and store managers.

External capacity. The discussion above shows that even where energy managers are present in an organization, they rely strongly on external expertise and hire third parties to provide data management, analytics, and display services. These capabilities are not provided "in house" but instead are provided by consultants who may work entirely off-site or, in some cases, be embedded within the organization. In Case 2, the consultants work on kind of a "secondment" basis, where they work in the headquarters of the company and have an access badge to the premises. Compared to "normal" employees, however, their badge is a different color, which distinguishes them from the store managers and others who are "core" employees. Interviewees in these situations were very committed to the work they did for their host organizations. One interviewee opined about a database which accurately contained all the details of the energy-consuming equipment in every store, even as he discussed the difficulty with gathering this information, particularly as an outsider. On a day-to day basis, the store managers are seen as delivering the strategic "core" of the organization's operations, whereas energy management is still seen as peripheral (Cooremans 2011). Store managers have considerable power to make independent decisions regarding sales displays and promotions, which includes adding feature lighting. Although these decisions may impact energy use, the store managers are not required to notify the energy managers or their team of making such changes. Their goal is to maximize sales, not minimize energy use.

Variation in Conditions

This set of variables in the 4C's model relates to the physical and technical conditions present in each portfolio, which extends to the presence and absence of meters and data. A perfect portfolio would have the database envisioned by the consultant in Case 2 above: an accurate and complete accounting of every energy-consuming item in every store, updated in real time and without flaws, matched perfectly with energy data at sufficient spatial and temporal resolution to be able to problem-solve deviations. Further, these deviations would be automatically detected and flagged by smart algorithms, which could learn over time what is and is not a genuine problem. Ideally, it would also have an accurate representation of the physical attributes of the buildings (size, composition, orientation, location, building quality) in the portfolio, as well as some operational data about the activity in the buildings (opening hours, footfall, etc.).

The ideal database envisioned above is far from the reality. Most existing databases are incomplete, some (such as Case 4) are largely non-existent. The shopping center manager in Case 4, like most "data poor", has a box of paid and neatly filed gas and electricity bills rather than an active database of information. Where databases do exist, the energy and building level data are often in separate spreadsheets that are matched only on an ad hoc basis. The norm is energy managers operating mainly with energy data, set at arm's length from 100s of stores, often without a complete list of the building-level data, let along equipment or appliance-level data. In our investigations we found common problems which include: heterogeneous building stocks; evolving data practices; and some difficulties in relating the stocks and data to each other, let alone to problem-solving.

Heterogeneous stock. Internally, the organizations identify their stock in different ways for business purposes. Case 1 had 9 different internal definitions for "store type", whereas Case 2's database used only three categories, and Case 3 used two. From an energy perspective, these business classifications add some meaning but do not provide a sufficient technical basis for an internal benchmarking scheme.

At the building level, some organizations had hired a 3rd party to check and aggregate the asset-level data through the lens of the EU-wide Energy Performance Certificate (EPC) level-data. Most cases, however, did not link their EPCs with their metered data. Interviewees mentioned concerns about the quality of EPC data as an accurate benchmark. However, aside from normalizing for building size and sometimes climate zone, little work has been done within companies to benchmark for building quality. The problems addressed by energy managers is often limited to pinpointing and troubleshooting "out of hours" energy use, rather than looking for retrofit opportunities within the building portfolio.

'Smart' meters and imperfections. In all cases, the metered data were imperfect. Meters and monitors fail. Across 100s of stores, at any given time there are missing data, broken meters, and anomalies to either correct or remove, lest they skew the analysis. In Cases 1 and 3, for example, respectively 3% and 2% of the meter readings were inaccurate. In Case 2, however, close to 30% of the electricity readings were null values.

Other flaws in the data set may also exist, but are difficult to filter out without gaining a better idea of the expected performance and consumption norms. This process of looking for anomalies can be automated, but it is unclear to what extent either the retailers or the 3rd party manager is actively engaged in fine-tuning the analysis to assist with granular assessment of the meters themselves (Janda et al. 2015). Close attention over time to fine details and fluctuations may or may not be part of the data package purchased from a 3rd party provider.

Beyond assessing the individual streams of metered gas and electricity data, braiding these and other streams into a joint "energy" profile has been challenging. Some stores are all electric; others have both gas and electricity, but the gas data may not have the same level of resolution or time stamp as the electricity data. These variations complicate combining the data sets and analyzing them in tandem.

Discussion and Conclusions

This paper presented and discussed findings from the first 18 months of WICKED, a 2-year research project on energy management in the UK retail sector. We presented the conceptual basis for the project and introduced a 4C's (concern, capacity, and conditions across communities) framework for understanding the behavior of firms. We discussed available data from 6 case studies: 4 data rich and 2 data poor. These cases show that retailers are not a homogenous group. As a result, one size does not fit all: the data rich and poor will need different energy management solutions. Smart meters will not solve everything: further analysis is necessary to turn numbers into knowledge. How organizational cultures frame employee duties, behaviors, and expectations requires further investigation.

The project results to date show that there is still a lot of room for improvement in the retail sector within the realms of data, organizations, and buildings. This is most obvious in Case 4, where the technical infrastructure of a budget shopping center does not provide detailed access to real-time energy information for its manager. This is a fairly common problem in the retail sector, as evidenced by British Land—the UK's largest listed owner and manager of retail space--posting a case study about adding automatic meter-reading to its retail properties as recently as 2013-14 (Webster 2014). Energy management is not a top priority in the retail sector (Whitson & Crawford 2013), and moving this item up the organizational agenda is a difficult task. The cases show us not just that similar stores are different, but also that the available data could be better contextualized, cleaned, and possibly used to pinpoint meters that are faulty. As energy data acquisition and use becomes more commonplace, meter maintenance and data quality control will need to be added to the ongoing processes of "standard practice" for all commercial organizations if they wish to use their information to best effect.

Across the cases, there are two "solutions" that look like they will be helpful in resolving some of the issues across the retail sector, particularly in terms of energy accounting and accountability. One is standardization of data identifiers and variables, and the second is development of flexible smart-er monitors to assist with new meter locations, participant education and engagement. Our initial explorations suggest that some protocols regarding energy data availability and meter functionality may be useful. More work is needed to understand how energy managers in "data rich" firms actually use the data that they have, and whether additional meta-data may be needed. "Data poor" firms will need to access additional data, and as Case 6 showed, local managers of "data rich" firms can use these devices to get detailed information at the local level, if this has not been provided centrally.

A 4C's framework helps to clarify socio-technical challenges and opportunities at different operational levels within firms. Broadly, the results confirm that interdisciplinary, multi-level problem-solving is important, particularly in the real world. From the perspective of each disciplinary approach in the project, there are some problems that are visible and interesting, others that are obdurate to the tools used by that discipline. An example is the indication of broken or malfunctioning meters in Cases 1-3. From a data analytics perspective, data should be clean and regular, so faulty information streams should be discarded to ensure that "the system" is represented in a functional form. From an energy and management perspective, however, these malfunctioning meters represent real buildings that require some kind of physical intervention (e.g., meters need fixing or replacement) for their data to play a useful role in energy management. The question of how often meters (whether smart or not) fail, who knows when or if they do, and how they should be fixed is a problem that presents an additional opportunity (or challenge) to energy managers on the ground. Better data and analytics can illuminate this challenge, but engineering (stuff) and organizational effort (staff) are required to fix it.

References

Axon, C. J., S. Bright, T. Dixon, K. B. Janda, & M. Kolokotroni. 2012. "Building communities: reducing energy use in tenanted commercial property." *Building Research & Information* 40 (4):461-472. DOI: 10.1080/09613218.2012.680701.

Biggart, N. W., & L. Lutzenhiser. 2007. "Economic Sociology and the Social Problem of Energy Inefficiency." *American Behavioral Scientist* 50 (8):1070-1087.

Christina, S., P. Waterson, A. Dainty, & K. Daniels. 2015. "A socio-technical approach to improving retail energy efficiency behaviours." *Applied Ergonomics* 47:324-335. DOI: http://dx.doi.org/10.1016/j.apergo.2014.08.003.

Cooremans, C. 2011. "Make it strategic! Financial investment logic is not enough." *Energy Efficiency* 4 (4):473-492.

CSE, & ECI. 2012. What are the factors influencing energy behaviours and decision-making in the non-domestic sector? A Rapid Evidence Assessment. Department of Energy and Climate Change London. https://www.gov.uk/government/publications/factors-influencing-energy-behaviours-and-decision-making-in-the-non-domestic-sector-a-rapid-evidence-assessment

Cushman, M., W. Venters, T. Cornford, & N. Mitev. 2002. Understanding Sustainability as Knowledge Practice. LSE Research Online. London School of Economics: London.

Deline, M. B. 2015. "Energizing organizational research: Advancing the energy field with group concepts and theories." *Energy Research & Social Science* 8:207-221. DOI: http://dx.doi.org/10.1016/j.erss.2015.06.003.

Geels, F. W. 2002. "Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study." *Research Policy* 31 (8-9):1257-1274.

Goulden, M., & A. Spence. 2015. "Caught in the middle: The role of the Facilities Manager in organisational energy use." *Energy Policy* 85:280-287. DOI: http://dx.doi.org/10.1016/j.enpol.2015.06.014.

Gouldson, A., & R. Sullivan. 2014. "Understanding the governance of corporations: an examination of the factors shaping UK supermarket strategies on climate change." *Environment and Planning A* 46 (12):2972-2990. DOI: 10.1068/a130134p.

Hoffman, A. J., & R. Henn. 2008. "Overcoming the Social and Psychological Barriers to Green Building." *Organization & Environment* 21 (4):390-419. DOI: 10.1177/1086026608326129.

Janda, K. B. 2014. "Building Communities and Social Potential: Between and Beyond Organisations and Individuals in Commercial Properties." *Energy Policy* 67 (April):48-55. DOI: http://dx.doi.org/10.1016/j.enpol.2013.06.024.

Janda, K. B., C. Bottrill, & R. Layberry. 2014. "Learning from the “Data Poor:” Energy Management in Understudied Organizations " *Journal of Property Investment & Finance* 32 (4):424-442.

Janda, K. B., S. Bright, J. Patrick, S. Wilkinson, & T. Dixon. 2016. "The evolution of green leases: towards inter-organizational environmental governance." *Building Research & Information*. DOI: 10.1080/09613218.2016.1142811.

Janda, K. B., J. Patrick, R. Granell, S. Bright, D. Wallom, & R. Layberry. 2015. "A WICKED approach to retail sector energy management." In Proceedings of *ECEEE Summer Study*, 1-6 June 2015 (Toulon/Hyères, France). Vol. 1 - Foundations of Future Energy Policy, pp. 185-195. European Council for an Energy-Efficient Economy: Stockholm, Sweden.

Janda, K. B., C. Payne, R. Kunkle, & L. Lutzenhiser. 2002. "What Organizations Did (and Didn't) Do: Three Factors that Shaped Conservation Responses to California's 2001 'Crisis'." In Proceedings of *American Council for an Energy-Efficient Economy 2002 Summer Study*, (Asilomar, CA). Vol. 8, pp. 8.117-8.128. ACEEE:

LCICG. 2012. Technology Innovation Needs Assessment (TINA): Non-Domestic Buildings Summary Report. Low Carbon Innovation Coordination Group (LCICG): London. http://www.lowcarboninnovation.co.uk/working_together/technology_focus_areas/nondomestic_buildings/
Lutzenhiser, L., K. B. Janda, R. Kunkle, & C. Payne. 2002. Understanding the Response of Commercial and Institutional Organizations to the California Energy Crisis 400-02-018C Consultant Report. California Energy Commission: Sacramento, CA. http://www.osti.gov/servlets/purl/832751-6WN6Z0/native/
McWilliams, A. 2015. Corporate Social Responsibility. In *Wiley Encyclopedia of Management*. Chichester, West Sussex, United Kingdom: John Wiley & Sons, Ltd. pp. 1–4
MEUC, & Power Efficiency. 2013. Powercut Britain: Are the lights about to go out for UK business? A Power Efficiency sponsored Major Energy Users’ Council Report. Major Energy Users' Council and Power Efficiency: London. http://www.powerefficiency.co.uk/Upload/Documents/MEUCReport.pdf
Parag, Y., & K. B. Janda. 2014. "More than Filler: Middle Actors and Socio-Technical Change in the Energy System from the "Middle-Out"." *Energy Research and Social Science* 3 (September):102–112. DOI: http://dx.doi.org/10.1016/j.erss.2014.03.014.
Rittel, H. W. J., & M. M. Webber. 1973. "Dilemmas in a General Theory of Planning." *Policy Sciences* 4 (1973):155-169.
Ruikar, K., L. Koskela, & M. Sexton. 2009. "Communities of practice in construction case study organisations." *Construction Innovation* 9 (4):434-448.
The Green Construction Board. 2013. Low Carbon Routemap for the UK Built Environment. The Green Construction Board: London. http://www.greenconstructionboard.org/otherdocs/Routemap final report 05032013.pdf
Thomas, R. J. 1994. *What Machines Can't Do*. Berkeley, CA: University of California Press.
Ürge-Vorsatz, D., N. Eyre, P. Graham, D. Harvey, E. Hertwich, Y. Jiang, . . . A. Novikova. 2012. Chapter 10 - Energy End-Use: Building. In *Global Energy Assessment - Toward a Sustainable Future*. Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria. pp. 649-760
Webster, M. 2014. *Power to the data – energy metering at our retail properties*. London: British Land, [Accessed: February 4, 2015]. Available from http://views.britishland.com/2014/10/power-to-the-data-energy-metering-at-our-retail-properties/.
Whitson, M., & H. Crawford. 2013. UK shopping centres and the sustainability agenda: are retailers buying? IP 2/3. College of Estate Management; British Council of Shopping Centres: London. http://www.cem.ac.uk/media/23710/uk_shopping_centres_op-final.pdf