Practice-oriented research into energy management and use in non-residential buildings: the reliability gap framework

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Abstract

Energy use during the operational phase represents the largest environmental impact for non-residential buildings. While much work has been geared at reducing energy use in buildings, the gap between the predicted and actual energy performance, the so-called reliability or energy performance gap, remains a considerable challenge. Creating change requires and involves many different actors and activities. The field of facility management is a relevant starting point for doing so, as it is concerned with the management of non-residential buildings. It has however to limited extents addressed energy-efficiency from a systemic perspective that links technology and the activities of different actors throughout the building lifecycle. This paper presents a framework for mapping activities of energy management and use in non-residential buildings, and for developing support for change. It does that by drawing on social practice theory and design theory. Social practice theory may help capture energy management practices and their relation to other practices, as well as the link between energy management, co-benefits and unintended consequences. Design theory comes equipped with tools and approaches for understanding the interaction between people and the built environment, and for developing interventions with and for different actors. Supplementing facility management literature with insights from these fields may help understand how the reliability gap occurs and is dealt with, and how it eventually may be closed. The article is part of a research project that aims at a) mapping the implementation of concepts, methods and measures promising to help close the reliability gap in Norwegian non-residential buildings, b) analysing the potential for improvement and c) developing improved and extended methods that go beyond the state of the art and integrate capacity building, communication aspects and learning processes. This paper contributes to the project aims of closing the energy reliability gap by presenting a framework that structures and supports the qualitative study of a limited number of cases and the identification of opportunities for improvement.

Introduction

Buildings are responsible for more than 40 percent of global energy use and one third of global greenhouse gas emissions, both in developed and developing countries (IEA, 2013; UNEP-SBCI, 2009). An increase in the global population and improvements in economic developments and living standards are leading to a sharp rise of energy use in the building sector, placing additional pressure on the energy system (IEA, 2013). The building sector has a high responsibility in diminishing this pressure, and it simultaneously has the largest potential in delivering long-term, significant and cost-effective cuts in energy use and greenhouse gas emissions (UNEP-SBCI, 2009). Governments aim at changing this growing trend of energy use and efficiency by tightening building regulations and planning policy for the construction and use of buildings. The European Commission for example developed the Energy Performance of Buildings Directive (EPBD) with the aim to support and implement energy-efficiency in the European building stock through energy certification schemes (European_Commission, 2002; Rademaekers, 2014). The operational phase of buildings has been identified as the largest contributor to energy use and demand in the lifecycle of a building (Azar & Menassa, 2012; UNEP-SBCI, 2009). More than 80 percent of the total energy is consumed during this phase. Focusing on the operation phase of buildings is therefore crucial in order to achieve long-term energy savings (Azar & Menassa, 2012; Kyrö, Heinonen, & Junnila, 2012) and to improve energy efficiency in the building stock.

As a result of regulations, advances in technological solutions and an increasing awareness of the need for a more energy efficient building stock, a growing number of new and retrofitted non-residential buildings have a high energy performance potential. However, the energy performance of a building in daily use does not often equal the estimated, potential performance of the building's design. This difference between the building's potential performance as it is commissioned to its users and its actual performance in daily use is referred to as the energy reliability gap or energy performance gap (Berker, Gansmo, & Junghans, 2014; Bordass, Cohen, & Field, 2004; de Wilde, 2014; Menezes, Cripps, Bouchlaghem, & Buswell, 2012). Up to now, there is limited understanding of why the discrepancies between the design and actual building performance occur. Causes of the energy reliability gap can be rooted in the design, commissioning or operation phase of a building, such as the use of wrong models, changes during construction, or deviations from the intended use of the building (Bordass et al., 2004). de Wilde (2014) describes current efforts that are being taken to get more profound insights into the reliability gap and its causes and how they can be overcome. The author emphasises the need for more research and a better understanding of the topic. Other scholars indicate the need for further addressing the complex interactions between architecture, technology and the people who use and maintain the buildings (Patanapiradej, 2006), with specific attention for the collaboration between different stakeholders in the design and operation stages of a building (Jensen, 2010; Shah, 2007; Valle & Junghans, 2014).

Following the need for more interdisciplinary insights, the research project *Methodologies for the Improvement of Non-residential buildings' Day-to-day Energy-efficiency Reliability* (MINDER) focuses on reducing the reliability gap in non-residential buildings by bringing together knowledge from the fields of facility management (FM), social practice theory and design thinking. The project aims at a) mapping the implementation of concepts, methods and measures promising to help close the reliability gap in Norwegian non-residential buildings, b) analysing the potential for improvement and c) developing improved and extended methods that go beyond the state of the art and integrate capacity building, communication aspects and learning processes (Berker et al., 2014). A literature review and a survey have been completed as the first stages of the project. The review resulted in an overview of upcoming and promising methodologies that aim at diminishing the energy reliability gap by linking the design and operation phase of non-residential buildings (Valle & Junghans, 2014). The overview includes methodologies such as soft landings, continuous commissioning, energy performance contracts and building performance evaluation. The survey offers insights on the state of the art of the energy reliability gap in non-residential buildings in the Norwegian context.

This article focuses on the following project phase, in which it is the aim to gain a deeper understanding of how the reliability gap actually occurs and is dealt with, as well as how it may be closed or diminished. A framework is presented in which FM literature gets supplemented with insights from the fields of social practice theory and design theory. This framework will structure and support the qualitative study of a limited number of cases and the identification of opportunities for improvement. The article first introduces the different perspectives that provide the elements of the energy reliability gap framework. Subsequently, the framework is presented with its different elements and how they are mutually connected, followed by a discussion on the added value of the framework, opportunities for further improvements, and subsequent steps.

Elements of the framework

FM as a field is concerned with the management of non-residential buildings. It has an important role in contributing to the reduction of the impact of the built environment, including energy management in the daily operation of buildings (Elmualim, Shockley, Valle, Ludlow, & Shah, 2010; Kyrö et al., 2012; Yao, 2013). It can thereby also play a significant role in diminishing the energy reliability gap. Up to now, the field of FM has to limited extends addressed energy-efficiency from a systemic perspective that links technologies with managerial methods and different actors from the design, commissioning and operation phase of buildings. To better understand what actually happens as buildings are commissioned, used and operated, and what opportunities there are for intervening in it and for reducing the energy reliability gap, we will outline the different elements of the framework. After describing the current knowledge on the energy reliability gap, we will introduce FM along with two supplementary theories in the following sections. For the first one, we turn to social theory, and more specifically, social practice theory. Social practice theory is relevant as it may help capture the systemic interplay between humans and the built environment as energy is managed and used, as well as the relationship between activities of design and use. Further, it may provide an understanding of what may help and hinder change. Second, we introduce design theory. Design is particularly relevant for its future-orientation. Focusing on the interaction between people and the built environment at different levels, it comes equipped with tools and approaches for the development of products, services and systems with and for different actors.

The energy reliability gap

A growing number of new and retrofitted non-residential buildings have high ambitions concerning energy efficiency, such as the passive house standard, zero emission buildings, low emission buildings, etc. Many buildings do however not manage to achieve the estimated energy performance during operation (Bordass et al., 2004; de Wilde, 2014; Menezes et al., 2012). Studying this energy performance or reliability gap, some researchers focus on identifying factors that cause it, whereas others develop methods that aim at bridging it. de Wilde (2014) classifies causes for the mismatch between energy prediction and (measurements of) actual use according to the lifecycle stage of the building: causes that pertain to the design phase, causes rooted in the construction phase, and causes that relate to the operational phase. In their study, Bordass et al. (2004) relate the energy performance gap to the use of wrong models in the design phase, changes and mistakes made during construction phase, bad routines in the commissioning of the building and deviations from the intended use in the use phase. These are repeated by others, who add causes such as mis-communication about performance targets between clients and the design team, unspecified building design details that need to be decided by the contractor, and at the operation phase, energy management and control, and occupant behaviour (de Wilde, 2014; Menezes et al., 2012; Yao, 2013). Occupant behaviour is often cited as the main reason for the performance gap (de Wilde, 2014; Yao, 2013) and forms the focus of several studies (Haldi & Robinson, 2008; Herkel, Knapp, & Pfafferott, 2008; Yu, Haghighat, Fung, Morofsky, & Yoshino, 2011). However, it is described as an extremely challenging area, and ways of better understanding and modelling occupancy, occupant behaviour and the related use of appliances are called for (de Wilde, 2014; Yao, 2013). Yao (2013) locates a key role in influencing behaviour with design and technology, by means of well-managed on-site control systems, feedback displays, and other future product and service developments.

Several methods are available that aim at diminishing the energy reliability gap. The majority of these methods are aligned with root causes and cover design and prediction, construction or measurement during operation (de Wilde, 2014). Many have a strong technological orientation. Examples of such methods are fault detection and diagnosis, building performance assessment tools, and energy prediction systems (Valle & Junghans, 2014). Focusing on a specific root cause, they can lead to incremental improvements in the energy reliability gap. However, concepts, methods and measures that link technologies with actors from the different sides of the energy reliability gap – design, commissioning and operation – can lead to more substantial improvements in the building's performance as well as in the design processes (Berker et al., 2014).

Facility management

Introduction to facility management

The discipline of FM is an emerging profession which brings together knowledge from design and knowledge from management in the context of buildings' everyday operation and efficiency (Leaman, 1992). The scope of FM includes different work packages or services such as security, cleaning, maintenance, catering, landscaping, hygiene, health and safety, waste management, energy management, etc. (Barrett & Baldry, 2003; Shah, 2007; Yao, 2013). In professional practice, these services aim at improving and supporting the productivity of an organisation's core activities. Catering, cleaning and other services for example support the educational function of a school building. The International Facility Management Association (IFMA) defines FM as a profession that encompasses multiple disciplines to ensure the functionality of the built environment by integrating people, places, processes and technology (Patanapiradej, 2006; Shah, 2007; Yao, 2013). The multidisciplinary scope of FM covers a wide range of activities, responsibilities and knowledge. Effective FM combines these resources and activities to contribute to the delivery of strategic and operational objectives of a building and of the organisation that uses it (Barrett & Baldry, 2003; Shah, 2007). Some scholars consider the operational level the main role of FM (Leaman, 1992), such as follow-up and improvement of a building's performance and ensuring everyday operation. On an operational, day-to-day level, effective FM provides a safe and efficient environment for the building's end users. Other scholars emphasise the need for a more strategic view of the discipline, focusing on facility planning where the building design and operation meets the business objectives (Yao, 2013). Patanapiradej (2006) distinguishes operational and management functions, in which the latter include strategic and tactical levels.

In the light of sustainability, facility managers have an important role in contributing to the reduction of the environmental impact of the built environment (Elmualim et al., 2010; Kyrö et al., 2012; Yao, 2013). While receiving growing international attention, research on sustainable buildings and sustainable FM has so far largely focused on developing and applying sustainable principles in building design and on the incorporation of retrofit solutions. When concentrating on the design stage and technological solutions, it is easy to miss out on the fundamental role the FM team plays in safeguarding and improving a building's environmental performance (Yao, 2013). Further, and although international ecological and economic pressures clearly direct sustainable FM towards energy reduction and energy efficiency, only limited attention has been paid to it (Jensen et al., 2012). Several scholars do however emphasise the need to focus on the reduction in energy consumption during building's operation as a primary sustainable FM research topic (Azar & Menassa, 2012; Hodges, 2005; Kyrö et al., 2012). Energy management is seen as key to successfully implement and realise energy efficiency: 'a well-functioning energy management system provides the enabling environment to identify opportunities for and to realize energy savings during operation in a sustained manner' (Worrell, 2011, p. 7).

Relevance to studies of the energy reliability gap

The energy management of a building forms a vital part of the myriad of activities of FM. While most of the energy usage, as mentioned, takes place during the operation of a building, a large part of the energy management strategy is defined as the building is designed (Azar & Menassa, 2012). As mentioned earlier, there is a need for concepts, methods and measures that link technologies with actors from the different sides of the energy reliability gap – design, commissioning and operation - in order to reach substantial improvements in a building's performance (Berker et al., 2014). Based on a literature review, Valle and Junghans (2014) give an overview of promising methods and approaches in the field of FM which directly or indirectly can strengthen the link between the different life cycle phases of a building: these multi-methods can be characterised by the use of hard tools (i.e. technological solutions) in combination with soft management approaches (e.g. briefings, workshops), and include soft landings, continuous commissioning, energy performance contracts and building performance evaluation. Despite the availability of these methods, selecting and implementing an appropriate method that suits the needs of a building and its organisation turns out to be difficult. A survey on the awareness and state of the art of the methods that deal with energy-efficiency reliability has been performed within the Norwegian building sector (Valle & Junghans, Forthcoming). The survey focused on actors, tools and processes, competences, outcomes and wider issues related to the awareness and implementation of energy-efficiency reliability methods. Preliminary results from the survey indicate a need for further exploration of a) the role, behaviour and impact of different actors within energy management during operation of a building, b) insights on the (lack of) use of specific technological and managerial tools, c) barriers for implementing energy-efficiency reliability methods and d) dysfunctionalities in the knowledge flow between the strategic, tactical and operational levels of energy management.

Literature on the energy reliability gap does thus indicate a strong need to focus future research on methods that link energy management during the design and operation phases of non-residential buildings. Different aspects come forward as significant to study, such as the need to:

- better understand the selection and (lack of) implementation of such multi-methods,
- gain profound insights into the collaboration between different actors in the different phases and on different levels (strategic, tactical, operational) within a building,
- and gain more profound insights concerning occupancy and occupant behaviour during the operation phase.

Adjacent fields such as social practice theory and design theory can provide complementary background, knowledge and insights that can broaden the current insights on the complex interactions between architecture, technology and the people that maintain and use the buildings.

Social practice theory

Introduction to social practice theory

To understand what causes the gap between predicted and actual energy use and what may be opportunities for reducing it, we need to know what actually goes on as buildings are designed and commissioned, and energy is managed and used. In studies of the interplay between humans and the built environment, social practice theory is often put forward as a relevant starting point. It is developed from the work of many different authors, including the writings of social theorists Bourdieu (1977) and Giddens (1984). It is promoted as a way of overcoming the dualism between individual agency and structure, and considered well equipped to overcome the perceived divide between technology and people so common in studies of energy use (Spaargaren, 2011). It does that by directing attention towards the purposes for which ordinary activities of work or leisure are performed and resources are used. It highlights that what is done in practice, for example as buildings are managed and inhabited, is organised around conventions or shared understandings of what is normal or ought to be expected (Schatzki, 2001; Warde, 2005). This is highly relevant given FM energy management goals to support the productivity of core organisational activities: social practice theory opens up for understanding what are considered the standards for good working practice, as well as the dynamic relationship between the built environment and human activity in everyday life. It does that by concentrating on the social practice, described as a routinized behaviour type (Reckwitz, 2002).

According to social practice theory, the ways in which activities are performed do not result from the characteristics of the built environment or individual human beings alone. They rather emerge from the interplay between a diverse set of interconnected ingredients such as mental and bodily activities, things, their use, understanding, know-how, emotional states and motivational knowledge (Reckwitz, 2002). E. Shove and Pantzar (2005) propose a shorter ingredient list consisting of images, artefacts and forms of competence, and later, the much used categories of 'material', 'image' and 'skill' (Pantzar & Shove, 2010). From such a perspective, tools or materials such as energy monitoring systems or efficient lighting systems are important as they open up for certain actions while preventing others (Akrich, 1992). They do however also require skills in order to be used. Skills may be distributed between humans and technologies, and actors must find the tools meaningful in order to use them.

A practice does further not exist unless it is performed and the links between its set of elements are made (Pantzar & Shove, 2010; Reckwitz, 2002). Such bodily performances are both routinized and unstable (Warde, 2005). While different practices relate to and influence each other in different ways, forming systems of practices, the reproduction or enactment processes keeping a practice alive both help and hinder its change and integration with other practices (Pantzar & Shove, 2010). Elements may further be part of many different practices. Tools for lighting such as lamps, bulbs and dimmers may be used in different ways and mean different things in different practices: other brightness levels may be found suitable for cleaning than for giving a business presentation. As a result, the actual performance and development of practices is unpredictable (Elizabeth Shove & Walker, 2010).

Relevance to studies of the energy reliability gap

The practice perspective may be helpful in understanding how the reliability gap occurs and how and to what extent it may be eliminated. From being a question about better predictions or improved technologies, a social practice orientation reframes the challenge as a socio-technical one. It directs attention towards what the energy is used for, what the standards of energy management are, and how that changes over time. Technologies and methods are not important per se, but in terms of what emerges from the relations in which they take part.

Apart from offering a different orientation to study energy management, a practice-oriented view also has methodological implications. Practice-based studies take the social practice as unit of analysis, rather than technologies or individuals. In studies of how the reliability gap is dealt with, a practice-oriented approach would imply conceptualising the professional activity of facility managers as a practice or system of practices, linked to and interacting with other practices. The same goes for the activities of occupants, be they administrators, teachers or students in a school buildings, or those who run the cafeteria in an office building. This means seeing energy management and use as happening within and between the practices of facility managers and building occupants, and as being linked to the practices of architects and construction workers.

Schatzki (2012, p. 24) points out that while their material components can be perceived, practices cannot. They must be 'uncovered' as they are spread out in space and time and organised in abstract ways. According to him, ethnography or participant observation, interviews or oral history and statistics are relevant methods for doing so. Getting acquainted with the use of language may however be a starting point before entering a field of practice. To gather detailed knowledge about practices however - about their organisation, how they are related, in which contexts they take place and how they develop, Schatzki (2012) points to ethnography as the preferred choice. While ethnography provides in-depth insight into current situations and conditions, interviews or oral history contribute with accounts of what has happened over time. To that, statistics provide quantitative information. When studying energy management, information on the actual use of energy over time is for example highly relevant.

For studies of everyday practices, relevant questions include why people do what they do, and how they do it (Warde, 2005). When the ambition is to change the current practice by developing interventions, additional points may be added. That can form the basis for taking the social practice as unit of intervention: what helps and hinders change, and what might form relevant intervention points (Pettersen, 2015). A practice-orientation does not say much about how to develop these interventions. It does however have implications for their development, and for the opportunities for closing the reliability gap. The built environment is shaped by many different professional actors, and resulting energy performance levels emerge from the practices of facility managers as well as occupants. This means that closing the reliability gap concerns a multitude of practices and actors. Importantly however, and while performance levels may be stabilised through the establishment of new routines, social practice theory acknowledges that change can always happen. Practices are reactive to their environment (Schatzki, 2012), meaning interventions can also have undesired consequences.

In this section we have described what social practice theory is, how it is relevant to studying the reliability gap, and what the implications are in terms of how to do that. We have further pointed out which social science methods may help uncover practices. In the following, we will move on to looking at how the field of design possibly can contribute to understanding the reliability gap, and exploring opportunities for closing it.

Design theory

Introduction to design

The field of design comes equipped with tools and methods for facilitating generative processes, with and for different actors. This includes approaches for studying and fostering change in the interplay between people and the built environment. The notion of 'design thinking', which refers to the ways in which designers work, may provide a starting point for further exploring what design is and how it may be relevant.

While no single definition or clear description of design thinking exists (Buchanan, 1992; Kimbell, 2011), the nature of the design process and practical design work has been a topic of much design research (e.g. Buchanan, 1992; Lawson, 1997; Schön, 1983). Kimbell (2011) identifies three main strands of research and understandings of design thinking. In one, design thinking is seen as a cognitive style (e.g. Cross, 2004; Lawson, 1997). Advocates of this school are concerned with designers and their thinking and doing (Kimbell, 2011). Designers are often thought to deal with ill-defined (Cross, 2004) or wicked problems (Buchanan, 1992). One related research topic is how the design 'problem' is defined in such situations. This is often seen as a key part of the creative work, and as co-evolving with the ideas about what to create (Dorst & Cross, 2001). Schön (1983) refers to such processes as 'problem framing', where new understandings or viewpoints are created from which problems can be tackled (Dorst, 2011). In a second stream of research (e.g. Buchanan, 1992), design thinking is seen as a general theory (Kimbell, 2011). Buchanan (1992, p. 9-10) for example points out four 'areas of design thinking', ranging from 'symbolic and visual communications' to 'the design of complex systems or environments for living, working, playing, and learning', in which design is explored, whether those who do so consider themselves designers or not. A third stream has emerged over the last years and is based largely on insights and methods emerging from design practice (e.g. Brown & Katz, 2011) and not academic design research. Often such work is without reference to the older design thinking literature (Tonkinwise, 2011). In this stream, design thinking is considered a resource for organisations (Kimbell, 2011). It is adopted for example in business and management communities as a strategy for tackling open and complex challenges (Dorst, 2011; Kimbell, 2011). It is argued that designers' skills can be exported from the realm of professional design and be used to tackle social problems, organisational management or strategic innovation (Brown & Katz, 2011). Brown and Katz (2011) describe design thinking as a process that starts with gathering insights, not by collecting quantitative data, but by intensive observation, which in turn is translated into insights and eventually, products and services.

Kimbell (2011) criticises these three accounts of design thinking for not acknowledging the situated and embodied work involved as design thinking actually is carried out in practical design work. Design cannot be reduced to cognitive activity, but happens in specific contexts and involves bodily routines and practical skills such as observation, sketching and model-making, as well as ranges of artefacts including markers, cameras and computers. She also questions its generalizability on the basis of the diversity exhibited in design practices and the institutions hosting them. There are also co-existing paradoxical claims, as in design being described as user-centred while designers are considered the main agents in design work. Against that background, Kimbell (2011) points out a fourth stream of research: ethnographic accounts of design thinking in which design work is seen as situated and embodied and the material artefacts designers work with and create are emphasised (e.g. Henderson, 1991). Such accounts resonate more with social practice theory as outlined above: in line with the management and use of buildings, design work may be conceptualised as (systems of) practices, carried by designers and others (Kimbell, 2012). In the words of Tonkinwise (2011, p. 2), 'there is a practice to design thinking'.

The willingness to de-centre designers and the important role materialisation plays in design work is acknowledged in the field of co-design. Sanders and Stappers (2014) describe how designers and non-designers work together and use *making* to make sense of the future, rather than it being shaped by designers alone. To them (2014, p.6), making is 'a creative act which involves construction and transformation of meaning'. They argue that it helps people describe future objects, concerns and opportunities, and that it can provide perspectives on future experiences and ways of living.

Just like there is no one single definition or description of design and design thinking, there is no agreement on how to describe the process of design. Many different versions exist, reflecting different views of design. They range from linear models such as that of Roozenburg and Eekels (1995), criticised for not capturing the chaotic nature of design work, to practice-based squiggles such as that of Sanders and Stappers (2014) and Brown (2008). What they do share is a distinction between analytically different phases or activities, and iterations between phases of convergence and divergence. To illustrate, the basic design cycle of Roozenburg and Eekels (1995) consists of analysis, synthesis, simulation and decision. Brown (2008) visualises the design process as a process that starts very chaotically but that, throughout the different, iterative phases of research, concept and design, moves towards clarity. The model of Sanders and Stappers (2014) depicts an iterative movement between phases of pre-design research via generative and evaluative work, to post-design research. While worldviews and wordings differ, some main features of design thinking and design work are often highlighted, and may be summarised in the words of Tonkinwise (2011, p. 1), as ‘action research that comes from failure-friendly, iterative prototyping in contexts of immersive social research’. Such features may come to use in the studies of and interventions in the management and use of the built environment.

Relevance to studies of the energy reliability gap

The design of the built environment, as well as the available approaches for managing energy, directly and indirectly influence the space for action of facility managers and occupants, and the opportunities for changing what is done. Over the last years, a number of studies have addressed the ways in which the interplay between humans and the built environment influence resulting energy use levels, and the possible role of design in fostering a development in sustainable directions. Some scholars do so drawing on social practice theory (e.g. Kuijer, de Jong, & van Eijk, 2013; Scott, Bakker, & Quist, 2012), arguing that a practice-orientation may help understand why and how energy is used, and identify leverage points for stimulating a development in new directions through interventions.

When studying the energy reliability gap in order to develop or improve methods to reduce it, the analytical and generative approach is thus a relevant supplement to the understandings provided by social practice theory. To summarise, this goes for the future-oriented tools and approaches developed to bridge activities of development of use, by emphasising social research and the inclusion of different perspectives, and by allowing different actors to come together to iteratively and through the use of material and visual representations and frequent testing, develop support for future practice.

The reliability gap framework

In the previous sections we introduced facility management, social practice theory and design thinking as separate perspectives. This section presents a framework with the different research fields and explains how they complement each other. The aim of the framework is to be able to map practices of energy management in non-residential buildings, analyse potentials for improvement and subsequently, based on these insights, propose interventions for improving and extending methods and approaches that can close the energy reliability gap.

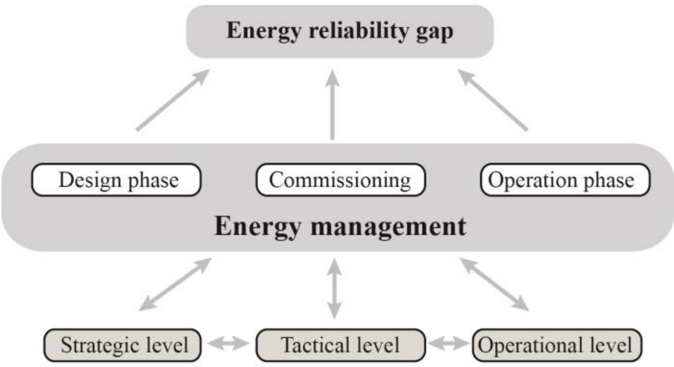

Figure 1: Overview of main aspects of energy management based on FM literature

The goal of closing the energy reliability gap forms the starting point for the development of the framework. Indications are given in the section on FM that there is a need for a) a better understanding of methods for energy management that link the design, commissioning and operation phases of a building, b) more profound insights on the collaboration between different actors in these different phases and on the different levels (strategic, tactical and operational), and c) more profound insights concerning occupancy, occupant behaviour and the use of appliances during the operation phase of a building. In order to gather insights on these issues and find opportunities for improvements, the presented framework focuses on three phases of the lifecycle of a building to which the energy reliability gap is related: design, commissioning and operation. Next to that, it incorporates the three levels or activity types in which energy management takes place in a building and how they are connected: strategic, tactical and operational. Figure 1 visualises the links between the different aspects of energy management, based on FM literature, and how elements within or between these aspects can lead to the existence of the energy reliability gap.

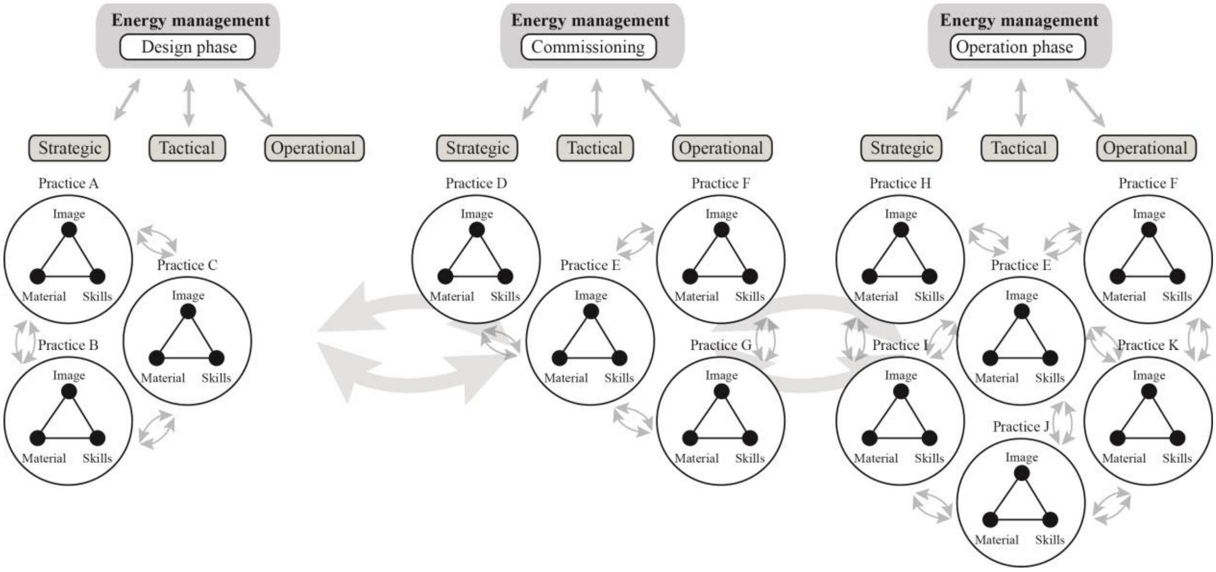

Figure 2: Studying energy management from the social practices perspective, inspired by Pantzar and Shove (2010)

In order to be able to map practices of energy management in non-residential buildings, it is important to look at the different aspects of energy management from the perspective of social practice theory, including *images*, *material* and *skills* and the connections between them in practice (Pantzar & Shove, 2010). Energy management exists out of several practices - such as measuring energy performance, developing an energy management strategy, etc. – that might be recurring or completely different in the subsequent life cycle stages of a building or in the strategic, tactical and operational levels within one life cycle stage. Figure 2 visualises how the different practices of energy management – a system of practices - can be mapped and linked to the design, commissioning and operation phase of a building, as well as to the different levels (strategic, tactical and operation) of energy management within each phase.

Design theory is included in the framework by offering a design process and activities within this process. It also provides design tools and approaches relevant to the research and development stage. Figure 3 represents the energy reliability gap framework, in which the perspectives of social practices and design theory are incorporated. The following sessions describe the framework more in detail.

Overarching research and design approach

Design thinking elements in the framework include the design process, activities of problem (re)framing, and the use of design tools and approaches for communication, collaboration and generative work in the research and development stage. The bottom of the framework represents an iterative design process, consisting of a research, concept and design stage and going from uncertainty, over finding patterns and gaining insights towards more clarity and focus towards the end of the process (inspired by Brown, 2008). It offers an overarching design approach for studying practices on energy management. This will support reframing the problem of the energy reliability gap within existing energy-efficiency reliability methods and it will form the starting point for developing future-oriented (improvements of) methods that can close this gap.

Social practice theory is interwoven in the framework as the practice of energy management works as the unit of analysis and entry point to studies of the related system of practices at the research stage, and as the (system of) practice of energy management forms the unit of intervention at the development stage. Social practice theory also adds to the framework methodologically. Each of these aspects is described more in detail below.

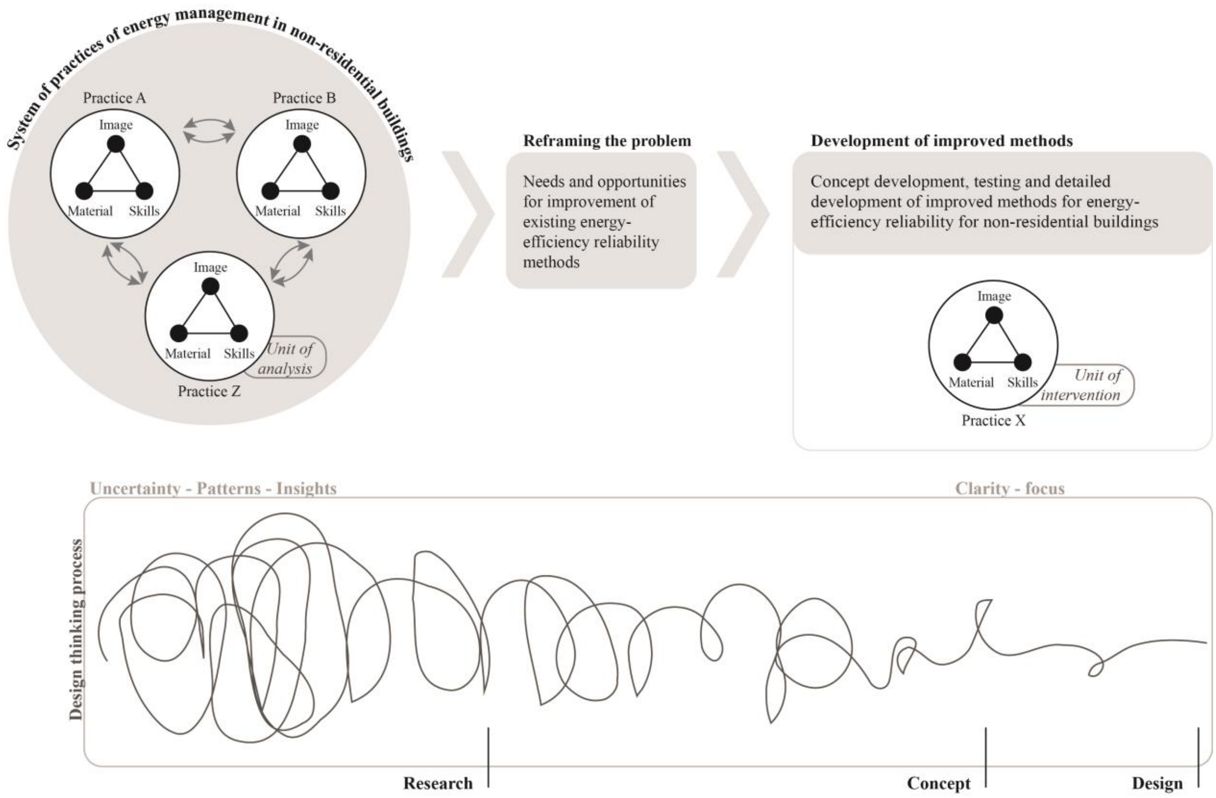

Figure 3: The energy reliability gap framework, inspired by Pantzar and Shove (2010) and Brown (2008)

Research on system of practices of energy management

The left side of the framework represents the research part of the process, in which it is the aim to look for patterns and gain insights on practices on energy management and their mutual connections. Both social practice theory and design theory add contextual and methodological knowledge, methods and tools that can support this stage.

Contribution of social practice theory

Social practice theory provides an ontological viewpoint. It says something about what can be known about the world, and how such knowledge can be gathered. By doing so, it provides heuristics as to what to study. It also has some consequences in terms of what it may take to create change in a new direction. For example, with its emphasis on the routinized, dynamic, situated and embodied character of practice, it highlights that while researchers and consultants can develop new strategies and methods for closing the reliability gap, it will always be up to the practitioners to make the integration happen and change or develop new bodily routines (e.g. Pantzar & Shove, 2010). What actually will occur – in terms of if and how they do so and with what result, cannot be predicted. In the words of Schatzki (2012, p. 22): 'The best that designers of lives and institutions can do is to create contexts that, as experience and thought show, make certain activities very or more likely.'

A practice of energy management thus forms the unit of analysis, consisting of material, image and skills and the interconnections between the three elements. Some examples of practices on energy management are: developing an energy management strategy in the design phase of a building, fine-tuning the technical energy systems of a building in the commissioning phase, as well as the tactical and operational aspects of energy management during the operation phase of a building (e.g. measuring energy performance, organising training programmes on energy efficiency, communicating on energy performance). As an illustration, studying the practice of measuring energy performance can offer profound insights into what helps and hinders energy performance measurements, what constitutes added value for different actors (image); how the energy performance is measured (e.g. indicators, methods, tools, processes) (material); and what competence and knowledge is available or needed, and to whom (e.g. available support systems) (skills).

Different practices that interact form a system of practices, in this case a system of energy management-related practices in non-residential buildings (Figure 2; 3). In the framework, the different practices in the circle at the left top side of Figure 3 illustrate this. This system of practices indicates that it is not enough to focus on one specific practice such as the measurement of energy performance of a building, but that it is necessary to study different relevant practices in energy management, as well as how they interact, compete or overlap with each other. The overall system of practices thereby offers a systemic overview of how energy management takes place and where there are opportunities for improvement.

As a last contribution to the research phase, social practice theory also offers methodological suggestions to the framework. In order to uncover practices, social practice theory scholars for example propose ethnography or participant observation, interviews or oral history and statistics as relevant methods (Schatzki, 2012). These research methods are included in the energy reliability framework and will support the collection of different types of data, such as information on the actual use of energy over time, insights into conditions and current situation of the building, the history of energy management through time, and insights into the communication of and cooperation between different actors within energy management.

Contribution of design

Design theory and design thinking may contribute to studies of why and how the reliability gap occurs and is dealt with, both at the level of single practices and systems of practices. The tools and methods used by designers to make sense of real-world situations and propose directions and opportunities for the future may also come to use in research. This goes for the use of probes designed to provoke or elicit responses (Gaver, Dunne, & Pacenti, 1999) in line with graphic elicitation tools for qualitative interviews (e.g. Crilly, Blackwell, & Clarkson, 2006) , and visualisation tools such as scenarios and storyboards to experience, test and further develop ideas and findings.

These methods allow for working with or for many different actors. In the framework, this makes it possible to involve the different actors that are engaged in or relevant to the energy management of a non-residential building. Relevant actors can be defined as building owners, facility managers (strategic and tactical levels), building operators (operational level), investors, tenants, end-users, visitors, design team and society (Jensen et al., 2012). Gathering insights from key actors of a building makes it possible to assemble an overview of energy management practices that incorporates the various actors' perspectives. Design thinking thus supplements social practice theory with tools and approaches for communication, collaboration and future-oriented work.

Reframing the problem

The research stage of the framework will offer new understandings and viewpoints on energy management practices, and thereby on how and why the energy reliability gap occurs. This makes it possible to (re)define and (re)frame the problem of the energy reliability gap, and to identify needs and opportunities for the improvement of existing or development of new energy-efficiency reliability methods.

Development of improved methods

In the last stage of the design process – at the right side of the energy reliability framework in Figure 3 - future-oriented concepts can be developed and interventions can be proposed that influence the current practices in energy management and support the closing of the energy reliability gap. By combining the two perspectives, support for future ways of managing energy in non-residential buildings can be proposed.

Contribution of social practice theory

When it comes to the development or improvement of approaches for closing the reliability gap, the contribution of social practice theory is limited. However, social practice theory contributes to the framework as the practice(s) of energy management may be taken as unit of intervention. This means that one aims at adapting the current practice by intervening in one or more dimensions of the practice, for example in its composition (i.e. image, material and skills) or by trying to establish entirely new practices. Intervening in practices rather than in specific, isolated aspects ensures that the development of improved or new methods is practice-oriented and focuses on systemic dynamics.

Contribution of design

Design theory and design thinking contributes with its innovative, future-oriented perspective and its methods for involving different actors in the design process and for developing and testing concepts for improved energy-efficiency reliability methods. Design thinking may contribute to the identification of opportunities to closing the energy reliability gap by providing a way of thinking and working that is oriented towards the future. Again, the field of design also offers knowledge, methods and tools for designers and non-designers to work together to make sense of the future. This opens up for involving different relevant actors in the development of improved energy-efficiency reliability methods. As a last contribution, design thinking offers a well-known development process with several tools and methods that may contribute to the development, prototyping and testing of such new or improved methods.

Discussion

The energy reliability framework offers an enriching and refreshing perspective to the mapping of energy management and use in non-residential buildings. To the field of FM, a focus on the practices of energy management offers the opportunity to understand what actually goes on as energy is managed and used. Such a systemic, socio-technical view can support the need for profound insights on the complex interactions between architecture, technology and the people that use and maintain buildings (Patanapiradej, 2006). To the field of facility management, and specifically focusing on the energy reliability gap, the framework makes it possible to step away from a traditional view on the gap between estimated and real energy use in a building as caused by technological, managerial or actor related aspects, and opens up the opportunity to look at energy management from a more systemic view that incorporates socio-technical dynamics.

Practice-oriented studies related to resource consumption in the built environment have previously been conducted, mostly focusing on domestic consumption (e.g. Karvonen, 2013; E. Shove, 2003). A similar observation can be made in the field of design (e.g. Kuijer et al., 2013; Scott et al., 2012). Studying energy management in non-residential buildings from a social practice and a design perspective can also add knowledge to these field and offer opportunities for further research, e.g. by studying similarities and different between domestic and non-domestic energy management practices. A study focusing on energy management in non-residential buildings would further add to studies focusing on processes involving multiple actors or practices. Examples include studies of ‘pro-environmental behaviour change at work’(Hargreaves, 2011), transitions to a decarbonised transport system (Watson, 2012), and domestic retrofit projects (Karvonen, 2013).

One of the difficulties of studying practices is that it might be challenging to decide which practices to study and where to draw the system boundaries (Pettersen, Boks, & Tukker, 2013). What goes on in a building as energy is managed at a given point in time relates to what happened during the processes of design, commissioning and its past, as well as to activities that take place outside it, for example in professional services and the everyday life of its occupants. The boundaries can be limited to the building, but several external elements of energy management do then get excluded and give an incomplete view on the (system) of practices. System boundaries that on the other hand are too broad, might lead to a situation in which the complexity of the system gets too high and the level of detail becomes insufficient to gather profound insights on the needs and opportunities for improvement.

In order to get a good understanding on the applicability and the benefits it offers to research on energy management, the framework needs to be tested. This will take place in the upcoming phase of the MINDER research project in the course of 2015, in which case studies will be performed on energy management in Norwegian non-residential buildings. The framework will be used to structure and support the data gathering and analysis of the cases in order to better understand the needs and opportunities for improvements on energy-efficiency reliability methods. Applying it will also provide the authors with feedback and insights on the strengths and weaknesses of the framework, and offers the chance to adapt and improve it where necessary. Future developments of the framework might focus on its usability and applicability in other domains than energy management.

Conclusion

In this article a theoretical framework has been presented that brings together knowledge on FM, social practice theory and design. It structures and supports research that aims at gaining a deeper understanding of how the reliability gap occurs and is dealt with in non-residential buildings, as well as how it may be closed or reduced. The framework will be used in a qualitative study of a limited number of cases and aid the identification of opportunities for improvement, as part of the larger MINDER research project. This will show whether and how introducing social practice theory and design thinking and the socio-technical perspective they provide to the field of facility management might contribute to closing the energy reliability gap.

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