Addressing human behaviour in assessments of energy efficiency in buildings

Maria Johansson
Environmental Psychology
Dept. of Architecture and Built Environment
Lund University
P.O. Box 118
221 00 Lund
Sweden
maria.johansson@arkitektur.lth.se

Lena Neij
International Institute for Industrial Environmental Economics (IIIEE)
Lund University
P.O. Box 196
221 00 Lund
Sweden
lena.neij@iiiee.lu.se

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Abstract

People's daily life has a significant effect on the outcome of any policy implemented or technology introduced with the aim to increase energy efficiency in buildings. Human behaviour should constitute a key factor in evaluations of such initiatives. This paper focuses upon how research in environmental psychology can contribute to strengthened evaluations of human behaviour in relation to the introduction of interventions to increase energy efficiency in buildings. The aim is to identify key questions to further develop an interdisciplinary evaluation framework with regard to the evaluation of user behaviour and behavioural change. Based on reviews of environmental psychology research on human pro-environmental behaviour and energy use, five overarching questions that could be added to such an evaluation framework are proposed. The questions concern the use of theory to explain human behaviour, operationalization of the behaviour studied, considerations of individual and social characteristics of the target group, potential antecedents of the behaviour, and the definition of the intervention and its motivation for behavioural change. Moreover, the importance of alignment between theory, target group, behaviour, antecedents and intervention in the evaluation is stressed. The relevance of the five questions was tested in a pilot-sample of 15 evaluations carried out on interventions in buildings in Nordic countries. All questions captured large variations between studies with regard to the identification, definition and assessment of behaviour, potential antecedents, and psychological processes of behavioural change. It is concluded that the proposed questions could support thorough evaluations of interventions targeting user behaviour by pointing at strengths and weaknesses in evaluations of interventions aimed to reduce energy use in buildings by changing human behaviour.

Introduction

Energy efficiency in buildings is considered an important strategy to combat climate change and, for this reason, various energy policies are implemented and new energy efficient technology is introduced to improve energy efficiency. The built environment accounts for approximately 32 % of the global final energy use and 19 % of energy-related GHG emissions. The potential for energy efficiency and for reducing energy demand has been estimated to 50–75 % and 50-90 % in existing and new buildings respectively, including changes in design practices, technology and behaviour (Lucon et al., 2014). People's daily life has a significant effect both on their patterns of energy consumption and consequently on the outcome of any intervention introduced.

A transition towards more efficient energy use in buildings calls for fundamental and wide-scale changes in human behaviour (Steg et al., 2105). Therefore, human behaviour should constitute a key factor in any evaluation of energy efficiency initiatives, but the consequences of an individual person's behaviour are often overlooked in current evaluation theory and practice (Mickwitz et al., 2016). This may have severe implications for understanding the actual potential of energy policy and the introduction and use of new energy technologies.

To achieve a transition in the building sector, further interventions will be necessary to overcome market failures, to provide new knowledge and to accelerate changes in socio-technical systems. To be effective, such interventions need to be evaluated to create learning from the actions taken. Evaluations have been conducted - and studied - for decades, but the evaluation approaches applied have been fragmented and strongly linked to different disciplines. In order to capture the complex changes required in the sociotechnical system and to create the learning necessary to understand transformative changes, new types of evaluation frameworks need to be developed, frameworks that go beyond traditional disciplinary approaches and which rely on interdisciplinary approaches. This study is part of a project financed by the Swedish Energy Agency that sets out to formulate a new evaluation framework that goes beyond the evaluation discourse of today. The focus of the project is on transformative changes and the evaluation of policy instruments targeting energy efficiency in the built environment. The ambition of the project is to build an interdisciplinary framework based on evaluation theory (e.g. Alkin, 2013; Shadish et al., 1995; Vedung, 2009), and to combine this theory with a number of social science theories, specifically transition theory, policy analysis, sociology of science and environmental psychology.

The current version of the evaluation framework consists of five main aspects i) *the context of the evaluation* – why is the evaluation carried out at all and by whom?, ii) *the focus of the evaluation* – what is being evaluated and who is evaluated?, iii) *the design, methods and data used to assess impact*, iv) *the criteria used for valuing* – which value criteria were used to judge the intervention? and v) *the approaches to facilitate use* – have key stakeholders been identified and involved in the evaluation process and what particular activities have been undertaken to facilitate use? (Mickwitz et al., 2016). This paper focuses specifically upon the second aspect, the focus of the evaluation and the third aspect, the design, methods and data. The paper addresses how research in environmental psychology can contribute to strengthened evaluations of human behaviour in relation to the introduction of strategies to improve energy efficiency in buildings. The aim is to identify key questions to further develop the evaluation framework to strengthen evaluation of user behaviour and behavioural change. The identified questions are used to explore how behavioural outcomes are addressed in a pilot-sample of empirical studies of interventions introduced to increase energy efficiency in buildings. The study is limited to the Nordic countries (Denmark, Finland, Iceland, Norway, and Sweden). Countries in this region face similar climate conditions with a relatively cold and dark winter season and they are fairly similar in socio-economic terms. Moreover, they have traditionally had a strong focus on energy efficiency in buildings.

An environmental psychology approach to energy use behaviour

Individual behaviour could be considered to be the result of the interplay between the physical and social environmental qualities of a setting and an individual's characteristics and experiences (Küller, 1991). To date a substantial amount of the research in environmental psychology has been devoted to understanding human behaviour in relation to the mitigation of climate change (also termed pro-environmental behaviour, sustainable behaviour or ecological behaviour). This research proposes the use of theoretical frameworks and concepts to understand the complexity of individual energy use and distinguishes between people's acceptance of technology and policy (e.g. Huijts., 2012; Steg et al., 2015) and the antecedents of pro-environmental behaviour, behavioural intentions, and overt behaviour as well as the broader implications of performed behaviour for quality of life and well-being (e.g. Dietz et al., 2013; Steg et al., 2015).

The environmental psychology literature also proposes frameworks to systematically encourage individuals' performance of pro-environmental behaviours (e.g. Geller, 2002; Steg & Vlek., 2009). Steg and Vlek outline four fundamental steps of the process: 1) identification of which behaviour should be changed, 2) definition of which factors determine the behaviour, 3) choice of interventions and 4) evaluation of effects on behaviour of the intervention. These steps point to a few critical topics to consider in the evaluation of interventions to reduce energy usage in buildings, namely the definition, categorization and operationalisation of relevant behaviour, the instrumental and psychological antecedents of the behaviour, and the choice of intervention in relation to the individual and behaviour to be targeted.

The environmental psychology approach offers theories that can be used to question the alignment between the target group, behaviour, antecedents and intervention under study. More specifically theory can be used to specify questions for the evaluation framework that considers what behavioural antecedents, behaviour and behavioural change are focused/not focused in an evaluation. Theory should, in this context, be considered as a guide to the identification of relevant psychological constructs to consider in the evaluation. The use of theory may help to identify relevant concepts, specify what concepts may have been neglected, and to pin-point gaps that could be filled with new additional concepts. A first question to be added to the evaluation framework therefore asks about the use of substance theory, i.e. topic related theory, in the evaluation.

1. Is the study based on theory related to pro-environmental behaviour and/or behavioural change?

Some key aspects of energy use behaviour identified in the environmental psychology literature drawn from review papers on energy usage in buildings are presented below.

Differentiating behaviour

From a psychological point of view, energy use behaviour can be differentiated between behaviours that involve the adoption of more energy efficient equipment, and behaviours that involve the recurrent use of equipment (Gardner & Stern, 1996). The former is referred to as efficiency behaviour and typically implies a single action whereas the latter is termed curtailment behaviour and implies behaviour changes on a frequent basis (Schuitema & Bergstad Jakobsson 2013). A single action required for adoption of energy-efficient solutions may be a relatively easier intervention to introduce and evaluate than an intervention aimed at curtailing the regular use of equipment.

Table 1. Type of energy use behaviour in households adapted from Strategier et al. (2012).

Category of behaviour	Description	Example
Cutting	Powering off devices or putting them in a low energy consuming state	Turning light off when leaving a room
Trimming	Using a lower setting when the device is being used	Lowering temperature at night
Switching	Use of different appliances to achieve approximately equal outcomes	Taking a shower instead of a bath
Upgrading	Replacement of an old device with a new more energy-efficient appliance	Taking electricity into account when purchasing new appliances
Shifting	Use of an appliance at a different moment	Shifting to off-peak hours when running the washing machine
Monitoring*	Awareness of energy use in the household	Keeping track of energy use

** Monitoring reflects awareness of energy use rather than actual behaviour.*

In the case of curtailment behaviour it would also be relevant to know if a regular use requires changes in habitual behaviour, since this kind of behaviour is more difficult to change. For habitual behaviour the individual must first be made aware of his/her current behaviour, often referred to as "defrosting" a habit, before a new (more energy efficient) behaviour can be established.

The division between efficiency behaviour and curtailment behaviour may, however, be too crude to specify which behaviour that should be targeted with a specific intervention addressing energy efficiency in buildings. Strategier et al. (2012) distinguishes between different types and focus upon behaviour in relation to household energy use. More specifically these authors present six categories outlined in Table 1. According to Strategier et al. (2012) there is a connection between efficiency behaviour (also referred to as purchase oriented behaviour) and upgrading. Cutting, trimming and switching resembles curtailment behaviour and are also likely to be habitual. Chatterton and Wilson (2013) argue that energy use behaviour in buildings must also be considered in a more complex social context and point to 4 Dimensions of Behaviour: The actor of the behaviour, the domain, the durability and the scope. In turn each dimension can be further differentiated from small scale to large scale context.

In the literature on environmental psychology, differences are made between behavioural intentions and overt behaviour. Behavioural intention concerns what people say they intend to do or would be willing to do, and does not necessarily translate into behaviour whereas overt behaviour concerns what has actually been done. Overt behaviour can be captured by self-reports in for example interviews or questionnaires. However, the reliability of self-reports is problematic as sometimes the correlation between self-reported and observed behaviour is low (Robson, 2011). In observed behaviour, the behaviour under study must be recorded either directly by another person attending the building or by recording people's behaviour, which may have ethical implications. It is also possible to indirectly observe behaviour by studying the outcome of the behaviour for example by reading electricity meters or looking for traces of the behaviour (Robson, 2011). Although final changes in energy use might be the most relevant outcome to judge an intervention, it says little about how an individual person behaves, how the reductions (or increases) were achieved and how this behaviour could be changed. Long term maintenance and internalisation of behaviour changes have rarely been studied. As there is significant potential for curtailment behaviours to reduce over time and for old behaviour patterns to be reinstated, it would be particularly valuable in evaluations to examine these with follow-up studies. In evaluations of effects of interventions on people's energy use behaviour in buildings, the relation between different behaviours should be considered as there might be spill-over effects, both positive and negative ones (Steg et al., 2015). Moreover, the consequences of a behaviour change should also be considered in terms of its broader implications for daily stress, quality of life and well-being (Moser, 2009).

Environmental psychology research offers a relatively nuanced description of energy use behaviour from the user's point of view that allows for precision of the behaviour in the evaluation framework. An assessment of current behaviour is necessary to establish a baseline for evaluating any effect(s). The behaviour under study should be specified and could at least be categorized as an energy efficiency behaviour or a curtailment behaviour, as the two types of behaviour is likely to differ in context they are performed and in motivators. Both groups of behaviour can be assessed by self-reports, direct and indirect observations and outcome in terms of energy use. Assessments should preferably address the extent to which the behaviour of interest is internalized and habitual. The validity and reliability of the chosen measure should be questioned. Moreover, the user's motivations for performing the behaviour should be identified. Hence in order to evaluate reported behavioural effects or lack of effects, the following issues regarding behaviour must be analysed:

2. How is the behaviour under study defined, operationalized and measured in relation to energy use in buildings?

Taking psychological antecedents into account

People's engagement in pro-environmental behaviour is not just limited to instrumental factors, e.g. costs and benefits in terms of price, time and comfort. It can also be motivated by affective factors and by social costs and benefits. Several theories of behaviour have been employed to increase the understanding of such psychological antecedents of pro-environmental

behaviour in general as well as energy use behaviour, including the model of Psycho-Social Determinants of Pro-environmental Behaviour (Hines et al., 1986/1987), Theory of Planned Behaviour (Ajzen, 1991), Value-Belief-Norm Theory (Stern, 2000), Goal-framing Theory (Lindenberg & Steg, 2007) and the Comprehensive Action Determination Model (Klöckner and Blöbaum, 2010). The factors specified by these theories have, in the empirical literature, been complemented by a plethora of other potential antecedents further described below. The idea of addressing antecedents in evaluations of behavioural change interventions is based on the fact that changes in the motivational structure of behaviour may be obtained without being observable in overt behaviour. However, such changes may have an effect upon behaviour indirectly or over time. Recently, research on antecedents investigated in relation to pro-environmental behaviour in general as well as more specifically in relation to energy use behaviour has been summarized as presented below. The overview is derived from recent reviews by Gifford & Nilsson, 2014, and Steg et al., 2015.

Gifford and Nilsson (2014) divide antecedents into those factors that are personal or individual and those attached to the social context of the individual. They discuss their impact on pro-environmental behaviour. One of the most common groups of antecedents are the individual's *socio-demographics*. So far there are no clear results with regard to the effects on age, but in general women tend to be more concerned about environmental issues than men. Individual childhood experiences seem to be important regardless of age and gender, with people who had more outdoor experiences in childhood and exposure to nature films and books about the environment being more concerned about environmental issues as adults. It should however be noted that concern does not necessarily translate into overt behaviour.

The role of *knowledge and education* is often investigated, however misconceptions, inaccurate estimations of energy use, and the use of simple heuristics limits the effects on behaviour. A certain level of awareness of the relation between personal behaviour and an environmental problem has been shown to be necessary but not sufficient for behavioural change. Knowledge will have limited effects when people are not motivated or when they do not feel able to engage in such behaviours. *Personality traits and how one sees oneself (self-construal)* have been put forward as relevant antecedents. Based on the theory of Big Five personality traits, openness to experience, agreeableness and conscientiousness have been found to be related to pro-environmental behaviour. Also, considerations regarding the personal relationship with the environment have been addressed, a feeling of being fundamentally interconnected with all living things has come across as relevant. Individuals who have an internal *locus of control*, i.e. that people perceive events to be controlled by their own behaviour or personal characteristics and/or with a high level self-efficacy, having the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations. Fundamental *values* serve as guiding principles in life and have been shown to affect how important people find different consequences of sustainable energy behaviours and how they evaluate these consequences. Values of self-transcendence such as altruistic values and biospheric values, as well as post-materialistic values have shown to be important. Moreover, political views and how people think about nature have been afforded as antecedents. Individual factors may also be more situationally bound in terms of time and context. *Engagement in outdoor activities*, especially non-consumptive ones such as appreciation of nature; *place attachment*, if people have a strong connection to a place, especially the natural aspects of a place, then the individual is more likely to want to protect it; and *feelings of responsibility* for the environment. *Personal goals* to engage in pro-environmental behaviour may also serve as additional motivators.

The social antecedents of pro-environmental behaviour can also be found in the context the individual's daily life. *Religion, social class* and *an urban versus rural context* are factors discussed in the psychological literature, but with inconclusive outcomes in terms of pro-environmental behaviour. Variations in behaviour due to *cultural and ethnic* antecedents have been identified, but identified differences seem to be more in structure of the concern for the environment than in level of concern. The *proximity to problem sites* seems however to show consistent results in that people who live closer to a problem site are more concerned. *Norms* constitute a powerful antecedent to behaviour, especially strong prescriptive norms (conveying which behaviours are expected) and injunctive norms (conveying social approval or disapproval) show strong relations to pro-environmental behaviour. *Status* may also motivate pro-environmental behaviour in the sense that a behaviour that is financially expensive to undertake can give off positive symbolic signals by indicating that the individual has sufficient resources to make altruistic sacrifices. It should however be recognized that pro-environmental behaviour may just be a side effect of other goals such as health or saving of money. Still, evaluations of the effect of interventions on energy use behaviour may benefit from the broader understanding of the underlying motivational structures among different user groups so as to better tailor the interventions to the intended users.

Attention to potential individual and social antecedents of energy use behaviour in the evaluation framework seems important for two reasons. It can help formulating questions that consider the characteristics of the target group investigated. Moreover, questions regarding the antecedents themselves serve to understand the broader impact on the individual of an intervention.

The alignment of the user and the intervention requires information about the target group as well as potential sub-groups within this group beyond age and gender. Considering the influence of a broad range of antecedents of pro-environmental behaviour, an intervention may be more successful if it can also be considered in relation to the participants, individual and social contextual factors, for example their personality, experiences of nature, and values and place attachment and norms. In empirical studies there might be various reasons why it is not feasible to ask an extensive list of personal background factors, rather it should be evaluated if potentially significant background questions for the intervention context have been considered. The third question asks about the target group.

3. How are individual and social characteristics of the target group described and are potential sub-groups considered?

Theory and a substantial number of empirical studies of pro-environmental behaviour point to the role of antecedent factors supporting or hindering behavioural intentions and overt

behaviour. An intervention may indirectly affect behaviour over time by changing the motivational structure if changes in antecedent factors are obtained. Questions regarding antecedent individual and social factors may therefore be important to include an evaluation to capture the broader impact on the individual. Consequently, the framework would question:

4. What are the considerations of potential antecedent factors to the behaviour under investigation, and how are these factors defined, operationalized and measured?

Strategies to change energy use behaviour

Interventions to reduce energy use in buildings can build on several strategies to support behavioural change. Lindén (2001) differentiates between information, economic instruments, administrative instruments and physical improvements. From a psychological perspective a distinction between structural strategies and psychological strategies may also be feasible. Structural strategies draw on external incentives that make behaviour with negative environmental impact more costly and behaviour with positive environmental impact less costly by, for example, subsidies. Psychological strategies, however, aim to enhance motivation to engage in pro-environmental behaviour by targeting the individual's intrinsic motivation (Steg et al., 2015). Abrahamse et al. (2005) present an overview of strategies in relation to the fundamental psychological principles for behavioural change set out by Dwyer et al. (1993). These authors make a somewhat different distinction between antecedent interventions aimed at influencing underlying behavioural determinants, which in turn are believed to influence behaviour, and consequence strategies based on the assumption that the presence of positive or negative consequences will influence behaviour. Below the strategies discussed by Dwyer et al. (1993), Abrahamse et al., (2005) and Steg et al., (2015) are presented.

Antecedent strategies include *information,* which is based on the assumption that if people do not have sufficient understanding of how to achieve a certain objective they will be less motivated to change their behaviour. The information may be general information about energy efficiency or it may focus specifically on relevant behaviours or possible solutions. Providing information is likely to increase awareness and knowledge but does not necessarily translate into behaviour changes. Information is more likely to encourage behaviour when it resonates with people's central values, when it is tailored to the needs, wants and perceived barriers of the target population, and when the source of the information is favourably valued and trusted. *Tailored information* is highly personalised and specific and therefore allows the individual to focus on personally relevant issues. Tailored information is often provided by personal encounters, for example by, persons serving as energy-guides. *Modelling of behaviour* is based on the idea that the individual should get information from another person (a role model) about how to perform a behaviour by showing how the behaviour should be carried out. It is assumed that the examples will be followed when they are understandable, relevant, meaningful and rewarding to people. Social influences, face-to-face interaction, block leaders, local volunteers that inform people in their neighbourhood on a certain issue seems to be particularly effective. *Commitment* is an oral or written promise to change behaviour and indicate how and when they will do so, based on the idea that the promise would activate a personal norm relating to the moral obligation in the present to case conserve energy. The effect of the commitment could be strengthened if the promise is made in public as it then also may act on social norms by stressing the expectations of other people. *Goal setting* gives the individual a reference point to achieve; this goal could be set by the individual or by external persons. Goal setting is based on the idea that individual behaviour is goal directed and that the anticipation of attaining a goal has a motivating effect. The goals ought to be high, yet realistic, to be effective. Goal setting is often combined with other strategies such as information and feedback to guide the individual's behaviour. *Prompts* offer a reminder and possibly encouragement to change behaviour. They have been found to be most effective when it comes to non-complex behaviours and when they are well-placed and well-timed.

Consequence strategies to change behaviour include *feedback*, which gives the individual information about a performed behaviour for example energy use. Feedback is thought to change behaviour as the individual can directly associate a certain outcome with specific actions. The feedback can be continuous, or given on regular intervals such as each, day, week or month. Feedback on behaviour, has been found to be more effective if given immediately after the performance of a behaviour. Comparative feedback gives the individual performance of a behaviour relative to the performance of other people's behaviour and may create a feeling of competition, social comparison or social pressure that may further strengthen the effect. Social influences in an anonymous way such as stressing descriptive norms may also work. *Rewards* are commonly monetary and serve to strengthen a desired behaviour. The reward can either be contingent on the amount of energy saved or a fixed amount when a certain energy saving is met.

The likelihood that the expected behavioural change resulting from an intervention will occur may not only depend on the intervention as such, but also that the intervention matches the current stage of the individual's behaviour. The proportion of individuals that will change in response to a certain intervention has been called the plasticity of the behaviour (Dietz et al., 2013). The plasticity depends on how supportive contextual factors are and on how well the intervention suits the specific individuals. Geller (2002) concludes that the intervention might need to be different depending at what stage the desired (curtailment) behaviour is at. At first a behaviour would be directed, meaning that the individual follows others or instructions on how to behave, then when the behaviour is learnt it becomes internalized and self-directed, and finally it becomes automated, habitual. Thus different interventions are likely to be more or less efficient depending on which stage the individual finds him/herself at for the behaviour in question.

Interventions could rely on structural changes and/or psychological principles. The different psychological strategies draw on different psychological processes and address either antecedents or consequences of behaviour. The strategies are therefore likely to be more or less suitable and/or efficient depending on the individual's personal and social situation, the

stage of the behaviour as well as the contextual boundaries. An obvious question to address in the evaluation therefore concerns the choice of intervention.

5. How is the intervention defined and described to motivate behavioural change and does the intervention draw on psychological principles?

An evaluation of a pilot-sample of Nordic evaluations

The five questions proposed above were added to the interdisciplinary evaluation framework described in the Introduction and tested in a pilot-sample of peer-reviewed internationally published empirical studies carried out in the Nordic countries. The search terms were derived from the study topic and covered "energy use" and "behaviour" and the countries of relevancy (Denmark, Finland, Iceland, Norway, Sweden) and were combined in a Boolean string applied in preliminary searches in Web of Science. The searches resulted in 393 hits in total. All abstracts were read and papers clearly outside the present study topic were discarded, for example papers on animals' energy use. Forty-four remaining papers were retrieved and read in full text. At this stage review papers, studies that did not exclusively focus upon buildings e.g. of more general environmental concerns and pro-environmental behaviour, and papers primarily aiming to describe antecedents of energy use behaviour in buildings without presenting an introduction of new technology or other intervention were excluded. The latter group of papers included amongst others several well-recognised studies departing from sociological theory that are highly relevant to enhance the descriptive understanding of antecedents and the potential for change in energy use behaviour, but do not intend to evaluate either structural or psychological strategies. They may therefore be of limited use for the present purpose. The final pilot sample consisted of 15 papers, listed in Appendix 1).

The included papers are, with a few exceptions, published in journals with a focus upon energy, and an interesting question is if additional search terms and further searches would show a broader disciplinary distribution between journals. Still, the studies represented do cover a wide range of disciplinary approaches including technology (e.g. Bruunsgard et al., 2012), economics (e.g. Ek & Söderholm, 2010), sociology (e.g. Palm, 2010) and psychology (e.g. Bergquist & Nilsson, 2016). Although no limitations were set with regard to publication year, the earliest that appeared was from 2007. The included papers are carried out in Sweden (n = 9), Denmark (n = 2), Finland (n = 2), and Norway (n = 1). No relevant studies from Iceland were found. In the searches for the pilot-sample of studies a generous definition of evaluation of intervention was employed, therefore, study designs vary considerably and include cross-sectional studies (n = 7), descriptive studies (n = 3), field-experiments (n = 2), case-studies (2) and action research studies (n = 1) (Appendix 1).

THEORY RELATED TO PRO-ENVIRONMENTAL BEHAVIOUR AND/OR BEHAVIOURAL CHANGE

Ten of the 15 studies included evaluations which presented theoretical frameworks. Some of the frameworks clearly addressed psychological aspects of behaviour such as the Value-Belief-Norm theory (Ek & Söderholm, 2010; Palm, 2010; Sopha & Klöckner, 2011) as well as theories on social norms (Bergquist & Nilsson, 2016; Ek & Söderholm, 2010), Goal-Framing-Theory (Bergquist & Nilsson, 2016), The Comprehensive Action Determination Model (Sopha & Klöckner, 2011) and the framework for encouraging pro-environmental behaviour presented by Steg and Vlek (2009) (Salo et al., 2016). A few studies drew on theories on adoption and diffusion of new technology that included user perspectives (Sopha & Klöckner, 2011; Tapaninen, 2008) or sociological theories that view the individual as part of a household such as Practice Theory (Gram-Hansen, 2007). In some studies, economic models were used (Ek & Söderholm, 2010; Lillemo et al., 2013; Palm, 2010). The other included studies relied on outlines of relevant previous research or in some cases completely lacked a theoretical foundation on behaviour or behavioural change. The first question of the proposed extended framework "Is the study based on theory related to pro-environmental behaviour and/or behavioural change?" clearly distinguishes between the reviewed evaluations and revealed a great diversity of theories employed. Showing that in the Nordic arena the study of energy use behaviour in buildings is approached in a multi-facetted way rather than guided by one dominant theory. This seems promising for a holistic understanding of current energy use behaviour. A theoretical base used to align the empirical study strengthens the conclusions that can be drawn with regard to behaviour. Studies that completely miss out on a theoretical specification of the social or psychological processes involved may result in no or an arbitrary choice of behavioural antecedents in the empirical work and/or the study of a vaguely defined user perception rather than behaviour, that may blur the understanding of the overarching outcome.

THE BEHAVIOUR UNDER STUDY

Energy use behaviour is defined, operationalised and measured in multifaceted ways, most commonly as energy consumption per household (Karlsson & Mosfegh, 2007; Palm, 2010; Vassileva et al., 2013) or office unit (Nilsson et al., 2015). Some studies identified electricity consumption per person per square meter (Vassileva et al., 2012). Other studies used triangulation to obtain a holistic picture. Nilsson et al. (2015) for example combined measurements of electricity, observation of traces of behaviour and self-reports. Vassileva et al. (2013) combined electricity use with self-reporting of the frequency of use of domestic appliances. A couple of studies addressed a behavioural intention by asking about the willingness to perform a certain behaviour such as willingness to install individual metering and costs (Ek & Söderholm, 2010; Siggelsten & Olander, 2013). Other studies discussed perception rather than behaviour (Bruunsgard, 2012; Karlsson & Mosfegh, 2007). Some studies addressed several different household behaviour (Ek & Söderholm, 2010; Zaljeska-Jonsson, 2012), but in most cases it was either general energy use that was under study or one specific behaviour. Self-reports were commonly used and many studies failed to report the question posed about behaviour in interviews or questionnaires which makes it impossible to compare outcomes between studies. The question "How is the behaviour under study defined, operationalized and measured in relation to energy use in buildings?" stands out as crucial for an extended evaluation framework. A lot could be achieved by the use of rather crude classifications such as

energy efficiency behaviour versus curtailment behaviour, and probably even more so by employing detailed specifications of the type and focus of energy use behaviour, or specifying the individual's stage of a behaviour. This kind of precision would allow for parallels between outcomes of different interventions and potential for generalisation. Furthermore, this information could facilitate the match between behaviour and choice of intervention in further applications.

INDIVIDUAL AND SOCIAL CHARACTERISTICS OF THE TARGET GROUP

The most researched target groups were households in apartments and single family houses, and sub-groups formed by these parameters. One study focused on the board members of housing cooperatives (Siggelsten & Olander), one on office workers (Nilsson et al., 2014) and another on university students and staff (Bergquist & Nilsson, 2016). In all studies the target group for the intervention and the choice of sample matched. Gender, age group and income levels were commonly reported whereas other individual or social characteristics given above are not reported. When such characteristics were included they were mostly addressed and treated as antecedents of behaviour, see further below. In a few cases other relevant contextual factors were given such as the climate conditions (Lillemo et al 2013) and details of the apartment building (e.g. Zalejska-Jonsson, 2012). The question "How are individual and social characteristics of the target group described and are potential sub-groups considered?" also differentiates between the studies and thereby supports evaluations of behaviour in intervention studies. The provision of more details on the target group for example with regard to their social context and the building considered would facilitate reflections on the match between individual and intervention. The pilot-sample of papers also points to the need to extend the question to comprise building characteristics.

POTENTIAL ANTECEDENTS

The majority of studies take potential antecedents into account (and frequently consider more than one). Behavioural antecedents are considered regardless of the disciplinary approach, but studies based on theoretical frameworks on human behaviour (see above) tend to include antecedents of psychological character to a greater extent whereas other studies focus upon instrumental factors that may serve to motivate behaviour. Still, these factors are neglected in the analysis of the outcome of the intervention. Just as for behaviour the wording used in self-report questions and items are often lacking. Awareness and knowledge (Gram-Hanssen, 2007; Palm, 2010; Vassileva et al., 2012), attitudes (Nilsson et a., 2015; Sopha & Klöckner, 2011; Vassileva et al., 2012) and norms (Ek & Söderholm, 2010; Nilsson et al., 2015; Sopha & Klöckner, 2011) are commonly investigated whereas antecedents reflecting social networks and social identities are less frequently investigated (Gram-Hanssen, 2007; Nilsson et al., 2015). The question regarding "What are the considerations of potential antecedent factors to the behaviour under investigation, and how are these factors defined, operationalized and measured?" yield extremely varied responses. This is partly due to the different disciplinary approaches and theoretical frameworks used, but also due to the variation in behaviours studied. Therefore, the question must consider the choice of antecedents in relation to the disciplinary and theoretical context. Moreover, in the analysis of the question one should look beyond the antecedents investigated and ask what antecedents could have been useful for the interpretation of the outcome. Antecedent factors may support or hinder a desired behaviour. Environmental psychology offers a plethora of potential antecedents and further studies on energy use behaviour in buildings may benefit from addressing a wider array of such psychological antecedents to achieve a more elaborated understanding of interventions. On the other hand studies based on psychological frameworks would be strengthened by adding both contextual and instrumental factors as antecedents.

DEFINITION OF INTERVENTION AND ITS MOTIVATION FOR BEHAVIOURAL CHANGE

The interventions concerned both structural strategies such as introduction of new building characteristics and technology, and psychological strategies, primarily information and feedback, but also in some cases prompts. Several of the studies adopted the idea of tailored information (please refer to Appendix 1). Two of the studies in particular evaluated the target population's perception of the intervention (Palm, 2010; Salo et al., 2016) which is useful for the understanding of how the intervention might motivate behavioural change. Here an action research approach helped to shape the intervention to fit stakeholders through recognising the importance of intermediates (Salo et al., 2016). Bergquist and Nilsson (2016) give an excellent description of how the designed informational intervention was expected to support the process of behavioural change. Tapaninen (2008) theoretically describes how the adoption process would function among different user groups, but does not follow-up on it in the analysis. Still the majority of the studies in the pilot-sample justify their approaches by referring to previous research regarding the usefulness of the evaluated intervention rather than considering the psychological relevance of the intervention in relation to their target group and context. None of the studies discussed the plasticity of the behaviour or the stage of behaviour as a reason for the choice of intervention. It is of little surprise that studies based on a psychological approach had stronger psychological arguments in favour of their choice of intervention, but at least some thoughts about how an intervention would affect human behaviour could be expected to be given in all studies addressing energy use behaviour. The fifth and final question proposed for the framework "How is the intervention defined and described to motivate behavioural change and does the intervention draw on psychological principles?" is essential to evaluate the relevance of any intervention aimed to change behaviour including energy use behaviour as the effect/lack of effect may be dependent on the match/mismatch between target group, motivation and intervention.

Discussion and conclusion

Individuals' daily practices at home, work and leisure will significantly impact on the energy use in buildings. Changes in human behaviour will be necessary to reduce energy use and combat climate change. Large investments are made in the Nordic countries to introduce interventions aimed at reducing energy use in buildings. This study proposes five overarch-

ing questions on behaviour and behavioural change that can be added to an interdisciplinary evaluation framework for interventions aimed at reducing energy use in buildings that is under development (Mickwitz et al., 2016). The proposed questions address the use of theory on human behaviour, the behaviour studied, considerations of individual and social characteristics of the target group, potential antecedents of the behaviour, and the intervention and its motivation for behavioural change. Moreover, the alignment between theory, target group, behaviour, antecedents and intervention in the evaluation is stressed.

All the questions captured the large variations between the studies in the pilot-sample with regard to the identification, definition and assessment of the behaviour, potential antecedents and psychological processes related to behavioural change. This analysis points to the difficulties in obtaining aggregated knowledge on the behavioural effects of interventions. There is a clear divide in the outcomes addressed between various disciplinary approaches. In many cases, studies developed from technical approaches – and not social science theory – fail to specify important psychological variables with regard to target group, behaviour, antecedents and intervention. At the same time studies firmly based in psychological theory show a lack of specification of building-related and other contextual factors. Also, many studies neglect a discussion about how the introduced interventions are expected to work for the intended users in practice (as discussed by Salo et al., 2016). There is much to learn from qualitative studies on energy use behaviour in different target groups.

It is concluded that the proposed questions could support a thorough evaluation of how interventions affect user behaviour by pointing at strengths and weaknesses in evaluations of interventions aimed to reduce energy use in buildings by behavioural change. The analysis further revealed that additional questions could be considered addressing the usefulness of the research design employed for evaluating behaviour. Moreover, questions about how choice of investigated variables and analysis support the alignment between antecedents, behaviour and intervention would be useful.

The questions formed draw on contemporary environmental psychology approaches to pro-environmental behaviour. It should be noted that environmental psychology is just one of several social sciences perspectives, and additional information on interventions aimed at changing energy use behaviour in buildings could be gained by for example applying a sociological approach (e.g. Hargreaves, 2010; Shove, 2010). The reviewed studies featured several disciplinary departures and at an overarching level the analysis strongly suggests that multidisciplinary and transdisciplinary evaluations of interventions are required. This is in line with the view of Wilson and Chatterton (2011) and has previously been explored in relation to for example travel behaviour (Kärrholm et al., 2014).

For the present purpose further literature searches are needed within set system boundaries in order to give a full picture of the status of evaluations of behaviour on interventions to reduce energy use in buildings. In the next phase, the proposed questions will be tested on a larger set of evaluations and the formulations further refined. The questions will also be integrated with the broader evaluation framework to meet the overarching project goal.

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Appendix 1.

List of articles included in the review presented in chronological order of publication year.

Year	Author/s	Title	Journal	Research design	Theory	Behaviour	Intervention	Country
2007	Karlsson, J. F., & Mosfegh, B.	A comprehensive investigation of low-energy building in Sweden	Renewable Energy	Case-study	No	Self-report Measurement	Building characteristics	S
2007	Gram-Hanssen, K., et al.	Do homeowners use energy labels? A comparison between Denmark and Belgium	Energy policy	Descriptive	Yes	Self-report	Information energy labels	D
2008	Tapaninen, A.	Do customers' personal attributes matter in the adoption of wood pellet heating	IEEE	Cross-sectional	Yes	Self-report	New technology*	F
2010	Ek, K., & Söderholm, P.	The devil in the details: Household electricity saving behaviour and the role of information	Energy Policy	Cross-sectional	Yes	Self-report	Information	S
2010	Palm, A.	The public-private divide in household behaviour: How far into home can energy guidance reach	Energy Policy	Descriptive	Yes	Self-report Measurement	Information: Tailored	S
2011	Sopha, B. M. & Klöckner, C. A.	Psychological factors in the diffusion of sustainable technology: A study of Norweigan households' adoption of wood pellet heating	Renewable and Sustainable Energy Reviews	Cross-sectional	Yes	Self-report	New technology*	N
2012	Brunsgaard, C. et al.	Evaluation of the indoor environment of comfort houses: Qualitative and quantitative approaches	Indoor and Built Environment	Descriptive	No	Self-report	Building characteristics	D
2012	Vassileva, I. et al.	The impact of consumers' feedback preferences on domestic electricity consumption	Applied Energy	Cross-sectional	No	Measurement	Feedback	S
2012	Zalejska-Jonsson, A.	Evaluation of low-energy and conventional residential buildings from occupants' perspective	Building and Environment	Case-study	Yes	Self-report	Building characteristics	S
2013	Lillemo, S. C et al.	Household heating investments: The effect of motives and attitudes on choice of equipment	Biomass and Bioenergy	Cross-sectional	Yes	Self-report	New technology*	N
2013	Siggelsten, S. & Olander, S.	Individual metering and charging of heat and hot water in Swedish housing cooperatives	Energy Policy	Cross-sectional	No	Self-report	Feedback Pricing	S
2013	Vassileva, I. et al.	Energy consumption feedback devices' impact evaluation on domestic energy use	Applied Energy	Cross-sectional	No	Self-report Measurement	Feedback	S
2015	Nilsson, A. et al.	Energy behaviours at the office: An intervention study on the use of equipment	Applied Energy	Field-experiment	Yes	Self-report Measurement Observation	Goal setting Feedback Information Prompts	S
2016	Bergquist, M. & Nilsson, A.	I saw the sign: Promoting energy conservation via normative prompts	Journal of Environmental Psychology	Field-experiment	Yes	Observation	Normative prompts	S
2016	Salo, M., et al.	Tailored advice and services to enhance sustainable household consumption in Finland.	Journal of Cleaner Production	Action research	Yes	Self-report	Information: tailored	F

** The studies on wood pellet were included since they provide interesting cases in relation to evaluation of behaviour.*