Improving interventions for the long-run

A systematic literature analysis of interventions for residential energy consumption reduction using a theory of motivation

Aakash Dhingra

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Abstract:

To address climate change, global greenhouse gas (GHG) emissions in the residential building sector, accounting for 39% in Sweden, need to reduce. While technological improvements and behavioural change are two commonly used strategies, the former is limited by rebound effects that range from 15-20% in Sweden. Focussing on individual behaviour is imperative. While Psychology (behavioural-based) and Sociology (practice-based) offer distinct understandings on unsustainable energy consumption and design of interventions, one, called feedback has been identified to be effective, albeit limited by lack of motivation and (in)ability to produce long-term reductions. To overcome these, use of additional motivational strategies have been recommended.

As no specific theory of motivation has been used to investigate interventions, this thesis used the Theory of Self-determination (SDT) to investigate how interventions from both behavioural-based and practice-based approaches motivate resident individuals to reduce energy consumption for long-term reductions, and reductions in rebound effects. Specifically, it asked what co-occurrences exist between the fulfilment of three psychological needs (autonomy, competence and relatedness) and long-term reductions.

It used a systematic literature review to analyse 40 studies including peer-reviewed studies (past 10 years) and grey literature that evaluated changes in energy consumption using an intervention involving feedback in the residential context.

Ten interventions were classified into four different levels of extrinsic motivations. No studies using interventions from practice-based approach or aiming at reducing rebound effects were found. Most studies used behavioural-based approach but some gave considerations to practice-based elements. Long-term reductions were found to co-occur with the fulfilment of psychological needs (autonomy, competence and relatedness) although only six studies reported long-term reductions. Conversely, a lack of fulfilment of psychological needs was found to co-occur with fall-back to higher consumption in the long-term.

Based on the data, how the fulfilment of needs should be done is stressed. Autonomy should be taken into account as interventions themselves either support or thwart autonomy, specifically rewards that were found to reduce autonomy and co-occurred with fall-back on high consumption in the long-term. Competence support can be enhanced through improving feedback that meets the informational and motivational needs of individuals. Further, group-based interventions can play a greater role as they provide more opportunities to support relatedness and motivation. Lastly, taking a practice-based approach can improve the design of interventions, especially with respect to rebound effects as practice-based approaches take a richer account of different factors (material, embodied skills and meanings) that are suggested to better support need fulfilment.

Keywords: energy consumption, intervention, motivation, long-term, rebound, behaviour

Word count (thesis): 13986

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List of Abbreviations

GHG	**G**lobal Green**h**ouse **G**ases
SABO	**S**veriges **A**llmännyttiga **Bo**stadsföretag
SDT	**S**elf-**D**etermination **T**heory
SPT	**S**ocial **P**ractice **T**heory

1 Introduction

1.1 Problem Introduction

Climate change caused by a rise in global greenhouse gas (GHG) emissions is one of the nine planetary boundaries that if exceeded would cause irreversible damage to earth systems (Rockström et al., 2009). To limit the emissions, nation-states signed the Paris agreement committing to a reduction in GHG emissions (United Nations, 2015). One of the sectors that greatly contributes to GHG emissions is the residential building sector. In Sweden, it accounts for 39% of the emissions (SABO, 2016; Swedish Energy Agency, 2015). Until now, strategies to reduce emissions have mostly focussed on improving technological energy efficiency but there's a rising trend in energy consumption and reports[1] of difficulties in achieving further reductions in energy consumption through technological changes (Swedish Energy Agency, 2015). One way to approach the problem is through behavioural changes that have been reported to hold significant potential (Wei, Jones & McMahon, 2011). Another reason to focus on behaviour change is that the full potential of emission reduction from technological improvements is limited by rebound effects[2] which in the case of Sweden range from 15-20% (Nässén & Holmberg, 2009).

Many interventions have been tested to change behaviour, however, the resulting knowledge is scattered among different disciplines. Both psychological (behavioural-based) and sociological (practice-based) approaches have offered distinct ways of understanding the problem of unsustainable energy consumption and subsequent design of interventions (Wilson & Dowlatabadi, 2007). However, both approaches use similar interventions and only differ in how they are applied (Spurling, McMeekin, Shove, Southerton, and Welch, 2013) and one intervention that has been identified to be effective is feedback (Karlin, Zinger, & Ford, 2015). Interventions involving feedback provide information to individuals about their energy consumption so that individuals might change their ways of consuming energy (Abrahamse et al., 2005). Even the recent EU mandate on smart meter installation where 80% households shall be provided with smart meters by 2020, requiring an investment of €30 billion (JRC European Commission, 2013), is based on the idea of feedback (Council Directive 2012/27/EU, 2012).

[1] The Swedish Housing Association's (SABO) annual report has mentioned failing to achieve the emission reduction target for 2020 as part of SABO's Skåne Initiative (SABO, 2016).

[2] Unexpected higher consumption after improvements in technology towards energy efficiency. There are economic, psychological and sociological explanations, see section 2.3.

However, feedback has been reported to be ineffective due to lack of individual motivation (D'Oca, Corgnati, & Buso, 2014; Oltra, Boso, Espluga, & Prades, 2013; Pasini, Reda, & Häkkinen, 2017; also see Darby as cited in Wilson, Bhamra, & Lilley, 2015). In the case of smart meters, achieving reductions have been reported to be challenging if users do not engage with the information provided. (D'Oca et al., 2014; Pasini et. al, 2017). Oltra et al. (2013) have recommended using a variety of motivational strategies and feedback mechanisms to match the needs of users. Schultz (2014) has also said that "feedback, in the absence of an added motivational source such as a competition, or cost, is unlikely to result in behaviour change." (p. 112).

While motivation is a clear challenge, theories that have been used to design and assess the effectiveness have used different factors such as attitudes (Abrahamse et al., 2005) and norms (Karlin et al., 2015) as motivational proxies. As such, motivational mechanisms of different interventions have not been explored through the use of any specific theory of motivation. According to Schultz (2014), the applicability of different interventions based on individual motivations is categorized by first, the presence or absence of motivation in an individual and second, the nature of motivation (extrinsic or intrinsic). Further, the effectiveness of an intervention depends on its ability to produce long-term reductions (Abrahamse et al., 2005). This has been reported to be a challenge (Oltra et al., 2013). However, Gifford, Kormos, and McIntyre (2011) have stated that intrinsic motivations are more likely to lead to pro-environmental behaviour for the longer term.

This thesis aims to contribute to the ongoing debate on the effectiveness and better design of interventions involving feedback to achieve better long-term reductions and reduced rebound effects through a theory of motivation.

1.2 Research Questions

Given the aim of this thesis, it takes a deductive approach to formulate research questions by using the Theory of Self-Determination (SDT). SDT has been used in health and educational contexts (Hagger & Chatzisarantis, 2009; Lazowski & Hulleman, 2016; Ng et al., 2012) but no previous literature was found that examined interventions aiming to reduce energy consumption using SDT. SDT has been chosen for two reasons that are further elaborated in the section on theory. First, SDT expands on different levels of extrinsic motivations and underlying explanations of what motivational regulations (mechanisms) are at play. This corresponds with the nature of interventions being extrinsic. Further, it describes the internalisation process of external behaviours (and values) that can contribute to long-

term reductions. This theory is also suitable to examine rebound effects, as interventions aiming at rebound effects would also aim at reducing consumption.

Therefore, this thesis specifically asks:

1. How do interventions involving feedback from behavioural-based and practice-based approaches motivate resident individuals to reduce energy consumption and reduce rebound effects? Specifically:

    1.1 What co-occurrences exist with long-term reductions in energy consumption and fulfilment of psychological needs?

2. Based on the findings, what implications can be derived for better designing interventions aimed at long-term reductions and reducing rebound effects?

1.3 Roadmap

First, section 2 describes the relevant background specifically, on the existing debate between behavioural-based and practice-based approaches, a list of interventions involving feedback and a review of how rebound effects have been understood in the literature. Section 3 presents the theoretical basis, describing SDT and how it fits in the context of analysing different interventions. Section 4 presents the methodology adopted in the thesis, specifically, data collection and analysis procedure for answering RQ 1 and 2 followed by the epistemological and ontological stance taken. Section 5 presents the main findings comprising of literature analysis (RQ1). Finally, section 6 discusses the findings with relevance to the theory and its implications (RQ2), draws conclusions with respect to the debate between the two approaches (behavioural-based vs practice-based), and presents contributions to sustainability and limitations of the thesis. All through the discussion, future research questions are also presented.

1.4 Relevance for Sustainability Science

Sustainability Science seeks to understand interactions between human (society) and nature “by combining different ways of knowing and learning” (Kates et al., 2001, p. 640), and specifically seek answers to seven core questions. This thesis contributes to one of the core question posed by Kates et al. (2001) on what incentives in society can “most effectively improve (the) social capacity to guide interactions between nature and society toward more sustainable trajectories?” (p. 641). It does this

by investigating how different interventions involving feedback from different approaches motivate resident individuals to consume less energy, which has a direct impact on nature through a reduction in GHG emissions and resource extraction. Further, this thesis seeks to incorporate studies and interventions from different disciplines "spanning the natural, social and technological sciences" (Kates, 2011, p. 49) and hence qualifies as an interdisciplinary study. Lastly, the thesis takes a problem solving and critical approach with the aim to produce knowledge that can aid in dealing with one of the sustainability challenges of climate change (Jerneck et al., 2011). It does this by aiming to provide actionable knowledge relevant to practitioners while still being critical by including both psychological and sociological approaches and discussing them on their own merits.

2 Background

2.1 Understanding Behavioural-based and Practice-based Approaches

Theories stemming from psychology (behavioural-based) **centre the individual as the information processing unit** capable of making decisions, albeit, limited by either cognitive abilities, internal factors (attitudes, value, etc.) or social influences (Steg & Abrahamse, 2010; Wilson & Dowlatabadi, 2007). Three theories have most commonly been used to design interventions aiming to reduce energy consumption in various contexts (residential, workplace, etc.), amongst other theories that have been presented in review studies (Abrahamse, Steg, Vlek, & Rothengatter, 2005; Delmas, Fischlein, & Asensio, 2013; Johnson, Horton, Mulcahy, & Foth, 2017; Karlin et al., 2015; Schultz, 2014; Schweiker & Shukuya, 2011). The Theory of Planned Behaviour describes behaviour to be a result of intention formed by attitudes, personal and subjective norms, and perceived efficacy (Sarkis Jr., 2017) The Norm Activation Theory posits behaviour to result from an intention that's formed by activation of personal norms, that's in turn due to a sense of awareness and ascription of responsibility (Abrahamse & Steg, 2009). Goal-Setting Theory describes the relation between the performance of behaviour and the difficulty of the goal that an individual sets with difficult goals leading to better performance. (Latham & Locke, 1991).

Conversely, theories from sociology (practice-based) take a broader look at behaviour and see them as **originating from a result of wider structural influences** (such as discourses, economic and political conditions, etc.) and **not only internal factors** as perceived by an individual in psychological theories. Specifically, practices are situated between the dialectical interaction of agents and structure with both agents and structure influencing the existence of practice (Callinicos, 2007; Wilson & Dowlatabadi, 2007). Different versions of Social Practice Theory (SPT) have been used but generally it comprises of three elements: materials (the infrastructure, stuff, etc.), skills (the embodied such as skills, knowledge, etc.) and meanings (the socially shared symbols or images) (Galvin & Gubernat, 2016; Sweeney, Kresling, Webb, Soutar, & Mazzarol, 2013). The practice emerges as a result of the interactions of the three elements with each other (Kurz, Gardner, Verplanken, & Abraham, 2015).

However, there exists an emerging debate on the usefulness of practice-based theories over behavioural-based theories in explaining energy consumption and subsequently designing interventions. On the basis of theoretical strengths, it has been argued that **practices should be the unit of analysis** as opposed to individuals (Spurling et al, 2013). Because practices have a spatial and temporal place in the society and **are inherently social**, a practice-based approach compels energy consumption practices to be seen as existing of themselves and not as individual endeavour (Davoudi,

Dilley and Crawford, 2014: Spurling et al., 2013). According to Spurling et al. (2013), then "**individual behaviours are, primarily, performances of social practices**." (p. 8) and changing of any **practice requires a systematic analysis** of all the elements that the practice is made of. This difference has implications for the design of interventions, for example, in the specific case of energy consumption, Shove, Walker, Tyfield, and Urry (2014) argue that energy should be seen as instrumentally playing a role in fulfilment of daily practices rather than a resource itself, to change how the problem of unsustainable energy consumption is understood. This reframing will lead researchers and practitioners to look into the dynamics of demand for energy embodied within the wider structures instead of focusing on individual preferences (Shove et al., 2014). Further, expanding on the above, Spurling et al. (2013), have presented a framework of different ways of framing the problem of sustainable consumption from behavioural-based and practice-based approaches. An adapted version specific for the case of energy consumption is shown in Table 1.

Table 1

Different Problem Framings of Energy Consumption from behavioural-based and practice-based approaches. Adapted from Spurling et al. (2013).

Problem framing	**Target of intervention**
	Behavioural-based
1.*Innovating Technology*	How to reduce the resource intensity of existing patterns of energy consumption through technical innovation?
2.*Shifting Consumer Choices*	How to encourage consumers to choose more energy efficient products?
3.*Changing Behaviour*	How to encourage individuals to adopt more sustainable energy consumption behaviours and discourage them from less sustainable ones?
	Practice-Based
4.*Re-crafting Practices*	How to reduce the resource-intensity of existing practices through changing the components, or elements, which make up those practices (socially shared material, skills and meanings)?
5.*Substituting Practices*	How to replace less sustainable practices with more sustainable alternatives. How can new or alternative practices fulfil similar purposes?
6.*Changing how practices interlock*	How can we harness the complex interactions between practices, so that change ripples through interconnected practices?

In this thesis, problem framings 2,3,4 and 5 describe the four relevant problem framings due to their focus on behaviour/practice and therefore, problem framings 1 and 6 have not been accounted for in the remainder of the thesis.

Lastly, there have been some mixed opinions about the superiority of one over the other. Davoudi et al. (2014) have acknowledged the ability of practice-based approaches to account for wider structures but they have also recommended that intervention designers should be aware of all approaches

because such approaches are after all theories which predict human action and need testing. Wilson & Dowlatabadi (2007) have suggested that even though interventions from behavioural-based approaches, aimed at internal factors might be limited by external conditions, intervention design from practice-based approaches can also "be less generic, less prescriptive, more complex, more diffuse, more gradual, far-reaching and so, in all senses, less palatable to intervention designers interested in verifiable impacts." (p. 189). Some light has also been shed on how these approaches understand habitual behaviours which has been cited as a strong barrier to the reduction in energy consumption (Gifford, 2013; Maio et al., 2007). Kurz et al. (2015) explain that practice-based approaches accommodate habits as an established routinized practice involving the agent and the socio-material context whereas behavioural-based approaches assume habitual behaviour to be a cognitive process. While there has been limited evidence to which approach is superior, Kurz et al. (2015) concluded that interventions are quite common between the two and that they might be improved with the understanding of the two approaches.

2.2 Interventions Involving Feedback

Feedback is one of the common interventions that has often been used in combination with other interventions. This section presents the specific interventions that involve feedback as background information to the analysis presented in section 5.

Information is often the focus in the design of interventions as knowledge and awareness are prerequisites for behavioural change but interventions can be classified based on when the information is given: antecedent (before the behaviour is performed) and consequence (after the behaviour is performed) (Abrahamse et al., 2005). Feedback, being one of the consequence interventions, comprises of information related to the particular behaviour (energy consumption) given to the individual after the behaviour has been performed (Abrahamse et al., 2005). Karlin et al. (2015) in their meta-review of feedback interventions, presented a useful overview of Feedback Intervention Theory by Kluger & DeNisi (1996). The theory describes how the purpose of feedback and its three components (standards, goals and attention) works to either direct an individual's attention to a comparison between feedback and standard information (which can be an own set goal, or a goal provided by an intervention) or better still to the feedback-standard gap via social influences (Karlin et al., 2015).

On this note, interventions have been distinguished by target audience type, individual or group-based (Fisher & Irvine, 2016). At the individual level, attention to the feedback-standard gap can be given by

incorporating social influences as an information device through different framings of information (Abrahamse & Steg, 2013). At the group level, social influences can be incorporated through using an appropriate medium of information such as an influential person modelling certain ideal behaviours or community-based social marketing where interpersonal peer influence is in action (Abrahamse & Steg, 2013). Further, feedback can be given to the whole group where group explores the information on feedback and the group dynamics help to maintain attention (Fisher & Irvine, 2016). In summary, a list of different interventions involving feedback is presented below with definitions:

1. *Comparative feedback*

   Giving comparison information on energy use to evoke feelings of social pressure or competition (Abrahamse et al., 2005).

2. *Goal setting and feedback*

   Stemming from Feedback Intervention Theory, feedback can be directed towards pre-set goals, both action related or identity related (Karlin et al., 2015).

3. *Commitment and feedback*

   A written pledge to serve a goal or plan activating personal norms (if private commitment) or social norms (if public commitment) (Abrahamse et al., 2005).

4. *Goal Setting, commitment and feedback*

   The combination of commitment and goal setting is often used as complimentary interventions (Abrahamse et al., 2005).

5. *Group feedback*

   Feedback is given at a collective level focusing on collective effort, or highlighting group norms and strengthening shared beliefs, see Bandura (as cited in Abrahamse & Steg, 2013).

6. *Community-based social marketing*

   Using social and behavioural science to design intervention that use social networks within a community to diffuse norms and information (Schultz, 2014).

7. *Competitions*

   Individual compete with each other for some kind of reward following a set of rules of the competition (earning points, monetary reward, etc.) (Vine & Jones, 2016).

8. *Group-based competitions*

   Similar to individual but groups compete with each other. In this intervention, peer pressure and social norms within the group are also exploited (Vine & Jones, 2016).

9. *Team-based*

   Teams voluntarily explore information to reduce environmental impact often involving regular meetings (Fisher & Irvine, 2016).

2.3 Rebound Effects

As regards to rebound effects, literature is scarce. However, similar theories described in section 2.1 have been used to explain rebound effects from both behavioural-based and practice-based approaches.

From the behavioural-based approach, no specific theory of rebound has been developed but Santarius and Soland (2016) offer a theoretical understanding of rebound effects based on the Theory of Planned Behaviour and Norm Activation Theory, adding to the work of Peters and Dütschke's (2016), who also used similar theories to examine rebound effects. According to Santarius and Soland's (2016) model, an energy efficiency improvement can cause either rebound or beneficial effects[3] through a reappraisal of three factors: ascription of responsibility (how responsible an individual feels), perceived control (how in control an individual feels), and awareness of consequences (how aware an individual is regarding the consequences of adopting a new technology). When an individual has both high awareness and responsibility, personal norms would activate and lead to beneficial effects. This would be supported if perceived control is also high. However, if an individual's adoption of energy efficiency technology reduces responsibility either through diffusing responsibility to others or to self, then rebound effects are likely to occur. Further, if awareness of consequences is low coupled with low perceived control, rebound effects are also likely to occur (Santarius and Soland, 2016).

From a practice-based approach, no specific theory has been developed as well. However, rebound effects have been explained to occur because of changes in material-human arrangements or in other words between the elements of practice theory (Galvin & Gubernat, 2016). As an example, Winther & Wilhite (2015) explored what causes rebound effects when people buy heat pumps and found that heating practices were influenced by the interacting agency of individual, supplier and technology. Specifically, rebound effects occurred due to a mismatch between individual and supplier's knowledge leading individuals to misuse the heating pumps. Further, the mismatch between individuals' limited knowledge about heat pumps and heat pumps' script led to using heat pumps for more than needed purposes. In conclusion, it can be said that practice-based understanding of rebound effects is context specific. Only through systematic analysis of the elements of a practice, especially how such practice changes with an introduction of an energy efficient technology (material element), can rebound effects be understood. A representative diagram is shown below for a better understanding.

[3] Beneficial effects are negative rebound effects defined as "behavioural changes that reinforce the technical savings potential" (Santarius, Walnum and Aall, 2016, p.108).

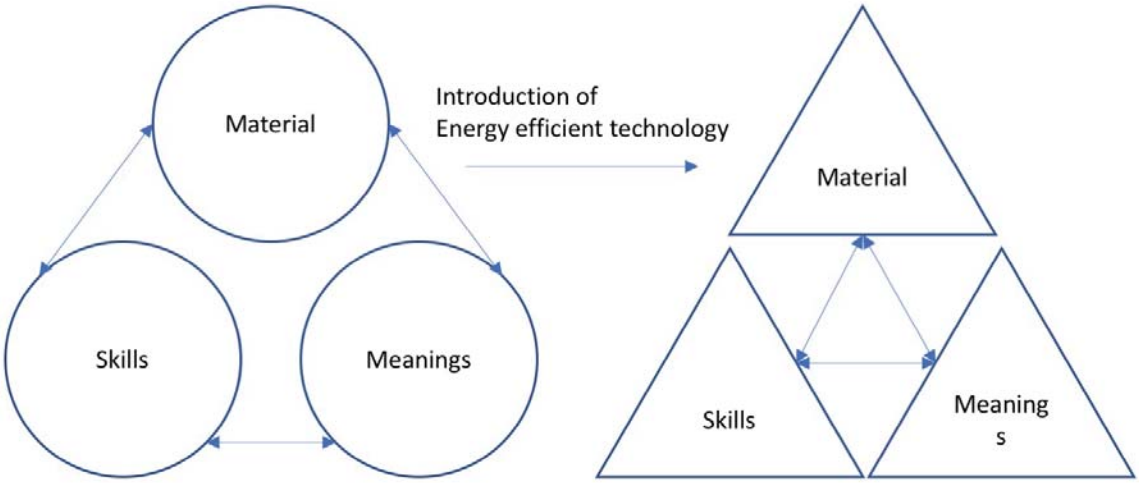

Figure 1. Representative diagram on rebound effects from a practice lens.
Figure on the left describes the practice composed of its elements in dialectical relationship. When an energy efficient technology is introduced or adopted by an individual, the elements of practices reconfigure until a new alignment is achieved between the different elements (figure on the right). This causes a new or changed practice to emerge. (Source: Own depiction based on Spurling et al. (2013) description of practice theory.)

3 Theoretical Basis

To explain interventions involving feedback from both behavioural and practice based approaches, SDT was chosen as a theoretical basis, inductively, based on the findings and gaps identified within the literature (presented in section 1 and 2). Below, section 3.1, describes the theory and section 3.2, the contextualisation of SDT with respect to two approaches.

3.1 Self-Determination Theory

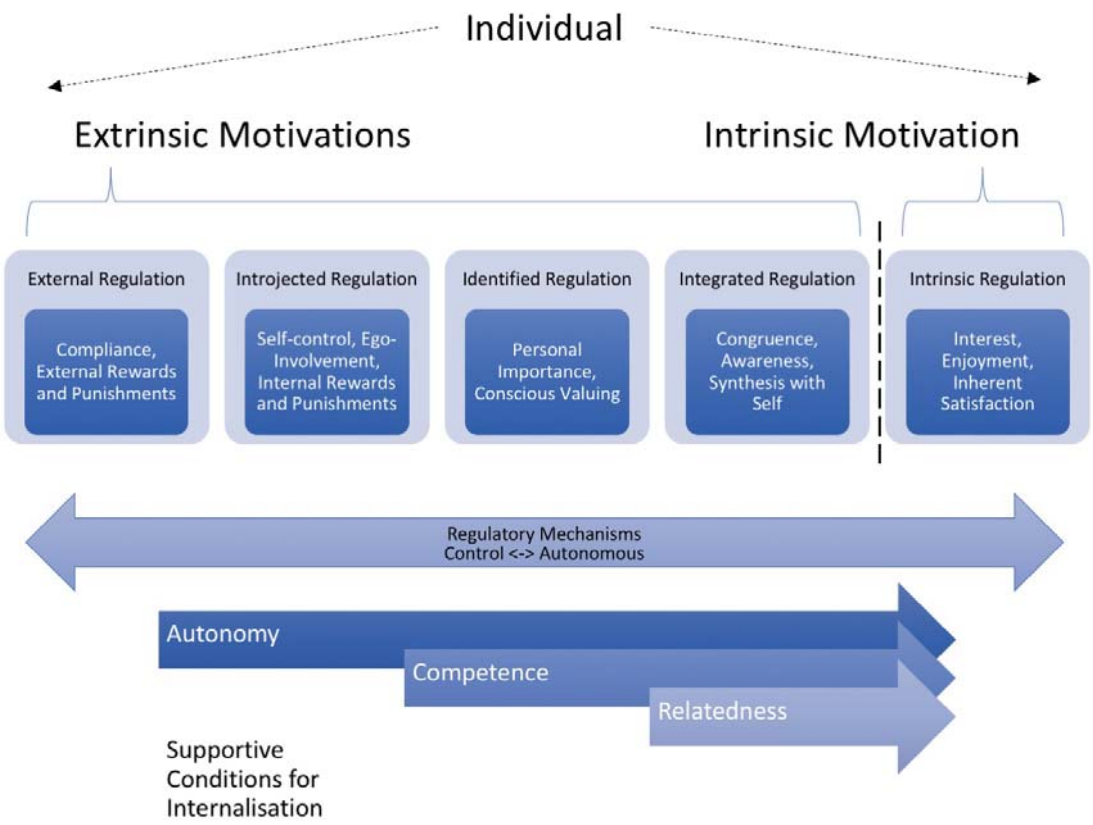

Figure 2. Diagram representing Self-Determination theory. Adapted from Ryan & Deci (2000).

3.1.1 Levels of Motivation

SDT describes different levels of motivation and what underlying regulations or mechanisms are at play that motivate an individual to perform a behaviour (see figure 2). To perform an activity or behaviour an individual is motivated by extrinsic or intrinsic motivations (Ryan & Deci, 2000). The underlying regulations of extrinsic and intrinsic levels of motivation range along the control-autonomy

continuum and cause behaviours to occur, based on how much autonomy they allow and how well they correspond to individual's internal values (Ryan & Deci, 2000). Extrinsic motivations have four underlying regulations that range from external, introjected, identified and integrated regulations with external on the control side of the spectrum and integrated on the autonomy side (see figure 2). These regulations also affect the individual's sense of well-being and performance of the behaviour. The more controlling they are, the less wellbeing is experienced by the individual and vice-versa. If an individual does an activity for the inherent satisfaction, intrinsic motivations are at play and provide well-being (Ryan & Deci, 2000).

3.1.2 Fulfilment of Needs and Performance of Behaviour

Individuals have universal innate psychological needs (autonomy, competence and relatedness), fulfilment of which leads to higher performance of behaviours and well-being (Ryan & Deci, 2000). As can be seen from the above paragraph, the different regulations describe different levels of autonomy that can be exercised by an individual. The individual pursues activities of interest (as influenced by his/her socio-material context) but will only perform better and gain well-being to the extent, the needs are met. If the needs are not met or conditions are such that the needs are thwarted, the individual shall experience less well-being, perform poorly or even try to change the activities (Deci & Ryan, 2000).

3.1.3 Self-Determined Behaviour

The individual performs any behaviour or activity out of inherent satisfaction and interest that represents an individual's intrinsic values. These values are shaped through socio-cultural processes that influence an individual all through the course of his/her life (Deci & Ryan, 2000). However, the individual can also internalise extrinsic values, when extrinsic regulations are at play, if supportive conditions are provided that sufficiently fulfil the psychological needs of autonomy, competence and relatedness, specifically, a feeling of "a sense of choice, volition, and freedom from excessive external pressure toward behaving or thinking a certain way." (Ryan & Deci, 2000, p. 74), being "efficacious with respect to those activities" and experiencing "belongingness and connectedness with others" (Ryan & Deci, 2000, p. 73), respectively. The internalisation process is hindered if the conditions are unsupportive and the needs are thwarted.

3.2 SDT in context

3.2.1 Behavioural-based approaches

Interventions from behavioural-based approaches aim to influence the determinants that cause behaviours. However, focussing on a theory of motivation allows to look at behaviours from a point of view of what initiates action and thus, the theory encompasses other psychological constructs such as values, and norms (Osbaldiston & Sheldon, 2003). Determinants within the Theory of Planned Behaviour (subjective norms and perceived control), Norm Activation Theory (personal norms), see Schwartz (as cited in Steg & Abrahamse, 2013) and Goal-Setting Theory (goals) are incorporated in SDT, through different forms of motivational regulations (extrinsic, introjected, identified, integrated and intrinsic), psychological needs (autonomy, competence and relatedness), and the role of values in influencing motivations (Ajzen, 1991; Latham & Locke, 1991; Ryan & Deci, 2000). Attitudes, which are one of the determinants in the Theory of Planned Behaviour, are not incorporated in SDT. But, there's available data that generally shows positive pro-environmental attitudes for Europeans and specifically, higher than average in Sweden (TNS Opinion & Social, 2014) and therefore, attitudes take less importance in the European context as a barrier. On the basis of different stages of motivation, SDT, specifically describes the internalisation of extrinsic values underlying behaviours or actions that the interventions aim to change (from extrinsic to intrinsic or controlling to autonomous) (Steg & Abrahamse, 2010). None of the theories discussed in the behavioural-based approach incorporate why behaviours persist. Because intrinsic motivations have been stated likely to lead to long-term reductions (Gifford et al, 2011), SDT, provides a mechanism (see section 3.1.3) and therefore, corresponds to the requirements set for change for this thesis.

3.2.2 Practice-based approaches

Interventions from practice-based theoretical understanding aim to change the elements (material, skills and meanings) of a practice. Therefore, interventions that aim for long-term reductions must reconfigure the elements such that the practice persists. However, these elements are broad concepts and the use of SDT can add to the explanatory power of the dynamics of how interventions aiming for changes in elements of practice influence motivation. First, values are the core of motivation in SDT and these values are shaped by socio-cultural processes. In SPT, values are imbibed as collective intentions constituted in the collective meanings associated with a practice, for example, finding cleanliness valuable in the case of washing behaviours (Gram-Hanssen, 2014). These meanings provide motivation as "people want something or mean something with what they say and do" (Gram-

Hanssen, 2011, p. 75). Both theories acknowledge the role of social context in shaping individual values. However, given the role of agency in SPT, an individual can exercise their agency and "consciously decide to change their routines, if they are engaged [motivated] to do so" (Gram-Hanssen, 2011, p. 75). This is where SDT becomes relevant as it also assumes an individual to be an agent driven by pursuing activities of interest and personal growth (Deci & Ryan, 2000). SDT provides the process of how extrinsic values can be internalised by supporting three psychological needs that can contribute to higher performance and engagement. Thus, adding to the identified linkage between meanings and motivation. While only meanings and motivation have been exemplified, given the interlinkages between different elements of the practice, it can be concluded that interventions that aim to change other elements (skills and material), also influence an individual's motivation.

3.3.3 Summarising postulates

From the above two sections, the following postulates, regarding how interventions trigger different regulations, can be deduced:

Behavioural-based approaches:

1. Interventions can trigger different regulations on the autonomy continuum.
2. Persistent behavioural change is more likely to be obtained when motivations are intrinsic in nature, thus, implying more autonomy.
3. This implies that integrated and identified motivations would allow more autonomy than introjected or external, fulfilling one of the three psychological needs.
4. The other two needs, if fulfilled, would make internalisation of extrinsic behaviours (and underlying values) more likely.

Practice-based approaches:

5. Interventions aimed at changing the elements of the social practice model would either change practices (re-craft) or create new ones (substitute).
6. Either process involve individuals as agents, although influenced by the structures but still retaining the capacity to influence structures. The altered relations between material, meanings and competence would trigger different motivational regulations (both extrinsic and intrinsic), but the fulfilment of the psychological needs would determine which practices the individual engages in.

4 Methodology

Taking a deductive approach, this thesis set out to find different interventions involving feedback from two approaches (behavioural and practice-based) and how they motivate individuals by asking specific questions informed via the self-determination theory (Bryman, 2016). The author used a systematic literature review as a method for data collection to analyse literature and answer RQ1 and specifically how psychological needs have been fulfilled and what co-occurrences exist with long-term reductions (RQ 1.1).

To answer the implications for rebound, this thesis uses systematic literature review once again to find how interventions have been designed for reducing rebound effects, how rebound effects have been understood from the two approaches (discussed in section 2) and what are the motivational mechanisms of interventions aiming to reduce rebound effects.

4.1 Systematic Literature Review

The systematic literature review consisted of peer-reviewed published papers for the past 10 years to capture studies conducted recently. Further, grey literature was searched on Google Search for the first 10 pages of results. The steps for the systematic literature review were inspired by a similar study and are described below (Johnson et al., 2017):

A. Inclusion Criteria
   - Must evaluate changes in energy consumption behaviour (self-reported or actual change).
   - Must involve feedback as part of the intervention package.
   - Must have a clear stated aim and a description of intervention used.
   - Must focus in a residential setting.

A. Exclusion Criteria
   - Energy efficiency/consumption mentioned but not related to research.
   - Theoretical perspectives on understanding energy consumption.
   - Studies using theories to understand energy consumption.
   - Studies in non-residential contexts.

C. Databases to be searched

Scopus, Lund University Libraries, Google Scholar, Google Search

D. Keywords

Different combinations of keywords were used to obtain literature and detailed keyword search strings are presented in Appendix A1. The following number of articles for each of the searches were found:

- Behavioural-based literature on energy efficiency and interventions
  (1132 found)
- Practice-based literature on energy efficiency and interventions
  (151 found)
- Grey Literature
  (50 found)

E. Screening Process

- First, selection of articles was done by reading titles.
- Next, selections of articles were done by reading abstracts following the inclusion/exclusion criteria.
- Finally, full text assessment was done to select the final list of articles.

In total, 95 studies were found relevant after reading abstracts. After reading full-texts, 40 studies were excluded as they didn't meet in the inclusion criteria. Next, studies were classified into those that evaluated changes in energy consumption due to an intervention (17 studies from peer reviewed articles and 5 studies from grey literature) and those that didn't evaluate changes in energy consumption but discussed the use of intervention (18 studies). These are labelled as **empirical** and **non-empirical** studies, respectively. The empirical studies were the main source of data for answering RQ1.1 on fulfilment of psychological needs and co-occurrences with long-term reductions. Non-empirical studies were also analysed even though these didn't evaluate changes in energy consumption to complement the main findings and bring out relevant discussion points. Another reason was that none of the studies from the empirical category stated using a practice-based approach for intervention design while the non-empirical studies contained most number of studies taking the practice-based approach. Therefore, studies in the empirical category were coded for instances where consideration to structural elements were mentioned (see point I. Coding). Another 15 studies were excluded due to access restrictions. A flow chart describing the review process is shown below in figure 3.

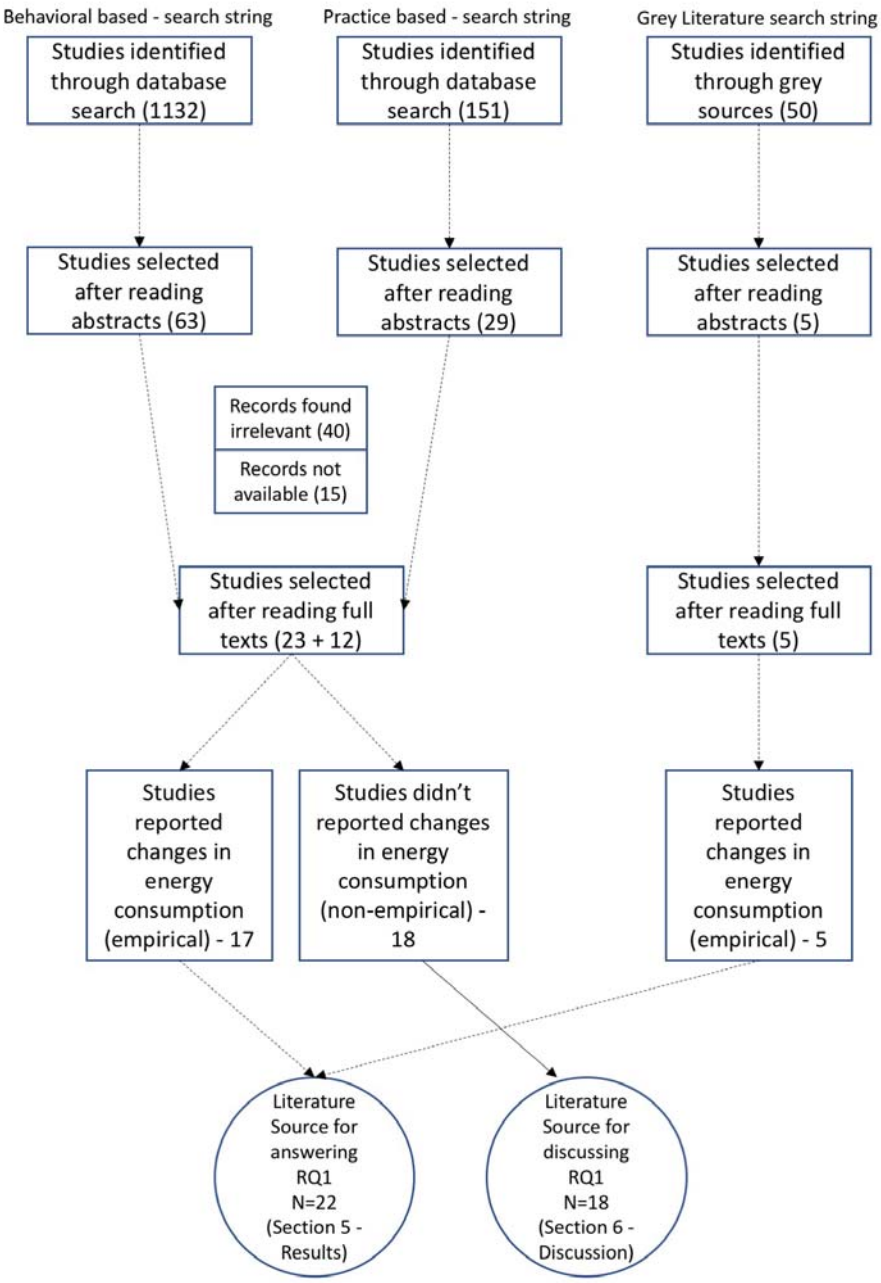

Figure 3. Flow chart describing the systematic literature review process.

F. Qualitative data extracted

- author, behavioural change, long-term reductions, mentioned or inferred changes in psychological needs, mentioned or inferred changes in structural elements, intervention type, theoretical approach

G. Data classified

- The studies were classified into empirical and non-empirical studies.

- Further, within the empirical part, studies were classified between studies that reported long-term behavioural change and studies which didn't. The duration for long-term reductions was chosen to be 6 months or more.

H. Data interpreted

- For both empirical studies and non-empirical studies, the data was interpreted to understand if interventions that resulted in long-term reductions also coincided with the fulfilment of psychological needs. Further, it was observed if interventions that didn't result in long-term reductions coincided with the lack of fulfilment of any of the psychological needs. It was also observed how any structural factors were discussed that undermined or supported the fulfilment of the needs.

I. Coding

Inspection of the full texts of the final selected publications was done and marked with codes (autonomy, competence, relatedness) on instances wherever it seemed that opportunities for fulfilment or thwarting of the three psychological needs are made available. The coding was informed via definitions of the three psychological needs by Deci & Ryan (2000) and specific operational elements (see subsequent bullet points) from a study that discussed SDT-based interventions in health context (Silva, Marques, & Teixeira, 2014).

Autonomy

The "feeling of being the origin of one's own behaviour" (Silva et al., 2014, p. 172), experiencing "volition in act[ion]" and "having internal perceived locus of causality" (Ryan & Deci, 2000, p. 70) .

- self-endorsement, respect, choice, avoidance of control

Competence

The feeling of being effective in producing desired outcomes and exercising one's capacities.

- Clarity of expectations, optimal challenges, feedback, provision of instrumental and practical skills-training, guidance, and support.

Relatedness

Feeling of being respected, "understood, and cared for by others" (Silva et al., 2014, p. 172) (Ryan & Deci, 2000).

- Empathy, dedication of resources towards individual, being available

Similarly, instances, where explicit considerations were given to broader structural elements (following SPT) were coded as well (materials, skills, meanings). An example of coding is shown below.

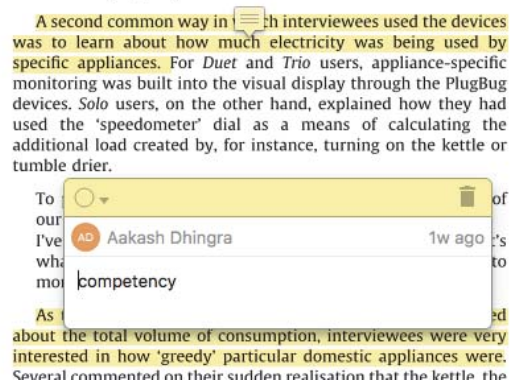

Figure 4: Snapshot of an article in Mendely showing coded information on psychological needs.

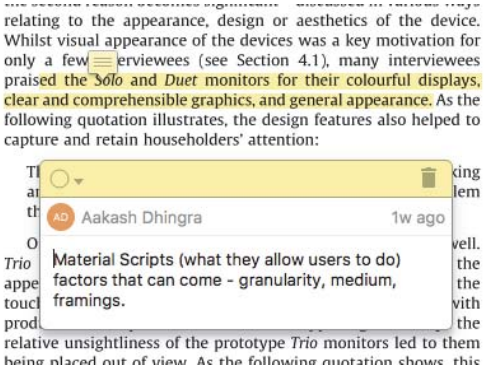

Figure 5: Snapshot of an article in Mendely showing coded information on structural elements.

4.1.1 Rebound Effects

Search criteria[4] were used for finding studies on rebound effects that evaluated the use of intervention with changes in energy consumption but no study was found. Studies were found that discussed the use of an intervention from a theoretical point of view. Further, one study was found from the search criteria used for RQ1 but it also didn't evaluate changes in energy consumption. Since only studies which didn't evaluate energy consumption were found, it was decided to include the theoretical implications of interventions aiming to reduce rebound effects in the discussion section.

4.2 Epistemology and Ontology

This thesis used critical realism as its ontological and epistemological stance. According to Sayer (2000), there are three domains or levels to ontology behind critical realism, namely, the real (where structures having the capacity to cause changes, exist and are separate from the human knowledge),

[4] See appendix A1 for keyword searches

the actual (where the interacting structure give rise to observable events) and the empirical (where the observable events are observed by researchers and forms part of human knowledge). This thesis aimed to understand the motivational mechanisms underlying different interventions with respect to long-term reductions and rebound effects. By using specific theories, it's possible to observe certain events in the empirical domain (reduction in energy consumption, long-term and rebound effects) amongst a set of observable events happening or not happening in the actual domain. Interventions might cause other effects that might not be identified. As an example, consider, when technological efficiency improvements were posited to obtain energy reductions, they also caused rebound effects due to the causal powers of material structures and cultural meanings (happening in the actual domain). However, studies in rebound have only recently accounted for the less than expected decrease in consumption when looked for the specific evidence for rebound (empirical domain). Through using the theory of self-determination, new (motivational) knowledge about the real domain can be obtained. However, it should be noted that this knowledge is not perfect and is one of the many forms of knowledge that can be obtained and that can explain the generative mechanisms in the real domain based on different theories and tools (Bryman, 2016).

5 Results

5.1 Underlying motivational regulations of interventions

Interventions from behavioural-based and practice-based approaches are similar but differ in use. Therefore, no distinction or hierarchy was assigned to interventions between the two approaches. Interventions were classified based on what motivational regulations they trigger by applying the five forms of motivational regulations from the theory of self-determination. The interventions were classified with an assumption that individuals are not initially intrinsically motivated to reduce energy consumption. Therefore, all the interventions occupied places in the extrinsic part of the motivational regulations. Since many interventions combine different forms of regulations, they were placed in multiple categories. First, the regulations are presented with definitions extracted from SDT and then it's discussed how and which interventions fit in each of the regulations. An overview matrix is presented in table 2.

A. Extrinsic Motivations

1. External Regulation

According to Ryan and Deci, (2000), external regulation is at play when there is an external demand to fulfil. This is done through rewards and punishments which translate into economic (dis)incentives. In addition to economic rewards and punishments, individual and group-based competitions also trigger external regulation as they involve rewards (Alberts et al., 2016).

2. Introjected Regulation

This regulation concerns mechanisms which prompt individual to do activities to "avoid guilt, anxiety or to attain ego enhancements" (Ryan & Deci, 2000, p. 72). The locus of control is not situated within the individual and are not valued by the individual (Ryan & Deci, 2000). This category may involve interventions such as those involving social influences where feedback on energy use is provided using social comparisons and evoking peer pressure motivations (Nolan, Schultz, Cialdini, Goldstein, & Griskevicius, 2008). According to Cialdini and Goldstein (as cited in Abrahamse & Steg, 2013), social norms place sanctions or gains for an individual. Therefore, the use of comparative feedback, group feedback and commitment strategies follow introjected regulations.

Table 2

Interventions (rows) vs Motivational regulations triggered (columns)

Interventions	External Regulation (EM)	Introjected Regulation (EM)	Identified Regulation (EM)	Integrated Regulation (EM)	Intrinsic Motivation
	More Controlling <----------> More Autonomous				
					Individual-based
Incentives and Feedback					
Goal-Setting and Feedback					
Commitment and Feedback					
Comparative Feedback					
Goal-Setting, Commitment and Feedback					
					Group-Based
Group Feedback					
Community-based Social Marketing					
Competitions					
Group-based competitions					
Team-based					

3. Identified Regulation

This form of regulation is more conscious in nature and involves an individual valuing the behaviour and its underlying values (Ryan & Deci, 2000) for its instrumentality (like exercising for health). Therefore, goal-setting, commitment, and group-based interventions fall into this category. According to Feedback Intervention Theory, goals are representations of meanings of importance and range from specific actions to identity based goals (Karlin et al., 2015). Thus, prompting the use of goal-setting in feedback to direct behaviour (Kluger & DeNisi, 1996; Latham & Locke, 1991). Group-based interventions such as community-based social marketing or competitions would also involve opportunities for individuals to value behaviours as those approaches also aim to increase awareness and knowledge sharing (Vine & Jones, 2016).

4. Integrated Regulation

This form of regulation involves congruence between individual's values and the values reflecting the behaviour and so to say, is the very intrinsic side of extrinsic motivation (Ryan & Deci, 2000). It differs from identified regulation in the sense that individuals do not only deem the behaviour as important but assimilate the values in self (Ryan & Deci, 2000). Such regulations can comprise of interventions of the group nature where individuals can form new values through group-based activities as in the case of EcoTeams and CRAGs in the UK who explore information and feedback as a group and learn from each other (Fisher & Irvine, 2016). Competitions also fit into this category as comparative feedback is used and people are encouraged to interact with each other but it's also noted that competitions create between group losses with possibilities for within group benefits (Vine & Jones, 2016).

B. Intrinsic Regulation

This form of regulation is inherent to the sense of enjoyment and satisfaction and thus, constitutes the type of people who already value reducing energy consumption (Ryan & Deci, 2000). None of the interventions which were found from the literature review fit into this regulation due to the assumption taken for this classification. Although, it can be said that interventions which aim to increase knowledge on energy conservation would fit as individuals are already motivated intrinsically.

5.2 Fulfilment of Psychological needs and long-term reductions

This section is divided into two parts. The first part presents the analysis of peer-reviewed studies and the second part presents the analysis of grey literature.

5.2.1 Part A – Peer-Reviewed Studies

Seventeen studies that met the inclusion criteria were found (Table 3). Studies were classified broadly by the target audience, group (8) and individuals (9) and based on the regulations. Table 4 and 5 present a summary of data coded for each study with the study aim, interventions used, fulfilment of needs, and percentage change in energy consumption for both target groups (table 4 – individual and table 5 – group). Further, two highlighted columns represent long-term reductions, and the triggering regulations, in both tables.

Table 3

Study author, journal published and target for intervention in for 17 studies in the empirical category.

Study Author	Published In	Target of Intervention*
(Black, Davidson & Retra, 2010)	Australian Journal of Environmental Education	G
(Emeakaroha, Ang, Yan, & Hopthrow, 2014)	Energy	G
(Conrady et al., 2014)	Energy Efficiency	I
(Shen, Young & Cui, 2016)	Energy Policy	I
(Mizobuchi & Takeuchi, 2013)	Energy Policy	I
(Kua & Wong, 2012)	Energy Policy	I
(Alberts et al., 2016)	Energy Policy	I
(Schleich, Faure, & Klobasa, 2017)	Energy Policy	I
(Dowd et al., 2012)	Energy Policy	G
(Bager & Mundaca, 2017)	Energy Research and Social Science	I
(D'Oca et al., 2014)	Energy Research and Social Science	I
(Reeves, Cummings, Scarborough, & Yeykelis, 2015)	Environment and Behavior	I
(Staats, Harland, & Wilke, 2004)	Environment and Behavior	G
(Geelen, Brezet, Keyson, & Boess, 2010)	Knowledge Collaboration & Learning for Sustainable Innovation ERSCP-EMSU conference	G
(Hargreaves, Nye, & Burgess, 2008)	Local Environment	G
(Haq, Cambridge, & Owen, 2013)	Local Environment	G
(Anda & Temmen, 2014)	Renewable Energy	G

Notes: *G represents group and I represents individual

Individual-Based

Studies targeting individuals (table 4) used interventions that triggered external (1), introjected (2), external and introjected (1), identified (2), introjected and identified (1) and external, introjected and identified (1) regulations. None of the interventions targeting individuals triggered integrated forms of regulations. Further, one study only used feedback. The percentage change in energy consumption varied from 2-22 percent. However, one study measured changes through self-reported behaviours. Most studies didn't report long-term reductions except two. However, only one qualified for long-term reductions with time duration being greater than six months. There were some studies that tested boundary conditions of feedback interventions. Bager and Mundaca (2017) used punishments (loss based framing of energy consumption) in feedbacks. Shen et al. (2016) tested comparative feedback at different proximities specifically, at street level, neighbourhood, and next-door neighbour and found that comparative feedback produced 5.4%, 2.8% and 2.1% reductions, respectively. Lastly, Mizobuchi

& Takeuchi (2013) found that rewards with comparative feedback and rewards led to 8% and 5% reductions, respectively.

Amongst these studies, the fulfilment of needs also varied. Many studies didn't include any special measures for autonomy. However, the use of intervention itself was either autonomy supportive or unsupportive. For example, interventions triggering external or (and) introjected regulations were less supportive of autonomy than interventions triggering identified regulations. Apart from this, autonomy was supported by providing energy saving tips and promoting choice[5]. Competence was mostly supported by providing feedback, appliance-specific feedback, using prompts and reminders, frequent feedback and other additional monitoring tools. Lastly, measures for relatedness for most studies was found to be not present. Where present, relatedness was supported by the social context of the intervention in the study, for example, student community or a neighbourhood. One study used a particular intervention[6] that used active listening with a focus on empathy.

Group-Based

Studies which targeted groups (table 5) used interventions that triggered external, introjected and identified (1), introjected and identified (1), and, identified and integrated (6) regulations. The reductions in energy consumption varied from 7-37 percent and five studies reported long-term reductions greater than six months. Out of the five studies, two studies reported fall back or lower reductions in the long run. The rest of the studies didn't report long-term reductions. Fulfilment of needs also varied in the studies. Compared to the studies targeting individuals, relatively, more studies targeting groups to take measures that fulfilled autonomy. Only two studies didn't take any special measures. Autonomy was mostly supported by providing energy saving tips, promoting informed choices, encouraging discussions amongst participants or with the eco-coach and by allowing participants to set own saving goals. In addition to feedback, competence was supported by workshops, practical skills training, contextualised feedback and by the use of additional monitoring tools. Lastly, there was a big difference in measures supporting relatedness when compared to individual targeting interventions. Relatedness was supported by having a social context within the intervention, for example, being in a student community and through being a member of a team. Further, some studies supported relatedness by having discussions as part of the intervention package, having local volunteers as conveners, providing discussion forums, and a range of fun eco-events.

[5] Choices were also promoted through active listening in one interventions (see footnote 6).

[6] Conrady, Kruschwitz, & Stamminger (2014) used motivational interviewing that's based on eliciting intrinsic motivations through interviews relying on active listening and empathy.

Table 4

Intervention studies targeting individuals (N=9)

Study Author and Aim	Interventions	Regulations	Autonomy	Competence	Relatedness	% change	Long-term reductions[3]
(Bager & Mundaca, 2017) To test the effect loss based framing towards energy consumption reduction.	Information and Feedback	External	None	Feedback	None	7-11% compared to control group	NR
(Shen et al., 2016) To test comparative feedback at different proximities of a neighbourhood.	Information and Comparative Feedback	Introjected	Energy saving Tips	Feedback	Neighbourhood comparisons	Average, 3.4% 1. street level, 5.4% 2. neighbour-hood level, 2.8% 3. next door level,2.1%	NR

(D'Oca et al., 2014) To assess evaluation and test effectiveness of energy@home smart metering	Information, Feedback, and Comparative Feedback	Introjected	Presentation of choices through prompts[1] in newsletters	Feedback, Prompts (appliance specific), clarity on expected performance, frequent feedback	None	18%	NR
(Mizobuchi & Takeuchi, 2013) To test the effectiveness of reward and reward plus comparative feedback on energy reduction.	Comparative Feedback, Reward	External and Introjected	None	Feedback	None	1. Reward only, 5% 2. Reward plus comparative feedback, 8%	NR
(Conrady et al., 2014) To test motivational interviewing as an intervention for reduction in energy consumption related to washing behaviours (hot water).	Motivational Interviewing, Feedback	Identified	Possibilities for behaviour change explored but decision retained with individuals.	Feedback (monitoring tools)	Active listening and confirmations as part of MI (Empathy).	Self-reported, reduced washing temperature, and increased washing load	NR

(Kua & Wong, 2012) To test the effectiveness of intervention (information and feedback).	Information, Feedback	Identified	None	Feedback	Face to face counselling	2%	NR
(Reeves et al., 2015) To test the energy reductions achieved through a social game.	Feedback, Competition	Introjected and Identified	Leaderboard[2] (-)	Feedback	Leaderboard rankings	2%	30 days
(Alberts et al., 2016) To test comparative feedback with rewards, comparative feedback.	Feedback, Information, Competition (Rewards), and Comparative Feedback	External, Introjected and Identified	Providing choices via tips.	Feedback	Student resident community, and Thank you letter (empathy)	22%	NR

(Schleich et al., 2017) To test the effectiveness of feedback.	Feedback	None	None	Feedback	None	5%	11 months

Notes
1. Prompts serve as reminders.
2. Leaderboard lists the participants in a ranking order based on their performance.
3. NR represents Not Reported

Table 5

Interventions studies targeting groups (N=8)

Study Author	**Interventions**	**Regulations**	**Autonomy**	**Competence**	**Relatedness**	**% change**	**Long-term reductions**
(Geelen et al., 2010) To test the use of game for reducing energy consumption	Competition, Rewards, Information	External, Introjected and Identified	Energy Saving tips (promoting choices)	Feedback	Member of a team	24%	8 months, (Only 2 out of 10 teams lowered after the experimen t)

(Emeakaroha et al., 2014) To test the effect of comparative feedback with appointed energy delegate in university residents.	Feedback, Group comparative feedback , and Energy delegates[1]	Introjected and Identified	None	Feedback, practical skills training (via teaching)	Community (student dorms), dedication of resources (energy delegates met housemates for discussions), housemates met for planning discussions	37%	Fall back after intervention period ended
(Staats et al., 2004)	Information, Feedback	Identified and Integrated	None	Feedback, Specific info through workbook	Team-based approach meeting	7%	2 years, Self-reported behaviour maintained

(Hargreaves et al., 2008)* To analyse Global Acton Plan's team-based approach on the effect of contextualised knowledge, feedback and supportive social context.	Information, feedback, Contextualised Knowledge[2]	Identified and Integrated	No restriction of choices, people encouraged to explore from their standpoint of consumption	Feedback, contextualised knowledge	Discussions encouraged, activities to find new meanings about sustainable lifestyle, provision of facilitators, starting from a local institution to take participation from people.	7%	6 years
(Haq et al., 2013)* To test CBSM as an effective strategy for reducing consumption.	Community-Based Social Marketing, Commitment , and Mentors	Identified and Integrated	Informed and conscious choice encouraged, Participants encouraged to have a clear target	Workshops, Feedback, Clear expectations set, and Milestones	Community, Discussion Forums, Regular Meetings, Events (EcoFun Night, Eco evening)	11% 20% in heating and powering	NR
(Anda & Temmen, 2014) To test the use of CBSM and feedback for higher behavioural changes.	Information, Feedback, Eco-consultant, door knocking campaigns	Identified and Integrated	Opt in for various tools for energy efficiency, Eco-coaches discussed options for reducing energy consumption	Feedback, contextualised knowledge, and advice through eco-consultation (through locally recruited members)	Social modelling (through celebrity interaction), eco-consultation (through locally recruited members) and letters of thanks	21.4%	NR

(Black et al, 2010)* To test the effect of combination of feedback and social marketing on university students.	Information, Feedback, and Community-based social marketing	Identified and Integrated	Choice promoted through suggestions to reduce energy consumption via posters	Feedback through meters and specific feedback instruments (shower timers)	Student community, Assistance available through project's research assistant.	17 to 28 %	NR
(Dowd, Ashworth, Carr-Cornish, & Stenner, 2012)* To test the impact of Energymark intervention on reducing energy consumption (and additional environmental behaviours).	Tailored Information, Feedback, Goal Setting	Identified and Integrated	Participants allowed to set own goals	Tailored Feedback, and Factsheets	Group discussions, availability of local volunteers as group convener and availability of a panel of experts	Self-reported, 23%, (emission reduction)	1 year

Notes
1. Energy Delegates were locally recruited members responsible for coordination and dissemination of activities for the intervention.
2. Contextualised Knowledge was locally produced knowledge through group interactions.
*Considerations given to practice elements

Summary:

Amongst the above 17 studies, 6 reported long-term changes, out of which 4 reported reductions in consumption and 2 reported, fall back or higher consumption after the intervention period. The co-occurrences between the fulfilment of needs and long-term reductions were found as different studies use similar methods of supporting the fulfilment of needs. Studies that reported achieving long-term reductions fulfilled all the needs and studies that reported achieving fall back didn't or thwarted one of the three needs. An abridged version of the tables 4 and 5 is presented below (table 6), showing coded information of fulfilment of needs and long-term reductions.

Table 6

An abridged version of tables 4 and 5, showing coded information on fulfilment of needs[1] vs presence of long-term reductions[2] for each study classified by the regulations triggered.

Study Author	Autonomy	Competence	Relatedness	Long-term reductions
				INDIVIDUAL-BASED
External Regulation				
(Bager & Mundaca, 2017)	-1	1	0	0
Introjected Regulation				
(Shen et al., 2016)	1	1	1	0
(D'Oca et al., 2014)	1	1	0	0
External and Introjected Regulation				
(Mizobuchi & Takeuchi, 2013)	-1	1	0	0
Identified Regulation				
(Conrady et al., 2014)	1	1	1	0
(Kua & Wong, 2012)	0	1	0	0
Introjected and Identified Regulation				
(Reeves et al., 2015)	0	1	0	0
External, Introjected and Identified Regulation				
(Alberts et al., 2016)	-1	1	1	0
Only Feedback				
(Schleich et al., 2017)	0	1	0	1
				GROUP-BASED
External, Introjected and Identified Regulation				
(Geelen et al, 2010)	-1	1	1	-1
Introjected and Identified Regulation				
(Emeakaroha et al., 2014)	0	1	1	-1
Identified and				

Integrated Regulation				
(Staats et al., 2004)	0	1	1	1
(Hargreaves et al., 2008)	1	1	1	1
(Haq et al., 2013)	1	1	1	0
(Anda & Temmen, 2014)	1	1	1	0
(Black et al., 2010)	1	1	1	0
(Dowd et al., 2012)	1	1	1	1

Notes:
1. For needs: 1 represents fulfilled in some way, 0 represents no special measures taken, -1 represents that needs were thwarted
2. For long-term reductions: 1 represents persistent reduction, 0 represents not reported, and -1 represents fall back

5.2.2 Part B - Grey Literature

Five projects from grey literature were found and none of the studies reported long-term changes. Two projects were group-based and three were individual-based. A table showing coded information on fulfilment of needs and long-term reductions is shown in table 7.

1. **Introjected Regulation:** EU Empowering project reported achieving 4-8% reductions in energy consumption by using comparative feedback (European Commission Intelligent Energy Europe, 2017a). Needs supporting elements found were: having energy saving tips (autonomy) and feedback (competence).
2. **External and Introjected Regulations:** Harries, Rettie, & Studley (2013) reported achieving 3% reductions by using comparative feedback and rewards. They found that there was no difference between the ones who just received feedback and those who received comparative feedback. Needs supporting element found was: feedback (competence). Further, need thwarting element found were: rewards (autonomy).
3. **External and Identified Regulations:**

   3.1. Group-based:

   Two EU projects were conducted in different countries but were very similar in their design of intervention. Both used group goal, setting, competition between different household and rewards. 'Bet to Win!' project was done in 9 European countries and achieved an average of 10% reductions in energy over a 6 months period (European Commission Intelligent Energy Europe, 2017b). Needs supporting elements found were: having locally trained volunteers for support and advice (competence and relatedness); climate debates with local authorities and citizens (relatedness); web-based feedback tool (competence). 'Energy Hunt' used the same method as 'Bet to Win!' and was done in 16 European countries and achieved an average of

11% reductions over a period of four months (Lang, 2015). However, for both projects rewards were not supportive of one need (autonomy).

4. **Only Feedback:** Goodhew, Pahl, Auburn, and Goodhew (2014) used thermal imaging as feedback to visually show heat loss and found 14.29% more reductions in carbon emissions for the treatment group. Feedback was the only need supporting element (competence).

Table 7

Coded information[1] on articles and project found in the grey literature.

Project Name / Study Author	Autonomy	Competence	Relatedness	Long-term reductions
				INDIVIDUAL-BASED
Introjected Regulation				
EU Empowering	1	1	0	0
External and Introjected Regulations				
Harries, Rettie, & Studley (2013)	-1	1	0	0
Only Feedback				
Goodhew et al. (2014)	0	1	1	0
				GROUP-BASED
External and Identified Regulations				
Bet to Win!	-1	1	1	0
Energy Hunt	-1	1	1	0

Notes:
1. For needs: 1 represents fulfilled in some way, 0 represents no special measures taken, -1 represents that needs were thwarted
2. For long-term reductions: 1 represents persistent reduction, 0 represents not reported, and -1 represents fall back

6 Discussion

6.1 Internalisation of values, Fulfilment of needs and Long-term reductions.

While the number of studies found reporting long-term reductions were few, most studies (five of six) were group-based. Out of the five, three reported persistent long-term reductions and mostly used interventions that triggered identified and integrated regulations. According to SDT, in the case of identified and integrated regulations, individuals either value the importance of behaviour or assimilate the values within themselves (Ryan & Deci, 2000). Such integration is likely possible as more opportunities were provided for individuals to internalise values for example through discussion forums. This indicates that group-based interventions may be better for long-term reductions. While none of the studies that used group-based interventions specifically investigated the question of how values amongst the participants changed, the study by Dowd et al. (2012), measured environmental values of participants before the use of the intervention and found that both groups of individuals, with and without pro-environmental values obtained similar reductions in energy interventions after using the intervention. While long-term reductions were not reported by them, their intervention package fulfilled all the needs and therefore, provides some evidence to the causality between more autonomous forms of regulations and internalisation of values. Apart from these group-based studies, there was one study that used only feedback (individual-based) and reported long-term reductions (Schleich et al., 2017). Being the exception, it also didn't fulfil two out of the three psychological needs (see table 6). According to SDT, this could be explained if individuals were already intrinsically motivated and receiving feedback met their informational needs, thereby allowing them to reduce their consumption for their own satisfaction. Because the study didn't report participants' prior environmental values (which could confirm the above hypothesis), it cannot be concluded that intrinsic motivations were at play.

Apart from the above, there were five studies out of 22 which fulfilled all the needs but did not measure long-term reductions. Three of them reported using interventions that triggered identified and integrated regulations (group-based). Judging from the available long-term data, it's possible that these studies would also have had success in achieving long-term reductions; however, this is still speculative due to lack of reporting on long-term reductions. The other two studies targeted individuals and used interventions triggering introjected (Shen et al., 2016) and identified (Conrady et al., 2014) regulations. While Shen et al.'s (2016) study used comparative feedback and comparative feedback (more on the control side of the control-autonomy spectrum), Conrady et al.'s, (2014) study

used motivational interviewing that seemed to provide more autonomy. Conrady et al.'s (2014) use of motivational interviewing was explicitly aimed at exploring individuals' values in relation to energy consumption, which had a role in increasing knowledge (competence) and assimilating environmental values. This intervention seemed to be a relatively unexplored intervention and should be further examined or combined with group-based approaches as it provides a framework on internalisation of values that also corresponds to ensuring that all needs are fulfilled.

While there is limited evidence to indicate internalisation of values, group-based interventions have surfaced to be crucial. SDT posits that internalisation of values is more likely when supportive conditions are ensured that fulfil the three and needs and therefore, the next sub-sections provide a deeper look as to how needs were fulfilled and what implications can be drawn. However, a recommendation for future research follows to focus on the content related to group-based engagements such as workshops from examining how each need was fulfilled. Most of the studies reported activities in form of checklists but didn't explain as to how individuals took part in the group activities, whether they were satisfied, whether they perceived a change in values, whether they felt competent, and whether they considered the interventions valuable. These additional insights in if examined in future interventions studies can further contribute to the design of interventions as these questions are relevant due to SDT that describes the conditions for self-determined behaviour to occur when an individual is intrinsically motivated and values the importance in the activities engaged in (Ryan & Deci, 2000).

6.1.1 Autonomy

Autonomy is defined as "a sense of choice, volition, and freedom from excessive external pressure toward behaving or thinking a certain way" (Ryan & Deci, 2000, p.74). Looking at the data obtained, autonomy was mainly supported through the use of different interventions triggering different forms of regulations with varying levels of autonomy support. Apart from providing energy-saving tips and setting no restrictions on the choice of behaviour to be changed, there were no more special measures found in the data. While only some of the studies mentioned the role of autonomy, most studies particularly did not discuss it in the design of the intervention. This points to the lack of attention paid to how interventions might support autonomy or thwart it. According to SDT, autonomy supportive conditions are crucial for an individual to perform well, especially when an individual perceives and values an action to be extrinsic in nature (Ryan & Deci, 2000). In the case of energy consumption reduction, interventions aim to cause reductions by demanding individuals to perform behaviours

which might be extrinsic in nature. Therefore, it becomes relevant to include autonomy as a mediating factor within the design of interventions.

Two particular observations were made from the data that support the above implication. First, studies that reported fall back or higher consumption in the long-term used interventions that also triggered (amongst other regulations), external (Geelen et al, 2010) and introjected (Emeakaroha et al., 2014) regulations i.e. using rewards and social influence to motivate, respectively. On the control-autonomy continuum, external and introjected regulations motivate people to achieve external demands, and avoid guilt, attain ego enhancement, respectively, with perceived external locus of control, thwarting autonomy which likely explains the fall-back (Ryan & Deci, 2000). Some explanations can be found in Burchell, Rettie & Robert's (2016) study which examined long-term engagement with feedback by using interventions (rewards, comparative feedback and community engagement) that triggered external, introjected and identified regulations. They interviewed participants and found, the competitive aspect (introjected regulation) of the feedback was engaging for some as participants became motivated to find out how others were doing, while some others, "were put off" by it (Burchell et al., 2016, p. 184). This supports the claim that group-based interventions are better off due to more support for autonomy.

Second, it was observed that specifically, rewards (external regulation) do not perform better than any other intervention. In total, four studies were found using rewards (external forms of regulation) either as a stand/alone intervention or in combination with others. Both, Alberts et al. (2016), and Mizobuchi & Takeuchi (2013) found that comparative feedback (introjected regulation) gave better reductions that to rewards (external regulation). Rewards were used by Geelen et al. (2010) in combination with other interventions (external, introjected and identified regulations) but the study reported fall back to high consumption after the intervention. This supports SDT as interventions triggering external regulation allow the least autonomy compared to introjected and identified regulations. However, there was an exception in the case of Bager & Mundaca (2017), who used punishments (external regulation) and found improved results. One conclusion can be drawn that rewards being the most external form of motivation do not motivate individuals due the perceived external locus of control but punishments might have the opposite effect in terms of energy consumption reduction. This conflicts with the theory of self-determination. However, there's also a possibility of an inherent limitation with the conceptualisation of punishment taken in this thesis. For example, punishments can take different forms in feedback. In this case, the authors cite the empirical phenomenon of loss aversion, where people value loses more than rewards as their basis for using the intervention (Bager & Mundaca, 2017). This framing of punishment that indicates 'You lose this much!' is different from

punishments that indicate, for example 'You didn't do well'. In conclusion, it's clear that rewards do not lead to higher reductions when compared to other forms of interventions.

6.1.2 Competence

Competence defined as the feeling of being effective (Ryan & Deci, 2000) was mainly supported via providing feedback. Further, feedback was provided in different ways, for example, appliance-specific feedback, or tailored information. While the SDT doesn't provide varying levels of how competence can be supported, certain conclusions can be drawn from the data, regarding how interventions involving feedback increased competence. Amongst the studies that targeted individuals, feedback was used exclusively except in the study by D'Oca et al. (2014) who used prompts and frequent feedback. They also reported the highest reductions amongst individual-based studies. Amongst the studies that targeted groups, training, workshops, tailored and appliance-specific feedback were the most common competence-enhancing measures. Another finding to note is that long-term reductions were also reported, mostly in group-based interventions except one study from individual-based interventions. A few studies which were found in the literature review (non-empirical) explored how feedback improved competencies through a practice-based lens. For example, Naus and Van Der Horst, (2016) found that individuals gained practical knowledge and new understandings on energy consumption through discussing with others in the workshops and local climate debates. However, they also, found that for some individuals, informational needs were not met through workshops due to time constraints or personal reasons. This highlights the role of improving feedback in the design of interventions to better fulfil the need of feeling competent. One of the challenges identified that motivated this thesis was that users either do not understand the information from feedback through smart meters or find it difficult to use that information (Oltra et al., 2013). The above data clearly shows that the feeling of being competent co-occurs with long-term reductions and further, different ways can be used to increase competence. Karlin et al.'s (2015) findings from their meta-analysis of feedback interventions complement this as they also found significant correlations with higher reductions when appliance-specific feedback was provided.

In addition, certain evidence of feeling competent is also connected to being motivated. Gölz & Hahnel (2016) found that users have multiple motivations to use feedback but most want to understand their own consumption patterns or in other words, feel competent. They also analysed if such motivations are connected to reductions in energy consumption however, they did not quantify the changes. They found no such connections and that additional measures were needed. This points to the fact that there are no fit-for-all interventions. Most literature on smart meters has focussed on improving the

technologies and focussing on how they meet users' informational needs (see reviews in Appendix A2.). However, according to the findings of this thesis, focussing on informational needs and increasing competence is only half the story and more measures need to be taken to ensure motivation. SDT prescribes fulfilling of the three psychological needs, and from the data obtained, it's clear that it does co-occur with achieving long-term reductions.

6.1.3 Relatedness

Relatedness defined as the feeling of "belongingness and connectedness with others" (Ryan & Deci, 2000, p.73) was mainly supported via deploying the intervention in a social context, whether through social games, competition, through local groups, student communities, face to face interactions, energy delegates, or energy masters. Amongst these, competition-based interventions have been found to thwart autonomy to some extent (see section 6.2). However, the role of community was increasingly relevant. First, the presence of group-based interventions co-occurred in the studies that reported achieving long-reductions reductions. In fact, five of six studies that reported long-term reductions used group-based methods. Second, group-based interventions add to both competence (see section 6.1.2) and relatedness, both of which are relevant in motivating individuals. Burchell et al. (2016) examined the role of community engagement with feedback and found that, for many, energy conservation was not the primary motivation to engage in energy consumption reduction; rather, being part of the community was a crucial motivating factor for individuals. Overall, they found that even two years later, 80% of the participants were still using smart metering (Burchell et al., 2016). From a practice-based approach, the role of community is also highlighted. Naus and Van Der Horst, (2016) found that through community engagements, individuals could form new rules and shared understandings on energy consumption, leading to new meanings being created. This shows that group-based interventions aid in internalisation of extrinsic values and leads to new motivations for individuals to act on energy conservation. Other social events that were part of the intervention also engaged the community, retained and recruited more participation (highlighting the internalisation processes) because individuals' energy information was not the primary motivating factor but a by-product that individuals also gained (Naus and Van Der Horst, 2016). Thirdly, an intervention study highlighted that group-based approaches worked because of the "safe, supportive, and informal environment established" (Dowd et al., 2012, p. 274). These reasons suggest that ensuring the fulfilment of relatedness as a need might increase the effectiveness of feedback interventions.

6.2 Reflections on behavioural-based and practice-based approaches

The most relevant finding of this thesis, which adds to the debate between practice-based and behavioural-based approaches, is that no studies from practice-based approaches were found that evaluated changes in energy consumption. This is, of course, limited by the search criteria used for the literature search and studies might exist but it highlights the need for more interventions to be tested from a practice-based approach.

However, there are reasons to argue for the superiority of practice-based approaches over behavioural-based approaches. Observing the data from studies which reported long-term reductions and targeted groups, it's seen that only these studies mentioned the role of the interconnectedness of the different elements of practice theory (meanings, skills or competence, and materials), although not using a practice-based lens. More focus in these studies was on justifying the choice of group-based methods and their specific role in changing how individuals understand their practices and meanings associated with them. For example, Hargreaves et al., (2008) emphasize the role of group discussions in the effectiveness of the intervention used, "allowing participants to expose their taken-for-granted routines and behaviours to reflexive scrutiny in the context of the environmental issues" (Hargreaves et al., 2008, p. 752). While debates exist on the use of practice theory, it's capable of seeing individuals as reflective beings and necessitates the participatory role of individuals (Gram-Hanssen, 2011). Group interventions encouraged this aspect of practice theory. This also supports the need for feeling in control and having an internal locus of causality (Deci & Ryan, 2000).

Further, practice-based approaches give an explicit consideration on competencies associated with a practice and, as the section on competence explains, competence plays a major role in determining the motivation of an individual, meeting informational needs and providing autonomy. Regarding competence, behavioural approaches seem to be on par with practice-based approaches with their focus on internal factors such as knowledge and skills. However, practice-based approaches highlight the interconnections between different elements. None of the studies seemed to explore this aspect explicitly but there were considerations given to the interconnectedness between different elements and their role in influencing the choice of interventions. Amongst the studies that reported long-term reductions, for example, Hargreaves et al. (2008) mention how "the needs which material goods fulfil are…socially constructed" (p. 746). However, a limitation in this observation is that even though many group-based studies emphasised on the role of discussions, they didn't explain what these discussions were about and didn't examine if such socially-constructed meanings were changed. This is where a practice-based intervention can be superior in uncovering these meanings. For example, a study found in the non-empirical category used a participatory backcasting intervention focussing on the "co-

evolution between material and cultural elements of a practice" that allowed participants to imagine a future and come up with suitable interventions and innovations, changing the meanings associated with a practice (Doyle & Davies, 2013, p. 262). This intervention was more focussed on changing meanings associated with a practice and fulfilled the needs of autonomy, competence and relatedness through the participatory nature of the intervention. Although it was not aimed at testing changes in energy consumption, it still highlights the role of meanings in changing motivations. A future research opportunity might involve combining backcasting with group-based interventions and feedback to examine the changes in energy consumption. This is important as using a practice/based understanding allows intervention designers to understand the socially-constructed meanings as opposed to the individual metrics in behavioural-based approaches (attitudes, values and knowledge). Given that group-based interventions are inherently social in nature, a practice-based approach can explain better how changes in meanings can lead to motivations and thus, contribute to the better design of interventions.

From the practice perspective due to its focus on the interconnectedness of material element with other elements, novel interventions involving different kinds of feedback have also been found in the literature review. For example, a study proposed that by designing 'transformational objects' that "intervene at the right spot and prevent us [individuals] from acting on impulse" (Liedtke, Baedeker, Hasselkuß, Rohn, & Grinewitschus, 2015), such objects are able to achieve reductions in energy consumption. Such types of feedback are more attuned towards individuals' existing level of competence and provide feedback at the right time, influencing the existing meanings associated with energy use (Keyson, Guerra-Santin and Lockton, 2017). One example presented in section 5 was thermal imaging, which was found to produce approximately 14% energy consumption reductions. Design-based approaches also aim to aid in new meaning-making as explained by the use of *Design with Intent Toolkit,* consisting of cards which portray different ways through which behaviour change can be achieved. These cards were used as a teaching tool allowing users to question assumptions and find different interventions which could be tailored to their needs (Lockton, Harrison, & Stanton, 2010). These interventions were not tested but present a valuable research opportunity, especially since studies indicate that there are no fit-for-all interventions and individuals' needs, motivations and values are diverse (Gölz & Hahnel, 2016). These in turn influence how effective an intervention is: including individuals in a more participative manner and allowing them to determine their choice of intervention can promote feelings of autonomy and relatedness, ensuring that long-term reductions are obtained.

The findings from this thesis are mixed and only preliminary evidence is obtained regarding the use of different approaches, mainly due to lack of empirical data. Although based on the coding of literature and non-empirical studies, it's argued that practice-based approaches can ensure how psychological needs are met and motivate individuals. These findings also support findings from a similar study that aimed to explore "key factors that are important ingredients in ensuring long-term, systemic change in energy use" in community-based programmes (Moloney, Horne, & Fien, 2010, p. 7615). They specifically investigated the underlying assumptions about behaviour change (behavioural-based or practice-based), agency, learning, systemic changes and barriers. They found that community-based programmes seem to have the potential to incorporate wider structures to change social practices.

Lastly, Wilson & Dowlatabadi (2007) suggest that integration of different decision models can provide a better understanding of energy consumption and intervention design. This thesis has explored linkages between different approaches and SDT and highlighted the ability of SDT to explain long-term reductions. However, certain elements are not incorporated with SDT and a future research opportunity lies in integrating these different theories.

6.3 Implications for Interventions for Rebound Effects

Very few studies on rebound effects were found and among those studies, only one used an intervention but did not involve feedback. This makes it difficult to derive implications for intervention design. However, the only difference between interventions aimed at reducing energy consumption and interventions aimed at reducing rebound effects is that rebound effects are caused due to an energy efficiency improvement that an individual has adopted. Other than that, both types of interventions ideally aim for reducing energy consumption. Therefore, the interventions discussed in this thesis can also be applied to reducing rebound effects.

With respect to interventions, examining the findings of this thesis, it's evident that the role of fulfilment of needs is crucial and using SDT to design interventions can be useful. Behavioural-based explanations of rebound focus on perceived responsibility, feeling of being in control and awareness. These factors can be incorporated in SDT informed intervention design. It's seen that all interventions accompany awareness-increasing measures through workshops, information, etc. Second, the use of feedback provides feelings of competence or control. Responsibility as a factor has not been discussed in interventions, however, interventions which allow individuals to internalise external values might

succeed in inculcating a sense of responsibility. Therefore, interventions such as group-based interventions which trigger identified and integrated regulations can be used.

Further, the design might be improved by taking a practice-based approach due to the emphasis on the uniqueness of each context and the material-human arrangements in explaining the rebound effects. Most studies found, also used a practice-based approach to understand and recommend interventions. Gram-Hanssen, Heidenstrøm, Vittersø, Madsen, & Jacobsen (2017) suggested that user competence is shared between material arrangements, and so both energy efficiency improvement and competence should not be seen in isolation. This thesis also argued for using a practice-based understanding for future intervention design. Such approaches can enable a richer account of different factors that cause rebound effects and a framework to explore the dynamics of how such factors have changed (see section 2). Consequently, interventions should target competence and meaning (practice elements) to align them with the improvement in energy efficiency (material changes). However, people's participation in those interventions would depend on their underlying motivations. According to SDT, such motivations have a higher chance to be intrinsic if external values are able to be internalised. This, in turn, depends on whether basic needs are met. One study that tested an intervention but didn't use feedback, provides some evidence in support of a practice-based approach and relevance for incorporating motivations. Jansson-Boyd, Robison, Cloherty, & Jimenez-Bescos, (2017) coupled retrofitting with a behaviour change programme through an intervention that incorporated exploring participants' values and encouraging them to seek knowledge (autonomy), education (competence), creating a sense of community (relatedness) over a two-year period. They found that these complemented each other in changing meanings associated with energy consumption, and reported individuals developing pro-environmental values (internalisation) and making changes to their behaviours. They, however, didn't evaluate the changes.

6.4 Contributions to sustainability (science).

From the sustainability perspective, this thesis has contributed towards addressing climate change by providing insights on how best to stimulate reductions in energy consumption. Further, by highlighting the role of changes in behaviours and practices in reducing emissions, it provided an alternative approach to technological and infrastructural changes that can create lock-ins as identified by Miller et al. (2014). This is relevant because of the policy implications of scenarios that do not account for changes in individual behaviour/practice, and predict high associated costs, for example, US$ 73 trillion to reduce 50% GHG emissions by 2050 (Akashi & Hanaoka, 2012). This thesis has highlighted the need to explore practice-based interventions more while at the same time providing conditions for

increasing the long-term effectiveness of interventions already in use (representing behavioural-based approaches). This is relevant in reaching peak emissions as early as possible especially when the possibility of limiting temperature rise to 1.5 degrees and peak emissions by 2020 has been labelled 'unlikely' by the IPCC (IPCC, 2014).

Apart from contributing to one of the fundamental questions posed by Kates et al (2001) (see section 1.4), it also contributed to two of the questions posed by Miller et al. (2014) on the future solutions oriented agenda for sustainability science. By highlighting the role of fulfilment of psychological needs and arguing for using a theory based on values and motivations in the intervention design to achieve long-term reductions and reduced rebound effects in energy consumption, it contributed in guiding future research to better answer, "What values support sustainable outcomes and how can they be activated in sustainable transition and decision processes?" and "What are promising strategies, tactics, interventions to transition from unsustainable to sustainable states and dynamics?" (Miller et al., 2014, p. 243).

Lastly, Schäpke & Rauschmayer (2014) criticised existing behavioural approaches towards reducing energy consumption and argued for incorporating altruistic values and motivations. Their argument centred on Sen's (2001) idea of capability approach that people do things not necessarily for self-interest but for different reasons which they value and derive well-being from. While this thesis particularly focussed on behaviour, SDT necessitates fulfilment of needs for individuals to experience well-being also. There exists "little research linking the sustainability of society, of lifestyle itself, and the happiness of individuals, but such research is desirable" (Kajikawa, 2008, p. 230) and as such SDT can incorporate this question, opening new research opportunities.

6.5 Limitations

First, the literature was analysed to find correlations between the fulfilment/thwarting of psychological needs and long-term reductions. This does not indicate causality between the two but mere correlations. The actual mechanisms might have differed but through correlations, theory and evidence-informed conclusions were drawn that opened up new research questions. Second, SDT doesn't provide any measures or extent to what level can or should the psychological needs be fulfilled except autonomy. Following this, interventions were classified based on varying regulations that also indicate varying levels of autonomy. For other needs, in this thesis, all types of measures were given equal weight under the assumption that none of the literature would have indicated to what extent the needs are fulfilled. Therefore, a comparison between studies is limited. Future research could

expand and explore on what measures best fulfil the needs possibly by additional qualitative data through participant interviews for example. Third, only SDT was used in this thesis as no previous study was identified and it suited the requirements of this study but there exist more theories of motivation such as the Maslow's hierarchy of needs, McClelland needs theory, Herzberg's two factor theory and Alderfer ERG theory (Alderfer, 1969; Herzberg, 1964; Maslow, 1943; Mcclelland, 1965) that differ on the number of needs**.** Fourth, this thesis did not conduct a meta-analysis involving statistical tools due to time and skills constraints. Lastly, it was limited by the small number of literature especially on rebound effects, forcing for limited but relevant conclusions to be drawn.

7 Conclusion

To reduce carbon emissions and tackle climate change, behavioural changes can have a significant impact especially when technological efficiency improvements are limited by rebound effects. In the residential sector, interventions involving feedback are promising, however, there are associated challenges with lack of motivation and different disciplinary approaches. Further, interventions should produce long-term reductions and reduced rebound effects.

By using SDT, this thesis aimed to find out how interventions involving feedback from both behavioural-based and practice-based approaches motivate individuals specifically for long-term and reduced rebound effects (RQ1), specifically finding out co-occurrences between the fulfilment of psychological needs and long-term reductions (RQ1.1). Further, this thesis aimed to identify implications based on the findings on designing better interventions (RQ2).

Overall, interventions varied in how they motivated individuals through ensuring three psychological needs. Ten interventions were found that were either individual-based or group-based and were classified based on which level of extrinsic regulations they triggered. However, group-based interventions were more autonomy allowing than individual-based interventions. Studies that reported achieving long-term reductions generally used group-based interventions and fulfilled all the psychological needs. Conversely, studies that reported not achieving long-term reductions didn't manage to fulfil all the needs. Therefore, it was recommended that attention should be paid on how needs are fulfilled in designing interventions. Scoping further to why the fulfilment of needs resulted in long-term reductions and how were they fulfilled, literature suggested that ensuring autonomy can allow individuals to internalise extrinsic values. Since interventions themselves can vary in supporting autonomy and most studies didn't address this aspect, it becomes important to consider autonomy in the design and implementation of interventions. In regard to competence, studies supported competence through improving feedback. Literature suggested that improving feedback can increase competence as individuals' informational needs and existing competencies vary, and in doing so can support an individual's motivation to utilize the intervention. Finally, ensuring relatedness was done through community or group-based interventions that also played a role in supporting autonomy and motivation compared to individual-based interventions. Therefore, the design of interventions could benefit from moving away from individual-based to group-based interventions.

Based on the scarce findings obtained on practice-based approaches, this thesis recommended using a practice-based approach for interventions aiming at both long-term reductions as studies that

reported achieving, emphasized on the role of practice-based elements (wider structural factors) in explaining unsustainable consumption and justifying their choice of group-based intervention. It was argued that psychological needs can more deeply be supported through a practice-based approach because of the inherently social nature of practice (relatedness), the agentive role of an individual (autonomy), the focus on embodied skills (competence) and meanings (motivation).

Very limited studies were obtained in regard to rebound effects but it was argued that similar interventions can be used for reducing rebound effects because the end goal is to reduce energy consumption. However. due to the explicit role of technology in causing rebound effects, it was argued that a practice-based approach can be beneficial in designing interventions as more explicit considerations are given to material aspects.

Lastly, given the above conclusions, recommendations were made for future research. It was recommended that first, a test of intervention based on SDT can refine the findings obtained in this thesis. Second, knowledge on interventions might be improved if researchers measure more variables and the determinants of change specifically, the changes in values, feelings of autonomy, competence and relatedness. Third, the thesis pointed to a research opportunity that has not received much attention on how interventions influence individual's wellbeing.

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Appendices

A1. Keyword search strings

- Psychological literature on energy efficiency and interventions

Scopus: (TITLE-ABS-KEY (energy OR electricity OR heating) AND TITLE-ABS-KEY (user OR resident OR residential OR household OR home OR occupant OR occupancy OR people) AND TITLE-ABS-KEY (behav*) AND TITLE-ABS-KEY (intervention* OR instrument* OR tool* OR strateg* OR approach* OR nudg*)) AND (EXCLUDE (SUBJAREA , "ENGI ") OR EXCLUDE (SUBJAREA , "MEDI ") OR EXCLUDE (SUBJAREA , "COMP ") OR EXCLUDE (SUBJAREA , "NURS ") OR EXCLUDE (SUBJAREA , "MATH ") OR EXCLUDE (SUBJAREA , "AGRI ") OR EXCLUDE (SUBJAREA , "BIOC ") OR EXCLUDE (SUBJAREA , "PHYS ") OR EXCLUDE (SUBJAREA , "BUSI ") OR EXCLUDE (SUBJAREA , "MATE ") OR EXCLUDE (SUBJAREA , "ECON ") OR EXCLUDE (SUBJAREA , "EART ") OR EXCLUDE (SUBJAREA , "CENG ") OR EXCLUDE (SUBJAREA , "HEAL ") OR EXCLUDE (SUBJAREA , "ARTS ") OR EXCLUDE (SUBJAREA , "CHEM ") OR EXCLUDE (SUBJAREA , "PHAR ") OR EXCLUDE (SUBJAREA , "IMMU ") OR EXCLUDE (SUBJAREA , "VETE ") OR EXCLUDE (SUBJAREA , "DENT ") OR EXCLUDE (SUBJAREA , "Undefined "))

- Sociological Literature on energy efficiency and interventions

Scopus: (TITLE-ABS-KEY("social practice" OR "practice theory" OR "energy culture") AND TITLE-ABS-KEY(sustainable* OR consumption OR conservation)AND TITLE-ABS-KEY(energy OR heat* OR water OR electricity)) AND (EXCLUDE (SUBJAREA,"AGRI ") OR EXCLUDE (SUBJAREA,"MEDI ") OR EXCLUDE (SUBJAREA,"EART ") OR EXCLUDE (SUBJAREA,"COMP ") OR EXCLUDE (SUBJAREA,"NURS ") OR EXCLUDE (SUBJAREA,"BIOC ") OR EXCLUDE (SUBJAREA,"CENG ") OR EXCLUDE (SUBJAREA,"MATE ") OR EXCLUDE (SUBJAREA,"MATH ") OR EXCLUDE (SUBJAREA,"CHEM ") OR EXCLUDE (SUBJAREA,"IMMU ") OR EXCLUDE (SUBJAREA,"PHAR ") OR EXCLUDE (SUBJAREA,"HEAL ") OR EXCLUDE (SUBJAREA,"VETE ") OR EXCLUDE (SUBJAREA,"PHYS ") OR EXCLUDE (SUBJAREA,"DENT "))

- Grey Literature

“practice” “behave*” “energy” “proceedings” “conference”

Name of the project databases (web links hyperlinked)	Comment
EU Databases: ➢ LIFE PROJECT (EU) ➢ Intelligent Energy Europé (EU) ➢ Manage Energy (EU) ➢ Horizon 2020 (EU) ➢ CORDIS (EU)	3 out of 41 projects found relevant

➢ Build up (EU) ➢ EU economic and social committee	
Conference Proceedings: ➢ ECEEE ➢ BECC ➢ BEHAVE ➢ ACEEE ➢ IEPPEC ➢ IAEE	Paid articles, not accessible.
Aalborg Research Group	Published journals, already included.
IEA	1 relevant project found
DEMAND	Not Relevant
Energy Cultures	Not Relevant
PEOPLE	Not Relevant
LEEDR	Not Relevant
PERSON	Not Relevant

- Rebound Literature

rebound AND intervention* OR instrument* OR tool* OR strateg* OR approach* AND behav* AND energy OR electricity OR heating

A2. Review of existing review studies.

Intervention Included	Study Selection Criteria	Evaluation Criteria	Source and Included Studies
Antecedent: 1. Goal Setting 2. Information - Workshops - Mass Media Campaign - Tailored Audits 3. Modelling Consequential: 4. Feedback - Continuous, - Daily, - Weekly and Monthly, - Comparative 5. Rewards	1. Target behaviour: energy behaviour 2. Target Group: household 3. Design: RCT/quasi-experimental 4. Outcome measure: Energy use 5. Quality: Peer Reviewed 6. Type of Intervention: N/A	1. Reduction of energy use and/or behavioural changes 2. Causality to intervention (research design – RCT) 3. Changes in underlying behavioural determinants determine effectiveness. 4. Longevity of behaviour change.	38 Studies (Abrahamse et al., 2005)

1. campus energy conservation competitions, 2. inter- and intra-community competitions, 3. inter-community home energy upgrade programs, 4. inter- and intra-organizational compe- titions, 5. a national building energy competition	1. Target Behaviour: energy behaviour, 2. Target Group: households, businesses, schools, etc. 3. Design: strong documentation 4. Outcome Measure: measured results 5. Quality: Strong documentation 6. Type of Intervention: Competition	1. motivations, 2. goals, 3. characteristics of the target audience, 4. communication channels utilized, 5. specific strategies employed 6. resources provided, 7. outputs (e.g., number of participants or number of audits), 8. outcomes (short-term [e.g., changes in awareness or knowl- edge of energy efficiency measures and behaviors], medium-term, and long-term [e.g., amount of energy saved or carbon emissions reduced]).	20 Studies (Vine & Jones, 2016)
1. EcoTeams Netherlands 2. EcoTeams UK 3. Carbon Reduction/Rationing Action Groups 4. Green Streets	1. Target Behaviour: multiple behaviours 2. Target Group: N/A 3. Design: N/A 4. Outcome Measure: objective data on energy use 5. Quality: Peer reviewed and grey literature 6. Type of intervention: group based intervention (face to face contact)	1. reliability, 2. speed of change, 3. durability, 4. generality, 5. particularism.	4 Studies (Fisher & Irvine, 2016)
1. information and feedback provision (social norm), 2. block leaders and social networks, 3. commitment, 4. modelling, 5. comparative feedback, 6. group feedback.	1. Target Behaviour: Single/Multiple behaviour 2. Target Group: N/A 3. Design: Treatment vs control or treatment vs other treatment 4. Outcome measure: self-reported or observed behaviour 5. Quality: Peer reviewed 6. Type of Intervention: based on social influence	1. Type of social influence approach 2. Type of target group 3. Type of target behaviour	30 Studies (Abrahamse & Steg, 2013)
1. feedback 2. Energy saving tips 3. Real time feedback 4. Audits and consulting	1. Target Behaviour: electricity use 2. Target Group: residential/household 3. Design: behavioural experiments	1. Individual usage feedback 2. Energy saving tips 3. Real time feedback	59 Studies (Delmas et al., 2013)

5. Monetary savings Info 6. Monetary incentives 7. Social comparisons	4. Outcome measure: quantitative treatment effect compared to baseline 5. Quality: Peer reviewed or NBER database 6. Type of Intervention: Information based	4. Audits and consulting 5. Monetary savings Info 6. Monetary incentives 7. Social comparisons Study level controls 1. Control group 2. Weather 3. Demographics 4. Treatment duration	
1. Feedback	2. Target Behaviour: energy use 3. Target Group: residential/household 4. Design: experimental design 5. Outcome measure: quantitative measure with statistical significance 6. Quality: Peer reviewed or NBER database 7. Type of Intervention: Feedback (isolation in at least one group)	1. Frequency 2. Medium 3. Measurement 4. Combination with other interventions 5. Comparison 6. Granularity 7. Duration 8. Control Group 9. Publication Bias	42 Studies (Karlin et al., 2015)