D 5.1 BEHAVIOURAL CHANGE MODELS AND DETERMINANTS FOR ENERGY CONSUMPTION

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EXECUTIVE SUMMARY

enCOMPASS delivers a sociotechnical system intended to induce behavioural change among its key target user groups in residential buildings, public buildings, and schools. This requires a solid understanding of the predictors of energy consumption behaviour and of the effectiveness of different behavioural change strategies. This deliverable serves this purpose, as specified in the enCOMPASS Description of Action: *„review behavioural change process models and determinants of energy saving behaviour, as well as an overview of effective informational, and social strategies to induce sustainable changes in energy consumption".*

The state-of-the-art analysis of energy consumption determinants and strategies in this deliverable serves as input to the requirements process, as they shape the functionalities that are included in the behavioural change applications in order to maximize energy savings. Early results have already been taken into account for the definition of scenarios, user stories, and use cases in *D2.1 Use cases and early requirements*. Furthermore, the behavioural change model analysis will, together with insights from D5.2 *Incentives and engagement strategies*, support the definition of the gamification model in *Task 5.3 Adaptive gamification for behaviour change*, and the design of energy consumption visualisations in *Task 5.2 Energy consumption visualisation and feedback*.

This deliverable is structured as follows:

- Introduction to the Deliverable *D5.1 Behavioural Change Models and Determinants for Energy Consumption* is presented in the *Section 1.*
- *Section 2* addresses behavioural change models, distinguishing between determinant models that identify psychological predictors of behavioural change (e.g. *Theory of Planned Behaviour*, Ajzen, 1991), and process models that focus on the process of behavioural change, identifying different stages, as well as the processes needed to progress from one stage to the other (e.g. the *Transtheoretical Model*, Prochaska & Velicer, 1997).
- *Section 3* provides an overview of different types of behavioural change techniques, drawing on the vast body of research on these techniques. Different classification schemes are presented that are often used in the domain of environmental psychology. Additionally, a cross-domain framework is described, termed the *Behavioural Change Wheel* (Michie et al., 2011). This framework identifies seven types of behavioural change techniques: education, persuasion, incentivization, coercion, training, environmental restructuring, modelling, enablement, and restrictions. These techniques can affect three prerequisites for behavioural change: motivation, opportunity, and capability.
- *Section 4* presents the approach for the review of the energy consumption behaviour determinants, as well as strategies to induce a change in this behaviour and/or the underlying determinants. Whereas for residential buildings a number of recent systematic reviews is available that provide an overview of the determinants and strategies, far less is known about schools and public buildings. Therefore, a systematic review was conducted to review these determinants and strategies for public buildings and schools.
- *Section 5* and *Section 6* present the results of the review for public buildings and schools, respectively. For each of these sections, first the psychological and social, socio-demographic, and contextual determinants, and second the strategies and interventions to reduce energy consumption were identified. The key determinants in energy saving in public buildings and schools are identified focusing on how often these determinants have been investigated and what impact on energy consumption do they have. Psychological determinants are most studied in public buildings and

schools. Strategies and interventions to reduce energy consumption in public buildings and schools were analysed, most interesting and effective interventions are described in *Subsections 5.2* and *6.2*. Most of the studied interventions in public buildings and schools may be addressed to the education and persuasion types of behavioural change techniques identified in the *Behavioural Change Wheel* (Michie et al., 2011).

- *Section 7* addresses residential buildings by summarizing insights from pre-existing systematic reviews on energy consumption behaviour in households. The strategies are classified according to the aforementioned *Behavioural Change Wheel* (Michie et al., 2011).
- *Section 8* presents an inventory of energy saving actions that users of residential buildings, public buildings, and schools can do in order to save energy, with the purpose of defining the range of behaviours enCOMPASS can influence.
- *Section 9* presents the conclusions of this deliverable.

1 INTRODUCTION

enCOMPASS was set up as a multidisciplinary project that brings together technology with knowledge from social and environmental psychology to construct a sociotechnical system that seeks to induce behavioural change for energy consumption. This deliverable reports the state-of-the-art in (environmental) psychological research with respect to the determinants of energy consumption behaviour and the strategies and interventions that have proven to be effective in changing energy consumption behaviour and its underlying determinants.

The conceptualisation of the enCOMPASS system requires a clear view on the process through which behavioural change is induced among different types of users in the enCOMPASS pilots. For that purpose, this deliverable will also address existing behavioural change models, covering models that target behavioural determinants, as well as process models, which assume that behavioural change occurs after the progression through a sequence of stages.

The state-of-the-art analysis in this deliverable will feed into the requirements process, as the identified determinants and behavioural change strategies can serve to shape the functionalities that are included in the behavioural change applications in order to maximize energy savings. The results have already been taken into account for the definition of scenarios, user stories, and use cases in *D2.1 Use cases and early requirements*. Furthermore, the *Behavioural Change Model* analysis will, together with insights from D5.2 *Incentives and engagement strategies*, support the definition of the gamification model in *Task 5.3 Adaptive gamification for behaviour change*, and the design of energy consumption visualisations in *Task 5.2 Energy consumption visualisation and feedback*.

Finally, an inventory of energy saving actions has been conducted that users of residential buildings, public buildings, and schools can do in order to save energy, with the purpose of defining the range of behaviours enCOMPASS can influence. Identifying the range of behaviours through the inventory of energy saving actions serves different purposes. First, it supports the requirements process with the scoping of the applications by prioritizing the concrete behaviour that enCOMPASS needs to influence. Second, the energy saving tips support the definition of the context-aware recommender in *Task 4.3 Collaborative recommender for energy saving* by providing the concrete actions that can be recommended to the users.

2 BEHAVIOURAL CHANGE MODELS FOR ENERGY SAVING

This section addresses psychological models for behavioural change that have been proposed within the domain of behavioural psychology. The assessment of these models serves as input for the enCOMPASS behavioural change applications introduced in residential buildings, schools and public buildings.

In this section a distinction between determinant models that seek to explain behavioural change from its underlying psychological determinants, and process models that focus on the *process* of changing behaviour over the course of time was made.

2.1 DETERMINANT MODELS

Research into behavioural change models has yielded a range of factors, referred to as determinants, that can explain human behaviour. These determinants are not only the subject of research into their interrelationships, but also constitute focal points for the design of interventions.

One of the most influential determinant models in that respect is the *Theory of Planned Behaviour* (Ajzen, 1991), which has also been applied to energy consumption behaviour (e.g. Tetlow et al., 2015; Gadenne et al. 2011). The *Theory of Planned Behaviour* (TPB) models the relationship between attitudes, intention, and the target behaviour (i.e. energy consumption). The TPB-model has been the basis for a longstanding line of research, as well as the design of interventions in various domains of practice. The TPB model is displayed in *Figure 1*.

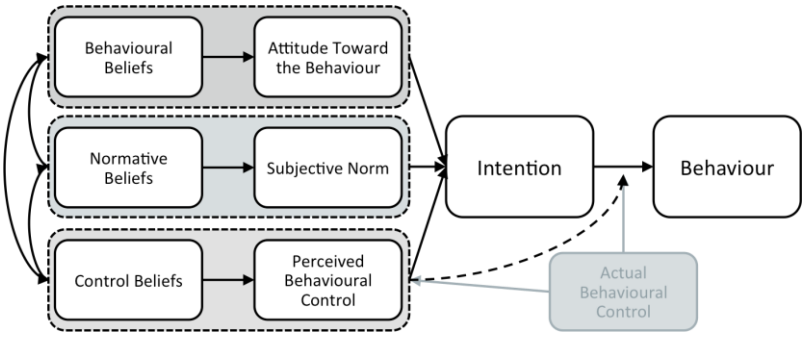

Figure 1: Theory of Planned Behaviour (Ajzen 2006)

The core constructs of the TPB model are:

- **Behavioural beliefs:** an individual's subjective estimation of the probability that a behaviour will have certain consequences.
- **Attitude:** an individual's positive or negative evaluation of self-performance of the particular behaviour.
- **Normative beliefs:** the perceived behavioural expectations of important referent individuals or groups.
- **Subjective norm:** perceived social pressure to engage or not to engage in a particular behaviour.
- **Control beliefs:** the individual's perception of the factors that facilitate or impede the performance of a particular behaviour.
- **Perceived behavioural control:** an individual's perception of the ability to perform a particular behaviour.
- **Actual behavioural control:** the extent to which a person has the skills, resources, and other prerequisites needed to perform a given behaviour.
- **Intention:** an individual's readiness to perform a particular behaviour.

Whereas this model has been applied in many different settings, one of its main criticism is the often-found attitude-behaviour gap, which refers to the difference on the one hand between attitudes and intention, and the target behaviour on the other hand (e.g. Kollmus & Agyeman, 2002), suggesting that the model is not capable of completely accounting for all relevant factors that affect the behaviour. Therefore, other theoretical notions as explanation for human behaviour in general and energy-related behaviour in particular should be taken in to account.

Second, the TPB model explains behaviour based on the *specific* beliefs and attitudes towards the targeted behaviour (e.g. the attitude towards reducing the room temperature with one degree within the next month). However, lessons from environmental psychology suggest that also more *general* beliefs and attitudes towards the environment impact behaviour (Bamberg, 2013).

Nature of the behaviour: purchasing decisions versus habits

Behaviour can be distinguished by the frequency with which it occurs. In order to reduce energy consumption, one-off purchasing decisions can be targeted, to influence the main drivers of energy consumption, such as heating and cooling devices, dishwashers, and so on. Second, a substantial share of energy behaviour concerns habitual behaviour. Habits are defined as automatic behavioural tendencies that arise as a result of repetition and practice of actions in similar situations (Ouellette & Wood, 1998). Habits become stronger when the frequency with which the behaviour is performed increases (ibid.). Behavioural change interventions therefore often encourage habit-driven so-called curtailment behaviour: reducing an activity that causes harm to the environment and/or choosing and repeating a pro-environmental behaviour (e.g., turning off the light when one leaves a room) needs to be encouraged (Fornara et al., 2016). Thus, curtailment behaviour refers to repeated, day-to-day habitual behaviours that, once changed, reduce energy consumption (Frederiks et al., 2015). The TPB model does not take this distinction between purchasing decisions, and habit-drive curtailment behaviour into account.

enCOMPASS primarily focuses on encouraging curtailment behaviour (e.g. habitual behaviour) will be made, as Information Communication Technologies (ICT) are expected to be ineffective to influence low frequency purchasing decisions. Purchasing decisions are influenced by a range of financial, contextual, and practical considerations that are difficult to influence with e.g. a separate application. Nevertheless, while curtailment behaviour is the focus in enCOMPASS, energy saving tips can address purchasing decisions as well (*see also D2.1 Use cases and early requirements)*.

Influence of goals

People have different motivations and associated goals they want to achieve. According to *Goal Framing Theory*, such goals are simultaneously present in any given situation, even though one goal is more in focus than others. The focal goal influences the way people process information and act upon it (Lindenberg & Steg, 2007). A goal frame is a focal goal together with its framing effects (i.e., its effects on cognitive processes, such as selective attention). Three different goal frames are distinguished: the hedonic goal "to feel better right now," the gain goal "to guard and improve one's resources," and the normative goal "to act appropriately." (Lindenberg & Steg, 2007, p. 119). When an individual has short-term hedonic goals in focus, s/he is particularly sensitive to what increases or decreases pleasure, or affects one's mood. In contrast, focal gain goals make people sensitive to changes in personal resources (e.g. money). Finally, the question about what one ought to do, is key for people who have a normative goal frame in focus. With respect to the normative goal frame, Lindenberg & Steg (2007) elaborate on smart norms, which are abstract norms that require cognitive effort to translate the norm to a decision about what is appropriate in a given situation. They state that in the case only smart norms are present, people are more likely to have selfish hedonic or gain goals in focus. Note that all three goal frames are likely to be active at the same time, while in different situations different goal frames can get the upper hand.

Influence of personal norms

The *Norm Activation Model* (NAM) for altruistic and pro-environmental behaviour explains an individual's intention towards a behaviour from one's personal norms, one's awareness of the consequences of the behaviour, and the extent to which one feels responsible for these consequences (Schwartz, 1977). Different interpretations exist about the interrelationships between these constructs, but the sequential model has collected most evidence. In this interpretation, problem awareness affects a personal norm that directly influences the behavioural intention, without a relationship between awareness and the personal norm (Han et al., 2014; see *Figure 2*).

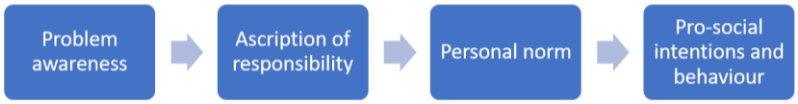

Figure 2: Sequential interpretation of the NAM model (Schwartz, 1977)

Han et al. (2014) have extended the constructs from the *Norm Activation Model* with attitudes toward the behaviour, and anticipated feelings of pride and guilt that are induced by pro-environmental and environmentally irresponsible behaviour respectively. The questionnaire data collected for validation revealed a good fit with the extended model. Han et al.'s (2014) *Extended Norm Activation* Model is displayed in *Figure 3*.

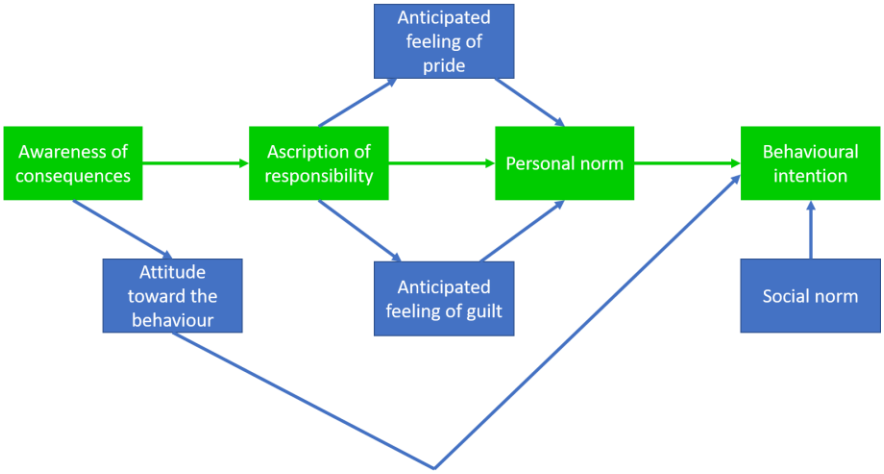

Figure 3: Extended NAM model, according to Han et al. (2014)

The model demonstrates that the behavioural intention is the result of the current social norm, one's personal norms, and the attitude towards the behaviour, while the personal norm is determined by the NAM model factors in their sequential interpretation (depicted with the green boxes). In addition to the extent to which a person feels responsible for a behaviour, anticipated feelings of pride and guilt also influence the activation of the personal norm.

The NAM model exemplifies the opportunity for a norm-based approach to induce energy efficient behaviour in enCOMPASS. Consumption visualizations are foreseen to target different factors in the NAM model. Personal norm-based messages, and social norm messages may be incorporated in the metaphors used to convey energy consumption data, while adaptive incentives are foreseen to connect suggested energy saving actions to the user's motivation for energy saving (see also *D2.1 Use cases and early requirements*). This can be used to activate feelings of guilt and pride as well.

2.2 BEHAVIOURAL CHANGE PROCESS MODELS

This subsection covers psychological models that perceive behavioural change as a process. Process models do not seek to predict behaviour as a result of assessing its underlying determinants, but are concerned with how behavioural change is achieved over time, as well as the cognitive progress that needs to be made in order to move forward towards achieving the behavioural goal.

2.2.1 Trans-theoretical Model of Behavioural Change

The *Trans-theoretical Model for Behavioural Change* has been developed in the health domain (Prochaska & Velicer, 1997), with the purpose of supporting the design of interventions to change addictive behaviours, such as smoking cessation. Different phases are distinguished through which behavioural change is induced:

- **Pre-contemplation:** pre-contemplation is the stage in which people are not intending to take action in the foreseeable future. People may be in this stage because they are uninformed about the consequences of their behaviour.
- **Contemplation:** people are intending to change in the foreseeable future. They are more aware of the pros of changing but are also acutely aware of the cons. People are yet undecided, which can last for long periods of time.
- **Preparation:** people are intending to take action in the immediate future.
- **Action:** people have made specific overt modifications in their behaviour over the last 6 months.
- **Maintenance:** people are working to prevent relapse but they do not apply change processes as frequently as do people in action.

Behavioural change occurs when people progress through the phases. This happens when an individual is exposed to one or more behavioural change processes. Prochaska & Velicer (1997) define these processes as the covert and overt activities that people use to progress through the stages. The progression is however not linear. Relapse can and will often occur. The authors identify the following behavioural change processes:

1. **Consciousness raising** involves increased awareness about the causes, consequences, and cures for a particular problem behaviour.
2. **Dramatic relief** initially produces increased emotional experiences followed by reduced affect if appropriate action can be taken.
3. **Self-re-evaluation** combines both cognitive and affective assessments of one's self-image with and without a particular unfavourable habit, such as one's image as a couch potato and an active person.
4. **Environmental re-evaluation** combines both affective and cognitive assessments of how the presence or absence of personal habits affects one's social environment (e.g. the effect of smoking on others). It can include the awareness that one can serve as a positive or negative role model.
5. **Self-liberation** is both the belief that one can change and the commitment and recommitment to act on that belief.
6. **Social Liberation** requires an increase in social opportunities or alternatives especially for people who are relatively deprived or oppressed.
7. **Stimulus control** removes cues for detrimental habits and adds prompts for better alternatives.
8. **Contingency Management** provides consequences for taking steps in a particular direction. Particularly reinforcements are emphasized, since a philosophy of the stage model is to work in harmony with how people change naturally.
9. **Helping relationships** combine caring, trust, openness, and acceptance as well as support for the behaviour change.

The authors argue that there is no one-on-one mapping of processes to the behavioural change phases, but rather processes are emphasized more in one phase than in the others. Consciousness raising, dramatic relief, and environmental re-evaluation are mostly associated to pre-contemplation, while self-re-evaluation is commonly found in the contemplation phase. Self-liberation is often found in preparation, whereas contingency management, helping relationships, counterconditioning, and stimulus control are the focal processes for the action and maintenance stage.

Note that the naming and definition of these phases reflect the context of addictive behaviours (e.g. quitting smoking), the domain of practice for which the model was originally developed. As such, a one-on-one application to the environmental domain is not possible.

The '**decisional balance**' reflects the weighing of the pros and cons of changing, which is the key factor to explain whether or not an individual will progress to the next stage, and ultimately whether behavioural change will take place. **Self-efficacy** is used to explain the situation-specific confidence people have to cope with high-risk situations. Finally, **temptation** reflects the intensity of urges to engage in a specific habit when in the midst of difficult situations. These constructs can be perceived as critical outcome measures of the behavioural change processes, even though this relationship is not precisely defined.

Several behavioural change interventions have been designed and evaluated based on the *Trans-theoretical Model*. Bridle et al. (2005) have conducted a systematic review of these studies. The review demonstrated that there was little evidence for stage-based interventions outperforming traditionally designed interventions. In addition, the authors identified several methodological, and conceptual issues in the reviewed studies, as well as the assumptions behind the model. First, the link between behavioural change processes and stage progression is not explained in detail. Second, it is unclear which barriers to behavioural change should be targeted in the different phases. In addition to the conceptual and methodological issues pointed out by Bridle et al. (2005), determining the stage of change for an individual user is problematic, as the different phases cannot be strictly separated (West, 2005). Additionally, West (2005) points out that the target behaviour is often substantially less planned than is assumed in the *Trans-theoretical Model*, whereas the role of motivation is underestimated.

2.2.2 Stages Model of Self-Regulated Behavioural Change

Bamberg (2013) have developed a *Stage Model* of which the stages resemble the stages in Prochaska & Velicer (1997). They distinguish four phases: pre-decision, pre-action, action, and post-action. However, there are also a number of differences in comparison to the *Trans-theoretical Model*. First, transitions between stages are denoted with intentions that ultimately result in the new behaviour. The transition between pre-decision and pre-action is called the goal intention. An individual forms a goal intention by weighting the desirability and feasibility of competing goals. Goals are personal goals towards which an individual feels committed. The behavioural intention marks the transition between pre-action and action. It is the result of an individual balancing the pros and cons of possible alternative behavioural strategies. Finally, the implementation intention forms the boundary between the action and post-action stage. The formation of an implementation intention mentally links a specific future situation to the initiation of the intended new behaviour. Bamberg (2013) assumes that if such a situation occurs, the individual can carry out the associated actions automatically.

Second, whereas in the *Trans-theoretical Model* (Prochaska & Velicer, 1997) processes are distinguished that drive the progression from one stage to the next, Bamberg (2013) identifies key determinants that can be targeted. As can be seen from *Figure 4*, the *Norm Activation Model* constructs (see *Section 2.1*) are introduced as predictors for the goal intention, while constructs of the *Theory of Planned Behaviour* (e.g. attitude toward and perceived behavioural control over alternative behavioural change strategies) predict the behavioural

intention. Finally, planning processes and self-efficacy are introduced as the predictors of the implementation intention. The complete model is displayed in *Figure 4*.

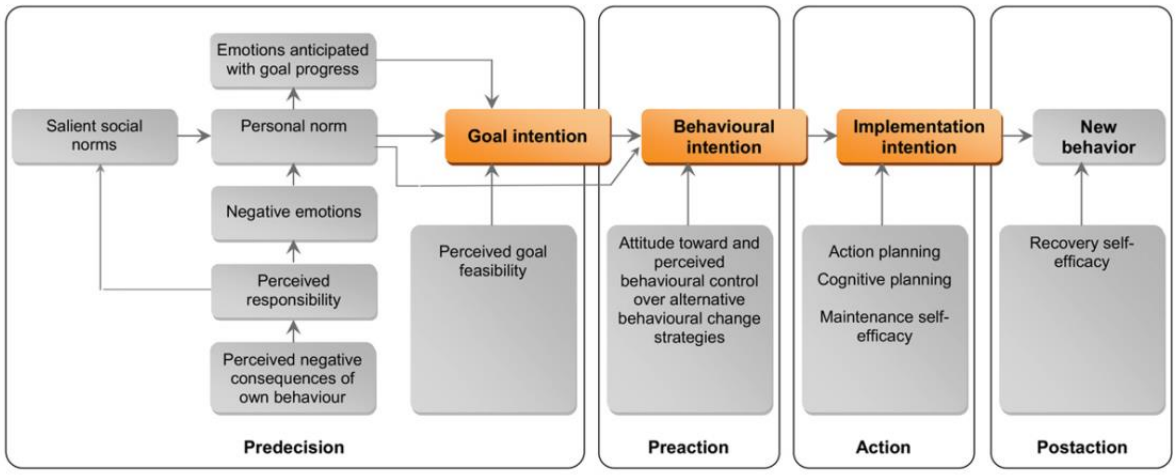

Figure 4: Stage model of self-regulated behavioural change

The current stage membership is determined by a combined measure of questionnaire-based self-reported past behaviour over the last month, and the goal with respect to the upcoming month, which can be a decrease or an increase of the problematic behaviour, the goal to remain at the same level, or having no goal at all. The model was validated in the specific field of car usage. Data collected on the model's key constructs provided evidence of the relationship between the constructs within each stage and the existence of three different intentions as predictors of the target behaviour.

2.3 Value of Determinant and Process Models for enCOMPASS

In this section determinant and *Stage Models* for behavioural change were reviewed. In enCOMPASS the models will support the design and the validation of the enCOMPASS application. Some of the models have only been developed in the environmental domain (e.g. Bamberg, 2013; Lindenberg & Steg, 2007), whereas others have been developed in other domains (e.g. the health domain, Prochaska & Velicer, 1991; Ajzen, 1991), with until now relatively little evidence for their validity in the domain of energy saving.

Both *Determinant Models* and *Stage-Based Models* are to some extent problematic, because their underlying assumptions are in some respects incompatible with the nature of energy saving behaviour. First, the rationality of energy saving behaviour is overestimated, involving conscious decisions about taking action. As energy behaviour is primarily habit-driven, the rationality of decisions whether to take action is questionable, since automated sequences of actions are repeated unless a change in context happens (Dahlstrand & Biel, 1997). Both *Determinant Models* and *Stage Models* do not adequately capture the non-rational, and non-conscious part of the behaviour.

Second, the models usually only target one individual behaviour (e.g. whether or not to take a car; Bamberg, 2013), whereas energy efficiency involves a range of different behaviours with different predictors. For example, determinants of energy-efficient air conditioning use are likely to be rather different from the determinants of dishwasher usage. Furthermore, little emphasis is put on motivational processes, whereas this is a crucial factor in keeping up attention of the target group. Finally, the role of the context of the behaviour is underestimated. In the *Theory of Planned Behaviour* (Ajzen, 1991) and the (extended) *NAM-Model* (Schwartz, 1977; Han, 2014) no attention is paid to contextual factors. In contrast, *Goal Framing*

Theory (Lindenberg & Steg, 2007) acknowledges the importance of context in that different goals are most important in different situations.

While in the *Trans-theoretical Model* contextual factors are taken into account through the behavioural change process of 'stimulus control', in Bamberg's (2013) model the importance of the context of the behaviour is present in action planning, which is a predictor of the implementation intention. According to Bamberg (2013), action planning encompasses the situational parameters of the target behaviour (e.g. the 'when', 'where', and 'how'. However, the *Trans-theoretical Model*, and the *Self-Regulated Model* for behavioural change provide guidance for neither the design of interventions tailored to the context-of-use, nor for the assessment of how such contextual factors have impacted the success of behavioural change interventions. For these two purposes, more explicit modelling of the context is necessary. Incorporating e.g. *Goal Framing Theory* (Lindenberg & Steg, 2007; see *Section 2.1*) could be a promising direction.

Even though conceptual contributions have attempted to apply such process models to the domain of natural resource consumption (e.g. He et al., 2010; Ohnmacht et al., 2017), little empirical evidence is yet available about the validity of these models within this domain, or about the added value of using a stage-based approach over a traditional approach. More research is needed within the domain of energy saving to effectively model behavioural change processes for energy saving behaviours in general, and for energy saving behaviour supported through ICT-based behavioural systems in particular.

3 BEHAVIOURAL CHANGE STRATEGIES FOR ENERGY SAVING

The enCOMPASS system is perceived as a behavioural change support system aimed at changing the users' energy consumption behaviour. A behavioural change support system is a socio-technical information system with psychological and behavioural outcomes designed to form, alter or reinforce attitudes, behaviours or an act of complying without using coercion or deception (Oinas-Kukkonen, 2013).

This section defines and categorizes the range of interventions that can be employed to change energy consumption behaviour. First, commonly used categorizations within environmental psychology are addressed: antecedent vs. consequence strategies, and informational vs. social strategies. To these categories, then motivational strategies are discussed that can help to alleviate the problem of a user's lack of motivation to expose oneself to incentives that can change one's energy consumption behaviour.

Subsequently, taking a broader outlook, the *Behavioural Change Wheel* (Michie et al., 2011), a comprehensive framework that links different types of strategies to three basic preconditions for behavioural change to happen: motivation, opportunity, and capability was described (Michie et al., 2011). The *Behavioural Change Wheel* will be used to categorize and describe the interventions which have been found in the systematic literature review that has been conducted for the three enCOMPASS pilot building types (public buildings, schools, and residential buildings).

3.1 CLASSIFICATION OF BEHAVIOURAL CHANGE STRATEGIES

Research on interventions to change environmental behaviour has yielded different categorizations. First, following Abrahamse et al. (2005, p. 274f.), a distinction needs to be made between **antecedent and consequence strategies**, with the former referring to strategies that seek to influence determinants prior to the significant environmental behaviour, while the latter are assumed to influence determinants after the occurrence of a pro-environmental behaviour, by means of providing a consequence which is contingent on the outcome of the behaviour. Setting consumption goals is a typical example of an antecedent strategy, while consumption feedback is often used as a consequence strategy.

Steg & Vlek (2009) have differentiated between **informational and structural strategies**. Informational strategies are aimed at changing prevalent motivations, perceptions, cognitions and norms, whereas structural strategies are aimed at changing the circumstances under which behavioural choices are made. Informational strategies are more commonly employed, particularly through the use of energy consumption feedback (e.g. Tiefenbeck, 2016; Webb et al., 2014; Abrahmse et al., 2007).

Social strategies employ social influence from other people or groups to influence an individual's thoughts, feelings or actions (Abrahamse & Steg, 2013). Their systematic review of social influence approaches for resource conservation yielded several examples of such social approaches, such as the use of social norms in information and feedback provision, the use of trusted volunteers to help peers with saving energy (referred to as 'block leaders'), public commitment-making, modelling, social comparison, and group-level feedback (Abrahamse & Steg, 2013).

While informational and social strategies can induce a change in energy consumption behaviour and/or its underlying determinants, exposure to such informational or social behavioural change incentives may be limited as a result of the goals of the user. *Goal Framing Theory*, as explained in 2.1, stresses that hedonic goals compete with normative and gain goals in any given situation (Lindenberg & Steg, 2007). In situations with hedonic goals at the centre of the user's attention, users are focused on the increase of pleasure or a positive change of one's mood. In such cases, promoting energy efficient behaviour can be linked to basic desires (Reiss, 2004) that are external to energy behaviour.

Gamification and serious games are often employed strategies that can fulfil this purpose. Gamification is defined as the use of game design elements in non-game contexts (Deterding, 2011). In contrast, a serious game is perceived as a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further objectives, such as government or corporate training, education, health, public policy, and strategic communication objectives (Wiemeyer & Hardy, 2013). Serious games distinguish themselves from gamification in the sense that (in this case) the change of energy behaviour is a by-product of play, whereas in gamification only game elements are added to an otherwise pragmatic application. Serious games and gamification both have the potential to appeal to various basic desires that have been distinguished by Reiss (2004), such as the desire to collect, to compete, to win, and the desire for status.

Evidence for the potential of using game elements to induce more energy efficient behaviour comes from Johnson et al. (2017). They have conducted a systematic review of serious games and gamified applications to promote energy efficiency in a domestic setting. Several methodological shortcomings aside (e.g. limited use of validated measures, lack of control groups, short trial durations), Johnson et al. (2017) have found positive influences of game-based approaches, in terms of behaviour, cognition (including motivation), knowledge, and the perceived user experience. The role of gamification and serious games in the enCOMPASS project will be further elaborated in *D5.2 Incentives and engagement strategies*, including examples of such games in the energy domain.

In *Table 1* the different categorizations of strategies to encourage energy saving are summarized, supplemented with a number of examples.

Table 1: Classification of behavioural change strategies

Time of intervention, in comparison to the behaviour	**Type of intervention**	
	Informational	*Social*
Before the behaviour occurs: *Antecedent strategies*	E.g. goal setting	E.g. block leaders, public commitment
After the behaviour occurs: *Consequence strategies*	E.g. consumption feedback	E.g. social comparison of energy saving achievements
Before and after the behaviour: *Motivational strategies*	E.g. gamification, serious games	

3.2 Behavioural Change Wheel

Beyond the domain of environmental behaviour, different attempts have been made at consolidating different behavioural change strategy categorizations into a comprehensive framework, to support practitioners with choosing the right interventions, given the context and the target group (Michie et al., 2011). The *Behavioural Change Wheel* was introduced by Michie et al. (2011) as the result of a systematic review of research that covered 19 of such frameworks that each mostly covered only a partial overview of the possible interventions. Drawing on the reviewed framework, Michie et al. (2011) have developed a novel comprehensive framework, referred to as the *Behavioural Change Wheel*, which intends to cover the full range of possible interventions. It is displayed in *Figure 5*.

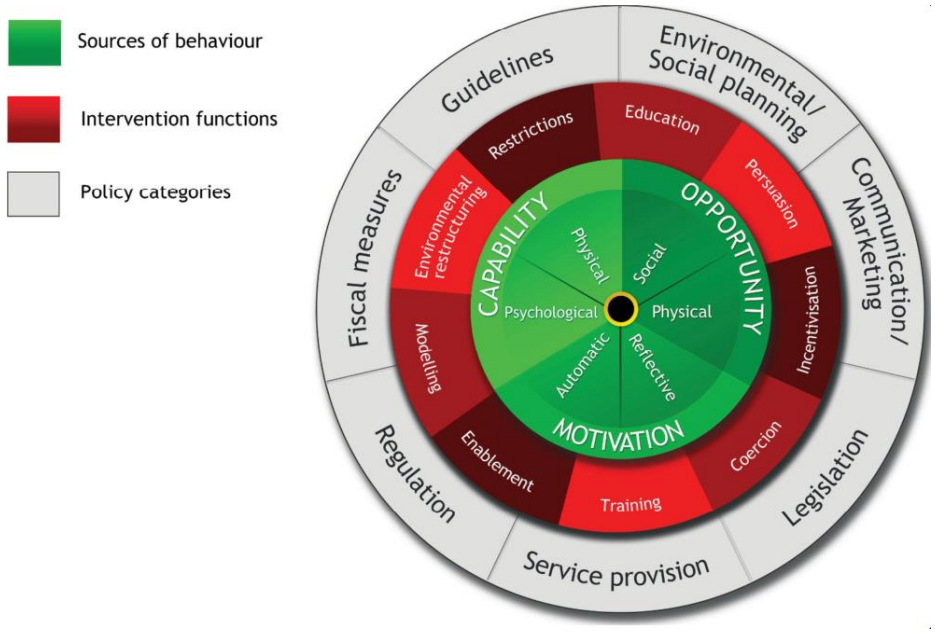

Figure 5: Behavioural Change Wheel. (Michie et al., 2011)

The centre of the *Wheel* contains three interacting prerequisites for behavioural change: motivation, opportunity, and capability. Capability is defined as the individual's psychological and physical capacity to engage in the activity concerned; motivation is defined as all those brain processes that energize and direct behaviour; opportunity is defined as all the factors that lie outside the individual that make the behaviour possible or prompt it (Michie et al., 2011, p. 4). The red second ring categorizes interventions that affect one or more of the prerequisites. As such, they represent strategies that can be used to induce behavioural change, affecting one or more prerequisites within the inner green circle. Interventions are grouped into nine categories. Their definitions are displayed in *Table 2*.

Table 2: Intervention categories according to Michie et al. (2011)

Intervention	**Definition**
Education	Increasing knowledge or understanding
Persuasion	Using communication to induce positive or negative feelings or stimulate action
Incentivisation	Creating expectation of reward
Coercion	Creating expectation of punishment or cost
Training	Imparting skills
Restriction	Using rules to reduce the opportunity to engage in the target behaviour (or to increase the target behaviour by reducing the opportunity to engage in competing behaviours)
Environmental restructuring	Changing the physical or social context
Modelling	Providing an example for people to aspire to or imitate
Enablement	Increasing means/reducing barriers to increase capability or opportunity

Even though the definitions of the interventions lack precision and the *Behavioural Change Wheel* has not been developed with ICT-based behavioural change support systems in mind, the intervention categorization

and their link to motivation, capability, and opportunity can provide guidance for the design of the enCOMPASS applications. Evidence for the usefulness of the framework comes from Wilson & Marselle (2016) who have assessed the content validity of the *Behavioural Change Wheel* intervention types for the design of energy consumption interventions. For this purpose, interventions were extracted from four comprehensive EU guidance documents, in which EU-based interventions and programmes were reviewed. The interventions were then coded according to the *Behavioural Change Wheel*. The authors conclude that the *Behavioural Change Wheel* offers a useful aid for the systematic design and development of behaviour change around end-use energy efficiency. Additionally, they argue that the *Behavioural Change Wheel* helps to explicate the path to behavioural change by breaking down interventions into their constituent parts. Finally, the *Wheel* can help to broaden the perspective of researchers from single interventions that in isolation have proven to be ineffective (e.g. education), to a more comprehensive view in which multiple types of interventions and their interrelationships are considered.

The outer ring represents policies, defined as actions on the part of responsible authorities that enable or support interventions. Policies are relevant to enCOMPASS because they can affect the impact of using enCOMPASS solutions on energy consumption behaviour. Additionally, lessons learnt from the pilots can yield policy recommendations, as foreseen in *Task 8.3 Energy saving guidelines and policy recommendations.* The *Behavioural Change Wheel* distinguishes seven types of policy interventions, as shown in *Table 3.*

Table 3: Policy intervention categories

Intervention	**Definition**
Communication/marketing	Using print, electronic, telephonic or broadcast media
Guidelines	Creating documents that recommend or mandate practice. This includes all changes to service provision.
Fiscal	Using the tax system to reduce or increase the financial cost
Regulation	Establishing rules or principles of behaviour or practice
Legislation	Making or changing laws
Environmental / social planning	Designing and/or controlling the physical or social environment
Service provision	Delivering a service

3.3 Conclusion: Behavioural Chang Strategies for Energy Saving

This section served to introduce different categorizations of strategies to encourage energy saving. The most comprehensive categorization was found in the *Behavioural Change Wheel* (Michie et al., 2011). The next sections present a systematic review of energy conservation research, covering both energy consumption determinants, and strategies employed to induce energy efficient behaviour. The reported strategies are then categorized in terms of the *Behavioural Change Wheel* (Michie et al., 2011).

4 APPROACH

In this section the approach is outlined for reviewing the determinants of energy saving and energy consumption behaviour for the three building types in enCOMPASS: public buildings, schools, and residential buildings.

4.1 RESEARCH QUESTIONS AND SCOPE

Whereas an abundance of research is available for determinants, strategies, and interventions with respect to household energy consumption, far less is known with respect to energy behaviour in public buildings and schools. Therefore, existing extensive reviews on energy consumption and energy conservation strategies for residential buildings from Abrahamse et al. (2005), Ohnmacht et al. (2017), and Frederiks et al. (2015) were summarized, to extract key findings relevant in the context of enCOMPASS that could inform the enCOMPASS application for residential buildings.

In addition, a systematic literature review was conducted for the substantially less investigated buildings types in enCOMPASS: schools and public buildings. In this section, the approach for this systematic review was outlined. The results are described in *Sections 5 and 6*.

The review was guided by the following research questions:

1. What are the determinants of energy consumption behaviour in residential buildings, public buildings and schools?
2. Which strategies are most effective in inducing a change in energy consumption behaviour among users of residential buildings, public buildings, and schools?

4.2 SEARCH AND SELECTION PROCEDURES

The research questions were operationalized into the following set of search terms (*Table 4*). Only studies published after 2000 were included. The query was restricted to search in the title, abstract, and keywords.

Table 4: Search terms of literature review of determinants for energy consumption in public buildings and school

Topic	**Search terms**
Energy consumption	(energy OR electricity) AND ((consumption OR efficiency OR saving OR conservation OR reduction) OR "energy use" OR "electricity use") AND behav*
Public building	workplace OR office visitor OR “public building” OR service OR compan* OR building OR employee* OR worker
School	school OR classroom OR university OR student* OR teacher*
Determinants	predictor* OR determinant* OR factor* OR attitude* OR value* OR knowledge OR belief* OR habit OR norm*
Intervention	intervention OR program OR campaign

Identified as some of the most relevant and accessible outlets for research on determinants of energy consumption, the following sources were consulted:

- ScienceDirect,
- EBSCO (EconLit, GreenFile),
- Emerald,
- Wiley Online,

- Oxford Journals,
- OECD Library.

Studies were excluded that:

- were non-empirical (e.g. position papers, literature reviews),
- were outside of the energy domain (e.g. water),
- addressed energy consumption in residential buildings,
- addressed energy consumption in other sectors (e.g. tourism, health care),
- focused on energy consumption in dormitories (closer related to residential buildings than schools) or laboratories (too specific equipment),
- focused on policy and regulations,
- focused on non-behavioural interventions such as energy efficiency measures for buildings,
- developed models or algorithms to forecast building energy consumption,
- covered a too broad scope (e.g. addressing pro-environmental or sustainable behaviour in general),
- were entirely out of scope.

4.3 Overview of the Studies

The search results were imported into a spreadsheet and subsequently either included or excluded, based on the title (first round), and abstract (second round). A summary of the search and selection process is provided in *Table 5.*

Table 5: Summary of search and selection process

Characteristic	**No. of papers**
Studies found	859
Accepted	
• Schools	30
• Public buildings	41
Main reasons for rejection:	
• Out of scope	>400
• Residential buildings studies	104
• Other sectors (e.g. travel, transport, tourism, culinary, health care)	38
• Building-related energy consumption, efficiency measures, renovation opportunities, emissions etc. (data-driven, no focus on occupants)	30
• Scope too broad (sustainability, pro-environmental behaviour, climate change)	18
• Policy and regulations	11
• Non-empirical (e.g. review, comment, essay)	7
• Focus on models and algorithms (e.g., modelling of energy-efficiency of building when changing specific parameters or taking certain measures)	7
• Focus on dormitories in schools (more links to residential buildings)	6
• Focus on laboratories in schools (too specific)	5
• Other resources (e.g., Water, waste management)	4

Out of the 859 search results, 71 were selected for the review (8,27% acceptance rate). 30 of the reviewed papers describe studies in schools and universities, while 41 papers focus on public or office buildings. The reviewed school papers consider different type of schools, and when considering determinants for behaviour of students, the age group of the students in the respective schools play a key role.

While a majority of rejected papers (>60 %) were widely out of scope, other main reasons for rejecting papers were that they covered residential buildings, other sectors, considered a scope too broad by focusing e.g. on sustainable behaviour in general, or that they presented studies that only considered the building's energy consumption and more structural measures to improve it without considering the building occupants (*Table 5)*.

In *Table 6*, a summary of the main characteristics of the studies that are included in the analysis is provided.

Table 6: Summary of selected studies

Public buildings *Target groups*	*Number of papers involving target group*
• Employees /office workers • Senior managers • Administrative employees • Staff members	30 1 1 1
• Building managers	4
• Building visitors	1
• All associated to the building	4 (not included in other total numbers)
• N/A	2
Schools *Target groups*	
• Teachers	4
• Building managers	–
• Students	10
• Other staff	12
• All associated to the building	2 (not included in other total numbers)

Studies of energy consumption behaviour in public or office buildings mainly focused on the employees or office workers in general, while less attention was e.g. paid to building managers, and only one to visitors. Selected studies focus on different types of office workers, e.g. administrative staff or managers.

A review with a particular focus on the role of visitors might yield some exploratory findings about visitors, but it is apparent that their role is rarely considered in energy saving studies. Whether this is just an oversight or due to an attributed assumed or shown lack of significance or influence of visitors on a given building's energy use, is yet to be investigated but is beyond the scope of the literature review conducted here.

Studies of school and university buildings most often consider staff and / or students.

Out of all the studies reviewed, roughly a third also presented interventions.

5 ENERGY CONSUMPTION IN PUBLIC BUILDINGS

There is evidence that occupants' energy use hold a large fraction of the total energy consumed at the public and office buildings. Energy saving in public buildings can be achieved changing occupants' behaviour and applying effective interventions. It is important to identify any evidence on the impact on occupants' energy consumption and saving behaviour. This section presents systematic literature review conducted on energy consumptions determinants and interventions to reduce energy consumption in public buildings.

5.1 DETERMINANTS OF ENERGY CONSUMPTION

There is a wide range of behavioural change influencing determinants, factors and predictors. Studies on pro-environmental behaviour in public buildings have recently been expanded. A review of studies suggests that pro-environmental behaviour in public buildings depend on psychological, social, sociodemographic, economic and contextual determinants. Following the literature studies the energy consumption determinants were integrated in three groups: 1. Psychological and social determinants, 2. Sociodemographic and economic determinants and 3. Contextual determinants. Detailed analysis of all groups of energy consumption determinants in public buildings is presented below.

5.1.1 Psychological and Social Determinants

Analysis of energy consumption and conservation covers explanation, prediction and changes of consumer's behaviour. Among others, psychological, and social factors have been intensively studied, in order to explain differences between individuals with respect to energy consumption and energy conservation behaviour. Psychological determinants of energy consumption are related to human psychology. Examples of psychological determinants are knowledge, awareness, beliefs, attitudes, motives, intentions, perceived behavioural control, personal norms, subjective norms, etc. Energy consumption and conservation in public buildings are associated with a wide range of social variables which influence opportunities and constraints. Social determinants can facilitate versus undermine intrinsic motivation. They characterize social norms, organizational culture, social influence, etc.

Table 7 below presents the psychological and social determinants of energy consumption behaviour in public buildings that were identified in the literature, their definitions, and measurements that have been used to evaluate them.

Table 7: Psychological and social determinants in public buildings

Determinant	References	Definition
Attitudes	Stokes et al. (2012, p. 89); Lo et al.2012, p. 229); Jurin & Fox-Parrish (2008); Loureiro & Lima (2009); Lee et al. (2013); Tetlow et al. (2015); Nilsson et al. (2015); Lokhorst et al. (2015); Manika et al. (2015b); Ucci et al (2014); Gustafson et al.8); Sawang & Kivits (2014); Greaves et al. (2013); Agha-Hossein et al.(2015); Nisiforou et al.2012); Wells et al.2016); Pellegrini-Masini & Leishman (2011)	"Attitudes comprise an individual's beliefs about the behaviour's consequences" (Stokes et al., 2012) "Attitudes are an individual's overall evaluation of a behaviour (Eagly & Chaiken, 1993) " as cited in Lo et al., 2012

Awareness	Tolias et al. (2015); Katzeff et al. (2013); Yun (2014); Lo, et al. (2012); Zierler et al. (2017)	*Not defined by the authors*
Values	Loureiro & Lima (2009); Pellegrini-Masini & Leishman (2011)	*Not defined by the authors*
Opinion	Nisiforou et al. (2012)	*Not defined by the authors*
Beliefs	Ucci et al. (2014); Xu et al. (2017)	*Not defined by the authors*
Moral norms	Loureiro & Lima, 2009	*Not defined by the authors*
Perceptions	Agha-Hossein et al. (2015); Yun et al. (2012)	*Not defined by the authors*
Perceived control	Stokes et al. (2012, p. 89)	"Perceived control comprises an individual's beliefs about what factors support or inhibit the behaviour"
Perceived behavioural control	Sawang & Kivits (2014, p. 26)	"Perceived behavioural control (PBC) is defined as the extent to which organisations have complete control over their adoption behaviour"
Perceived behavioural control	Lokhorst et al. (2015); Sawang & Kivits (2014); Greaves et al. (2013)	*Not defined by the authors*
Subjective norms	Sawang, & Kivits (2014, p. 26); Stokes et al. (2012, p. 89); Lo, et al. (2012, p. 230); Sawang & Kivits (2014); Greaves et al. (2013, p. 110)	"Subjective norms are the social influences impacting on an individual's intention to perform or not to perform (Ajzen, 1991)" as cited in Sawang & Kivits, 2014 "Subjective norms are determined by the normative expectations of others and motivation to comply with these expectations" (Sawang & Kivits, 2014) "Subjective norms comprise an individual's beliefs about how others view the behaviour" (Stokes et al., 2012) "Subjective norms are defined as the perception of other people's evaluation of a behaviour (Schultz et al., 2007) ", as cited in Lo et al., 2012 "Subjective norms are the social influences impacting on an individual's intention to perform or not to perform" (Greaves et al., 2013)
Social norms	Tetlow et al. (2015); Metzger et al.(2011); Nilsson et al. (2015); Ucci et al. (2014); Gustafson et al., 2008	*Not defined by the authors*
Intentions	Zierler et al. (2017); Lokhorst et al. (2015)	*Not defined by the authors*
Motivation	Karatas et al. (2016, p. 541); Handgraaf et al. (2013); Jáñez Morán et al. (2016); Azizi et al. (2015)	"Motivation is a goal-directed arousal to engage consumers in the desired behaviour to process (Govindaraju et al., 2013; Richins & Bloch, 1986; Steg & Vlek, 2009; Zaichkowsky, 1985)" as cited in Karatas et al., (2016)

Education	Lee et al. (2013)	*Not defined by the authors*
Use of feedback (motivation for energy saving)	Coleman et al. (2013, p. 38)	"Use of feedback is the notion that more specific information increases the visibility of energy consumption, raises people's awareness of the opportunities for reduction, and allows people to experiment and manage their energy use more effectively (Darby, 2008)" as cited in Coleman et al., 2013
Habit	Endrejat et al. (2015, p. 940); Tetlow et al. (2015); Lo, et al. (2012)	"Habits can be understood as 'automatic responses to specific cues' that spare us the effort to reassess each behaviour and its respective outcomes before we engage in it (Verplanken & Aarts, 1999)" as cited in Endrejat et al., 2015
Bounded rationality	Schleich (2009, p. 2153)	"Bounded rationality may result in satisfying behaviour, using routines, or rules of thumb (Simon, 1957, 1959)" as cited in Schleich, 2009
Engagement	Tetlow et al. (2015); Tolias et al. (2015); Bull et al. (2015)	*Not defined by the authors*
Competition	Metzger et al. (2011)	*Not defined by the authors*
Technology awareness	Zierler et al. (2017, p. 43)	"Technology Awareness is a measure of how readily participants adopt new technologies, and their level of awareness regarding the organisation's most recent technology upgrades"
Opportunity for intended energy use	Karatas et al. (2016, p. 541)	"Opportunity is defined as executional factors (e.g., exposure time to ads) that are not in the control of consumers to enable the desired actions (Bigne´ et al., 2010; Hallahan, 2001; MacInnis et al., 1991; Rothschild, 1999)" as cited in Karatas et al., 2016
Ability for intended energy use	Karatas et al. (2016, p. 541)	"Ability is defined as consumers' perception of their capacity to access the brand information, and interpret this information to create new knowledge structures (Bigne´ et al., 2010; Celsi & Olson, 1988; MacInnis et al., 1991; Parra-Lopez et al., 2012; Rothschild, 1999)" as cited in Karatas et al., 2016
Individual determinants	Lo, et al. (2012, p. 229); Manika et al. (2015b, p. 664)	"Individual determinants are defined as determinants of a psychosocial nature that are relevant on the individual level. (Lo et al., 2012)" as cited in Manika et al., 2015b
People factors	Chung & Hui (2009, p. 698)	"People factors (occupants' behaviour and maintenance factors, indoor temperature set point) in terms how people determine energy using systems operation."

Self-efficacy	Lo, et al. (2012, p. 229); Zierler et al. (2017, p. 43)	"Self-efficacy refers to a person's evaluation of whether one has the necessary resources, knowledge, and/or skills to attain a goal (Bandura, 1997)" as cited in Lo et al., 2012 "Energy Self-Efficacy represents whether participants feel responsibility for- and have an ability to influence their own energy use, with reference to how easy it would be for their own company department to do so" Zierler et al., 2017
Self-Appraisal	Zierler et al. (2017, p. 43)	"Energy Self-Appraisal is a measure of how careful participants believe they are with their own energy use, and their level of emotional involvement with saving energy"
Feedback	Nilsson et al. (2015, p. 435)	"Feedback consists of providing people with information about some given performance they have undertaken"
Personal norm	Zhang et al. (2013, p. 1121); Lokhorst et al. (2015)	Personal norm is defined as "moral obligation to perform or refrain from specific actions (Schwartz and Howard, 1981, p. 191)" as cited by Zhang et al., 2013
Group norms	Xu et al. (2017, p. 3)	"Norms – culturally shared beliefs about how people behave or how they should behave (Cialdini & Trost, 1998)." as cited in Xu et al., 2017 "Correlational evidence links employees' perceptions of supportive organizational norms to employee environmental behaviours (Norton et al., 2014), as well as group norms to more general organizational citizenship behaviours (Kidwell et al., 1997)" as cited in Xu et al., 2017
Organisational culture	Goulden & Spence (2015); Lo, et al. (2012)	*Not defined by the authors*
Organisational focus	Lo, et al. (2012, p. 230)	"Organisational focus, defined as the primary aim of an organisation, may be directly related to pro-environmental behaviour in the sense that it, at least on the organisational level, sets the priorities, which may or may not be aligned with environmental sustainability"
Organizational electricity saving climate	Zhang et al. (2013, p. 1122)	"Organizational electricity saving climate is defined as employee's perception that saving electricity is encouraged and supported in the organization"
Organizational perceptions of incentives	Manika et al. (2015b)	*Not defined by the authors*
Organizational perceptions of support	Manika et al. (2015b)	*Not defined by the authors*
Organizational support	Xu et al. (2017)	*Not defined by the authors*

Social interaction and communication	Jáñez Morán et al. (2016)	*Not defined by the authors*
Goal flexibility	Zierler et al. (2017, p. 43)	"Goal Flexibility measures respondents' perceived ease of fitting energy-saving goals around their existing suite of other financial and non-financial performance measures"

In total 35 papers analysed psychological and social determinants of energy consumption and 38 different determinants were identified in these papers. Attitudes (17 papers) were the most often studied determinants, then subjective norms, awareness, social norms and motivation (five papers each). Clear definitions for 21 of these determinants were found in these papers. As it is seen in the *Table 7*, many authors did not present the definition of the determinants investigated (17 out of 38 determinants). Presented definitions of psychological and social determinants of energy saving behaviour are very similar, the differences are not essential. However, the same meaning of the determinants is revealed in the papers in which the definitions were not found. Questionnaires were the most often used methods to assess the determinants as well as surveys and case studies. Interviews, pilot studies, pre and post – tests were used as well, but not as often.

Goulden & Spence (2015) analysed the role of the facility manager as a key actor in organisational energy management and how facility managers can apply these insights to support energy reduction in workplaces. Stokes et al. (2012) presented research, in which behavioural determinants are defined as internal versus external barriers. They use the *Theory of Planned Behaviour* to create ten different barrier subcategories. Stokes et al. (2012) focused on the **individual's beliefs** about what factors support or inhibit the behaviour. With their research on **attitudes** and **motivation toward energy conservation**, Jurin & Fox-Parrish (2008) found four principle dimensions that affected how people thought about conservation of energy; namely, comfort and health, high effort–low payoff, role of individual consumer, and legitimacy of the energy problem. Jáñez Morán et al. (2016) link **motivation** to the **level of education**. Loureiro & Lima (2009) pointed out that **attitude** is an important predictor of individual determinants on pro-environmental behaviour. **Subjective norms** as courtesy and norms, diffusion of responsibility and safety were discussed in Stokes et al. (2008). **Education** in the analysed research is presented as effective both in government and business outreach programs, and energy conservation education in elementary schools (Jurin & Fox-Parrish, 2008; DiMatteo et al., 2014). Lee et al. (2013) argued, that **knowledge** needs to be linked to action in teaching and learning, the reflection of knowledge on attitudes and responsible behaviour is important. Tetlow, et.al (2015) pointed out **habit** as a crucial determinant in energy-related behaviour and defined social determinants important for psychology, which could potentially drive energy use. Authors analysed **awareness** define it in some different ways: awareness, awareness of energy consumption, energy awareness, technology awareness (Tolias et al., 2015; Lo et al., 2012; Zierler et al., 2017). However, all meanings are related to energy consuming and saving behaviour. **Values, beliefs and intentions** were analysed as important predictors of individual determinants on pro-environmental behaviour and important determinants acting in network with other occupants (Loureiro & Lima, 2009). Metzger et al. (2011) argued that **competition** is important for social norming. As a way to receive information about each other's behaviour and raise people's awareness of the opportunities for reduction of energy consumption, the feedback about energy consumption was analysed in Deci et al. (1999) as cited in Handgraaf et al. (2013); Kluger & DeNisi (1996) as cited in Nilsson et al., (2015) works. Number of contributing authors below discussed **organizational factor** in terms of energy saving and pro-environmental behaviour. Emphasis was placed on **organisational focus** related to pro-environmental behaviour (Lo et al., 2012), **organizational electricity saving climate** (Zhang et al., 2013), **organisational culture** (Tudor et al., 2008) as cited in Lo et al.

(2012). Lokhorst et al. (2015) studied **perceived behavioural control**, emphasizing on commitment combined with feedback as useful interventions attracting employees to the process. Changes in energy-use behaviour and attitudes of employees should be considered as coherent options for cost-effective energy saving (Nisiforou et al., 2012). **Organizational determinants** as a whole (organizational focus, organizational structure, organizational/site type and size, departmental type and size, organizational culture) were analysed by Lo et al. (2012), while organizational electricity saving was studied by Zhang et al. (2013). **People factors** (occupants' behaviour and maintenance factors, indoor temperature set point) were introduced and analysed by Chung & Hui (2009) emphasizing on how people determine energy using systems operation (switching on/off appliances). **Perceptions of organization's incentives and support** were studied by Manika et al. (2015b) underlining that general environmentally friendly attitudes might influence perceptions of an organization's incentives and support. Zierler et al. (2017) focused on **energy intentions, self-appraisal, self-efficacy, energy awareness, goal flexibility and technology awareness** in their study about energy efficacy behaviour of individuals in large organizations. Games as tool for engagement were presented in the research of Tolias et al. (2015), in the sense that competitions could be introduced with the aim to increase engagement among employees. Feedback (public and private) was studied by Handgraaf et al. (2013) where authors underline that in order to have more effective feedback the acknowledgement is important. **Motivation** to overcome energy efficiency barriers in terms of limited resources, either human or financial as a determinant for energy consumption, was studied by Henirques & Catarino (2016).

Psychological and social determinants according to the reviewed literature were analysed mainly in the office buildings (26 papers), studies in any type of buildings and non-residential buildings were conducted in one paper each. The most often studied target group in office buildings were office workers (21 papers), whereas all persons associated to the building were in the focus of two papers, senior and building managers in one paper each. Two papers investigated any type of buildings, analysing responses of students.

Jurin & Fox-Parrish (2008) made a survey of three different groups of undergraduate college students (years 1995, 2002, and 2003) to determine their attitudes regarding the environmental issues, and particularly energy use. Staff members of the organization installed IdleWars, a pervasive game designed to raise awareness and promote behaviour change in relation to energy waste in the workplace (Tolias et al., 2015). A sample of administrative employees of the municipality have been involved in Lokhorst et al. (2015) study. Building managers and office workers were involved in many of the reviewed studies. Office workers as well as manufacturers took part in the research of Ucci et al. (2014), senior managers were involved in the survey of Sawang & Kivits (2014).

5.1.2 Sociodemographic and Economic Determinants

The concept "sociodemographic" refers to a group defined by its sociological and demographic characteristics. Sociodemographic determinants are attributed to age, gender, education and literacy, employment status, socio-economic status and income, dwelling characteristics, geographical location, etc. Economic determinants are associated to cost and benefit of energy saving. All these characteristics are important in analysing energy consumption and saving.

Sociodemographic and economic determinants of energy consumption behaviour in public buildings that were determined in the literature, their definitions, and measurements that have been used to assess them are presented in *Table 8*.

Table 8: Sociodemographic and economic determinants in public buildings

Determinant	References	Definition / Studies
Climate	Li et a. (2014); Chung & Hui (2009)	*Not defined by the authors*
Quality of social interaction and communication	Jáñez Morán et al. (2016, p. 135)	Social interaction – "way of thinking, and acting of end users are not only influenced by external factors but also by internal aspects as personal habits, values, experiences"
Building type factors	Chung & Hui (2009, p. 698)	"Building type factors are those factors related to the principal activities performed in a building (Piper, 1999)" as cited in Chung & Hui, 2008
Building size	Li et al. (2014)	*Not defined by the authors*
Risk and uncertainty	Schleich (2009, p. 2152)	"Risk and uncertainty is defined as a possible financial risk (business-specific risk, regulatory risk, or general economic risk caused by business cycle, fluctuation of exchange rates and energy prices, etc.), technical risks (risk of breakdowns and disruptions)"
Lack of time to improve energy efficiency	Schleich & Gruber (2008, p. 453)	Lack of time to analyse potentials for energy efficiency is a barrier to energy efficiency
Investor/user dilemma	Schleich & Gruber (2008)	*Not defined by the authors*
Split incentives and appropriability	Schleich (2009, p. 2153)	Split incentives and appropriability mean landlord/tenant or user/investor dilemma (type of ownership)
Operation and maintenance	Li et al. (2014)	*Not defined by the authors*
Efficient technologies	Li et al. (2014)	*Not defined by the authors*
Benefit evaluation	Zierler et al. (2017, p. 43)	"Benefit Evaluation represents respondents' appraisal of the economic and environmental benefits of pursuing energy efficiency to the organisation, and supporting the spread of pro-environmental technologies"
Investments for energy efficiency in buildings	Pellegrini-Masini & Leishman (2011)	*Not defined by the authors*
Hidden costs	Schleich, (2009, p. 2152)	"Hidden costs: inferior performance of energy - efficient technologies, costs as a part of the production costs associated with individual technologies, general overhead costs of energy management"
Access to capital	Schleich (2009, p. 2152)	Access to capital is defined in terms if it is own or borrowed
Motivation to overcome energy efficiency barriers	Henriques & Catarino (2016, p. 4)	Motivation to overcome energy efficiency barriers are defined in terms of limited resources, either human or financial

In total eight papers analysed sociodemographic and economic determinants of energy consumption and 15 different determinants were identified in these papers. Climate was studied in two papers and the rest of determinants are analysed each in separate paper. Determinants "Investor/user dilemma" and "Split

incentives and appropriability" have similar meaning however the titles of these determinants are different. Definitions of determinants are presented in nine papers. Different methods were used to assess the sociodemographic and economic determinants: portfolio analysis and case studies, benchmark study, data analysis from EU projects, personal interview, comprise information collection, interview, semi- structured interview, survey, and study.

A more detailed analysis of studied determinants by individual authors is presented as well. **Building type factors, occupancy factors** (floor area, operational schedule, number of employees), **climate factors, energy end-use factors** (chiller equipment type, air side distribution type, air side control, water side distribution control, lighting equipment, lighting control, office equipment) were studied in the benchmark study conducted by Chung & Hui (2009). **Climate factors, building size** were also included in the study of Li et al. (2014) and Chung & Hui (2009). **Time determinant** (lack of time to analyse potentials for energy efficiency) and type of ownership (investor/user dilemma) were defined as some most important barriers to energy efficiency in companies (Schleich & Gruber, 2008). Schleich & Gruber (2008, p. 454) in their study argued that: "If a company is renting office space, neither the landlord, nor the company (tenant) may have an incentive to invest in energy efficiency, because the investor cannot appropriate the energy cost savings. On the one hand, the landlord will not invest in energy efficiency if the investment costs cannot be passed on to the tenant, who will benefit from the investment through lower energy costs." **Lack of time** to improve energy efficiency as a determinant of energy saving is introduced by Schleich & Gruber (2009) and is not defined directly, but is analysed in terms of lack of time to analyse potentials for energy efficiency. **Hidden costs, access to capital, risk and uncertainty, split incentives and appropriability** were investigated by Schleich (2009). Jáñez Morán et al. (2016) emphasized on social interaction as effective tool for energy saving.

Sociodemographic and economic determinants were studied in office buildings (eight papers). Four of these papers focused on different human groups: all persons associated to the building; office workers; building managers and office building in general, not focusing on any type of employees. There were also two studies where only buildings were in focus, not the employees. These studies were conducted in public and social buildings, as well as in small and medium enterprises. All persons associated to the building were involved in the studies of Schleich & Gruber (2008), Li et al. (2014), Henriques & Catarino (2016), office workers took part in the research of Zierler et al. (2017). Data analysis from EU pilot projects was done by Jáñez Morán et al. (2016) - target group covered users and visitors.

5.1.3 Contextual Determinants

An individual's personality can be described and understood in terms of various contexts in which that individual is embedded. The contextual determinants take both personal factors as well as daily activities in the individuals' environment and can be defined in different contexts: historical, cultural, developmental, and interpersonal. Contextual determinants and interrelations between them affect the individual behaviour in consumption and saving which can be applied for the energy saving behaviour as well. Contextual determinants of energy saving describe different types of norms and restrictions, such as laws, regulations and policies, building characteristics, etc.

Definitions of contextual determinants of energy consumption behaviour in public buildings that were determined in the literature and measurements that have been used to assess determinants are presented in *Table 9*.

Table 9: Contextual determinants in public buildings

Determinant	References	Definition / Studies
Environmental norms	Zierler et al. (2017, p. 43)	"Environmental Norms relates to how satisfied respondents were with the organisation's handling of environmental issues, and with the overall level of information they are able to access"
Technology adoption norms	Zierler et al. (2017, p. 43)	"Technology Adoption Norms represents respondents' impression of how easily other parts of the organisation adopt new technologies in general, and the organisational support available for necessary adaptations"
Technological Frustration	Zierler et al. (2017, p. 43)	"Technological Frustration relates difficulties with learning new technologies to conflicts between performance goals"
Window opening and closing	Fabi et al.(2012)	*Not defined by the authors*
Company policy	Agha-Hossein et al. (2013)	*Not defined by the authors*
Activity-based	Goulden & Spence (2015)	*Not defined by the authors*
ICT support	Jáñez Morán et al. (2016)	*Not defined by the authors*
Awareness of the governmental regulation	Zhuang, & Wu (2014)	*Not defined by the authors*
Lack of information about energy consumption	Schleich & Gruber (2008, p. 449)	Lack of information about energy consumption is defined as a barrier to energy efficiency
Imperfect information	Schleich (2009, p. 2151)	"Imperfect information: inadequate information, lack of information on specific energy saving opportunities, information on the energy consumption of new and refurbished buildings"
Occupancy factors	Chung & Hui (2009)	Occupancy factors are defined as floor area, operational schedule, number of employees
Energy end use factors	Chung & Hui (2009)	Energy end-use factors are defined as chiller equipment type, air side distribution type, air side control, water side distribution control, lighting equipment, lighting control, office equipment

Nine papers focused on contextual determinant of energy consumption and 12 different determinants were highlighted. It could be noted that determinant "Lack of information about energy consumption" is a part of the wider meaning having determinant "Imperfect information". Different methods were used to assess the contextual determinants of energy saving behaviour in public buildings: benchmark study, data analysis from EU projects, personal interview, comprise information collection, interview, semi-structured interview, survey, pre- and post-occupancy survey-questionnaires and literature review.

ICT solutions were discussed in the research of Jáñez Morán et al. (2016) as important factors for energy management and resources integration in terms of energy efficiency. They also present ways in which information in terms of energy efficiency in the building could reach employees. **Information** (lack of

information about energy consumption patterns in different types of companies) were defined as some of the most important barriers to energy efficiency in companies (Schleich & Gruber, 2008). Endrejat et al. (2015) identifies that information about energy saving provided to employees could lead to higher awareness but it does not necessarily influence behaviour. Authors emphasize that improved technical energy efficiency rebounds to negative effects on user behaviour. Similar findings are described in Metzger et al. (2011, p. vii) research: "The control system had significantly higher energy and cost savings compared to behavioural change methods." The **awareness of governmental rules** according to Zhuang & Wu (2014) is only a necessary but insufficient condition of behaviour change. Fabi et al. (2012) studied window opening and closing, and emphasized the dynamics of the relationship between indoor environment, occupant behaviour and energy consumption. These factors are important for developing behavioural models of occupants. Research by Agha-Hossein et al. (2013, p.122) showed that "Disempowering employees in terms of reducing their control over their environment helped the company to save energy without having a significant negative impact on employees' satisfaction and productivity." However, Goulden & Spence (2015, p.286) point out that "maximising energy efficiency within workplaces requires that the task of energy reduction would go to all building users."

While in some studies of contextual determinants all persons associated to the respective building were involved (one paper, analysing commercial and service buildings), including office workers, employees, building managers, senior managers, etc., others focused only on office workers in office buildings (seven papers). One study in public buildings focused on the building occupants and the other study conducted in public and social buildings analysed buildings as a whole not focusing on the type of employees. One research was focused on any type of buildings, analysing students as a target groups.

5.1.4 Importance of Determinants for Energy Behaviour and Their Interrelationships

The comprehensive review was done on papers analysing psychological, social, sociodemographic, economic and contextual determinants in energy saving and consumption behaviour in public buildings. It allowed to determine five most important determinants in terms of their influence on energy consumption:

1. Attitudes,
2. Awareness,
3. Social norms,
4. Feedback (information),
5. Organizational encouragement and support.

Attitudes were analysed in 17 papers of 44 reviewed (Pellegrini-Masini & Leishman, 2011; Lo et al. 2012; Wells et al., 2016; Stokes et al. 2012; Ucci et al. 2014; Nilsson et al., 2015; Sawang & Kivits, 2014; Greaves et al., 2013; Agha-Hossein et al., 2015; Gustafson et al. 2008; Manika et al., 2015b; Nisiforou et al., 2012; Loureiro & Lima, 2009; Tetlow et al., 2015; Lee et al., 2013; Jurin & Parrish; 2008, Lokhorst et al., 2015). Seven of these reviewed papers indicated an energy consumption decrease while the others did not indicate specific results of the change of energy consumption.

Awareness was underlined in six of 44 reviewed papers (Tolias et al., 2015; Zhuang et al., 2014; Lo et al., 2012; Katzeff et al., 2013; Yun & Ray, 2014; Zierler et al., 2017). Three of these studies showed a decrease in energy consumption, one measured an increase in consumption and two did not measure results about energy consumption.

Social norms (interaction) were studied in six papers of 44 reviewed (Ucci et al., 2014; Nilsson et al., 2015; Gustafson et al., 2008; Metzger et al., 2011; Jáñez Morán et al., 2016; Tetlow et al., 2015). Five of these

studies indicated a decrease in energy consumption and only one did not present any data about change in energy consumption.

Feedback (information) combined with the motivation for energy saving was studied in eight papers or 44 reviewed (Coleman et al., 2013; Handgraaf et al., 2013; Nilsson et al., 2015; Yun et al. 2015; Azizi et al., 2014; Karatas et al., 2016; Henriques & Catarino, 2016; Jáñez Morán et al., 2016). Five of these studies represent decrease in energy consumption and only three of them did not measure it.

Organizational encouragement, support was underlined in five studies of 44 reviewed (Goulden & Spence, 2015; Lo et al., 2012; Zhang et al., 2013; Xu et al., 2017; Manika et al., 2015b). Three of these studies did not present results about change in energy consumption while two of them identified a decrease.

Al-Shemmeri & Naylor (2017) presented positive correlations in the socio-economic factors group between energy saving/knowledge and home owner status, older age and group membership as well. Increased awareness due to available information will not necessary lead to corresponding behaviours (Endrejat et al., 2015). In this case, it can be argued that there is no strong relationship between awareness and behaviour. Loureiro & Lima (2009, p. 11,13) intended to study the hierarchical relation between values, attitudes, moral norm and energy saving intention, testing the mediating effects between these different variables. Authors concluded: “the mediation relationship between environmental values, environmental attitudes, moral norm towards the environment, and intention to saving energy in the organization was found. The mediation relation between altruistic values, altruistic attitudes, moral norms, and intention to saving energy in the organization weren’t found.” On the basis of the *Theory of Planned Behaviour* Zierler et al. (2017, p. 43) have measured correlations between the following determinants of energy saving: technology adoption norms, benefit evaluation, energy intentions, goal flexibility, energy awareness, energy self-appraisal, energy self-efficacy, technology awareness, technological frustration, environmental norms. "Study results showed that benefit evaluation has a strong positive association with energy intentions. Goal flexibility (defined in *Table 7*) has a weak positive association with energy intentions. Energy self-efficacy (defined in *Table 7*) has a weak positive association with both energy intentions and energy saving behaviour. Energy intentions are also seen to have a moderate positive association with behaviour.” A study conducted by Xu et al. (2017) examined how attitudinal factors (energy saving belief and belief about the link between comfort and productivity) and contextual factors (group norms and organizational support) were associated with first employees’ willingness to save energy in the workplace at some cost of comfort and second the perceived ease of communicating to co-workers about saving energy.

In the literature reviewed the following theories and theoretical models were used: *Theory of Planned Behaviour, Value-Belief-Norm Theory, Process Model, Theory of Reasoned Action, Goal-framing Theory, Goal Setting Theory, Social Identity Theory, Influential Theory of Persuasion, The Theory of Interpersonal Behaviour, Rational Choice Models, Norm Activation Models and Norm Activation Theory.*

Jáñez Morán et al. (2016) emphasized the fact, that the biggest barrier to implement energy efficiency measures in public buildings is that people involved in energy consumption are not the same who benefit financially from energy savings. Authors define this financial incentive gap as a key factor selecting user behaviour transformation tools. Fabi et al. (2012) emphasized on the lack of research in window opening behaviour focusing on the driving forces for the transition of windows state rather than keeping the state of the windows as the aim of the research. Some articles were pretty narrow analysing only one aspect of energy saving possibilities e.g. Azizi et al. (2014) was focused on energy consumption by PC. Some studies were very specific because the results were influenced by climate or special governmental norms (Zhuang & Wu, 2014, Zhang et al., 2013). Some limitations of questionnaires may be noted. Questionnaire results do not prove an intention of the workers to be responsible and change their behaviour in terms of energy consumption (Nisiforou et al. 2012). Wells et al. (2016) underlined that self-reported behaviour may not always reflect the actual behaviour. The validity of self-report questionnaire methods as a means of determining pro-

environmental attitudes was often debated (Zierler et al. 2017). Sometimes duration of the studies is too short in order to get more accurate results (Yun et al. 2012, Agha-Hossein et al., 2015). Some of the studies included a big number of companies and faced some limitations as data was collected from many different companies, so the energy consumption and saving patterns and methods may be very different (Schleich, 2009). The influence of visitors behaviour to public buildings energy saving was investigated only in one paper by Jáñez Morán et al. (2016). There could be pointed that there is a lack of research of visitors' energy saving behaviour in public buildings. It should be paid more attention investigating visitors' behaviour impact on energy saving in public buildings.

5.2 Strategies and Interventions to Reduce Energy Consumption

To achieve effect of energy saving behaviour the determinant of energy consumption may be affected by different types of energy efficiency interventions. The analysis of interventions to reduce energy consumption in public buildings was made applying *Behavioural Change Wheel* by Michie et al. (2011) and is presented in *Table 10.*

Table 10: Interventions to reduce energy consumption in public buildings

Type of intervention	Definition	Energy efficiency intervention	References	Target group	Effect on consumption	Type of determinants
Education	Increasing knowledge or understanding	Trainings and seminars (energy for computers); pamphlets on energy efficiency; briefing on the objectives and goals of the organisations commitment to energy efficiency to new employed staff; guidelines for efficient energy use (computers).	Azizi et al. (2014)	Office workers, 267 responses from 1640 building's occupant's	% unknown	Psychological
		Training	Ucci et al. (2014)	62 office workers and 51 manufacturer	% unknown	Psychological
Persuasion	Using communication to induce positive or negative feelings or stimulate action incentivisation	E-mail to staff from time to time; reminder sticker labels on computers; posters on energy efficiency features of the building; updating occupants on energy consumption of the building; encouraging staff to work together with the facility management team to identify opportunities for further improvement; participation in third party energy scheme; building manager assigned on each floor to remind staff to save energy.	Azizi et al. (2014)	Office workers	% unknown	Psychological
		Game for smart phones and desktop computers	Tolias et al. (2015)	20 staff members	5,6 % in 2 weeks	Psychological
		Wireless Behaviour Information (Wi-be) system	Coleman et al. (2013)	11 office workers	N/A	Psychological
		Energy use feedback	Ucci et al. (2014)	62 office workers and 51 manufacturers. Office workers and manufacturers	% unknown	Psychological

				133 questionnaires (62 office staff, 51 factory staff)		
		Goal setting – during start up meeting goal was set to reduce energy consumption by 8%; prompts were placed at the personal work desk; feedback was sent via e-mail and contained information about the change in consumption of electricity (comparison was made between the past week and the baseline, displayed as change figures in percent, as well as in bar charts); group identity manipulation - respondents were asked to state up to three things people at their department did (a) relatively often and (b) relatively seldom, and that they (c) generally did well, and (d) generally did badly. A group identity salience was used in the prompts and feedback.	Nilsson et al. (2015)	93 office workers	6 to 12.9 % decrease in electricity consumption	Social, psychological
		Web-based energy dashboard to provide feedback	Yun (2014)	35 office workers	% unknown	Psychological
		Smart phone application	Bull et al. (2015)	Building managers, office workers	N/A	Psychological
		Interactive poster to motivate to save energy (use stairs instead of lift), to collect information (collect touches of those who took stairs) and provide visual feedback information	Agha-Hossein et al. (2015)	600 office workers	% unknown	Psychological
		Conservation Action! used Community Based Social Marketing to persuade, influence, motivate, and create a lasting change to the social norm at our office. Commitment, prompts, norms, communication, incentives, and convenience were leveraged to get participation and results.	Gustafson et al. (2008)	160 office workers	Total building consumption declined by 5 % in first year of program activities and by an additional 4 %	Psychological

					in the second year.	
		Information feedback (weekly letters with information on the energy use associated with a variety of plug load devices as well as conservation tips)	Metzger et al. (2011)	126 employees	Consumption decrease, from 0 % using letters, to 6 % having competition and to 21 % using control system)	Psychological, technological
		Provision of Watt-lite TWIST - designed as an over-sized torch, projecting energy statistics in the form of a pie chart	Katzeff et al. (2013)	Office workers from 4 offices	% unknown	Psychological
Incentivisation	Creating expectation of reward Coercion	Energy saving campaign (social and monetary reward)	Handgraaf et al. (2013)	83 office workers	6.4 % in 13 weeks	Psychological
Enablement	Increasing means/reducing barriers to increase capability or opportunity	Provide laptops	Azizi et al. (2014)	267 Office workers, 267 responses from 1640 building's occupant's	% unknown	Psychological
		Intelligent Dashboard for Occupants, equipped with the most commonly used feedback features (self monitoring, advice, comparison) and online controls (manual and automated). To enable monitoring and control of each desktop technology's electricity usage through the ID-O.	Yun et al. (2015)	80 office workers	% unknown	Psychological
		Automated and remote control of individual appliances	Yun (2014)	35 office workers	% unknown	Psychological

Most of energy efficiency interventions described in *Table 10* applied in public buildings have affected energy consumption through effect on psychological and social determinants. Most often in the case of public buildings the interventions of persuasion and education types were applied as well as few of incentivisation and enablement types. There were no interventions of modelling, environmental restructuring, restrictions, coercion and training types investigated in the literature reviewed. 20 interventions are addressed to the persuasion type of interventions and these interventions were studied in 11 papers. Five interventions were introduced by two papers, which were addressed to educational type or interventions. Three papers presented three interventions of enablement and only one intervention from reviewed papers can be addressed to the incentivisation type. It is worth to note that usually one intervention combines several intervention types in one complex approach, e.g Azizi et al. (2014) applied trainings and seminars, used pamphlets, organized briefing on the objectives and goals of the organizations commitment to energy efficiency to new employed staff, prepared guidelines for efficient energy use (type of intervention: education) and also sent e-mails to staff from time to time, reminder stickers and labels were put on computers, posters on energy efficiency features of the building were hanged in the building, building managers were assigned on each floor to remind staff to save energy, staff was encouraged to work together with the facility management team to identify opportunities for further improvement (type of intervention: persuasion). Overall effect of this complex intervention was consumption decrease, but it is not possible to assess which of these separate interventions made a stronger effect on energy saving behaviour.

Not every effect of investigated interventions was evaluated quantitatively. Therefore, it is difficult to compare the effects of separate studies. It is important to note that energy savings may be significantly higher in the short term after the application of the intervention however diminishing in the long term. Some of the studies conducted have measured the effect of the intervention only during the period of the study and just a few of them measured energy savings for a longer period after the intervention was applied. The following two studies described below are particularly interesting and represent effective interventions, especially in the light of the enCOMPASS project.

The study by Agha-Hossein et al. (2015) was conducted applying intervention in the office building as well as in the university halls. Their pilot studies were based on the *Elaboration Likelihood Model*, interactivity. They used an interactive poster and prompt to attract occupants' attention towards energy saving behaviour. The poster encouraged building occupants to save energy by taking the stairs, rather than the lifts and provided them with cumulative metaphorical feedback. The prompt was placed in the student halls and reminded to turn the light off providing them with an immediate playful reward. This study proved that interactivity can impact occupants' behaviour towards energy saving when it is combined with a clear feedback.

The study of Nilsson et al. (2015) tested two behavioural intervention programs that were aimed at changing energy-related behaviours in an office setting. Participants were office employees in three different departments of a construction company. Each department was randomly assigned to a four-week intervention to one of conditions: control (1. list of suggestions for how to save electricity), intervention program (1. + 2. prompts about saving energy and paper, as well as feedback by e-mail) and intervention program with group identity salience (1. + 2. + 3. provision of feedback about colleagues' energy saving behaviour). The results show that the employees who got more feedback used to change their behaviours more than the control group. This study is a good example of application of several interventions and highlights the importance of feedback for energy saving behaviour.

The interventions described below represent significant energy savings during the period of the studies. Gustafson et al. (2008) study lasted two years and showed diminishing energy consumption which was not very significant (5 % and 4 %), but lasting. In this study the complex of several interventions was applied (commitment, prompts, norms, communication, incentives, and convenience). Reasonable intervention results were observed in the study by Nilsson et al. (2015) when under the set goal of 8 % reduction of energy

consumption the decrease in electricity consumption was 12.9 %. Metzger et al. (2011, p. vi) research results showed that the best case of energy saving is caused by operating control system (21%) and the competition (6 %). “Based on these findings the best case scenario for energy savings would include a control system and occupant competition with significant promotion for occupant education. Alternatively, implementing a competition as a behavioural change mechanism without a control system may be the most cost effective. However, without the sub-metering system, the savings could not be verified and normalized comparisons of occupant energy consumption would not be possible.” The results of these studies show that good results in energy saving could be achieved applying no single intervention but combining several interventions.

One of the gaps of the studies investigating impact of different interventions to energy savings is that they do not investigate how the energy saving behaviour changes after the interventions are terminated.

5.3 Conclusion: Energy Consumption in Public Buildings

The recent research and systematic literature review on energy consumption in public buildings allows us to define the most important determinants in energy saving area. Key determinants affecting behaviour of energy consumption in public buildings are: attitudes, awareness, social norms, feedback (information), organizational encouragement and support. Performing pilots within enCOMPASS framework it should be emphasized on these determinants. In addition, the visitors’ energy saving behaviour in public buildings could be investigated in enCOMPASS pilots.

According to the analysis made on interventions, used in the reviewed papers there could be recommended for the enCOMPASS pilots to focus on education (increasing knowledge or understanding) and persuasion (using communication to induce positive or negative feelings or stimulate action incentivisation) types of interventions in public buildings. On the basis of these insights it would be recommended to use a mix of interventions covering education, persuasion and enablement types of interventions in public buildings. The examples of education type of interventions that can be applied in enCOMPASS pilots are: trainings and seminars, pamphlets on energy efficiency, guidelines for efficient energy use, training and briefing on the objectives and goals of the organisations commitment to energy efficiency to new employed staff as well as smart phones applications and games for smartphones and desktop computers. It is important to enable occupants and visitors of the public buildings to contribute to energy saving activities as well.

For enCOMPASS pilots in public buildings should be recommended to focus on the following insights:

- Energy consumption feedback is the best combined with other interventions.
- Organizational encouragement and support in public buildings is one of the most important determinants in energy saving.
- Investigation of visitors’ behaviour in public buildings in terms of energy saving would contribute to the quite low studied research area.

6 ENERGY CONSUMPTION IN SCHOOLS

Energy saving behaviour within the educational sector provides an important opportunity to conserve energy. Energy saving in schools can be achieved changing occupants' (students, administrative staff, and teachers) behaviour and applying effective interventions. This chapter presents results of systematic literature review on energy consumptions determinants and interventions to reduce energy consumption in schools.

6.1 DETERMINANTS OF ENERGY CONSUMPTION

Detailed analysis of all groups of energy consumption determinants (1. Psychological and social determinants, 2. Sociodemographic and economic determinants and 3. Contextual determinants) in schools is presented below.

6.1.1 Psychological and Social Determinants

Papers analysing energy consumption in schools focus on wide range of determinants including psychological and social determinants. Psychological and social determinants of energy saving behaviour have been already determined in *Subsection 5.1.1.*

Analysis of energy consumption and conservation covers explanation, prediction and changes of consumer's behaviour. Among others, psychological, and social factors have been intensively studied, in order to explain differences between individuals with respect to energy consumption and energy conservation behaviour. Psychological determinants of energy consumption are related to human psychology. Examples of psychological determinants are knowledge, awareness, beliefs, attitudes, motives, intentions, perceived behavioural control, personal norms, subjective norms, etc. Energy consumption and conservation in public buildings are associated with a wide range of social variables which influence opportunities and constraints. Social determinants can facilitate versus undermine intrinsic motivation. They characterize social norms, organizational culture, social influence, etc.

Table 11 presents the determinants of energy consumption behaviour in public buildings that were identified in the literature, their definitions, and measurements that have been used to evaluate them.

Table 11: Psychological and social determinants in schools

Determinant	**References**	**Definition**
Attitudes	Azar & Ansari (2017); Dixon et al. (2015a); Al-Shemmeri & Naylor (2017); Staats et al. (2000); Murtagh et al. (2013)	*Not defined by the authors*
General energy saving attitudes	Manika et al. (2015a)	*Not defined by the authors*
Workplace energy saving attitudes	Manika et al. (2015a)	*Not defined by the authors*
Peers personal attitudes	Pisello et al.(2016)	*Not defined by the authors*
Awareness	Axaopoulos & Pitsilis (2007); Ishak et al. (2012); Craig & Allen (2015); Kamilaris et al. (2015); Whittle et al. (2015)	*Not defined by the authors*

Knowledge	Axaopoulos & Pitsilis (2007); Azar & Ansari (2017); Kalpana et al. (2013); Craig & Allen (2015); DeWaters & Powers (2011)	*Not defined by the authors*
Knowledge of energy-saving technologies and practices	Castleberry et al. (2016)	*Not defined by the authors*
Education	Axaopoulos & Pitsilis (2007); Craig & Allen (2015); Kamilaris et al. (2015)	*Not defined by the authors*
Perceived behavioural control	Dixon et al. (2015b, p. 122); Dixon et al. (2015a, p. 123)	"Perceived behavioural control … refers to whether individuals perceive they have ability (i.e. the necessary resources and skills) to perform a certain behaviour (Ajzen, 1991)" as cited in Dixon et al., 2015 a,b
Perceived efficacy	Schelly et al. (2010)	*Not defined by the authors*
User perception	Salleh et al. (2016)	*Not defined by the authors*
Values	Azar & Ansari (2017); Murtagh et al. (2013)	*Not defined by the authors*
Personal values	Mtutu & Thondhlana (2016)	*Not defined by the authors*
Beliefs	Azar & Ansari (2017)	*Not defined by the authors*
Engagement	Murtagh et al. (2013)	*Not defined by the authors*
Difficulty of specific actions	Azar & Ansari (2017)	*Not defined by the authors*
Descriptive norms	Dixon et al. (2015a)	*Not defined by the authors*
Injunctive norms	Dixon et al. (2015a)	*Not defined by the authors*
Intentions	Dixon et al. (2015a)	*Not defined by the authors*
Incentive to adopt energy saving technologies	Castleberry et al. (2016)	*Not defined by the authors*
Socio-economic groups	Al-Shemmeri & Naylor (2017)	*Not defined by the authors*
Situational factors	Mtutu & Thondhlana (2016, p. 143)	"Situational factors define external - influences that do not occur from within the individual but from elsewhere like the environment and others around"
Use of appliances (computers, lighting)	Fehr & Andrade (2016)	*Not defined by the authors*
Motivation for energy saving	Kastner & Matthies (2014)	*Not defined by the authors*
Behavioural expectations	Schelly et al. (2010)	*Not defined by the authors*
Environmental identity	Murtagh et al. (2013)	*Not defined by the authors*
Environmental personal norms	Scherbaum et al. (2008)	*Not defined by the authors*

Environmental worldviews	Scherbaum et al. (2008)	*Not defined by the authors*
Institutional policy	Kalpana et al. (2013)	*Not defined by the authors*
Organizational culture	Schelly et al. (2010)	*Not defined by the authors*
Organizational policies and incentives	Schelly et al. (2010)	*Not defined by the authors*

23 papers analysed psychological and social determinants of energy consumption and 31 different determinants were identified in these papers. Attitudes (eight papers), knowledge (six papers) and awareness (five papers) were the most often analysed determinants. Only two determinants were clearly defined: perceived behavioural control and situational factors. Questionnaires, surveys and different studies were the most often used methods to assess the determinants.

Environmental personal norms and environmental worldviews studied by Scherbaum et al. (2008) are not defined, but based on *Value-Belief-Norm Theory*. Energy-related knowledge was not defined in the paper of DeWaters & Powers (2011), but it was investigated in their study as general knowledge and understanding by students about energy use and saving issues. Peers' personal attitudes according to Pisello et al. (2016) represent a key variable to be considered while predicting the overall building thermal-energy behaviour of university buildings. In the study of Mtutu & Thondhlana (2016) **personal values and situational factors** are defined as the determinants of environmental behaviour. Castleberry et al. (2016) studied knowledge of energy-saving technologies and practices as a variable which can have an effect on energy saving in school.

Azar & Ansari (2017, p. 569) presented research, in which they underlined that significant energy savings can be achieved in buildings operating various building systems by occupants and decision-makers. Authors identified, that "respondents who reported that their motivation to save energy is mainly driven by instructions from facility management have shown both low motivation/intent and energy saving actions levels." Dixon et al. (2015a) studied **community influence, descriptive norms, injunctive norms, perceived behavioural control, attitudes, and intentions.** The authors focused on sense of community highlighting social ties. User perception of energy efficiency in school buildings was investigated by Salleh et al. (2016) in terms of measurement of the user perception of energy efficiency in school buildings towards to benchmarking energy efficiency. Al-Shemmeri & Naylor (2017) presented strong correlation between energy saving/environmental knowledge and membership of community group. Börner et al. (2015) evaluated the effect of different variations of ambient learning. The approach presented affects an increase of awareness, initiate pro-environmental behaviour, and point out alternative behaviour at the workplace in school.

Psychological and social determinants were analysed mainly in the higher education institutions (14 papers) and one paper studied schools in general. In four papers the target group was school's employees, three papers focused on office workers in schools, two papers on students. All persons associated to the higher education institutions were the focus of two papers while other three papers focused on different combinations of target groups: staff and graduate students; staff, graduate students and faculty; students and administrative staff.

6.1.2 Socio-demographic and Economic Determinants

Socio-demographic and economic determinants of energy saving behaviour in public buildings have been determined in *Subsection 5.1.2.* Description presented in the mentioned section can be applied to the review of determinants of energy consumption in schools as well.

Socio-demographic and economic determinants of energy consumption behaviour in schools, their definitions, and measurements that have been used to assess them are presented in the *Table 12*.

Table 12: Socio-demographic and economic determinants in schools

Determinant	References	Definition
Demographic factors	Mtutu & Thondhlana, 2016	"…demographic factors such as age, income and education influence individual behaviour (Hanyu, Kishino, Yamashita, & Hayashi, 2000)" as cited in Mtutu & Thondhlana, 2016
District population	Castleberry et al., 2016	*Not defined by the authors*
Household income	Castleberry et al., 2016	*Not defined by the authors*
Learning	Börner et al., 2015	*Not defined by the authors*
Social recognition	Azar & Ansari, 2017	*Not defined by the authors*
Funding to overcome energy saving barriers	Castleberry et al., 2016	*Not defined by the authors*
Average property value	Castleberry et al., 2016	*Not defined by the authors*

Socio-demographic and economic energy saving behaviour determinants in schools were analysed in four papers. Authors of these papers focused on seven socio-demographic and economic determinants. Clearly definitions of these determinants were not provided in the reviewed papers. To assess socio-demographic and economic determinants on line survey, cluster analysis, study, questionnaire and focus groups were used.

Demographic variables in the study of Mtutu & Thondhlana (2016) were described theoretically as age and income. In their study only data about age as demographic variable was studied. Castleberry et al. (2016) studied district population **household income, district population, average property value, percent minority** in terms of how they can influence funding available to school to adopt energy saving measures. **Funding to overcome energy saving barriers and incentive to adopt energy saving technologies** was analysed by Castleberry et al. (2016) as a possibility to adopt new technologies, which can enable energy savings.

Azar & Ansari (2017) points, that social recognition among peers would incentivize respondents to save more energy at work. Al-Shemmeri & Naylor (2017) present significant correlation between environmental issues and housing type, homeowner status, age (the youngest staff members demonstrate the most positive correlation). The research and its outcomes presented by Craig & Allen (2015) demonstrates the importance of curriculum-based experiential learning on elementary school students.

Authors of three papers conducted research in higher education schools and only one paper focused on school in general. All persons associated to the building were studied in two papers. Campus employees, students and students/administrative staff were in the focus of one paper each. In the research of Mtutu & Thondhlana (2016) academic and administrative staff, students were in the focus. Castleberry et al. (2016) as a target group of their study had all persons associated to the school building. Azar & Ansari (2017) collected data from students, faculty, researches and staff. The faculty, staff and graduate students were taken by Dixon et al. (2015a, b) to make survey to measure energy conservation attitudes. Al-Shemmeri & Naylor (2017) present analysis based on data from employees at higher education institution. The target group in Craig & Allen (2015) research is school students.

6.1.3 Contextual Determinants

Contextual determinants are important studying energy saving behaviour in schools. Description of contextual determinants is presented in *Subsection 5.1.3.*

Definitions of contextual determinants of energy consumption behaviour in schools and measurements that have been used to assess determinants are presented in *Table 13*.

Table 13: Contextual determinants in schools

Determinant	References	Definition
Institutional policy	Lourenço et al. (2014); Azar & Ansari (2017); Al-Shemmeri & Naylor (2017); Kalpana et al. (2013)	*Not defined by the authors*
Activity-based	Axaopoulos & Pitsilis (2007)	*Not defined by the authors*
Physical environment constraints	Azar & Ansari (2017)	*Not defined by the authors*
Sense of community	Dixon et al. (2015a, p. 123)	"A feeling that members have a belonging, a feeling that members matter to one another and to the group, and a shared faith that members needs will be met through their commitment to be together (McMillan, Chavis, 1986)", as cited in Dixon et al. (2015a)
Energy culture	Ishak et al. (2012)	*Not defined by the authors*
Technology upgrades	Tornelli & Phil (2008)	*Not defined by the authors*
Metering consolidation	Tornelli & Phil (2008)	*Not defined by the authors*
Control system changes	Tornelli & Phil (2008)	*Not defined by the authors*
Levels and occupant's intervention	Serghides et al. (2015)	*Not defined by the authors*

Contextual energy saving behaviour determinants in schools were analysed in nine papers and nine different determinants were investigated in these papers. The determinant "Institutional policy" was highlighted in four papers while the rest of determinants were studied in one paper each. The most often used methods to measure contextual energy saving behaviour determinants in schools were by questionnaire and survey.

Azar & Ansari (2017) summarized, that contextual factors, which include the ability of occupants to perform a particular action such as changing thermostat set point temperatures, can partially explain why motivation/intent to save energy did not necessarily translate into actions (Azar & Ansari, 2017). Serghides et al. (2015) paid particular attention to the number of equipment in use turned out to be one of the most important variables determining energy consumption, however occupant's intervention on temperature control also affect energy consumption. Lourenço et al. (2014) analysed the need to improve energy use management in the schools besides the building's design and systems. Tornelli (2008) identified, that savings could be achieved by monitoring and evaluating school usage profiles, making control adjustments, and then analysing the effects of recommended changes to equipment settings and operating schedules.

Six papers studying contextual determinants focused on higher education institutions while schools in general and secondary school were analysed in one paper each. All persons associated to the building and school staff were analysed in two papers each. One study focused on graduate students, faculty and staff, another study analysed school staff and students and one more study had students and administrative staff in focus.

Azar & Ansari (2017) collected data from students, faculty, researches, and staff. Serghides et al. (2015) collected data from occupants of university buildings. Lourenço et al. (2014) selected eight secondary schools

for their study. Tornelli & Phil (2008) made research in schools looking at existing equipment, new construction designs, and behavioural modifications.

6.1.4 Importance of Determinants for Energy Behaviour and Their Interrelationships

According the review of research papers, the most important determinants of energy consumption in schools in terms of their influence on consumption are:

1 Attitudes,

2 Incentives/intentions/motivation,

3 Knowledge,

4 Awareness.

Attitudes were analysed in eight papers of 28 reviewed analysing energy consumption behaviour in school buildings (Murtagh et al., 2013; Dixon et al. 2015a; Manika et al., 2015a; Agha-Hossein et al., 2015; Pisello et al., 2015; Azar & Ansari, 2017; Dixon et al.2015b; Al-Shemmeri & Naylor, 2017).

Eight of 28 reviewed papers also pointed out different kind of **incentives, intentions and motivation for energy saving** (Schelly et al., 2010; Azar & Ansari, 2017; Castleberry et al., 2016; Kastner & Matthies, 2014; Scherbaum et al., 2008; Murtagh et al., 2013; Dixon et al. 2015a; Dixon et al., 2015b).

Next very often noticed determinant among the reviewed papers was **knowledge** (knowledge/awareness, knowledge transfer, knowledge about energy efficiency, knowledge level, knowledge of energy-saving technologies, etc.). **Knowledge** was mentioned in six of 28 reviewed papers (Axaopoulos & Pitsilis, 2007; Lourenço et al., 2014; DeWaters & Powers, 2011; Azar & Ansari, 2017; Kalpana et al., 2013; Castleberry et al., 2016).

Awareness was analysed in four papers of 28 reviewed (Kemp-Hesterman, 2014; Lourenço et al., 2014, Whittle et al., 2015; Ishak et al., 2012).

According the research of Scherbaum et al. (2008) environmental personal norms are statistically a significant predictor of self-reported conservation behaviour at work and behavioural intentions. Environmental worldviews are statistically significant predictor of environmental personal norms and they mediate the relationship between environmental worldviews and reported conservation behaviours and behavioural intentions. No direct effect of environmental worldviews on self-reported behaviours and behavioural intentions was confirmed. De Waters & Powers (2011) state that high correlations between student's energy-related affect and their energy consumption behaviours, in contrast to low correlations between cognitive and behavioural aspects, suggest that effective educational programs should target not just content knowledge, but should also strive to impact student attitudes, beliefs, and values. On the base of Manika et al. (2015a) research conducted in schools there may be concluded that general energy saving attitudes have positive and significant relationship with workplace energy saving attitudes and home energy saving behaviours. On the other hand, general or workplace specific attitudes might not be predictors of workplace energy saving behaviours of employees. According to the Mtutu & Thondhalana (2016) research, most personal values and situational factors were not positively related to pro-environmental behaviour and the few factors that yielded significant correlations showed weak relationships. Study of Castleberry et al. (2016) was devoted to evaluate relationship between different variables of energy consumption in schools. This research revealed that statistically significant relationship (it may be positive, as well as negative) was found between: 1. knowledge of energy-saving technologies and practices and their implementation within school districts; 2. district population and implementation of energy-saving technologies and practices; 3. influence of partnership and cost barriers; 4. funding to overcome barriers and median household income; 5. district

population and cost savings as an incentive to adopt energy-saving technologies and practices; 6. cost savings as an incentive to adopt energy saving technologies and practices and average household income.

In the literature reviewed the following theories and theoretical models were used: *Theory of Planned Behaviour, Value-Belief-Norm Theory, Theory of Collective Action, Theory of Normative Conduct, Self-Determination Theory, Coherent Theory of Environmentally Significant Behaviour and Theory of Basic Values.*

In spite of the relatively wide range of energy saving determinants found in the literature review, some gaps can be identified. Study of DeWaters & Powers (2011) studied a big number of questionnaires asking students about their energy-related knowledge, but this knowledge may not be addressed to particular buildings, it is general. Pisello et al. (2016) in their research analysed data of office rooms in school however this research may also be attributed to public building (office) findings. Study of Castleberry et al. (2016) used only qualitative data and just the relationship among different variables was evaluated. Kalpana et al. (2013) declared the purpose of the study to find out the effectiveness of specific behaviour change, in reducing the energy consumption by university students. However, particular attention is given to the university policy of sending emails on regular basis to all students instructing energy conservation in terms of using laptops, and stairs avoiding lifts. Such a policy could have short term impact on the energy saving behaviour of students.

6.2 Strategies and Interventions to Reduce Energy Consumption

Different types of interventions may be applied to achieve effect of energy savings. To conduct the analysis (*Table 14*) of interventions to reduce energy consumption in schools *the Behavioural Change Wheel* by Michie et al. (2011) was used.

Table 14: Interventions to reduce energy consumption in schools

Type of intervention	Definition	Energy efficiency intervention	References	Target group	Effect on consumption	Type of determinants
Education	Increasing knowledge or understanding	Knowledge based intervention programme: posters and flyers were implemented promoting three energy efficient behaviours, monthly emails, recommendations for energy efficient behaviour, integrated quiz to test knowledge.	Kastner & Matthies (2014)	15 trial buildings, 157 answered questionnaires (from 913) – school staff	N/A	Psychological
Persuasion	Using communication to induce positive or negative feelings or stimulate action Incentivisation	A feedback application MyEcoFootprint - gadget installed on all work computers, providing feedback, tips, and social comparison	Muragh et al.(2013)	83 office workers	% unknown	Psychological
		Habit intervention: 1) a set of prompt stickers 2) a thermometer 3) a coupon for a switchable multiple power socket strip 4) a commitment sheet integrated in 5) the intervention website, 6) kick-off day; web based intervention - to offer detailed information about the energy situation.	Kastner & Matthies (2014)	15 trial buildings, 157 answered questionnaires (from 913) – school staff	N/A	Psychological
		CALS Green program (website)_ - continual feedback of participants' individual and collective progress as well as the progress of their competition.	Dixon et al.(2015b)	Faculty, staff, graduate students, 2009 - 2112 responses; 2012 -1601 responses; six academic buildings	average 6.5 % decrease in kWh/ft2 electrical consumption	Psychological
		Weekly e-mail on performance feedback, posters, leaflets	Kamilaris et al. (2015)	Office workers 18 occupants (University in Singapore)	15 % during office hours and around 30 % after office hours and during weekends.	Psychological
		Brochure informing about energy saving possibilities; collective feedback - during both intervention periods, weekly updated collective feedback was provided via 20 bulletin boards; poster put up on the 20 bulletin boards for 10 days as a reminder; individual feedback – personal letter.	Staats et al. (2000)	384 offices	6 % reduction of gas consumption	Psychological
		Energy awareness campaign; energy efficiency charrette - an energy conservation planning workshop that engages faculty, students, and staff in an effort to increase participant awareness.	Kemp-Hestermann et al.(2014)	Students, teachers, staff of 2 similar high schools	% unknown	Psychological

All reviewed interventions applied in the schools affected psychological determinants of energy consumption. 11 interventions were addressed to the persuasion type of interventions and they were analysed in six papers and only one intervention from the reviewed papers can be addressed to education type of interventions. No investigations of incentivisation, coercion, training, enablement, modelling, environmental restructuring and restrictions were studied in the literature reviewed. Most studies, investigating energy saving behaviour in schools focus on education and persuasion as types of interventions. Research conducted by Kastner et al. (2014) covered many kinds of separate investigations, which can be attributed to the education intervention as well as to the persuasion intervention.

There should be noted that studies conducted to investigate energy saving in schools usually apply not a single intervention but combinations of several interventions. Some interesting and effective interventions from the reviewed papers which were applied in schools are described below.

Kamilaris et al. (2015) highlighted using combination of interventions in order to affect occupants to change their behaviour. Their study was aimed to link well-accepted individual determinants of energy use with the design of intervention techniques to encourage pro-environmental behaviour. Posters, personal leaflets and emails were used as communication channels to provide the feedback to the study participants. “These channels were selected since they are easy to implement, less costly and were approved by the office administrators as non-annoying methods for the employees “(Kamilaris et al., 2015, p. 75).

In the study of Dixon et al. (2015b) “CALS Green” program was implemented as competition among six mixed-use (lab and office space) buildings to reduce energy consumption weekly. The extent to which the campaign positively influenced individual determinants of behaviour was examined using data from surveys.

Interventions in the study of Kastner & Matthies (2014, p. 91) were introduced not at the same time, combining intervention program (knowledge based and habit) with web-based intervention. This study represents very comprehensive results on the intervention methods effectiveness in terms of how they affect energy saving behaviour. Kastner & Matthies (2014) in their study combined many kinds of interventions. “Knowledge based intervention programme” included such interventions as: posters, flyers, monthly emails to all staff members, recommendations for energy efficient behavior as well as quiz for the staff members to test their knowledge. “Habit intervention group” means that staff members were provided with thermometer, coupon for a switchable multiple power socket strip, commitment sheet with a number of energy efficient behaviors, website (for public commitments) integrated in the intervention and kick off day at the start of the intervention. The most helpful element for energy saving in the “habit intervention” was thermometer, followed by the coupon for a switchable multiple power socket strip and website. In the “knowledge based intervention” the most helpful elements were brochure, flyers, posters and emails.

The study of Kemp-Hesterman et al. (2014, p. 4,6,7) used mixed methods design of interviews and historical electrical use data to assess two treatments impacts on electrical consumption over time at two high schools. “The intervention was applied as Energy awareness campaign and energy efficiency charrette (an energy conservation planning workshop that engages faculty, students, and staff in an effort to increase participant awareness). The key attributes of communication, motivation, and leadership were identified as necessary at the high school facilities level to ensure long-term success in decreased electrical consumption” (Kemp-Hesterman et al., 2014, p. 4,6,7). There should be noted that all studies presented above demonstrate the effectiveness of application of various combinations of interventions.

The most effective interventions in terms of energy saving results were presented by Kamilaris et al. (2015) and Staats et al. (2000). The impact of intervention applied by Kamilaris et al. (2015) was measured by 15-30 % decrease of energy consumption. Four ways of interventions were applied in the Staats et al. (2000) research: brochure, collective feedback, poster and individual feedback resulted energy consumption

decrease by 6 %. These two studies represent effectiveness of applied interventions, which were focused on feedback (individual and collective).

6.3 CONCLUSION: ENERGY CONSUMPTION IN SCHOOLS

Literature review topics on energy consumption in schools provide importance of these determinants: attitudes, incentives/intentions/motivation, knowledge and awareness. Performing pilots by implementing enCOMPASS project these determinants should be taken as most important for energy consumption in schools. In addition, it should be pointed that occupants in school buildings can be defined as permanent and temporary occupants depending on how often they are in the building or how often they change the places within the building.

Most of the reviewed studies on energy consumption in schools focused on persuasion type of interventions. Similar as it was in public buildings more than one intervention usually is applied for behavioural change in energy use. The examples of persuasion type of interventions that can be applied in enCOMPASS pilots are: feedback application, web based intervention, posters, leaflets, brochures, individual and collective feedback, energy awareness campaigns and energy efficiency workshops. Based on the reviewed researches it could be recommended for enCOMPASS pilots to a apply complex of interventions (education and persuasion) in school buildings taking into account different types of occupants (permanent and temporary).

For enCOMPASS, the following conclusions should be taken into account:

- Energy consumption feedback is the best combined with other interventions.

7 ENERGY CONSUMPTION IN RESIDENTIAL BUILDINGS

7.1 REVIEW APPROACH

In comparison to public buildings and schools, energy consumption and conservation in residential buildings has been investigated to a significantly larger extent. Several systematic reviews have already been undertaken, surveying both determinants of energy consumption (Frederiks et al., 2015; Lopes et al., 2012; Bhattacharjee & Reichard, 2011), as well as interventions to change energy consumption behaviour (Abrahamse et al., 2005). Two reviews have been found that focus on specific types of intervention: consumption visualization (Murugesan, 2015), as well as gamification and serious games (Johnson et al., 2017). This section summarizes the findings from these reviews, supplemented with individual studies that are particularly relevant for the enCOMPASS context.

7.2 DETERMINANTS OF ENERGY CONSUMPTION

This subsection addresses the psychological, socio-demographic, and contextual determinants of residential consumption, based on two reviews (Frederiks et al., 2015; Bhattacharjee & Reichard, 2011).

7.2.1 Psychological and Social Determinants

First, the psychological and social determinants of household energy consumption are reviewed. An overview is presented in *Table 15*.

Table 15: Psychological and social determinants of household energy consumption

Determinant	References	Definition
Knowledge and problem awareness	Van Raaij & Verhallen (1983, as cited in Frederiks et al., 2015); Bhattacharjee & Reichard (2011)	Knowledge, awareness and understanding of energy costs, energy-saving behaviour, and the consequences of such behaviour
Values	Frederiks et al. (2015); Bhattacharjee & Reichard (2011)	A global, abstract and relatively enduring set of beliefs, ideals and standards that serve as guiding principles in life
Attitudes	Frederiks et al. (2015); Bhattacharjee & Reichard (2011)	Positive or negative evaluations of a particular idea, object, person, situation, or activity
Beliefs	Frederiks et al. (2015)	*Not defined by the authors*
Motives	Frederiks et al. (2015)	The driving forces or impulses that initiate, guide and maintain goal-directed behaviour
Intentions	Frederiks et al. (2015)	*Not defined by the authors*
Goals	Schwartz (1994, as cited in Frederiks et al., 2015)	*Self-transcendence goals:* promoting the interests of others and the external world *Self-enhancement goals:* focusing on oneself and one's interests. *Hedonic goals:* desire to achieve positive self-esteem and improve how one feels at a particular moment *Gain goals:* desire to protect and improve one's resources or possessions *Normative goals:* desire to act appropriately in line with social and moral standards *Note. Derived from Goal Framing Theory (see Section 2.3)*

Social status	Bhattacharjee & Reichard (2011)	*Not defined by the authors*
Normative social influence	Frederiks et al. (2015)	The explicit and/or implicit rules, guidelines or behavioural expectations within a group or society that guide what is considered normal and/or desirable
Personal norms	Schwartz (1977, as cited in Frederiks et al., 2015)	Feelings of strong moral obligation to perform certain types of pro-social behaviour, including pro-environmental actions *Note. Derived from Norm Activation Model (see Section 2.1)*
Perceived responsibility	Van Raaij & Verhallen (1983, as cited in Frederiks et al, 2015)	Attribution of responsibility (self-blame, accountability, liability, obligation, etc.) for energy conservation to oneself rather than away from oneself to other people
Locus of control, self-efficacy, perceived behavioural control	Frederiks et al. (2015)	A person's perception of whether they have the capability to enact change and/or control events that impact them
Perceived cost-benefit ratio	Frederiks et al. (2015)	*Not defined by the authors*
Inertia to change	Bhattacharjee & Reichard (2011)	The inherent nature of people to be wary of investing in the energy efficiency of their dwelling in spite of the probability of receiving higher returns on investment
Need for personal comfort	Frederiks et al. (2015)	*Not defined by the authors*

As can be seen from *Table 15*, the identified determinants mainly follow the determinant models of energy consumption addressed in *Section 2.1*. **Beliefs**, **attitudes**, and **intentions** are behavioural predictors in the *Theory of Planned Behaviour* (Ajzen, 1991). It is often assumed that an increase in either of these determinants results in improved energy conservation behaviour. However, Frederiks et al. (2015) found inconsistent evidence about this claim, pointing to often-found gaps between knowledge, goals, attitudes values, and behaviour (e.g. Courtenay-Hall & Rogers, 2017).

Frederiks et al. (2015) distinguish the **social norms** in injunctive norms and descriptive norms. The former refers to perceptions of what attitudes and behaviour are approved/desired by a social group with whom one associates or identifies, while the latter is defined as the perceptions of what attitudes and behaviour are normal or common among this social group, or in other words, the prevalence of the behaviour within a group (Frederiks et al, 2015; He et al., 2010; Steg et al., 2014). Frederiks et al. (2015) have found consistent evidence for the effect of these norms on conformity with the socially approved behaviour (e.g. energy saving).

Perceived behavioural control proved to be positively related to pro-environmental behaviour, according to Frederiks et al. (2015). The authors found that the relationship was contingent upon the locus of control (i.e. whether one ascribes what happens to either oneself or external factors).

Personal norms and **perceived responsibility** are predictors of behavioural intention in the *Norm Activation Model* (Schwartz, 1977). Even though the authors have found a range of possible mediating and moderating variables, in general good evidence has been found for the *Norm Activation Model* (Schwartz, 1997), demonstrating the influence of personal norms, and the perceived responsibility on environmental behaviour.

The perceived loss of **personal comfort** as a result of an energy saving measure has been found to strongly influence households adopt energy saving measures, explaining up to 30 % of the variability between households (Frederiks et al., 2015). This means that the stronger the perceived loss of comfort or negative impact on health, the more energy a household consumes.

Frederiks et al. (2015) have assessed studies that take a behavioural economics perspective on predictors of the intention to save energy. Research they have reviewed focused on the perceived **costs and benefits** of

energy saving behaviour. Costs may involve e.g. time, effort, money, and loss of comfort, while examples of benefits include money, status/prestige, or social approval. The authors question the behavioural economic perspective regarding its potential to predict energy saving and consumption behaviour, given the range of cognitive biases, heuristics and other anomalies in human decision-making and behavioural choices people are prone to make (Frederiks et al., 2015, p. 596).

7.2.2 Socio-demographic Determinants

In *Table 16*, the socio-demographic determinants of energy consumption that were found in the literature reviews of Ferderiks et al. (2015) and Bhattacharjee & Reichard (2011) are listed. As the factors are self-explanatory, they have not been defined in the reviews. Therefore, no definitions are available.

Table 16: Socio-demographic determinants of residential energy consumption

Determinant	References
Education	Frederiks et al. (2015), Bhattacharjee & Reichard (2011)
Employment status	Frederiks et al. (2015), Bhattacharjee & Reichard (2011)
Household income	Frederiks et al. (2015), Bhattacharjee & Reichard (2011)
Household size	Frederiks et al. (2015), Bhattacharjee & Reichard (2011)
Homeownership	Frederiks et al. (2015), Bhattacharjee & Reichard (2011)
Stage of family lifecycle	Frederiks et al. (2015), Bhattacharjee & Reichard (2011)
Technical expertise	Frederiks et al. (2015)
Time spent at home	Bhattacharjee & Reichard (2011)
Distribution of age within the household	Bhattacharjee & Reichard (2011)

Frederiks et al. (2015) have found that the higher the **educational level**, the stronger the knowledge, awareness and concern regarding environmental issues (such as energy efficiency). However, once more there is a gap between knowledge and behaviour: higher levels of education generally do not automatically lead to saving energy. **Employment status** of household occupants (e.g., full-time, part-time, retired or unemployed) may indirectly impact energy consumption, as it has an impact on the household's income, which subsequently affects the capacity to invest in efficiency measures, and the ability to spend money on energy consumption.

The higher the **household income**, the higher the residential energy consumption. This effect may be mitigated by the household's capacity to invest in energy-efficient products. Not surprisingly, the number of people in the household (the **household size**) is also positively related to energy consumption, even though this relationship is non-linear, presumably due to the sharing of energy services among multiple residents.

Stage of family life cycle appears to be an important predictor of household energy use. Energy consumption reaches its peak in households with small children. Frederiks et al. (2015) assume that the changes in house work, childcare, and family activities are the cause of the increase in energy consumption. Obviously, changes in household composition due to children being born or children moving out of the house also have a significant impact on energy use.

7.2.3 Contextual Determinants

In *Table 17*, the contextual determinants of residential energy consumption are displayed, as reviewed by Frederiks et al. (2015), and Bhattacharjee & Reichard (2011).

Table 17: Contextual determinants of residential energy consumption

Determinant	References	Definition
Home ownership	Frederiks et al., (2015)	*Not defined by the authors*
Dwelling size	Frederiks et al., (2015), Bhattacharjee & Reichard (2011)	The size of the building, in terms of area size, number of rooms, and number of floors
Dwelling characteristics	Bhattacharjee & Reichard (2011)	The degree of home insulation, wind exposure, glazing, efficiency of HVAC system, etc., which have a direct influence on energy end use
Dwelling age	Frederiks et al., (2015), Bhattacharjee & Reichard (2011)	*Not defined by the authors*
Economic condition	Bhattacharjee & Reichard (2011)	*Not defined by the authors*
Energy price	Bhattacharjee & Reichard (2011)	*Not defined by the authors*
Energy Efficient Equipment Affordability	Bhattacharjee & Reichard (2011)	The cost of new and improved appliances in accordance with the wage level of a society
Technology ownership	Frederiks et al. (2015)	Ownership of non-energy technology
Regional differences (weather and climate zone)	Frederiks et al. (2015), Bhattacharjee & Reichard (2011)	Climate, temperature, and geography
Dwelling microclimate	Bhattacharjee & Reichard (2011)	The local temperature around a dwelling

Home-ownership is associated to more investments in energy conservation measures when compared to rental housing. The **dwelling size** also affects energy consumption. The larger the house (in terms of floor space, number of rooms, floors, etc.) the more energy is used, while in detached houses, more energy is consumed than in apartments and other multi-unit dwellings. Albeit the relationship being less clean-cut than expected, **dwelling age** is positively related to energy consumption, as older buildings were often built in a less energy-efficient way.

According to Bhattacharjee & Reichard (2011), when considering the impact of **weather** and **climate differences** on energy consumption, not only the regional climate must be considered, but also the microclimate around a dwelling. The **dwelling microclimate** refers to the influence of topography, urban forms, water bodies, vegetation, etc. Both the regional climate and weather conditions and the microclimate have shown to impact energy consumption.

7.3 Strategies and Interventions to Reduce Energy Consumption

Energy consumption reduction in households has received a lot of attention over the last decades. Different reviews have covered either the full range of adopted strategies (e.g. Abrahamse et al., 2005), or focused on specific strategies, such as gamification and serious games (Johnson et al., 2017), or consumption feedback (Murugesan et al., 2015; Nachreiner et al. 2015).

The attention for behavioural change has sparked an increase in the number of households in which smart meters have been installed. This has spurred research in consumption-feedback-based interventions. Nachreiner et al. (2015) have assessed these interventions in terms of Bamberg's (2013) S*tage Model* for self-regulated behavioural change (see also *Section 2.2*). She has distinguished several functionalities for smart

meter feedback information systems, by feedback techniques and supplementary information strategies (Nachreiner et al., 2015).

The analysed reviews not only differ in terms of their scope, but also in terms of their objectives. For example, while the reviews conducted by Abrahamse et al.'s (2005) and Johnson et al. (2017) focused on uncovering effects of strategies on energy consumption behaviour and its underlying determinants, the objective of Murugesan et al. (2016) was to distil design criteria for consumption visualisations. In this section the findings from these reviews of strategies and interventions to reduce energy consumption are concisely summarized.

The summary can be found in *Table 18*, in which the identified interventions are categorized according to the *Behavioural Change Wheel* (Michie et al., 2011). The target group of each of the interventions was residential consumers. This was left out of the table for reasons of readability.

The results show that education and persuasion have been found often in the reviewed literature, whereas coercion, enablement, environmental restructuring, and restrictions have not been found. Results are consistent with findings from public buildings and schools (*Section 5 and 6*), in terms of the types of interventions that have been employed.

Even though the interventions in the *Table 18* are listed separately, studies reviewed by both Abrahamse et al. (2005), and Nachreiner et al. (2015) often already employ a combination of interventions, beyond providing feedback alone. More research is needed on specific combinations of interventions, as well as on the effect of individual interventions. The reviewed studies that employ combinations of interventions do not allow for a causal attribution of energy saving effects to individual measures.

Table 18: Strategies to reduce energy consumption in residential settings

Type of intervention	**Energy efficiency intervention**	**References**			**Effect on consumption**
		Abrahamse et al. (2005)	*Nachreiner et al. (2015)*	*Johnson et al. (2017)*	
Education	Continuous (high-resolution) consumption feedback	X	X		-13 % (mixed effects)
	Social comparative feedback	X	X		only one study with no effect; other studies negative effect, but effect of comparative feedback unknown
	Historical comparative feedback		X		N/A
	Analysis of own feedback		X		N/A
	Workshops about energy saving measures	X			N/A
	General and tailored action-related information (e.g. tips)		X		N/A
Persuasion	*Commitment:* an oral or written pledge or promise to change behaviour	X	X		% unknown
	Goal setting: giving households a reference point to save energy	X	X		- 15 % (in experimental condition with ambitious goal) 0 (in experimental conditions with easy goal)
	Mass media campaigns	X			
	Social norm-based interventions		X		N/A
	Reminders		X		N/A
Incentivisation	Monetary rewards	X			- 6 % to – 12 % (long-term effect unknown)
	Game elements: • Levels • Points, leader boards • Challenges • Rewards • Rankings and leader boards • Feedback and tips • Avatars • Social sharing • User generated content • Competition		X	X	- (19 of 25 studies reviewed; consumption effects reviewed, but no percentages were reported; 6 out of 25 studies reported mixed effects)
Training	Energy audits: home visits by an auditor who gives a range of energy-saving options based on current situation	X			0 - (mixed effects, between 0 and 21 %)
Modelling	Tailored tv program targeted at middle class homeowners	X			- (10 % compared to control group)

The reviews demonstrate that consumption feedback alone is not capable of inducing a sustainable change in energy consumption behaviour (Nachreiner et al., 2015). Above and beyond the reviews presented here, several problems have been identified in the literature, suggesting that a combination of incentives is necessary (e.g. Wilson & Marselle, 2016). One of the problems is what has been referred to as the 'salience bias', which refers to human behaviour being biased toward the salient and immediately visible (Tiefenbeck et al., 2016). In terms of the *Behavioural Change Wheel* (Michie et al., 2011), this emphasizes the importance of both opportunity (i.e. the context) and motivation as preconditions for behavioural change.

Tailoring feedback to the context of use, as intended in enCOMPASS, is one of the possible directions to improve the impact of feedback. For that purpose, an understanding is needed of the context in which feedback systems are used. Fréjus & Martini (2016, p. 469) conclude that "the context must be defined from the user's point of view and considered as distributed over time: in connection with ongoing activities and questionings already experienced, resolved or persisting". Feedback-based interventions reviewed in Abrahamse et al. (2005) do not take into account the context of use, nor the changing role of feedback over time. Nachreiner et al. (2015) depart from a stage-based model, suggesting a different combination of interventions depending on the stage in the behavioural change process (as shown in *Figure 6*).

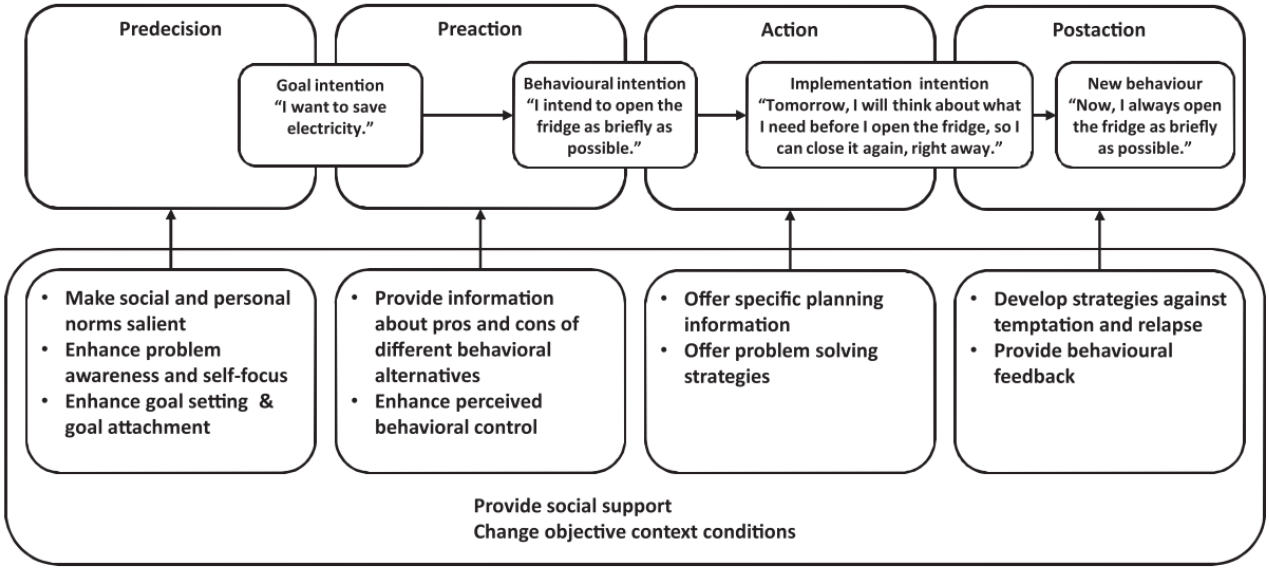

Figure 6: Energy interventions mapped on Bamberg's (2013) Stage Model for behavioural change (Nachreiner et al., 2015, p. 90)

Their review shows that in existing systems little attention is paid to the transition from pre-action to the action stage, as well as from the action to the post-action stage (Nachreiner et al., 2015). Even though a stage-based perspective could be a first step towards a more fine-grained conceptual understanding of how interventions could induce behavioural change over time, a more detailed, empirical insight of how change is induced by the introduction of energy feedback systems in household is needed, as a starting point for what Nachreiner et al. (2015) refer to as a holistic action plan, promoting behavioural change in a systematic way in accordance with user needs in different stages of the behavioural change process.

A good example of such exploratory research comes from Skjølsvold et al. (2017) who have investigated the impact of introducing a feedback system on household dynamics. Four changes have been found. First, households increase their awareness of how much energy appliances and behaviours in their house consume. Second, as a result of this increased awareness, the feedback system brought about changes in the building or the appliances used within the buildings, to increase energy efficiency. Third, some of the interviewees indicated that changes were introduced to the social relations within the households, such as attempting to establish new rules for how, when and why electricity could be used. Additionally, feedback technology

triggered discussions between household members on the level of comfort (e.g. room temperature, lighting) versus the need to efficiently use energy. Finally, the feedback system led to the establishment of new modes of routinized interaction or co-existence with the feedback technologies.

The short-term duration of the trials reported in the reviews is problematic in the sense that often long-term effects cannot be assessed. Continuously attracting the attention of the users is an important challenge of feedback systems, as users have, in terms of Tiefenbeck et al. (2016), a salience bias towards the salient and immediately visible. One often-used approach to capture the attention of users and to keep them engaged is the use of gamification, and serious games. Johnson et al. (2017) have systematically reviewed game-based interventions. Their review has yielded examples of several game elements used to incentivize users, some of which are also used separately in interventions that otherwise do not employ game elements (e.g. challenges, goal setting, rewards). Regrettably, the reviewed studies in Johnson et al. (2017) often do not address sustainable effects of such incentives on energy consumption behaviour, which complicates the assessment of their effectiveness. Nevertheless, their recent review demonstrates that the use of serious games and gamification is both a promising strategy to reduce energy consumption and an important direction for additional research, especially with regard to long-term effects.

7.4 Conclusion: Energy Consumption in Residential buildings

This section has reviewed determinants of energy consumption and strategies to induce energy saving behaviour in residential buildings. A wide range of psychological, social, and contextual determinants have been found. It has been shown that their relationship with energy consumption behaviour is often complex, involving various mediating and moderating variables. In terms of the intervention, most attention in research on residential energy saving has been paid to consumption feedback. This section has provided current evidence for its effectiveness, as well as pointed out several issues that need to be overcome. The enCOMPASS approach in which behavioural change incentives are offered to users depending on the context-of-use and characteristics of the users is a promising approach in the light of these findings from the literature.

For enCOMPASS, the following conclusions should be taken into account for the specification of the user awareness applications and the underlying incentive model:

- Energy consumption feedback is best combined with other interventions.
- The context of use and the social dynamics within a household must be considered to fully leverage the behavioural change potential of ICT-based persuasive applications for energy saving.
- Triggering attention to draw continuous attention and ensure salience of the interventions is a critical success factor.

8 ENERGY SAVING ACTION RECOMMENDATIONS

The theories described in the previous chapters support the principled design of advanced persuasive applications, built on the motivation and determinants of user's consumption behaviour. In addition to such theoretically-grounded methods, also simple tools, such as energy saving tips and recommendations of various kinds addressing various target groups, are frequently used by practitioners to foster energy awareness and saving. This section gives an overview of recommendations for saving energy for different target groups in different kinds of buildings which are given in both the academic and 'grey' literature. The presented overview of the saving tips is not related to theories, models and approaches, but to what recommendations are actually given in practice. Though these lists of recommendations make no claim to be complete, they do provide a comprehensive overview that shows that a vast amount of recommendations are known and used in practice. This provides an initial basis for the selection of the energy saving recommendations to be integrated in the enCOMPASS system, in accordance with the target group, the building type, and the used incentive approaches. In this way, this section complements the theoretical analysis of the energy determinants and behavioural change strategies from the previous sections with the final element that is required for informing the design of the enCOMPASS behavioural change system: the different types of actual energy saving recommendations that can be provided to the end-users.

8.1 ROLE OF ACTION RECOMMENDATIONS IN ENCOMPASS

This section covers a first inventory of actions different kinds of users in different types of buildings can do to save energy. Source of the tips comes from both the academic and the 'grey' literature.

All collected energy saving actions will be presented in the following Tables (*Table19 –Table 12*). The tables consist in four columns; a rough structuring, the area (E=Electricity, C=Cooling, H=Heating), a general topic by which they are divided and a short explanation. Further information and references can be requested by contacting the enCOMPASS team.

Due to the distinct reference, persons in several parts of building types, the recommended energy saving actions have been divided into four different sections. Energy saving action that may count for nearly every building type will be presented in *Subsection 8.2* (Common Recommendations for all Three Categories). The remaining energy saving actions have been categorized by residential, schools and public buildings. Further information will be revealed in the following subtopics.

To get a rough idea of the concept and of the collected energy saving actions, we will emphasise a few highlights of each building sector. The amount of highlights of each building sector is correlated to the quantity of collected energy saving tips.

8.2 COMMON RECOMMENDATIONS FOR ALL THREE CATEGORIES

Interdisciplinary recommendations include the building sections and tools that are indispensable. Ubiquitous general structure like lighting, insulations or heating can be found in this category and are shown in the following *Table 19*.

Table 19: Interdisciplinary recommendations

	Area	Topic	Explanation
1	E	**Energy efficiency categories**	Keep an eye on eco labels like "blue angel", "energy star", “TCO” or "EU-flower"
2	E	**Energy reduction**	Use high efficiency energy vacuum cleaner
3	H	**Heating system**	Checking ventiles and pumps periodically
4	H	**Heating/ radiator Optimization**	Proceed Hydraulic balancing
5	H	**Heating/ radiator Optimization**	Check lagging circulation of recuperator
6	H	**Heating/ radiator Optimization**	Substitute pumps in the heating system
7	H	**Insulations**	Insulate roof, windows & shutter, tubes
8	H	**Insulations**	Especially insulate the tubes next to the heating pump
9	H	**Insulations**	Usage of Indirect instead of direct (enamel) heated hot water tank
10	E	**Sensor - Feedback**	By medium (in written form (1,5-8,5 % energy savings), online, SMS, IHD (In-Home-Display, 5-10 % savings))
11	E	**Sensor - Feedback**	By frequency (daily, weekly, monthly, real-time (18-22 % energy savings))
12	E	**Sensor - Feedback**	By combination (comparing with historical data, social aspects, financial aspects, energy saving tips)
13	E	**Sensor - Feedback**	Preterm determination of aberrations utilized as controlling elements and comparison to database
14	E	**Light switches**	Use LED (lowest energy consumption) > Fluorescent lamp (CFL) > halogen lamp > conventional light bulb
15	E	**Light switches**	Use Light switch with integrated motion detector
16	E	**Light switches**	Use Light switch with integrated timer
17	E	**Light switches**	Use bright light colours
18	H	**Various Heating Sources**	Redirect industrial waste heat to residential heating
19	H	**Various Heating Sources**	Use Solar heat
20	H	**Various Heating Sources**	Use Air-water heat pump
21	H	**Various Heating Sources**	Use Brine-water heat pump
22	H	**Various Heating Sources**	Use Geothermics
23	E	**General advices**	Produce power with photovoltaic on the roof top
24	E	**General advices**	Eco-power for heat pump (e.g. by the power utility "Elektrizitätswerke Schönau")

25	E	**General advices**	Energy calculators like "EngyCalc" can measure losses and help to install a pre-/post-alarm-system
26	H	**Various Heating Sources**	Build up decentral heating-grids
27	H	**Various Heating Sources**	Abandon electric heating, instead use natural gas
28	C	**HVAC Systems**	Reduce energy of/Timing A/C by adopting either VAV (variable air volume) system or TPFC (think pad fan controller) system instead of unitary system
29	C	**HVAC Systems**	Reduce energy of/Timing A/C by increasing set point up to (e.g.) 28°C during unoccupied periods
30	C	**HVAC Systems**	Reduce energy of/Timing A/C by: "Investigated retrofit techniques included air-bypass control on cooling coils, reset and setback control, improved HVAC system start–stop times and economising on outside air intake."
31	C	**HVAC Systems**	Reduce energy of/Timing A/C by "HVAC system start–stop times together with air-bypass, reset and setback control was found to be the most lucrative."
32	C	**Various cooling systems**	Decrease power (kW) of Compression Refrigeration System (10-150 kW)
33	C	**Various cooling systems**	Recuperator, better thermo conductivity (compared to ventilation)-> better cooling, but difficult installation
34	C	**Various cooling systems**	Ventilation, air is absorbing and transporting the thermal energy
35	C	**Various cooling systems**	Use Solar, desiccant system with drying material (silica gel) to draw the moisture in the air
36	C	**Various cooling systems**	Use Solar, absorption chiller system (most common) with solar water heating collector and a thermal-chemical absorption process to produce air-conditioning without using electricity (like fridge without compressor)

- Maintaining the building's hydronic heating or cooling system will increase its performance. A conventional hydraulic balancing will cost around 100€. An efficient and maintained hydronic heating system can save you up to 20% of the heating energy or 1,400 kWh a year. Furthermore, a hydraulic balancing might be federally subsidized in some countries.
- Installing sensors in several rooms of a building to measure and regulate important energy saving indicators like the mean temperature will be indispensable to smart manage the inhabitant's energy consumption. Even though it is stated as difficult to measure, research has shown that In-Home-Displays (5-10% savings) and computer feedback (up to 20%) have been the most utilized sensor types.
- While air conditioning a building in hot summer, you can reduce the energy by setting or timing a threshold (e.g. 28°C) during unoccupied periods. When out of office or house
- Even though the energy saving actions are not about huge investigations at all, but intelligent management and moderate actions nearly everybody can achieve. At the point of purchasing a new product, like a fridge or a washing machine, you should still keep an eye on the international eco labels like "blue angel", "energy star", "TCO" or "EU-flower".

8.3 RECOMMENDATIONS IN PUBLIC BUILDINGS

Public buildings are comparable to regular households as they also include just like the domestic building sections kitchens or bathrooms. Recommendations address all users like temporary visitors and employees

but also the building manager or owner that in flats or apartments might diverge from the usual residents. As findings on public buildings are expected to be sparse, *Table 20* also covers findings on recommendations for the workplace in more general terms (offices etc.).

Table 20: Public energy saving actions

	Area	Topic	Explanation
1	E	**Lighting**	Motion detectors for lighting system of corridors and partially used areas
2	E	**Office Devices**	Use multi sockets and connector strips with integrated toggle switch
3	E	**Office devices**	Device usage and long term download can be reduced with faster internet connection
4	E	**Office devices**	Get to know and use power management features of your pc
5	E	**Office devices**	Use connector strips with integrated toggle switch
6	E	**Public Buildings**	Rebates & Feedback in public buildings/ rented flats (originally used in student domiciles)
6	E	**Office devices**	"No-Load Loss": Stop Standby or Sleep Mode, turn off device (also temporarily)
7	E	**Office devices**	Turning reading lamps off when not in use
8	E	**Office devices**	Turning desktop computers off when not in use
9	E	**Office devices**	Turning off multi sockets when not in use
10	E	**Office devices**	Put computer into sleep mode after a short period, e.g. 15min.
11	E	**Office devices**	No High-tech pc for regular office is needed
12	E	**Office devices**	Make PC adjustable to stay up-to-date in the future
13	E	**Office devices**	Use MiniPCs instead of regular PC
14	E	**Office devices**	Use Laptop instead of regular PC
15	E	**Office devices**	Multifunctional tools (All-in-one printer, fax, scan etc.) instead of each tool on its own
16	E	**Office devices**	Use software like "Winoptimizer" to lower the PC's energy consumption
17	E	**Office devices**	Cut off routers power when not in use for a longer term (in some periods it consumes as much energy as a fridge)
18	E	**Office devices**	Open Source Software consumes less energy, due to their adjusted potential
19	E	**Office devices**	Conscious data treatment and reduced resources will save energy too
20	E	**Office devices**	Concern about the internet contract, buying more mbs while consuming less kWs will save energy too
21	E	**Office devices**	When using google, ask precisely to avoid longer searching
22	E	**Office devices**	Don't overwhelm digital structures with printing emails or saving data/music on a hard disk
23	C	**General advices**	Adjust ventilation to amount of people in building (day-/night-time)
24	C	**HVAC Systems**	Reduce energy of/Timing A/C by shifting half of chiller load during the building peak to night time operation using thermal chilled store
25	C	**Cooling systems**	Use an air conditioning system using the waste heat from production processes or the heat from CHP (combined heat and power) cogenerators

- Reduce the energy of the A/C by shifting half of chiller load during the building peak to the night-time operation using thermal chilled store. You can reduce the energy demand around 20%.
- For some public building type, rebates & feedback system can have a positive impact on the energy consumption. By that, the financial aspect of energy saving is shared between the customer and the host. Originally used in a 3-week-project at a student's campus in New Zealand, it has saved al lot of money (up to 170€) and as a result a lot of energy too.

8.4 RECOMMENDATIONS IN SCHOOLS

Schools are also public buildings, but special as the users (teachers, students, facility managers) and the period of usage is well defined. Therefore, *Table 21* shows a summary of given recommendations in schools.

Table 21: School energy saving actions

	Area	Topic	Explanation
1	E	**Lighting**	Redesign the setup of the lighting system in school corridors
2	E	**Lighting**	Adjust the HVAC Systems to the school's curriculum. Adapt lighting to operating hours in classrooms
3	C	**General advices**	Adjust the HVAC Systems to the school's curriculum. Adapt ventilation to amount of people in building (day-/night-time)
4	C	**HVAC Systems**	Adjust the HVAC Systems to the school's curriculum. Reduce energy of/Timing A/C by shifting half of chiller load during the building peak to night-time operation using thermal chilled store.
5	E	**Governmental support**	There is a huge amount of subsidies by state, council & municipality that might fit into the schools requirement

- Schools belong to the largest consumers of energy. A huge part is wasted by not coordinating lighting or ventilation systems to the operating hours in classrooms. Demands of a school differ a lot between day- and night-time.
- The lighting system of many school corridors is pretty inefficient. Not only with their outdated light bulbs, but also with the quantity and location of the bulbs.

8.5 RECOMMENDATIONS IN RESIDENTIAL BUILDINGS

Table 22 lists energy saving recommendations in residential buildings with a focus on the users (household members, adults and children). Residential buildings like a regular household include the domestic building sections like kitchen or a private bathroom. It includes all house members (adults and children) but also the building manager/ owner that in flats or apartments might diverge from the usual residents.

Table 22: Residential energy saving actions

	Area	Topic	Explanation
1	E	**Kitchen**	Vacuum the heat exchanging pipes on the back of your fridge/freezer
2	E	**Kitchen**	Reduce the opening time of the fridge to a minimum, e.g. when unpacking the shopping, sort it out first and then put all your cool things away in one go – constantly opening and closing the fridge door increases its temperature

3	E	**Kitchen**	Cool down food before putting it into the freezer/fridge
4	E	**Kitchen**	While purchasing, keep an eye on climatic class of freezer/fridge
5	E	**Kitchen**	Cover liquids and wrap foods stored in the refrigerator. Uncovered foods release moisture and make the compressor work harder
6	E	**Kitchen**	Lowest fridge level will create excessive moisture, ice build-up and so consume more electricity to sustain the lower temperatures (7°C recommended)
7	E	**Kitchen**	Keep fridge away from solar radiation, stoves etc.
8	E	**Kitchen**	Defrost freezer from time to time to melt ice layer (e.g. before vacation)
9	E	**Kitchen**	Allow air to circulate freely around and above the refrigeration units to guarantee proper ventilation
10	E	**Kitchen**	Use fresh products & tins instead of frozen products
11	E	**Kitchen**	Fill up your freezer with plastic bottles filled with water or even old newspapers, if it's not full, but don't overfill. It will consume less energy
12	E	**Kitchen**	Stop cleaning programme of the dish washer after the washing and before the drying period and let it dry on open door
13	E	**Kitchen**	Always fully load the dish washer
14	E	**Kitchen**	Scrape, not rinse, off large food pieces before washing plates etc.
15	E	**Kitchen**	No pre-heating in baking oven
16	E	**Kitchen**	Using circulating air in the oven, it's the more efficient way
17	E	**Kitchen**	Don't cook your meal without using the cap
18	E	**Kitchen**	Avoid raclette/table grill & deep fryer. They consume a lot energy
19	E	**Kitchen**	Use electric kettle (low watts) to heat up water instead of a pot
20	E	**Kitchen**	Use induction cook top instead of ceran stove/hob
21	E	**Kitchen**	Use citric acid or vinegar to descale electric kettle
22	E	**Kitchen**	Think ahead and make the most of your oven by cooking 2 meals at one go
23	E	**Kitchen**	Keep the window of the oven clean so that you don’t need to open the door to check the progress of your meal
24	E	**Kitchen**	Turn the oven off 5 minutes before the meal has finished cooking to use the residual heat of the oven to finish it off
25	E	**Kitchen**	Cut the food down into smaller pieces before cooking – it makes cooking time quicker
26	E	**Kitchen**	Try a pressure cooker, it can save as much as 70 % of the energy needed to cook your food
27	E	**Kitchen**	Reduce energy of dishwasher by connecting the warm water usage to hot water pipe
28	E	**Kitchen**	Reduce energy while cooking by using gas stove instead of electric stove
29	E	**Household**	Avoid high temperature programme of your washing machine, 30-40°C are generally sufficient
30	E	**Household**	Always completely fill up the washing drum
31	E	**Household**	Dry wet clothes outside or on a laundry rack

32	E	**Household**	Dryer operating with gas
33	E	**Household**	Dryer operating with fresh-air
34	E	**Children**	Use fun, colourful stickers in prominent places to remind kids to turn things off
35	E	**Children**	Competition between your kids, e.g. for the least energy saving effort by parents for them
36	E	**Children**	Turn of the kids' gaming consoles instead of standby
37	E	**Children**	Let the kids do research for the most environmentally friendly or energy saving product on their own, it increases self-esteem & responsibility
38	E	**Children**	Buy as less electric toys for your kids as possible, also relatives, birthday presents a.s.o.
39	E	**Children**	Avoid batteries, use rechargeable batteries
40	E	**General advices**	Save energy while showering by using single handle mixer taps it won't take as long for the water to reach the desired temperature
41		**General advices**	Have a cold or tepid shower in summer
42	H	**Heating/ radiator**	Reduce heat loss by modulated circulating pump (usually for hot water tap), lower level at night
43	H	**Heating/ radiator**	Reduce heat loss by water saving shower head and restrictor
44	H	**New Heating Sources**	Heating with wood in large rooms, e.g. in living room to save heating energy loss
45	H	**New Heating Sources**	Heating with wood pellet kettle with low particulate matter emission

- Figuring out the right temperature while showering can last a few seconds or minutes. Especially when you have two separated taps for hot and cold water. Adjusting the water temperature with a single handle mixer taps will not take as long for the water to reach the desired shower. You might also just have a cold or tepid shower in summer more easily and quickly.
- You do not need to set the refrigerator's temperature level to the minimum. The optimal temperature is stated as 7°C, while the lowest fridge level is normally around 5°C. Not only will a lower temperature consume more energy, it will also create excessive moisture and formation of ice. This will lead to even bigger energy consumption. Another adverse side effect of a lower temperature and the ice formation is the chilling injury of vegetables and other sensitive foodstuff. Therefore, adjusting the right chilling temperature will serve you twice, less energy consumption and food's elongated shelf-life.
- When cooking food like beans, peas or even potatoes, try a pressure cooker. It will save you a lot of time and as much as 70 % of the energy to would have needed to cook the food conventionally. You don't even have to spend more money than for a common cooking pot.

9 CONCLUSION

In this deliverable *Behavioural Change Models*, determinants of energy consumption behaviour, and strategies for energy saving were examined with the purpose of supporting the identification of focal points that can be targeted with the enCOMPASS user awareness and behavioural change applications.

Two types of *Behavioural Change Models* were reviewed: *Determinant Models* and *Process Models*. While *Determinant Models* define the type factors that can be targeted in the applications and how they are related, *Process Models* give insight into how users change their behaviour over time and what processes they need to engage in to progress from one stage to the other. The reviewed models provide the theoretical foundation for the *Behavioural Change and Incentive Model* in the enCOMPASS applications.

A systematic review of the determinants of energy consumption behaviour in schools and public buildings was done. The analysis on the importance of the determinants was focused on the frequency of determinants studied in public buildings and schools as well as on the impact of the determinants on energy consumption. The results of the analysis suggest that the most important determinants for energy saving in public buildings are: attitudes, awareness, social norms, feedback (information), organizational encouragement and support. The most important determinants in schools are: attitudes, incentives/intentions/motivation, knowledge and awareness. The identified determinants serve as input to the requirements process in WP2 as they support the definition of the pilot scenarios and user stories, in terms of the type and content of the messages that should be exposed to the users (e.g. the tips, the (adaptive) recommendations, and the consumption visualizations). The interim findings of the analysis have already been taken into account and informed the early user stories and use cases described in *D2.1 Use cases and early requirements,* while the final results of the determinants analysis will inform the work on *D2.2 Final requirements*.

Additionally, the determinants analysis for the three pilot buildings provides input for the validation methodology that will be defined in *D7.2 Validation methodology*. This will include a baseline measurement of energy saving awareness. The questionnaire that will be developed can draw on the determinants and measurements in underlying papers that have resulted from the systematic review presented in this deliverable.

The inventory of strategies demonstrated that across the different building types, the most commonly applied behavioural change strategies are consumption feedback, education and persuasion. Particularly, consumption feedback is often employed, yielding savings between 6% and 13%. Additionally, goal setting is often used, reducing consumption up to 16 % across building types, with easy goals in the residential buildings yielding no savings at all. The strategy overviews also demonstrate that the specific effect of particular interventions is difficult to assess, as in a significant share of the studies no reduction percentages were reported. Furthermore, if consumption impact has been measured, the combinations of interventions make it difficult to attribute the effects to one particular strategy. Another observation is that some of the applied strategies already bare a high incentive quality, e.g. goal setting, while others rely on additional incentives for users to actively respond to the strategies. *D5.2 Incentives and engagement strategies* takes a closer look at what kind of incentives and engagement strategies are applied in research and practice to stimulate energy saving and other sustainable behaviour. Its output further informs the design of the enCOMPASS *Incentive Model* and applications.

The substantial differences in saving potential also demonstrate that the combination of interventions should be carefully considered and adjusted to the needs of the target groups in the specific context-of-use, as has been demonstrated in several studies discussed in this deliverable (e.g. Hargreaves et al. 2013). This particularly applies to the enCOMPASS pilots. For that reason, end-user involvement is an important part of

the enCOMPASS approach in both *WP2 Requirements and user-centred design for behavioural change* and *WP5 Energy visualization and game-based behaviour change for energy saving.*

In academic and as well as in 'grey' literature a vast amount of *Energy Saving Actions Recommendations* are given for basically all target groups in all kinds of buildings. For enCOMPASS relevant recommendations are either general, which fits for residential, public buildings as well as for schools, or specific for each building type. General recommendations mostly address the overall energy efficiency and quality of the thermal design of a building as well as sensor feedback, and the energy-aware behaviour of users. In particular, in residential buildings energy saving recommendations are greatly focussed on the energy-aware behaviour of the users. Suitable recommendations for public buildings are mostly addressing the efficient usage of electronic devices and electricity adjusted to the building specific use case. In schools, most relevant recommendations address the coordination of the appliances, heating and the operating hours, but based on the specific context and organizational policy of a given school (centralized vs. decentralized control), other types may also play an important role (e.g. energy-aware behaviour of teachers and pupils with respect to lighting and heating control).

Overall, for enCOMPASS, the following main conclusions should be particularly taken into account for the specification of the user awareness applications and the underlying incentive model:

- Consumption feedback is the most effective combined with other interventions and should be applied in all types of buildings.
- Organizational encouragement and support in public buildings is one of the most important determinants in energy saving.
- Investigation of visitors' behaviour in public buildings in terms of energy saving would contribute to this little studied research area.
- The context of use and the social dynamics within a household should be considered to fully leverage the behavioural change potential of ICT-based persuasive applications for energy saving.
- Triggering attention to draw continuous attention and ensure salience of the interventions is a critical success factor in residential buildings. Attention triggering is also discussed in more detail in *D5.2 Incentives and engagement strategies*, also in the light of how this can be applied in enCOMPASS.
- The provision of energy saving recommendations needs to distinguish between general recommendations suitable for all three settings and building types, and context-specific recommendations adjusted to the specific use case, user group and type of building.

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