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DELIVERABLE 1.4.1
Analysis of factors influencing consumer choices

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Executive Summary

This deliverable *D.1.4.1 Analysis of factors influencing consumer choices* provides an analysis of the literature in order to identify the main factors influencing consumer energy-related behaviour. It also presents applicable models of behavioural change. This literature review is extended by preliminary considerations of demand models for SIT4Energy services, including analyses around user acceptance and willingness to pay. First reflexions on how to capture users' changes for short- /med- term decisions are included at the end.

The deliverable is structured as follows:

An introduction to the deliverable is given in Section 1. Section 2 gives an overview of main determinants influencing energy consumption behaviour. It was found that many different, and often interfering socio-demographic and psychological factors influence energy-related behaviour. These variables tend to be very closely interrelated. Overall, the influence of socio-demographic factors is more stable than that of psychological factors. The so-called 'intention-behaviour gap' is often discussed in the literature and points to the substantial discrepancy between people's 'good intentions' and their actual behaviour. It seems that overcoming this gap and enabling people to *consistently act* in accordance with their underlying pro-environmental values and attitudes is paramount to achieve tangible changes in people's energy-related behaviour.

Section 3 describes state-of the-art models seeking to explain consumer behaviour and decision making. It also presents evidence-based intervention strategies to achieve behavioural change. Two types of models are distinguished: determinant and process models. The discussion includes prevalent models such as the Theory of Planned Behaviour, the Norm-Activation Model and their recent modifications. Main findings are derived from Goal Framing theory and Fogg's Behavioural Model. Both have highlighted the importance of well-timed triggers to induce certain behaviours at specific points in time. Costanzo's Socio-psychological model suggests that positive feedback loops can reinforce pro-environmental behaviour after an energy-saving device has been purchased and installed. Overall, different models have different advantages and shortcomings. Many exceed the needs and the scope of the SIT4Energy project. In relation to the prosumers in the SIT4Energy project, the provision of energy consumption feedback and recommendations for specific actions might serve to increase user's engagement and motivation. Visual analytics could be useful to make people aware of the consequences of their behaviour.

Section 4 focuses on demand models for SIT4Energy services, discussing the findings of the survey raw data regarding Greek and German end-users. Their purchasing intention and willingness to pay for the tools/services that will be developed in the SIT4Energy project have been measured. 46.7 % of Greek end users indicated that it is rather important for them to purchase efficient energy management services. 20% of survey respondents found it very important. Greek end-users think that less than 10 Euro is the most appropriate amount for energy efficient solutions and almost all prefer to involve this price in their yearly/monthly energy bill. 27.3 % of German end users indicated that it is rather important to them to pay for efficient energy management services in order to automatically minimize their energy consumption. 6.1% respondents indicated that it is very important to them. The majority of the German prosumers thought that less than 5 Euro is the most appropriate amount for energy efficient solutions. They preferred to involve this price in their yearly/monthly energy bill The section ends with an overview of possibilities to capture short-/medium term changes in user decisions.

Section 5 presents the main conclusions.

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List of Acronyms and Abbreviations

Term	Description
EU	European Union
HAPA	Health Action Process Approach
FBM	Fogg's Behavioural Model
NAM	Norm Activation Model
TPB	Theory of Planned Behaviour
TTM	Trans-theoretical Model of Behavioural Change
VBN	Value-Belief-Norm theory

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1. Introduction

The goal of the SIT4Energy project is to show how an integrated energy management for prosumer clients of utilities can be realized through a smart IT solution that considers efficiency potentials in the local energy production and consumption. A second aim is to increase user engagement with and acceptance of the developed IT solutions in order to foster their use throughout society as part of the energy transformation. This includes the analysis of demand models for the SIT4Energy services.

In order to actively support prosumers in optimizing their energy production and consumption behaviour and thus reducing their energy costs and carbon footprint, it is paramount to understand the underlying factors and variables that influence their decision making. To this end, this deliverable contains an overview of current models and theories regarding human behaviour and decision making processes that are relevant and applicable to the context of energy consumption, as well as possible intervention strategies. Preliminary demand models for the SIT4Energy services focusing on user acceptance, willingness to pay and behavioural change estimation make up the last section of this deliverable.

1.1 Scope and objectives of the deliverable

This deliverable provides an analysis of the influencing factors on consumer choices that might need to be factored in when developing the smart IT-solutions for this project. This is extended with a preliminary consideration of demand models for SIT4Energy services.

The objective of this deliverable is to:

- Give an overview of the current body of knowledge concerning determinants and processes that shape human behaviour and decision making around energy consumption
- Discuss and evaluate these theories in the context of the needs and specificities of the SIT4Energy project in order to frame its theoretical foundation
- Identify demand models of SIT4Energy services

1.2 Structure of the deliverable

This deliverable D1.4.1 *'Analysis of factors influencing consumer choices'* is structured in 5 sections. Section 1 introduces this deliverable. Section 2 gives an overview of main determinants influencing energy consumption behaviour. Section 3 is concerned with state-of the-art models seeking to explain consumer behaviour and decision making, as well as evidence-based intervention strategies that can help achieve optimal results. Section 4 focuses on demand models for SIT4Energy services. Section 5 presents the conclusions of this deliverable.

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2. Determinants of energy-related behaviour (HOST)

There is already a considerable amount of research concerning the factors that influence energy consumption and energy saving behaviour. Several reviews and meta-reviews have already been conducted and provide a good overview of the current knowledge on the subject (Bhattacharjee & Reichard, 2011; Cibinskiene, Dumciuviene, Melenhorst, & Micheel, 2017; E. Frederiks, Stenner, & Hobman, 2015; Lopes, Antunes, & Martins, 2012).

While these reviews made clear that there is still a considerable lack of consistency across the findings of the studies examined, certain variables have been found to have an important impact on energy consumption behaviour. As shown in Figure 1, these can be divided into three main categories: socio-demographic and psychological determinants, as well as contextual/structural factors.

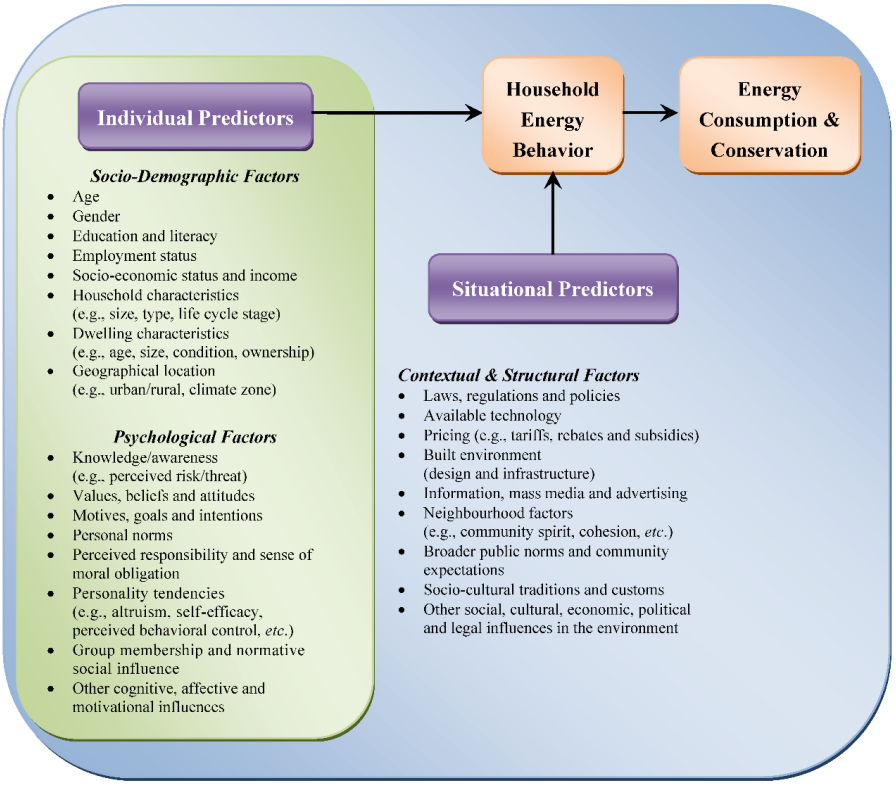

Figure 1. Integrative conceptualization of influencing factors (E. Frederiks et al., 2015)

While the first two relate directly to the individual and their personal circumstances, contextual factors refer to the larger socio-economic, political and communal context in which the person is living. Their influence is thus more indirect and cannot be easily changed on an individual level. For this reason, studies seeking to understand, and ultimately change, private energy consumption behaviour, mainly focus on socio-demographic and psychological factors, since contextual factors usually lie outside their scope and their intervention abilities.

This is also true for this literature review here. Even though contextual variables like energy pricing, energy-efficient technology availability and affordability, home ownership, ownership of technology, dwelling characteristics and so forth certainly do play a role for the prosumers in the SIT4Energy project and their choices, they do so at a different moment in time. These

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variables are, in a sense, prerequisites that influence if someone might become a prosumer or not in the first place and if so, what prosumer type they might become. While these are important processes, they lie outside the project's reach here, since the SIT4Energy IT-solutions are aimed at supporting *existing* prosumers in making energy-efficient choices. They cannot influence the contextual variables mentioned above and this is also not their aim. One exception are energy prices, since they might continue to influence prosumer's choices on an on-going basis. While they cannot be directly influenced by the SIT4Energy IT-solution they could be indirectly considered in terms of providing information about pricing and/or price forecasts if available (e.g.in case of dynamic pricing).

In the following, the socio-demographic and psychological factors of energy-related behaviour will be discussed in more detail, since they are more directly related to the aims and influence possibilities of the project.

Both sets of variables come into play in different situations and their impact might not always be straightforward. It might also vary depending on the specific behaviour that is being examined or might be mitigated by other variables factoring into the situation that have not been accounted for in the design of the study (Abrahamse & Steg, 2009). The explanatory power of these determinants is thus highly contextual and limited when examined on their own. They need to be understood in the specific context of the study and in their interaction with each other.

For example, it has been found that household energy consumption and energy saving are not related to the same determinants. While energy consumption is related to socio-demographic factors such as household income and size, but not to psychological factors, energy saving behaviours were more closely associated with psychological factors such as attitude, perceived behavioural control, personal norms, awareness of consequences and ascription of responsibility, and were not explained by socio-demographic factors. Moreover, different energy related behaviours were also associated with different determinants (Abrahamse & Steg, 2009).

This example shows the complexity of the issue and the many possibilities to conduct studies on it. A certain extent of the inconsistency found in the literature might thus be explained by differences in study design and the examined behaviours chosen by the researchers. Nonetheless, there is also a general consensus that certain factors do indeed play a re-occurring role when explaining individual energy consumption behaviours. This includes socio-demographic factors, such as income, education, household size, dwelling type, stage of family life cycle and psychological factors, such as knowledge, values, attitudes, motivations, intentions and social norms, among others (E. Frederiks et al., 2015).

For the context of the SIT4Energy project, which is concerned with prosumers specifically, it makes sense to start the discussion with a short overview of determinants relating to prosumers' choices before focusing on determinants for energy-related behaviour more generally. Figure 2 shows a classification of prosumers' needs and motivations that has been suggested by Rodríguez-Molina et al. (2014) in order to explain why people chose to become prosumers and what outcomes they might expect from this choice:

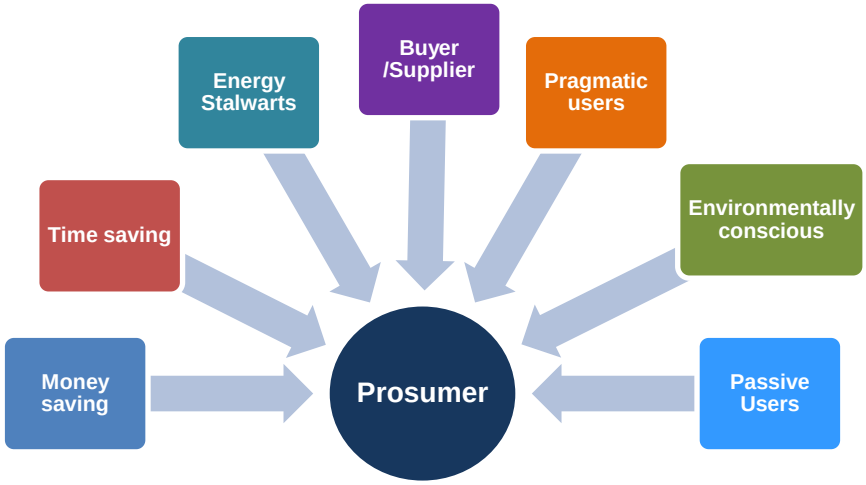

Figure 2. Prosumers value proposition based on Rodríguez-Molina et al., 2014 (Grimaldo, 2018)

According to these value propositions, prosumers are characterized by and concerned with the following seven aims and goals (Rodríguez-Molina et al., 2014, p. 6162): *Money saving* describes the fact that prosumers demand the lowest possible price for their energy. *Time-saving* means that prosumers prefer and require 'set-it-and-forget-it' solutions for managing their energy needs. *Energy Stalwarts* means that prosumers are motivated to adopt and appreciate the benefits of new technology. *Buyer/supplier* expresses the double role prosumers play as purchasers and sellers of energy. *Pragmatic users* means that prosumers are sensitive to new technology in energy usage but are also constrained by the risks and improvements involved. *Environmentally conscious* shows that eco-friendly and efficient energy options are central to prosumers. *Passive users* expresses prosumer's expectations around a 'no-frills service' without any surprises on the bills.

Overall, the reduction of electricity bills and environmental care have been identified as the two main drivers for consumers to become prosumers. The research reviewed in *D1.3. – User Information Models* has also shown that after becoming successful prosumers, consumers are starting to expect rewards for their services as producers (Grimaldo, 2018). These insights on prosumers' goals and motivations are useful to keep in mind for the following discussion of the factors that influence households' energy consumption and individual energy saving behaviour.

2.1 Determinants of energy consumption: socio-demographic factors

As already mentioned above, research suggests that socio-demographic factors do play a role for energy consumption behaviour. The main influences identified in the literature are education, employment status, household income, household size, home ownership, and stage of family life cycle. Technical expertise, time spent at home and the distribution of age within the household are also mentioned (Bhattacharjee & Reichard, 2011; E. Frederiks et al., 2015).

Education and **household income** are good examples for the multi-facetted role that socio-demographic factors play in the prediction of energy consumption behaviour. Generally, a higher level of **education** also increases the awareness of environmental issues and one might expect a more conscious (and therefore limited!) energy consumption as a result of this. And indeed, some studies have reported that higher education levels led to lower

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energy consumption or were a relevant factor for individual's efforts towards energy conservation (Bhattacharjee & Reichard, 2011). Yet, there is also ample evidence of the much-cited 'attitude-behaviour' gap, showing that there is no direct correlation between education levels and environmentally-friendly behaviours like energy saving (Courtenay-Hall & Rogers, 2002; Guagnano, Stern, & Dietz, 1995). Thus, while education is an important factor, it does not automatically reduce energy consumption. At the same time, education might also lead to a higher **household income,** which has also been found to be a strong predictor for a higher energy consumption in the home. Yet again, higher income households are also more able and willing to invest in energy-efficient technologies, appliances and products, which in turn might reduce their energy consumption over all.

Another variable that has a non-linear relationship with energy consumption is **household size**. While larger households tend to consume more energy, their energy use per capita is lower, due to residents sharing electric devices and services in the home. **Employment status** also influences energy consumption indirectly, as it impacts on the household income and the time spent at home. Both variables in turn have mixed effects on energy consumption.

As already mentioned, a lower income might prevent households from investing into energy efficiency measures but it also restricts their ability to pay for high energy bills, which might be an incentive to save energy. At the same time, **time spent at home** might also reflect a lower income, since most paid work is still being done outside the home, yet, a direct correlation has been found between energy consumption and time spent at home: the more time a person spends at home during the day, the more energy they use for their daily activities (Bhattacharjee & Reichard, 2011).

Time spent at home is also related to the **age distribution in the household** and the **stage of family life cycle**, which also influence the amount of energy being used. It has been found that families with young children where one or both partners stay or work from home, use considerably more energy than households without children where both partners work outside the home. This is usually explained with the changes in paid and domestic work patterns, due to child care and family activities that accompany the birth of a child.

Household energy consumption usually drops once children move out of home, but then tends to rise again in the later years of life, when people become elderly. Elderly people, who usually need a warmer room climate to feel comfortable than younger people, also tend to stay at home more (E. Frederiks et al., 2015; Van Raaij & Verhallen, 1983). The presence of especially young children and elderly people is thus also a predictor for an increased energy consumption in a household.

Gender has also been mentioned as influential on pro-environmental behaviour, but this finding is not consistent across studies (E. Frederiks et al., 2015; Kollmuss & Agyeman, 2002). It has been suggested that women generally tend to have less extensive environmental knowledge than men, but are more emotionally engaged with environmental causes and show more concern about environmental destruction. They also believe less in technological solutions, which makes them more willing to change their behaviour (Kollmuss & Agyeman, 2002). Yet at the same time, they are also often limited by gender differences in socio-economic conditions, such as exposure to poverty, and lifestyles, such child rearing responsibilities, being stay-at-home mothers, etc. that might prevent them from conserving energy. Overall, it has been found that gender-based differences tend to disappear once the effects of confounding variables such as household size, income and age are controlled for (E. Frederiks et al., 2015).

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The last socio-demographic factor that has been discussed in relation to its influence on energy consumption is **technical expertise**, especially when combined with home ownership, a higher disposable income and ownership of modern, non-energy home technology, such as 'high-tech' consumer gods like computers and other innovative technological home appliances (E. Frederiks et al., 2015). Individuals who fall into these categories might have a general affinity with technological innovation and might thus be more
inclined to also purchase more specific equipment to improve the energy efficiency of their homes (such as photovoltaic systems for their roof-tops or energy-efficient appliances). And indeed, some of the SIT4Energy prosumers might fall into this category, yet it would be wrong to assume that this is a tendency they all share.

In a similar vein, researchers have also suggested that **technical knowledge** that extends to DIY home repair skills, such as mechanical or electrical skills, could also a be predictor for energy conservation in the home, since these types of 'handyperson' might also be able to install and maintain energy-saving technology in their homes (Costanzo, Archer, Aronson, & Pettigrew, 1986). Yet, as we know from many other studies and contexts, ability alone is not a sufficient predictor for a certain behaviour to occur (see for example Fogg, 2009). And this is also true here: it has been shown that detailed technical knowledge is not directly linked to pro-environmental behaviour (Kollmuss & Agyeman, 2002). A reason for this might be the fact that purchasing and installing unfamiliar energy equipment oneself can turn out to be more of a hassle than one is willing to go through or require some complicated expert skills that an average DIY-handyperson might not possess in the end.

2.2 Determinants of energy consumption: psychological factors

The previous section has discussed how socio-demographic factors might predict, foster or prohibit positive energy-related behaviours in people. This section will now turn to the internal factors, which might influence these choices as well. Like it is the case with the socio-demographic factors, it has also been found that even though there is a vast body of research on the psychological variables impacting household energy usage, the reviewed findings were again 'far from consistent and conclusive' (E. Frederiks et al., 2015, p. 598).

As will be seen later in section 3, this inconsistency also extends to the determinant models using these variables, since different determinants are being used in different behavioural models, sometimes with interchangeable meanings, sometimes defined differently. It is therefore hard to always draw a distinct line between terms like intentions and motivations, or values and attitudes. In the following discussion, these terms will be grouped together in the way, they are also being used by the respective determinant behavioural models discussed in section 3, even though this might lead to occasional overlaps in terminology or lines of argument.

The key set of determining psychological factors that has been identified in the literature includes: knowledge and problem awareness of environmental and energy issues; beliefs, values and attitudes; motives, intentions and goals; subjective appraisals and perceptions as well as personality tendencies; and personal and social norms (E. Frederiks et al., 2015). They will be examined more closely in the following:

Knowledge and problem awareness of environmental and energy issues mean here specifically the understanding of energy costs and energy-saving behaviour, as well as their respective consequences. While there is a positive relationship between an individual's level of such knowledge and their efforts towards pro-environmental behaviour, this relationship is not straightforward. As is the case with education mentioned earlier, a higher awareness of

environmental issues does not necessarily translate into more environmentally-friendly behaviour, such as energy saving. Again, we are faced with the 'knowledge-action' gap

pointed out by various researchers before, which might be caused by other interfering factors that shape people's energy-related choices (Abrahamse, Steg, Vlek, & Rothengatter, 2005; Barr, Gilg, & Ford, 2005; Courtenay-Hall & Rogers, 2002). Some research even suggests that at least 80% of the motives for pro-environmental action are located in internal and situational factors *other than* knowledge and problem awareness (Kollmuss & Agyeman, 2002). This is an example for the strong interconnectedness of various influential variables that make it hard to identify single key variables as main predictors for energy-related behaviour.

Beliefs, values and attitudes are the variables that most research tends to focus on when examining energy consumption behaviour. Since they are very similar terms, it is important to define them first for a better understanding of the nuances. There is no universal definition of *beliefs* being used in the literature. In the context of environmental movements, they have been described as a set of ideas or convictions that environmental activists share about the world such as: '*human action has the potential for adversely affecting the biophysical environment' or 'changes in the biophysical environment can harm things people care about'* (Stern, Dietz, Abel, Guagnano, & Kalof, 1999, p. 82). In general terms, *beliefs* could thus be understood as firmly held opinions or as the acceptance of something as true and real, for which one might or might not have proof. *Values* have been defined as 'a global, abstract and relatively enduring set of beliefs, ideals and standards that serve as guiding principles in life' (E. Frederiks et al., 2015, p. 587). They thus have a more universal, moral component to them and are less factual than beliefs. Lastly, *attitudes* have been described as reflecting 'more specific positive or negative evaluations of a particular idea, object, person, situation or activity' (E. Frederiks et al., 2015, p. 587). *Attitudes* tend to be informed by our general values and specific beliefs. They can be understood like a lens, through which we see the world and make sense of it.

It has been found that even though attitudes are related to behaviour, they do not cause it necessarily. Again, there is a gap between the energy-conscious attitudes of an individual and their actual energy consumption behaviour. Attitudes may lead to 'good intentions' but may be blocked by other internal and situational factors from actually being realized. Such intervening factors between attitudes and behaviour include the acceptance of personal responsibility, energy knowledge and knowledge of effective actions (or lack thereof), the perceived effectiveness of one's contribution, self-efficacy, (expected) cost-benefit trade-offs, and social norms, to name a few (E. Frederiks et al., 2015; Van Raaij & Verhallen, 1983).

This 'attitude-action gap' (sometimes also 'value-action gap') is not limited to energy consumption alone, but can be observed across all aspects of human life (E. Frederiks et al., 2015). The discrepancy between one's knowledge, values and attitudes and one's actual behaviour in daily life, which can sometimes be quite detrimental to those, has been explained by researchers either with the presence of intervening factors such as the ones named above, or with the way people generally make decisions in life. It has been argued, that people typically make choices and behave in ways that minimize their immediate personal costs while maximizing their benefits in terms of time, effort, money, comfort, and so forth, rather than basing their decisions on what is 'best' for others and the environment
(E. Frederiks et al., 2015). Short-sighted selfishness might thus be the main intervening factor blocking the necessary, but inconvenient long-term investments in a better future for all.

Motives, intentions and goals are another set of variables often examined by researchers. *Motives* are conceptualized as 'the driving forces or impulses that initiate, guide and maintain goal-directed behaviour' (E. Frederiks et al., 2015, p. 588). In other words, they explain why a person is acting in a certain way at a given time. Closely related to this is *motivation* as 'the process that shapes the intensity, direction and persistence of effort' toward achieving a

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particular goal (E. Frederiks et al., 2015, p. 588). Not so clear, however, is the meaning of *intentions*, which are not defined explicitly in the literature but are commonly understood as something that one wants to achieve or is planning to do. Using the definitions above, *intentions* could thus simply be understood as another dimension of the 'goal-directed behaviour' that is set in motion by the initial motive and is further shaped by motivation. Cut short, motives could be seen as the initial *why*, motivations as the *how* (*much)* and intentions as the *to what end* of a 'goal-directed' behaviour. Thus, while *motives* are suggested to be the initial driving forces propelling an individual forward in life, the direction, form and shape that a person's actual or planned behaviour is taking in order to achieve a certain goal or outcome, might in turn be directly or indirectly shaped by his/her *motivations* and *intentions*.

The literature differentiates five different types of *goals: self-transcendence, self-enhancement, hedonic, gain and normative.* This distinction is being used in Goal Framing Theory, which will be explained in more detail in section 3. For now, the definition and evaluation of their impact shall suffice. *Self-transcendence goals* aim at promoting the interests of others and the external world; the individual thus reaches beyond the boundaries of his/her own self-interest in order to further a goal that is larger than him/herself. Not surprisingly, *self-transcendent goals* have been found to have a positive relationship with pro-environmental behaviour. Unlike *self-enhancement goals*, that seek to solely further one's own self-interest, which have been found to be either statistically non-significant or negatively correlated with environmental-friendly action. *Hedonic* goals express the desire to achieve positive self-esteem and improve how one feels at a particular moment. *Gain* goals are aiming to protect and improve one's resources and possessions and *normative* goals express the desire to act appropriately, meaning in line with social and moral standards (Cibinskiene et al., 2017). The impact of these three goal 'frames' on energy consumption behaviour has not yet been explicitly measured, but while it has been argued that multiple goals are usually present and acted upon at the same time, *hedonic* goals are assumed to have the strongest effects on people's behaviour (E. Frederiks et al., 2015).

In the context of environmental behaviour, moral and normative concerns that stem from altruistic motives based in pro-social and biospheric value orientations have been found to be positively related to pro-environmental behaviour, suggesting that there is a moral component to environmental concerns and efforts, that reaches beyond the egoistic cost-benefit maximization suggested by some. The terms used here are based on Stern et al.´s (1999) adaptation of Schwartz' (1977) theory on altruism, which seeks to explain the occurrence of altruistic behaviour. The authors distinguish between an 'altruistic' or 'social' orientation, which is concerned with alleviating the suffering of others, an 'egoistic' orientation, aimed at preventing one's own harm or suffering, and a 'biospheric orientation', which is concerned with ending the destruction and suffering in the non-human world (Kollmuss & Agyeman, 2002, p. 245).

These three orientations are present in everyone, yet developed to a different extent. They are seen to be causal for the development of environmental concern, with egoistic values having found to be the strongest influence, followed by social and biospheric value orientations (Kollmuss & Agyeman, 2002). This finding bridges the gap between purely egoistic or altruistic conceptions of environmental behaviour in humans, since it is also in every person's self-interest not to destroy the environment.

Yet, egoistic motivation, even though it might cause environmentally-friendly behaviour in some cases, only does so as long as the eco-friendly behaviour also serves the self-interest of the person at the same time. It can thus be argued that this type of environmental effort remains superficial and is easily overridden by other factors. Egoistic orientation becomes a hindrance to environmentally-friendly behaviour the moment this particular behaviour is seen as detrimental to one's own interest, like in the example of not flying to the tropics for a

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holiday (Kollmuss & Agyeman, 2002). It can thus be argued that, even though weaker in their influence on eco-friendly behaviour, it is actually the social and biospheric orientations that serve to create more reliable sustainable habits in people.

It has also been found that *intrinsic motives* weigh stronger than external pressures or rewards for individuals to engage long-term in sustainable behaviour (De Young, 2000). If an individual is motivated by personal interest, enjoyment or satisfaction stemming from an activity itself, it makes sense that the person naturally engages in this activity. Environmental sustainability has the potential to inspire four different kinds of intrinsic satisfactions in people: striving for behavioural competence, such as gaining satisfaction from solving problems and completing tasks; enjoying one's survival on limited consumption, which entails the careful management of finite resources; satisfaction from participating in the community; and satisfaction from luxuries, such as convenience and access to new/novel products (De Young, 2000; Kollmuss & Agyeman, 2002).

Yet, once again, while ecological motives and intentions are important for durable, environmentally-friendly behaviour to occur, the relationship between intentions and actions remains weak. A notable 'intention-behaviour' gap has been found in the literature, showing that while people with eco-friendly intentions may be generally more inclined to engage in energy-saving behaviour, it is not enough to simply possess these intentions for such behaviour to also occur (E. Frederiks et al., 2015). In fact, a meta-analysis concluded that a medium-to-large sized change in intention leads to only a small-to-medium change in behaviour (Webb & Sheeran, 2006). The reason for this might be that such intentions are based on general pro-social, pro-environmental values and motives, but are often trumped by more immediate concerns that are perceived as more pressing because they evolve around one's own personal needs, such as being comfortable, or saving time and money, and so forth (Kollmuss & Agyeman, 2002). It seems that moderating factors are once again decisive when it comes to successfully translating eco-friendly behavioural intentions into respective actions.

Subjective appraisals and perceptions, as an umbrella term, includes various sub-sets of variables relating to personal tendencies and judgements, such as perceived responsibility; locus of control, self-efficacy, and perceived behavioural control; perceived cost - benefit ratio; the need for personal comfort and inertia to change (Bhattacharjee & Reichard, 2011; E. Frederiks et al., 2015).

Perceived responsibility means that an individual attributes the responsibility for environmental degradation to their own actions and lifestyle choices, such as excessive energy consumption, air travel etc., rather than shifting the blame away from themselves to other people and social actors like state authorities or the industry. It has been shown that assuming responsibility for environmental problems in this way is also positively related to pro-environmental efforts, such as saving energy and consuming more sustainably. This makes sense, given the fact that being part of a problem entails a greater moral obligation to also try and find solutions to it, than if one feels to be merely an innocent by-stander. Perceived responsibility is thus also linked to individual ***personal norms*** of moral responsibility, which also require an awareness of the negative consequences of one's own behaviour in order to be activated and acted upon (E. Frederiks et al., 2015).

Locus of control, self-efficacy, and perceived behavioural control all relate to a person's perception of whether they have the capability to enact change through their own behaviour and whether they cause or control events that impact on them or not. People who have a strong internal locus of control tend to ascribe what happens to their own actions, while people with an external locus on control have the feeling that their actions are rather insignificant and are determined by external factors or powerful others. Perceived

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behavioural control and self-efficacy, as expressions of an internal locus of control tend to be positively associated with pro-environmental behaviour like energy conservation. This is not surprising since it would be natural to assume that individuals with a more external locus of control would be less motivated to engage in such actions since they would be more likely to perceive them as futile or inconsequential (Hines, Hungerford, & Tomera, 1987). However, different studies have produced mixed results on this. There is also evidence suggesting that even though some people might share similar perceptions of behavioural control their actual behaviour still often differs (Sheeran & Abraham, 2003).

Perceived cost - benefit ratio has already been mentioned several times in this discussion. It alludes to the idea that individuals seek to maximize their benefits and minimize their costs when making decisions. In terms of energy usage, it has been shown that people were more likely to make investments to improve energy-efficiency when they perceived their energy costs to be high, than if they perceived their costs to be low (Nair, Gustavsson, & Mahapatra, 2010). This suggests that increased energy prices may motivate consumers to actively reduce their energy consumption.

Research has also shown that timing plays a major role in creating behavioural inconsistency (E. Frederiks et al., 2015): People tend to be very short-sighted when costs or benefits are immediate, but more farsighted when all costs and benefits are in the future. This cognitive bias can lead to seemingly 'irrational' choices and courses of action, as is often the case with energy consumption. People's tendency to delay actions because they are viewed as costly in the short-term, despite offering long-term benefits also means that, consumers may be reluctant to pay the high financial prices for one-off efficiency measures today, even if they generate substantial monetary savings on energy bills and important environmental benefits, such as reduced carbon emissions, in a few years' time. This reluctance has also been described as ***inertia to change*** (Bhattacharjee & Reichard, 2011). In short, it has been well documented that people value immediate rewards and seek to avoid immediate costs far more than they value future rewards and try to avoid future costs.

Need for personal comfort or the perceived loss thereof when adopting energy saving measures has been found to have a strong impact on household energy consumption. Energy consumption in the home is greatly shaped by perceptions around health and comfort: the more energy-saving is perceived as leading to discomfort or ill-health, the more energy is consumed by the household (E. Frederiks et al., 2015).

The variables discussed so far have been focusing on individuals only, leaving out their social context until now. However, **social norms** have been found to majorly shape people's behaviour, also in relation to energy, where *normative social influence* is said to be especially powerful (E. Frederiks et al., 2015).

Normative social influence refers to the explicit and implicit rules, guidelines and behavioural expectations within a group or society that guide what is considered normal and/or desirable. The power of social comparisons and an inherent tendency to seek normalcy in the form of conformity with a social group has been confirmed by various studies. Group membership and normative perceptions regarding acceptable energy-related practices are having significant impacts on energy consumption and conservation, because people tend to compare and orientate their behaviour to those around them (E. Frederiks et al., 2015).

What is especially interesting hereby to note, is the importance of the way how information is being diffused. Studies have shown that people tend to favour interpersonal sources of information such as friends and family over expert advice, even if the former are less informed about the subject (Costanzo et al., 1986; Stern, 1992). It has therefore been

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suggested that friends and family may be more influential than official channels of communication, like for example the media, in achieving sustained reductions in energy use. The reason for this seems to be the fact that information spread via social diffusion tends to be more vivid, making it easier to be perceived and positively evaluated. It tends to also be better understood and remembered than the relatively impersonal information transmitted via traditional means of education, marketing and advertising (E. Frederiks et al., 2015).

2.3 **Summary**

This section has provided an overview of the current body of knowledge concerning the main influencing factors on household's energy consumption and individual inclinations towards pro-environmental actions, such as energy conservation. Two main points have become obvious: first, there is a plethora of socio-demographic and psychological factors influencing energy consumption and environmentally-friendly energy-related behaviour. Second, these variables tend to be very closely interrelated, which makes it difficult to pinpoint the influence of a singular factor without also considering the others. It seems that no matter, which determinant is being examined, the influence of moderating and mediating factors is always considerable, weakening and diffusing the impact of each variable in complex, non-linear ways. This inconsistency of influence and of the resulting energy-related behaviour has to be taken into account, when considering the issue.

It is therefore not surprising to routinely find considerable gaps between people's knowledge, values and attitudes towards environmental concerns and their actual behaviour in daily life. The substantial discrepancy between people's 'good intentions' and their actual behaviour seems to be one of the few consistencies that can be drawn from this literature review. These gaps also explain why many psychological factors (like values, attitudes and beliefs) often fail to reach statistical significance in explaining subsequent energy behaviour, especially when compared to the effects of socio-demographic factors, that seem to be more stable and less messy in their influences than psychological variables overall (E. Frederiks et al., 2015).

One important conclusion, however, might be drawn from this: Energy-saving initiatives that successfully manage to bridge the 'intention-behaviour gap', have the chance to unlock a significant potential for energy conservation. It seems that enabling people to *consistently act* in accordance with their underlying pro-environmental values, beliefs and attitudes would be a crucial step towards achieving tangible changes in their energy-related behaviour. To do so, it is necessary to gain a clearer understanding of behavioural change models and possible intervention strategies. This will be the topic of the coming section.

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3. Behavioural change models and interventions (HOST)

Different models and perspectives have been developed by many researchers seeking to conceptualise pro-environmental behaviour in more encompassing models that go beyond the impact of single variables alone. Given the high contextuality of the energy-related determinants discussed earlier, this surely makes sense. Some of the most commonly cited perspectives using determinants as focal points for research and design of interventions include Ajzen's (1991) *Theory of Planned Behaviour* (TPB), Schwartz' (1977) *Norm Activation Model* (NAM), that has later been developed further by Stern et al. (1999) into their so-called *Value-Belief-Norm* (VBN) theory, *Goal Framing Theory*, *Fogg's Behaviour Model* (FBM) and Kollmuss and Agyeman's (2002) *Model of Pro-Environmental Behaviour.*

While these models conceptualise (pro-environmental) behaviour more generally, other models have focused exclusively on household energy consumption, such as Van Raaij and Verhallen's (1983) *Behavioural Model of Residential Energy Use* and Costanzo et al.'s (1986) *Socio-psychological Model of Energy Conservation Behaviour*. Prosumers have not received a lot of attention from researchers yet, but this is slowly changing. In their study on Danish prosumers, Hansen and Hauge (2017) have applied their *CIM-model* of social practice to examine the transition consumers undergo when becoming prosumers. There are also a few models focusing on the process rather than the determinants of behavioural change and intervention strategies. Out of these, Bamberg's (2013) *Stage Model of Self-Regulated Behavioural Change* and Michie et al.'s (2011) *Behavioural Change Wheel* are deemed the most relevant for the context of this project. Given the limited space and scope of this literature review, not all models will be discussed in detail. But a short overview of their main arguments will be given in the following.

3.1 Determinant behaviour models

The models discussed in this section fall into the category of the so-called *determinant behaviour* models, which focus on specific factors or variables in order to explain human behaviour. They are different to the *process models*, which have a distinct interest in how behavioural change is achieved over time and what cognitive processes are involved in order achieve such a change. These types of models will be discussed in section 3.2.

3.1.1 Theory of Planned Behaviour

Despite some criticism concerning the somewhat contested rational choice rationale underlying this behavioural model and other limitations regarding its explanatory power, Ajzen's (1991) theory of planned behaviour, or TPB, remains one of the most influential determinant behavioural models and has been applied in many different settings and contexts.

Figure 3 provides a modified, extended version of the model and its variables.

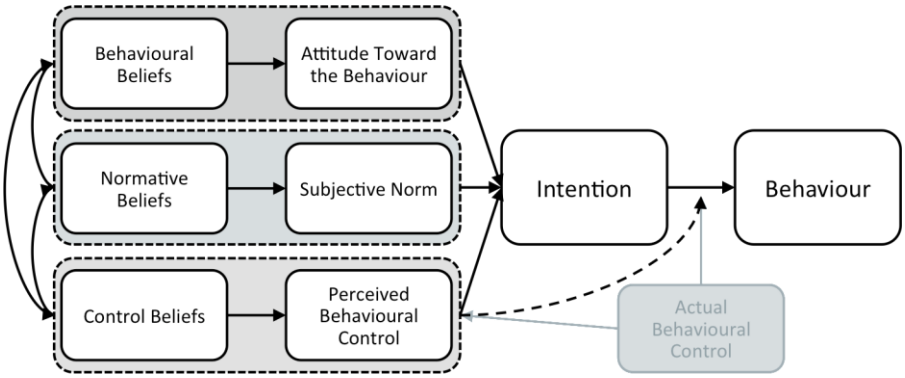

Figure 3. Theory of Planned Behaviour Model based on Ajzen (Ajzen, 1991; Cibinskiene et al., 2017)

There are three sets of beliefs: *behavioural beliefs*, reflecting an individual's subjective assessment of the probability that a behaviour will elicit certain consequences, *normative beliefs* referring to perceived behavioural expectations stemming from the individual's social context, such as important individuals or reference groups, and *control beliefs* describing the individual's perceptions of the factors that might facilitate or hinder a certain behaviour. *Behavioural beliefs* inform individuals' *attitudes* towards the behaviour, which are defined here as an individuals' subjective positive or negative evaluation of their own performance regarding this behaviour. *Normative beliefs* lead to the formation of *subjective norms*, which mean here the perceived peer pressure to engage in or sustain from a certain behaviour. *Control believes* are the antecedents of *perceived behavioural control*, which is defined here as an individual's perception of the ability to perform a particular behaviour (Ajzen, 1991; Cibinskiene et al., 2017).

As
Figure 3 shows, the model assumes a direct relationship between intention and behaviour, which might be too simplistic, given the findings of the studies discussed earlier. And indeed, the fact that this model does not explain the intention-behaviour gap is seen as one of its main shortcomings. Another criticism relates to the fact that the model is limited to very specific beliefs as predictors for certain behaviours but does not account so much for the way, in which more general beliefs impact environmental behaviour (Cibinskiene et al., 2017).

The TPB proved to be successful in explaining various types of environmental behaviour, such as travel mode choice among university students, household recycling, composting, the purchase of energy saving light bulbs, unbleached paper use, water use, and meat consumption (Lindenberg & Steg, 2007). Attitudes were hereby often found to be the strongest contributors to the explanation of pro-environmental intention or behaviour, suggesting that people tend to engage in pro-environmental behaviour if they think that it has positive consequences for themselves (Lindenberg & Steg, 2007). In their study of university students' travel mode choices, Bamberg and Schmidt (2003) found the TPB more successful in explaining travel mode choice than as a model for the activation of moral norms. Still, all relations postulated by the TPB were confirmed empirically with one exception: Perceived behavioural control did not have a direct effect on the actual car use (Bamberg & Schmidt, 2003).

3.1.2 Norm Activation Model and Value-Belief-Norm theory

Schwartz' (1977) Norm Activation Model, or NAM, which is part of his theory on altruism discussed in earlier sections, has been used by many researchers as a starting point for further extensions and modifications. It has also been successfully applied to the context of environmentalism. As Figure 4 shows, Schwartz initially assumes a rather straightforward

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relationship between initial problem awareness and the subsequent steps that are leading to pro-social intentions and behaviour.

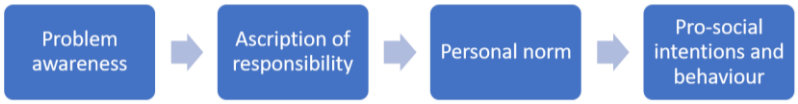

Figure 4: Sequential interpretation of Schwartz' (1977) NAM model (Cibinskiene et al., 2017)

As already discussed above, more recent research has shown that this understanding does not sufficiently reflect the complexity of human decisions making when it comes to acting in pro-social and environmentally-friendly ways.

Figure 5 below is an example for an extended version of the model conceived by Han (2014), which introduces the variables *attitude toward the behaviour* as mediating factor between *awareness of consequences* and *behavioural intention.* It also introduces the *anticipated feelings of pride and guilt* that environmentally-friendly or -harmful behaviours may induce in a person and which might lead to the activation of *personal norms*. The consideration of how *social norms* influence the formation of *behavioural intention* was another important addition to the model. The introduction of these variables allows for more fluidity in the conceptualisation of the decision making process, while maintaining the basic idea of a norm-based approach for the explanation of environmentally-friendly behaviour. Another distinctive change to the original model includes the fact that it is now aiming to explain how *behavioural intentions* are formed, not how these intentions translate into real-life behaviours. This artifice elegantly circumnavigates the problem of the intention-behaviour gap. When tested in the field, the findings revealed a good fit with the extended model (Cibinskiene et al., 2017).

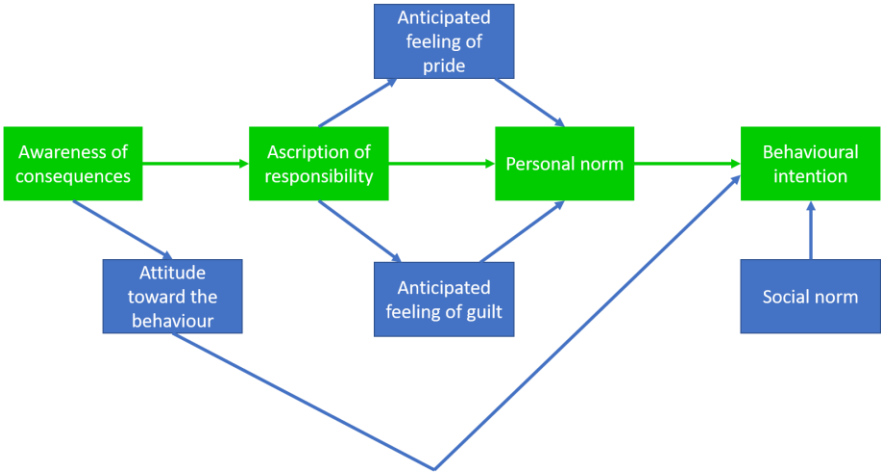

Figure 5: Extended NAM model based on Han et al., 2014 (Cibinskiene et al., 2017)

Another variation of Schwartz's initial ideas can be found in Stern's Value-Belief-Norm theory (VBN) of environmentalism (Stern, 2000), which maintains the initial distinction of egoistic, altruistic and biospheric value orientations but then elaborates further on how these values inform environmental beliefs that lead to many different forms of pro-environmental behaviour and activism.

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Stern's (2000) model offers a more differentiated view on the various types of 'environmentally significant behaviour' and the social spaces in which such actions can occur. His model is based on the theoretical groundwork put forward by Schwartz, which suggests that altruistic behaviour (and pro-environmental behaviour can be seen as such) is a moral response in individuals (activation of personal norms), who perceive certain conditions as posing threats to others (awareness of adverse consequences, or AC) and believe that they can take actions to alleviate this (ascription of responsibility to self, or AR). The model also draws on other theories such as value theory and the New Environmental Paradigm (NEP) theory, which will not be elaborated on further in this context.

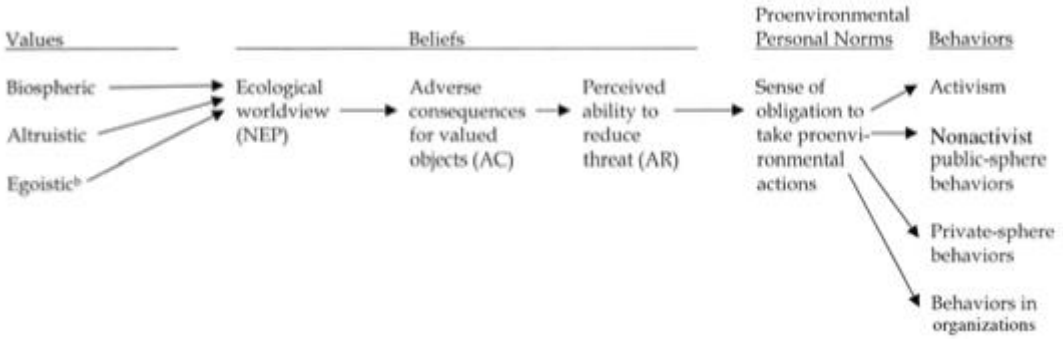

Figure 6. Variables in the VBN theory of environmentalism (Stern, 2000)

As shown in Figure 6, Stern's model suggests a causal chain of variables that directly affect each other in a one direction flow. Starting from the relatively stable, central elements of personality and belief structure, the chain moves to more specific beliefs about human-environment relations (NEP), their consequences, and the individual's responsibility for taking corrective action (Stern, 2000). It is hereby central to note that personal norms to take pro-environmental action are activated by beliefs that environmental conditions *threaten* things the individual values (AC) and that the individual can act to reduce the threat (AR). These two aspects (beliefs about human-environment relations and perceived adverse consequences to valued things and beings) are seen as the decisive elements for the activation of personal norms, which lead to the adoption of a general environmentalist predisposition from which all kinds of behaviours with pro-environmental intent will follow (Stern, 2000).

Another novel aspect in Stern's discussion of environmentalism is the differentiation between an impact-oriented view, measuring the direct or indirect impact that human behaviours are having on the environment, and an intent-oriented view on environmental action, measuring what people are intending to achieve with their activities (regardless of their success). This broadens the way in which environmentally significant behaviour can be understood and evaluated, thus allowing for a more differentiated understanding of human actions and inactions in this domain. In a study testing this theoretical framework, strong initial support was found for the VBN theory's assumption that personal moral norms are the main basis for individuals' general predispositions to pro-environmental action (Stern, 2000).

In summary, all three theories discussed so far give reasons to suggest that personal and social norms might indeed be a means through which certain behavioural intentions could be activated in users, after making them aware of the consequences of their behaviour first.

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3.1.3 Goal Framing Theory

This theory has already been partially touched on in the previous section and will only be briefly resumed here. Goal framing theory belongs to the field of cognitive social psychology which examines the influence goals have on cognitive processes. As already mentioned earlier, 'the central idea is that goals govern or "frame" what people attend to, what knowledge and attitudes become cognitively most accessible, how people evaluate various aspects of the situation, and what alternatives are being considered.' (Lindenberg & Steg, 2007, p. 119). It is therefore a modular model of explanation, which is able to integrate different motivations and influences on a person's decision making behaviour, depending on the specific context and situation.

Representatives of this perspective argue that even though the NAM and VBN theory are quite successful in explaining 'low-cost' environmental behaviour and 'good intentions' (like the willingness to change or sacrifice, policy acceptability and the like), they have less explanatory power in settings where behaviour change is highly constrained by costs in terms of effort, inconvenience, money, or time (Lindenberg & Steg, 2007). The so-called 'low-cost hypothesis' of normative behaviour states that concerns with gain will quickly over-ride concerns with norms when costs increase (Diekmann & Preisendörfer, 1992), a re-occurring hypothesis in this literature review. However, goal framing theory can also account for these types of high-cost situations by arguing that normative concerns are then not completely absent, but are more directly competing with other goal frames, such as the gain goal, which is weakening but not erasing their influence on the final decision (Lindenberg & Steg, 2007). This flexibility is making it a potentially more encompassing model than the previous ones, as it mirrors the shifting aims and desires of people without losing explanatory power.

An important aspect of this theory is the fact that even though all three goals are present simultaneously, the switching of focal 'frames' does not happen intentionally, but is instead the result of 'automatic priming effects' caused by internal and external cues that trigger the goal and give it temporarily a stronger weight than the other two (Lindenberg & Steg, 2013). Such cues can be manifold. They can be verbal primes, socially full or empty environments, instructions by - or the mere presence of - significant others and even simply the goals of others. All these factors can cue goal frames to shift, without any deliberate choice involved.

Given the fact that norms are 'smart' or abstract (such as the norm to act pro-environmentally, which does not tell us what to do), they require cognitive effort in order to be translated into moral behaviour, leaving plenty of room for individuals to rationalize hedonic and gain-oriented behaviour as moral behaviour. It has been found that even concrete information does not always prevent this type of moral hypocrisy from occurring, where people stretch norms in order to suit themselves while still feeling good about themselves and their actions (Lindenberg & Steg, 2013). Knowing this tendency in people, goal framing theory can be particularly useful for the design of concrete interventions that support people's self-regulation by taking the triggers of hedonic or gain goals that are contrary to pro-environmental behaviour and their moral rationalisations into consideration. For the example of energy-use, it has been suggested that consequent and frequent feedback might help prevent the interference of this type of self-serving rationalisations and misconceptions about one's own behaviour.

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3.1.4 Fogg's Behavioural Model of 'Motivation-Ability-Triggering'

Another model that is working with the idea of 'cues' or 'triggers' is Fogg's Behavioural Model (FBM) of 'motivation-ability-triggering' (Fogg, 2009), which is coming out of persuasive system design, where socio-technical systems are meant to support behavioural change. Even though it has a limited validity due to its lacking theoretical foundation and the limited conceptualisation of the terms it uses, it is frequently being used by persuasive system designers due to its intuitive appeal. The essential assumption of this model is that for a person to perform a target behaviour three factors need to be present simultaneously: The person must be sufficiently motivated, have the ability to perform the behaviour, and needs to be triggered to perform the behaviour.

As shown in Figure 7 below, increasing *motivation* and *ability* are said to also increase the likelihood of behavioural change to occur, meaning that there are two possible levers for behavioural interventions: increasing the motivation or making the desired behaviour easier. Yet, sufficient motivation and ability alone are not enough to induce behavioural change, a *trigger* is also needed to set it off. In order to be effective, a trigger has to fulfil three conditions: It must get noticed by the user, it must be associated to the target behaviour and it must be well-timed, at a moment where both the motivation and the ability is high (Novak et al., 2018). In order for a trigger to successfully induce the target behaviour, the ability level and motivation level of the individual must be above a so-called 'behavioural activation threshold'.

Fogg (2009) distinguishes three types of contrastive pairs of motivation that can be targeted by interventions seeking to increase motivation for behavioural change: pleasure – pain, hope – fear, social acceptance – rejection. In order to increase ability, systems have to be made simple, by limiting the amount of time and money one needs to invest to perform the target behaviour, and by reducing the physical effort and amount of thought required to perform it. It is also important to make sure people do not have to go against established social norms (social deviance) or depart too far from their existing habits (non-routine).

Depending on the situation, different triggers need to be used. If a person lacks motivation, a *spark* is needed combining the trigger with a motivational element, such as a video that instils hope or fear for example. If a user is sufficiently motivated, but lacks ability, a *facilitator* is needed, aiming to trigger the behaviour while also making it easier to do. Like sparks, a facilitator can be embodied in text, video, graphics, and the like (Fogg, 2009). Lastly a *signal* is used when people have both sufficient ability and motivation to perform the target behaviour but need a reminder to engage in the target behaviour.

Goal Framing Theory and Fogg's Behavioural Model both draw attention to the importance of triggers as drivers for behavioural change. This is important for the SIT4Energy context, since energy behaviour usually has a low level of involvement and attention, even though this might slightly more elevated in prosumers. Nonetheless, it can be argued that triggering the attention of the SIT4Energy users in opportune moments, might be a useful means of engagement. However, such types of design decisions will have to wait until a later point in the project.

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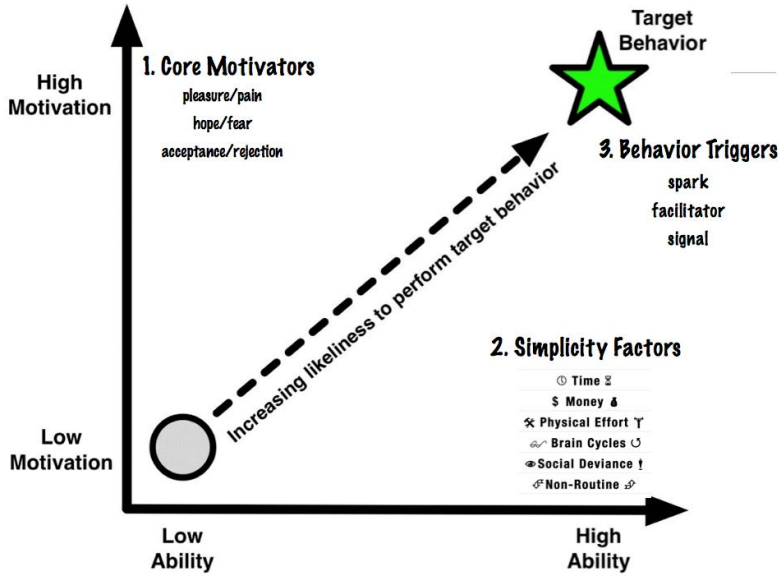

Figure 7: The Fogg Behaviour Model (Fogg, 2009).

3.1.5. Model of pro-environmental behaviour

Lastly, a brief look shall be casted onto the pro-environmental behaviour model designed by Kollmuss & Agyeman (2002). Their model is interesting because it pays attention to the manifold barriers that block pro-environmental behaviour. As shown in Figure 8 below, they identify old behaviour patterns as one of the largest barrier to pro-environmental behaviour, which is an aspect that previous models have not explicitly mentioned.

Habitual behaviours are substantial drivers of energy consumption in the home as well (for example heating and ventilating the home, washing clothes, showering, cooking etc.) and are often targeted by behavioural interventions seeking to reduce energy consumption in households. Habits have been defined as 'automatic behavioural tendencies that arise as a result of repetition and practice of actions in similar situations' (Ouellette & Wood, 1998). Bamberg & Schmidt (2003) also mentioned the effect of habit on the car use of the students in their study, suggesting that car use is a 'habitual choice process' that involves 'routine-shaped automatic associations between stimulus situations and habitually chosen options', once conscious considerations about pros and cons were made. Habits mark therefore the end of a deliberate cognitive process. They are reinforced by the frequency with which the behaviour occurs and are only changing slowly over time.

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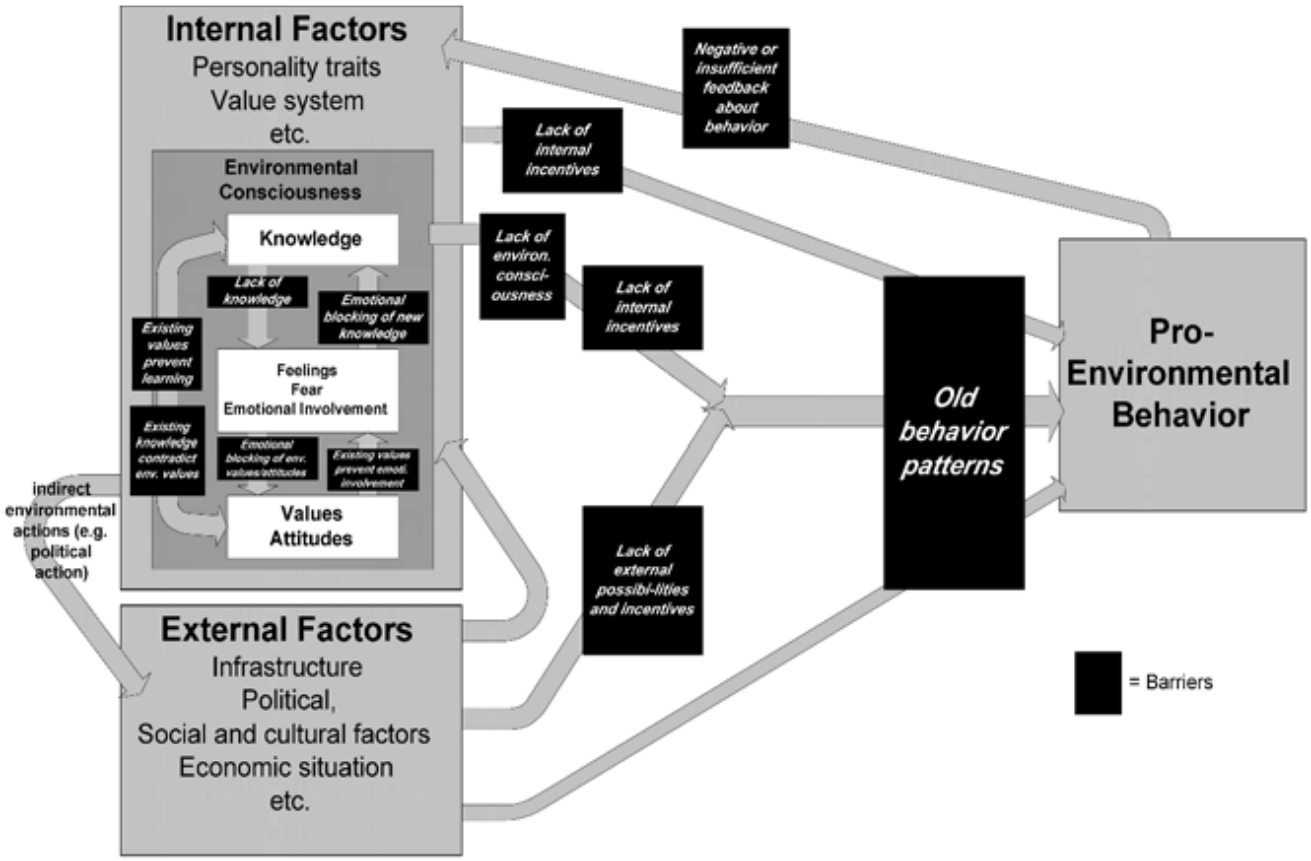

Figure 8. Model of pro-environmental behaviour (Kollmuss & Agyeman, 2002).

Interventions interested in achieving a reduction in energy consumption often seek to inspire so-called 'curtailment' behaviour in people, which is the habitual reduction of a harm causing activity and its replacement by more environmentally-friendly alternatives of action. Habit-driven curtailment behaviours need to be repeatedly encouraged until they become daily routines with the potential to reduce energy consumption in a lasting manner. Their counterpart are one-off purchasing decisions (such as home appliances with good energy ratings or, applied to our context, technologies like PV-systems), which can also be targeted by intervention measures but are less often the focus of these types of efforts. However, in the context of the SIT4 energy project, both types of behaviour might be relevant for the prosumers and are valuable to keep in mind for later design decisions.

3.1.6 Specific models of residential energy use

While the models discussed so far have been focusing on explaining how people make (pro-environmental) behavioural decisions when confronted with competing goals and shifting contexts and situations, the following models are more specifically designed to understand residential energy consumption and conservation, two topics that are also relevant for the understanding of prosumers.

3.1.6.1 Behavioural model of residential energy use

Overall, this model is the most comprehensive one discussed so far. It accounts for a large amount of the variables discussed in the literature and brings them together in a meaningful way. As shown in Figure 9 below, this model includes not only socio-demographic and

individual or 'person' variables, social and situational factors, but also contextual and structural conditions when explaining households' energy use. It also serves as a useful overview of the determinants influencing residential energy use. While most variables have already been discussed in the literature review, a few central aspects of the model shall be highlighted in the following.

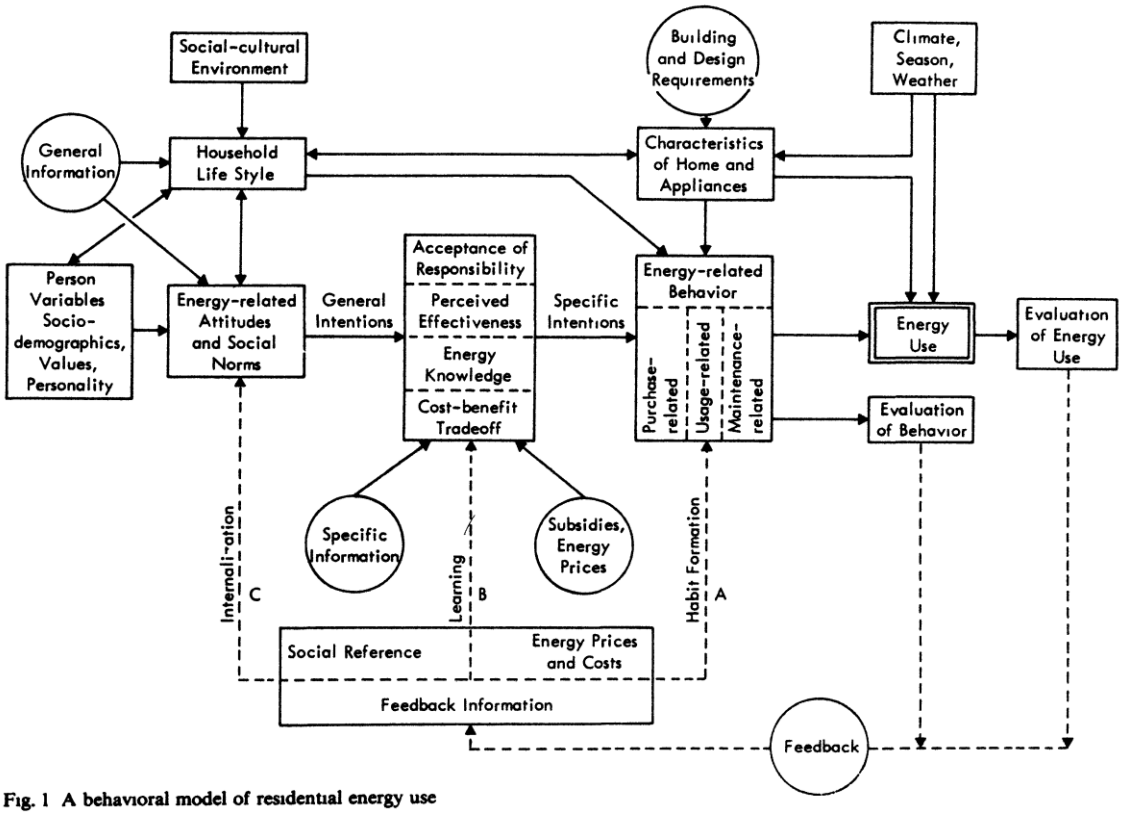

Fig. 1 A behavioral model of residential energy use

Figure 9. Behavioural model of residential energy use (Van Raaij & Verhallen, 1983)

Energy use is conceptualised as a dependent variable of energy-related behaviour, season, climate and weather conditions and home characteristics and appliances. Energy-related behaviour is distinguished in three types: *Purchase-related* behaviour includes the purchase of household appliances, heating equipment, and ventilators, and the consideration of their energy efficiency during the purchase process. *Usage-related* behaviour refers to the day-to-day usage of appliances in the home and of the home itself. It is the frequency, duration, and intensity of the use. *Maintenance-related behaviour* refers to the behaviour aiming to maintain the in-home heating system and appliances. This includes servicing, small repairs and small home improvements (Van Raaij & Verhallen, 1983). Different types of behaviour are influenced by different factors. While habits inform daily usage decisions, perceived effectiveness has a direct effect on one-off purchase decisions.

This model also accounts for the *attitude – behaviour gap* mentioned in previous sections, by introducing *acceptance of responsibility, perceived effectiveness, energy knowledge and cost-benefit considerations* as intervening factors between attitudes and behaviours. Energy related *attitudes* entail concerns about the environment, the energy supply, and health and well-being, such as the concern with personal comfort and warmth for example (Van Raaij & Verhallen, 1983).

An interesting feature of the model are the *feedback loops* that connect the evaluation of energy use and behaviour with the intervening factors between attitudes and behaviour, and

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the energy-related attitudes and social norms. Feedback information is said to include information about energy use in a particular period, for a particular activity, or momentary energy use. The authors suggest that 'the shorter the feedback period or the better related to a specific activity, the more effective the feedback information will be' (Van Raaij & Verhallen, 1983). Interestingly, maintenance behaviours feed directly into the feedback loop since they are an opportunity to evaluate one's behaviour and its outcomes.

Energy prices are identified as another important factor of the feedback loop. While price increases tend to reduce demand (at least temporarily), the price elasticity of energy may be relatively limited, meaning that large changes in price might only lead to a comparatively small amount of change in the quantity demanded (Van Raaij & Verhallen, 1983). Returning to the initial points made about prosumers at the outset of this discussion, it could also be argued that today, high energy prices might sometimes also have another effect: they might be an incentive for some consumers to search for alternative options of energy supply, such as potentially becoming a prosumer.

The model also seeks to identify the factors that can be successfully influenced by an energy-conservation campaign. In Figure 9, these are marked with circles and include:

(1) *General information* concerning the energy problems of the society at large, such as energy-supply, energy-inefficiencies of products and lifestyle, and related political questions.
(2) *Specific information and behavioural advice*, referring to energy costs, the energy usage of certain behaviours, and the effects of energy-conserving behavioural change.
(3) Subsidies and energy prices
(4) Building and design requirements
(5) Feedback information

Figure 9 also shows how these five factors are related to energy use and where they are situated within the model. The authors suggest for example, that general information has the longest path to energy use and will thus probably be the least effective when compared with the other factors that could potentially be influenced by campaigns (Van Raaij & Verhallen, 1983). This notion ties in with Costanzo et al.'s (1986) assessment of the superior influence of information that is socially diffused, individual and vivid compared to the rather impersonal, public information diffused via official channels of communication, mentioned earlier. His socio-psychological model of energy conservation behaviour will be briefly discussed in the following section.

3.1.6.2 Socio-psychological model of energy conservation behaviour

Compared to the previous model, this one is quite a simple conceptual model focusing on the process of how pro-conservation information leads to the adoption of an energy-saving device such as solar technology, home insulation, etc. and the intervening factors of this process (Costanzo et al., 1986). This model might be interesting for the context of this project for two reasons, first, it provides useful information on how information needs to be cognitively processed in order for it to be translated into behaviour, which is important for the overcoming of the attitude-behaviour gap. Second, it might also be applicable to the process of how someone becomes a prosumer in the first place, potentially shedding more light on this still under-researched area.

As shown in Figure 10 below, the model identifies two interacting sets of factors: psychological and positional. Psychological factors refer to how information is processed by individual decision makers, and positional factors refer to characteristics of the decision

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makers' situations that support or constrain action. Both sets of variables need to be fulfilled before an informational campaign will result in conservation behaviour. The interactive nature of the two sets of variables becomes clear with the following examples: Even if energy consumers perceive, favourably evaluate, understand, and remember a persuasive communication, their 'positional' factors must also allow for the adoption of a particular energy-conserving technology. In other words, if an individual is highly motivated to purchase an energy-conserving technology (e.g. solar heating) but does not have the disposable income to afford it or the roof top to install it on, the technology will not be purchased (Costanzo et al., 1986).

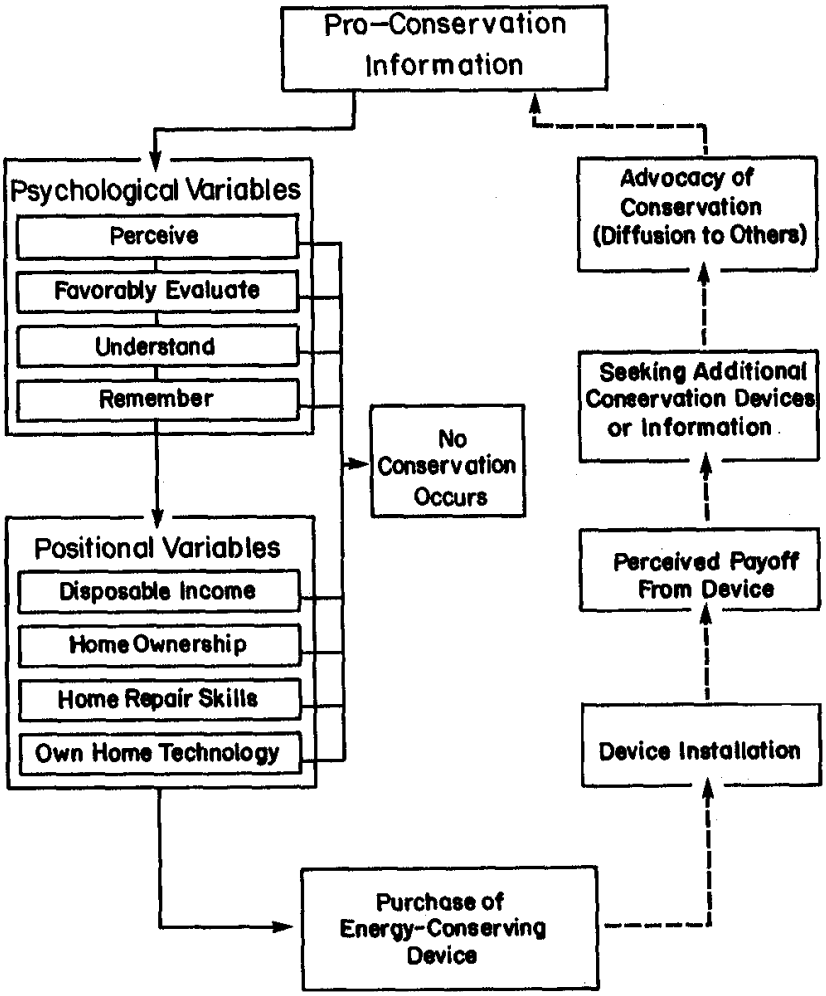

Figure 10. Psychological and Social Factors in Energy Conservation Behaviour (Costanzo et al., 1986)

The final steps of the model are also interesting because they suggest a somewhat self-enforcing cycle of positive behaviours once the first step is made and an energy-conserving device has been purchased and installed: The individual perceives that the adoption of the device has resulted in some payoff. Becoming more convinced and interested now, the individual seeks additional information about conservation devices, and advocates conservation devices to others. Now, the cost-benefit maximization discussed earlier is starting to work in the favour of environmentalism: The perception of some benefit increases the user's confidence in energy-conserving devices. This makes the user more receptive to future informational appeals, increases the probability that the individual will take further steps to

conserve energy, and leads the conserving individual to persuade others to adopt the beneficial device (Costanzo et al., 1986). The potential of creating a cycle of positive reinforcement and further diffusion amongst users of energy-conserving devices is a promising outlook for the SIT4energy solutions aiming to support prosumers, who are by definition situated in the post-adoption phase described by the model.

3.1.6.3 Social practice theory approach: CIM-model

It has already been mentioned that there is still a considerable lack of research focusing specifically on prosumers. Hansen & Hauge's study (2017) on prosumers and their practices is one of the rare exceptions.

Drawing on social practice theory in the tradition of Bourdieu and Schatzki, they argue that an in-depth understanding of people's unique, everyday practices is the first step to also change the lived experience they constitute. Rational choice theories as represented for example by the TPB model are seen as lacking appreciation for the social relations, material infrastructure and context, that are deemed relevant to the study of how people engage in energy consuming practices.

The concept of practices is a useful addition to this discussion since it is a more refined concept than habits. Like habits practices are defined as 'a routinized type of behaviour' but are seen to consist of several interconnected elements such as: 'Forms of bodily activities, forms of mental activities, 'things' & their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge (Reckwitz, 2002, pp. 249–250).

The main idea is that life is lived in the *doing*, as a performance of practices which become routinized over time. As such they are *embodied*, meaning they reflect people's bodily needs throughout their life courses. The routine aspects of the active everyday life and the organization of everyday activities are at the centre of this perspective. Within this theoretical framework, people's habits are described as 'practices performed routinely' and are made up of three intertwined elements:

(1) *Competences*, specifically corresponding to what people need to know to *perform* the practice, including the related 'doings,' the bodily performance of the actions (e.g. turning the heat on or off);
(2) *Images*, covering *how people perceive the practic*e (including how energy savings may be communicated in the intervention), and the (self-)*image* of being a 'tech front runner' as a result of taking part in a progressive intervention;
(3) *Materials* or ('havings'), which involve all the physical parts required for performing the practice, such as manuals, technology, and the grid.

These three parts - competences, images and materials - or CIM - constitute the core of a practice and reflect what people need to be able to perform it, be it new or old (Hansen & Hauge, 2017). Such a detailed break-down of the elements constituting people's behaviour might seem tedious at first but it also offers some interesting insights in the way that practices do change over time, especially after a complex intervention like the installation of smart grid technologies.

Hansen & Hauge (2017) found that participants did indeed change their energy practices as a result of the intervention and they did so in manifold and sometimes unexpected ways: They began to relate to their natural environment in new ways, constructing new practices according to the movements of the sun (like sweeping instead of vacuuming on cloudy days).

They gradually became skilled practitioners and prosumers; and they also *increased* consumption (due to perceptions of low-costs of energy and injustices around the tariffs they

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were subjected to by the utilities). They also developed expectations towards the energy company, requesting better dialogue on energy consumption and control (Hansen & Hauge, 2017). This finding is also in accord with the initial comments made about prosumers' goals and motivations at the beginning of this discussion.

Overall, these findings suggest that given the right tools, meanings and skills, people are indeed able to change their behavioural patterns of energy-related behaviours *over time*. However, this change might be too slow to be detected by studies that only provide behavioural snapshots of particular moments, which could be another reason why many studies have found large gaps between people's intentions and their actions. In the following, the *process* of behavioural change will be examined closer before considering possible interventions.

3.2 Behaviour change process models and intervention strategies

Fewer models have been focusing on the process of how people come to change behaviour and possible interventions facilitating behavioural change. Examples often come from the domain of health and addiction research and include Schwarzer's (2008) 'Health Action Process Approach' (HAPA) that distinguishes between a motivational and a volitional stage of behavioural change and the Trans-Theoretical Model (TTM) proposed by Prochaska and Velicer (1997), which conceptualizes behavioural change as a transition through five stages: Pre-contemplation, as the stage at which individuals are not intending to take action yet. Contemplation, as the stage at which they develop the awareness that a change may be necessary. Preparation, as the stage at which individuals form the intention to take specific actions soon. Action, as the stage at which they actually change their behaviour. And maintenance, as the stage at which individuals are working to prevent relapse (Bamberg, 2013). However, due to their limited fit to the specific context and aims of the project, they will not be included here.

For the SIT4Energy project, the following two models might provide valuable insights: Bamberg's (2013) *Stage Model of Self-regulated Behavioural Change* and Michie et al.'s (2011) *Behavioural Change Wheel* matching specific sources of behaviours with interventions. They will be described in the following.

3.2.1 Stage Model of Self-Regulated Behavioural Change

Bamberg's (2013) stage model of self-regulated behaviour change, which incorporates elements of the TPB and NAM models distinguishes four phases: predecisional, preactional, actional, and postactional. The constructs of goal intention, behavioural intention, and implementation intention provide the criteria for when an individual transitions from one stage to the next. Central to this model is the assumption that 'behavioural change is best conceptualized as a transition through a time-ordered sequence of qualitatively different stages' (Bamberg, 2013, p. 152). The stage approach thus assumes behavioural change to be self-regulative.

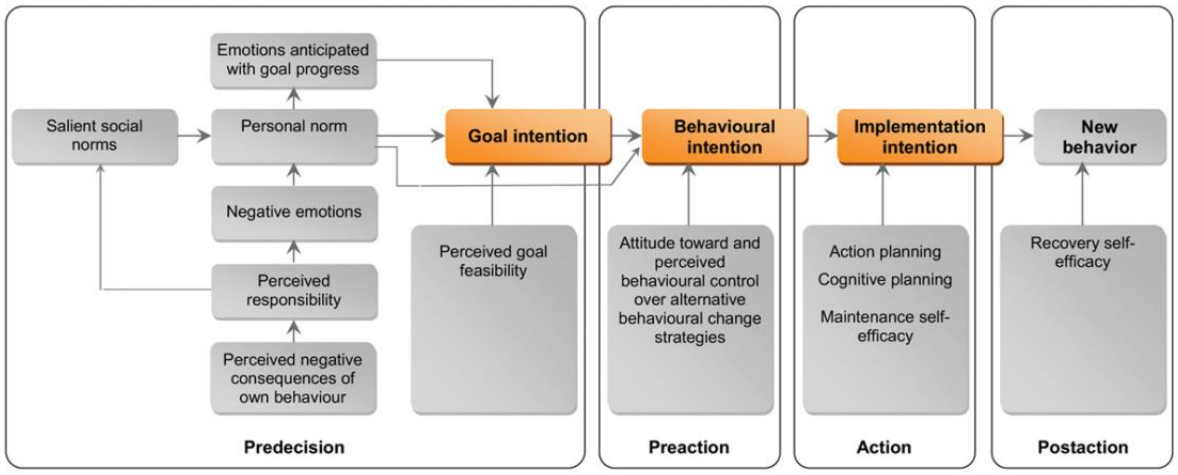

Figure 11. Stage model of self-regulated behavioural change (Bamberg, 2013)

In order for an individual to transit from one stage to the next, they need to formulate specific intentions, which will ultimately lead to the adoption of the new behaviour. *Goal intention* describes the first transition from pre-decision to pre-action. An individual forms a goal intention by weighting the desirability and feasibility of competing goals. At the 'predecison stage', constructs from the NAM model are introduced as predictors to explain how an individual comes to formulate the goal intention, since it is assumed that at this stage, behaviour is performed habitually and without much deliberation. For this shift to happen, an individual has to become aware that her or his current behaviour has harmful consequences for others and/or the environment (awareness of consequences) and has to then also accept personal responsibility for causing this harm (ascription of responsibility). Through this process, negative feelings of guilt are elicited and lead to the activation of personal norms, making it a goal to act more in line with one's own moral standards (Bamberg, 2013).

In a second step, b*ehavioural intention* is needed to transition between pre-action and action. The formulation of behavioural intention is explained with constructs of the TPB model, and is seen as the result of an individual balancing the pros and cons of possible alternative behavioural strategies and their perceived difficulty. Once the person has decided for a course of action, they form the intention to implement this decision. These planning processes and self-efficacy are seen as the predictors of the implementation intention, allowing the individual to cross 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. It is then assumed that if such a situation occurs, the individual is able to carry out the new behaviour automatically (Bamberg & Schmidt, 2003;
Cibinskiene et al., 2017). This model has been empirically tested and validated in the field of car use.

This model provides a convincing synthesis of the different models mentioned before, allowing the combination of rational choice based and norm-based approaches to behavioural change. The additional stage of implementation intention also seems to be a good way to account for the intention – behaviour gap identified earlier, since it introduces specific conditions that need to be met for an individual to transition from the behavioural intention to the new behaviour.

Yet, this model, along with other determinant models such as the NAM and TPB, has been criticised for only targeting one type of behaviour, while energy efficiency is made up of many different actions, that are determined by differing factors. The model is also seen to be

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lacking an adequate capturing of the non-rational and unconscious part of human behaviour and it does not pay much attention to the context in which the individual is situated. Lastly, the crucial question of the motivational processes that keep people engaged with the process of moving towards sustainable energy-habits is not sufficiently addressed (Cibinskiene et al., 2017).

Despite these limitations and the little existing evidence concerning the usefulness of stage models in the area of energy saving, it remains an informative conception of human decision making processes. It is questionable however, if this process model is suitable for the limited scope of the SIT4Energy project, since it is rather complex and does not provide many insights into how context-aware interventions should be designed. The question of interventions and motivational strategies will be addressed in the following section.

3.2.2 Types of intervention strategies

Many researchers are concerned with the question of how people can be persuaded to adopt more sustainable and energy-efficient lifestyles. The question of how individual energy consumption can be reduced is thus not new and a range of behavioural change interventions have been developed by now. They can be classified into the following categories: antecedent or consequential strategies; informational and structural; or social strategies (Abrahamse & Steg, 2013; Steg & Vlek, 2009).

Antecedent strategies are employed before the behaviour occurs, *consequence strategies* are targeting the time after the behaviour has already occurred (Abrahamse et al., 2005). They can be further divided into *informational strategies*, aiming to change prevalent norms, motivations and perceptions and *structural strategies*, aiming to change the circumstances in which the decisions are made. Since structural changes are harder to achieve remotely, informational strategies are the more common form of intervention strategy used. *Social strategies* aim to employ social norms and use the normative social influence that other people and groups are having on an individual's behaviour.

A common example for an antecedent informational strategy is the setting of consumption goals, while consumption feedback is often employed as an informational consequence strategy. An antecedent social intervention would be for example the use of trusted volunteers to help peers with saving energy (referred to as 'block leaders') or public commitment-making to saving energy. The social comparison of energy saving achievements would be an example for a social consequence strategy (Abrahamse & Steg, 2013). Given these manifold possibilities to design a behavioural change intervention, it might be difficult to choose the right one. Michie et al.'s (2011) *Behavioural Change Wheel* provides a comprehensive framework aiming to facilitate this decision.

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3.2.3 Behavioural Change Wheel

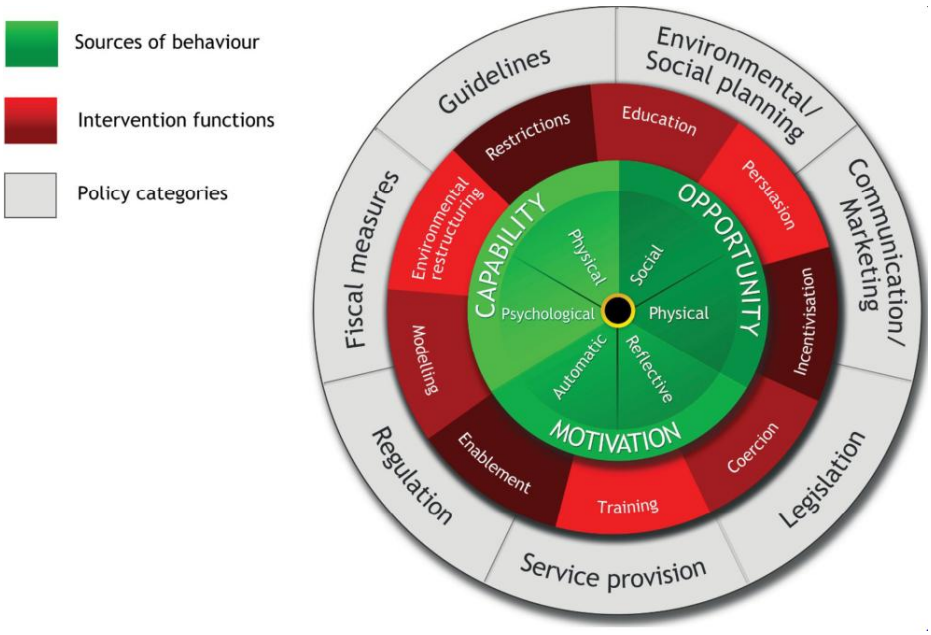

Figure 12. Behavioural Change Wheel. (Michie et al., 2011)

Three interacting prerequisites for behavioural change are at the centre of the wheel. In Figure 12, they are marked by the green fields and constitute the individual factors influencing behaviour: motivation, opportunity, and capability. While *opportunity* is situated outside of the individual and is defined as all the factors that make the behaviour possible or trigger it, capability and motivation are situated inside the individual. *Capability* refers to the individual's psychological and physical capacity to engage in the targeted activity; and motivation is defined the brain processes that energize and direct behaviour (Michie et al., 2011). In the second red ring, interventions are listed that affect one or more of the prerequisites. They stand for specific strategies that can be used to induce behavioural change, affecting the corresponding prerequisites within the inner green circle. Interventions are grouped into nine categories: education, persuasion, incentivisation, coercion, training, restriction, environmental restructuring, modelling and enablement.

Education relates to measures that are increasing knowledge or understanding. *Persuasion* means using communication to induce positive or negative feelings or stimulate action. *Incentivisation* is creating an expectation of reward. *Coercion* means creating the expectation of punishment or cost. *Training* entails teaching specific skills. *Restriction* can refer to two things: if the aim is a reduction of the target behaviour, rules can be used to diminish the opportunity to engage in this specific behaviour. If the target behaviour is supposed to be increased, restrictions can be used to reduce the opportunity to engage in competing behaviours. *Environmental restructuring* is defined as changing the physical or social context. *Modelling* refers to the idea of role modelling by providing an example for people to aspire to or imitate. And *enablement* means supporting a target behaviour by increasing the capability or opportunity to engage in it, either by increasing means or by reducing barriers (Michie et al., 2011).

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These definitions provide a good overview of the general types of interventions available. Yet, it remains rather broad and some measures might be more suitable for the specific aims and context of the SIT4Energy project than others. At a first glance, education, persuasion, incentivisation, environmental restructuring and enablement seem to be potentially useful means to support prosumers in achieving optimal outcomes. Coercion, training, restriction or modelling do not seem adequate in this context.

The third ring in Figure 12 refers to policy interventions that can be used by state authorities. They include: communication/marketing, guidelines, fiscal regulation, legislation, environmental/social planning, and service provision. They provide the larger social and political framework in which the SIT4Energy solutions will be used, but they do not represent accessible strategies for intervention.

3.3 Summary

In this section determinant and process models pertaining to energy-related behaviour and decision making have been discussed, followed by a brief overview of commonly used behavioural change interventions. Different models have different advantages and shortcomings and many of them exceed the needs and the scope of the SIT4Energy project.

The main findings can be summarized as such: Rational-choice approaches have highlighted the tendency of people to avoid immediate costs and seek short-term benefits when making decisions, even if they are irrational in the long run. Similarly, goal framing theory has shown the prevalence of hedonic and egoistic goals that guide large portions of human decision making. Norm-based approaches have given a counterweight to these theories by showing that personal norms around morality and the need to act in line with social norms and expectations can spawn individuals to refrain from harming behaviours once they have identified them as such. Goal Framing theory and Fogg's Behavioural Model have highlighted the importance of well-timed triggers that might be useful for inducing behaviours at specific points in time. Research on prosumers has shown the way in which individual practices have changed over time and Costanzo's model suggests that positive feedback loops can be created after an energy-saving device has been purchased and installed.

In relation to the prosumers in the SIT4Energy project, it might be thus useful to consider the following aspects: The provision of energy consumption feedback and recommendations for specific actions to increase user's engagement and motivation and the use of visual analytics to make people aware of the consequences of their behaviour.

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4. Demand models (ITML, supported by CERTH, SHF)

This section presents preliminary demand models for SIT4Energy tools and services. Analyses mainly focus on users' acceptance and willingness to pay. A brief discussion of the literature on how it might be possible to 'capture' users' behavioural changes concludes this section.

4.1 SIT4Energy acceptance and willingness to pay

The SIT4Energy output can have a positive impact on local energy market which subsequently can offer multiple benefits to the various stakeholders. The customers can become more active and participate in demand response services, increased energy independence and increased transparency of their costs. While the network operators can defer investments in distribution networks through lower (peak) loads, lower network losses and new opportunities through innovative business models. In overall service, technology and energy providers can benefit from the growth and diversification of the energy market as well as new business opportunities. However, some challenges exist on technical, policy and legislation, economic and societal spheres. Among all, the societal challenges are recognised as having the deepest impact on the acceptance and the willingness to adopt and pay for innovative efficient energy solutions.

An important factor in the creation of an acceptance is the balance between knowledge and trust. As reported in [1] the information and communication strategies play a crucial role in creating acceptance. Rather than aiming at creating or improving social or societal acceptance the knowledge and communication about an acceptance object should be targeted. Societal acceptance will be achieved indirectly, if the benefits as well as the risks are transparently communicated to the relevant societal target groups assuming that the features of the acceptance object meet general societal needs and demands. The interested target groups should clearly understand what is required in order to achieve their needs and energy demands thus they should be involved in innovative projects from its early stage and throughout the whole process.

By taking into consideration of the aforementioned aspects the rise of awareness and knowledge of SIT4Energy benefits (developed ICT-enabled tools and systems) have been started from the beginning of the project (and will continue throughout of the project life). For instance, in the context of SIT4Energy WP1: Consumer Requirements Analysis and more specifically in the frame of the T1.1: "Markey Research Survey Tool" we surveyed individuals belonging to initially defined SIT4Energy target groups. The aim was to engage the end-users from the early design stages of the SIT4Energy ecosystem. Furthermore, two workshops have been organized for the SIT4Energy Greek and German pilots' end-users (T1.3: User Information Model). The results obtained from these tasks have been reported in D1.1 and D1.3 respectively. Some valuable outputs obtained from the end-users' willingness to pay will be presented in the following subsections.

[1] https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2010/0219.pdf

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4.2 End-Users willingness to pay based on SIT4Energy survey results

This section primarily focuses on the main output of survey raw data regarding the German and Greek end-users (defined as TG1 and TG3 in the project) acceptance and willingness to pay for tools/services that will be developed in the frame of SIT4Energy. It is good to mention that the major analysis was done by the survey engine converting and visualising data into graphs and diagrams. The automatically generated graphs for responses received for each question in the survey give the basic understanding of the types of answers received by the individuals. The summary of the responses related to the acceptance and willingness to pay for SIT4Energy tools/services is provided in the sub sections below.

4.2.1 *German end-users (both consumers and prosumers) purchasing intention*

To probe the respondents' efficient energy management services' purchasing intention two questions were involved in the main questionnaire (please refer to D1.1 for the whole questionnaire results) were initiated and below are presented the obtained data. The results are illustrated in the following two figures (Figure 13 and Figure 14). As it can be seen 27.3 % of end users voted that it is rather important while 6.1% respondents indicated that it is very important for them to pay for efficient energy management services and thus automatically minimize their energy consumption. Almost similar answers were gained for energy prosumers as 24.2 % end users voted that it is rather important while 3% respondents indicated that it is very important for them to pay for efficient energy management services and thus automatically maximize their energy productions.

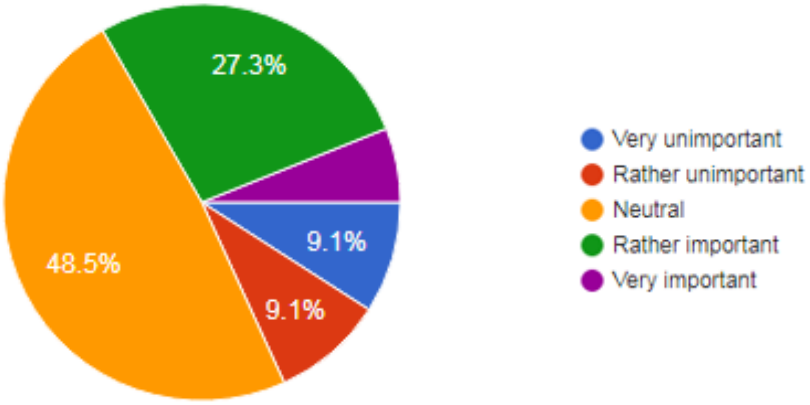

Figure 13. Question: How important is it for you to pay for efficient energy management services and thus automatically minimize your energy consumption?

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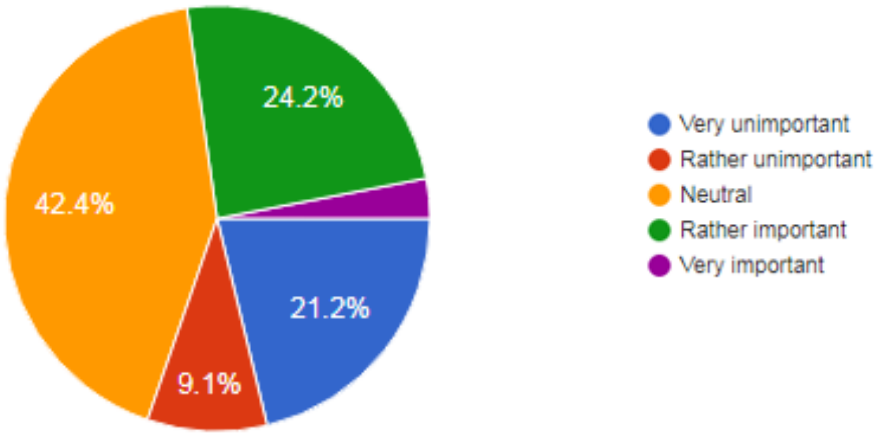

Figure 14. Question: How important is it for you to pay for efficient energy management services and automatically maximize your energy production?

Figure 15 illustrates the willingness of respondents to buy energy management services. Interestingly 75% respondents would like to pay for receiving tips and notifications about their energy consumption while around 45.8% end-users wish to pay for receiving tips and notifications about their energy production. Furthermore, end-users would like to buy services that provide mainly monthly energy production (29.2% respondents) and monthly energy consumption (37.5%). Very small percentage of respondents (16.7 %) would like to buy other services such as *receiving notifications via email*, *for fully automatic management services* or *for information on savings potential from the measures.*

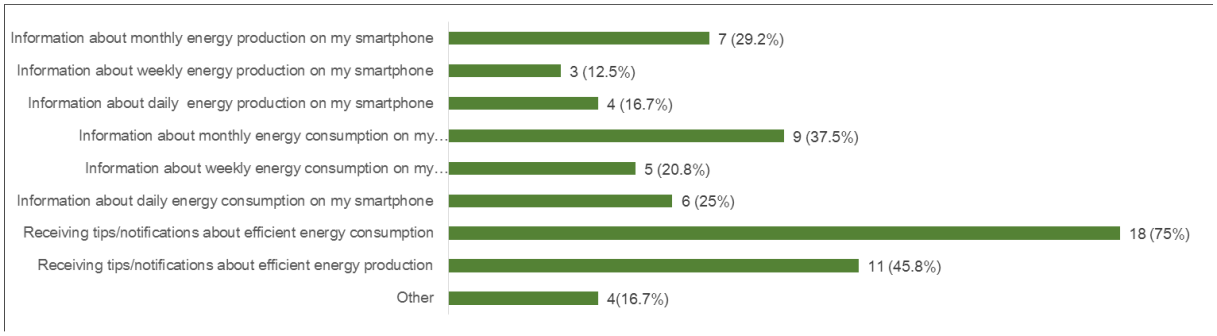

Figure 15. Question: What kind of energy management services would you like to buy?

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4.2.2 **Greek end-users' (only consumers) purchasing intention**

The Greek respondents' efficient energy management services' purchasing intention has been also investigated and the results are given in the following figures (Figure 16 and Figure 17). As given in Figure 16, 46.7 % of end users voted that it is rather important while 20% respondents very important for them to purchase efficient energy management services.

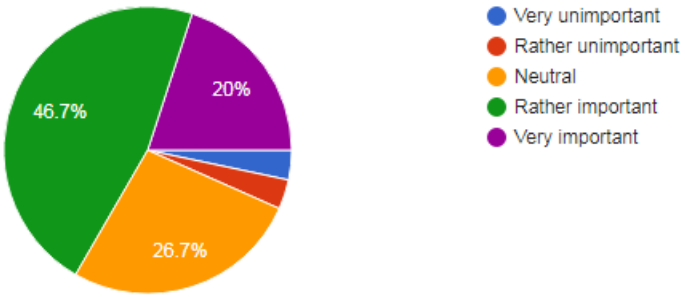

Figure 16. Question: How important is it for you to pay for efficient energy management services and thus automatically minimize your energy consumption?

Figure 17 illustrates the willingness of respondents to buy energy management services. Interestingly 20 respondents would like to pay for receiving tips and notifications while around 25 end-users wish to buy services providing information about their energy consumption (monthly -12 answers, weekly-8responses, daily-5 responses). Very small percentage of respondents (only 1.3%) does not have willingness to buy such services while other services such as comparative data about my energy consumption (actual versus recent/ past) was also recorded in the 'other' section of this question.

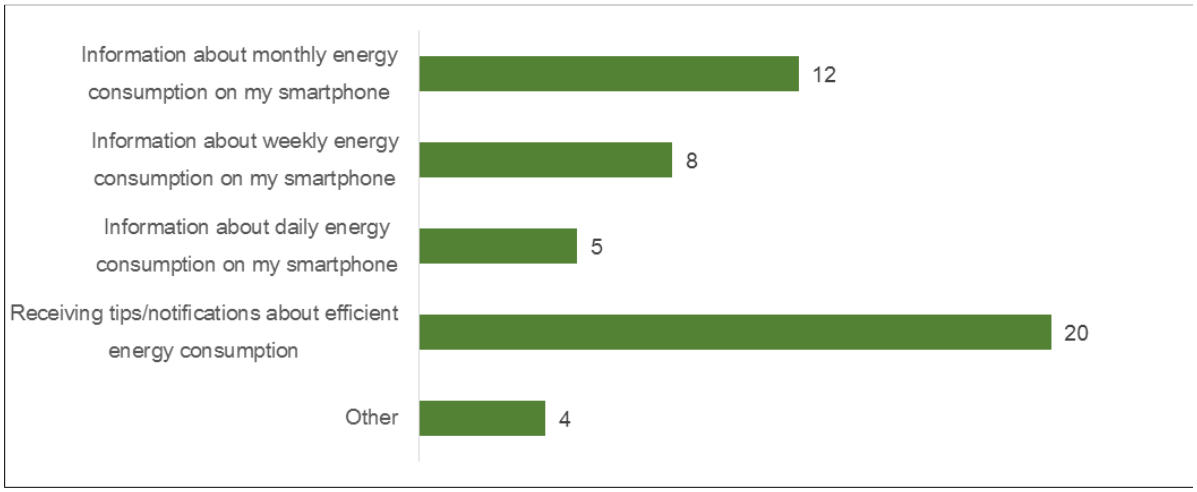

Figure 17. Question: What kind of energy management services would you like to buy?

4.3 End-Users willingness to pay based on SIT4Energy workshop results (ITML)

Two workshops were organized by SIT4Energy partners related to end-users' involvement and engagement design of two main components of SIT4Energy platform. One of the workshops took place in Greece at ITML's premises for energy consumers, while the second workshop took place in the headquarters of the German utility company Stadtwerk Haßfurt GmbH (SHF) for energy prosumers. The events had aiming to get the first insights in the design of a Mobile app and Smart Energy Management Dashboard for energy consumers and prosumers respectively. The events started by briefly presenting the SIT4Energy Project (the scope, objectives and expected outcome) and followed by illustrating the important insights as an outcome of SIT4Energy survey already accomplished on M6. After that the initial mock-ups of the mobile app and Smart Energy Management Dashboard were demonstrated to the attendees. During that events the participants had the opportunity to gather and exchange their ideas during the presentation as it was integrated by short intervals by letting them to express their ideas or comments, to generate feedback and to make notes. During the events the participants were also invited to fill in questionnaire about their experience regarding their energy management as well as their opinion about the presented mock-ups. The questionnaire included also three more questions about the willingness to pay for these services. The following subsections focuses on the main output of workshop questionnaires raw data regarding the German and Greek end-users' willingness to pay for SIT4Energy mobile app and Smart Energy Management Dashboard.

4.3.1 Greek end-users' purchasing intention

Three questions were given to consumers in order to understand their purchasing intensions. As obtained from the answers the majority of the participants give neutral answer to the question of trying energy efficient services/tools for 10€ per month (45% neither likely nor unlikely). Moreover, they think that less than 10 Euro is the most appropriate amount for energy efficient solutions (Figure 19) and almost all prefer to involve this price in their *yearly/monthly* energy bill (Figure 20).

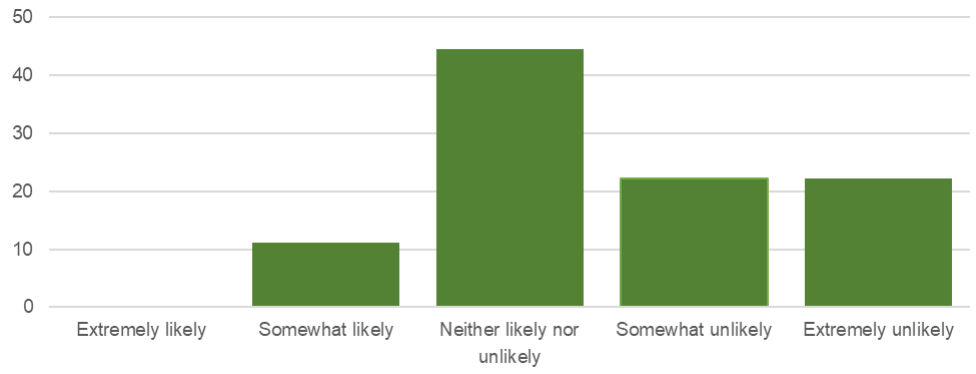

Figure 18. Question: How likely would you be to try the Energy efficient services/tool for 10€ per month?

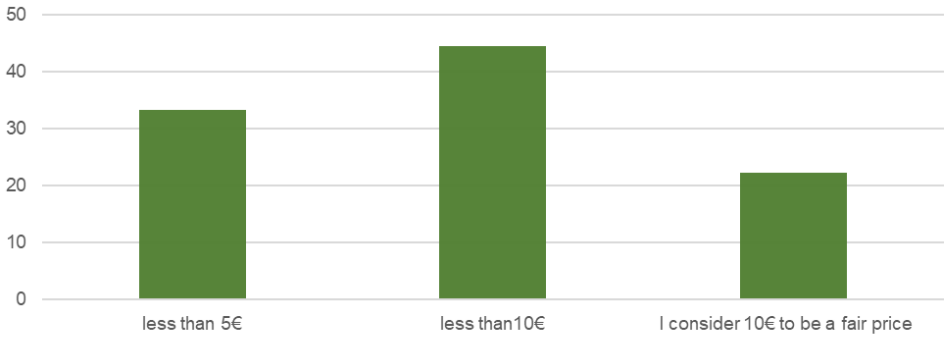

Figure 19. Question: If you consider the above price as being too expensive, what would you consider an appropriate amount?

Figure 20. Question: If you agreed to the above statement (Figure 19), would you prefer a yearly or monthly payment?

4.3.2 German end-users' (consumers and prosumers) purchasing intention (SHF)

Three questions were asked orally to consumers in order to understand their purchasing intensions in Germany. The majority of the participants gave a negative answer to the question if they would be trying energy efficient services/tools for 10€ per month. Moreover, they thought that less than 5 Euro would be the most appropriate amount for energy efficient solutions, and all preferred to include this price in their yearly/monthly energy bill. Including this fee meant for them, that the price for using the Energy Management Dashboard should be included in the base price of SHF's tariff models. If the use of the portal should claim an extra fee, the user acceptance of the product would fall.

4.4 Capturing short- /med-term change in end user decisions (CERTH)

The following section provides an overview of possibilities to capture short-/medium term changes in user decisions.

4.4.1 Surveys

In the study 'Segmentation and Characterization of Energy Consumers' (Sütterlin, 2012) surveys were conducted. The questionnaire included various fields of questions aiming to assess respondents' energy-saving efforts, their acceptance of different policy measures, and different energy-related beliefs including response efficacy, self-efficacy, and perceived personal efficacy. Questions around the awareness of consequences, ascription of

responsibility, and personal norms, were included as well. Various other questions focused on the respondents' general energy-related attitudes, assessed their energy knowledge, and collected socio-demographic information. Different activities related to energy-saving behaviour were listed and participants were asked to indicate, on a six-point Likert scale, how often they performed the described energy-related activity.

A European case study researching 'Changing Energy Behaviour' (Dahlbom, Greer, Egmond, & Jonkers, 2009) in the context of the *Intelligent Energy's Behave* project, aimed to assess user behaviour policies mostly through repeated surveys, a randomised telephone survey and meetings with residents and owners' associations. Sensors to measure temperature, CO2 emissions, humidity and decibels were also used, but more rarely.

In 'Effective User Interface Designs to Increase Energy-efficient Behaviour in a Rasch-based Energy Recommender System' (Starke, Willemsen, & Snijders, 2017) the method was slightly more complex. An initial questionnaire using Rasch Model and objective metrics was conducted, so that user profiles and users' energy saving abilities could be derived. Then a Web app followed offering tailored advices to users based on their profile. Users could choose preferred advices and receive further recommendations upon them. Finally, follow-up surveys were administered four weeks later. The users were surveyed on subjective constructs: perceived support, perceived effort, system satisfaction and choice satisfaction. For all survey items, users had to indicate on 7-point Likert scales to what extent they agreed or disagreed with them. A confirmatory factor analysis (CFA) using ordinal dependent variables was used to analyse the data.

A research review called 'Intervening to change behaviour and save energy in the workplace' (Staddon, Cycil, Goulden, Leygue, & Spence, 2016) assessed the effectiveness of various methods of behavioural change, such as education, persuasion, incentivisation, coercion, training, restrictions and environmental restructuring. Various methods were applied. Half of the papers utilised quantitative questionnaires to survey participants self-reported behaviour pre- and post-intervention behaviour. 5 studies used qualitative methods such as interviews, focus groups and participant observation in order to understand participants' experiences during the interventions.

4.4.2 Sensors and measurements

In the aforementioned study "Changing Energy Behaviour" (Dahlbom et al., 2009) an additional method was used. Sensors were employed to measure temperature, CO2 emissions, humidity and decibels. The sensors were installed in 12 social housing dwellings and boulevard air trees to verify energy saving, reduction of emissions and comfort levels.

In 'Changing-Energy-Behaviour. - What-Works' (SEAI, 2018) actual changes in energy use were measured using objective data from meter reads or billing information. Changes in energy use were measured for all relevant energy sources including electricity, gas, and non-metered fuels (particularly oil). Power analyses were conducted in order to recruit a sufficiently large and representative sample of the population of interest.

In 'Behavior Change Interventions; What Works, What Doesn't and Why' (Harris, Hummer, & Thompson, 2010) two types of feedback were recognised, which are commonly employed in residential energy efficiency today: Direct feedback (typically in-home energy use monitors) and indirect feedback (typically enhanced or comparative billing practices). Closely related to feedback is the use of online carbon calculators, which are less accurate than direct and

indirect feedback mechanisms, but are cost-effective ways to integrate the concept of feedback into a communications-based campaign.

In “Evaluating Energy behaviour change programs using randomised controlled trials: Best practice guidelines for policy makers” (E. R. Frederiks, Stenner, Hobman, & Fischle, 2016), the authors examine the durability of the intervention’s effect over the trial period. Household energy consumption is monitored repeatedly over time using direct and objective measures, e.g., electricity/gas meter readings. In a similar study undertaken by Tsang et al. (2012) the household bills were used as an assessment meter and it was found that participating households saved, on average, about £570 per year, proving the behavioural policy effective.

Additionally, Staddon et al.’s (2016) research review assessed the effectiveness of various methods of behavioural change interventions, like education, persuasion, incentivisation, coercion, training, restrictions an environmental restructuring. Various methods were applied. Most of the papers reported changes in energy consumption (electricity or gas) during the course of the intervention. 4 papers observed energy-using appliances and equipment, or artefacts of energy use (e.g. the extent to which lights are turned on or off, the coverage of heaters, the use of stairs vs. lifts, the time computers are spent ‘idle’).

In ‘Low-energy dwellings: the contribution of behaviours to actual performance’ (Gill, Tierney, Pegg, & Allan, 2010) both methods were used to take the building performances into account. Annual consumption of electricity, water and heat was monitored with installed meters in high performance buildings following sustainable design principles and utilizing renewable technologies. A survey was also developed to assess the targets’ behaviour using five point Likert scaled questions and interviews. According to ‘The Impact of Building Occupant Behaviour on Energy Efficiency and Methods to Influence It: A Review of the State of the Art’ (Paone & Bacher, 2018), a survey is required in order to quantify behaviours exhibited by occupants and to compare the effects of those behaviours with the actual monitored performance. The objective is to capture occupants’ actual behaviour in buildings, to verify the reliability of the survey, and to identify wasteful energy behaviour. The following list summaries the most commonly methods used in the research presented.

Survey-centric measures included:

- Questionnaires (some questions use six-point Likert scale)
- Randomised telephone surveys
- Other surveys and meetings with residents and owners’ associations
- Multi-stepped surveys: initial questionnaire using Rasch Model for the user profile and users’ energy saving ability, an interfering web app used as the basic research tool to change user energy behaviour and a final follow-up survey to point out the preceding tailoring advice’s effectiveness
- Qualitative methods including interviews, focus groups and participant observation in order to understand participants’ experiences during the interventions.

Sensor-centric methods of measurement included:

- Sensors to measure temperature, CO2emissions, humidity and decibels
- electricity/gas meter reads, repeated monitoring of household energy consumption and power analyses
- billing information
- measure changes in energy use for all relevant energy sources including electricity, gas, and non-metered fuels
- Observing energy-using appliances and equipment, or artefacts of energy use (e.g. the extent to which lights are turned on or off, the coverage of heaters, the use of stairs vs. lifts, the time computers are spent ‘idle’).

A combination of methods included both, consumption monitoring and survey use.

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5. Conclusion

In this deliverable *Analysis of consumer choices*, determinants of energy behaviour, applicable behavioural change models and possible intervention strategies have been discussed. The main determinants for energy-related behaviours are socio-demographic and psychological factors. They influence different types of behaviour. Socio-demographic determinants have been found to influence energy consumption behaviour, while psychological determinants are related to energy-saving efforts.

As shown in Section 2, the main socio-demographic factors of influence identified in the literature are education, employment status, household income, household size, home ownership, and stage of family life cycle. Technical expertise and knowledge, time spent at home and the distribution of age within the household are also relevant. Gender has received some attention but studies reported mixed results on the impact of this variable. Statistical effects often disappeared after controlling for confounding variables.

The key set of determining psychological factors that has been identified in the literature includes: knowledge and problem awareness of environmental and energy issues; beliefs, values and attitudes; motives, intentions and goals; subjective appraisals and perceptions as well as personality tendencies; and personal and social norms. It has been suggested that normative social influence has a strong effect on people's behaviour. This also extends to messages and information diffused via social networks. They are more influential than those disseminated via official media channels because the information is more vivid and easier to relate to and remember.

Another key finding of Section 2 were the considerable gaps between people's knowledge, values and attitudes towards environmental concerns and their actual behaviour in daily life reported by many studies. These gaps also explain why many psychological factors (like values, attitudes and beliefs) often fail to reach statistical significance in explaining subsequent energy behaviour, especially when compared to the effects of socio-demographic factors. It has been suggested that short-term goals aiming to improve the individuals' immediate situation often over-ride more environmentally friendly, but costly and inconvenient long-term goals of sustainability. Energy-saving initiatives therefore need to overcome the 'intention-behaviour gap' in order to realise the significant potential for energy conservation currently lying dormant.

Different models and perspectives have been developed by many researchers seeking to conceptualise (energy-related) human behaviour in encompassing models. They have been discussed in Section 3 and include Ajzen's (1991) *Theory of Planned Behaviour* (TPB), Schwartz' (1977) *Norm Activation Model* (NAM), that has later been developed further by Stern et al. (1999) into their so-called *Value-Belief-Norm* (VBN) theory, *Goal Framing Theory*, *Fogg's Behaviour Model* (FBM) and Kollmuss and Agyeman's (2002) *Model of Pro-Environmental Behaviour.* These models use determinants as focal points for research and the design of interventions.

Rational choice approaches like the TPB highlighted the tendency of people to avoid immediate costs and seek short-term benefits when making decisions, even if they are irrational in the long run. Similarly, goal framing theory has shown the prevalence of hedonic and egoistic goals that guide large portions of human decision making. Norm-based approaches like the NAM and VBN theory have given a counterweight to these theories by showing that personal norms around morality and the need to act in line with social norms

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and expectations can spawn individuals to refrain from harming behaviours once they have identified them as such. Goal Framing theory and Fogg's Behavioural Model have highlighted the importance of well-timed triggers that might be useful for inducing behaviours at specific points in time. Costanzo's Socio-psychological model suggests that positive feedback loops can reinforce pro-environmental behaviour after an energy-saving device has been purchased and installed.

There are also a few models focusing on the process rather than the determinants of behavioural change and intervention strategies, such as Bamberg's (2013) *Stage Model of Self-Regulated Behavioural Change*. But overall, this model was seen as too complex and exceeding the needs of the project. Michie et al.'s (2011) *Behavioural Change Wheel* provided a good overview of possible intervention methods, such as education, persuasion, incentivisation, environmental restructuring and enablement, which might potentially be useful means to support prosumers in achieving optimal outcomes.

In summary, the different models discussed in Section 3 have different advantages and shortcomings. Many exceed the needs and the scope of the SIT4Energy project. In relation to the prosumers in the SIT4Energy project, the provision of energy consumption feedback and recommendations for specific actions might serve to increase user's engagement and motivation. Visual analytics could be useful to make people aware of the consequences of their behaviour.

Section 4 has discussed the findings of the survey raw data regarding Greek and German end-users. Their purchasing intention and willingness to pay for the tools/services that will be developed in the SIT4Energy have been measured. 46.7 % of Greek end users indicated that it is rather important for them to purchase efficient energy management services. 20% respondents found it very important. Greek end-users think that less than 10 Euro is the most appropriate amount for energy efficient solutions and almost all prefer to involve this price in their yearly/monthly energy bill. 27.3 % of German end users indicated that it is rather important to them to pay for efficient energy management services in order to automatically minimize their energy consumption. 6.1% respondents indicated that it is very important. When asked orally during a workshop, the majority of the prosumers thought that less than 5 Euro is the most appropriate amount for energy efficient solutions. They all preferred to involve this price in their yearly/monthly energy bill.

The section ends with an overview of possibilities to capture short-/medium term changes in user decisions.

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