D2.2 | *Final comprehensive literature review setting the scene for the entire study*

Deliverable: *Final comprehensive literature review setting the scene for the entire study*

Author(s): *Emilie Magdalinski, Thomas Pellerin-Carlin Tiphaine Milliez (JDI), Arlan Brucal, Daire McCoy (LSE), Madeline Werthschulte (WWU), Alessandro Silvestri, Sébastien Foudi, Amaia de Ayala, Ibon Galarraga (BC3), Mária Bartek-Lesi, Gábor Harangozó, Alfa Diallo, Adrienn Selei (REKK), Hege Westskog, Nina Holmelin, Jennifer Joy West, Helene Amundsen, Steffen Kallbekken (CICERO), Todor Galev, Martin Vladimirov (CSD), Sanja Filipovic, Jelena Cvijovic, Marija Reljic (EI), Alistair Smith (CE), Aleksandra Gawlikowska-Fyk, Lidia Puka-Kjøde (PISM), Serhii Zhuk, Vitalii Martyniuk (CGS21), Stefano Proietti, Loriana Paolucci (ISINNOVA)*

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Coordinators: Silvia Gaggi and Stefano Proietti, ISINNOVA

E-mail: sgaggi@isinnova.org
sproietti@isinnova.org

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Executive Summary

In the context of the energy transition, the ENABLE.EU project seeks to contribute to more science-based policy decisions and to help identify the right incentives to enable energy choices that support the successful implementation of the Energy Union. To that end, ENABLE.EU aims at providing an excellent understanding of the social and economic drivers of individual and collective energy choices, with a focus on understanding changes in energy choice patterns.

This literature review sets the scene for the project by reviewing research on drivers of energy choices, pointing out to their contribution as well as their limits. Analysing over 400 academic articles, this review testifies to the abundance of explanatory elements and findings through various disciplines. This literature review is structured in four parts: a first focusing on economic drivers of energy choices, a second looking at socio-behavioural drivers, a third analysing governance factors, and a fourth part taking stock of the overarching models of energy choices as well as highlighting the interactions between the factors studied in the literature.

Market and non-market drivers of energy consumption and the adoption of energy efficient technologies

With respect to economic drivers of energy choices, the literature on the relationship between energy prices, non-market factors, electricity consumption and consumer investment in energy efficient-technologies is reviewed. Context is critically important when examining consumer response to energy prices.

The wide range of demand elasticities reported in the literature reflects the numerous methodologies, geographies, fuels and sectors considered. The measurement of price response can be improved through RCTs and smart-metering. Gaining a better understanding of how consumers process information, and how this maps to their consumption and investment patterns needs to be a key research objective.

Low responsiveness to energy prices may be due to inefficiently low energy prices which do not fully take environmental externalities into account, or regulatory mechanisms resulting in prices not fully reflecting production costs. A range of behavioural biases and management failures may also pervade causing an inability to process information and ultimately resulting in sub-optimal decision making.

Socio-cultural, demographic and behavioural factors influencing energy choices

Energy choices are also shaped by social, cultural, demographic and behavioural aspects, as highlighted through the lens of several energy sectors studied within ENABLE.EU, namely mobility, heating and cooling, and prosumers. This approach can be useful in attempts to predict people's behaviour in a particular situation and to identify a specific group that can be more responsive to a certain policy.

Culturally determined social dynamics may affect people's response to specific policies, but also their daily routines and practices. It might even be socially dangerous not to comply with the established norm, which can thus be more important than new technology in shaping behaviour. New technology can however redefine social conventions.

Demographic variables like income and age affect energy behaviour differently depending on the energy service and the empirical setting. Income, considered here as a determinant of social status, strongly shapes households' energy behaviours, but based on different motivations (e.g. raising comfort, affording energy, producing one's own energy). Energy poverty appears as a main issue and increasing dwellings' energy efficiency is a first step towards its eradication. Last but not least, gender is given particular attention within ENABLE.EU as research shows that the motivations for and barriers to taking up energy-saving technologies can be gendered.

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Behavioural aspects tend to be neglected in the study of energy choices. Yet, the routinized nature of many energy behaviours might represent a hindrance to their change. Successful habit breaking strategies can use direct experience policies (e.g. trial periods). Furthermore, environmental awareness and values have an uncertain impact on behaviour as discrepancy is often observed between one's awareness, attitude and values, and actual energy behaviour.

Drivers of energy choices made by public authorities

Considering collective energy choices, several drivers and bottlenecks lie at the governance level. A low carbon energy transition requires disrupting the current energy system based on fossil-fuels, centralised generation and supply-side orientation, while at the same time introducing sustainable alternatives. This raises the challenge of good governance and of consistent policy-making that is based on a long-term strategy that cannot be easily overturned in the future.

When implementing a new technology shift, one needs to make sure that consumers accept it as their opposition can represent a major barrier to success. With the gradual shift to more distributed systems based on renewables, consumers can become more active and central in the transition. On the other hand, institutions still prevent the active liberalisation of markets. Path dependency can hinder the energy transition. Local communities may not yet be empowered enough to actively contribute to it.

The success of the energy transition will thus also depend on the removal of barriers to green innovation. The completion of the energy transition requires a long-term, consistent policy plan, including with a view of further developing low-carbon energy technologies, which depends on the structure of the market, the regulatory barriers to technological diffusion, the support to R&D and the active engagement of stakeholders in the diffusion.

Green innovation support programmes should strike a balance between the provision of financial incentives and eliminating barriers to private investment. A paradigm shift enabling the full liberalisation of energy markets, giving attention to demand-side solutions and actively involving consumers in energy production and policy design is thus strongly needed.

Synthesis on factors driving energy choices

The theoretical and empirical background on energy consumption and pro-environmental behaviours has been developed over several decades and offers solid foundations for mapping all the issues and dimensions involved in energy choices. Our understanding of the topic within ENABLE.EU builds on this high-quality background.

We further aspire to bring our analyses of the economic, socio-behavioural and governance drivers together in order to provide a more comprehensive framework to address energy behaviour change. Although it is difficult to generalise the findings and to draw an accurate picture of the drivers of energy choices based on a portion of the literature, the review attempts to highlight points of consensus, and conversely, elements backed by mixed findings. For instance, strategies like social comparison and targeting of specific groups in general seem to positively influence energy conservation, while studies differ on the impact of different types of information provision. Above all, the combination of several strategies (e.g. information provision and social norms) can be particularly effective, but cost-effectiveness should also be considered. Beyond the effectiveness of a specific strategy, the design of a policy should not neglect several other essential aspects, such as synergies between factors and strategies, policy cost, timing, consistency with other policies and institutional context.

The analysed literature suffers nonetheless from several weaknesses and difficulties. Some lie in the methodology and scope of research, while some are linked to the complexity of the energy sector. ENABLE.EU's empirical approach will build on the identified gaps and difficulties to maximise its added value in understanding what drives energy choices.

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General Introduction

The Energy Union Framework Strategy laid out on 25 February 2015, and the European Commission Clean Energy Package for all Europeans unveiled on 30 November 2016, aim to foster a cost-efficient energy transition able to deliver secure, sustainable and affordable energy to all European consumers. It has embraced a citizen-oriented energy transition based on a low-carbon transformation of the energy system. Ultimately, the successful implementation of the Energy Union will require a change in energy production and energy consumption choices. Such choices are shaped by economic prerequisites, existing technologies, value systems, gender-based preferences, efficiency of governance and the maturity of civil society.

The ENABLE.EU project seeks to contribute to more enlightened, evidence-based policy decisions, to help identify the right incentives for individuals and groups to reach the twin goals of successful implementation of the Energy Union and Europe's transition towards a decarbonised energy system. To this end, ENABLE.EU aims to provide an excellent understanding of the social and economic drivers of individual and collective energy choices, with a focus on understanding changes in energy choice patterns.

Energy has the characteristic of being "doubly invisible" (Burgess and Nye, 2008): not only is it viewed as an abstract force difficult to visualise (electricity in particular), it is also grounded in daily life (i.e. in habits and practices) (Shove, 2003). Therefore, ENABLE.EU devotes its attention to energy choices – the notion of choice, in this context, does not imply that decisions made by individuals are rational or conscious. They refer to actions undertaken by individuals affecting their energy consumption – e.g. driving a car, keeping the room temperature of a dwelling at a certain level and deciding to produce their own energy. The aim of the study is to identify the factors, also called drivers or variables, influencing these choices. They represent all elements that might shape individual and collective energy choices and behaviours, such as age, income, prices, available technologies, the institutional context, etc. As underlined in the different Parts of this review, these factors can be classified and our approach differentiated between techno-economic, socio-cultural and governance factors. Research attempting to understand the links between these factors and behaviours relies on strategies and interventions, i.e. external changes acting on factors to induce specific behaviours. As developed below, such strategies include policies, changes in prices, information provision, social comparison, etc.

This literature review relies on scientific articles and books relevant to the understanding of energy choices. It sets the scene for the project reviewing existing theories, qualitative and quantitative studies of the drivers of energy choices, and pointing out to their limits and encountered difficulties to optimise the research design within ENABLE.EU.

Methodology and characteristics of the reviewed literature

The literature related to energy choices is rich with many contributions written over the last 40 years, in various disciplines. An exhaustive analysis of this entire literature is thus difficult.
This literature review is based on 662 references, virtually all of them are social sciences articles published in academic journals, other sources include books and reports published by public authorities. Answering to the need for an interdisciplinary approach, which is inherent in the study of energy choices, the references used are rooted in various academic disciplines: psychology, economics, sociology, environmental science, energy policy, political science, anthropology, engineering and marketing. This selection is based on those contributions' relevance for ENABLE.EU, to root the project in the current state of knowledge provided by social sciences on energy choices.

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Those 662 references were selected by ENABLE.EU's partners based on their abstracts, date of publication and number of quotations (in particular, to assess the influence of older articles). A significant part of the articles was discarded after complete reading when the methodology was deemed poor or when the content seemed too distant from ENABLE.EU's core activities. This literature review thus mainly builds on over 400 articles, which can be found in the bibliography, judged most relevant for setting the background.

These references tackle energy choices in various ways: they lead different types of research, study various energy services and usage, frame the issue differently and thus address it through various approaches.

First, when it comes to the type of research, many resources are rooted in *theory* and develop a deepened theoretical understanding of energy-related behaviours. On the other hand, *empirical research* is expanding to test strategies suggested by theoretical framing. Some research combines both theory proposal and empirical testing. While most of empirical studies present quantitative findings, this review also relied on several qualitative studies. The use of meta-analyses[1] is also growing in the field with primary studies multiplying and statistical data being more solid.

Second, in terms of energy services, many studies remain general, encompassing all sorts of energy use and services. This approach reaches its limits as soon as the study gets into more depth. General trends can be observed among services and be relevant when aiming at more general findings, but each of them has their own particularities which are better approached separately. For more specific findings, a large part of the studies selected focus therefore on individual energy services, i.e. mobility, heating and cooling, and electricity, and these are highly relevant for our subsequent case studies' work.

Third, we have included in our study literature both on choices related to energy consumption and on pro-environmental behaviour. As will be discussed below, a large portion of the literature frames energy-related behaviours in a more 'environment'-oriented manner. In spite of a different framing appealing to different terminology, research from both sides brings strongly pertinent knowledge for ENABLE.EU. Besides, some articles also refer to 'resource' use and conservation, including water, and to 'waste' management, which although not directly related to energy, have strong similarities to the topic and thus sometimes cover relevant findings for our study (e.g. in Part 1, a study on water and RCT shows energy-relevant findings). Furthermore, this study addresses different actors and levels of action, i.e. both individual (households and firms) and collective choices.

Finally, research on energy choices is very diversified and has different aims articulated through various approaches. More concretely, each study tends not to fit into a clear framework where all new findings add up. Overlaps and inconsistencies appear in research and empirical studies on the same topic frequently reach different findings because they are based on different samples, methodologies, geographic locations, periods of time, framing of the question, etc. (Frederiks et al., 2015a). Therefore, it is difficult to have a clear overview of the findings and to generalise them. This review attempts to highlight dominant patterns that emerge from this research.

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[1] The rich literature and the complex articulation of fields, domains and determinants underlying energy choices make it an opportune area for meta-analyses. Meta-analysis can be defined as "the art of calibrating and combining statistical evidence from separate studies into a single analysis to provide a quantitative, systematic overview of an empirical effect in the literature" (Delmas et al., 2013, p.732). This method is increasingly used to synthesise findings, as it improves accuracy and elicits more reliable statistical significance (Delmas et al., 2013; Abrahamse and Steg, 2013).

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In short, this review attempts to bring together the main findings on energy choices to date by:

- providing an overview of the factors influencing energy choices,
- analysing the theoretical background on which most of the subsequent research is based,
- understanding the diversity of approaches to this topic, and
- pointing out to the gaps that can be bridged within the framework of the ENABLE.EU project.

This literature review is structured in four Parts reflecting our initial categorisation of factors. Part 1 is rooted in an economic approach of energy choices considering market drivers affecting energy consumption and the adoption of energy-efficient technologies. It provides insights into the responsiveness of consumers to energy price changes and the economic barriers to energy conservation behaviours as well as an assessment of the Randomised Controlled Trial's (RCT) method which will be employed within ENABLE.EU. This Part also takes into account firms' behaviour towards energy price changes. Part 2 investigates the influence of socio-cultural, demographic and behavioural aspects on energy choices. The findings for these factors are mainly related to transportation, heating and cooling, and the shift to "prosuming". Part 3 adopts a governance perspective focusing on collective energy choices. After introducing the theory on energy transition governance, the motives driving policy decisions and the obstacles hindering the implementation of an energy transition governance are presented. Finally, Part 4 draws from the three preceding Parts as well as from other elements of the literature to provide a cross-disciplinary overview. Rooted in a theoretical framework, it attempts to identify points of consensus and divergence in empirical research on energy choices. Pointing out to the limits and weaknesses of the literature, it sets the scene for ENABLE.EU which will build on these findings to maximise its added value in the research and policy landscape. This Part also covers concrete applications of the findings on several topics which will be developed as case studies within ENABLE.EU – namely, electricity consumption, low-carbon mobility, heating and cooling, the shift from consumer to prosumer and governance frameworks.

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1. Market and non-market drivers of energy consumption and the adoption of energy efficient technologies

1.1 Introduction

Reducing energy consumption could bring in numerous private and social benefits, which can come in the form of lower energy bills or reduced carbon emissions associated with energy use. To realise these benefits, governments around the world have adopted policies to reduce energy consumption. Among these policies, price-based interventions (such as emissions tax, cap-and-trade programme or subsidies to use energy efficient technologies) provide an appealing solution simply because changes in energy price provide incentives for consumers[2] to reduce their energy consumption (Jacobsen, 2015). This contrasts with imposing standards that are viewed to be associated with higher pollution abatement costs (Holland, 2012) or unnecessary infringement of consumer choice (Gayer and Viscusi, 2013), which may negatively impact consumer welfare.

How consumers reduce their consumption due to price changes has huge policy implications. Jacobsen (2015), for example, argues that, in the presence of unexploited high-return investment opportunities, the loss in consumer surplus due to a policy-induced increase in energy price may be small (or even negative under certain conditions) if the price change prompts consumers to invest in energy efficient technologies. In contrast, if consumers respond by reducing their consumption of energy services (e.g., lowering down the thermostat), the loss in consumer surplus may be significantly greater, abstracting from any benefits arising from reduced externalities associated with energy consumption. The presence of behavioural anomalies (e.g., inattention to long-term energy savings or to electricity conservation actions (Taubinsky, 2013) may also make consumers deviate from cost-minimising consumption. Because of this, price-based policies may not be well-suited to induce high-return energy efficiency investments, which are also regarded as an efficient means to reduce emissions (Gillingham et al., 2009). Furthermore, the choice of instrument (i.e., carbon tax or cap-and-trade) may result in different outcomes depending on the effect on energy price. For example, a carbon tax may be viewed by a business manager as a permanent increase in energy price while the volatility of permits may be viewed a transitory change in energy price, which may have different effect on the manager's propensity to invest in energy efficient technology. Finally, the design of instruments may also be improved to minimise any unintended consequence associated with consumer (and producer) response to price change if policymakers have a better idea of consumer behaviour. For example, consumers may decide to drive more (and increase the risk of accident) because of having more efficient cars (i.e., rebound effect[3]) or buy light vehicles which are more vulnerable to damage than bigger (but less efficient) ones.

There is a vast body of literature analysing different policy interventions impacting consumer demand. Earlier studies built on small scale pilots, which had difficulty to identify causal effects and generalizable results (Faruqui and Sergici, 2010; Faruqui et al., 2010). More recently, large-scale randomized controlled trails (RCTs) have increasingly been employed (Allcott and Rogers, 2014; List et al., 2017; Jessoe and Rapson, 2014). The studies prove that both neoclassical factors, such as prices and information, and behavioural factors, such as social norms and inattention, impact energy demand.

[2] Unless otherwise stated, consumers in the context of Part 1 comprises residential, commercial and industrial customers.

[3] The rebound effect is the reduction in expected gains from new technologies that increase the efficiency of resource use, because of behavioural or other systemic responses. See Sorrell et al. (2009).

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Consumer investment in energy efficiency fundamentally involves decisions over higher initial capital costs and uncertain lower future energy operating costs at present values (Gillingham et al., 2009). The initial cost, in its simplest case, is the difference between the purchase and/or installation cost of a relatively energy efficient product (plus some other costs such as adjustment) and the cost of an equivalent product that provides the same energy service (e.g., heating/cooling a 25 sq. ft. room) but uses more energy. Meanwhile, assessing future energy operating costs requires expectation of future energy prices, in addition to changes in other costs related to energy use (e.g., carbon tax), and the equipment lifetime. Overall, an optimal decision requires choosing over a set of alternatives of the investment that minimises the total costs of energy service.[4]

A large body of literature illustrates how consumers appear to underinvest in energy efficient technologies. The seminal work of Hausman (1979) first illustrated the consumers' apparent excess discounting of future energy savings when purchasing air conditioners. The study compares the trade-off between upfront purchase price and operating costs in the lifetime of the equipment to calculate consumers' implicit discount rates, which is about 20 %. This implies that consumers do not seem to value future benefits from investing in more efficient technologies. Subsequent studies investigating this trend emerge, including the well-cited review of Train (1985) that shows how calculated consumer discount rates from different categories of energy intensive durables tend to largely exceed normal market returns. The notion of private consumers underinvesting in energy efficient technology has been coined as "energy paradox" (Jaffe and Stavins, 1994b), while "energy efficiency gap" refers to the notion that socially efficient technologies are not adopted (Jaffe and Stavins, 1994a; Gerarden et al., 2015a). The factors most economists adopt in trying to explain these notions can be grouped into three broad categories: (1) market failures; (2) behavioural effects, and (3) modelling flaws (Gerarden et al., 2015a).

Explanations centring on market failures involve: information problems, which include principal- agent problems emanating from split incentives of landlords and tenants (Levinson and Niemann, 2004; Davis, 2012; Gillingham et al., 2012) and asymmetric information between sellers and buyers of energy efficient products (Howarth and Andersson, 1993); energy market failures such as un- accounted externalities associated with energy use like carbon emissions (Gillingham et al., 2006) and inefficient average-cost pricing (Joskow and Tirole, 2007); capital market failures such as liquidity constraints among low-income households and small business owners (Golove and Eto, 1996); and innovation market failures such as externalities associated with introducing new technologies/products in the market (Houde and Spurlock, 2016; Brucal and Roberts, 2016) and learning-by-doing spillovers, which

[4] Gerarden et al. (2015b) formalise this consumer investment decision as a cost minimization problem:

$$min \left[\underbrace{TC}_{\text{total cost of energy service}} = \underbrace{K(E)}_{\text{equipment purchase cost}} + \underbrace{\mathrm{O(E,P}_E) \text{ x } \mathrm{D(r,T)}}_{\text{discounted operating cost}} + \underbrace{Z}_{\text{other cost}} \right] \quad (1)$$

where:

$$\begin{aligned} \mathrm{E} &= \text{annual energy use} \\ \mathrm{O(E,P}_E) &= \text{annual operating cost} \\ \mathrm{P}_E &= \text{price of energy} \\ \mathrm{D(r,T)} &= \text{consumer discount factor} \\ \mathrm{r} &= \text{discount rate; and} \\ \mathrm{T} &= \text{time horizon} \end{aligned} \quad (2)$$

which allows for a clear decomposition of factors that might be influencing consumers underinvestment in energy efficient technologies.

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had not been explored in the context of energy efficiency gap (Gerarden et al., 2015b). Explanations relating to behavioural anomalies include: consumer inattentiveness and salience issues (Busse et al., 2013; Allcott and Taubinsky, 2015); myopia/short-sightedness, bounded rationality, and systematically biased beliefs (Allcott, 2011a). A major problem in analysing the relative contribution of these behavioural factors is the difficulty of disentangling potential confounders such as incomplete information (Gerarden et al., 2015a). Meanwhile, there are also studies suggesting that the perceived underinvestment of consumers in energy efficient technologies may not be as paradoxical as previous analysts have pointed out. This part of the literature highlights the idea that previous studies were based on assumptions that contributed to miscalculation of the size of the gap. For example, previous studies may have neglected unobserved or understated costs of adoption (Allcott and Kessler, 2015), irreversibility of the investment (Van Soest and Bulte, 2001), and option value (Sanstad et al., 1995), which, if added up, may lead to implicit discount rates that are comparable to market rates.

This review aims to take stock of the studies that focus (but not exclusively) on the relationship between energy prices, non-market factors, electricity consumption and consumer investment in energy efficient technologies. In particular, we focus on the part of the literature that asks whether the discounted operating costs are inefficiently priced and/or understood (i.e. the second term of equation 1). The goal is to identify gaps in the current literature as well as future research opportunities. The review proceeds as follows: Section 2 provides a brief overview of the literature concerning the measurement of consumer response to price movements. This will help in understanding the challenges in analysing the relationship between energy price, energy conservation actions and energy efficiency investment behaviour of consumers; Section 3 describes the randomized controlled trial methodology and its role in interventions examining energy consumption and investment in energy efficiency; Section 4 presents literature on the response of consumer behaviour to energy price changes and provides a number of factors, both economic and behavioural, that might explain the way consumers respond to energy price movements; Section 5 discusses other potential barriers that may be confounding the effect of price movement and may be useful in the choice and design of policy instruments that promote energy conservation or investment in energy efficient technologies.

1.2 Measuring consumer responsiveness to energy price changes

Before we analyse energy-price-efficiency-investment nexus, it is fundamentally important to ascertain if consumers change their consumption behaviour when energy prices change. In general, most economists would agree that market prices influence consumer and firm decisions on how much commodities to consume; energy services are not an exemption. However, consensus has not been achieved on the magnitude of the price response, which seems to be largely dependent on the type of data used, geographic or sectoral coverage and time horizon employed in previous studies.

The easiest way to determine the extent of demand responsiveness to changes in energy price is to calculate the price elasticity of energy demand. For example, in a meta-analysis by Labandeira et al. (2017), we can observe that long-run price elasticities are larger than short-run elasticities, which may imply more energy efficiency improvements in the long run as capital turns over or consumers reallocate towards alternative energy source (e.g., gas to electric heating) (**Table 1**). On average, electricity price has high short-run elasticity compared to other energy inputs, although consumers tend to be more sensitive to natural gas price movement in the long run, which may suggest differing salience in the price for each energy source or presence of alternatives in different time horizons. There is also significant variation in energy own-price elasticity estimates across sectors, with commercial customers having the most responsive demand to price changes. Elasticity estimates may also have changed over time because of changes in trends in energy prices and efficiency of products as illustrated by the relatively low elasticity estimates post-2008 period. This is consistent with Hughes et al. (2008) who observe that short-run elasticity of fuel for motor vehicle use has significantly dropped in the early

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2000s compared to the 1970-1980 levels following the drop in the fuel prices in the 1990s. Within residential customers, there can also be different price elasticities of electricity demand for different household types or income groups (Schulte and Heindl, 2017).

The literature is replete with studies that attempt to measure how consumers, both residential and non-residential customers, reduce their energy consumption as energy price increases (see for example, Dahl, 1993 for an earlier review on energy inputs and Dahl, 2014 for a more recent one on gasoline). Over the years, a wide range of estimated consumer elasticities have been produced, potentially because of the diverse type of data used (experimental, time-series, cross-sectional, and panel), geographic coverage, extent of price variation observed, sectors and energy inputs included, and methodologies employed. Overall, whether the magnitude is significantly large or the response is similar across sectors, time horizon or energy inputs remains to be an empirical issue.

A problem with most energy demand elasticity estimates, such as those presented above, is that they are based on what the analyst can observe. This implies that estimates presented in the table, which are based on actual consumer behaviour, may be influenced by other factors. For instance, it is possible that any increase in energy use resulting from increased energy efficiency (i.e., the rebound effect), which may result from responding to subsequent price increases, is embedded in the estimates (Gillingham et al., 2009). Thus, it is possible that the calculated elasticities may be underestimated if one wants to look at the effect of a pure idiosyncratic price shock on energy demand.

Table 1: Range of estimates of energy own-price elasticities across different categories

Determinant	Observations	Average Elasticity	
		Short-run	Long-run
Good			
Energy	372	-0.149	-0.570
Electricity	516	-0.203	-0.520
Natural gas	229	-0.184	-0.566
Car fuels	82	-0.180	-0.358
Gasoline	465	-0.194	-0.526
Diesel	136	-0.157	-0.391
Heating oil	44	-0.188	-0.534
Consumer			
Residential	693	-0.216	-0.620
Industrial	259	-0.166	-0.508
Commercial	59	-0.230	-0.721
Total	833	-0.162	-0.435
Country			
Net energy exporter	481	-0.189	-0.514
Net energy importer	1363	-0.185	-0.527
Developed	1432	-0.186	-0.515
Developing	412	-0.184	-0.550
Data			
Cross-section	182	-0.337	-0.861
Time series	1174	-0.167	-0.446
Panel data	488	-0.204	-0.514
Sample period			

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Determinant	Observations	Average Elasticity	
		Short-run	Long-run
Pre-1973	101	-0.224	-0.634
Post-1973	1743	-0.183	-0.518
Pre-1979	354	-0.191	-0.551
Post-1979	1490	-0.184	-0.518
Pre-2008	1817	-0.186	-0.526
Post-2008	27	-0.175	-0.323
Publication			
Peer-review journal	1461	-0.193	-0.567
Other	383	-0.151	-0.382
Estimation method			
Least squares	1151	-0.188	-0.458
Instrumental variables	265	-0.184	-0.559
Other methods	428	-0.180	-0.641

Adapted from Labandeira et al. (2017)

More fundamentally, in the absence of more detailed data, the analyst must assume that perfectly-optimising and perfectly-informed consumer is purchasing at the point where the consumer's marginal value of energy service is equal to (or below) the marginal price she faces.

Recently however, there has been a growing recognition that consumers make decisions with limited information, attention and cognitive abilities particularly when purchasing energy service (see, for example, Borenstein, 2009). Ito (2014) provides a strong evidence that households respond to average electricity price, instead of marginal or expected marginal price, primarily due to the cost of understanding complex pricing structure. This has policy implications particularly when nonlinear pricing is viewed to promote energy conservation or investment in energy efficient technologies, an issue that we will revisit later in the discussion. Meanwhile, Wolak (2011) and Jessoe and Rapson (2014) provide evidence that information provision helps US consumers respond more sensitively to price changes. Matsukawa (2004) and Gans et al. (2013) have similar results for Japan and Northern Ireland consumers, respectively. Unfortunately, a study that determines whether non-residential customers respond to marginal prices does not exist.

Consequently, the literature is unclear on which price variable should be used in measuring consumer response. For residential customers, the use of average price seems to be popular (see, for example, Bernstein and Griffin, 2006; Paul et al., 2009; Alberini and Filippini, 2011). Provided that households respond to average price rather than marginal price, average price is no longer endogenous to consumption, albeit the presence of increasing block pricing schemes that most utilities have. However, even if we assume the average price and energy consumption are not simultaneously determined, the average price variable is likely to be affected my measurement error, which, if not considered for, may understate the absolute value of the estimated elasticity (Alberini and Filippini, 2011; Alberini et al., 2011).

There is also a concern on whether to use the current price (Linn, 2008), a moving average of prices from recent periods (Poyer and Williams, 1993), or predictions from econometric models. If consumers respond to the expected price, then the current price is a good approximation provided we assume that the evolution of energy prices follows a random walk[5] (Pindyck, 1999). More recently, there has been

[5] A movement of a variable follows a random walk if the pattern or trend is non-discernible.

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evidence to suggest that "no-change" forecast is a better predictor of future prices than those generated from complex econometric models (Alquist and Kilian, 2010). It is unclear, however, whether this kind of behaviour also applies to non-residential customers.

For non-residential customers, the measure of energy price movement is more challenging. For instance, Sato et al. (2015) find that energy prices for industrial sectors are harder to obtain for most countries, with figures often reflecting an average across sectors and with considerable missing values. To overcome this challenge, previous studies have calculated energy price indices, which exploit variations stemming from differences in industry locations and energy mix (see, for example, Linn, 2008; Steinbuks and Neuhoff, 2014; Aldy and Pizer, 2015). While these price indices seem to capture a lot of exogenous variations, there are still many potentially confounding factors that might bias estimates of firm response. For example, a firm may respond differently to a carbon price that is deemed permanent compared to a pure exogenous energy price shock that is believed to be transitory. Some firms may also have some market power that enables them to purchase energy inputs at a lower price. Depending on the distribution of firms being studied, failing to disentangle this effect may result in an upward bias in the price index at a particular period.

Synthesis:

The optimal price regime, which may involve policies that affect energy price directly and indirectly, will depend on how consumers respond to energy price movements. There seems to be a wide acceptance amongst analysts that energy price seems to influence consumption, although consensus has not been attained as to how large the response is and whether the results from one sector or location can be applied to other. Certainly, a wide range of estimates of consumer responsiveness to price changes have been generated but their policy implication may still be limited to geographic coverage, time periods, or included sectors.

More pragmatically, future research should illustrate how the price for each energy input (electricity, coal, natural gas, etc.) has evolved over time, and identify how much of these movements is due to government regulation, market structure or from exogenous energy price shocks. This can be potentially helpful if one would want to more accurately estimate how consumers and firms respond to energy price movements relative to government policies that directly and indirectly affect energy prices and/or energy demand. Potentially, such analyses can contribute to the literature by determining how salient policies (e.g., carbon tax) perform relative to pure energy price movements.

1.3 An overview of randomized controlled trials and other interventions to reduce energy consumption

Field experiments may be able to overcome this effect, particularly if households are unaware that they are taking part in a trial. Relatively recently, field experimentation has been used to address resource conservation and attenuation of environmental externalities in the economy at large. For instance, several field experiments have demonstrated effectiveness of interventions in residential electricity and water use. Perhaps most famously, Opower experiments demonstrate that provision of social norm information to households can lead to an average 2% savings in electricity use (Allcott, 2011c). Ayres et al. (2012) also analyse Opower experiments, finding that the messages are most effective among households with the highest consumption and that the frequency of messaging matters[6]. This is also true in other non-energy domains. In a natural field experiment on residential water conservation,

[6] Costa and Kahn (2013) detect heterogeneity in the effects of the home energy reports according to political ideology, demonstrating a perverse effect on households in conservative areas that is outweighed by the effect on households in liberal ones.

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Ferraro and Price (2013) demonstrate that the use of normative messages is more effective than either prosocial appeals or technical information on their own, and again that high-use households (i.e., the most price insensitive subjects) are most susceptible to these messages. The norms effects persisted well beyond the intervention relative to control groups (and relative to prosocial and technical messaging groups in the water conservation experiment), indicating that norms may nudge individuals into making more energy- and water-efficient decisions on a habitual basis (Ferraro et al., 2011; Allcott and Rogers, 2014). However, Tiefenbeck et al. (2013) warn against the potential negative spillovers, demonstrating a perverse effect of a water-saving campaign on residential electricity consumption. In this case, the authors ascribe this result to a moral licensing effect – where engaging in a positive behaviour in one domain "licenses" one to act negatively in another. Negative spillovers were also found by McCoy and Lyons (2016) when examining how information provision targeting energy consumption can also affect energy efficiency investments in the home.

In addition to testing norm-based messaging, experimental economists have explored the potential for dynamic pricing schemes to increase the efficiency of residential energy consumption. Wolak (2007) was the first to randomize dynamic energy pricing. In a field experiment in Anaheim, experimental subjects received smart meters and were assigned to remain on the business-as-usual pricing plan or to receive a critical peak pricing (CPP) plan. In the CPP plan, customers received rebates worth 0.35 cent per kWh reduction relative to their households' average use for the most consumptive non-CPP days during that time. While treated customers reduced their consumption by 12 % relative to control customers during critical peaks, there is a large perverse effect on non-CPP days due to the structure of the CPP plan, which incentivises treated subjects to consume more on non-CPP days to increase their rebate. Additionally, customers were guaranteed their CPP bill would not exceed their bill under a standard increasing block tariff, potentially dampening the incentive to reduce consumption.

In an extension, Wolak (2011) verifies the effectiveness of CPP plans in reducing consumption during peak events, especially when CPP does not simply reward a customer with rebates if consumption is below a reference level; the most effective treatment by far is the CPP plan where a customer pays the high tariff for every kWh consumed during peak events. Additionally, he investigates the existence of an individual "cost of taking action" phenomenon whereby an individual's cost of reducing energy use must be overcome by a sufficiently large price spike; he finds no evidence for such a cost of action, as (price adjusted) reductions in consumption on hourly and CPP tariffs are equal. A review of pilot studies on dynamic pricing by Faruqui and Sergici (2010) estimates a decrease of household peak usage by 3-6 % under a Time-Of-Use (TOU) tariff and by 13-20 % under a Critical-Peak-Pricing (CPP) tariff. Both tariffs are preliminary steps to Real-Time-Pricing (RTP) which aim to address peak load challenges. This difference can be explained by higher peak prices under CPP. The peak reductions under CPP increase up to 44% if smart technologies (e.g., smart thermostats, smart gateways) are used. Allcott (2011b) also detects significant effects of dynamic pricing in the context of salient hourly price changes, finding that consumers are fairly price elastic, reducing consumption considerably during peak hours, and that they do not consequently increase consumption in off-peak hours.

Having demonstrated the effects of dynamic pricing, others have introduced interventions to evaluate additional or relative efficiencies. Jessoe and Rapson (2014) demonstrate an effect of real-time price change updates (0-7 %), which grows considerably when interacted with real-time consumption feedback (8-22 %), demonstrating the importance of salience in both price and quantity information. Kahn and Wolak (2013) also find that improved comprehension of marginal pricing schemes in combination with understanding of the consumption of electricity-consuming appliances reduces consumption 1.5 and 3 % on average for the customer bases of two California utilities. Ida et al. (2013) compare dynamic pricing (i.e. extrinsic motivation) to moral suasion (i.e. intrinsic motivation). They find that consumption decreases monotonically with increases in the marginal CPP price. While moral suasion significantly reduces consumption during peak events (3 %), the effect is only a fifth as strong as that of the marginal price increase (15 %). Using follow-up data, they find that only economic

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incentives have a persistent effect, likely owing to habit formation and the incentives' effectiveness among low-income households.

A literature survey examining pilot studies by Faruqui and Sergici (2010) finds an average reduction of electricity consumption by 7% if households are equipped with In-Home-Displays giving real-time usage information. This effect was greater in the morning (12 % on average), compared to 8 % on average in the evening. Houde et al. (2013) find that this effect reduces over time and do not observe a significant effect after four weeks. Lynham et al. (2016) try to disentangle whether the reduction in energy usage is due to a salience effect or a learning effect. The authors estimate a significant, but decreasing learning effect. A significant saliency effect cannot be identified. The results of Lynham et al. (2016) suggest that information campaigns are more cost-effective in reducing electricity consumption than installing costly IHDs. However, these results might also be driven by small sample size issues.

As noted above the effect of information provision on consumption can vary over time. Allcott and Rogers (2014) find that on receipt of a Home Energy Report, households immediately reduce their consumption, but this effect attenuates over time and reverts to its previous level. This pattern is then repeated for each report, but the magnitude of the "action and backsliding" decreases over time. The households in this study received reports monthly and quarterly. To date, no significant research has been conducted systematically examining how the frequency of information provision affects consumption, and how the length of treatment affects the persistence of the energy savings achieved.

Several inattention models could help to explain such behaviour. Theoretical models explain household behaviour by assuming limited attention towards information. For example, Sims (2003) argues that individuals have only limited information processing capacity. Similarly, Gabaix (2014) and Koszegi and Szeidl (2012) assume that households focus in their decision making on some product attributes more than on others. These models could explain why consumers might just "ignore" or undervalue electricity costs in their utility maximization. Taubinsky (2013) also presents an inattention model, but argues that households might be inattentive to energy conservation actions. Following this argument, uninformative reminders could decrease electricity usage, as they prevent households from simply forgetting to engage in electricity conservation.

In line with Taubinsky's (2013) argumentation, Gilbert and Zivin (2014) find a decrease in electricity consumption of 0.6-1 % after each electricity bill when testing the effect of intermitting billing due to smart meter systems. Gilbert and Zivin (2014) attribute the reductions to reminder-effects which are inherent in bill reception. According to Taubinsky (2013), inattention towards energy conservation actions could be mitigated either through reminder or through engaging in repeated energy conservation actions. Hence, Taubinsky (2013) argues that reminders and habits serve as substitutes. This result is also supported by Allcott and Rogers (2014), who report a diminishing effect of Home Energy Reports (HERs) on electricity reductions. The reason is that HERs serve as reminder, but when the energy conservations actions become habit, there is no need for the households to be reminded anymore.

Finally, a recent line of literature aims to understand and price the effects of behavioural phenomena on energy-saving technology adoption. For instance, in a door-to-door field experiment, Herberich et al. (2011) structurally estimate the effects of social pressure and norms on the purchase of compact fluorescent light bulbs (CFLs), finding that both have an influence on buyer's decisions in this context. While social norms (i.e. informing the buyer of the proportion of similar households using CFLs) affect buyer decisions on the extensive margin – that is, whether to buy CFLs – price variation influences decisions on the intensive margin, so that buyers purchase more CFLs when they are cheaper. Interestingly, the data suggest that individuals who are not warned that a salesperson will approach the house may experience negative utility from the purchase due to social pressure to buy when confronted with the salesperson, a finding concordant with DellaVigna et al. (2012). Finally, Yoeli et al. (2013)

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demonstrate the importance of observability – what they term "indirect reciprocity" in voluntarily contributing to peak demand reductions. The authors provide evidence that reputational concerns are driving the observability effect.

Synthesis:

The method of randomized controlled trials, both for households and for firms, is promising, as it guarantees internal validity. External validity ideally requires non-voluntary participation and large sample sizes. Given this, large-scale field experiments offer promise. Open avenues of research that can be examined using this methodology include: 1) disentangling the impact of social norms from pure information provision in reducing consumption; 2) examining the extent to which households are inattentive towards energy conservation actions; 3) systematically examining the extent to which the frequency of information provision affects habit formation and the persistence of energy saving behaviours.

1.4 Why would consumers NOT respond to energy prices?

While the relationship between energy prices and investment in energy efficient technologies seems to have huge implications on policy, the literature on this area appears to be sparse. Earlier studies such as Hausman (1979) and Dubin and McFadden (1984) employed cross-sectional data and discrete choice models of consumer choice across types of air conditioners and heating equipment. More recent studies looking at this issue are predominant in the automobile industry (Busse et al. 2013; Allcott and Wozny, 2014) and household appliances (Rapson, 2014; Houde, 2014; Jacobsen, 2015), but very little has been done on industrial and commercial consumers potentially due to lack of access to reliable micro-level data.

Gerarden et al. (2015b) point out that energy efficient technologies may be adopted at a socially suboptimal rate, even if consumers are making privately optimal decisions. One of the reasons is that energy prices can be inefficiently low if they do not fully capture the externalities associated with energy consumption - this is for example the case of gasoline prices in the US. Gerarden et al. (2015a) find that externality estimates (which include the cost of global and local emissions, congestion and accidents) are more than six times larger than the current gasoline taxes in the US. Meanwhile, Owen (2006) argues that EU countries only considered the direct external costs of greenhouse gas emissions of power generation. For example, nuclear power emits negligible CO2 emissions, but is associated with high radioactive waste management costs that are not normally accounted for.

Energy prices can also be inefficiently low due to regulation. For example, the absence of real-time pricing in the power sector suggests that consumers may consume an inefficiently high amount of electricity power when the price is set below marginal costs, leading to distorted investment in and utilisation of generation capacity (Joskow and Wolfram, 2012). Real-time pricing (RTP) can correct this distortion, but the effect of this pricing scheme to total use and in the investment on energy efficient technologies amongst consumers is ambiguous (Gillingham et al., 2009). The total effect will also depend on which equipment or appliance is being used when the price is inefficiently low and which set of equipment or appliances will be altered after the change in the pricing scheme. Now, most utilities implement two-part tariffs to facilitate the recovery of system fixed cost while preserving marginal incentives through volumetric charges. The tariffs are not set optimally, with marginal prices set above marginal cost to recover fixed costs (Gerarden et al., 2015a). This also does not provide incentives to households since they respond to the average price, suggesting that further information is needed in order for them to perceive and respond to the actual marginal price (Ito, 2014).

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While increasing energy prices through taxation or otherwise may seem to be the optimal direction to improve efficiency, the existence of other externalities may further complicate the analysis (see for example, Anderson and Auffhammer, 2014; Jacobsen, 2014). Thus, knowing the unintended consequences of environmental policies may improve how environmental policies are implemented.

Meanwhile, a number of studies have focused on determining the factors influencing consumer adoption of energy efficient technologies, finding that energy price increases are associated with significantly greater adoption of energy efficient equipment. Automobile purchases offer an avenue to study this issue because gasoline price has fluctuated dramatically over time (Helfand and Wolverton, 2009). Earlier and more recent studies seem to confirm that fuel costs (or gasoline price) significantly influence car purchases and consumer choice on fuel efficiency (see, for example, Goldberg, 1998; Busse et al., 2013; Allcott and Wozny, 2014). The problem with these previous analyses is that the automobile industry had been subject to fuel economy standards for many years, which makes the estimated effect of energy price potentially biased upward (in absolute terms) (Gerarden et al., 2015b). The bias may be significant when environmental regulation influences suppliers' innovation and deployment of energy efficient products (Brucal and Roberts, 2016), and more advanced technologies in general (Newell et al., 1999; Popp, 2002; Miller, 2014; Calel and Dechezlepretre, 2016). Thus, it is important to disentangle the effect of pure energy price changes to environmental policies that influence energy prices.

Other studies analyse the impact of energy prices on the adoption of energy efficient technologies by looking at home appliances (see, for example, Jacobsen, 2015 and Rapson, 2014). Results of these studies generally reflect the idea that consumers are less sensitive to energy price changes when purchasing household appliances than when spending on cars. Interestingly, Houde (2014) finds significant heterogeneity amongst consumers; some are very responsive to electricity costs, some are insensitive to electricity costs, and some are overly sensitive to certification labels well beyond what can be justified by the associated energy savings. For natural gas, there may be a tendency to overestimate price and overinvest in energy efficient gas-using appliances, which may be exacerbated by the presence of minimum energy efficiency standards (Houde and Spurlock, 2016). This is largely the case since the industry saw recent technological advance in oil and gas extraction, which may continuously drive down prices. Assuming that consumers maintain a "no-change" expectation of price like gasoline prices (Alquist and Kilian, 2010), they may overlook the price decline and overinvest in more efficient appliances.

For non-household energy consumers, many studies have been done at the cross-country (e.g., Roy et al., 2006), country (e.g., Fan et al., 2007; Webster et al., 2008) and industry level (e.g., Steinbuks and Neuhoff, 2014), looking at how they respond to energy price changes. Significant variations can be observed from the estimates. For example, Steinbuks and Neuhoff (2014), using industry-level data from OECD manufacturing industries, reveal that higher energy prices reduce energy use due to both improved energy efficiency of capital stock and reduced demand for energy input. Estimated own-price elasticities of energy demand vary in the range of 0.21 and 0.86. The investment response to energy prices also varies considerably across manufacturing industries, being more significant in energy-intensive industries.

Investigations of the effects of energy price movement on firm-level energy use are scarce. One of the rare examples is the work of Martin et al. (2014) estimating the effect of imposing a carbon tax on UK manufacturing plants from 1999 to 2004. They find that the carbon tax, which is equivalent to a 10% increase in electricity prices, decreases plant-level energy use by 20%, while not affecting employment. Flues and Lutz (2015), using data on German manufacturing firms for the period 1995-2005, find no significant effect of increasing the marginal tax rate on electricity on turnover, export and employment. Similarly, Gerster (2015), using the same data but for the period of 2008-2011, finds no significant effect on the same economic variables, but the lowered marginal tax rate increased electricity use by 30%. All of these studies imply that energy use and its associated externalities can be reduced by increasing

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energy costs without adversely affecting firms' competitiveness. Meanwhile, Aigner et al. (1994) compared the electricity usage of industrial and manufacturing SMEs, which were randomly allocated to a control group with a flat- rate tariff and two treatment groups with Time-Of-Use (TOU) tariff. The TOU tariff induces small but significant load shifting from peak to off-peak. In winter they estimate price elasticities of -0.05 to -0.08, which decrease in other seasons. Consistent with these results, Jessoe and Rapson (2015) find that TOU pricing has negligible effects on overall usage, peak usage and peak load of commercial and industrial customers. This is because TOU pricing typically captures only a small fraction of the wholesale market variation, and perhaps a more granular policy like Real-Time-Pricing may be more effective in prompting behavioural change.

The literature on firm's investment response to energy prices is equally scarce, potentially due to the absence of detailed data on energy efficient investments. Most studies focus on the role of regulations and on environment-friendly technologies (see **Table 2**). Rare studies that looked into the energy price-investment nexus include Rose and Joskow (1990), who find a positive correlation between fuel prices and the adoption of a new fuel-saving technology in the US electricity-generation sector, with the statistical significance of the effect depending on the year of the fuel price. Boyd and Karlson (1993), using data on US steel producers, find that an increase in electricity price would have a negative impact on the firm's decision to adopt a technology that substitutes electricity for fossil fuels, although the magnitude is modest. Pizer et al. (2001), using combined plant- and parent-level data on US manufacturing, reveal that both fuel price and firm's financial health are positively related to the adoption of energy-saving technologies. Anderson and Newell (2004) use data from US manufacturing firms and results from US DOE's Industrial Assessment Centers (IAC). They find that about 40% of the firms are more responsive to investment costs than to energy savings. Their results are somewhat consistent with the findings of Steinbuks and Neuhoff (2014) and imply that energy prices are less salient compared to the upfront cost of the investment.

A related but different question points to the incidence of environmental policies (which increases energy input costs) imposed on certain sectors, which may also affect their decision to reduce energy consumption and/or invest in energy efficient technologies. For example, there is consensus in the literature, both at the theoretical (see Sijm et al., 2006; Bonacina and Gulli, 2007) and empirical front (see, among others, Zachmann and Von Hirschhausen, 2008; Hintermann, 2010; Fabra and Reguant, 2014) that the cost of the EU Emission Trading System is being passed through in electricity markets. The measured pass-through is high, with a recent estimate of about 80 % (Fabra and Reguant, 2014), implying a huge redistribution of the EU CO_2 costs from the producers to consumers. In the US, Ganapati et al. (2016) use changes in energy prices to gain insight on how a carbon tax might influence producer and consumer welfare. They find that the pass-through rate is about 70 %. However, by relaxing the assumptions of complete pass-through and perfect competition, they postulate that consumers bear 25-75% less of the welfare burden than what conventional methods assume.

Synthesis:

Certainly, a number of studies have been analysing the factors influencing consumer energy use and, at some level, energy efficiency investments. The literature concerning individual consumers and households seems to suggest that they generally reduce consumption and invest in energy efficient technology when gasoline prices increase but much less on electricity. At the moment, there is no clear understanding of the difference in consumer responsiveness and the mechanism by which this difference may occur. Some RCTs try to explore the price elasticities of energy demand, suggesting rather inelastic demand functions. However, in these studies the external validity is often questionable, as they build on pilot designs or voluntary participation.

Table 2: Some studies in the literature showing factors influencing environment-friendly investments

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Article	Technology	Data	Key results
Kerr and Newell (2003)	Lead-reducing refining technology	US oil refineries, 1971–1995	Increased stringency increases adoption. Larger and more sophisticated refineries adopted first
Keohane (2007)	SO2 scrubbers	US coal-fired power plants, 1995–1999	Adoption decision was more sensitive to cost differences under tradable permits
Kemp (1998)	Water pollution treatment facilities	Dutch food and beverage plants 1974–1991	Effluent charges increase adoption
Purvis and Outlaw (1995)	Water pollution-control technologies for the US livestock production	N/A	Regulations led to adoption of "time-tested" rather than innovative technologies, because EPA was more likely to approve permits for these
Snyder et al. (2003)	Membrane-cell technology for chlorine production	US chlorine manufacturers, 1976–2001	Regulation not only encourages adoption but also leads to the shutdown of plants using older technologies
Popp (2006d)	Combustion modification and postcombustion controls for NOX emissions from coal-fired power plants	US coal-fired power plants, 1990–2003	Regulation is the dominant factor. Technology improvements lead to more adoption for combustion modification, but not for more expensive postcombustion controls, which are only adopted when needed because of regulatory pressures
Frondel et al. (2007)	End-of-pipe versus process abatement	Survey of OECD firms	Regulations are more likely to lead to end-of-pipe solutions. Market forces influence cleaner production processes
Wolfram and Bushnell (2008)	Modifications at coal-fired electric power plants	US power plants, 1998–2004	Effect of new source review on capital investment is small
Fowlie (2007)	NOX pollution-control techniques	702 US coal-fired power plants covered by the NOX Budget Program, 2000–2004	Plants in restructured markets are less likely to install costly abatement equipment
Blackman and Bannister (1998)	Cleaner fuels	Traditional brick kilns in Mexico	Community pressure and local nongovernmental organizations are important
Popp et al. (2008)	Low-chlorine production of pulp and paper	Pulp plants in the United States, Canada, Sweden, Finland, Norway, and Japan, 1990–2005	Consumer pressure spurred adoption

Adapted from Popp et al. (2010).

More empirical studies looking at firm-level microdata are deemed valuable in order to deepen our

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understanding of firm behaviour towards energy price changes. One area where we can contribute is on the manner by which firms invest in environmental-friendly technologies in response to changes in energy prices or environmental policies that has the same energy price outcome. Here we can ask the following questions: (1) given the same cost, would a firm invest in emission-reducing technology or purchase an emission permit? (2) Does increased carbon tax influence firm behaviour to invest in carbon-reducing technologies? (More like pay or invest trade-off).

It could be valuable to also consider looking at the incidence of carbon cost using actual policy change. This initiative can build on the work of Ganapati et al. (2016) who use price changes to estimate firm-level response to an equivalent carbon tax. While laudable, the authors assume that firms see price changes from carbon tax and idiosyncratic price shock as equivalent. However, firms may have the tendency to see price shocks as transitory, which may underestimate firms' response to an actual implementation of a carbon tax. It may be valuable to also consider the potential difference in the response of firms that are subject to different schemes (i.e., carbon tax and cap- and-trade) in order to draw more meaningful policy implications. Lastly, it may be interesting to look at potential spillovers of environmental policies. Miller (2014) and Calel and Dechezlepretre (2016) were the first ones to look at the potential spillover effect of EU-ETS on firm's patenting on non-regulated firms. Future research may build on these existing studies in order to determine the spillover effect of actual environmental policies on competitive outcomes (e.g., marginal costs, markup, concentration, etc.) for non-regulated sectors.

1.5 What are the barriers to consumers' reduction in consumption and investment in energy efficiency?

This section discusses the literature on other barriers to consumers' investment in energy efficiency. As argued previously, this section may appear to be tangential to the energy-price-efficiency- investment nexus but it is highly important in gaining deeper understanding as to why energy price movement may seem to be weak in some cases and strong in others. In other words, the existence of these barriers may confound with the effect of idiosyncratic price shocks on consumer behaviour. Because the optimal price intervention will depend on how consumers respond to prices, it is valuable to get deeper understanding on how these barriers may interact with price changes.

Information problems have been one of the most commonly-cited explanations for consumers' perceived underinvestment in energy efficient technologies, and thus the most commonly-cited justifications for policy intervention in this realm (see, for example, Sanstad et al., 2006; Gillingham et al., 2009; Palmer et al., 2013). Gillingham et al. (2009) enumerated these information problems as consumers' lack of information about the availability of and savings from energy efficient products, asymmetric information, principal-agent or split-incentive problems, and externalities associated with learning-by-using.

Most of these information problems have been studied with individual consumer or household's perspective. For example, Stern (1986) finds that most consumers hold incomplete and incorrect information regarding household energy use. Generally speaking, consumers tend to overestimate energy use and save in technologies that are visible (such as TVs), in contrast to more energy-using but less visible ones (e.g., refrigerators and washing machines) (Howarth and Sanstad, 1995). Meanwhile, a number of recent field experiments document how information provision (i.e., peer comparisons) can result in immediate and, at some level, persistent household energy consumption (Allcott, 2011c; Costa and Kahn, 2013; Ayres et al., 2012; Allcott and Rogers, 2014; RWI, 2017; List et al., 2017), taking into account differences in location, ideology, and longevity of the information provision, interactions with financial incentives and the way information is delivered.

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A number of previous studies also looked into some of these informational problems in the context of decision making by firms. For example, DeCanio (1993) observes that the internal hurdle rates – the minimum rate that a company expects to earn when investing in a project – are often set at higher levels than the cost of capital for comparably risky investments to the firm.[7] This is consistent with what Martin et al. (2011) find using results from interviews from 800 manufacturing firms in six European countries. Meanwhile, Anderson and Newell (2004) analyse the response of manufacturing plants to the DOE's Industrial Assessment Center (IAC), which has been providing energy assessments at no financial cost to small- and medium-sized manufacturers[8] since a 1976 programme. The authors explore the influence of information, along with technology costs, expected energy savings, and individual firm characteristics, on the likelihood of adopting projects. They employ models of varying flexibility to examine and compare the degree of response to differences in capital costs and operating cost savings, as well as the energy price and quantity differences that underlie savings. Similar with previous studies, Anderson and Newell (2004) seem to confirm that the implicit hurdle rates used by these firms are many times higher than the cost of capital. In particular, they find that the investment threshold typically used by the plants in evaluating which energy audit recommendations to adopt was about a one to 2-year payback, which corresponds to an implicit hurdle rate of 50-100% for projects lasting 10 years or more. Using the reasons cited by respondents, the authors find that initial costs and financing issues play an important role in the reasons for not adopting energy efficient technologies. Moreover, the authors find that lowering the cost of upfront cost of investments may seem to be more effective in prompting firms to invest in energy efficient technologies compared to increasing energy prices.

While laudable, Anderson and Newell (2004) were unable to establish the counterfactual; that is, what could have happened to the performance of selected firms had the IAC audit did not happen. Bloom et al. (2013) address this concern by conducting field experiment on large, multi-plant Indian textile firms and randomly allocating their plants to treatment and control groups. Treatment plants received five months of extensive management consulting from a large international consulting firm. Consultants from the commissioned firm diagnosed opportunities for improvement in a canonical set of management practices during the first month, followed by four months of intensive support for the implementation of these recommendations. The control plants received only the one month of diagnostic consulting. The treatment intervention led to significant increases in productivity and profitability, which implies cost-minimising technologies are available but are not adopted due to information problems (e.g. lack of information, incorrect information or path dependence). Financial costs, in contrast, do not seem to be the most significant hurdle to adopting cost-reducing technologies and management practices. Whether this result is applicable to other geographic and cultural settings is an empirical question.

Meanwhile, some studies (e.g., DeCanio, 1993, 1998; DeCanio and Watkins, 1998) push the literature further by emphasising the importance of firm-level characteristics as a major source of systematic underinvestment to energy efficient technologies amongst firms. For example, using combined data of firms from the US Green Lights membership and the Disclosure data, DeCanio and Watkins (1998) find that the characteristics of firms do influence the probability that a company joins an energy efficiency programme. These characteristics include number of employees, earnings per share and the historical growth of industry's earnings, expected future earnings growth, price/earnings ratio, a measure of insider control, industrial sector, and Environmental Protection Agency (EPA) region. De Groot et al. (2001) surveyed Dutch firms and conclude that firm size, energy intensity and competitive position were found to be important distinguishing factors in explaining differences in investment behaviour and attitude towards various types of energy policies, as well as in terms of responsiveness to changes in

[7] The hurdle rates from previous studies range from 12% to 56%, compared to historical real rate of return on equities in the US of 7% since the 1920s.

[8] Anderson and Newell (2004) state that SMEs make up 98% of all manufacturing firms and more than 42% of total manufacturing energy consumption. Despite their importance, studies that focus on SMEs are rare.

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environmental policies. Linn (2008) finds that entrants tend to adopt more energy-saving technologies relative to incumbents when price changes, but by a small amount. These studies give us hints that perhaps there is considerable heterogeneity in firm-level responses to price changes (or policies that influence energy prices). Knowing how these heterogeneous/nonlinear effects to price changes across firms (or industries) may improve the design of price-based environmental policies.

Synthesis:

The presence of market and behavioural/management failures seem to suggest that other factors such as information or financial constraints are more relevant to consumer decisions than energy price changes. Yet, this does not imply that price-based interventions are ineffective and irrelevant in inducing energy consumption reduction or efficiency investment. In contrast, future research should dwell on determining how the choice and design of instruments can be improved to address some of these market and behavioural failures. This can be done by, for example, exploiting the potential heterogeneous response of industries and, at some level, firms (Linn, 2008). It would be interesting to look at how the structure of firms (whether foreign-owned or not, energy-intensive or not, etc.) contribute to how they respond to energy price fluctuations (and other exogenous shocks that influence the price), which previous literature has overlooked. Targeting of price-based interventions, which, for instance, makes use of the differences amongst consumers in terms of their susceptibility to information problems, may provide a new direction towards policymaking.

From the household perspective, there seem to be significant interactions between financial and informational incentives, which should be explored in greater detail before implementing new billing structures. Moreover, the roots of behavioural changes are often unexplored. For policy recommendations, it is however important to understand why informational interventions have such strong effect on energy conservations, such that policymakers can directly target the underlying behavioural bias.

1.6 Conclusion

This review has examined the literature on the relationship between energy prices, non-market factors, electricity consumption and consumer investment in energy efficient-technologies. The aim was not to provide an exhaustive summary, but to outline key research questions and identify potentially fruitful avenues for future work.

Context is critically important when examining consumer response to energy prices. The wide range of demand elasticities reported in the literature reflects the numerous methodologies, geographies, fuels and sectors considered. Future research should aim to examine how this varies across different energy inputs (electricity, coal, natural gas, etc.), and disentangle the relative impact of government regulation, market structure and exogenous energy price shocks.

The measurement of price response can be improved through RCTs and smart-metering. The use of RCTs is appealing, due to the internal validity of the estimates produced. Embedding randomization in large-scale policy implementation can assist in making policy more robust. Large-scale smart metering roll-out offers an opportunity to implement RCTs that come close to being representative of wider populations, addressing concerns of external validity. Gaining a better understanding of how consumers process information, and how this maps to their consumption and investment patterns needs to be a key research objective. High-frequency communication and consumption data offered by smart meters provides an opportunity to further understanding in this domain.

Low responsiveness to energy prices may be due to inefficiently low energy prices which don't fully take

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environmental externalities into account, or regulatory mechanisms resulting in prices not fully reflecting production costs. A range of behavioural biases and management failures may also pervade causing an inability to process information and ultimately resulting in sub-optimal decision making. Further research should examine how market and behavioural failures interact, and how the choice and design of instruments can be improved to address these factors.

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2. How do socio-cultural, demographic and behavioural factors influence energy choices?

2.1 Introduction

The transition to a low carbon energy system necessarily requires the analysis of aspects pertaining to how consumers develop their energy consumption decisions. This Part investigates the role of socio-cultural and demographic factors as well as the influence of behavioural aspects in shaping these decisions. The first refers to characteristics that are easily recognizable and they influence the predisposition of people to behave in a particular way. Socio-cultural drivers encompass aspects inherent to a society such as cultural background, social norms, etc. while demographic characteristics refer to individual aspects such as gender, age, level of education and income[9]. Special attention is devoted to the role of gender in energy choices. The main added value of an approach focusing on socio-cultural and demographic characteristics is that it can help to define groups and patterns within a certain population. This can be useful in attempts to predict people's behaviour in a particular situation and to identify a specific group that can be more responsive to a certain policy. The category of behavioural aspects includes factors impacting the internal formation of a specific behaviour, such as attitudes, values, beliefs and habits. Furthermore, it is to note that in this review the concept of consumer decision-making is bounded to the consideration of how households perform their energy related choices and doesn't cover firm choices, where different dynamics can be more significant (e.g. profit maximisation, management, firm structure).

Both these energy decisions and the aspects influencing them can be widely different depending on the sector of analysis. For instance, these might be subject to different policies; they might have a different infrastructure; or, the same concept of energy can take different forms (e.g. electricity or fuel). Hence, for each type of factors, this Part highlights the findings in three different energy related topics (mobility, heating and cooling, and the shift to prosuming) where consumer's choices play a particularly important role. Since this review sets the scene for the project ENABLE.EU, this Part is structured around these three topics, which will be covered as case studies – focusing on social and cultural factors – in the project. This is also a reason why this Part does not refer to the literature on electricity consumption, which is mainly tackled from an economic perspective within ENABLE.EU (see Part 1).

The first sector to be discussed is transport. The idea of improving energy efficiency in the transport sector translates into the promotion of a movement towards a mobility involving lower CO2 emissions. From a general perspective, this means either to reduce the quantity of emissions for a given distance travelled (e.g. by improving vehicles fuel efficiency) or to encourage people to avoid unnecessary use of carbon intensive transport modes, e.g. by using public transport, car sharing, bicycle or walking (Banister et al., 2011; Chapman, 2007; Whitmarsh and Koehler, 2010). The reduction of emissions in the transport sector passes through the implementation of policies, which can either be supportive of development and adoption of new technology, or seek to trigger a deep infrastructural and behavioural change. The implementation of technological regulatory measures (so-called "hard" policies), such as road pricing, financial incentives or viability modifications, as studied in Part 1 of this Report, is often blocked for acceptability or political reasons as studied in Part 3 of this Report (Harrington et al., 2001; Graham-Rowe et al., 2011; Gossling and Cohen, 2014). This and the pressing need of short-term results

[9] Income can be seen as an economic and socio-demographic factor. When considered from a sociocultural and demographic perspective, it refers to social status and may be a bearer of meanings other than the simple financial limitation. Therefore, income is also considered in this Part.

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fostered the development of milder strategies, less costly and easier to implement. These "soft" policies include, for example, travel plans, public transport marketing and information campaigns. They specifically target human behaviour and may be helpful to reduce emissions sources such as car use (Matthies et al., 2006). However, so far their effectiveness has brought about mixed results and a deeper understanding of contextual factors and how they affect these policies is fundamental (see Möser and Bamberg, 2008).

Moreover, the distinction between hard or soft can be referred to an innovation pursued by the demand side, consumers' travel behavioural change, or by the supply side, technological and infrastructural change (Whitmarsh and Koehler, 2010). What appears from the literature is that these two kinds of innovation paths need to be treated as complements rather than substitutes as strategies supporting technological change alone are unlikely to bring about a relevant societal transition to low-carbon mobility (Anable et al., 2012; Liu and Helfand, 2012). In fact, the transition will necessitate consumers' modal, cultural and socio-spatial changes (Geels, 2012). Even though technological change will have a crucial role in the long run, it will hardly bring significant results in the short term, while behavioural change in attitudes, practices and habits can (Chapman, 2007).

From these considerations it follows that people's socio-cultural and demographic characteristics and their behaviour play important roles in successful transitions to low-carbon mobility. These factors affect, inter alia, transport related choices, including car purchasing decisions and travel mode choices (Whitmarsh and Koehler, 2010).

One of the most discussed topics in the literature refers to alternative fuelled vehicles, in particular Electric Vehicles (EV). Such technology is potentially zero-emission, independent of oil price fluctuations, and offers companies the opportunity of pioneering a new market (van der Vooren et al., 2013). Nevertheless, EVs are still far from being competitive with traditional fuels for performance and infrastructure. Hence, it still needs to be deeply policy supported (Ewing and Sarigöllü, 2000; Seixas et al., 2015). Furthermore, EV emissions are dependent on electricity production sources, which imply complex geographical externalities (i.e. pollution from energy production) and unclear effects on total emission levels (Aasness and Odeck, 2015; Holland et al., 2016).

Conversely, the choice of travel mode is commonly less connected to new technology and involves innovations in, or alternative uses of, existing travel modes. Chapman (2007) identifies three main sources of emissions that can be influenced by peoples' choices of travel modes: car use, road freight and aviation. He argues car use to be the most relevant of these, given the share of emissions that it accounts for and the large number of people that it involves. In fact, road transport accounts for 65% of the transport related CO_2 emissions. He also identifies public transport as the most viable alternative to car use in urban contexts. Although acknowledging that buses have several limits to competition with respect to cars (e.g. lower flexibility, lower comfort), he argues that they are more efficient than cars once more than 3 people are served and can potentially help with solving congestion problems. Moreover, under the direct management of local public institutions they can be easily kept up to new technology developments. Bresson et al. (2004) find the patronage of public transport to be directly connected to car ownership and predicts that there will be future growth of this instrument in developed countries as individual car ownership growth is decelerating.

An innovative alternative and complement to public transport is car-sharing, which has become more popular in recent years (Costain et al., 2012). This instrument gives users more flexibility than the bus and other public travel modes, and can enlarge the use of alternatively fuelled vehicles in cities (Kent and Dowling, 2013). Moreover, practices such as walking and cycling are valuable alternatives to motorized transport modes. They can be enhanced through infrastructural changes and promotion of several practices (e.g. the so-called 'walking buses' or the 'motorized school run').

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Second, this study investigates factors influencing heating and cooling decisions. Thermal energy markets are local, fragmented markets, providing heat based on various technologies ranging from small, individual heating and cooling devices to large energy generating plants serving district heating and cooling systems. The sector relies primarily on fossil fuels (mainly natural gas), contributing with 75% to heat generation in the EU.

EU legislation sets binding measures targeting the reduction of energy consumption in member states in the industrial and residential, as well as the public sector, while governments introduce measures to induce energy-conservation. Although there is substantial energy saving potential in buildings, a large share of the cost-effective investments and measures remain unrealised. The most often cited reasons for the gap are the lack of financial resources, insufficient information on technical solutions and related costs, and the behaviour of consumers (EC, 2016).

Third, the review focuses on factors influencing the transition from being a consumer to being a prosumer. Here, the term prosumer refers to the emerging class of people who decide to install households' electricity production systems (e.g. photovoltaics systems). This emerging trend is gaining interest as opportunity to shift towards a growing number of consumers producing their own electricity.

The number of consumers producing electricity at home is rapidly increasing in many European countries. The planned roll-out of smart meters together with falling prices of solar Photo Voltaics (PVs) is also expected to facilitate a shift towards a growing number of prosuming households. Photovoltaic cells allow different types of consumers to produce their own electricity and as such the technology is disruptive in the way it operates with a bottom-up logic rather than relying on a centralized energy system. Hence, solar Photo Voltaics (PVs) technology, may pave the way for a global transition of power generation by challenging the traditional centralized power systems with the bottom-up feed-in of electricity to the grid (Schleicher-Tappeser 2012). In Germany as well as in UK, the governments started to support decentralized energy production in the early 2000s (Walker et al. 2007; Jacobs 2012). While Germany had this as a main element in its renewable energy support scheme, the UK introduced a range of smaller state aid schemes that underpinned local, on-site energy production. During the 2000s, this feature became even stronger in the two countries (see Devine-Wright and Wiersma 2013, Stefes 2010). While this resulted in dramatic changes in the way the German electricity market functioned, the energy system in the UK continued to rely primarily on large-scale, centralized production. Decentralized energy has been given less attention by Norwegian policymakers (see Boasson 2014). Although there has been a growth in small hydro and district heating in Norway, the plants tend to be too large to be regarded as part of a "consumer to prosumers" shift. Understanding the drivers underlying the shift to prosumption would therefore help to enable an energy transition with the prosumer at its heart.

2.2 Socio-cultural characteristics influencing energy choices

Consumer side energy choices are influenced by many factors. Among others, social and cultural factors (social background, cultural differences, social norms) seem to be very influential or even decisive; they guide everyday practices, and might also result in suboptimal choices (e.g. replacing heating or cooling equipment only at the very end of their lifetimes to save money in the short run, instead of optimizing long-run costs). As proposed by Aldred and Jungnickel (2014), the concept of 'culture' refers to an external influence ('something given to us'), which is the focus of this section; whereas 'practice' is the result of an individual (internal) choice, a dimension expanded in the section on behavioural aspects. The next sections look at the empirical evidence on how different socio-cultural factors affect decisions.

2.2.1 The role of social conventions in understanding energy choices

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The relationship between cultural conventions including gender norms[10], and the ability of actors to resist or challenge such norms, interact with technology in analyses of co-evolving social-technological systems (Ortner 1990, Pantzar 1997, Shove 2003).

In an article on energy behaviours related to comfort and cleanliness, Shove (2003) finds that individual attitudes are not the main driver of consumption choices and energy behaviour. Rather, social conventions of what is considered as normal guide consumption patterns. As conventions are historically and culturally specific and may change with introduction of new technologies, there is a need to understand the systemic redefinition of 'normal practice' through construction and transformation of collective conventions.

Wilk and Wilhite (1984) use an ethnographic approach to explain why cheap and easily available measures to reduce energy consumption in Californian households were not adopted, while more expensive and less energy saving measures were chosen instead. In their study, the most cost efficient and energy saving measure of weatherizing homes was neglected for three reasons: Firstly, weatherization did not fit into people's mental categories as it was not maintenance, nor home improvement, and consequentially it was avoided. Secondly, to accept that the house needed weatherization was to admit that there was something wrong with the house. Campaigns to promote weatherization made people annoyed because they felt that it criticised the family home, and metaphorically the family's "self" or body. Thirdly, the logic of conspicuous consumption made people more inclined to install expensive new stoves or to make other visible improvements which could be noted by neighbours and friends, rather than to correct the non-conspicuous lack of weatherization. The study shows how the economic rational goal of saving energy expenditure was less important than other cultural values in explaining the household's energy behaviour.

Wilk and Wilhite (1984) argue that the cultural context must be investigated and understood to explain people's energy practices and choices for investments in new energy technologies. For instance, what is considered normal practice of laundry changes when the washing machine takes over for the traditional boiling of clothes (Shove 2003): The meaning of clean clothes changes from "being spotless" under the boiling technology to "smelling good" when the washing machine becomes prevalent. Technological systems and the meanings of cleanliness co-evolve and result in more frequent laundry but at much lower temperatures than boiling, leading to increased water consumption but less energy use for hot water. Through the examples of bathing and laundry, Shove presents four models of change in social-technological systems, where two of the models implicate escalating energy and water consumption, while the other two models demonstrate how systems co-evolve toward standardization of consumption patterns that are less resource intensive. The four models of change show how technology, practice and meaning are connected and influence each other in complex and iterative ways. Sometimes the result is more resource intensive practices, while other times resource use is reduced.

This conclusion is similar to that of Pantzar (1997) who investigates the process of how technological innovations are introduced in a society, and whether they stabilize and become routinized or whether they disappear. Domestication of new technology takes place in complex interaction with changes in consumption rituals, routines and habits. While new commodities are rarely introduced as a response to basic needs but rather as interesting "toys" and "luxuries", over time they evolve to become required instruments and necessities that are integrated into people's daily routines. When a new piece of technology becomes part of a larger network of technology, it becomes integrated and deeply rooted in people's lives and routines, thereby influencing their choices and practices. Pantzar (1997) and Shove (2003, 2010) both show the need to shift the analytical focus away from individual behaviour over to collective conventions, routines and habits and how systems of technology interact with everyday practices and cultural norms.

[10] Gender is given particular attention in Part 2.4 and is therefore not covered here.

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The cited studies emphasize the importance of seeing cultural structures such as norms and conventions in relation to actual practices and technological contexts, and that these interact in complex social-technological systems that together influence everyday energy practices (Ortner 1990, Pantzar 1997, Shove 2003). Also common for these studies is the acknowledgement that there are multiple models of change in social-technological systems (Pantzar 1997, Shove 2003, Shove 2010), and that people interact with technology and relate to cultural norms in multiple ways that also include resistance and active opposition (Ortner 1990, Pantzar 1997) for reasons that cannot be reduced to economic rationality but that also involve mental and cultural categories, metaphors and social conventions (Wilks and Wilhite 1984, Shove 2003).

In their review of experimental studies, Hahn and Metcalfe (2016) conclude that social norms can induce energy conservation and the adoption of energy-efficient technologies. The important influence of social norms and social values on preferences towards climate change adaptation and mitigation policies is emphasized for example by Alló and Loureiro (2014), showing that cultural and social dimensions are relevant in promoting the acceptability of climate change policies. Axsen and Kurani (2012) also highlight the role of interpersonal influence in the adoption of new low-carbon products and practices. Customers living in pro-environmental neighbourhoods are more likely to adopt energy efficiency programs (Hahn and Metcalfe, 2016). Feedback on energy consumption is particularly effective in reducing energy use, if consumers can compare their level of consumption to other consumers (e.g. neighbours) and to their own previous energy use (Ivanov et al., 2013; Roberts and Baker, 2003).

Furthermore, community based initiatives (programmes designed to involve people from the same neighbourhood, workplace or community to carry out energy conservation measures or activities voluntarily) are considered successful both in motivating actions and inducing behavioural changes that are maintained over a prolonged period of time (EEA, 2013). One of the reasons for this is that the group of people acting together know each other, can exchange ideas and receive feedback on their own consumption, forming a basis for establishing common rules and even changing social norms.

Group pressure can influence energy efficiency decisions also through energy efficiency standards or labelling (Szlávik et al., 2000), although many studies claim that it is difficult to prove that consumers opt for higher rated devices or buildings because of their improved energy efficiency (Tabi et al., 2014; Hahn, Metcalfe, 2015; EEA, 2013). Researchers recommend that regulators improve the availability and presentation of eco labels, and try to influence social norms through raising awareness.

2.2.2 How do socio-cultural factors drive transport, heating and cooling and prosuming choices?

In transport related choices, from a 'choice' perspective, socio-cultural characteristics can be seen as the decision-makers' features in comparison to product specific attributes, namely technological and economic factors (Sierzchula et al., 2014). The relevance of these characteristics can be different at international or local level. For instance, in the domain of the adoption of Electric Vehicles (EV), Sierzchula et al. (2014) show that social and demographic characteristics have a lower explanatory power than specific product and economic factors (i.e. EV charging infrastructure and financial incentives) when comparing results obtained in different countries. On the contrary, Hidrue et al. (2011) find these characteristics to be significant for propensity to buy an EV in the US, suggesting targeting policies to specific groups of people (i.e. young and educated). The authors also acknowledge the important role of technological development for EV, especially with regards to battery life.

Cairns et al. (2014) highlight the importance of individual and societal levels (national, local, specific groups) in driving travel related choices. Evidence of the relevance of this distinction can also be found in Rienstra et al. (1999). In their study, they find perception of transport related problems, namely

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safety, congestions and environment, to have different weights if analysed from individual or societal perspective. Indeed, they find environment to be a bigger concern as societal problem rather than individual.

Culture also influences transport choices. Cairns et al. (2014) claim that behaviours and attitudes of different social groups need to be taken into account in designing any new transport solution as it has been the case for the diffusion of the car in the 20th century. In fact, they identify the car as a cultural object symbol of the 20th century, whose incorporation into art, film, television, literature, etc. has contributed to determining the social identity and roles of specific groups (e.g. young people, parents, etc.).

An interesting study on culture is proposed by Aldred and Jungnickel (2014) on cycling practices. They study the impact of cycling infrastructure in different cities in the U.K. and find this to largely vary across different cities. Furthermore, they link this variance to reasons that are associated with being cyclist in these cities. Additionally, they consider the comparison with the more developed cycling culture in The Netherlands, and conclude that it is important to take cultural considerations as complements to infrastructural interventions.

In a given place there might be people having many different origins, cultural backgrounds and traditions that shape individual attitudes. For instance, Harrington et al. (2001) find ethnic groups to have different opinions and propensities towards congestion charges. In particular, they find Hispanics and Asians to be systematically more favourable to congestion pricing than Caucasian and African-Americans. However, it is worth mentioning that this studied has been conducted in the U.S. where the issue of ethnicity is much different from the situation in Europe.

Social norms and cultural differences also influence heating and cooling energy choices, having an effect for example on what is considered as 'normal' or 'comfortable' room temperature or how often a warm shower should be taken (Ürge-Vorsatz et al., 2007). As highlighted above, neighbours can influence people's behaviour towards energy (Hahn and Metcalfe, 2016). Noonan et al. (2015) show that the installation of HVAC (Heating Ventilating and Air Conditioning) systems by neighbours was one of the most important drivers of homeowners' zoned adoption of the technology in the US. Similarly, Pantzar (1997) offers perspectives on the process from the first emergence of a technology on the user side towards the normalization of this technology. He illustrates how air conditioning in a given context moved from being a desired novelty (expressing social status), to an object that could be legitimized in functional terms (considered to serve a specific purpose, such as a comfortable indoor climate), and finally to being considered "normal". Mass consumption takes place in the "normal" phase, and at this point it may even be socially dangerous not to comply with the established norm. Cultural drivers also played a decisive role in the penetration of air-conditioning in the US, South Europe or Hungary (Novikova and Ürge-Vorsatz, 2007).

Finally, culturally determined social dynamics constitute a driver for change (Shove 2003, Wilhite 2008) and might influence prosumers in their energy practices. According to Shove's framework, the drivers behind new technical solutions and demands are shaped through two main forces:

- Development, implementation, configuration and marketing of the systems of provision influence what people can do with the technology (cf. "scripts" Akrich 1994).
- Socially situated end–users influence the extent to which the new solutions will be utilized. This drive for demand is socially conditioned (cf. Pantzar 1997).

Social groups have enabling, mediating, and aggregating functions which affect actors in the system (Janda and Parag 2013). Pantzar's (1997) perspective presented above is also important for understanding the development of prosumer households, where we expect the prosumer role and adhering technologies to have the status of being a novelty and thus a marker of difference and identity.

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2.3 The influence of demographic factors on energy choices

Moving the analysis to demographic characteristics, within the considered literature, several factors are studied in relation to energy choices: household and dwelling characteristics, geographic location, age, education and income. This section distinguishes between findings on mobility, heating and cooling, and prosumers, as they appeared specific to each topic within the studied literature. Findings related to gender are gathered in a separate section.

2.3.1 Demographic factors influencing mobility choices

In many studies on transport, households are taken as a demographic unit, since many mobility related choices (e.g. car ownership and use) are taken within this context and behaviour often depends on household characteristics (e.g. the use of a car to bring children to school). Households are the source of many daily practices whose evolution continuously brings about novel features which have to be taken into account. For example, separated, divorced, step-families or people living on their own may have different transport practices (Cairns et al., 2014). Indeed, household structure is found to be a significant variable in explaining transport related choices in several studies.

Modelling U.K. car ownership, Dargay and Vythoulkas (1999) find a significant positive impact of the number of adults, in fact, this might heighten the number of households' members with driving license. The same result regarding the number of adults is found in Nolan (2003) using micro-data in Ireland. The author argues that more adults in the household increase the elasticity for bus fare expenditure, suggesting that more competition for the household car increases the choice of different transport modes. In addition, he finds younger households to be more mobile than older ones, since they might be involved in more activities.

Another important aspect to be considered is where the household decides to live. People living in urban or rural areas have clearly different needs and travel possibilities. Car ownership and use can be expected to be higher outside of cities, as found for example by Dargay and Vythoulkas (1999). However, Aditjandra et al. (2013) find diverse travel behaviours between cities and suburban areas also in short length travels, which underline choice differences that go beyond the infrastructural restrictions. From this, they argue that householders sort themselves in neighbourhoods according to their preferences. Hence, people living in a same place might have, to some extent, similar transport preferences and behaviours that can be tackled by specific policies or investments, e.g. in public transport infrastructure.

Age is a discriminant present in almost every study that investigates individual choices. People of different ages have peculiar needs and lifestyles which affect their choices and behaviours. First, travel demand follows a pattern linked to age by what Dargay and Vythoulkas (1999) describe as 'lifecycle effect': on average, car use increases with age until the age of 50, and then starts decreasing. Moreover, these authors mention the presence of a 'generation effect', that is: over time, at each age, travel demand is higher, in a way that seems to be partly explained by income, technological development and other determinants. Second, younger people are found to be more concerned by environmental and transport problems, and are more likely to accept environmental policies (Golob and Hensher, 1998; Rienstra et al., 1999). Third, they seem to be more inclined towards technological innovation. In particular, in the U.S., Hidrue et al. (2011) find young people to show higher propensity for EV adoption. In Germany, Hackbarth and Madlener (2013) find them to be more disposed towards alternative fuels in general, while Achtnicht (2012) states that young people have a higher consideration of car emission performance attributes when choosing a vehicle.

Education also seems to play an important role in these same aspects. Highly educated people are found

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to have higher propensity towards alternative fuelled vehicles and EVs (Hackbarth and Madlener, 2013; Hidrue et al., 2011) and to take transport problems of congestion, safety and environment, more seriously (Rienstra et al., 1999). In contrast to this last statement, Harrington et al. (2001) find more educated people to be less supportive of congestion policies, and claim as a possible justification to this result a more sceptical view on policy effectiveness or a lower reliability on government operate.

Finally, even though it is normally considered an economic factor, income can be seen as a determinant of different social classes. Hence, it may be a bearer of meanings other than the simple financial limitation. This is why in several of the discussed studies it is taken into account. However, its significance and impact is different depending on the specific transport related aspect analysed. For instance, Golob and Hensher (1998), in Australia, find households with higher income to be more environmentally concerned and Rienstra et al. (1999), in the Netherlands, find them to support more transport restriction policies. However, Achtnicht (2012) argues that income doesn't represent a main discriminant in car-buyers' willingness to pay to reduce emissions. Moreover, income also seems to play a less important role in the propensity to adopt electric or alternative fuelled vehicles (Hackbarth and Madlener, 2013; Hidrue et al., 2011).

2.3.2 Demographic characteristics shaping heating and cooling choices

Heating and cooling consumption highly depends on two main aspects of the dwelling: its geographic location and its physical characteristics. The density of population, availability of resources and infrastructure affect the cost of heat provision and consumer choice (e.g. district heating versus individual heating based on natural gas, biomass or other fuels). Thermal energy demand varies according to climate conditions; in the northern region, a large amount of energy is used for heating, while in the southern countries mostly cooling energy is demanded. Brounen (2012) claims that the demand for heating energy is determined by the technical and physical determinants of dwellings, as opposed to demand for electricity, which is rather related to the composition of the household (age, number of family members) and social standing (income).

Brounen et al. (2013) investigate how 'energy literacy' (rational decision-making on energy efficiency investments), daily measures (e.g. setting thermostats to lower temperature at night), adoption of energy-saving technology and use of renewable energy are related to demographics, attitude and ideology. The study reveals that rational decision making on investments (energy literacy) is mainly related to the level of education, but is unrelated to ideology or attitude. Neither income nor education influence energy-awareness (being aware of monthly energy bills), but older consumers tend to be more aware of their consumption. A study on heating-related investment highlights that more educated people practice energy curtailment, but are less inclined to engage in energy-saving investments (e.g. insulation or exchange of the heating system) (Lillemo, 2014).

With respect to income, Lillemo (2014) drawing on a sample of 1004 Norwegian households, detected a positive relationship between household income and investments related to heating. However, tenants of high-income households were less likely to follow everyday energy-saving practices (such as lowering temperature at night, or heating only rooms that are in use).

However, income has a determinant role on the level of consumption, through affordability. The depreciation of ready-made, low-cost panel buildings is a critical issue in some EU countries, where low-income population live in higher shares, thus generating 'poverty islands' (Novikova and Ürge-Vorsatz, 2007). The process results in a negative spiral: as more low-income inhabitants move in the same neighbourhoods, the opportunity to collectively perform energy efficiency investments decreases. Pivo (2014) studies multifamily housing units in the US and finds that i) low-income renters living there are overrepresented compared to the national average, ii) they have significantly less energy efficiency features introduced in their homes than the average, and this gap increased over time. These results

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imply that a comprehensive database on building characteristics, energy consumption data and social condition of inhabitants can help both local and national authorities to develop strategies targeting energy poverty. Household income not only correlates with energy efficiency decisions but also with other attributes of energy consumption. Novikova and Ürge-Vorsatz (2007) investigate the characteristics of the tenants living in district heated apartments with lower energy efficiency, and they found that they are mostly young families with lower income or elderly people who got access to such apartments decades ago, and have limited options to invest in increased energy efficiency. To provide efficiently targeted support, it is important to gather information on both the social background and energy consumption of tenants.

As an outcome of energy efficiency investments, the improvements in efficiency might be partly or fully neutralized by increased consumption (rebound effect – for more details, see Oikonomou et al. (2009) who provide a review of estimated rebound effect values based on the related literature). By researching how the effectiveness of heat pump replacement investments is influenced by social characteristics, Alberini et al. (2016) find that savings (measured in percentage change compared to the original level) are higher in larger dwellings, in homes with insulation, and in households with older tenants.

2.3.3 The role of income in inducing the shift to "prosumption"

Smart grid and smart meters[11] have the potential to give end-users a more active role by empowering them with tools that make it possible to monitor, understand and manage their energy behaviour (Da Silva et al., 2012) and also to produce electricity and deliver it to the grid. However, there is a question as to who will have the opportunity to become prosumers, and who will involve themselves as prosumers. Darby (2012) discusses how smart metering could affect fuel-poor households. She finds that the effects are ambiguous. The restricted access to new technology, know-how and resources might affect the fuel-poor negatively by creating hindrances that prevent them from becoming involved in the smart metering technology. On the other hand, the use of smart meters might increase awareness through the potential to develop clear, accurate information by, for instance, the deployment of energy displays. Also, a study from Norway shows that households with lower income levels might have fewer opportunities to engage in flexible energy consumption practices (Westskog, Winther and Sæle, 2015). This might indicate that the early adopters of prosumer technology will come from the higher income groups.

2.4 The influence of gender on energy choices

2.4.1 Why is the study of gender important in energy choices?

Gender perspectives are important for understanding how and why energy practices and behaviour may differ within and across households and societies and what social, economic and environmental implications this may have. Energy policies are often formulated in a gender-neutral way that assumes that men and women have the same perspectives, needs, experiences, values, resources and aspirations concerning domestic energy access, production and use. The underlying assumption is that men and women will respond to and benefit equally from such policies. However, research shows that the motivations for and barriers to taking up energy-saving technologies are gendered. Gender is one of several factors that may influence the social acceptability and behavioural responses to energy saving policies and uptake of environmentally friendly energy investments, policies. Gender also matters for

[11] The EU directive on internal markets stipulates that at least 80% of customers shall be equipped with intelligent metering systems by 2020 (SmartRegions, 2013). In Norway the requirements are that smart meters should be installed within 1.1.2019. In the functional specifications from NVE it is required that the new meters should be able to meter both electricity consumption and electricity fed into the grid by the customer.

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the agenda-setting work of the energy sector and energy science more broadly. Gender should thus be a core concern for policy-makers seeking to design and implement socially, economically and environmentally feasible and sustainable energy policies as it may have consequences for the equity, efficiency and effectiveness of these policies. Below we summarize key strands of the literature on gender and energy, concentrating on how gender influences household energy practices and the uptake of energy-saving technologies. In addition, we point to literature contributions that show how the whole energy field is gendered.

Debates about the nature and extent of gender inequality have been thoroughly discussed within gender studies and feminist literature over the last 40 years (Ortner, 1990). Key questions in this literature concern the relative prestige and status accorded to men and women in different societies, the extent of women's autonomy in decision-making, and the degree of control that women and men are able to exert over different spheres, or aspects, of their lives (ibid). Gender norms and behaviour are an outcome of wider social and cultural processes and practices (Ortner, 1990) that mediate how objects, technologies and commodities are perceived and taken into use, and that dictate what is deemed to be 'appropriate' behaviour in different contexts (Shove, 2003). Although the specific constitution of male and female spheres of decision-making may vary from one social and cultural context to another, there is general agreement that certain areas of social and domestic life are more gendered than others. This perspective has relevance for understanding potential entry points for sustainable household energy practices, as it suggests that women and men may exert relatively more or less control over certain spheres or niches of their social, cultural and economic surroundings.

2.4.2 A scarce literature on gender and energy in Northern countries

While several studies on gender and energy have been undertaken in northern/industrialized country contexts (e.g. Clancy and Roehr, 2003), to date, studies on gender and energy have largely focused on developing countries in the global south. Heavy reliance on natural resources, including wood biomass and charcoal, for household energy needs, and the environmental and human health implications of such energy reliance, help to explain this focus. Studies of gendered energy practices in developing countries are often preoccupied with whether access to modern energy and efficient technologies can be used to tackle poverty and alter gender roles and power relations between men and women (Clancy et al., 2012). Drawing on studies from Tanzania, Winther (2012) concludes that the introduction of electricity in one Zanzibari village did not alter unequal power relations between men and women. Although the technology benefitted females in terms of schooling and empowered women in the short term, results of unequal intra-household negotiations over energy use resulted in electricity becoming a domain that was largely controlled by men. Winther (2012) further argues that, despite popular perceptions, there are wide discrepancies between gender ideologies (the socially constructed and normative ideas of how the relations between men and women should be) and how gender relations are practiced even within cultures that are considered to be relatively egalitarian (such as in Scandinavia). Lack of attention to the discrepancies between gender ideologies and practices may also help to explain why the literature on gender and energy practices in the northern countries remains scarce.

Even with gender ideologies tuned towards equality between men and women, Clancy and Roehr (2003) show, drawing on examples from different segments of the energy field in northern countries, how gender relations matter when studying energy practices in households. Taking a gendered perspective on energy practices reveals that there are different perceptions, value judgements and practices between men and women. One obvious example concerns energy poverty. In general, more women than men fall below the poverty line also in northern countries (Clancy and Roehr, 2003). This restricts households' energy choices and reduces the ability to use heating and cooling equipment and to cook, which may affect women more than men. Also, when it comes to how men and women favour energy choices there are differences. Women tend to favour renewables whereas men to a greater extent favour fossil fuels and nuclear (Clancy and Roehr, 2003). Further, in her study from Sweden, Henning (2005)

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shows how men and women have the responsibility for different zones in the house. Men are responsible for the outside of the house and some areas inside, such as the heater/boiler room, whereas women are responsible for the interior of the home. Energy choices taken by the one that is considered responsible for a particular zone or domain in the household is generally not up for negotiation and is easy to implement as long as the decision is considered useful by the part that takes the decision.

Acknowledging that collective social and cultural structures and norms shape gendered energy practices requires alternative explanations for human behaviour than individualist and utilitarian ones put forward in classical economic theory. According to Shove (2010), European policy documents concerning measures to mitigate climate change tend to rely on a quite narrow model and theory of human behaviour and social change. The model, called ABC, assumes that social change depends on values and attitudes (A) which drive the kinds of behaviour (B) that individuals choose (C) to adopt. All responsibility for change in energy consumption is thus put on individuals, ignoring the role and possibility of policy to alter the conditions and structures that frame peoples' practices. A new frame of thinking is proposed by Shove (2010), based on practice theory and coevolving systems theory, which addresses the structures and conditions that enable and shape practice. Such a model is better suited to analyse how gender structures and dynamics influence energy practices in households, compared to the ABC model, which dominates in applied energy and climate policy. Households can here be pictured as social arrangements, where members cooperate or are in conflict regarding who does what, who gets to consume what and who takes the decisions (Sen, 1999, p.12). The shift of focus away from individual attitudes and behaviour towards social coevolving systems involves searching for the 'rules of the game', the underlying structural factors that shape practice, such as social conventions of normality and gender norms (Ortner, 1990; Shove, 2003; Shove, 2010). However, the relationship between cultural norms and social practice is not a simple one-directional causal connection where people are dictated by every cultural norm and convention. Rather, any set of gender norms or other social norms in a society can be viewed as a cultural hegemony (Ortner, 1990), an overarching but not totalizing system of cultural structures. In the view of practice theory, social actors may adhere to, but also find ways to resist, negotiate or oppose the dominant hegemony, thereby contributing to social change.

Clancy and Roehr (2003) illustrate how gender matters within other areas than households' negotiations over energy technologies and practices. They argue that the energy sector has a clearly masculine image that attracts more male, compared to female, workers. The perception that the type of work performed in this industry involves heavy labour is a factor that may discourage women from applying for work in the sector. Although energy companies increasingly acknowledge that women's competences are complementary to those of men, and are valuable for developing a more balanced and efficient organisation, female workers remain a minority within the sector. Ryan (2014) further demonstrates how education within energy sciences is dominated by men. She argues (Ryan, 2014, p.101) that women often meet professional obstacles ranging from biased hiring in labs, hostile climate in universities towards women and fewer informal technology transfer opportunities. Ryan (2014) ends her study by suggesting four research agendas related to gender and identity that are ripe for further investigation: eliminating indoor air pollution, strengthening community resource management, developing feminist energy jurisprudence and increasing women's representation in science, technology, engineering, mathematics and energy fields.

2.4.3 Gender-related differences in transport and heating and cooling energy choices

Gender is often found to be a relevant aspect underlining diverse considerations related to transport and environmental problems. Although this is a characteristic that could be considered an individual feature, it plays a higher role at societal level since in different societies women might have different roles within household decision making processes. For instance, the role of women in a particular society can be a cultural discriminant at local and national levels (Aldred and Jungnickel, 2014). Women

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are found to be more concerned about transport problems than men (Rienstra et al., 1999), to positively evaluate car emission performance attributes (Achtnicht, 2012) and to have lower car use and ownership and higher bus fare expenditures in general (Nolan, 2003). Interestingly, Golob and Hensher (1998) find that women have a higher environmental commitment and use more public transport, but also find them to be more disposed to see cars as a status symbol. Hence, they argue that women are more likely to choose solo-driving all else being equal.

The number of studies specifically addressing the role of gender in efficient and sustainable heating and cooling is rather limited, mainly focusing on the role of women in developing countries (see Elkanat and Gomez, 2015, for a review of relevant studies). Clancy and Roehr (2003) point out that relatively little is known about the possible roles women can play in enhancing energy-efficiency, and highlight the need for more focused research and data collection to assist in formulating targeted policies.

Elnakat and Gomez (2015) explore whether there is a difference between the energy use of families dominated by females and males, based on a survey of single-family residential households in the U.S. Their review of previous studies supports the notion that traditional gender-based division of labour is still prevalent in most countries. Drawing on their survey data they find that households led by women consume more natural gas, due to their preference for warmer temperatures for both space heating and water use. The study concludes that the relationship between gender and sustainability should be better understood and conservation policies should promote the engagement of female occupants, given their determinant role in the daily routines of operating home appliances, as well as their influence on the behaviour of children and other family members. Several studies provide evidence on different thermal sensation of women, especially regarding air-conditioning, claiming that females are more sensitive to fluctuations in temperature in comparison to men (e.g. Schellen et al., 2012, or Karjalainen, 2012). One possible solution is applying technology that enables personalized heating and cooling. Using an optimal mix of ventilation, humidity, heat conduction and radiation can improve personal comfort, while energy consumption can be decreased by up to 40-60%, depending on the ambient air and the thermal conditions required (Veselý and Zeiler, 2014).

Brounen et al. (2013) show that women are less aware of the energy consumption of their dwellings than men. In another study, Henning (2005) illustrates the importance of gendered household zones and negotiation processes between men and women. The pellet burner is often installed in single family houses equipped with a boiler room such that the burner easily fits the energy system that has already been installed. Secondly, the pellet burner is most often placed in the male zone of the house, where it is not subject to gendered negotiations and adjustments. However, the pellet stove is often placed in the living room, where it may conflict with norms for tidiness and how the room is decorated. The installation needs to be negotiated between men and women and often meet requirements in excess of energy efficiency or environmental concerns. In other words, installation of a pellet stove involves negotiating gendered household zones and boundaries and may lead to conflicts.

However, the findings above should be considered with caution, as there are also studies that found no evidence on existing differences between the attitudes of male and female consumers towards energy consumption and renewable heating solutions (e.g. Michelsen and Madlener, 2017; Tabi, 2013).

Regarding the shift from consumers to prosumers, gender might play a significant role, considering how men and women interact differently with technologies in the household (see for example the findings above on the pellet burner which involved gendered negotiations). Depending on whether the head of the household is a man or a woman, the household's approach towards energy sources and own energy production could be different. While findings on the relationship between engagement as prosumer and gender are still scarce, ENABLE.EU will investigate this issue in the context of its case study on prosumers.

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The studies reviewed here largely take as their point of departure that gendered identities are culturally and socially embedded and enacted. The implication for gendered studies of household energy practices is that it is important to be attuned to the different values and identities that shape men and women's energy roles and how energy decisions are negotiated within households when making energy investments. In-depth knowledge of the cultural contexts and social arrangements shaping gendered energy practices is needed in order to design energy policies and direct energy investments in ways that are gender-sensitive and socially, economically and environmentally efficient, effective and sustainable.

2.5 Behavioural characteristics influencing energy choices

Behavioural aspects include all those factors which impact on the internal formation of a specific behaviour, such as attitudes, values, beliefs habits and practices. Several aspects of the identified factors can overlap. For instance, while we place habits among behavioural drivers, habits are often shaped by socio-cultural aspects. As such, it should be kept in mind that the types of factors provided for framing in this review are a tool to organise the findings but in practice factors appear strongly interrelated and cannot be easily disentangled.

2.5.1 A dichotomy between reasoned and unconscious energy behaviours

A major distinction is made with regard to the nature of human behaviour. In this context, it is often highlighted that there exists a dichotomy between a reasoned component, which translates into a planned action under the control of human consciousness; and an unreasoned form of automaticity, which implies an action driven by habits and practices or by external influences (Bamberg and Schmidt, 2003). These aspects are not mutually exclusive but are often complementary and treated in conjunction (e.g. Klöckner, 2014; Nordfjaern et al., 2014). However, it seems that depending on the particular application, one can be found to be more important than the other. For instance, Bamberg and Schmidt (2003) assert a significant impact of both intention and habits on car use, while Bamberg et al. (2003) find evidence of a reasoned decision in the choice between car and public transport. In any case, these natures have their own determinants and peculiarities and are connected with different policy strategies. Two main factors have the power to influence them: knowledge and experience.

In this context, a mention needs to go to the debate on sociological theories on behaviour as reasoned action that is influenced by attitudes, subjective norms and perceptions, or as a result of personal norms, influenced by values and moral obligations (see Bamberg and Schmidt (2003) for a detailed description of these theories). Although most of the papers presented in this section specifically refer to these theories, and the implication of their results is provided as support to the one or the other theory, the inclusion of the findings in more theoretical dissertation on cognitive aspects goes beyond the scope of our research.

Szlávik et al. (2000) claim that the general attitude of the society might be influenced by providing proper information on alternative technologies improving efficiency and related costs. Positive and favourable changes in consumer behaviour can raise demand for successful technological solutions, promoting their development, while maintaining a healthy competition on the supply side. The authors also emphasize the role of media, the non-governmental sector and the educational system, as very important channels, which can direct consumers towards energy-conscious behaviour. Jakob (2007) draw attention to the general problem of lack of information on available technologies, the magnitude of potential savings, and the lack of awareness of consumers.

Lillemo (2014) analyses the relationship between energy-saving behaviour, environmental awareness, socio-economic factors and the tendency of consumers to procrastinate decisions. According to his results, inhabitants who are generally more inclined to procrastinate are less likely to make investments

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in energy conservation. Higher level of environmental awareness is positively related to everyday curtailment behaviour, but cannot be associated with energy-saving investments.

Perceived risks related to innovative technologies can also be important behavioural barriers for energy conservation. It is difficult to decide whether to invest in a technology if new, more favourable solutions might become available in the near future, or if consumers envisage a further fall in prices of present technologies, and thus decide to postpone their investments (Csutora and Zsóka, 2011). The authors claim that unmotivated energy users should be in the focus of support policies.

To date, several researchers have examined the relationship between pro-environmental attitude and energy consumption, and found attitudes to be a poor predictor of actual energy-saving behaviour. This controversy, called 'value-action gap' or 'belief-behaviour gap' (Gadenne et al., 2011) is primarily explained by the fact that energy-related decisions are influenced by a mix of interrelated factors, including habits, practices, and the costs related to a particular choice, expressed not only in money terms, but in terms of time and effort as well (Tabi, 2013). However, other researchers, such as Sapci et al. (2014) find a positive relationship between observable environmental attitudes and energy consumption behaviour.

As seen in the section on cultural factors, Shove (2010) points to the importance of consumption practices, which lock consumers into repeated behavioural patterns, forming everyday routines that can influence energy consumption in the longer run. These routines are carried out by people unconsciously, being built in everyday practices; therefore, it is important to investigate their emergence and evolution (EEA, 2013). Shove also draws attention to the ever-increasing demand of consumers for convenience, as one of the main determinants of consumer choice. Steg (2008) maintains that people invest more readily in energy-efficient appliances serving important needs, wants and preferences, and are less likely to engage in energy saving when it requires higher amounts of money, effort or inconvenience.

2.5.2 Implications of behavioural aspects on energy choices in transport, heating and cooling and prosuming

Intentional nature of behaviour – Attitude-related aspects

An extensive literature is directed towards the study of human behaviour that may influence the transition towards low-carbon mobility. With respect to the intentional nature of behaviour, decisions are considered to be the result of an evaluation of consequences and available alternatives influences (Bamberg and Schmidt, 2003). This evaluation is influenced by different factors such as values, beliefs and perceptions. For instance, values, such as environmental preservation or altruism, are found to be significant in the willingness to cooperate in car use reduction policies; and specific beliefs on perceived fairness and freedom granted connected to a specific policy to influence its acceptability (Eriksson et al., 2006; Nordlund and Garvill, 2003). In this context, Schuitema et al. (2010b) argue that convincing people about positive outcomes on congestion and environment is important to heighten the acceptability of car use reduction policies. In addition, Krupnick et al. (2001) also find a significant impact on support for pricing policies to depend on political views and perceived effects of car pollution on health.

In the domain of EVs adoption Bockarjova and Steg (2014) investigate people's risk evaluation regarding possibility to adopt electric vehicles (EVs) in the short term and acceptability of EVs as future replacement of fossil fuel cars. They find in the short term evaluation a prominence of concerns related to environmental problems, while in the long term a higher importance of considerations on sources of electricity production. On the same topic, Graham-Rowe et al. (2012) identify a series of typical beliefs and consideration on EVs, the majority of which act as barrier to EV adoption. In particular, they

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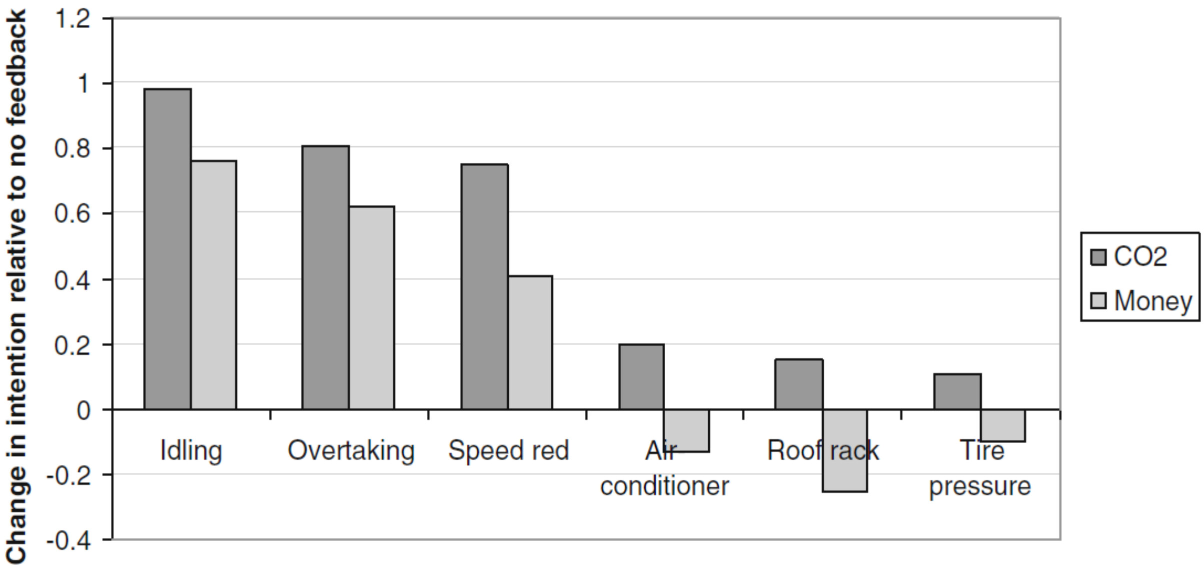
interviewed people that claimed issues regarding costs and savings, vehicle performance, adaptation to new routines and the risk connected to EV as a 'work in progress' technology. Finally, Greene et al., (2008) argue consumers' uncertainty and loss aversion to be cause of failure in choices of fuel efficiency as consumers tend to undervalue future fuel consumptions.

Another line of factors that influences intentional behaviour are connected to people's knowledge and problem awareness. The former have an influence on the latter, suggesting a positive role of providing information about environmental issues on travel behaviour. Evidence of this relation can be found in Rose and Ampt (2001), who analyse the impact of a program providing participants with quantitative feedback about travel activity. In this case, the information provided influenced participants' awareness and actively changed their travel behaviour. Moreover, in a similar context, Dogan et al. (2014) investigate the impact on eco-driving behaviours of feedbacks regarding financial or environmental aspects. They find a positive impact of both, suggesting the important role of information provision in itself rather than its content. Nevertheless, environmental feedbacks are found to be considered more worthwhile than the financial ones in influencing the intention to uptake an eco-driving behaviour (**Errore. L'origine riferimento non è stata trovata.**).

Figure 1: Differences between mean scores of environmental and financial feedback groups compared to the control group on intention to adopt specific eco-driving behaviours for each scenario (Dogan et al., 2014)



With regards to car purchasing decisions[12], Baltas and Saridakis (2013) find a significant role of pre-purchase information sources in consumer preference formation on car type choice and identifies seven different informational channels used: brochures, showrooms, car magazines, TV advertisements, internet, friends and personal knowledge. Furthermore, an important role seems to be played by car labels as tool enabling people consumer to perform informed choices (Haq and Weiss, 2016). In fact, there is evidence of a positive and significant willingness to pay for cars labelled with a higher energy efficiency and emission performance, which ranges between 5-11% of the final retail price (Alberini et al., 2014; Galarraga et al., 2014). In addition, Codagnone et al. (2016) contribute to this discourse by

[12] The purchasing decision can be referred to as the 'car type choice'. This involves evaluation of fuel type, fuel efficiency and other characteristics (Chapman, 2007; Galarraga et al., 2014) and presents the most relevant connection with technological change. For instance, Ajanovic et al. (2012) find that improvements in cars' fuel efficiency have been compensated by trends in buying bigger cars, hence reducing the gain obtained by innovation. Moreover, consumer possibilities are deeply determined by the range of available options on the market and their relative competitiveness with the actual technology.

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focusing on the effect of the information provided in labels and in promotional materials on cognitive processing and car purchase choices. Through a laboratory and an online experiment, they argue the importance of these tools to be easily understandable. Indeed, they find promotional tools to be more effective than labels, since they convey simpler information and are more specifically designed to capture attention.

In the study of mobility, symbolic meanings i.e. values related to the identity of an individual are connected to behavioural choices (Steg, 2005). With respect to travel mode choice, Steg (2005) compares instrumental and symbolic means associated with car use and finds a relevant impact of the latter. She also defines a series of groups more influenced by these means, namely young, male, frequent drivers and people with positive attitudes towards cars. Based on these results she claims the need of taking affective and symbolic means into consideration when designing policies. Symbolic meanings are also found to play a role in the EV domain. Heffner et al. (2007) argue them to be of multiple natures. These can be not only connected to environmental benefits, but also to political means (opposition to wars or oil producers) and pro-technology identity. Moreover, they also claim it is important to consider these aspects in order to promote adoption. Finally, Turrentine and Kurani (2007) also find symbolic meanings in relation to fuel economy, suggesting that the evaluation of what is often treated as a mere economic consideration is more complex than what it seems. The underestimation of these aspects can deeply affect success of policies also in this context.

Heating and cooling choices are also influenced by attitude-related aspects (problem awareness, perceived risks). Based on Shove's (2010) and Steg's (2008) analysis, Brounen et al. (2013) conclude that a large share of consumers is not aware of their energy consumption, and is "not considering the thermostat night settings to save on energy". They also find that households with higher income tend to set higher temperature in their homes, and a lower propensity to set thermostats to lower temperature, drawing attention to the importance of technologies providing comfortable solutions, e.g. user friendly, automatic temperature controlling devices, that can be programmed easily.

On the question of prosuming, several studies point to the characteristic of electricity as a largely invisible good, which means that it tends to escape human consciousness and reflexivity (Lindén et al. 2006, Pedersen 2000). Electricity's invisibility forms one of the underlying barriers to electricity conservation and might also negatively influence the likeliness of households becoming prosumers. On the other hand, consumers' engagement with electricity generation might lead to increased "visibility" and awareness, and affect energy practices in households (see Bergman and Eyre 2011). Also, several authors have shown that electricity is dominated more by external factors such as price and income rather than by internal factors such as values and emotions (Sælen et al. 2012, Pedersen 2000). Winther and Bouly de Lesdain (2013) indicate that the low price of Norwegian electricity discourages household customers from saving. It might be hypothesized that low prices will also discourage households from becoming prosumers.

Practices, habits and quality of life – routinized behaviour

However, the repeated nature of many transport related decisions, such as car use and travel mode choice, denotes a form of action which cannot be completely explained as intentional and has to be referenced to forms of automaticity (Bamberg and Schmidt, 2003; Fujii and Gärling, 2003; Schwanen et al., 2012). Schwanen et al. (2012) assert these behaviours, namely habits and practices, can act as link between intention and actual behaviour and can be conceptualized as the impact of past experience on future behaviour. Moreover, they highlight the equal importance of targeting processes that bring to the habit formation and to the habit breaking. In addition, Fujii and Gärling (2003) argue their presence as possible source of biases in stated preferences in travel demand analyses and stresses the importance of accounting for them in surveys.

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A series of studies argues in favour of the positive role of direct experience as habit breaking strategy (Jensen et al., 2014; Matthies et al., 2006; Thøgersen and Møller, 2008). For instance, in Germany, Matthies et al. (2006) study the effectiveness of a free month ticket for public transport on habitual car users as habit defrosting technique. They find a significant impact of the intervention, although rather small, and argue in favour of its utility as initiator of a 'trying-out' behaviour[13]. However, they state that a long term change requires a positive evaluation of the new behaviour. Indeed, in a similar experiment conducted by Thøgersen and Møller (2008) in Denmark, the initial significant effect of the free ticket on the population sample loses its impact after four months. From this, they derive the consideration that even if habitual, travel mode derives from an informed preference and suggest the use of direct experience techniques as complement of informational systems.

With respect to EVs, Jensen et al. (2014) study the impact of direct experience in using an EV on preferences towards this technology. Comparing ex ante survey data with post experiment data, they found people to be less incline to adopt an EV after trying it for a three-month period. From this result, they argue the relevance that direct experience plays in attitude and preference formation and its relevance in policy forecasting.

Routinized behaviour (habits and practices) can also be an important barrier to improving household energy characteristics related to heating: for instance, insisting to long lifetime products or solutions, even in situations when they clearly hinder energy efficiency improvements. Csutora and Zsóka (2011) provide the examples of less efficient heating systems or draughty windows which owners might insist to keep until the very end of their physical lifetimes, or even longer. Whether this phenomenon has economic reasons, or is due to habits or inertia, is a question for further research. If policies are solely based on the assessment of cost-saving potential of efficiency improvement opportunities, the rebound effect can neutralize the achievements considerably, therefore a higher attention should be paid on understanding, and if necessary, modifying consumer behaviour (see also Csutora and Zsóka, 2011). The effectiveness of financial subsidies, contributing to energy efficiency investments of households, also depends on the habits and comfort of consumers.

Alberini et al. (2016) surveyed US households that replaced their heat pumps in a 5-year period, to examine the effect of available tax credits and rebates. They found that a large share of incentive recipients (more than 50% of households in their sample) were free riders (their investments would have been realized without the subsidy), and many of them used the incentives (tax credits or rebates) to increase the capacity of their heating systems (upsizing) instead of taking measures to decrease their thermal energy needs. In case of low-income households, this could be the result of raising their initially low thermal comfort level. However, by analysing their dataset, the authors revealed that consumers receiving larger incentive payment (proportional to the value of investments) realised less reduction in their electricity consumption, suggesting that the subsidies were often turned to upsizing.

2.6 Conclusion

[13] A similar phenomenon appears in the context of policy acceptability. Winslott-Hiselius et al. (2009) study the change in public attitude regarding congestion charge in Stockholm, firstly implemented as trial in 2006. They found a progressive supportive attitude towards the policy during the trial period and conclude that this form of experience can be particularly helpful in the implementation of `difficult` policy measures. Based on the same trial, Schuitema et al. (2010a) conducted a field experiment analysing the change in public support to the policy, which grew progressively during the trial period. Their results support the thesis of a relevant role played by direct experience on acceptability. In particular, they argue acceptance to be due to the experience of the related positive consequences.

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The analysis of aspects pertaining to how consumers develop their energy consumption decisions passes through the understanding of the role of individuals' socio-cultural environment, demographic and behavioural characteristics. Through the lens of several energy topics studied within ENABLE.EU, namely mobility, heating and cooling and the shift to prosuming, different patterns can be observed in energy choices.

Social conventions appear as an important driver for all three energy related topics. Culture may affect how people respond to specific mobility policies, depending on how practices are considered and on the city where it is implemented. Social norms as well as interpersonal influence have important effect on heating and cooling energy choices, and might shape daily routines. Culturally determined social dynamics is also a driver/hindrance that might influence energy consumers in the energy practices and choices of technology, hence, also influencing prosuming possibilities and the energy practices following from those.

On the other hand, demographic variables like income and age do not show clear patterns in shaping behaviours – their impact seems to depend on the energy service or topic and the empirical setting. Income, considered as a determinant of social status, strongly shapes households' energy behaviours, but based on different motivations – these can be the demand for increased comfort, affording basic energy needs, the ability to invest and the desire to produce energy independently. Energy poverty appears as a main issue and increasing dwellings' energy efficiency is a first step towards its eradication.

Gender is given particular attention within ENABLE.EU, especially in the shift to prosuming, as research shows that the motivations for and barriers to taking up energy-saving technologies can be gendered. Findings show for instance that women are more concerned by environmental issues, have lower car use and prefer higher room temperatures. On the other hand, no clear difference was observed between the energy-saving attitudes of male and female consumers.

The behavioural dimension, while sometimes neglected in research on the drivers of energy choices, encompasses crucial aspects which can hinder behaviour change. These include habits and practices shaping daily behaviour, as they are often unconscious processes. Habit breaking strategies should therefore be considered. Consumers' engagement with electricity generation might also lead to increased "visibility" and awareness, and affect energy practices in households. The influence of environmental awareness in shaping behaviour remains however uncertain. Values and beliefs also tend to shape attitudes towards the environment to a certain degree. The influence of these factors will be further researched in the context of ENABLE.EU's case studies.

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3. What drives the energy choices made by public authorities (governance)?

3.1 Introduction

While the Energy Union has developed a coherent plan for a sustainable energy transition, there are large differences between the countries' specific policy paths to achieving this goal and regarding the capacity of their economies and societies to achieve it. The transition to low-carbon energy requires disrupting the current energy system based on fossil-fuels, centralised generation, supply-side orientation, and all the practices, policies, technologies, norms and attitudes linked to this system, while at the same time developing and introducing sustainable alternatives. This raises the challenge of good governance and of consistent policy-making that is predictable and based on a long-term strategy that cannot be easily overturned in the future.

The governance of energy transition is performed by a multitude of actors including the energy industry, local and central governments, civil society organisations, citizens and businesses as well as individual actors and lobby groups. The disruption of the existing energy system and the transition to a low-carbon one, requires also a complex set of innovations that affect not only the development of new technologies but also social, political and economic transformations. The emergence and the diffusion of these innovations in the economy and society face specific difficulties and barriers which may slow down, shift away or even break off the processes. The barriers could stem from the existing constellations of social, political, economic, cultural and technological barriers in the countries but could also arise as a result of the introduction of new products and services or related modes of human behaviour.

Studying energy transition governance raises the question of how the term governance is understood. Beside the vast number of definitions, the term will be used in the current analysis as referring to two major processes – the process of decision-making and the process by which decisions are implemented (or at least there is an effort to be implemented). In the literature on energy transition governance, usually the terms refer to the notion of "good governance", which is understood as the way in which public affairs are managed, i.e., in a manner that is transparent, inclusive (or participatory), responsive and accountable, effective and efficient, equitable and following the rule of law (Doeveren, 2014; Weiss, 2010). In this aspect, the governance of the transition to a low-carbon economy and society is seen as aiming at steering important societal sub-systems (such as the energy system) in a more sustainable direction (Laes et al., 2014, p.1131).

The main aim of this Part is to review and analyse how the policy decisions regarding energy transition are taken and implemented and how their sustainability is secured in the long run, as well as who are the actors driving the respective policies and the main factors influencing their behaviour. A secondary goal is to systemise the theoretical approaches in the literature studying energy transition governance and to analyse how they are embedded into the policy-making theory and practices. This Part is based on the analysis of mainly peer-reviewed publications and some grey literature, such as policy- and research-oriented reports and publications. Most of the publications cover studies of European countries, while only few refer to case studies outside the continent. The review considers the implication of previous studies on a heterogeneous set of governance frameworks, taking as a reference point the energy trilemma – under which policy instruments may not be used to alter energy security, energy sustainability, and energy affordability independently of each other[14]. The main focus of the study on governance challenges in the energy transition pathway would be on the penetration of

[14] Pascual, C. and Elkind, J. (eds.) (2010). Energy Security: Economics, Politics, Strategies and Implications. Brookings Institution Press. Washington D.C.

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renewable energy technologies in the energy system. Issues related to energy savings and efficiency are discussed in more detail in the preceding Parts on socio-cultural and economic determinants of energy choices.

The structure of Part 3 includes four major sections. The first one presents a brief review of theoretical approaches that are used in the analyses of energy transition governance. The second section focuses on the drivers of policy decisions, made by public authorities regarding the transition to low-carbon economy and society and presents an analysis of three main topics: i) path dependency of governance practices in social, economic and political aspects; ii) consumer engagement in the policy design; and iii) the role of the research and business community as drivers for policy change and how their R&D priorities and the related public funding influence the energy transition pathways. The third section focuses on possible obstacles to the design and implementation of policies, faced by governance regimes: i) regulatory, legislative and financial obstacles; ii) socio-political barriers in terms of traditions and diverse political cultures; and iii) public acceptability of new technologies and policies related to the transition to low-carbon energy. The last section centres on the sustainability of energy transition policies, incl. the long-term engagement of consumers with their transition.

3.2 Theoretical frameworks in the studies of energy transition and energy transition governance

The analysis of energy transition governance usually focuses on public policy as a factor co-evolving with other system factors. In this respect, some of the most often employed theoretical frameworks are related to transition theory, public choice theory, path dependency and innovation system approaches (Laes et al., 2014, Eikeland and Inderberg, 2016; Kivimaa et al., 2017; Roelich, 2016; Araujo, 2014; Lawrence et al., 2016; Fabra et al., 2015; Geels, 2002, 2014; Hielsher, 2011; Van der Schoor and Scholtens, 2016). However, the extensive number of studies on energy transition, which have emerged particularly since the late 1990s, documented well the multi-disciplinary nature of energy transition, and thus have created broad opportunity for the application of diverse theoretical and methodological approaches[15]. The current analysis is focused on the governance aspect of energy transition and reviews only some of the theoretical frameworks that have been applied most often in the reviewed literature.

In addition to the already mentioned theoretical approaches that refer directly to the governance aspect, other theoretical frameworks are focused on sociological concepts in the analysis of energy and technology. Among them, the concepts, most often applied, are covered under the umbrella of behavioural economics or behaviour change approach, socio-technical approaches (e.g. large technical systems, social shaping of technology, or science technology studies), stakeholder engagement and public acceptance (Bolton and Foxon, 2015; Pollitt and Shaorshadze, 2011; Fast, 2013; Wolsink, 2007; Devine-Wright, 2005; Wüstenhagen et al., 2007)[16].

3.2.1 Behaviour-related concepts

The behaviour change approach assumes that by providing the right information to people, they will

[15] For example, Van der Schoor and Scholtens (2016) applied a bibliometric approach to analyse 168 articles, dealing with both “community energy” and “sustainability” topics, published in peer-reviewed journals and categorised them as being part of six broad theoretical clusters or theoretical perspectives and namely: multi-level perspective, evolutionary systems, social practice theory, acceptance perspective, governance oriented studies and spatial design, with additionally innovation systems as horizontal framework. The authors concluded that boundaries between approaches (and perspectives) are not very sharp and there is considerable overlap in concepts.
[16] For more details, see the respective sub-sections below.

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change their attitudes towards a particular subject, in this case, environmental and sustainability issues, altering their behaviour. However, a direct link between attitudes and behaviour is not always clearly visible, as this is underlined in much of the reviewed literature (Hielscher, 2011). One of the main assumptions of the behavioural change approach is that individuals are decision makers who are of full control of their actions. However, existing research has demonstrated that within the boundaries of complex socio-technical environments, such as energy systems, behaviours are not controlled mainly by individuals but are shaped by existing structures and conventions; moreover, people often feel disempowered when they face individually the enormity of the tasks such as to change the existing energy systems or to tackle the climate change (Hielscher, 2011, p.38-39). Another main assumption highlighted by behavioural economics is that individuals may not behave rationally as classical neoliberal economics assumes but there could be an "irrational" aspect in the individual decision making, which is referred to as "behavioural failures", and which could lead individuals to act against their own long-term interest (Pollitt and Shaorshadze, 2011, p.2). As the research on energy transition shows, both assumptions disregard the communal aspect of energy transition, especially when it comes to the governance issues, i.e. the communal aspect enhances the degree of rationality in the decision making processes and increases the level of sustainability and effectiveness in the long-term goal setting (Hilescher, 2011; Eikeland and Inderberg, 2016).

In terms of energy transition governance, the studies on "community energy" reveal how groups have often created a strong sense of community, thus developing high levels of civic engagement and self-governance. The result is not only a better representation of community interests and goals to the relevant stakeholders, including local and central-level policy makers, and the wider public, but also an increased level of social and economic rationality of the community initiatives due to formalisation and optimisation of the decision-making processes in the community.

3.2.2 Socio-technical approach

The socio-technical theoretical approaches put in their focus the study of technologies, analysing the social character and implications of technical change (Bolton and Foxon, 2014; Mackenzie and Wacjman, 1999; Callon, 1998). The technical change is seen as a dynamic non-linear process, where outcomes are not determined only by economic and technological factors, but are shaped by wider social processes. It should be studied through a systemic approach, which looks at technical change on three interrelated levels.

As described below, the socio-technical approach is often used in combination with transition theories for explaining the transition to low-carbon economy and society. In most Western European countries, the energy transition policy since the early 1990s has developed a strong market-oriented framework for energy infrastructure investments. Here, public policy treats the market as a vehicle that provides just enough incentives for private actors to invest in infrastructure assets, which ultimately leads to greater economic efficiency and socially optimal outcomes. However, this framework could not explain the increased need for higher levels of public investments to meet the societal objectives of the so called energy trilemma, i.e. reducing CO2 emissions and maintaining energy security, whilst simultaneously keeping energy services affordable to consumers. To account for these challenges, a new conceptualisation would be needed regarding the relationship between governance structures and markets (Bolton and Foxon, 2014).

3.2.3 Public acceptance

A common denominator for the socio-technical, behavioural change and behavioural economics theoretical frameworks is the concept of public acceptance of a new policy and technology. To implement a new technology shift successfully, one needs to not only develop the physical ('hardware') and institutional ('software') infrastructure, but to also make sure that consumers/citizens accept the

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shift. For the diffusion process to be completed, not only the energy transition interest groups need to accept the policy and technological changes, but also these parts of societies not directly involved in energy transition. In this respect, the notion of governance is better applicable for explaining the public acceptance of energy transition than the concept of government. The former evokes a more pluralistic pattern of rule than does government: governance is less focused on state institutions, and more focused on the processes and interactions that tie the state decision making to citizens and civil society institutions (Bevir, 2010). The concept of governance as distinct from the concept of government, addresses both formal aspects of government as well as the informal social and political expectations that accompany the application of authority. However, despite the essential role of public acceptance both for the practical success of energy transition, and for its theoretical conceptualisation, there is still little research on the topic. The framework, to which the studies of energy transition (governance) most often refer to, is based on the typology, presented by Wüstenhagen et al. (2007) analysing three aspects of public acceptance: socio-political, market and community. Fast (2013) argues that the socio-political aspect of public acceptance is the most widely studied one. The major focus here is the mismatch between community and political support towards promotion of technologies, known as "Not in my backyard" (NIMBY) phenomenon.

The market aspect of public acceptance refers to the process of market adaptation to the innovations in energy production (Wüstenhagen et al., 2007). The third aspect comes from the community. One of its major characteristics according to Wolsink (2007) is that it follows a U-curve shape. In the beginning and at the end of the energy transition implementation process, a green project has high public support and rather low public acceptance in the site phase. A common concept used in the majority of research on the topic is that local community engagement has an essential effect on the positive attitude towards energy transition projects. However, any conclusions based on the conducted studies should be considered critically, as when it comes to studying community attitudes towards the energy transition process, the majority of studies have taken place mainly in the United Kingdom, Denmark, the Netherlands and Germany, which excludes a big part of the European Union.

3.2.4 Transition theories

As already mentioned, energy transition governance is analysed through the theoretical lenses of the transition theory, often in combination with some of the other approaches described already, like path dependency or innovation systems approaches. As Laes et al. (2014) point out, due to the co-evolution of energy systems and other important societal subsystems (e.g., transportation, housing, and industry), the transition to a low-carbon energy system presents first and foremost a "systemic" challenge. The authors have analysed how technologies, institutions, political and general culture, and social practices are reformed in a coordinated way to guarantee a more environmentally sound and equitable development trajectory in the energy transition governance of Germany, the Netherlands and the UK.

Based on previous studies using the transition theory approach, the authors emphasise the importance of some of its general characteristics:

a) Radical innovations are in the centre of technical change and they emerge usually on the micro-level within dispersed "niches", representing protected spaces where new technologies and practices are shielded from the full selective pressures operating in the incumbent environment. The diffusion of these innovations into the wider meso-level of the current "regime", seen as a dominant set of stable but continuously evolving infrastructures, actors and institutions, has a destabilising effect on the regime, which gradually changes its constellations. While in the short to medium term, new technologies and practices may co-exist with old ones, in the long run they gain enough power to change the whole regime constellations, thus bringing the technological change to the macro-level of "landscapes", which represents a set of processes that operate beyond the direct influence of actors in a given regime, i.e. global social, economic and

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technological trends (Bolton and Foxon, 2014; Laes et al., 2014; Geels, 2002, 2004).

After conducting a comprehensive literature review of articles on climate governance published between 2009 and 2015, Kivimaa et al. (2017) argue that energy transition projects in the form of experiments, used as an approach in the policy development process, have four widespread implications – niche creation, market creation, societal problem solving and spatial planning. The first two implications coincide with the micro- and meso-levels, identified by Laes et al. (2014) and refer to two different stages in the development of energy transition projects. The initial stage considers pilot projects that create favourable, but limited in time and space, conditions for conducting an experiment introducing new and innovative forms of energy production and use. The later stage refers to a situation, when the newly-developed forms are diffused in the society and economy to a degree which allows for a new market in terms of products and services, but also an institutional and regulatory framework to be created and to become self-operational. The third and fourth implications of experiments in low-carbon governance, i.e. societal problem solving and spatial planning, identified by Kivimaa et al. (2017), could be referred to the macro-level of "landscapes" (Laes et al., 2014) on condition that in the former case the agency behind the design and implementation of the experiments is much stronger and active, while in the latter case, the concept of "landscapes" presupposes the evolving set of processes which operate beyond the direct influence of actors. An important feature of the policy development through applying experiments, highlighted by the authors, is the need for ex-ante and ex-post evaluation of the projects in order to set up proper and achievable goals and to account for their implementation and impact assessment. The lack of or the improperly conducted evaluation could seriously hinder the implementation of the experiments and could become an important governance bottleneck.

b) Transitions are multi-actor processes, involving a large variety of social groups and cutting across established functional specialisations and jurisdictional boundaries. In this respect, energy transition pathways require societal involvement and engagement. Laes et al. (2014) underline that low-carbon development cannot be achieved by (local or central) governments alone. To achieve such far-reaching changes, energy transition policies require strong and consistent public support and understanding, self-directed change in many domains of society, and collaboration among diverse social actors.

c) Transitions involve moving away from established ways of doing things (in terms of principles, business models, end-user practices, etc.), and this inevitably provokes resistance from groups that fear that their interests will be harmed. In this respect, low-carbon development requires the simultaneous pursuit of multiple goals and the management of issues that cut across established administrative responsibilities. Researchers stress that transition governance should not just balance trade-offs between economic, social, and environmental concerns, but should also create win-win situations for all involved stakeholders. Particularly, the shift in the goal setting of the respective state authorities is of great importance, as existing administrative structures and procedures tend to encourage a partial vision of problems. As evidence from the German case study shows, even the reluctant support by the central government of the energy transition agenda at its early formative stages (roughly 1975–1990), which supports a gradual reorientation of research and development (R&D) funds, was enough to open up small space for experimentation and learning in wind and solar power for a range of companies and academic departments (Laes et al., 2014).

d) Due to the inherent complexity of contemporary industrial societies and the rigidity of the systems in place, transitions are long-term processes, as witnessed also by historical evidence on past energy transitions not driven by sustainability concerns.

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3.3 Factors driving policy decisions made by public authorities

3.3.1 The governance of energy transition innovation

While it is clear that technological and social innovations are crucial to achieving green growth, it is still difficult to understand what drives green innovation and energy transition technologies. As there is no single widely accepted set of indicators or methodology to measure their development or their adoption, they are usually assessed in terms of the number of climate control or environment related patents. The other common approach is by looking at the funding made available for green research and development (R&D) activities. While financial resources are crucial for developing the new technologies themselves, their environmental impact is dependent on how widely they are adopted. This in turn relies on high demand levels and the absorption capacity of the product and labour markets, as well as widespread awareness about their benefits.

Successful energy transition policies should be designed in such a way as to impact the long term development and application of Renewable Energy (RE) technologies. Endemic to the problem of designing efficient policies to that end is that restrictive energy policies will necessarily influence the optimal amount spent on research and development (R&D) by firms in the market. The Porter hypothesis maintains that “strict environmental regulations do not inevitably hinder [a firm’s] competitive advantage” (Wagner, 2013, p.20). Rather, the innovation effect associated with environmental regulation is such that the cost saving technologies developed in order to meet regulation are sufficient to compensate both the compliance costs directly attributed to new regulations and the innovation costs (Wagner, 2013). In his broad review of the empirical literature on the Porter hypothesis, Wagner identifies four dimensions for assessing the different instruments for supporting energy transition:

a) Efficiency: the degree to which policies make use of the market mechanism to achieve specific RE targets.
b) Dynamic incentive effects: the degree to which the policies induce technological change.
c) Distortionary effects: the degree to which the policies distort competition or have a negative effect on structural objectives or regional policy objectives.
d) Environmental effectiveness: the policies ability to meet predefined environmental targets.

Accordingly, in relating the Porter hypothesis to energy transition policies, the next section of the review will make use of the first three criteria of Wagner.

One of the key mechanisms for supporting the deployment of RE technologies is the use of standards and regulations (Wyns et al., 2014), which, as other researchers have pointed out, could be defined differently in terms of processes and outcomes (Blind et al., 2016). Formal standards could be defined as “the result of a consensual negotiation process carried out by firms and other interested stakeholders”, while a regulation refers to a policy instrument “developed and enacted by the government to shape the market environment and influence the behaviour of the concerned actors” (Blind et al., 2016, p. 2). Thus, while the introduction of formal standards constitutes a market based policy approach, regulation is rightly viewed as a top down policy instrument. The overarching theme of the literature considered was found to be that (with a view to Wagner’s criteria) no unique effect could be attributed to the introduction of standards and regulations into energy markets; rather, the effect of introducing formal standards and regulations into a market depended on several variables, including the initial structure of the domestic energy market and the maturity of the particular RE technology under examination. This observation is explained in detail by Blind et al.’s analysis of the German Community Innovation Survey (CIS), which found that “formal standards and regulations have different effects, depending on the extent of market uncertainty, information asymmetry and regulatory capture” (Blind et al., 2016, p.2).

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The success of the energy transition would depend to a large degree on easing the penetration of innovative technologies. In this sense, public policy is a key facilitator of environmental innovation (Nicolli and Vona, 2016). Depending on the type of technology, public support schemes can play the most important role in driving forward energy prices and technological breakthroughs especially when we consider the renewable and energy efficiency sectors (Johnstone et al., 2010). Using patent data on a panel of 25 countries for the period between 1978 and 2003, Johnstone et al. (2010) emphasise the role of guaranteed public support schemes such as feed-in-tariffs to drive forward technologies still at early stage of development as was solar power in the 1980s and 1990s. For more mature technologies that have levelized cost of electricity (LCOE) closer to that of fossil-fuel-based power generation, tradable certificates such as the widely-used in the EU green certificates would be more appropriate as they would not distort market signals. As Frondel et al. (2010) argue in their analysis of the German renewable energy policy, feed-in-tariffs have been largely proven a success story in skyrocketing the development of solar and wind-based capacity. However, the authors noted that due to the fixed, long-term nature of the support schemes, after the initial boost to renewable energy technology development, they create market distortions that ultimately contribute to more costs for society removing the market incentives to develop even more efficient technologies in the long term. The excessive feed-in tariffs provided to PV installations across Europe have in fact stifled innovation. Not surprisingly, because of the EU support programmes and the import tariffs shielding European solar PV producers, costs of solar power in Europe have not dropped as quickly and profoundly as in China or the rest of the world, hindering an even greater penetration of renewable energy. Hence, establishing a level playing field for the different renewable energy sources and investing more in R&D would ultimately contribute to substantial cost reductions. A spillover effect would be lower costs for societies. Parts of Central and Eastern Europe have revolted against green energy perceiving it as a corrupt scheme that diminishes their purchasing power.

Demand for green technologies is more difficult to ensure in countries like Bulgaria, Hungary, Poland, Portugal or Greece where populations have lower disposable income and the economy is dominated by micro and small enterprises with limited finances available to invest in green technologies. While everyone will suffer from the deterioration of the environment if green innovations are not more widely adopted, demand is unlikely to grow unless public policy is used effectively to create the right environment for their development, coupled with financial incentives to stimulate their adoption. In theory, publicly supported introduction of green innovations will lower their prices, thus making them more affordable for both industries and individual consumers, and will create jobs. In practice however, mismanagement may lead to waste of precious public resources. The impact of public interventions on the greening of the economy is highly dependent on regulatory quality, on the flexibility of the product and labour markets, and other characteristics, making the management of such a transition a highly politicised and difficult issue.

Another factor driving renewable energy technology innovation is the structure of the energy market. Nesta et al. (2014) have developed the argument that the more open energy markets are, the more effective renewable energy policies are in fostering green energy innovation. In addition, the authors argue that renewable energy support schemes would be more effective if market competition was guaranteed (Nesta et al., 2014). The logic is in a sense inverse to that of Frondel et al. (2010). Public support schemes are in essence market enablers as they allow for new energy producers (i.e. PVs, wind turbines and biomass installations) to join the market imposing competitive pressure on large-scale incumbent producers that have little incentive to invest in renewable energy technologies.

The liberalisation of energy markets assists the penetration and development of renewable energy technologies in two ways. First, increasing competition boosts the number of green technology patents, according to a UK-based analysis by Jamasb and Politt (2011). Second, the entry of mostly small-scale decentralised generation units provides more incentive for specialised manufacturers of electrical equipment to innovate in order to satisfy the requirements of a newly-developing industry. One

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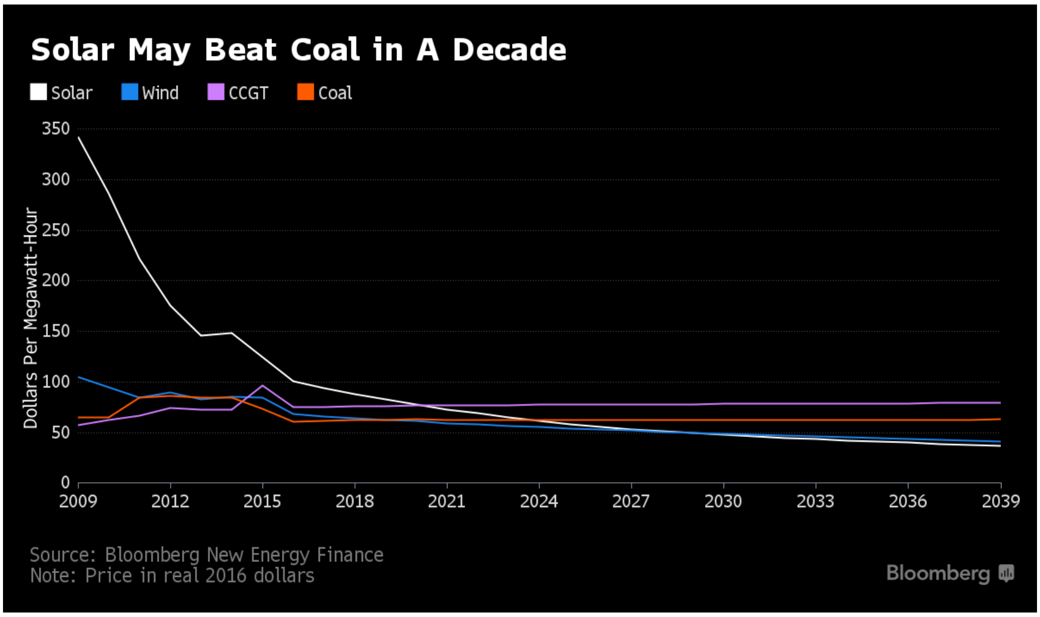
impediment to this logic is regulatory and policy uncertainty, which has been quite typical for the development of EU green policy. This comes on top of the more traditional obstacles to technological innovation such as the inability to reproduce learning curves in newer technologies.

These fears expressed in earlier academic writings might not be fully justified by most recent developments. According to the research firm Bloomberg New Energy Finance, solar prices have decreased by 62% since 2009 and PVs could actually become cheaper than new coal by 2025 (Shankleman and Martin, 2017). So what are the key determinants of successful renewable energy innovation?

Figure 2: The decline of renewable energy levelized costs of electricity vis-à-vis traditional sources of power generation



Source: Shankleman and Martin, 2017

First is environmental policy itself. Targeted subsidies and preferential access to the energy market have stimulated innovation as R&D investments lead to even higher profits for independent producers (Popp et al., 2009). R&D subsidies in the early-stage of technological development diminish uncertainty, while guaranteeing market access through quotas that could protect renewable energy technologies already allowed to compete with traditional energy sources without the provision of support mechanisms. Renewable energy innovation would also be positively correlated with a country's overall climate change policy. Naturally, the development of an efficient emissions trading scheme would further incentivise investments in renewable energy technologies in contrast to the reduction of capital inflows into more traditional energy sources (Fischer et al., 2003).

Previous studies have suggested that imperfect competition could boost the innovation potential of a company as its larger profits could allow it to invest more in innovative new technologies. Later research however shows that in a more competitive environment, innovation creates more profit opportunities that are struggling to claim a bigger market share (Aghion et al., 2005). Firms with larger market share could take advantage of their accumulated capital to invest in R&D in order to prevent new entrants to challenge their dominance. Meanwhile, in markets, where incumbents do not have the capacity to develop technologies far from their manufacturing characteristics, competition could have the opposite effect on the innovation potential. Without distinguishing between levels of uncertainty, Blind et al. (2016) find that "regulation leads to an increase of innovation costs, while formal standards have no significant effect" (Blind et al., 2016, p.8). In a review of locally induced innovation activities for RE

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technologies in Italy, Corsatea (2014) notes that liberalisation of the electricity market allowed for "an ongoing increase in the number of distributed producers" (Corsatea, 2014, p.449). The author goes on to observe that "patterns of solar and wind technologies were significantly correlated with public incentive packages for market deployment" (ibid.)

Sanyal and Ghosh (2013) show in their study that the deregulation of the US electricity market has benefitted the innovation propensity of upstream cable suppliers as their bargaining power on wholesale market increased proportionally to their R&D investments. The diffusion of new technologies tends to be stronger with decentralised power producers including renewables and local heating systems (Nicolli and Vona, 2016). As with markets with rigid market behaviour and path dependency, the utility sector is not well disposed to innovate by introducing new renewable energy technologies. Hence, the innovators and the new market entrants are largely small and medium-sized firms aiming to compete with established utility companies for market share (David and Wright, 2003; Lehtonen and Nye, 2009). Lowering entry barriers in an established market tends to also diffuse new knowledge, as visible in the enormous reduction of solar and wind power costs over the last decade, concurrent with an unprecedented liberalisation of the energy market in Europe and around the world. The effects of market liberalisation should not be confused with those of privatisation and market concentration through M&As, also typical of the recent energy market transformations. The latter have instead created more impediments to renewable energy innovation as larger energy conglomerates see little value in additional R&D investments, while smaller producers find it harder to compete against ever stronger incumbents.

Several of the studies reviewed highlight connections between the degree of market uncertainty and the likelihood for market failure to occur through such avenues as regulatory capture. Blind et al. (2016) echo some previous studies in noting that in markets with low levels of uncertainty, it is easier for firms to influence formal standards to align with their technological preference set. Similarly, where market uncertainty exists, "it is difficult to influence all possible future developments via standards to increase a firm's competitiveness, e.g. by raising rivals' costs" (Blind et al., 2016, p.5). Consequently, in those markets, it is to expected that regulation will positively influence the RE R&D efforts of energy firms in the market, whereas standards will have the same effect in markets with high levels of uncertainty (Blind et al., 2016).

3.3.2 Path dependency

As some of the studies on energy transition show, the negative effects of market uncertainty on renewable energy innovation may partially be mitigated by historical policy path-dependencies in the development of energy systems (Meyer, 2003; Reiche et al., 2004). However, in certain cases, these dependencies have hindered the transition process. The description of the UK energy system as "based on 'top down' control that directs energy from highly centralised generation to meet unmanaged demand at any point on the system" (Roelich, 2016, p.1) could be applied to all the European countries with minor exceptions that need to accommodate the degree of partial decentralisation or local ownership of the energy system in some of them, e.g. in the Nordic countries (Eikeland and Inderberg, 2016). In this sense, the energy system governance is focused on generation ignoring the role and drivers of the power demand. The development of trade and regulatory systems has historically also followed the centralised policy pattern for the development of the energy sector's infrastructure. The path dependency has locked countries in a supply-driven governance framework, limiting their potential to steer the change to demand-driven and user-centred framework. Path dependency limits also the potential for interventions by other energy market actors to create disruptive changes replacing the existing energy system and its governance model. As Roelich (2016) highlights, most often the path dependency theory is applied to the analysis of technological development, with little consideration of the role of governance. However, the development of the UK energy supply regulations and the energy efficiency policy in late 1990s and early 2000s provides an apt example of the implications of path

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dependency in governance itself. Although in principle governance frameworks coevolve with the technology system, its major characteristics have hindered the ability of policy makers (and the government) to impact energy consumption patterns. The established energy governance regime that excludes citizens and end-users as active participants in policy-decision making and energy production, has also been reinforced by the narrow conceptualisation of energy as a commodity and by the complexity of regulation. In combination, these three characteristics of the governance regime limited for a certain time the ability of the governance system to support demand-driven technological development (Roelich, 2016).

Unlike the case of the UK, where the path dependency perspective is successfully used to explain the resistance to energy transition, the analysis of the Danish energy policy shows that path dependency could also be used to explain long-term political commitments to low-carbon energy, even when these commitments are temporary abolished by major policy changes (Eikeland and Inderberg, 2016). The authors conclude that in Denmark, path-dependency could explain the shift in Danish energy policy in 2008 because the shift represented de-facto a re-entering into the previous path that existed until 2001. In the 1990s, this transition path was based on initial strong political commitments to local ownership and not-for-profit principle in electricity supply and district heating, and local municipal and private co-operatives evolved as main actors that shape the governance (Eikeland and Inderberg, 2016). In 2001, the new government abolished the not-for-profit principle in electricity supply (although not for district heating), slashed subsidies and removed support to local-level organisations. As a result, new actors from policy, business and civil society emerged, expressing their joint interests together with the municipal and private co-operatives. These new actors included not only the opposition parties in the Parliament, environmental and renewable energy associations and representative of business sectors that had most clearly benefited from the energy policy before 2001. These include wind turbine manufacturers and windmill owners but also groups that the ruling party usually views as an integral part of its constituency, e.g. some of the largest Danish manufacturing companies, the Danish Federation of SMEs and the Danish Society of Engineers (Eikeland and Inderberg, 2016). The new actors' activities have reinforced the public acceptance of energy transition in society and thus has stabilised the transition pathway.

The path dependency principle is reflected in the Danish energy transition governance framework also through the specific mechanisms of institution building, as the new state structures have been established on top of and adapted to the existing local-level structures without any fundamental dismantling of previous structures. As Eikeland and Inderberg (2016) show with the example of the Riso nuclear laboratory, the adaptation of existing state institutions to the new opportunities that have emerged alongside the transition pathway, could require substantial changes in their role and functions, similar to the new role acquired by Riso as a new test centre for wind power, thus ensuring its survival when nuclear energy became politically unacceptable.

Combining the theoretical approaches of studying large socio-technical systems and path dependency in analysing nuclear energy development in Europe, Lawrence et al. (2016) refer to previous studies of energy systems to underline how particular institutional frameworks guiding energy policy have contributed to the sinking of large volumes of labour and capital. The institutional commitment based on large-scale investment in energy infrastructure creates strong path dependencies that have a long lasting impact on sociotechnical systems, such as the nuclear energy sector. In the case of nuclear policy, researchers underline that the political commitments are driven not only by economic or technical factors, but from the very beginning by ideological, psychological and political factors, related to the nature of the nuclear technology[17].

In general, the use of the path dependency approach in the analysis of energy transition governance

[17] "Another factor ensuring commitments to nuclear trajectories is the immense investment in time, capital and operations to plan, build and maintain nuclear waste management facilities" (Lawrence et al., 2016, p. 634).

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refers to the policy inertia created by prior choices that have the ability to constrain or lock-in future decisions, based on self-reinforcing limits like sunk investment costs, increasing returns, inter-relatedness of technologies and network effects (Araujo, 2014). As mentioned above, path dependency is applied to explain why new energy technologies may not be adopted even if they are superior and economically more feasible, as well as to explain how energy transition policies may sustain a policy shift towards a more decentralised and demand-driven energy system.

3.3.3 The inclusion of local communities in the policy design

Most of the reviewed research, which offers an analysis of the inclusion of energy consumers into the policy design processes, refers either to the inclusion of community initiatives and "community energy" activities or to the inclusion of grass-root citizens' organisations (Hielscher, 2011; Fournis and Fortin, 2016; Corsatea, 2016; Devine-Wright, 2005; Fast, 2013; Kemp et al., 2007; Longo et al., 2008; Eikeland and Inderberg, 2016). As some of the studies highlighted, although community and grass-root activities have existed since the 1960-1970s, they have generally remained outside the countries' energy policies (Hielscher, 2011; Eikeland and Inderberg, 2016; Laes et al., 2014). Only in the late 1990s, the wider proliferation of such activities and the shift in national and EU energy policies towards sustainability and climate change issues have led to the recognition of the importance of better integrating energy consumers in the energy decision making processes. Still, this has not contributed to a shift in the policy-makers' thinking but rather to a fragmented recognition of the role that decentralised energy generation could play in addition to the established energy supply sources. The inclusion of consumers in the policy process was grounded in the assumption that they can encourage and broaden the expansion of decentralised energy production and the RE market, decrease the public opposition towards climate change policies, and increase capital investments in energy transition projects through innovative local-based financial schemes. As the study on "community energy" in the UK reveals, the upcoming community-related discourses established themselves in policy through the inclusion of the word "community" in two major national strategic documents – the Energy White Paper, published in 2003 and the Planning Policy Statement 22, published in 2004 (Hielscher, 2011). These policy documents emphasised the need for more effective community engagement to avoid potential conflicts between community members and implementing stakeholders, so that the former actively take part in the policy design (Hielscher, 2011).

However, still in the mid- and late 2000s, policy-makers began looking at the participation of consumers in the policy decision making mainly through the lenses of "access to information", raising awareness, and "public consultations", i.e. policy-makers preserved their monopoly over energy decisions only rarely treating consumers as stakeholders with equal rights to participate in the policy design, as for example business organisations and unions have already gained. Not surprisingly, energy policies have been mainly designed to support large-scale energy projects, while consumer-centred initiatives remained mainly small, short-term and often non-coordinated by the different government departments and agencies (Hielscher, 2011). The change in the policy approach towards the inclusion of UK consumers came with the publication of the "UK Low Carbon Transition Plan" and the "UK Renewable Energy Strategy" in 2009, which set up a new role for energy consumers. "Local authorities and community groups were encouraged to work in partnership to not only address carbon and energy related issues but also wider policy needs, such as the community well-being, the creation of green jobs and the development of new sustainable housing." (Hielscher, 2011, p.46).

The interaction between the consumers and the government authorities in the UK is indicative for the experience with energy transition of many other European countries (Eikeland and Inderbers, 2016). However, most of the research explores mainly consumer behaviour and consumers' motivations to become prosumers (Gangale et al., 2013), while analyses of consumers' participation in policy design and implementation from the viewpoint of governance are almost missing.

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3.3.4 The role of research community in energy transition governance

The comparison of energy transition pathways in the UK, Germany and the Netherlands (Laes et al., 2014) shows that there are major differences in the countries' governance frameworks regarding the role of the research community and the key factors that determine the development in each of them. In Germany, the combination of two factors was decisive. First, the initial reluctant support by the government for development of RE technologies actually shifted the R&D funding towards these technologies and as a result a new market of RE technologies opened. The second factor was the gradual increase of societal engagement by the general public. In the Netherlands, the energy transition agenda was developed under a rather small research programme, which benefited from the Dutch experience in studying relations between technology and society, supported since the 1970s by several environment-technology research programmes. The enduring albeit narrowly-focused research field provided ample opportunities for dialogue between researchers and policy makers, thus ensuring the legitimacy of the transition policy in both the world of science and of politics.

The building of a coalition between researchers eager to see their ideas having a policy impact and policy advisors in need of new ideas to invigorate the national environmental planning (NMP) process led to the adoption of the transition management approach in the fourth National Environmental Plan. The new policy, which concentrated human, financial and institutional resources to achieve critical mass in a few targeted areas of fundamental science and applied R&D in the respective business sectors, was a significant break in the former policy of broad allocation of research resources. As the authors underline, "it is important to realize that in the Netherlands transition thinking has been introduced as part of innovation policy, and, more specifically, as a socio-technical alignment mechanism situated in a complex network of technology push and market pull policies" (Laes et al., 2014, p.1140). In the UK, the initial demand for setting up national targets for mitigating climate change aimed at developing a legally binding framework and was initiated and led by the environmental non-governmental organisation, Friends of the Earth, as well as local communities and members of parliament representing the same communities. As a result, the concept of a climate change law made up of binding targets and policy support budgets became the focus of major public and political campaigns. Later on, the Committee on Climate Change was established as an independent expert advisory body that can make recommendations to the government concerning the pathway to the 2050 environmental targets. The Committee reports annually to Parliament, while the government had been required to formally reply to its reports. The merit of having an independent watchdog lies in its ability to force the government to publicly justify its own actions on a regular basis. This in turn contributes to a credible government commitment to long-term policies, which has been a necessary precondition for creating a stable investment climate (Laes et al., 2014; Sartor et al., 2017).

3.4 Barriers to the implementation of energy transition governance

3.4.1 Regulatory, legislative and financial obstacles hindering the promotion of low-carbon energy technologies

When it comes to support schemes for the promotion of low-carbon energy, the European Union provides guidance to the Member States in terms of policy design and appropriate regulations that could overcome the problem of limited investment in the RE sector. However, such regulatory changes do not necessarily lead to more social acceptance of energy transition technologies. As Negro et al. (2012) present it, a "stop-and-go" approach could be one of the biggest obstacles to energy transition policies, whereas the government announces a subsidy regime but delays its implementation. Similarly, Haas et al. (2011), who have focused on the implementation strategies for RES and their promotion in terms of effectiveness and efficiency, argue that the system's credibility is crucial for the diffusion of innovation and investment flows. A promotional strategy needs to be consistent and to avoid uncertainty as it

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should generate a list of concrete planned activities. When it comes to the financial side of subsidy programmes, the level of government involvement does not refer only to the amount of investment but also to the priority setting of the public funding. As researchers point out, technology-specific financial support measures are much more effective, compared to general subsidy instruments, which could turn into an important obstacle for the sustainable transition to low carbon and decentralised energy system. An example of the latter case could be the development of RES in Bulgaria in the period 2009-2013, when the centrally-planned and executed renewable energy support programmes led to an unsustainable boom in renewable energy installed capacity. For the same period, new RES capacity amounted to 1,568 MW, while the total installed capacity reached 1,651 MW, i.e. 95% of the total solar and wind capacity was installed between 2009 and 2013[18]. The uncontrollable installation of renewable energy capacity resulted in the sharp increase of electricity prices for the final customers and a subsequent significant decline in the public support for low carbon energy transition (CSD, 2014).

The establishment of multi-level governance regimes can also produce obstacles for the successful diffusion of RES technology. Smith (2007) follows the difficulties in establishing a multi-level governance system in the UK energy market. His focus is on the ineffectiveness of regional governance processes as a result of their dependence on the national level. By providing an overview of the main elements in the implementation of energy policies, Smith argues that a horizontal relationship between the representative institutions on national and regional level has to be established in order to optimise policy development and implementation.

The horizontal integration should be supported also by the proper vertical integration of EU and national policy options and institutional frameworks. As detailed below, the existing research shows that often the specific policy frameworks of the individual countries could lead to mismanagement and ineffectiveness of the governance process regarding the implementation of support schemes for RES[19] even if the same support schemes are highly successful and effective in other countries. In other words, every strategy on European level should be adjusted to the geographical particularities of the Member States (Reiche at al., 2004). Examples of such specificities are numerous: the analysis on Bulgaria shows that to a large extent the introduction of feed-in-tariffs for RES and CHP (combined heat and power) electricity production in the country has contributed to a speculative investment environment that has not been part of a strategic framework planning with clear and well leveraged financial and capacity demand projections (CSD, 2014). Similarly, Meyer (2003) argues that the green certification can be a suitable RES policy support tool only in those cases where the energy suppliers are flexible enough in their market strategies, while they could be much less effective in highly regulated markets. The investment in wind power capacity in Germany through green certificates could thus be sub-optimal (Reiche et al., 2004). Furthermore, as the stage of liberalisation of the energy market varies between EU countries, it is difficult to implement a unified policy that would cover each country specifics. Germany and Spain have been given as good examples of the adoption of feed-in tariffs as a powerful instrument for the increase in the share of wind energy and photovoltaics in the beginning of 2000s. However, according to Reiche et al. (2004), in the long-run the feed-in tariff instrument might not be sufficient to

[18] The exponential growth of RES installed capacity in Bulgaria came as a result of the introduction of feed-in tariffs for RES development and CHP energy production. The price for solar and wind energy as of 2013 was respectively EUR 118.13 per MW/h and EUR 66.35 per MW/h. For reference, the price for electricity produced by Kozloduy NPP was then EUR 13.5 per MW/h.

[19] Among the most common support schemes are: 1) feed-in tariffs/premiums which involve a contractual relationship between consumers and producers based on a fixed price of the electricity generated by a given RES technology; 2) the green certificates, that serve both as an accounting mechanism in the case obligations set by the government have to be met or as facilitators of the creation of a green certificate market that functions independently from the market of electricity; and 3) green or renewable energy quotas, defined by national, regional or local governments, refer to the definition of minimum shares of RES in the energy mix of power utilities, electricity suppliers or sometimes also large electricity consumers. The fulfilment of their quota obligations could be achieved not only by own production but also by means of a dedicated market for renewable energy certificates, often also referred to as tradable green certificates.

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sustain the growth and implementation of renewable energy technologies. More recently, the feed-in tariffs have appeared to be less efficient as they fail to ensure that electricity is sold on minimum cost, to foster innovations and in general to meet the market needs and particularities for promotion of low-carbon energy (Frondel et al., 2010).

The use of green quotas, on the other hand, has also been criticised in terms of environmental and economic efficiency. By analysing the impact which they have had in the Netherlands, where quotas are the main support instrument, Reiche et al. (2004) concluded that the quota mechanism has not been able to produce sufficient wind power uptake in comparison to Germany and Spain for the period 1990-2002.

The institutional and legislative obstacles for promoting low-carbon energy are not the only factors weakening the energy transition process. Internal opposition from special interest groups and the society as a whole could also be a major barrier. As Geels (2014) suggests by studying the case of the United Kingdom, promoting energy transition could be restricted by coal, gas and nuclear producers. He argues that actors of the incumbent regime could use instrumental, discursive, material and institutional forms of power to resist climate change-related pressures, pointing out that scholars should focus not only on niche-innovation, but rather on the dynamics of policy regimes and decision-making in order to observe the resisting actors as actively involved in the process and to add power relations on regime level as part of the variables influencing energy transition.

When it comes to the discussion of the promotion of low-carbon energy, the financial aspect is often put as one of the main challenges. Low-carbon energy is often presented as expensive and economically inefficient with detrimental effects on the country's economic competitiveness. The different arguments put forward as explanation for the opposition against energy transition policies have been analysed by Geels (2014). As the financial crisis in 2008 weakened the public, business and political attention towards environmental issues, the investment in and the development of low carbon energy production suddenly lost their attractiveness. The first barrier observed is the difficulty to mobilise large amounts of additional investment during an economic crisis, which should support the research and development phase, as well as the period of innovation implementation. As the investment in niche-technology is going to be promoted with greater difficulties in times of crisis, there is a wider need for more concrete policy and institutional support to tackle market uncertainties including by using fiscal reforms and the promotion of price-based policy instruments.

Another study tested the relationship between market stability and innovation in a given country. Blind et al. (2016) argue that as market uncertainty increases, inconsistent regulations disincentivise companies to invest in R&D. Meanwhile, as market uncertainty decreases, the standardisation of the regulatory framework creates a positive effect on the promotion of innovation. The authors test their hypothesis using the data from the German Community Innovation Survey. The results from the analysis show that when an organisation is operating on a European level, it is also more likely that it would be innovation-active, compared to a locally-based organisation. Another finding of the study leads the authors to the conclusion that even though the relation between the level of education in the organisation and the level of innovation is significant, the effect of the former is rather low. The work of De Santis et al. (2016) to a large extent confirms these findings although the main focus here is the general relationship between the consistency of policy implementation and the general level of innovation, arguing that as the former grows, so does the latter.

The external financial factors are not the only ones influencing the energy transition process. One should also consider the process of determining the low-carbon energy prices, which may have negative effects on the diffusion process. Kalkuhl et al. (2014) state that despite the subsidies for green energy production, renewable energy sources are still not competitive enough with the more traditional fossil-fuel based ones. Recent studies on the LCOEs of different power plants show that currently the building

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of new on-shore wind and solar parks are competitive to the construction of a new coal, gas or nuclear plants. It further illustrates that the notion that renewables would never be competitive to traditional sources is crumbling (Mayer et al., 2015).

3.4.2 Socio-political barriers: traditions and diverse political cultures

The next observed governance barrier is related to the socio-political relations in the implementation of the energy transition process. In the previous sub-section where the focus is put on national policy actions, regulations and legislative processes, most research is based on case studies. In this sub-section, governance barriers are analysed through the lenses of the interplay between social and political realms in the society. As a result, most of the researchers in the field prefer using surveys and in-depth interviews as methods for data collection to test their hypotheses.

Marques et al. (2010) combine and analyse many studies in the field of renewable energy and draw several conclusions on the country-specific variables that influence the transition process. Their observation on the geographical particularities to a large extend repeats the findings of Meyer (2003), concluding that the size and the resources of a country are crucial for determining its renewable potential. Using data from the OECD Factbook, Eurostat, the UN, DG Energy and BP, Marques et al. (2010) find a statistically significant negative correlation between the use of coal and oil and the success of the renewable energy support programmes. Meanwhile, a bigger energy dependency ratio of a country was positively correlated with a more positive outlook for renewable energy sources. This could be interpreted as a result of the higher oil and gas prices countries pay when they do not have access to a diversified energy import portfolio or have not developed domestic fossil-fuel resources. Household income levels and energy prices also show positive correlation with the attractiveness of renewable energy technologies. In this respect, the attitudes of mid- and high-income level households and the presence of affordable energy prices in terms of purchasing power, correlate with higher attractiveness of RES and vice versa. The negative correlation between the predominant use of coal and oil and the success of renewable energy support programmes on local and national level reveals that traditions in energy use (either personal or collective) are difficult to be changed. These traditions could pose important obstacles for the implementation of the policies towards the transition to low-carbon energy system. As already mentioned, the active engagement and participation of citizens in the design and implementation of energy transition policies is highlighted as vital for the success of RES programmes through gradually increased public support.

The division of power on different governance levels is another factor, which as many scholars argue, usually complicates the energy transition process. Rio et al. (2008) focus on the obstacles for promoting renewable energy sources caused by the lack of interest of local authorities to spend time and resources to engage in renewable energy promotion programmes. Insufficient local community engagement and participation has been one of the biggest roadblocks for the implementation of local transition programmes. Local communities are not empowered to actively join the energy transition, while their efforts are being replaced by centrally-planned support programmes that benefit large investors instead of community-owned generation (CSD, 2011, 2011a). Rio et al. (2008) also argue that there is lack of empirical research of the factors driving energy investments on the local level and of the benefits the energy transition could bring in terms of employment, demography, education and generally, wealth.

When it comes to analysing the success of the energy transition on the local level, one of the most important factors to be considered is the public engagement of the community. The level of interaction between individual and collective behaviour in the energy sector is determined by the level of public engagement. The role of the public in low-carbon transitions tends to be framed as an issue of social acceptance of the technologies and deployment measures involved. However, this suggests that the consumers' passive agreement could be enough for a certain policy initiative to take hold. In the case of the Energy Union, which involves a large-scale transformation of energy choices both on collective and

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individual level, the active participation of whole social groups including local communities is required.

A study conducted by Van der Schoor and Scholtens (2014) focuses on the opinion and the attitude of the local community towards the factors that accompany the transition process. In their research, the authors ask the key question of how initiatives by local communities contribute to the decentralisation of the energy system. By analysing the cases of 13 local initiatives in the Netherlands, they point to the challenges associated with building a sustainable relationship between the public and private sector to overcome institutional and legislative bottlenecks. On a practical level, the main observed obstacle is the ability of the community leaders to maintain the interest and participation of community members in day-to-day tasks associated with licensing, financing and management procedures. The lack of consistency and predictability of procedures undermines the commitment of community members to complete an energy transition project from the start to the end. Broader challenges such as the establishment of leadership and coordination on local level are also mentioned. What is lacking in this case is a narrower vision on concrete energy goals which will lead to the achievement of the common vision of the community.

Locally-based support schemes have been seen as positively correlated to the success of the implementation of new energy technologies. A study, conducted by Corsatea et al. (2016) focuses on the case of Italy, arguing that subsidies and support schemes on the local level increase local innovation. Their findings confirm the results of Van der Schoor and Scholtens (2014) in terms of the positive relationship between the level of governance independence on local level and the promotion and deployment of renewable energy technologies in the local communities. The penetration of decentralised energy systems on local levels seems strongly correlated to the independence of regional governments based on information gathered between 1998 and 2007 in 20 different Italian regions. The findings also show that the party affiliation of the region has only a limited correlation with the promotion of renewable energy technologies, irrespective whether a particular party has supported or opposed the RES policies.

However, the study of energy transition processes on the community level faces several methodological problems. Community case studies, even when spanning across a multitude of different geographic and socio-economic contexts, are limited in their scope for deriving universal conclusions. Since no unified methodology and theory are being used in these studies, their replicability is almost impossible if the results are to be consistent. The information gathered is usually too detailed and country-specific making it dependent on the concrete circumstances not fitting a standardised pattern of social behaviour. In order to better understand common deficits in enabling energy transition policies on a local level, further data aggregation is necessary, according to Sarrica et al. (2016).

As energy transition is closely related to both technological and social innovation, the literature tries to understand what are the prerequisites for the success of an innovator, whether it is an individual or a company. Verbong and Geels (2007) observe that the main driver behind the innovation in energy transition technology in the Netherlands has not been the concern for environmental issues or the national policy agenda, but rather the "Europeanisation" of energy policy. The same is confirmed in the case of the Bulgarian RES policies that have been developed mainly under the pressure of aligning the national regulatory framework with the European one and particularly of fulfilling the EU targets. Fabra et al. (2015) point out the different path dependencies in the energy policies of Germany, the UK and France. They show how despite the fact that the three countries developed large conventional power generation capacities making the energy transition process harder to accept, they have gradually adopted a long-term low-carbon energy policy. The latter has been most evident in Germany.

Germany's commitment to an energy transition has fostered a pan-European agreement on decarbonisation plans. Germany has achieved a great progress in fostering an energy transition towards decarbonisation of the energy supply and improving energy efficiency. Furthermore, Germany is

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opposed to nuclear power and has decided to phase it out while insisting on higher renewable energy targets for 2030. In fact, Germany urged the Commission to reinforce the governance standards for renewable energy policy, including in terms of legal implementation of the plans for renewable energy and energy savings. In Germany, the government has also developed a comprehensive and ambitious energy-saving plan, based on a three-pronged approach, including strict national regulation on renovations and use of renewable energy resources, financial incentives such as loans and grants provided by a government-sponsored public investment bank (Kreditanstalt für Wiederaufbau) and dissemination of information and awareness raising through pilot projects aimed at behavioural change (Fabra et al., 2015). In France, where the electricity mix was composed by 92 % of low-carbon sources in 2014, i.e. nuclear (74%) and renewables (18%, mostly hydro), the adoption of an energy transition strategy had been more difficult. Despite the prevalence of low-carbon energy sources in the country, the new strategy has required significant justification of subsidy schemes that were seen as potentially adverse due to their impact on the increase of the electricity prices (Fabra et al., 2015).

3.4.3 Public acceptability of technologies and policies

As mentioned in the sub-section on theoretical approaches, crucial for the diffusion and adoption of new technologies and practices is the need that not only the energy transition interests groups accept the policy and technology change but also these parts of the society (and politics) not directly involved with the energy transition. However, as highlighted above, there is still little research on the topic. Following Wüstenhagen et al.'s (2007) typology, which analyses public acceptance in three dimensions (i.e. socio-political, market and community), the current sub-section will review the most relevant research findings on the topic.

Socio-political dimension of public acceptance

One of the most commonly used explanation for the lack of public acceptance of new energy transition policies or technologies is the dysfunctional socio-political relations between the different stakeholders in the implementation phase of a project. The implementation gap becomes the direct outcome of the divergent agendas of community members, institutions and private actors. Wolsink (2007) denies this so-called 'Not in my backyard' problem by emphasising that the real reason behind the sometimes negative public attitude towards green energy production is the lack of adequate communication during the policy implementation process. By studying the cases of wind energy promotion in Denmark, the Netherlands, the UK and Germany, he claims that the essential part of all good practices correlates with the public involvement in the process, incl. discussions on local level and active participation in all stages of the policy implementation cycle. Therefore, he argues, where NIMBY phenomenon has been detected, it is caused by hierarchical governance structures and top-down policy implementation rather than by individual selfishness.

The argument that NIMBY factor should be treated consciously has also been made by Devine-Wright (2005). He addresses the empirical studies on public acceptance of wind energy production and points out their main weakness in terms of case selection such as presenting predominantly industrialised countries and failing to operationalise the public attitude in valid and reliable manner. When adding the lack of sufficient theoretical background, he concludes that even though the empirical interest in the topic is growing, it remains rather fragmented and misleading. An argument in favour of these findings are the lack of NIMBY studies in low-carbon energy different from wind-energy.

As an amendment to the work of Wüstenhagen et al. (2007), Fast (2013) refers to the findings of Bailey et al. (2011) that while the majority of public opinion surveys conducted in the United Kingdom signalled considerable support for RE, "public concern about the visual and environmental impacts of RE projects [is nonetheless] a major factor behind the stalling or rejection of many planning applications for on-shore renewables developments" (p.139). However, Bailey et al. (2011) points out that the degree to which public consultations dictate the success of new RE infrastructures is very much unique to the

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UK because it is part of the already-developed institutional framework and culture. As the authors highlight, the design and implementation of the UK government policies on renewable-energy developments have revealed some tensions between the government's desire to promote policy consultation practices and the need to set up strategic energy goals, irrespective of the public opinion.

Market dimension of public acceptance

In the market dimension of public acceptance, consumers become individual decision-makers, which have the final say on which energy to consume. Bird et al. (2002) point to education and marketing as the most important variables for green energy consumption and as related to the market aspect of public acceptance. Even though customers tend to be influenced by low prices, what seems to matter more is the consistency of government policies on energy transition and the public engagement techniques used by the authorities.

However, the most important factor for the market acceptance or renewable energy technologies often remains the individual price evaluation given by the consumers, as studied in Part 1 of this review. Many studies on the topic analyse this factor, using the contingent valuation (CV) model for determining the levels of the willingness to pay (WTP). RE technologies are in general characterised by a higher initial per unit cost than energy generated from non-renewables. Even when energy from renewables is subsidised by a centralised body, some metric of WTP is crucial in assessing the viability of green energy technologies.

The contingent valuation (CV) method has been widely used in different case studies to determine how much people value a certain good or service, where markets either do not exist or are yet to be formed (Arrow, 1993). Preferences for renewable energy and energy efficiency technologies based on CV methodology have been done in Japan, the US and Spain (Nomura and Akai, 2004; Zarnikau 2003; Li et al., 2009; Solino et al., 2009). The common denominator for all of these studies is that CV method could help policy-makers to design such renewable energy support schemes as to make the energy transition both more appealing and more cost-effective for households. Measuring welfare gains from environmental sustainability programmes would always contain a subjective assumption that would differ across population groups based on the geographical, socio-economic and socio-cultural context, thus resulting in different WTPs. Yet, the valuation results could potentially lead to the implementation of only those projects that would be most easily accepted by the general population. This prevents a possible backlash against green technologies as has been visible in a number of Southern and Central European members of the EU. A lower WTP value could signify a need for more efforts to raise awareness about the benefits of renewable energy and energy efficiency on household level. It could also mean that households do not see direct economic benefit from engaging in renewable energy production and are not particularly engaged with the climate change topic.

The vast majority of the literature reviewed finds a positive correlation between WTP and household income. A notable exception was found in Akcura's (2015) reference to a previous study, which found the effect of income on average WTP to be statistically insignificant. Zografakis et al. (2010) executed a contingent valuation of the willingness to pay of the citizens of the Greek island of Crete in attempt to ensure fact-based support for the policy, which aims at increasing the share of renewable energy in the island's electricity production. This valuation research revealed that the vast majority of households of Crete is very positively disposed towards the implementation of RES in Crete and places high value on the advantages of RES. Mean willingness to pay is calculated at EUR 17.88 per person per year. The CV exercise aimed to also provide a better idea for the urban citizen's attitude towards the introduction of more green technologies in the electricity supply. The authors note that in general households that are considering climate change to be a big problem for Crete want to pay more for the introduction of RES technologies than those respondents caring mostly about the energy security of the island or those not interested in climate change. In addition, as expected, households with more knowledge about climate change were naturally inclined to spend more on mitigating its effects including diminishing the share

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of fossil-fuel based power generation. Knowledge about the potential of different technologies is also contributing to a higher WTP. Similar to the findings of Longo et al. (2008) and Carlsson and Martinsson (2008), in the study on Crete the reliability of power supply is positively correlated with more WTP for extra RES capacity (Carlsson and Martinsson, 2008).

Also, households in bigger dwellings report a higher WTP, which could be associated not only with more wealth but also with the willingness to save energy through the use of technology for energy self-production such as the well-spread solar water heaters. Finally, WTP increases for those households that perceive the development of the RES potential as a policy for increasing local employment and generating new income as it was proven by a study on the Scottish rural population (Carlsson and Martinsson, 2008).

WTP is also found to be contingent upon a number of demographic variables. Chiefly, the literature reviewed finds statistically significant interactions between the gender and age of surveyed respondents, and the household's WTP. Bollino's study of households in Italy, for example, found that where respondents were willing to pay more for RE, females possessed a lower mean WTP (Bollino, 2009). With respect to the age of respondents, Akcura's study of households in the UK finds that "age is a significant factor only in the decision on how much to contribute" (Akcura, 2015, p. 25); the paper revealed that older respondents on average had a lower WTP. Doubt is cast upon this finding by Bollino's observation that older respondents simply possessed a more "widespread WTP distribution" (Bollino, 2009, p. 92). In all studies considered, households are found to be willing to pay more for renewable sources when the positive environmental externalities associated with RES are emphasised. Longo et al. (2008), for example, highlights that respondents were on average willing to pay an additional "£29.65 to decrease the greenhouse gas emissions by 1% a year" (Longo et al., 2008, p. 141). **Figure 3** below summarises the findings of a number of similar studies as presented by Longo et al. (2008).

Figure 3: WTP for improving renewable energy

Study	Goett et al. (2000)	Champ and Bishop (2001)	Roe et al. (2001)	Wiser (2003)	Batley et al. (2001)	Bergmann et al. (2006)
Data year	1999	1997	1997	2001	1997	2003
Stated preference method[a]	CE	CV, SBDC	CE	CV, SBDC	CV, OE	CE
Questionnaire type	Phone–mail–phone	Mail	Intercept	Mail–phone	Mail	Mail
Completed questionnaires	1205	193	835	1574	742	219
Surveyed area	US	Madison, Wisconsin (US)	8 US cities	US	Leicester, England	8 Council Districts in Scotland
Hypothetical scenario	Increase in renewable share (25% of energy supplied by hydro)	WTP for wind energy	Increase in renewable energy of 1% and a decrease of emissions of 1%	Increase renewable energy from 2% to 8%	Increase in renewable sources	Renewable energy projects that have no increase in air pollution
Households WTP/year	98.44[b]	71.79	16.32[c]	39.72[d]	95.20	25.26

Source: Longo et al., 2008, p. 142

A number of studies also considered the impact of energy security on WTP. The majority finds that WTP increases if RE is presented concomitantly with increased energy security (see **Figure *4*** – Longo et al., 2008).

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Figure 4: WTP for avoiding energy shortages

Study	Hartman et al. (1991)	Beenstock et al. (1998)	Layton and Moeltner (2005)	Baarsma et al. (2005)	Carlsson and Martinsson (2004a)
Data year	1988	1990–1991	1998	2003–2004	2004
Stated preference method[a]	CV, OE	CR	CE	CR	CV, OE
Questionnaire type	Mail	In person	Mail	Mail	Mail
Completed questionnaires	1501	2950	1421	12,409	1678
Surveyed area	California, US	Israel	US	The Netherlands	Sweden
Hypothetical scenario	1 h shortage	1 kWh unsupplied electricity	1 h shortage	1 h shortage	1 h shortage
Households WTP/ year	65.77	10.46	16.12	78.16	1.29[e]

Source: Longo et al., 2008, p. 142

The effect of energy security on WTP is found to be highly dependent upon the country in which the study is conducted, however. While Longo et al.'s study conducted in the city of Bath (UK) fails to reject the hypothesis that "it is more important to internalize external costs affecting human health and the environment than guaranteeing energy security" (Longo et al., 2008, p. 146), in Crete, Zografakis et al. find that over 70 % of respondents consider the impact of renewables on the energy security of the island to be very important. With this in mind, it is therefore essential to tailor energy transition projects within the EU to the specific energy security needs of the country in question.

Community acceptance dimension

The third dimension refers to the acceptance of energy transition on community level. It refers to the acceptance of citing decisions and more generally – to decisions for implementing low-carbon energy projects by local stakeholders, particularly residents and local authorities. Community acceptance focuses on issues of procedural and distributive justice[20], as well as those of trust towards external actors (those who initially suggest and then implement the project). As discussed above, the majority of research on the topic refer to the engagement of the local community as having an essential effect on the positive attitude towards energy transition projects.

Bailey et al. (2011) tackle on the first phase in the innovation diffusion and the community attitude towards it by studying the perception of local communities in UK towards the potential development of wave energy. The results show that the acceptance relies on the efficiency of the technology towards climate change, its economic efficiency and the lack of potential for future negative effects. However, following the critiques made by Wright (2005), it is important that these results are treated consciously, having in mind that the UK is already an industrially highly-developed country with well-recognised high level of public and policy engagement with climate change and RES policies.

A major argument in favour of the positive community attitude towards the renewable energy implementation refers to ownership. What Warren et al. (2010) find by conducting a survey among the inhabitants of Isle of Gigha and its adjacent Kintyre peninsula in Scotland is that people tend to have positive attitude towards energy production in their region if they have some share in the company ownership. The authors conclude that, generally, people share this positive attitude as a contradiction to the NIMBY approach.

[20] Procedural justice refers to the fairness in the administrative/regulatory processes that resolve disputes and allocate resources, while distributive justice refers to the perceived fairness in the distribution of rights or resources. The perceived fairness could differ significantly from the procedural fairness, as the former depends on what one considers as moral irrespective whether it is aligned with the administrative or regulatory prescriptions and procedures.

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3.5 Governance factors for sustainability of energy transition policies

The analysis of the energy transition pathways' development in the UK, Germany and the Netherlands (Laes et al., 2014) demonstrates that due to the long-term nature of the transition processes, the most important challenge for energy transition governance is the credible commitment for future governments to the overall transition visions and goals. However, as the authors point out, such commitment is always a matter of degree, since no government can "bind" irreversibly future governments to carry out specific plans or programmes. The study reveals the composition of what the authors call "commitment devices", which make it considerably harder for future governments to overturn previous commitments. "Commitment device" refers to a composition of actors, procedures and practices, and institutional frameworks that are established in order to prevent future governments from decreasing their commitment to the transition visions and goals. In Germany, it was the early engagement of both the government and the general public with climate change issues which led to the gradual and sustained building of new advocacy coalitions centred on RES deployment, as well as political long-term commitment to building a low-carbon society powered largely by RES, institutionalised by the creation of the German National Ethics Commission. The Commission, which has had a major role for the reassessment of the nuclear power policy options after Fukushima's disaster in 2011, actually framed the German energy transition (Energiewende) as a collective process, implying a shared responsibility for government, business, civil society and individual citizens (Laes et al., 2014).

In the UK, the most crucial element for setting up the long-term goals of climate change legislation has been the combination of efforts by grass-roots organisations, based on the use of local groups and supporters to build a public campaign, and lobbying with MPs who are backing the initiative. In the Netherlands, on the basis of long-term climate change research and multiple stakeholder consultations in 2004-2005, seven "transition platforms" were created that would manage the future energy transition policy of the country. Their main tasks were to develop and facilitate different policy pathways by encouraging market developments and advising the government on creating the appropriate framework conditions. In the three countries, the increased "political cost" (in terms of losing public support) has been the major factor for preserving the long-term energy transition policy path. In this respect, the degree and quality of public engagement is crucial for the sustainability of the transition processes. However, in terms of short- and medium-term goals setting, the authors argue that in the existing literature there is a disagreement whether short- to mid-term incentives should take the form of target-setting or a commitment to particular types of regulation or institution building (Laes et al., 2014).

Social mobilisation and non-technical barriers

The interplay between market and social dynamics leads to the creation of a number of non-technical barriers including the quality and consistency of governance, the public trust in institutions and the acceptability of long-term policy shifts, which can all hinder the deployment and effective uptake of RE technologies. If properly designed, governance frameworks can be used to overcome such non-technical barriers.

The sub-section on public acceptability above explored the effect of location on the acceptance of RE technologies. Particularly in the UK, public opposition to RE infrastructure projects leads to their rejection already at the planning stage (Bailey et al., 2013). Where governance frameworks are used to engender a sense of community, however, public acceptability of RE technologies has been seen to significantly increase. Fast (2013), for example, draws attention to the emergence of autonomous "energy regions" in Austria and Switzerland. He notes that while the boundaries of such regions coincide with existing municipal or district boundaries, they are nonetheless "hardened by deliberate choices to become energy autonomous and meet all energy needs with sources endogenous to the region" (Fast, 2013, p.859). The existence of such examples led commentators such as Peeters et al. (2012) to note

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that the establishment of energy self-consuming regions may in fact be a more viable solution to Europe's RE goals than "big solutions such as DESERTEC" that are centrally planned and financed[21] (Peeters et al., 2012, p.188).

The reviewed literature also shows community engagement to be effective in targeting non-technical supply side barriers, e.g. ensuring the involvement of a large number of smaller investors. Bollino (2009), for example, observes that in Italy, regions with governments composed of coalitions of centre-left and green parties, which tend to be more inclined to support RES policies benefitted from a 12 % increase in RE energy patent applications. Additionally, Fast (2013) finds that price-based incentives aimed at fostering community engagement are also effective in overcoming non-technical supply side barriers; incentives that guarantee producers a high price for electricity produced (i.e. feed-in-tariffs) are found to be more likely to facilitate the involvement of large numbers of smaller investors (communities and farmers) than quota-based incentives. The author thus concludes that "feed-in-tariffs [...] help contribute to community acceptance, although evidence is mixed" (ibid.)

Huang et al. (2015) investigate the effects of the managerial hierarchy of Taiwanese firms on their likelihood of adopting RE technologies. Their study makes use of behavioural theory to distinguish between the investment decisions of family controlled firms and non-family controlled firms. It is observed that "family businesses incorporate emotional values in their profit function, such as the desire for status, reputation, […] and continuous control over the company" (p. 1176). Their conclusions echo previous studies in observing that "long tenures by family managers create a type of tunnel vision that reinforces a commitment to the status quo" (ibid., p.1176). The paper concludes that both family ownership and family control are negatively associated with the adoption of RE innovations. Considering the above findings, a governance framework, which imposes greater levels of heterogeneity on the upper management and ownership of energy firms, would therefore be more likely to lead to higher levels of RE uptake and R&D.

Finally, Corsatea (2014) investigates the underlying determinants of locally induced innovation activities in Italy during the 1997-2007 period. The period coincided with the liberalisation of the retail energy market with the passing of the "Bersani Decree" in 1999 (Deloitte, 2015, p. 3), as well as a wave of financial incentives for RE technologies. Corsatea (2015) finds that together seven Northern regions of Italy "hosted approximately 1.6 per cent of the total installed MW in wind and photovoltaic, but had originated 66.3 per cent of patents pertaining to those technologies" (Corsatea, 2015, p.449). This is not surprising considering that Northern Italy is typified by a higher than average concentration of research-focused institutes and universities.

3.6 Conclusion

While the Energy Union has developed a coherent plan for a sustainable energy transition, there are large differences between countries regarding their ability to sustain the costs of energy reforms and the investments needed. A low carbon energy transition requires disrupting the current energy system based on fossil-fuels, centralised generation, supply-side orientation, and all the practices, policies, technologies, norms and attitudes linked to this system, while at the same time developing and introducing sustainable alternatives. This raises the challenge of good governance and of consistent policy-making that is predictable and based on a long-term strategy that cannot be easily overturned in

[21] DESERTEC was a large scale project supported by a foundation of the same name and the consortium Desertec industrial initiative created in Germany. The project aimed at creating a global renewable energy plan based on the concept of harnessing sustainable power from sites where renewable sources of energy are more abundant and transferring it through high-voltage direct current transmission to consumption centres. All kinds of renewable energy sources are envisioned, but the sun-rich deserts of the world play a special role. For more information, see http://www.desertec.org/

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the future.

The governance of energy transition should be performed by a multitude of actors including the energy industry, local governments, civil society organisations, and consumer and prosumer associations. The notion of governance can also be seen as a two-sided process. On the one hand, decision makers try to implement a policy according to an already detected problem, and on the other, there is the general public which can be seen as the final evaluator and policy-taker. To implement a new technology shift successfully, one needs to not only develop the physical ('hardware') and institutional ('software') infrastructure, but also make sure the consumers accept the shift. For the diffusion process to be completed, not only the energy transition interest groups need to accept the policy and technological change, but also these parts of societies not directly involved in the sector. Hence, the institutional and legislative obstacles for promoting low-carbon energy are not the only factors weakening the energy transition process, as strong internal opposition can also represent a major barrier.

The more informed consumers are, the more likely that they would become active market participants and would accept the Energy Union initiatives for energy transition as they would get to understand the economic and social benefits of supporting renewable energy technologies, prosumption and energy efficiency. Paradoxically, however, namely these institutions (mostly the national energy regulators), which are responsible for expanding the information about the energy market functioning, are those that prevent the active liberalisation of markets. In addition, local communities are not empowered to actively join the energy transition, while their efforts are being replaced by central-planned support programmes that benefit large investors instead of community-owned generation.

The gradual shift from centralised and fossil based production to more distributed systems based on renewables will potentially integrate also electricity production into everyday life. This may create new types of interaction between traditional energy suppliers and customers whose roles might become much more hybridised. Decentralisation will lend itself to micro-grids, micro-generation and micro-storage, new modes of renewable energy production, etc. Smart grids may also require a much higher level of interaction and technology literacy of customers. While the human factor in the energy system in the past has been understood as passive, we now see a potential for a mind-set and everyday practice shift[22].

With these types of scenarios as a backdrop, a key prerequisite for the success of the energy transition, will be the removal of barriers before green innovation. The promotion of low-carbon energy in the European countries goes through a complicated innovation process that depends on the structure of the market, the easing of regulatory barriers for technological diffusion, the use of market-based support mechanisms to drive R&D spending and the active engagement of stakeholders to help the technological diffusion. The completion of the energy transition requires a long-term, consistent policy plan on the development of new technology.

The literature reviewed above shows that to succeed, green innovation support programmes should strike a careful balance between the provision of financial incentives and eliminating barriers to private investment. The same goes for the overall energy transition agenda. To escape the path dependency created by years of government policies focusing almost entirely on fossil and nuclear-based energy sector development, there is a need for a paradigm shift that would not only be buttressed by a mix of subsidies, but would also hinge on removing bottlenecks stopping the full liberalisation of energy markets, a new attention to demand-side solutions, the active involvement of consumers in energy production and policy design. The energy transition envisioned by the future of the Energy Union hinges upon the ability of markets to adapt to the new consumer-driven framework that would allow for the decentralisation of energy systems and a significant redefinition of how energy choices are done.

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[22] With volatile renewables on the rise combined with hype around smart grids, micro grids and storage, people are actually expected to take on a much more active role in the shaping of the future energy system.

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4. Synthesis on factors driving energy choices

4.1 Introduction

The question of what drives energy choices is a complex one and involves a wide range of factors. The three preceding Parts distinctly highlight economic, technological, socio-cultural, demographic, behavioural and governance factors driving such choices. However, one should keep in mind that our categorisation is not a clear-cut separation but rather an attempt to organise these variables as they can belong to several categories[23]. The review adopts this structure based on a typology of factors for the sake of clarity, thus not preventing overlaps between the topics covered and through different disciplines.

This final Part aims at providing a more comprehensive perspective of how these factors interact in shaping energy behaviours. As the effects of each individual factor are difficult to disentangle from one another, this Part is committed to synthesising the main trends identified throughout the literature and the previous Parts. The analysis of the literature sets the stage for the ENABLE.EU project by highlighting theoretical foundations and empirical findings on which to build, main points of consensus, weaknesses in the methodologies and gaps to be bridged. By adopting this perspective, ENABLE.EU can maximise its added value. These findings will then provide insights for the next steps of the project, which is structured around five case studies, namely electricity use, low-carbon mobility, heating and cooling, the shift to prosuming and governance.

This review and synthesis of findings also support the final purpose of the project, which is the formulation of energy policy recommendations for EU, national and subnational policy-makers. By identifying the most influential factors of energy choices and strategies to change energy behaviours, the review is a first step in sketching the potential most effective policies for EU energy policy, which will be later confirmed or mitigated by ENABLE.EU findings.

This Part is structured as follows: ee analyse the main theoretical frameworks and concepts attempting to structure energy choices through various scientific disciplines before identifying the elements of consensus and contradiction, as well as interactions and gaps in the existing literature. The latter support the need for further research on these questions which is where ENABLE.EU steps in to identify where it can add most value and with its approach oriented towards the formulation of policy recommendations. Finally, we propose a concrete overview of the findings and challenges in the scope of the five case studies led in the context of ENABLE.EU.

4.2 What are the main theoretical frameworks developed in the literature to understand energy choices?

This section presents how energy choices are framed in the literature by introducing the main concepts, theories, models and frameworks. Theoretical literature on energy choices questions the relationships between factors, behaviours and strategies by proposing theories, models and frameworks. Theories formulate an explanation of a causal relationship between specific factors and subsequent behaviours. The theories presented below are often empirically supported. A conceptual model refers to a theoretical construct attempting to link different elements, while a framework pictures all the variables pertaining to the central question, making it a very useful tool when adopting an interdisciplinary

[23] Income, for instance, is both an economic and socio-cultural factor. It defines a consumer's purchasing power while at the same time it is representative of an individual's social status.

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approach.

4.2.1 Categorising different types of factors, behaviours and strategies

Most theoretical research attempts to clarify the picture by developing complex graphical models and classifying factors, as well as types of behaviours and strategies inducing behavioural change. Such categorisation helps to visualise the various dimensions and levers at play and some of them can support empirical research in offering clear sets of factors or behaviours to work with.

Several categories and concepts have been proposed to classify and articulate the numerous interrelated factors influencing energy use (see Table *3*). Stern (2000) formulates a typology of the causes of environmentally significant behaviours: attitudinal factors (e.g. perceived costs and benefits of action), personal capabilities (e.g. social status, knowledge) and contextual factors (e.g. regulations, social norms, advertising), and habits and routines. Kollmuss and Agyeman (2002) propose three categories: demographic, external and internal factors (cf. **Figure 8**). Abrahamse et al. (2005) suggest a distinction between micro-level factors (e.g. attitudes, values, opportunities) and macro-level factors (e.g. economic situation, governmental policies, availability of new technologies). Steg and Vlek (2009) distinguish between motivational, contextual factors and habitual behaviour. Considering these examples and further research, the interplay of socio-demographic, psychological and external/situational factors in shaping energy choices is now generally accepted (Frederiks et al., 2015a). ENABLE.EU aims to identify articulations between factors motivating energy behaviour change by studying precise cases and adopts its own typology (i.e. economic, socio-cultural and governance factors structuring this review).

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Table 3: Selection of typologies of factors influencing energy choices used in research

Study	Typology proposed			
Stern (2000)	Attitudinal factors (e.g. norms, beliefs, values)	Contextual forces (e.g. interpersonal influences, advertising, regulations, monetary incentives, technology and infrastructure constraints)	Personal capabilities (e.g. knowledge, skills, resources like time, literacy, money, power; but also sociodemographic variables)	Habits and routines
Kollmuss and Agyeman (2002)	Demographic factors (e.g. age, gender)	External factors (institutional, economic, social and cultural)	Internal factors (e.g. motivation, environmental knowledge, values, attitudes, emotional involvement)	
Abrahamse et al. (2005)	Macro-level factors (e.g. technological developments, economic growth, demographic, institutional and cultural)		Micro-level factors (i.e. individual factors like preferences, attitudes, abilities and opportunities)	
Steg and Vlek (2009)	Motivational factors (i.e. weighting costs and benefits, moral and normative concerns, affect)	Contextual factors (e.g. infrastructure availability, quality of service, pricing regimes)	Habitual behaviours (i.e. automated cognitive processes)	
Frederiks et al. (2015a)	Socio-demographic factors (e.g. income, dwelling and household size)	Psychological factors (e.g. beliefs, intentions, cost-benefit appraisals)	Contextual and structural factors (e.g. economic, political, socio-cultural forces)	
Typology used within ENABLE.EU	Economic factors (e.g. price, propensity to invest)	Socio-cultural and behavioural factors (e.g. norms, dwelling, gender, values)	Governance factors (e.g. regulations, path dependency, public acceptance)	

A second level of categorisation is developed around the types of behaviours. Considering that many studies refer to pro-environmental behaviour, actions covered can be refusing plastic bags, recycling, reducing water consumption, etc. More specifically, energy choices can refer to buying a less polluting car, to cutting back on driving or to changing light bulbs. Each of these actions involves different levels of involvement, effort and sacrifice. A widely used typology distinguishes between efficiency and curtailment behaviours (Stern & Gardner, 1981; Gardner and Stern, 2002). Efficiency behaviours refer to one-shot actions, such as the purchase of energy-efficient equipment (e.g. electric car, insulation), and thus have more lasting effects. Curtailment behaviours are associated with repetitive actions to conserve energy, such as carpooling, turning down the thermostat and reducing use of electric appliances (Gardner and Stern, 2008). Stern (2000) further proposes to differentiate intent-oriented and impact-oriented measures of environmentally significant behaviour. The former refers to actions people do aiming to protect the environment (e.g. recycling), while the latter concentrates on the actual environmental impacts this behaviour has (e.g. energy and water use). This distinction is useful for researchers, on the one hand, to address how people act depending on their pro-environmental intentions, on the other, to identify behaviours having a large impact and how to influence them (Gatersleben et al., 2002).

A third level of categorisation concerns existing strategies and potential interventions to induce

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behavioural change. Abrahamse et al. (2005) for instance categorise policy interventions in two groups: antecedent interventions aiming at influencing determinants of behaviour before its performance (e.g. goal setting, commitment) and consequence interventions, which influence determinants of behaviour after it occurred (e.g. as feedback or rewards). Steg and Vlek (2009) distinguish between informational strategies and structural strategies. The former aim at changing how people perceive energy use, i.e. increasing knowledge, strengthening social norms and altruistic values; while the latter refer to changes in contextual factors, i.e. availability of better alternatives, legal regulations and pricing policies. These two categories can also be referred to as 'soft measures' and 'hard measures' respectively (Abrahamse and Matthies, 2012). Abrahamse and Steg (2013) work on social influence theories and discuss the effectiveness of six frequent approaches in psychology: use of social norms, block leaders, making public commitment, modelling, use of social comparison, and feedback about group performance. The diversity of strategies available to foster energy behaviour change offers a wide range of opportunities for policy-making.

4.2.2 Presenting the main theories used by the literature

Since the 1970s, several theories have emerged as a hard core basis for explaining how energy-related decisions are made. We present below some main theories and models which have significantly shaped the context for research on energy choices.

The Theory of Planned Behaviour (TPB) formulated by Ajzen (1985) supports the idea that behaviour occurs as a consequence of behavioural intention, which can be predicted by the attitude towards the behaviour, perceptions of behavioural control (i.e. ability to perform the behaviour) and social norms (i.e. perceived social pressure) (Ajzen, 1991). Strongly backed by evidence, this theory supports that individuals make reasoned choices (Burger et al., 2015; Steg and Vlek, 2009; Bamberg and Möser, 2007). For instance, they avoid punishment and seek rewards, meaning they weight costs and benefits of their actions. The TPB has been successful in predicting many energy-related behaviours, for instance in transportation (Bamberg and Schmidt, 2003). The Opower experience, one of the largest field experiment using Randomised Controlled Trial (see part 1.3 for a more in-depth analysis of the roles of RCTs), was also based on the TPB and the pursuit of self-interest (Schultz et al., 2007; Brosch et al., 2014).

Several renowned theories also applying in this field put forward different motives for 'pro-environmental behaviour', related to moral obligations. The Norm-Activation Model (NAM) (Schwartz, 1977) is widely used to explain pro-social behaviour as determined by moral or personal norms. Guilt, for instance, is an emotional reaction induced by a harmful behaviour, and has a strong pro-social power as it activates a moral norm to act more appropriately (Bamberg and Möser, 2007).

These two main theories (TPB and NAM) are often quoted together in subsequent research and considered as complementary: individual choices tend to be motivated by both self-interest and social norms (Delmas et al., 2013). However, this interaction is not always clear in research where financial incentives sometimes crowd out prosocial and environmental behaviour (Bolderdjik and Steg, 2015) while in some cases economic and selfish appeals can backfire in favour of maintaining a positive view of oneself (Bolderdijk et al., 2013).

The Value-Belief-Norm Theory (VBN) introduced by Stern et al. (1999) builds on the NAM, coupled with the theory of personal values and the New Ecological Paradigm (NEP)[24]. This theory aims at explaining the support for environmental movements. More specifically, it proposes a causal chain implying that if a movement is in line with one's general values and beliefs, the latter can translate into behaviour-

[24] The New Ecological Paradigm (NEP) is a widely used measure of environmental concern developed by Dunlap and Van Liere (1978) in 'The new environmental paradigm: A proposed measuring instrument and preliminary results'. Journal of Environmental Education.

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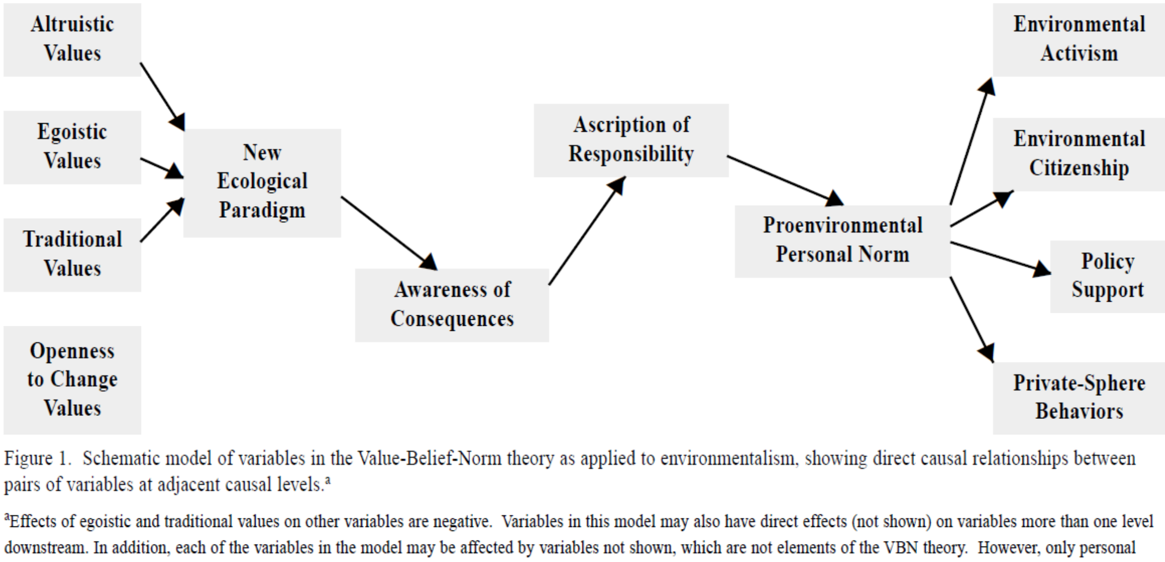
specific beliefs and norms, which turn into a predisposition to support this movement (see **Figure 5**). Stern et al. measure that 19 % of the variance in consumer behaviour could be explained by the VBN theory.

Figure 5: Schematic model of variables in the Value-Belief-Norm theory as applied to environmentalism (Stern et al., 1999, p.84)



The Attitude-Behaviour-External conditions (A-B-C) model is presented by Guagnano et al. (1995) and is formulated by Stern (2000) as follows: "behaviour (B) is an interactive product of personal-sphere attitudinal variables (A) and contextual factors (C)" (p.415). This implies that A and C (also called 'external conditions') are distributed for any behaviour in relation to each other – i.e. when A (or C respectively) is positive (e.g. attitude favouring behaviour or supportive conditions respectively), the behaviour will be common; when A (or C respectively) is negative (e.g. unpleasant conditions or strong opposition respectively), behaviour will be rare. The authors highlight the added value of their model: it includes contextual factors in shaping behaviour and in explaining the relation between attitude and behaviour; it theorises why findings on behaviours (and attitude) are different depending on the context; and it creates a link between theoretical research and the implementation of policy measures which influence the contextual conditions (Guagnano et al., 1995).

Several theories not specific to energy behaviour are also very influential as they frame concepts which strongly apply in understanding behaviour and its change. Research on energy behaviour often refers to theories widely used in various disciplines of social sciences, namely Rogers' innovation theory (1995), Bem's self-perception theory (1972), Bandura's social learning theory (1977), Tajfel and Turner's social identity theory (1986), Kluger and DeNisi's feedback intervention theory (1996), and the knowledge-deficit model (see for more details Schultz, 2002). Other interesting theories to consider are for instance related to the influence of norms and goal-setting.

The theory of normative conduct (Cialdini et al., 1990) introduces a distinction between descriptive and injunctive norms, a typology validated by Cialdini et al. in an experiment on littering, but also widely tested in subsequent empirical studies (e.g. see studies reviewed by Abrahamse and Steg, 2013). Descriptive norms refer to how common a behaviour appears to be, while injunctive norms are related to how a behaviour is approved or disapproved of by others. The theory also establishes that a norm should be salient to guide behaviour. Additionally, Sherif (1936) highlights the informational influence of social norms, i.e., norms act as indicator of the appropriate behaviour to follow – meaning that they

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raise awareness rather than social pressure fear (Bamberg and Möser, 2007).

As highlighted by Steg and Vlek (2009), theories, among which the ones above (TPB, NAM, VBN), often fail to include contextual factors (e.g. availability of infrastructures and products) and tend to be too strongly rooted in the assumption that individuals make reasoned choices, while neglecting the power of habits. An interesting approach is thus developed through the lens of a more recent theory: the goal-framing theory (Lindenberg, 2006). It assumes that people process information and act being influenced by their goals. Steg and Vlek (2009) manage to integrate the main theories in this approach: a gain goal-frame (i.e. benefit one's own resources) relates to the TPB, while a normative goal-frame (i.e. act adequately) fits values-related theories (i.e., NAM and VBN). Finally, a hedonic goal-frame (i.e. feel well) corresponds to theories linked to affect. Although seldom referred to in energy and environmental literature, the goal-framing theory illustrates how frameworks and theories can interact with and complement each other, becoming more complete over time.

Individually, these theories cannot fully explain how energy choices are made but taken together they build up a rich theoretical foundation to support subsequent literature, especially empirical studies which are often rooted in these theories.

4.2.3 Presenting the main conceptual models and frameworks

Articulating the determinants of behaviour in one model or framework does not aim at creating a complete list of potential factors with all their interactions in shaping behaviour. When researchers do this structuring theoretical work, they attempt to bring a visual aid for mapping groups of factors and for identifying potential links between them. These models by nature take sides, they shape questions for further empirical research by highlighting and suggesting interactions to explore. Therefore, there is no right or wrong model. They bring complementary perspectives for researchers investigating interactions between factors influencing energy choices. This section highlights several models deemed valuable and constructive for shaping research paths in the scope of ENABLE.EU.

In the 1970s, some first models appeared and presented rather simple, rational and linear patterns: for instance, a progression from environmental knowledge leading to awareness and thus to pro-environmental behaviour (Kollmuss and Agyeman, 2002). In assuming that information alone leads to pro-environmental behaviour, this simplistic model fails in explaining behavioural change. Policy action expecting that information campaigns alone will trigger energy-related behaviour are indeed unlikely to be efficient (Van Raaij and Verhallen, 1983). Over time, models have become more complex, depicting the challenge of gathering all aspects of environmental behaviour in one figure.

Among numerous approaches, Van Raaij and Verhallen's (1983) behavioural model brought a complex articulation of groups of variables explaining residential energy use (see **Figure 6**). This comprehensive review has the advantage of including relationships between personal, environmental and behavioural factors, and of showing the impacts different policy options can have. In other models, relationships are often linear and limited to main categories as a whole (e.g. between internal and external factors). This behavioural model focuses on households and can therefore provide a precise structure with a concrete understanding of the variables. To illustrate, the weather and building requirements influence the characteristics of a house, which affect the household's energy-related behaviour and thus its energy use. The authors also marked in circles the factors which can be influenced in a campaign aiming at reducing energy consumption (i.e. general information, subsidies and energy prices, etc.). Based on the length of the path from these factors to energy use, one can estimate how direct the effect of a policy could be on energy use, with information provision being the furthest. This model does not include a temporal dimension (apart from the feedback loop) and does not fully explain processes like learning and socialisation (Van Raaij and Verhallen, 1983).

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Figure 6: A behavioural model of residential energy use (Van Raaij and Verhallen, 1983, p.121)

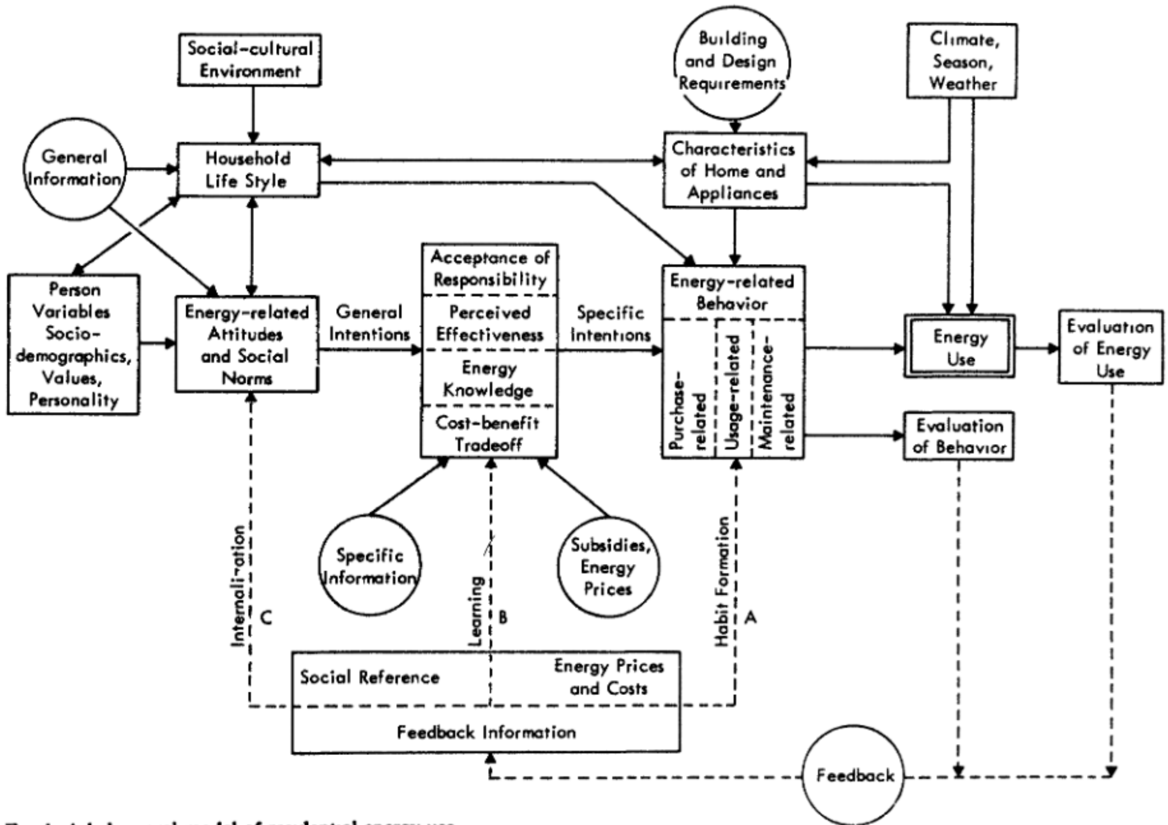

Fig. 1 A behavioral model of residential energy use

Hines et al. (1986-1987) realised a meta-analysis of 128 primary studies on responsible environmental behaviour. Their study focused on measuring quantitatively the strength of relationships between socio-structural variables and pro-environmental behaviour (Bamberg and Möser, 2007). The authors found that intention to act (incl. knowledge of environmental issues and of action strategies, but also personality variables like the locus of control, attitudes, verbal commitment and the sense of responsibility) and situational factors (e.g. economic constraints, social pressures) are associated with responsible environmental behaviour (see **Figure 7**). Their study has encouraged research on psycho-social factors and was replicated by Bamberg and Möser (2007) in order to bring more recent and solid evidence of their findings – which have been confirmed. It should be reminded that the tests are correlational, not claiming any causal inferences. However, Hines et al.'s correlational study is criticised for its methodology as neither the sample nor the method are explicitly presented (Osbaldiston and Schott, 2012), while the identified factors are rather weak in explaining responsible behaviour (Kollmuss and Agyeman, 2002).

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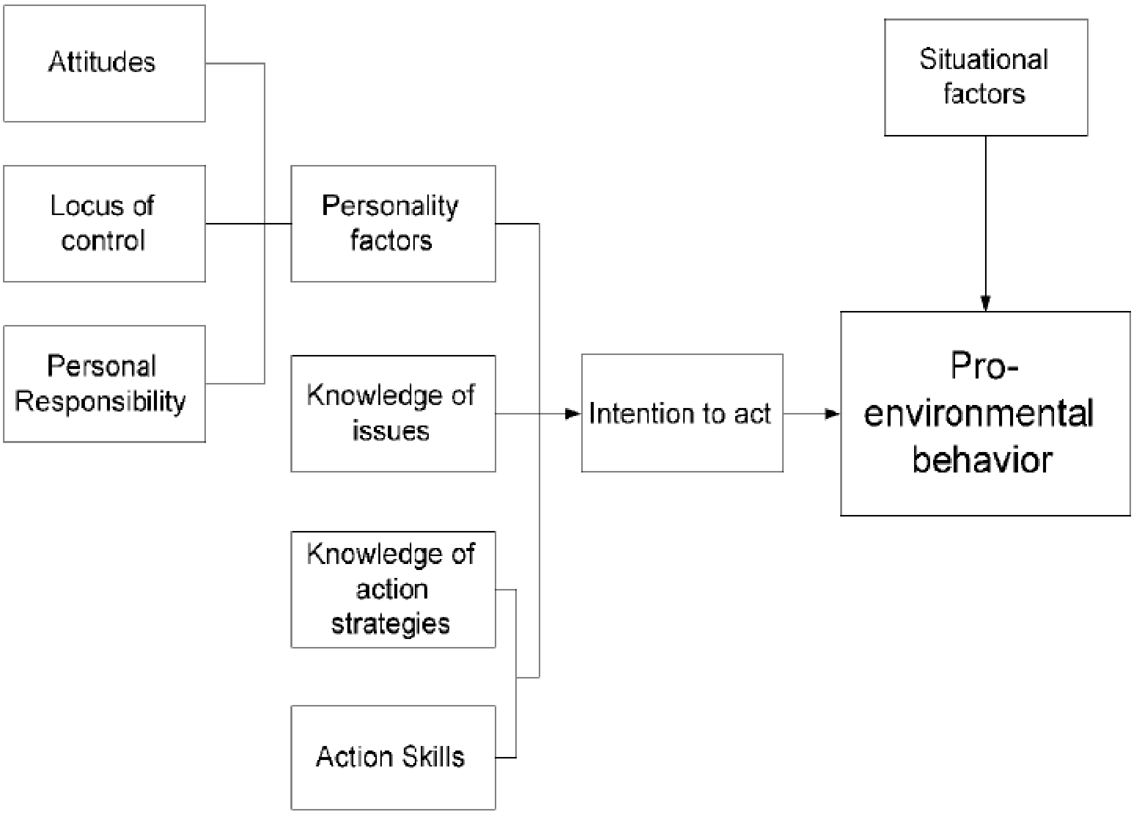
Figure 7: Models of predictors of environmental behaviour (Hines et al., 1986)



Building on prior findings and theoretical work, Kollmuss and Agyeman (2002) propose a clear model not attempting to be an exhaustive representation of determinants of pro-environmental behaviour but to provide a visual support to categorise factors (**Figure 8**). They are aware of the difficulty of gathering all factors in one model and this way underline the complexity of the field. They identify internal and external factors (demographic factors are left out of the model), whose synergy can have the largest influence on pro-environmental behaviour. They rightly point out that many factors are difficult to distinguish and classify because they are "vaguely defined, interrelated, and often do not have clear boundaries" (p.248). This model appears as a meticulous work performed by assessing the strengths and weaknesses of prior models – thus including the concept of 'barriers' preventing pro-environmental behaviour based on Blake's model (1999), and excluding the long-lasting assumption that environmental knowledge has a direct impact on pro-environmental behaviour. They rather introduce it as part of a complex of 'pro-environmental consciousness' encompassing other personal aspects such as values and emotions.

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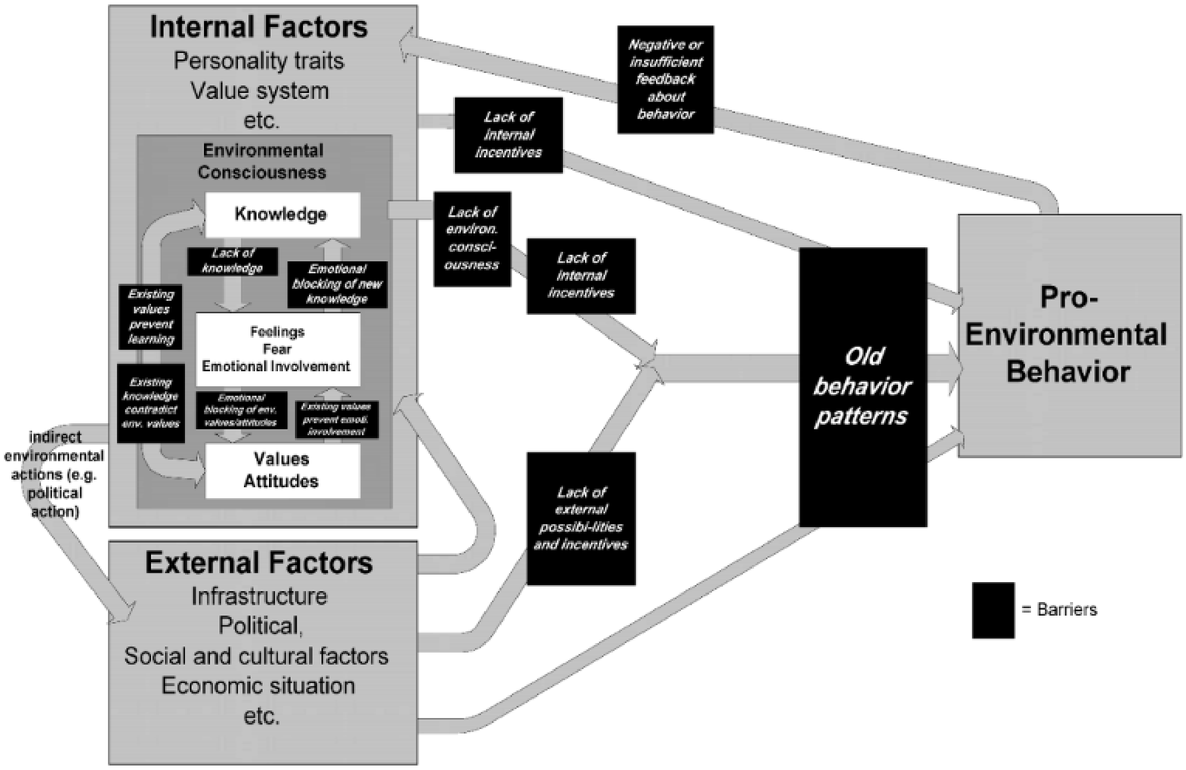
Figure 8: Model of pro-environmental behaviour (Kollmuss and Agyeman, 2002, p.257)



Frederiks et al. (2015) show that there are three categories broadly accepted in the literature, i.e. socio-demographic, psychological and contextual factors. Their conceptualisation speaks for itself and offers an extensive list of the variables at play in explaining energy consumption (see **Figure 9**).

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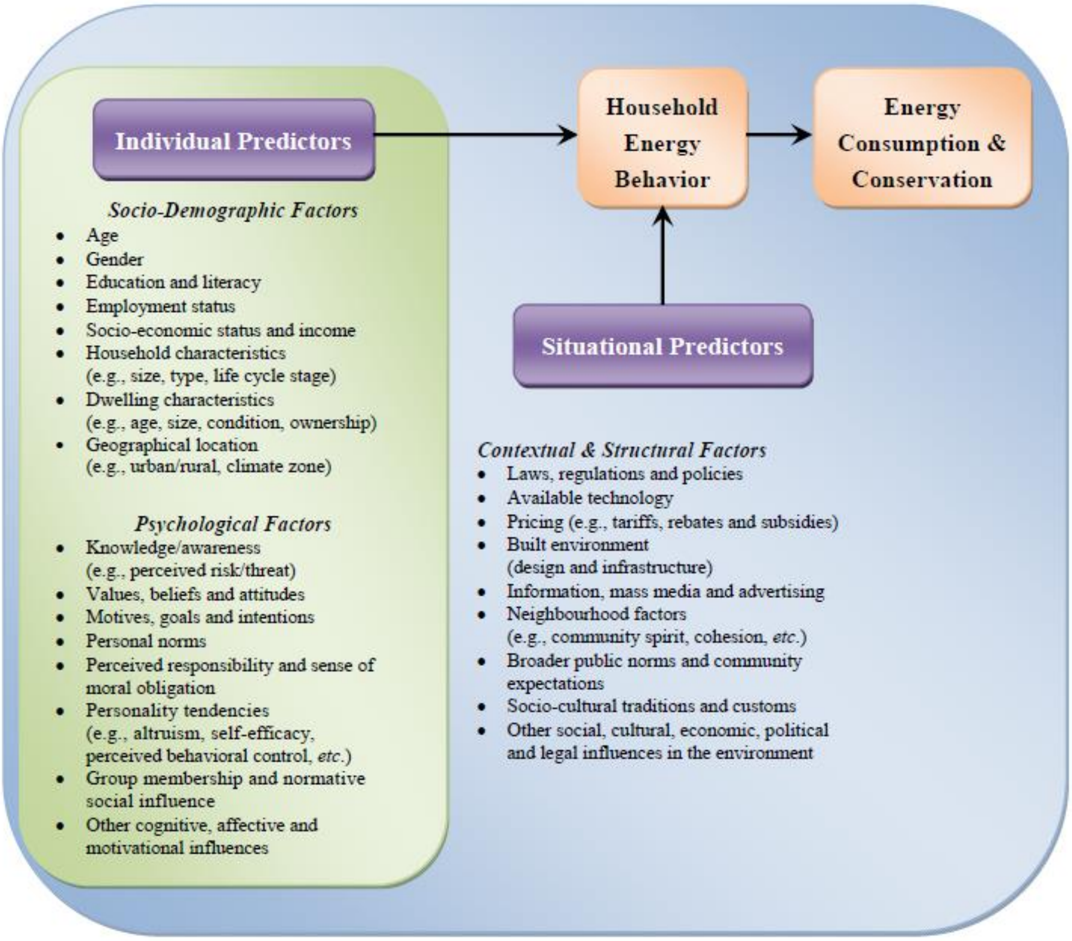
Figure 9 : Integrative conceptualization of the various individual and situational factors that may influence household energy consumption and conservation (Frederiks et al., 2015a, p.577)



Recently, one of the most comprehensive approaches to energy consumption behaviour (ECB) has been developed by Burger et al. (2015). Their framework builds on solid knowledge in several fields to offer "an interdisciplinary basis for linking different aspects in empirical settings" (p.15). This tool can therefore be useful to visualise the possible links between factors of different natures, valuable when adopting an interdisciplinary approach in empirical research (**Figure 10**).

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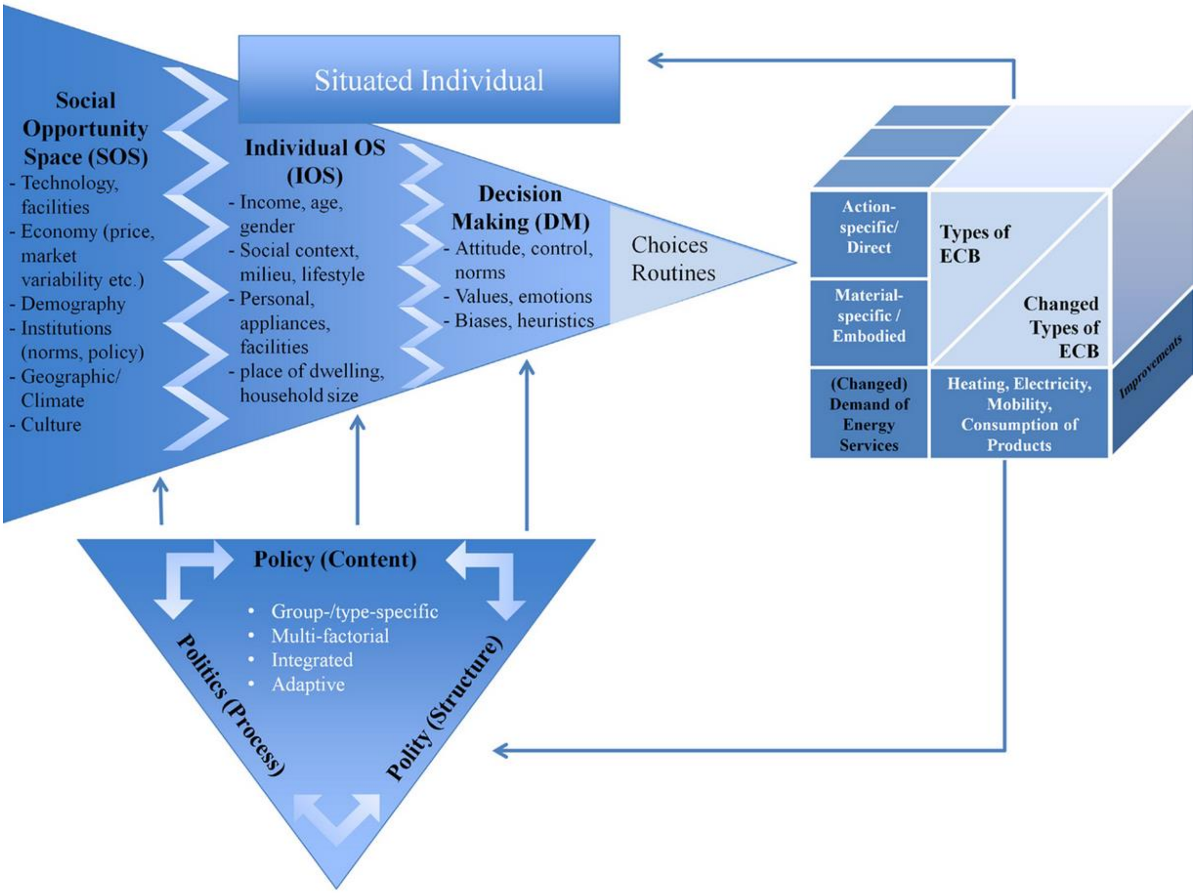
Figure 10: Integrated framework – understanding ECB and the governance of its change (Burger et al., 2015, p.16)



Achieving a thorough analysis of literature, the authors point out to reasons why despite policy makers' efforts to encourage reductions in energy consumption, success is not overwhelming so far. First, scientific studies attempt to explain this trend by numerous individual barriers (e.g. information and motivation deficit, lack of incentives) to which add up "frame conditions" (e.g. social norms, availability of facilities, policy failures), and external variables that are more difficult to influence. But determinants of energy consumption as well as the drivers explaining behavioural change are still insufficiently understood. Literature tends to address domains of consumption separately, and most importantly, according to Burger et al., does not distinguish between the drivers of behaviour and those explaining its change. Secondly, embodied energy (i.e. energy associated to purchased products which required energy for their production and transportation) does matter while it is often neglected.

To answer these failures, Burger et al. build step by step an innovative framework, in which, through the lens of various disciplines (i.e. psychology, economy, consumer behaviour, business science, sociology and political science), they define ECB and its change, and propose factors explaining both (see **Figure 10**). For example, going out for a meal is an ECB and its change could be a change of diet, such as eating less meat; mobility-related ECB like driving or purchasing a car can be altered by driving less, using a bike or car-sharing. Furthermore, they structure the determinants by social (macro-level) and individual (micro-level) factors in a so-called Opportunity Space (see the triangle in **Figure 10** representing "individuals living embedded in complex social environments" (p.12)). These potential determinants are completed by decision-making of individuals, also encompassing choices and routines. The inclusion of governance in this framework brings an essential dimension, seldom brought into the complexity of a model and as highlighted, "governance is about the design of complex instrumental arrangements that address different factors in a coordinated way" (p.14).
However, when referring to this framework, one should keep in mind that it remains a theoretical basis for empirical research to become more inclusive, more exhaustive and thus more accurate when

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assessing energy consumption situations. Burger et al.'s analysis aims at similar outcomes to ours: based in Switzerland, they study individual energy-related consumption behaviour in order to formulate governance recommendations. Sharing findings on both sides could be valuable for the confirmation of the results and discussion around divergences.

This synthesis is only based on a selection of theories, models and frameworks among many attempts to capture the patterns of energy consumption and pro-environmental behaviours. There is no agreement among researchers to define a universal conceptualisation of energy choices (Frederiks et al., 2015a). Many other models were not developed here for the sake of brevity while they also bring compelling approaches of energy-related behaviour (e.g. see Costanzo et al.'s model of the influence process in energy conservation, 1986; Balderjahn's causal model of ecologically conscious consumer behaviour, 1988). Our aim is not to provide an answer to create consensus but rather to raise understanding of the interactions between these identified factors, thus finding support in these conceptual models. Models and frameworks are not an end in themselves, they should serve as theoretical foundations and be kept in mind when designing empirical research for adopting a holistic approach.

4.3 Is there a consensus within the literature on energy choices?

The literature on energy choices cultivates many points of consensus and dissension in the findings. This subsection highlights the most important ones. It also shows how factors and strategies can interact in shaping energy behaviours. Based on this literature review, we suggest a typology of observable effects on behaviour – namely, trigger, catalyst and enabler effects, that can be of particular relevance for policy makers seeking an overview of the factors that can trigger changes in energy choices.

In our definition, a trigger effect occurs when an action or a factor has a causal influence on a behaviour. A catalyst fastens and/or multiplies behavioural change. An enabler is a necessary condition for a change in behaviour to occur, but is unable to lead to change on its own.

4.3.1 Several points of consensus on the effect of a single variable on energy choice

As highlighted in the first part, many articles referenced in the review are rooted in the presented theoretical background. They often begin with a review of the Theory of Planned Behaviour, the Norm Activation Model or another underpinning theoretical framework, as a reminder of the rich literature and existing framework for anchoring the studied topic. This confirms that in spite of the diversity of approaches, of energy domains and factors influencing behaviour, the basis for studying them is widely accepted.

The essential role of raising awareness in influencing energy choices has been widely acknowledged in the literature. A common strategy used to deal with a knowledge deficit is the provision of information, which can be defined as "an intervention where people are provided with information about environmental problems, information on the opinions or behaviour of others, or information that can help them to take action" (Abrahamse and Matthies, 2012, p.231). In this context, basic descriptive information is distinguished from informational strategies based on norms, feedback or tailoring, on which this review elaborates later on. As highlighted in Part 1 on economic drivers of energy choices, most research explains that consumers tend to underinvest in energy efficient technologies mainly because they face information problems, such as a lack and asymmetry of information (Gillingham et al., 2009). Nonetheless, even when individuals have access to complete information, its impact is not straightforward in encouraging behavioural change as explained in the theoretical background.

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Conversely, studies frequently point out to the ineffectiveness of information provision alone (Cherry et al., 2014; Carrico and Riemer, 2011; Ölander and Thøgersen, 2014; Filippini et al., 2014). Information provision thus appears as an enabler of behavioural change: raising awareness is useful to allow this change, but can hardly achieve it by itself (Attari et al., 2010; Collins et al., 2003). The impact of information depends on other criteria than just its provision, such as how and what sort of information is provided, how frequently, for how long and to whom. This is where more elaborated forms of information provision come into play, e.g. norms, feedback and tailoring, which have stronger motivational effects than simply raising energy consumption awareness.

Furthermore, several studies point out to individuals' lack of awareness but also inattention when it comes to energy consumption. In terms of heating and cooling, many people do not think of setting their thermostat on the night mode (see Part 2 – Brounen et al., 2013) while in the domain of electricity, some researchers argue that households tend to ignore some aspects of their electricity use or to be inattentive to energy conservation actions (see Part 1). These examples illustrate again that having access to information does not systematically lead to reasoned energy choices.

A large share of the literature investigates the influence of social norms on energy choices. Findings generally agree on their "power" in shaping behaviour (Schultz et al., 2007). Energy consumption and support for climate change policy for instance can be strongly influenced by social norms (e.g. Allcott, 2011c; Dolan and Metcalfe, 2015; Alló and Loureiro, 2014; Goldstein et al., 2008; Handgraaf et al., 2013; Nolan et al., 2008). Drawing on normative social influence can therefore appear as a reliable strategy when designing policy to influence energy behaviours. Some studies however point to limits in the effectiveness of social norms. An important issue to take into account lies in the general use of social norm intervention potentially leading to the boomerang effect: those who consume less might increase their consumption when they are exposed to social comparison and observe that their peers consume more than them (Schultz et al., 2007; Ayres et al., 2012). Furthermore, a study points out to varying effects depending on the country where social norms are used: while the method is well accepted and brought positive results in the US and in Norway, a study based on focus groups shows that people in the UK are not responsive to normative feedback (Roberts et al., 2004; Vine, Buys & Morris, 2013; Allcott, 2011c; Schultz et al., 2007; Nolan et al., 2008).

The literature also highlights the need of targeting policies at specific groups. The same message does not affect all sorts of public in the same way. Policy should be designed by identifying different demographic groups – e.g. women, young parents, families with many children, elderly people, low-income households; or based on people's views, for instance whether they care about the environment or not (Collins et al., 2003). An example could be car use: middle-aged people, men and people with higher income and education are more likely to drive cards and hence should be targeted in campaigns to reduce car use as to ensure more cost-effectiveness of the policy (OECD, 2011). A RCT study suggests that health and environmental messaging can be more effective when targeting families with children (Asensio and Delmas, 2015, see infra for more details on this study). Similarly, price-based interventions could target different consumers' susceptibility to information problems in order to foster more energy conservation (see Part 1). Westskog et al. (2015) also find a different effect of feedback depending on households' affluence. Less affluent flat owners reduced their electricity consumption when using an In-Home Display as it helped them manage their finance, while more affluent households used it as a tool to simply check their energy use but not to reduce it. Each targeted group linked by one common variable can respond differently to a policy and it would be therefore highly relevant to identify such trends in order to be able to implement optimally-designed interventions.

4.3.2 Several points of dissension on the effect of a single variable on energy choice

Difference of nature in the findings

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Research on the effect of a factor on energy choices suggests different findings which in some cases can be linked to different energy services. Differences of nature refer to unclear findings on the nature of the influence of a specific factor or strategy (e.g. whether a given factor leads to an increase or a decrease in energy consumption).

Income plays overall a significant role in explaining the energy use of households throughout energy domains – high-income households can pay more for energy and tend to consume more per capita (Brounen et al., 2012). However, this can differ according to the studied energy service and metric: for instance, in terms of heating and cooling, lower-income households consume more energy per square-foot, meaning their dwellings are less energy efficient than those of high-income who consume more per building (see Part 2). With regard to concern about environmental issues, the effects of income are unclear: the findings on mobility show that higher income households tend to be more environmentally concerned but that this effect of income disappears in the context of car purchase.

The study of gender in energy practices shows various trends among energy domains. While women are more likely to be sustainable consumers according to surveys (OECD, 2008, 2014), in the area of heating and cooling, the studies mentioned in this review highlight that women tend to consume more gas for heating than men, but less electricity (Brounen et al., 2013). When it comes to mobility, findings seem to point out to a more consuming behaviour among men. The degree of involvement to reduce energy consumption or to improve sustainability can also vary. For instance, men seem more engaged with technologies and often show higher involvement with smart monitors (Hargreaves, 2010). Different patterns of consumption are also observed: while women have a larger role in consumption decisions (purchase of household goods), men have more influence on large purchases (e.g. car, house) (OECD, 2008). In terms of renewable energy, a study led in Italy highlights that in households willing to pay more for renewable energy, women had a lower willingness to pay than men (Bollino, 2009; see Part 3). On the other hand, women tend to favour renewables more than men (Clancy and Roehr, 2003). These findings cannot be generalised as they identify mixed trends and concern only some countries with different experimental settings. ENABLE.EU will therefore put emphasis on the gender question – as the central question of a case study rather than just a demographic variable – to provide solid empirical findings from several countries.

Regarding the variables affecting the adoption of electric vehicles, Part 2 highlights divergent findings. A study led in the US finds a significant impact of socio-demographic factors, especially age and education, on the propensity to purchase an EV (Hidrue et al., 2011); while Sierzchula et al. (2014), collecting data from 30 countries (including the US), suggest that socio-demographic factors do not explain the adoption level as opposed to contextual factors being the main predictors (i.e. number of charging stations, financial incentives, presence of local EV manufacturing).

Research analysing how people perceive different types of information provision – notably, economic savings compared to moral appeals – brings diverging findings. For instance, a study comparing the influence of economic and biospheric concerns on behaviour – testing for the motives of tyre check – shows how biospheric appeals are more effective in encouraging the behaviour (Bolderdijk et al., 2013). Findings from a study on eco-driving behaviour suggests that while information provision is effective overall, environmental feedback has a more significant impact than financial feedback (Dogan et al., 2014). A RCT study led in California finds health and environmental messaging to reduce on average households' consumption by 8.2%, up to 19% in families with children, while monetary saving information have the opposite effect with an increase in the electricity use of the households (Asensio and Delmas, 2015). According to Delmas et al. (2013), information on monetary savings can crowd out altruistic motivations and thus even be counterproductive.

On the other hand, Part 1 stresses the effects of price signals. A study on labels analyses the added value

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of information in guiding decision of buying appliances and finds that simple monetary information on energy savings has the highest influence on consumer's decision, followed by information on physical energy use of the appliance, and finally information on CO2 emissions of the appliance (Newell & Siikamaki 2014).

Differences in consumers' response to economic and environmental or moral information lie in several possible explanations. First, economic savings associated with the action can be so low that they do not motivate behavioural change. Second, people attempt to make reasoned decisions when making cost-efficient investment (e.g. when purchasing appliances), so they rely mainly on economic information. Third, when people want to keep a positive view of themselves, they tend to favour moral and biospheric appeals (Bolderdijk et al., 2013). Pecuniary strategies, while often considered by policy-makers as the most pertinent tool, need therefore to be put into perspective.

Difference of degree in the findings

Different levels of effectiveness can be found among studies, e.g. for real-time feedback on consumption. Several empirical studies have assessed the potential savings that can be achieved by households being able to track their energy usage. Using findings from the UK, North America, Scandinavia and the Netherlands, Darby (2006) shows that direct feedback from a meter – or an associated display on monitor – can achieve energy savings from 5 to 15 %. A subsequent study, mainly based on North American pilot programmes, reviews the impact of In-Home Displays (IHD) providing immediate information on energy consumption and costs. It identifies an average of 7 % (ranging from 3 to 13 %) reduction in electricity use among households actively using the IHD (Faruqui et al., 2010). In households relying on an electricity prepayment plan and an IHD, savings were even twice as high. More recent findings are also consistent with these results. A large-scale experiment led in Northern Ireland and based on data from 1990 to 2009 measures the impact of an advanced metering device introduced in 2002 and documents electricity consumption reductions ranging from 11 to 17 % (Gans et al., 2013). A study led in the US with 1,743 voluntary Google employees finds an average reduction of only 5.7 % in electricity consumption and no significant effect remaining after a month (Houde et al., 2013). Finally, a recent study shows a mitigated success of IHD feedback finding only 2 % short-term energy savings when consumers engage with the IHD (Buchanan et al., 2015).

While all these findings on real-time feedback technology are positive on its effects, they provide a large range of effect estimates which can stem from varying methodologies, samples and locations, making it difficult to assess the precise effectiveness of this strategy. As presented in Part 1 however, costly IHDs (when they achieve low savings) might be less cost-effective than simple information campaigns (Lynham et al., 2016).

A part of the literature focuses on a notable limit to energy efficiency actions, the so-called rebound effect. This trend can be observed in households undertaking energy efficiency investments (e.g. retrofit). Energy savings often appear to be lower than expected because improved energy efficiency induces lower costs for an energy service so that people take advantage of it by improving their comfort and increasing their consumption. Similarly, people purchasing electric vehicles might drive more than before due to the increased efficiency of their car. However, there is no consensus on the extent to which the rebound effect reduces savings. Studies find various degrees of rebound effect. In terms of household heating and cooling, Sorrell (2007) finds an average of 30 %, with other estimates varying between 5 and 30 % (Haas and Biermayr's, 2000; Gillingham et al., 2013). With respect to mobility, improved fuel economy can have effects ranging from 5 to 23 % (Gillingham et al., 2013; Sorrell, 2007). Estimates vary on a large scale depending on the study: from 0 to 552 % with most results up to 30 % (Freire-González, 2017; Sorrell, 2007; Sorrell et al., 2009; Galvin, 2014). Research on the rebound effect in the EU shows that it tends to reach high levels in developing regions as increasing consumption has a more significant impact on improving life comfort in these regions (Galvin, 2014).

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This phenomenon demonstrates that energy efficiency gains cannot reliably predict energy consumption reduction. The potential loss in energy savings should therefore be considered from the early stages of an energy efficiency policy to avoid an overestimation of the gains (Barbu et al., 2013). In this respect, researchers agree that it is crucial to take into account behavioural factors beyond technical and economic aspects of energy efficiency measures (Sunikka-Blank and Galvin, 2012). These findings on the rebound effect should not justify inaction. Energy-efficiency measures remain useful to save energy and such policies can be coupled with tools, such as carbon pricing, mitigating the rebound effect (Gillingham et al., 2013; Sorrell, 2007). Last but not least, according to Freire-Gonzalez (2017), the rebound effect can be even desirable in some cases: achieved energy efficiency and raised consumption can indeed serve economic growth.

4.3.3 The impact of time on energy choices

An essential aspect to take into account when designing an intervention is how its effects persist on the long-term. Several studies investigate the changing effects over time.

The implementation of trial periods like a free month ticket for public transport (see part 2) can be a trigger – or an initiator – for behaviour change on the short term. The novelty can encourage people to drop habits and adopt a 'trying-out' behaviour. On the longer term however, if the new behaviour is to be maintained, individuals need to evaluate this change positively. Similarly, running a trial of an environmental tax can raise its acceptability (Cherry et al., 2014). Trials can thus be an enabler of long-term change, as change (or acceptability, respectively) could not have happened without this trial, but it still needs to be sustained by other drivers.

Similarly, in the case of Opower large-scale experiments testing the effects of social comparison through discontinued long-term intervention (Allcott and Rogers, 2014), reporting on social comparison acts as a trigger: at the beginning of the intervention, consumption decreased immediately. While this positive impact quickly fades, energy conservation is constantly renewed through repetition (i.e. regularly receiving consumption reports). Frequency being crucial to ensure the effectiveness of feedback and leading to sustainable habit formation, the repetition of intervention can be considered as a further necessary trigger for household energy behaviour change. Findings on long-term intervention show that feedback bring more persistent effects with time, even after the treatment is discontinued. The temporal dimension of a strategy is therefore central to trigger long-term behaviour change.

The change in effect is also visible in the case of energy monitors. While this strategy combines feedback with the use of technology, its effects are often expected to be promising. Indeed, several studies on their effectiveness have shown significant energy savings (Darby, 2006; Gans et al., 2013). However, effects on energy conservation quickly decrease after the novelty period of the technology. By way of illustration, Houde et al. (2013) found no significant effect remaining after just a month, while a qualitative study led by Hargreaves et al. (2010, 2013) observed that after a year participating households lost interest in the monitor. While these findings cannot be generalised, it is highly interesting to note that the monitors became part of the household routine so that real-time feedback via monitors seems to have a significant short-term effect which should be sustained through other strategies for long-term change. While they raised the level of awareness, they also established a base level of energy consumption in the household, with potentially some unsustainable energy consuming actions considered as "normal". Being more aware of their consumption, people became more resistant to further efforts in energy conservation. This trend could imply that sometimes increased awareness can act as an inhibitor of energy saving behaviour.

Finally, some strategies have an acknowledged limited effect in time. For instance, the use of prompts can trigger a direct effect on behaviour, mainly at small scale for easy behaviours like switching off the

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light, but the effect is weak and short-term (Abrahamse and Matthies, 2012; Osbaldiston and Schott, 2012).

4.3.4 How combined factors and strategies can impact energy choices?

The relation between the identified variables and behaviour is seldom a straightforward causal link but is rather contingent upon diverse moderating factors that can constraint or enable the targeted behaviour (Frederiks et al., 2015a). In the case of psychological and motivational variables for instance, failure to adapt behaviour to one's knowledge, attitudes and intentions has been formulated as the "knowledge-action gap", the "attitude-action gap" and the "intention-action gap" respectively. Many empirical studies acknowledge the existence of such gaps. For instance, a study for the UK Department for Environment, Food and Rural Affairs (DEFRA) identifies a high level of consciousness of climate change among respondents, while it is disconnected from adequate behaviour change (Brook Lyndhurst, 2007). They insist on the fact that this "attitude-behaviour gap" appears particularly strong in the area of energy, a specificity which could be linked to its embedded nature in people's life.

When designing an intervention or a policy, the effectiveness assessment needs to take into account all identified factors since their interplay might shape the outcome of the policy. For instance, a German policy on heating standards assessed higher expected energy and economic savings than the actual outcomes as it did not take into account non-technical factors like behaviour in its calculation (Sunnika-Blank and Galvin, 2012); on the other hand, in the Opower programme, the assessment of potential savings did not consider the persistence and habituation effects on consumers leading to an initial underestimation of its success (Allcott and Rogers, 2014).

Additionally, the environment and context of intervention (i.e. contextual factors) can strongly contribute to its impact on energy choices – for instance, when it is part of a programme, used in a community or in the workplace. Community engagement can indeed motivate positive change as people commit to it together whether it is with neighbours or work colleagues (Barbu et al., 2013).
The Dutch EcoTeam Program (ETP) gathered small groups of neighbours and friends who each month discussed how to save energy and received feedback on individual and other groups' savings (Staats, Harland and Wilke, 2004; Abrahamse et al., 2005). This programme appeared very successful as participants saved on average 20.5 % on gas use and 4.6 % on electricity use, with savings remaining similar two years later (16.9 and 7.6 %, respectively).
Several studies have been conducted in the workplace, considered as a social context where people learn and can integrate new habits (e.g. Southerton et al., 2011; Carrico and Riemer, 2011). Handgraaf et al. (2013) show that the provision of public feedback in the workplace motivates energy conservation more than private feedback. A campaign to reduce air conditioning use in Japan even led to changes in the work dress code and thus altered social norms. While inexpensive, this policy contributed to CO2 emissions reductions.

Country-specific factors are difficult to assess in a study, but can also have a strong moderating role in shaping energy behaviours. A study on electric mobility for instance analyses the explanatory factors of EV adoption. Discrepancies in the findings between the countries studied – i.e. 30 developed countries with 19 from the EU – are difficult to explain and may lie in factors specific to each country like government procurement plans among many others (Sierzchula et al., 2014). Similarly, Part 3 of the review insists on different geographical particularities, political cultures, path dependency, level of public and local engagement, public support for national policies, etc. which inherently produce diverse national contexts for the implementation of a policy and thus potentially leading to uneven effects on behaviour. Differences in practices between cities in one country should also be taken into account as illustrated in a study on the impact of cycling infrastructure in UK cities (Aldred and Jungnickel, 2014 – see Part 2).

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The combination of strategies is often required and almost unavoidable to foster energy behaviour change. As mentioned above, information provision is a strategy widely used to encourage behavioural change, but by itself cannot trigger behavioural change (Abrahamse and Matthies, 2012). Its effectiveness can be improved through the tailoring of the message, with a normative approach or via modelling (i.e. people performing an action to induce the same behaviour – based on social learning theory). Feedback appears thus as a more effective informational strategy. This strategy works better when coupled with an interactive technological tool, tailored to the household (i.e. providing information related to their dwelling, family size, etc.), providing specific information per appliance, delivered frequently hence shaping habits, and appealing to internal motivations like goals (Vine, Buys & Morris 2013; Stern, 2011; Wilson and Hawkins, 2011; Burgess and Nye, 2008). It can also be combined with cognitive dissonance, showing consumers the discrepancy between their consumption and expressed attitude (Abrahamse and Matthies, 2012). Combining different types of information can also appear effective: real-time price change updates and real-time consumption feedback have a stronger effect on energy conservation when they interact together (see Part 1 – Jessoe and Rapson, 2014).

These findings also support that strategies used should be adapted to the behaviour: treatments requiring low levels of engagement (e.g. prompts) would be more efficient for low-effort behaviours (e.g. public recycling) while high-engagement treatments (e.g. commitment) appear more appropriate for high-effort behaviours (e.g. gasoline conservation) (Osbaldiston and Schott, 2012, see table p.278 for further examples).

Overall, empirical findings show that the combination of informational strategies (i.e. information provision, goal setting, commitment, prompting, feedback) tends to increase their effectiveness – this trend could be linked to the salience of the message, the learning effect and habit formation. Although multiplying strategies has the potential of increasing their impact on behaviour, the cost-effectiveness of these strategies cannot be neglected as it is an essential aspect of their implementation in policy-making. Considering the complexity of energy choices, informational techniques should work hand in hand with structural strategies to stimulate durable behavioural changes (Abrahamse and Matthies, 2012). Based on 253 experimental treatments identified in the literature, Osbaldiston and Schott (2012) find that calling on social modelling (i.e. a person demonstrating the behaviour) jointly with commitment making is effective to promote home energy conservation while providing rewards and making action easier (e.g. bringing recycling bins closer) are more adapted in encouraging curbside recycling. Single policy has less chance of success than designing a policy mix to address energy behaviour (Filippini et al., 2014).

The impact of joint strategies could nonetheless turn out to be inefficient in some cases. Hahn and Metcalfe (2016) point out in their meta-analysis to research showing the inefficiency of combining two frequent strategies: social norms and financial incentives. The latter's effects on energy conservation seem to vanish when added to the normative social messages (Dolan and Metcalfe, 2015). Such a double policy is thus suboptimal as its general effectiveness on energy consumption might not decrease, but its cost-effectiveness does.

Some researchers also stress the importance of spillover effects into other behaviours. When people perform a pro-environmental action, especially when it is based on economic appeals or incentives, the propensity to engage in other environmental domains might be reduced (see Part 1.3 – also, Bolderdjik and Steg, 2015; Thøgersen and Ölander, 2003; Evans et al., 2013). Individuals may indeed feel that they have accomplished their moral obligation so that there is no need to make further proenvironmental effort. Negative spillover can especially occur on vacation: people performing pro-environmental behaviour at home are less inclined towards such behaviour on vacation (Truelove et al., 2014). On the other hand, when a behaviour is motivated by environmental concerns rather than financial incentives or social status, it is more likely to foster spillover into other proenvironmental behaviours (Thøgersen and Crompton, 2009). For instance, adopting a fuel-efficient driving style can foster environmental self-

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identity, and hence future environmental-friendly intentions, such as reducing meat consumption (Van der Werff et al., 2014). Such positive spillover effects can be rooted in people's motivation to act consistently and their social identity (Truelove et al., 2014). Therefore, when designing policies, policy-makers should be aware of the extent to which intervention can be effective in fostering changes in energy behaviours.

4.4 The limits in the current state of the literature on energy choices

This part identifies the main weaknesses and gaps of the literature to date and highlights the difficulties encountered in research addressing the drivers of energy choices.

4.4.1 A geographical bias limits the capacity to generalise findings to some/all EU societies

A geographical bias can be observed in the articles used for this literature review. We attempted to identify studies led in European countries, extending our research to other developed countries experiencing similar energy consumption patterns. Despite this inclusive approach, most studies we analysed were led in the United Kingdom, in the Netherlands and in the United States. A significant share of the studies attempts to adopt an international approach. They are frequently based on datasets built by researchers (Nicolli and Vona, 2016), retrieved from large statistical databases (e.g. Eurostat, Odyssee, World Bank) (Galvin, 2014; Sierzchula et al., 2014; Lenzen et al., 2006; Broin et al., 2015), or led by organisations like the OECD having an international reach and hence more means to survey populations from different countries (OECD, 2014). Empirical approaches at international level also rely on tools like Internet surveying (De Groot and Steg, 2007). The most comprehensive studies to date which have gathered empirical data from several European countries are European projects, among others REMODECE leading a large-scale monitoring campaign and a consumer survey on electricity use in twelve European countries (De Almeida et al., 2011) and ELIH-Med targeting energy efficiency in six countries in the Mediterranean area (Podgornik et al., 2016).

To our knowledge, however, apart from such projects, relatively few researchers have led experimental interventions in several countries in real-life conditions. Such a procedure is indeed more difficult to set up because of required resources and constraints (i.e. time, financing, size of research team).

Furthermore, energy remains a domain strongly confined to national policies and cultures, so comparing interventions led in several countries with different backgrounds might be a complex process and could lead to inconclusive findings.

ENABLE.EU aims at filling the identified geographical gap as comparison of determining factors of energy choice in several European countries is at the heart of the project. The complexity of international comparison will be tackled with a consistent methodology of face-to-face surveying through all countries and meticulous work performed by teams based in all countries of study interest. In the context of the electricity case study, RCTs will be led in four countries (Bulgaria, Germany, Serbia and the U.K.). They will adopt a joint approach to take advantage of the synergy of the findings. The four empirical studies will aim at revealing the techno-economic drivers of energy choices, but the comparison might also highlight sociodemographic differences between countries with different levels of development.

4.4.2 The importance of timing and time is yet under-studied

Most empirical studies evaluate the effects of intervention throughout the whole experiment but seldom measure the effects when intervention ends and whether they persist in the long-term (Delmas et al.,

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2013; Abrahamse and Steg, 2013). This dimension, while essential from a policy effectiveness perspective, appears difficult to test in many experimental conditions due to resource and time constraints. To test for long-term effects, the study needs to follow respondents throughout the time of intervention and afterwards. For instance, in the case of informational strategies like prompts or feedback, once the targeted pro-environmental behaviour has occurred, evidence on the further effects of the intervention of individuals cannot be gathered due to the experimental setting, e.g. hotel guests responding to descriptive norms encouraging pro-environmental behaviours (Goldstein et al., 2008; Abrahamse and Matthies, 2012). The diffusion of interactive and real-time information technologies, such as smart metering with In-Home-Displays, may however help researchers to tackle this issue. The electricity case study in the context of ENABLE.EU will take into account this temporal dimension so that its design will be able to study the long-term impacts of the intervention (due to time constraints, this long-term study will however occur outside of the scope of ENABLE.EU).

Identifying the optimal length of an intervention and the effects of repeated intervention also tend to be neglected. The former is crucial in ensuring cost-effectiveness of a strategy, while reminders on how to behave might strengthen the induced behaviour. These questions have been addressed by Allcott and Rogers (2014), as described in Part 1, in their study based on the Opower programme analysing the effects of social comparison on electricity consumption over a two-year period. Not only did they assess the effect of longer intervention, but also the effect of discontinued treatment on energy conservation behaviour. Their findings are promising: over time of intervention, people form a "capital stock", i.e. technological (efficient appliances) and behavioural (new habits) changes enhancing energy conservation, which makes effects more persistent. Repetition of intervention even stimulates a new "capital stock". When the treatment is discontinued after two years, the effects tend to fall by 10 to 20 % only, but continuation shows that incremental effects of treatment are still visible (Allcott and Rogers, 2014). The authors even highlight that the persistence of effects tends to be neglected in the cost effectiveness calculation of a programme while they can in fact double its effectiveness. Such findings point out to the importance of taking into account the length and frequency of a treatment in the initial design of the programme to maximise its success[25].

4.4.3 More interdisciplinary approaches are needed to better understand energy choices

The topic of 'energy choices' covers a large variety of behaviours (e.g. driving, heating…) and potential drivers. The question's complexity has raised wide attention in the research community from many disciplines as it addresses an essential – albeit seldom visible – aspect of everyday life. This large interest for energy choices has built strong expertise on energy choices in social sciences but this diversity of disciplines has also shaped diverse approaches of the topic – i.e. in terms of framing, wording used, methodology... Many authors talk about "household energy use" (Abrahamse and Steg, 2011), "resource conservation" (Abrahamse and Steg, 2013), "energy conservation" (Schultz et al., 2007). In economics, the wording is quite intuitively generally related to energy, for instance with "energy conservation" (Allcott and Rogers, 2014; Dolan and Metcalfe, 2015; Asensio and Delmas, 2015), "energy use behaviour" (Sunnika-Blank and Galvin, 2012) and "energy efficiency behaviour" (Newell and Siikamaki, 2014). Yet, a large part of researchers orients their approach towards the 'environment' rather than to 'energy', thus often referring to "pro-environmental behaviour" (Van der Werff et al., 2014; Lokhorst et al., 2013), "sustainable consumption" (Spaargaren and Mol, 2008) or "behavioural responses to climate change" (Whitmarsh, 2009).

These differences in terminology do not seem discipline-related. They imply nonetheless a different

[25] Despite the difficulty to assess the effects of frequency and length of intervention as well as its long-term implications, more resources should be devoted to such research, crucial for policy-makers to design effective and long-lasting programmes.

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framing of the question and thus potentially different perspectives of energy use and environmental harming. The most common framing refers either to factors of pro-environmental behaviour or to energy conservation behaviour. Studies oriented towards "pro-environmental behaviour" might support a more judgemental view of which behaviours are good or bad, anchored in a context of environmental sustainability, whereas the use of "energy behaviour" can be more neutral. An interesting point to note in the scope of ENABLE.EU is the fact that the concept of 'choice' is rarely associated with energy consumption in the literature. By contrast to the word 'behaviour', the word 'choice' can pertain to a more conscious level of decision-making.

While the literature vastly acknowledges the need for interdisciplinary approaches[26], disciplines tacking energy choices struggle to connect with one another. An illustration of this difficulty is the rare coverage of psychological factors in econometric studies (Van den Bergh, 2008). This shortfall of an interdisciplinary approach can be explained by several reasons. First, while interdisciplinary theory encompasses a multitude of factors affecting various disciplines, the interaction of these factors is challenging to apply and test in empirical settings. Second, proposing a cross-cutting study requires the implication of researchers from the disciplines involved, as well as financial and material resources to lead a large-scale study in order to encompass all factors. Third, studying the influence of several factors of the same type (e.g. socio-demographic factors like age, gender and education), involving also factors from a different level (e.g. contextual factors like existing regulations and technologies) can complicate the research. Depending on each contextual factor, socio-demographic variables might have different effects so that the way they interact, reinforce and mitigate one another can be complex to analyse.

Many researchers stress the urgency of interdisciplinary collaboration to deepen the knowledge and understanding of the drivers underpinning energy choices (Van den Bergh, 2008; Steg and Vlek, 2009). This gap is being partly addressed through the creation in 2014 of the academic journal Energy Research & Social Science aiming at "developing an integrated, trans-disciplinary science of human interactions with energy and energy systems" (Stern, 2014, p.41).

4.4.4 Several studies suffer from methodological weaknesses undermining the usefulness of their findings

Although many high-quality papers have been written on energy-related behaviour, several researchers and our assessment highlight shortcomings in the methodology used in numerous studies.

These flaws often lie in the nature of the sample, which is sometimes not representative of the population. This can skew the findings and make them inapplicable to a wider public: for instance, when they are based on a very small sample or when they only consider a specific group, such as university students (Graffeo et al., 2015; Asensio and Delmas, 2015; Cherry et al., 2014). Bias also emerges in the selection phase when participants are volunteers: they tend to be more motivated than the average individual (Abrahamse et al., 2005). A qualitative study on the integration of smart-metering monitors in households shows that observed reactions need to be considered with caution since participating households were early adopters who decided to enrol in the programme and invest in a monitoring system (Hargreaves et al., 2010).

As highlighted by authors of meta-analyses based on numerous primary studies (Delmas et al., 2013; Abrahamse and Steg, 2013; Frederiks et al., 2015a), many studies lack in rigour in their experimental design and thus are more suitable to confirm correlations than to present firm conclusions on the impact

[26] To illustrate the importance of interdisciplinary approaches, single disciplines cannot manage to explain all the different levels of actors' involvement. Individuals (and households) interact with energy systems through several roles: as energy consumers, as citizens, as energy producers and as members of organisations and institutions. Multiple disciplines are thus required to understand and influence their interactions with energy systems (Stern, 2014).

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of studied factors on behaviour. First, some studies do not rely on a control group when testing the effects of an intervention. Second, they tend to neglect weather and demographic characteristics. Such omission can strongly impact the findings: in Delmas et al.'s meta-analysis, energy savings were overestimated by 5.8-7.3% in studies without demographic controls. Third, many studies test several strategies per experimental group leading to confounding effects and lack of independent findings per strategy (Osbaldiston and Schott, 2012; Delmas et al., 2013; Abrahamse et al., 2005). A critical conclusion of this quality assessment states that the most rigorous studies tend to find considerably less significant effects of interventions. A bias can also be observed among published studies: non-significant findings are generally less published so they are seldom covered in meta-analyses, which might tend to assess larger effect sizes of interventions on behaviour than they actually are (Abrahamse and Steg, 2013).

Furthermore, embodied energy, also called indirect energy use (i.e. energy consumed in the production and transportation process of a product or a service), is often neglected in the energy consumption of a household, while according to an analysis in the Netherlands, about 55% of the total household energy use stems from indirect energy use (Gatersleben et al., 2002). To highlight the importance of embodied energy, Burger et al. (2015) do not only categorise their energy services by action-specific (i.e. direct energy use) and material-specific (i.e. embodied energy use) energy consumption behaviour, but also include "consumption of products" as a differentiated energy service, covering goods like cosmetics and furniture (Burger et al., 2015, p.11). This hidden energy is nonetheless tricky to include in household energy use measure as researchers do not have access to detailed information on all consumer goods in a household – such as their age, frequency of use and maintenance (Gatersleben et al., 2002).

A further drawback lies in the methodology chosen to assess drivers of energy choices. In research on energy efficiency measures for instance, few studies rely on actually implemented investments by households (these include studies by Michelsen and Madlener, 2013; Aravena et al., 2016). They rather use choice experiments based on hypothetic settings, which can result in important insights into the drivers and barriers of investing into energy efficiency, but might induce different results than research based on real-life choices (e.g. Poortinga et al., 2003; Achtnicht and Madlener, 2014). Methodological limitations can also be rooted in real-life context. While confounding effects can blend the findings, strategies are often combined in practice (Osbaldiston and Schott, 2012; Steg and Vlek, 2009).

So as to ensure solid and reliable results, Randomised Controlled Trials (RCT) should be one of the privileged research methodology as it guarantees internal validity (i.e. treatment and control groups are comparable). RCT should also rely on non-voluntary participation and large sample sizes to answer the methodological issues raised above (see Part 1 – also, Frederiks et al., 2015a). Steg and Vlek (2009) also encourage a strict discipline in experimental research followed by systematic evaluation to assess the efficiency and improvement options of an intervention.

A dimension often neglected in research on energy behaviour is the distinction between behaviour and its change. Gatersleben et al. (2002) stress that household energy use is primarily related to sociodemographic variables, like household size and income. Brounen et al. (2013) also find the characteristics of the dwelling (i.e. size, household size, age) to be the only predictors of energy consumption. These findings are further developed by Abrahamse and Steg (2009), who identify energy savings in households to be rather associated with psychological factors – e.g. attitude, perceived behavioural control, personal norms and awareness. The distinction between behaviour and its change is crucial since understanding how current behaviours are shaped might not be sufficient to identify how to change them. Abrahamse and Steg rightly acknowledged this difference, further supported by Burger et al. (2015) who clearly distinguish between energy consumption behaviour (ECB) and change in ECB. Considering that ENABLE.EU's objective is to study what drives energy choices in the context of the energy transition, identifying the drivers of change is more valuable to formulate policy recommendations aiming at changing current energy behaviours into more sustainable behaviours.

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Last but not least, our review relies on a significant share of old publications and their validity has seldom been reassessed since their publication. For many, their value in the literature remains high, especially those carrying theory. However, considering the changing context for energy questions, some pertinent empirical studies twenty years ago might not apply to nowadays' energy choice circumstances. The emergence of technologies and digital innovation for instance could disrupt previously relevant findings, offering new opportunities for influencing energy behaviours.

4.4.5 The complexity of the factors impacting energy choices hinders a more granular understanding of these drivers

As mentioned above, the complexity of the topic has generated many conceptual models attempting to frame the multiple aspects of energy choices. Considering the amount of unknown and changing variables involved in understanding energy behaviour, even when a study is based on a solid methodology, the generalisation of findings can be risky. The example of community case studies in energy transition processes illustrates this complexity (see Part 3). Replicability of such studies is almost impossible because of different methodologies, geographic and socio-economic contexts. Such studies depend on concrete circumstances, country-specific to some extent, and therefore require high caution when their findings are to be generalised. Attention should further be devoted to the temporal and geographical dimensions raised above, but also to the interaction between variables at individual and societal level, and to the diversity of behaviours to target.

On the other hand, findings to date show that factors and strategies are often entangled and as a consequence their influence is difficult to isolate from one another (e.g. the influence of energy price changes and environmental policies in Part 1; the effects of learning and salience on behaviour (Asensio and Delmas, 2015)). As developed above on the interactions between factors, Frederiks et al. (2015a) summarise the picture: "there are a multitude of variables that together influence the nature, intensity and duration of behaviour around energy consumption and conservation" (p.597). Beyond the diversity of variables, strategies used in experimental setting also display various intensity, public targeted and levels of involvement (Delmas et al., 2013).

Uncertainty in the definitions of wording can also lead to confusion in the findings. A recent literature review points out to changing definitions of some factors, especially 'beliefs', 'values', 'attitudes' and 'motives' (Frederiks et al., 2015a). These words can sometimes be confounded or interchangeable if not precisely defined. As a consequence, overlaps between these factors exist in the literature and prevent drawing firm conclusions on the influence of each of these psychological factors.

The challenge in understanding the underlying reasons of energy behaviour lies in the heterogeneity of interventions investigating a large panel of interacting dynamic factors. This interplay of dimensions in empirical setting reflects the complexity of capturing all elements in one theoretical model. Generalising the findings of empirical studies analysing specific effects should therefore be done with caution and awareness of all the identified challenges.

While unable to fully discard this complexity, ENABLE.EU adopts a case-study-based approach deemed most adapted to study and differentiate the trends within various energy sectors and topics (e.g. between behaviours related to transportation, heating and cooling and prosuming, as highlighted in Part 2 and in the case study boxes). The cross-country studies based on comparable methods (e.g. surveys of a representative sample in all countries) and the meticulous choice of wording in each language might also help to generalise the results with more certainty. Finally, the project takes heed of the frequently observed confounding effects in research in order to design experiments isolating as much as possible each factor and strategy and thus to ensure robust findings.

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4.5 Case studies: A concrete view of the identified factors in several areas

This section consists of case studies presenting concrete examples of how the identified factors apply in each sector or topic subsequently studied in the ENABLE.EU project and shows how ENABLE.EU will contribute to research in these areas.

4.5.1 Electricity consumption and the use of RCT

For ENABLE.EU's case study on Electricity, the method of Randomized Controlled Trials (RCTs) is employed. As illustrated by numerous studies in Part 1, RCT is a quantitative method, which aims at identifying the causal effect of a policy intervention on an outcome variable, which is electricity consumption in the context of ENABLE.EU. The method derives from the Potential Outcome Framework by Rubin (1974): To identify a causal effect, one would like to observe the same household in two conditions, with and without policy intervention. A comparison of the electricity consumption in both conditions will then determine the causal effect of the policy intervention. It is, however, impossible to observe the same household in two different conditions. On the one hand, by comparing a household with intervention to any other household without intervention, the causal effect of the intervention cannot be isolated. This is because the households will also differ in other, potentially unobservable, characteristics. On the other hand, applying a before-after-comparison of the same household will not account for general time trends.

Hence, within RCTs the policy intervention is randomly assigned to households. Households with policy intervention are denoted "treatment group" and households without the intervention are called "control group". Due to the random intervention assignment and given a large sample size, we expect all households in the treatment group to be on average identical to all households in the control group with respect to their characteristics. The causal effect of the intervention can thus be determined by comparing the average electricity consumption of the treatment group with the average electricity consumption of the control group. Due to this framework RCTs guarantee internal validity when identifying the causal effect of an intervention. However, RCTs are often criticised for their external validity. Due to a selection bias the results only hold for the subject pool studied. Because households voluntarily decide to participate, they might differ from households who do not choose to participate, such that a transfer of results is not possible. Large-scaled field experiments avoid this problem, as households do not enrol for participation and are also unaware of being part of a scientific study. Allcott's (2011c, 2014) OPower studies are a famous example of such large-scaled field experiments.

Existing RCTs on household electricity consumption vary regarding the applied policy interventions in three ways: dynamic pricing schemes, behavioural interventions and informational feedback (see Part 1.3 for detailed description of these interventions). RCTs on dynamic pricing schemes test the effect of different tariff schemes and estimate the price elasticity of energy demand (e.g. see Wolak, 2007, 2011; Allcott, 2011b). Behavioural interventions are motivated by psychological insights on household demand, they encompass concepts such as social norms, altruism, reference-dependence and inattention. Informational feedback is often combined with such behavioural interventions. It concerns especially energy saving tips, and real-time consumption and cost feedback (e.g. Houde et al., 2013; Lynham et al., 2016). For these policy interventions, large-scale field experiments only find modest electricity consumption reductions (e.g. Allcott, 2011c; Allcott and Rogers, 2014).

Given this literature, there is various knowledge regarding the size of effects of different interventions, but only little is known regarding the underlying mechanism which induces the effects. Future research therefore should aim to relate the RCTs to hypotheses on electricity consumer demand in order to deepen the understanding about why different interventions influence energy consumption. To add to

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the literature on social norms, a disentangling of a pure information effect from a norm effect should be analysed. Furthermore, the effect of information provision on habit formation is unexplored. Given existing studies, the effect of information provision attenuates over time. Varying the frequency and duration of information provision will allow to derive results on how habit formation and the persistence of effects can be increased. In addition to giving information, feedback also serves as a reminder to engage in electricity conservation actions. Households might be inattentive towards these actions, such that reminders will decrease electricity consumption, even without giving additional information. This effect of reminders will not persist once the energy conservation action is a habit. These interrelations of information provision, feedback and habit formation are to be explored in greater detail within the context of ENABLE.EU.

4.5.2 The shift to low-carbon mobility

The idea of improving energy efficiency in the transport sector translates into the promotion of a movement towards a mobility involving lower CO2 emissions. In order to foster this transition, it is important to consider economic and technological aspects, socio-cultural factors and governance implications.

A first economic factor to take into consideration in the transport sector is the dependence on fossil fuels and their price fluctuations. These fluctuations have been wide over the past decades (Helfand and Wolverton, 2009) and they have been found to significantly influence car purchases and consumer choice on fuel efficiency in several studies (for example, Goldberg, 1998; Busse et al., 2013; Allcott and Wozny, 2014). In particular, these show that energy price increases are associated with higher adoption of energy efficient vehicles. However, it is also to note that the elasticity of fuel for motor vehicles dropped in recent years compared to 1970-1980 levels (Hughes et al., 2008).

In the design of measures to nudge the adoption of energy efficient technology, it is also important to avoid unintended responses to price changes. Road transport is in fact linked to a series of problems other than climate change, especially health, through pollution, and safety. In particular, safety in some cases seems to be negatively affected by improving energy efficiency and needs to be carefully taken into consideration when developing specific policies. For instance, an efficient vehicle can induce to drive more since the cost of driving has decreased (rebound effect), heightening in this way the risk of accidents. Moreover, these vehicles are often small and more vulnerable than larger (but less efficient) ones (Jacobsen, 2014).

Furthermore, the transition to a low-carbon mobility passes through the understanding of the role of consumers' social and cultural characteristics and their behaviour. In fact, on these factors depends the acceptance of the policies implemented and the modification of purchase and travel mode choices.

With respect to social and cultural characteristics, household structure is found to play a significant role. In particular, the number of children in the household positively affects car ownership (Dargay and Vythoulkas, 1999); the number of adults as well but it also increases competition for the family car, resulting in more bus fare expenditures (Nolan, 2003); while the household decision to live in urban or rural areas underlines transport preferences which can be tackled by location-specific policies (Aditjandra et al., 2013). Culture may also affect how people respond to policies, depending on how practices, such as cycling, are considered (Aldred and Jungnickel, 2014). Moreover, gender underlines different choices and propensity. In particular, women are found to be more concerned and committed to environmental issues and transport related problems (Golob and Hensher, 1998; Rienstra et al., 1999), to positively evaluate cars emission performance attributes (Achtnicht, 2012) and to have lower car use and ownership and higher bus fare expenditures (Nolan, 2003). Several other individual characteristics, such as age, education and income, influence transport related choices. For instance, younger, higher educated and high income people are found to be more concerned about environmental

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and transport policies and more likely to accept environmental policies (Golob and Hensher, 1998; Rienstra et al., 1999).

Looking at the behavioural aspects, values and beliefs play a significant role in determining attitudes towards the environment, which translates into higher acceptability of car-use reduction policies and propensity to adopt electric vehicles (Bockarjova and Steg, 2014; Schuitema et al., 2010). Moreover, being aware of transport related problems is determinant in decision to change travel behaviour (Dogan et al., 2014; Rose and Ampt, 2001). This suggests an important role of informational tools such as feedback systems and labels. However, the routinized nature of several transport related behaviours give space to the formation of habits and practices which can bound people's rationality in evaluating different alternatives (Fujii and Gärling, 2003; Schwanen et al., 2012). Direct experience policies, such as trial periods, can have a positive role as habit breaking strategy (Jensen et al., 2014; Matthies et al., 2006). Finally, several transport related choices are linked to symbolic meanings and their role in the formation of a personal identity. These can influence car type choice or the decision to opt for an electric vehicle so they need to be taken into consideration when designing policies (Heffner et al., 2007; Steg, 2005).

From a governance perspective, the reduction of emissions in the transport sector can be pursued by two main categories of policies. The first one refers to policies that directly trigger the existing infrastructure to nudge the development and adoption of new technology. These are the so-called "hard" policies, such as road pricing, financial incentives or viability modifications, as studied in Part 1 of this review. However, they often encounter barriers in terms of acceptability or for political reasons, as discussed in Part 3 (Harrington et al., 2001; Graham-Rowe et al., 2011; Gossling and Cohen, 2014). The presence of barriers and the pressing need to obtain short-term results encouraged the development of policies which directly target human behaviour. These go by the name of "soft policies" and they include, for example, travel plans, public transport marketing and information campaigns. Compared to "hard policies", the former have the advantage of being less costly and easier to implement and may be helpful to reduce car use (Matthies et al., 2006). On the other hand, their effectiveness has brought about mixed results and some authors claim for the need of a deeper understanding of contextual factors and how they affect these policies (Graham-Rowe et al., 2011; Möser and Bamberg, 2008). Hence, what appears from the literature is that these two kinds of innovation paths need to be treated as complements rather than substitutes as both of them have their limits. Used jointly they could help achieve short and long term environmental political targets (Anable et al., 2012; Chapman, 2007; Liu and Helfand, 2012).

In the context of ENABLE.EU and based on this review of the literature to date, the case study on low-carbon mobility will aim at exploring transport related choices made by European citizens. A better understanding of the influence and interplay of the identified factors will support the formulation of well-crafted solutions for enabling the shift to low carbon transportation.

4.5.3 Factors influencing decisions related to heating & cooling

Given that heating and cooling accounts for a major part of households' energy consumption, this energy service is a central issue for ENABLE.EU which will undertake a case study aiming at understanding the drivers underlying heating and cooling choices and devoting particular attention to most vulnerable consumers.

Housing attributes, such as the size, vintage and building type appear to be the principal predictors of households' heating and cooling energy demand (Santin et al., 2009). This study based on 15,000 Dutch households further shows that the effects of social and demographic characteristics are also important, albeit to a smaller extent: income, age and household size show positive relationship with heating energy consumption. The influence of gender, albeit often neglected, has mixed results in the literature so far: while some findings show that women might consume more gas for heating but less electricity

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than men (Brounen et al., 2013), other studies find no evidence of differences in attitudes between men and women (e.g. Tabi, 2013; see Part 2). Energy conservation behaviours, such as adjusting the level of temperature in the building through the modification of thermostat setting and heating only the bedrooms that are in use, resulted in energy savings, but the mere presence of adjustable thermostats was associated with higher, rather than lower energy consumption. Brounen et al. (2013) claim that household income largely determines thermal comfort preferences, as high-income households have higher willingness to pay for higher temperature in their dwellings. Analysing Dutch household data, they observed that a one-% increase in disposable income is associated with an 18% increase of natural gas consumption.

Csutora (2012) also draws attention to the significance of housing attributes. She claims that in rural Hungary, where the average income is lower than in the urban areas, the size of dwellings does not positively correlate with the income level, because people usually own their houses, often inherited through generations, and their willingness to move is low. Despite daily energy saving practices, their energy spending does not deviate from that of higher income households living in dwellings of the same size, given the poor energy efficiency performance of their houses. The author claims that supporting the retrofit of these houses would help middle- and low-income families to ensure adequate thermal conditions in their buildings.

Urban and Ščasný (2012) used data of 9242 households from 10 OECD countries to assess whether residents' environmental concern shows any relationship with their energy-saving behaviour and efficiency investments, including adjusting thermostat settings to save energy and investing in the thermal insulation of their dwellings. They found heating/cooling related energy saving habits (turning down heating and/or cooling when leaving a room) to be positively related to environmental concern. Age showed a positive relationship with performing curtailments and investing in energy efficiency. Income did not turn out to be a significant predictor of daily behaviour in general, except in Italy, where wealthier households seem to care less about energy savings in their daily routines. However, households with higher income are more likely to invest in efficiency measures (wall and roof insulation, double glazing). Interestingly, being concerned about the environment is not associated with investments in insulation, except in the case of Italian households. No difference between the energy saving behaviour of households could be detected according to their level of education. Installation of thermal insulation was also more likely to be implemented by families with more children.

Podgornik et al. (2016) examined the effect of providing information and feedback on the energy consumption of low-income households living in various countries of Mediterranean Europe (primarily using thermal energy for air conditioning and water heating), to see whether information about energy use, combined with household-specific awareness campaigns, can result in energy savings without investments in efficiency measures. The aim of the research was to check the savings potential related to a possible change in automatic habitual behaviour, based on the assumption that raising awareness and consumption feedback can activate new norms and considerations that lead to a change in daily routines related to energy use. Observed savings of the low-income households varied between 22% and 27%.

Abrahamse and Steg (2009) analysed the outcome of an internet-based questionnaire study involving 314 households in the Netherlands, with the aim of examining the role of socio-demographic and psychological factors in relation to energy use and energy conservation. During the 5-month period of the study, the experimental group received tailored information on possible measures to reduce their energy use, including gas consumption for heating purposes. A 5% reduction goal was set for the participants, and they received continuous feedback on their consumption. While the original energy use of the households could be explained mostly with socio-demographic factors (income and family size), the achieved change in consumption (energy savings) was rather related to psychological factors (variables associated with the attitude toward energy conservation), indicating that energy

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conservation requires conscious efforts to change behaviour.

Aravena et al. (2016) analysed a database of Irish households applying for investment grant to carry out energy efficiency upgrades in their homes. They found that the main motivation to apply for grants, indicated by 91% of the respondents in the sample, were purely economic: expected savings from decreased energy consumption. Having information on applicants who realized their investments (adopters) as well as applicants who failed to complete their planned efficiency upgrades (non-adopters), the authors could identify the key barriers to investments. The most prevalent barriers found were the lack of own funds, and the belief that the investment would not result in sufficient returns. Interestingly, the income of households was not significantly related to the probability of adopting wall and attic insulation, only to the likeliness of upgrading gas boilers and installing heating controls, suggesting that adopters considered insulation to be a worthwhile investment irrespective of their income level.

Energy saving generated through energy efficiency measures is often less than expected, due to the rebound effect. Haas and Biermayr (2000) measured the rebound effect related to building retrofits in Austrian households to range between 15 to 30%. Chitnis and Sorell (2015) estimated the rebound effect resulting from the improvement of the efficiency of domestic gas use for heating purposes to be 41% in the UK. Gram-Hanssen et al. (2012), found evidence of 100% rebound effect in case of summerhouses in Denmark following the installation of air-to-air heat pumps, detecting no reduction in electricity consumption on the average. However, in case of permanently occupied dwellings a 26% average reduction was achieved after the installation.

Although the rebound effect reduces the magnitude of savings attributable to investments in energy efficiency, in case of low-income households the increase in heat consumption is associated with reaching the appropriate temperature level. Howden-Chapman et al. (2009) investigated the effects of insulating homes of low-income tenants in New Zealand, based on results of a community-based trial, and observed a 5% reduction in the energy use of the intervention group, while the consumption of the control group increased 8%. 16% of the tenants decided to take the advantage of energy savings in the form of financial gains, whereas the rest chose to benefit at least partially from the insulation in the form of higher indoor temperature. Poortinga et al. (2017) also provide evidence on the positive effects of a policy-led energy-efficiency programme targeting low-income households in Wales. Their monitoring study involved 88 households, receiving interventions tailored to their homes. As a result of the investments, average daily gas usage dropped by 37% as compared with control households. The intervention raised indoor air temperature in the order of 1.0–1.5 °C, helping most of the households maintain temperature within the healthy comfort zone.

The large range of identified factors influencing heating and cooling choices and behaviours justifies the need for a thorough study taking into account demographic diversity, economic constraints and institutional contexts. ENABLE.EU will raise these questions by leading focus groups on heating and cooling behaviours in order to formulate solutions to energy poverty and foster energy conservation.

4.5.4 From consumer to prosumer

While the number of consumers producing electricity at home is rapidly increasing in many European countries, this aspect of energy still tends to be overlooked in research. ENABLE.EU attempts to fill this gap by studying the question of prosumers in a dedicated case study.

The planned roll-out of smart meters together with falling prices of solar Photo Voltaics (PVs) is expected to facilitate a shift towards a growing number of prosuming households. Photovoltaic cells allow different types of consumers to produce their own electricity and as such the technology is disruptive in the way it operates with a bottom-up logic rather than relying on a centralized energy

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system. Hence, solar Photo Voltaics (PVs) technology, may pave the way for a global transition of power generation by challenging the traditional centralized power systems with the bottom-up feed-in of electricity to the grid (Schleicher-Tappeser, 2012). In Germany as well as in UK, the governments started to support decentralized energy production in the early 2000s (Walker et al., 2007; Jacobs, 2012). While Germany had this as a main element in its renewable energy support scheme, the UK introduced a range of smaller state aid schemes that underpinned local, on-site energy production. During the 2000s, this feature became even stronger in the two countries (see Devine-Wright and Wiersma, 2013; Stefes, 2010). While this resulted in dramatic changes in the way the German electricity market functioned, the energy system in the UK continued to rely primarily on large-scale, centralized production. Decentralized energy has been given less attention by Norwegian policymakers (see Boasson, 2014). Although there has been a growth in small hydro and district heating in Norway, the plants tend to be too large to be regarded as part of a "consumer to prosumers" shift.

Several studies point to the characteristic of electricity as a largely invisible good, which means that it tends to escape human consciousness and reflexivity (Lindén et al., 2006; Pedersen, 2000). Electricity's invisibility forms one of the underlying barriers to electricity conservation and might also negatively influence the likeliness of households becoming prosumers. On the other hand, consumers' engagement with electricity generation might lead to increased "visibility" and awareness, and affect energy practices in households (see Bergman and Eyre, 2011). Also, several authors have shown that electricity is dominated more by external factors such as price and income rather than by internal factors such as values and emotions (Sælen et al., 2012; Pedersen, 2000). Winther and Bouly de Lesdain (2013) indicate that the low price of Norwegian electricity discourages household customers from saving. It might be hypothesized that low prices will also discourage households from becoming prosumers.

Smart grid and smart meters have the potential to give end-users a more active role by empowering them with tools that make it possible to monitor, understand and manage their energy behaviour (Da Silva et al. 2012) and also to produce electricity and deliver it to the grid. However, there is a question as to who will have the opportunity to become prosumers, and who will involve themselves as prosumers. Darby (2012) discusses how smart metering could affect fuel-poor households. She finds that the effects are ambiguous. The restricted access to new technology, know-how and resources might affect the fuel-poor negatively by creating hindrances that prevent them from becoming involved in the smart metering technology. On the other hand, the use of smart meters might increase awareness through the potential to develop clear, accurate information by, for instance, the deployment of energy displays. Also, a study from Norway shows that households with lower income levels might have fewer opportunities to engage in flexible energy consumption practices (Westskog, Winther and Sæle, 2015). This might indicate that the early adopters of prosumer technology will come from the higher income groups.

Culturally determined social dynamics also constitute a drive for change (Shove, 2003; Wilhite, 2008) and might influence prosumers in their energy practices. According to Shove's framework, the drivers behind new technical solutions and demands are shaped through two main forces:

- Development, implementation, configuration and marketing of the systems of provision influence what people can do with the technology (cf. "scripts" Akrich, 1994).
- Socially situated end–users influence the extent to which the new solutions will be utilized. This drive for demand is socially conditioned (cf. Pantzar, 1997).

Social groups have enabling, mediating, and aggregating functions which affect actors in the system (Janda and Parag, 2013). Pantzar (1997) offers perspectives on the process from the first emergence of a technology on the user side towards the normalization of this technology. He illustrates how air conditioning in a given context moved from being a desired novelty (expressing social status), to an object that could be legitimized in functional terms (considered to serve a specific purpose, such as a comfortable indoor climate), and finally to being considered "normal". Mass consumption takes place in

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the "normal" phase, and at this point it may even be socially dangerous not to comply with the established norm. This perspective is important for understanding the development of prosumer households, where we expect the prosumer role and adhering technologies to have the status of being a novelty and thus a marker of difference and identity.

Finally, policies, regulations and practices of businesses might influence prosumers. An example of how policies might be decisive for the outcome of household practices is provided by Westskog and Winther (2014), who found that many Norwegian end-users consider electricity to be a common good. This perception is not congruent with the principle underlying the liberal market pricing system, and the authors show how this mismatch in "logics" reduces people's willingness to engage in energy savings. Similarly, Schleicher-Tappeser (2012) argues that the transition of the energy system that might be envisioned by an extensive prosumer development will signify a change from a top-down energy system towards bottom-up dynamics. Schleicher-Tappeser (2012) points out that the speed and ease at which this change will take place depend to a great extent on the evolution of regulatory frameworks, business strategies and practices, and this needs to be researched.

This will be done within ENABLE.EU's case study, which will focus on understanding the reasons motivating households to become prosumers and how they respond to regulations. Emphasis will be put on the question of gender. Studying the different approach of men and women towards the production of their own energy can help to adapt policies and communication to each gender's perspective. Moreover, the case study taking place in several countries, it will provide insights into cultural differences and their implications for policy.

4.5.5 Assessing governance bottlenecks and their impact on individual and collective energy choices

The ENABLE.EU case study on governance is focused on studying the governance bottlenecks that impact individual and collective energy-related behaviour and choices in the transition to low-carbon economy and society in Europe. The case study employs qualitative methods, relying mainly on expert assessments of diverse group of stakeholders – academic scholars, officials from the executive, regulatory and legislative powers, private and public energy business experts, and civil society representatives. The energy transition requires disrupting the current energy system based on fossil-fuels, centralised generation, supply-side orientation, and all the practices, policies, technologies, norms and attitudes linked to this system, while at the same time developing and introducing sustainable alternatives. This raises the challenge of good governance and of consistent policy-making that is predictable and based on a long-term strategy that cannot be easily overturned in the future.

The governance of energy transition should be performed by a multitude of actors including the energy industry, local governments, civil society organisations, and consumer and prosumer associations. To implement a new technology shift successfully, one needs to not only develop the physical ('hardware') and institutional ('software') infrastructure, but also make sure the consumers accept the shift.

Following Wagner's theory (2013), the case study on governance barriers will assess the first three dimensions of policy design and implementation for supporting the energy transition:

- Efficiency: the degree to which policies make use of the market mechanism to achieve specific renewable energy (RE) targets.
- Dynamic incentive effects: the degree to which the policies induce technological change.
- Distortionary effects: the degree to which the policies distort competition or have a negative effect on structural or regional policy objectives.
- Environmental effectiveness: the policies ability to meet predefined environmental targets.

Among the key mechanisms for supporting the deployment of RE technologies is the use of standards

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and regulations[27] (Wyns et al., 2014). While the introduction of formal standards constitutes a market based policy approach, regulation is rightly viewed as a top-down policy instrument. The effect of introducing and coupling these two mechanism into a market depends on several social, economic, technological and policy variables, including path-dependent initial structure of the domestic energy market, the maturity of RE technologies and economic feasibility of their diffusion, as well as the extent of market uncertainty, information asymmetry and regulatory capture (Blind et al., 2016).

The success of the energy transition will depend to a large degree on easing the penetration of innovative technologies, not only in terms of supporting the technological development itself but also in terms of building and supporting the socio-technical and economic environment of technology emergence and diffusion. In this sense, public policy is a key facilitator of technological and social innovations towards low-carbon future (Nicolli and Vona, 2016). Public support schemes can play the most important role in driving forward energy markets and technological breakthroughs, especially in the renewable and energy efficiency sectors (Johnstone et al., 2010). Demand for low-carbon growth is more difficult to ensure in countries with lower income and economies dominated by micro and small enterprises with limited finances available to invest in innovative technologies. It is even unlikely to grow unless public policy creates the right environment coupled with financial incentives for their development and adoption. Besides, practice has shown that when mismanaged, public support to green innovations may lead to waste of precious public resources instead of stimulating job creation and falls in prices. The impact of public interventions on the greening of the economy is highly dependent on regulatory quality, on the flexibility of the product and labour markets, and other characteristics, making the management of such a transition a highly politicised and difficult issue.

Another factor driving renewable energy technology innovation is the structure of the energy market. The more open and competitive energy markets are, the more effective renewable energy policies and support schemes are in fostering green energy innovation (Nesta et al., 2014). Another line of research argues that public support schemes are in essence market enablers as they allow for new energy producers (i.e. PVs, wind turbines and biomass installations) to join the market, imposing competitive pressure on large-scale incumbent producers (Frondel et. al., 2010).

Most European energy systems could be described as based on 'top down' control (Roelich, 2016) and governance is thus focused on generation ignoring the role and drivers of the power demand. The development of trade and regulatory systems have historically also followed the centralised policy pattern. This path dependency has locked countries in a supply-driven governance framework, limiting their potential to steer the change to demand-driven and user-centred framework.

The development of demand- and user-driven governance framework requires a shift in the national and local energy policies, and is based on the assumption that consumers can encourage the expansion of decentralised energy production and RE market, reduce public opposition towards climate change policies, and increase capital investments in energy transition projects. In the late 1990s, the wider proliferation of such activities and the shift in national and EU energy policies towards sustainability led to the recognition of the importance of better integrating energy consumers in the energy decision making. More recently, the role of decentralised energy generation started to be recognised in addition to the established energy supply sources. Not surprisingly, energy policies have been mainly designed to support large-scale energy projects, while consumer-centred initiatives remained mainly small, short-term and often non-coordinated by the different government departments and agencies (Hielscher, 2011).

The change of the policy approach in some countries, e.g. the UK, Germany, and Denmark, has proved both the environmental effectiveness and economic efficiency of low-carbon policies, thus supporting

[27] See Part 3 for a definition of standards and regulations by Wyns et al. (2014).

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the development of prosumer behaviours (see Part 4.5.4). However, most of the research, explores mainly consumers' motivations to become prosumers (Gangale et al., 2013), while analyses of consumers' participation in policy design and implementation from the viewpoint of governance are almost missing. The case study on governance tries to overcome this weakness, focusing on barriers towards user involvement in policy decision making – both in terms of regulatory frameworks and everyday practices of policy decision making. Hence, the introduction of regulatory changes will be analysed as an issue of social acceptance of energy transition policies and technologies. Uncertainty and delays in the implementation of such policies could be major obstacles to social acceptability and thus to the diffusion of innovation and investments flows (Negro et al., 2012; Haas et al., 2011).

The establishment of multi-level governance regimes can also be an important barrier to the implementation of low-carbon policies and to the successful diffusion of RE technologies. Even in countries leading the energy transition, there are barriers (e.g. dependence on central government) that lower the effectiveness of the governance process on local level (Smith, 2007). Besides, every strategy on European level should be adjusted to the geographical particularities of the Member States as using similar support schemes does often show different results in two countries (Reiche at al., 2004). Examples of such specificities are numerous: the introduction of a feed-in-tariff policy on electricity production in Bulgaria has largely contributed to a speculative investment environment (CSD, 2014). Similarly, green certification can be a suitable RE policy support tool with flexible energy suppliers, but much less in highly regulated markets (e.g. in some CEE countries) (Meyer, 2003).

When it comes to the discussion of the promotion of low-carbon energy, the financial aspect is often put as one of the main challenges. Low-carbon energy is often presented as expensive and economically inefficient with detrimental effects on the country's economic competitiveness.

A further governance barrier is related to the socio-political relations in the implementation of the energy transition process. Again, the active engagement and participation of consumers in the design and implementation of energy transition policies is highlighted as vital for the success of RE programmes through gradually increased public support. The case study is focused on these characteristics but takes them into account as structural features of the policy-decision making process, e.g. considering energy poverty and hence energy affordability as a key challenge for the design and implementation of low-carbon energy policies.

The division of power on different governance levels is another factor, which as many scholars argue, usually complicates the energy transition process and is of a specific interest in the case study. Rio et al. (2008) focus on the obstacles for promoting renewable energy sources caused by the lack of interest of local authorities to spend time and resources to engage in renewable energy promotion programmes. As research on Bulgaria points out, the policy has not supported the empowerment of local communities to actively join the energy transition but was replaced by centrally-planned support programmes that benefit large investors instead of community-owned generation (CSD, 2011; CSD 2011a). As a result, the local authorities have not been able to develop the necessary administrative and technical capacities, reinforcing the centralisation of policy decision making. The case study also devotes special attention to the establishment of energy transition governance as horizontal priority for diverse sectoral policies (e.g. in the fields of energy, climate, science and technology, economy, transport, etc.) and how these horizontal priorities are inbuilt in the regional and local policy and institutional frameworks.

Last but not least, the case study on governance focuses on the impact of public trust in political institutions, incl. those developing and implementing energy transition policies. The links between consumer engagement and the level of public trust in political institutions and policy-makers will be analysed as a key determinant of the acceptance of energy transition on individual and community level. It focuses on issues of procedural and distributive justice, as well as those of trust towards external actors, engaged in the implementation of low-carbon projects. As discussed above, research on the topic

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mainly refers to the engagement of the local community as having an essential effect on the positive attitude towards energy transition projects (Wright, 2005; Warren et al., 2010; Bailey et al., 2011), but research on public trust as a factor is vastly missing.

4.6 Conclusion

After a review of economic, socio-cultural and governance factors, this last Part aspires to bring these aspects together and provide a more comprehensive framework to address energy behaviour change. The theoretical background on energy consumption and pro-environmental behaviours has been developed over several decades and offers solid foundations for mapping the central questions related to energy choices. Several theories and concepts are widely relied upon in the subsequent literature. In addition, conceptual models and frameworks have attempted to bring a global picture of all the issues and dimensions involved in energy choices. Our understanding of the topic within ENABLE.EU draws from this high-quality theoretical background.

Based on the findings of the preceding Parts and additional literature, this Part attempts to highlight points of consensus and divergence but also to insist on elements deemed most relevant to orient future research and policy recommendations. While generalisation of the analysed findings is difficult due to different settings, locations and methodologies, their review offers valuable insights to understand energy consumption patterns through different energy topics and sectors.

Yet, the reviewed literature suffers from several weaknesses and difficulties: some lie in the methodology and scope of research, while some others are linked to the complexity of the energy sector and are thus even more difficult to overcome. In the scope of ENABLE.EU, our empirical approach will attempt to build on the identified gaps and difficulties.

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General Conclusion

This literature review examines the drivers of energy choices identified by the social science research led over the last 30 years. The analysis of these findings aims at mapping the drivers at play and setting the scene for the next steps of the ENABLE.EU project. This also explains our choice of factors' categorisation into technological, economic, social, cultural and governance aspects. ENABLE.EU is rooted in this interdisciplinary approach in order to capture the interactions of the numerous drivers and barriers to energy behaviour change.

The final purpose of this project is to deliver well-crafted policy recommendations for policy-makers at EU, national and local level. Keeping this purpose in mind, we developed this review as a basis for determining the drivers or combination thereof with the highest potential in fostering energy behaviour change. This further implies identifying gaps in the empirical research to date in order to frame and position the studies led within ENABLE.EU so that they can bring the highest added value for the formulation of innovative recommendations, and in the end benefit the Energy Union.

Analysing over 400 academic articles, this review testifies to the abundance of explanatory elements and findings through various disciplines. Although it is difficult to draw an accurate picture of the drivers of energy choices based on a portion of the literature, the review attempts to highlight points of consensus, and conversely, elements backed by mixed findings. For instance, strategies like real-time feedback provision, social comparison and targeting of specific groups in general seem to positively influence energy conservation, while studies comparing the impact of different types of information provision diverge on the effectiveness of financial and environmental appeals. Demographic variables like income and gender also show various effects on energy behaviour depending on the studied topic/sector and the empirical setting. Furthermore, some studies question the use of several strategies to induce a specific behaviour as their synergy often heightens their general effectiveness but also the cost of intervention. This illustration shows that beyond the effectiveness of a specific strategy, policy should not neglect several other essential aspects, such as synergies between factors and strategies, policy cost, timing, consistency with other policies and institutional context.

The comparative approach of ENABLE.EU based on eleven European countries will provide insights about energy consumption patterns in countries with diverse energy cultures, institutional contexts and levels of development. While limited in time, some experiments led throughout our project will be designed in a way allowing for continuation. Long-term research can indeed bring substantial insights for assessing the accurate impact of a policy. Some parts of the project will also assess the role of intervention frequency, an aspect often neglected, while it could be crucial to optimise a policy design. The joint work of a large consortium of partners contributes to enhancing the diversity of approaches and disciplines. This international and interdisciplinary collaboration helps to build on a more comprehensive framework of interrelated variables to further apprehend the challenges of energy use. Moreover, empirical research within ENABLE.EU will take into account all the weaknesses identified and thus attempt to rely on the most reliable methods, providing solid findings. Finally, to account for the complexity inherent in the study of energy issues, the project adopts a case-study-based and comparative approach (as illustrated above in Part 4.5) with research designs specific to each case study and attention devoted to avoiding confounding effects.

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