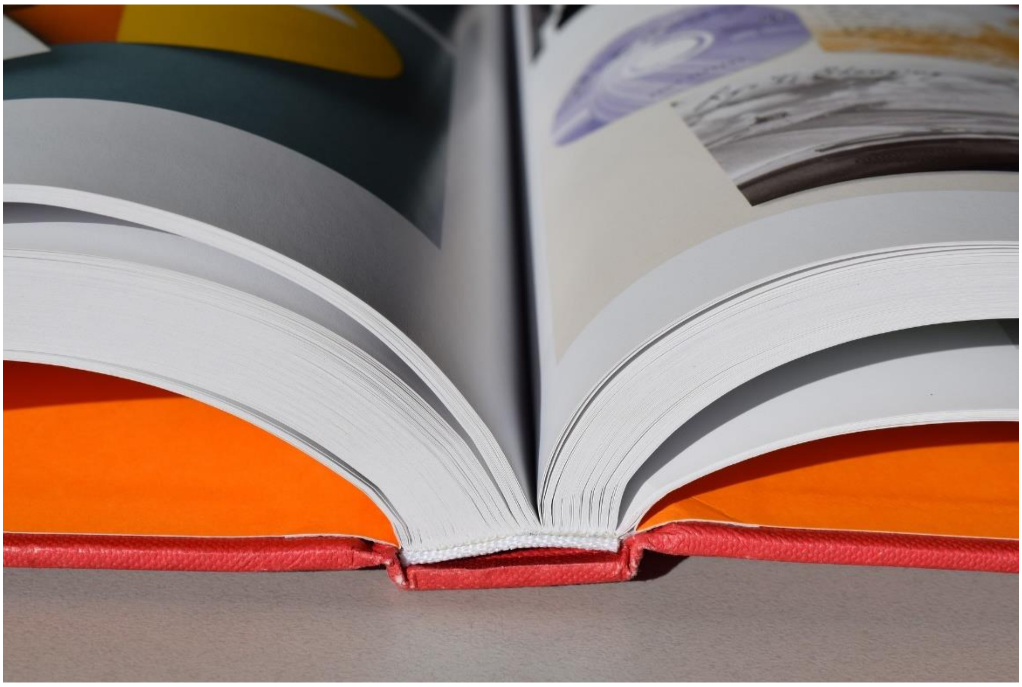
Report No ECHOES 3.1 – D3.1 Literature Review

ECHOES Report

Social Science Perspectives on Electric Mobility, Smart Energy Technologies, and Energy Use in Buildings – A comprehensive Literature Review



ECHOES Report

Social Science Perspectives on Electric Mobility, Smart Energy Technologies, and Energy Use in Buildings – A comprehensive Literature Review

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ABSTRACT

This report forms the basis for further research in ECHOES and gives at the same time an overview about the state-of-the-art. Based on a literature review with an initial screening of several thousand sources (and 597 sources reviewed), research from all three ECHOES research perspectives and technology foci were mapped and research gaps identified which will be addressed in ECHOES. The overall conclusion is that there already is a considerable amount of research that deals with specific technologies, problem areas, or research perspectives, but there are shortcomings related to more comprehensive and integrated analyses. The existing literature identifies factors playing a role in decision-making on the household level with respect to all of the listed issues in relation to all three foci, i.e. micro-, meso- and macro-level. However, it does so in a fragmented and disciplinary siloed way.

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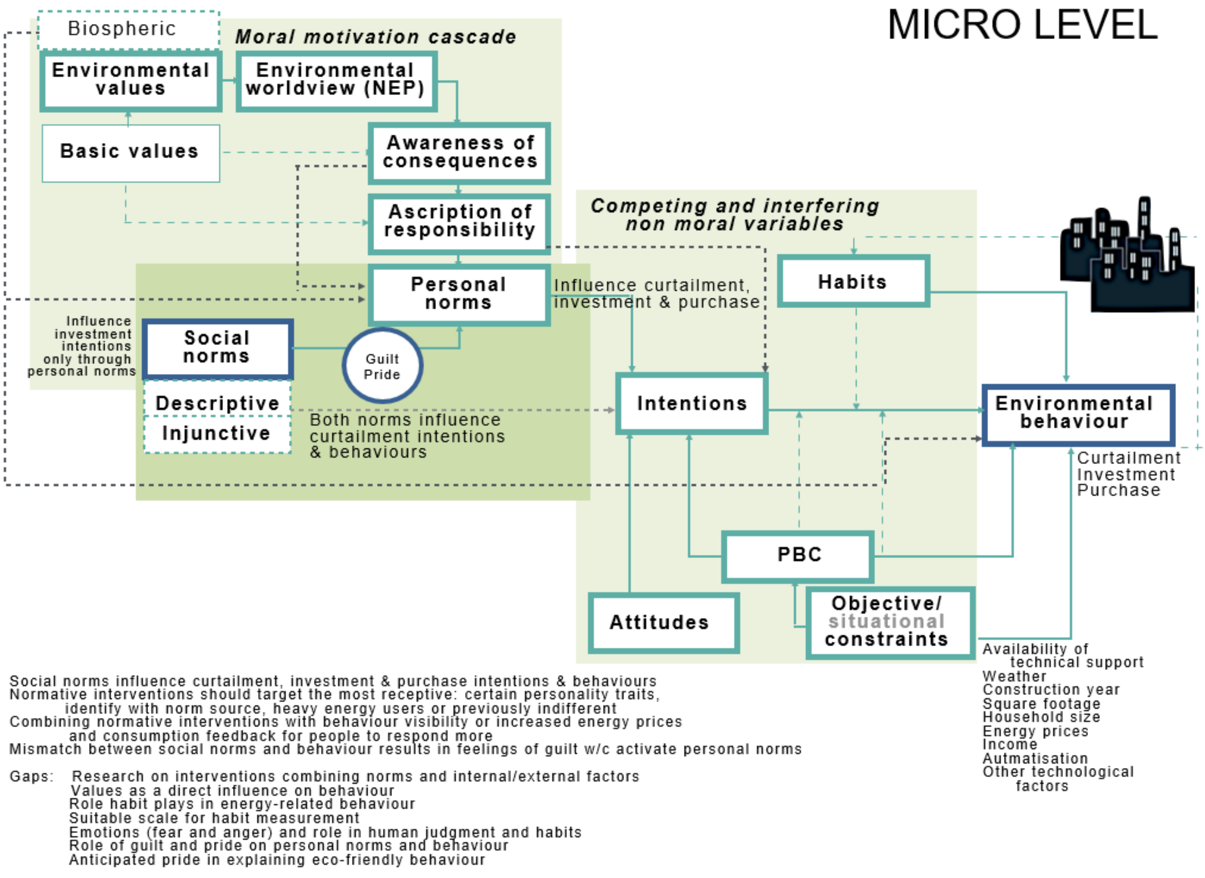
EXTENDED SUMMARY

This report forms the basis for further research in ECHOES and gives at the same time an overview about the state-of-the-art. Based on a literature review with an initial screening of several thousand sources (and 597 sources reviewed), research from all three ECHOES research perspectives and technology foci were mapped and research gaps identified which will be addressed in ECHOES. The overall conclusion is that there already is a considerable amount of research that deals with specific technologies, problem areas, or research perspectives, but there are shortcomings related to more comprehensive and integrated analyses. The existing literature identifies factors playing a role in decision-making on the household level with respect to all of the listed issues in relation to all three foci, i.e. micro-, meso- and macro-level. However, it does so in a fragmented and disciplinary siloed way. Thus, there are gaps to fill in describing the decision-making processes from a comprehensive standpoint and with a multilevel perspective. The research identified does not allow to predict decisions in a satisfactory way, nor does it derive integrated policy or market recommendations. Hence, the literature review has confirmed the need for the type of comprehensive and integrated analysis that will be conducted in ECHOES.

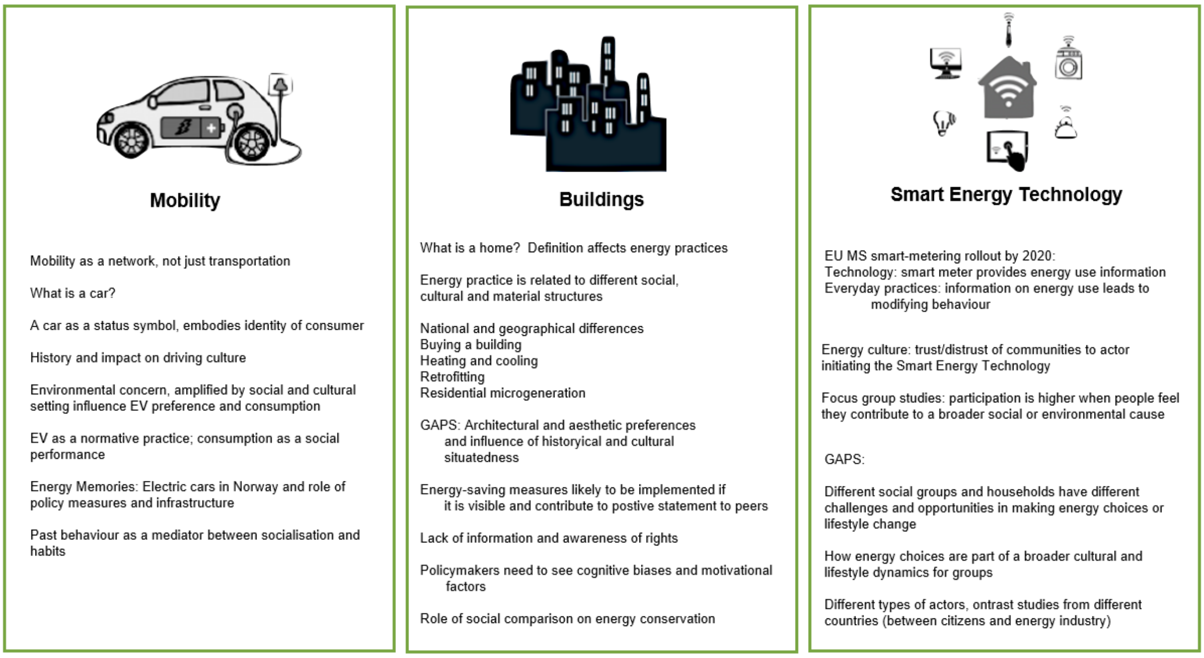
			
MACRO Motivators and barriers at formal, collective and individual levels	**Motivators** **Formal** Effective policy & regulatory instruments, Environmental concerns, Market based factors **Collective** Effective incentives, Environmental concerns, Confidence in business, Local participation **Individual** Social factors, Environmental awareness, Economic advantages, Incentives, Educational factors, Individual motivation, Attitude, Trust, Demographics	**Motivators** **Formal** Effective policy & regulatory instruments, Environmental concerns, Market based factors **Collective** Effective incentives, Environmental concerns, Confidence in business, Open market, Local participation **Individual** Social factors, Environmental awareness, Economic advantages, Incentives, Functional aspects	**Motivators** **Formal** Effective policy & regulatory instruments, Transparency, Environ-mental concerns, Economic performance, Infrastructure, Smart controls, Innovation, Energy profile, Prosumers **Collective** Local participation, Energy self-sufficiency **Individual** Social factors, Environmental awareness, Individual motivation
MESO Energy culture, lifestyles and memories	Car as a status symbol, embodies identity, driving culture, EV preference, EV as a normative practice, role of history on Energy memories	Home definition influence on energy practices, National and geographic differences, Buying a building, Heating and cooling, Retrofitting, Residential microgeneration, Social comparison and energy conservation	Smart metering rollout by 2020, provides information and changes consumer energy practices, Place attachment
MICRO CADM and SIMPEA	Use CADM and SIMPEA Distal factors may also play a closer role to influencing behaviour and attitudes NEP influences intention to adopt fuel-efficient vehicle via its effect on attitude Egoistic values have a direct effect on adoption of alternative fuel vehicle Objective constraints include: Household size, Income Policy measures, Toll waivers, Bus lane access, Number of cost factors, Purchasing price, Range, Long charging time, Charging infrastructure	Use CADM and SIMPEA Objective/situational constraints: Availability of technical support, Weather, Construction year, Square footage, Household size, Energy prices, Income, Automatisation, Other technological factors Social and personal norms influence curtailment, investment and purchasing behaviours. Emotions such as guilt and pride are mediators between social and personal norms Guilt results from mismatch between behaviour and social norms For increased response, combinine normative interventions with behaviour visibility or increased energy prices and consumption feedback	Use CADM and SIMPEA Several models and theories used for technology acceptance studies. The higher the perceived risk, the more negatively it affects acceptance of technology and intention to use The higher the usefulness, the lower are the concerns about risk The consumers´understanding of the smart grid is necessary due to its influence on PEOU and PU TAM as the most robust model in considering technology acceptance VBN and VIP both underline the importance of focusing on the benefits to the environment Media and pulic figures as secondary sources influencing intentions Perceived risk as major factor to accepting smart grid Attitude is most influential on intention

The comprehensive literature study has uncovered a number of relevant factors and starting points for the work in ECHOES. The table above shows the main reviewing concepts and findings as an overview, distributed by analytical levels and technological foci. At the macro level, the main concept is to map motivators and barriers for each technology and for the three different sub-levels defined as different formal units. This produced an interesting overview of which factors are relevant for one specific decision-making level or technology, and which factors are of overarching importance. At the meso level, the main contribution of this report was to review literature on the socio-cultural aspects of energy use through the analytical lens of the concepts *energy culture*, *energy lifestyles* and *energy memories*. These place the decision-making units into a cultural and historical context and tap into explanations of energy use behaviour that go unnoticed by by the individual or societal focus. At the micro level, a comprehensive review of the individual centred approach is provided, which shows how commonly used concepts such as values, worldviews, personal and social norms, attitudes, habits and routines, objective and subjective constraints and facilitators interact to determine decisions in the three technology focal areas of ECHOES. The factors received good support by the literature review, though the concepts of emotion (most importantly guilt and pride) as a driver of energy and social identity/identification were found as missing.

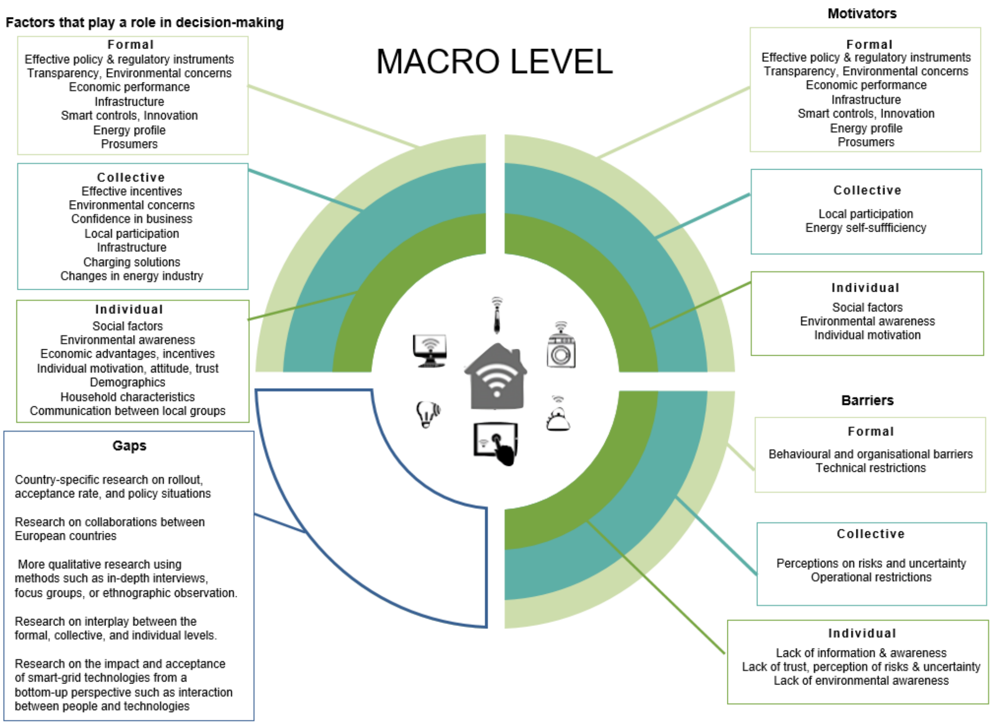
In general, the review of individual factors shows that most of the influences postulated have received considerable attention in past research, with some differences between the technologies in focus here. However, it remains unclear if the differences are substantial or rather circumstantial, due to a specific study advocating for a particular effect selecting only one of the three technology foci. It is for example likely that the emotion reaction resulting from mismatch between own behaviour and social norms (a feeling of guilt or shame) is not specific to the building focus, but will in the same way be found in the other technological foci. It is also interesting to note that for some technology foci, a modelling tradition related to the CADM is rather common (energy in buildings, electric mobility), whereas for adoption of smart energy technology, technology adoption models (TAM) are more common in the literature, although also energy choices in buildings and electric mobility can be framed as problems of technology adoption and smart technology can be analysed from the perspective of the CADM. The figure below shows an example of the relations between individual factors found supported by the literature.



At the meso level, the key conceptual approach for reviewing the literature has been through the lens of the theoretical concepts 1) energy culture, 2) energy memories (which is a new development in the ECHOES project), 3) energy lifestyle and 4) place attachment. Here, the social and historical embeddedness of energy decisions regarding the three technology foci was the core of the analysis. Important gaps identified at the general level are that 1) there are advantages and analytical improvement of using the energy memory approach over the related concepts of energy culture and energy lifestyles because energy memories not only include the cultural and contextual rooting of the behaviour, but also the temporal/historical dimension, and 2) place attachment and place-related meanings are not investigated with respect to the energy memories development. At the technology-specific level, the main findings are presented in the figure below.



The review at the macro level has been completed by distinguishing three sub-levels that all focus on the three technological focuses, mapping 1) factors important in decision-making, 2) barriers, 3) motivators and 4) research gaps, the figures present the results within each technology. An important general finding is that there is a need for more research on energy choices in collective social units as well as research, which takes into account the necessary interplay between the formal, collective, and individual levels. For the main results distributed by technologies, see the figures below. An example of the results on the macro-level is given in the figure below.



Main research gaps identified in the literature review:

			
MACRO	More collective and formal level research to understand EV market diffusion International level research on collaboration of European countries Investigating all levels of attitude (cognitive, affective and behavioural) Total cost of ownership (TCO), key variables Impact of social networks on individual´s preferences Studying the neighbour effect of the diffusion of new technologies	Establishing a methodological framework Overview & Guidance Requirements for new buildings Sensitivity studies of building standards: further development for products Software development Studies on private sector and energy efficiency Cross-country comparisons Policy development Exploring attitudes, habits and experience	Country-specific research on rollout, acceptance rate, and policy situations Research on collaborations between European countries More qualitative research using methods such as in-depth interviews, focus groups, or ethnographic observation Research on interplay between the formal, collective, and individual levels More research on the impact and acceptance of smart-grid technologies from a bottom-up perspective such as interaction between people and technologies
MESO	Mapping of advantages and for making analytical improvement of using the Energy memory approach Place attachment and place-related meanings investigations with respect to energy memories development Research on mobility as a network Definition and meaning of car as a concept History and impact on driving culture EV as a normative practice; consumption as a social performance Electric cars in Norway and role of policy measures and infrastructure Past behaviour as a mediator between socialisation and habits	Mapping of advantages and for making analytical improvement of using the Energy memory approach Place attachment and place-related meanings investigations with respect to energy memories development Architectural and aesthetic preferences and influence of historical and cultural situatedness Exploring the role of social comparison on energy conservation	Mapping of advantages and for making analytical improvement of using the Energy memory approach Place attachment and place-related meanings investigations with respect to energy memories development Exploring advantages and analytical improvement of using the Energy memory approach Exploring place attachment and place-related meanings with respect to energy memories development Exploring how energy choices are part of a broader cultural and lifestyle dynamics for groups Studies on different types of actors, contrast studies from different countries (between citizens and energy industry)
MICRO	Studies on causal effects of long term experience with e-vehilcle on adoption and formation of habits Exploring attitude-internalized objective constraints Exploring the role of distal factors in influencing behaviour and attitudes	Research on interventions combining norms and internal/external factors Studying values as a direct influence on behaviour and the role habit plays in energy-related behaviour Finding a suitable scale for habit measurement Exploring emotions (fear and anger) and their role in human judgment and habits Role of guilt and pride on personal norms and behaviour Exploring anticipated pride in explaining eco-friendly behavior	Further studies of human understanding of smart grids and smart energy technology (meters, et cetera) Further exploring and testing of choices and priorities and the role of technologies in relation to this (energy feedback)

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1 INTRODUCTION AND OVERVIEW

This report presents the results of an extensive literature review of texts relevant for the scope of ECHOES. This implies a comprehensive corpus of texts as ECHOES covers three theoretical perspectives as well as three technological foci. It also implies that it is a multidisciplinary review both by disciplines covered and disciplines conducting the review. Therefore, the structure of the report very much reflects the structure of the ECHOES project itself; although the deliverable is placed and coordinated by WP3, the main bulk of the work is conducted by WPs 4, 5 and 6, and their different levels of perspective (micro, meso and macro) are presented in separate chapters (chapters 2,3,4).

The reviews levels of perspective

- MICRO: Exploring the impact of groups as small-scale energy collectives that provide a social identity for people and that guide personal cognition, motivation, and behaviour by distinct group-processes (e.g., group norms, collective efficacy beliefs, collective action) in the context of individual or household decision-making. This perspective also includes how norms and values around energy choices in such smaller groups emerge and stabilize.
- MESO: Cultures or lifestyles as constituents of medium-sized energy collectives: a set of energy practices, cognitive norms, and material culture (e.g., technology, available financial resources) that jointly influence people's decisions about energy-related behaviour, but varying across different social contexts and roles (including gender). Introducing the concept of "energy memories" as a container of previous individual or collective energy choices and experiences.
- MACRO: Formal social units as large-scale energy collectives, such as the EU, member states or municipalities with policies and decisions on an institutional level that shape people's energy-related choices but are in turn also influenced by the decisions of the individual actors.

Although the literature covered is comprehensive and heterogeneous, there is an unambiguous understanding of what limits the review as a whole – such as the project has a common denominator by "Energy Collectives". The concept acknowledges that energy choices are affected by different layers reaching from the individual as part of collective actions via the impact of cultures, life-styles and practices to the impact of larger formal social unit. Energy collectives reflect a multi-disciplinary approach to define collective processes as well as its antecedents, and consequences for peoples' and collective actors' energy behaviour, decisions, and acceptance. The unique insights from all three perspectives will be outlined in the following three subsections.

In addition to a theoretical denominator, the review is united through a common focus on three technologies and their relevance to the SET-plan. These are 1) Smart energy technologies, 2) Electric mobility, and 3) Buildings.

1) *Smart energy technologies* are at the core of what the integrated roadmap for realizing the SET-plan describes as an energy revolution (p.1). This includes distributed, small-scale renewable energy production technologies (typically rooftop solar thermal and PV, micro wind, heat pumps and biomass), but also a range of technologies for the traditional "demand side" (e.g. In-home displays, home automation, smart home appliances, new tariffs etc.) and energy storage.

The SET plan identifies 2) *electric mobility* as one of the core technologies to be implemented and developed further to increase road transport efficiency. Both passenger and goods transportation account for a substantial amount of the environmental impact of the member states of the EU (Hertwich & Peters, 2009[1]).

[1] Hertwich, E. G., & Peters, G. P. (2009). Carbon footprint of nations: A global, trade-linked analysis. Environmental science & technology, 43(16), 6414-6420.

The last technology focus is 3) *buildings* - including construction activities, insulation, energy efficiency upgrading, heating, cooling, illuminating, and energy use behaviour in buildings. A reasonable use of the territory resulting in compact urban structures was outlined among the four main aspects of key importance for urban sustainability (Leipzig Charter on European Sustainable Cities, 2009[2]).

As Figure 1 shows, the technological foci are consistent in all perspectives, which is reflected in the structure of this report. First (chapter 1.1), the scope and corpus of texts is presented as a total and for the different perspectives separately. The main chapters (chapters 2, 3, and 4) present a) main findings, b) state of the art, c) research gaps, d) suggested research and finally e) how ECHOES should contribute to filling the research gaps. Chapter 5 summarize the main findings.

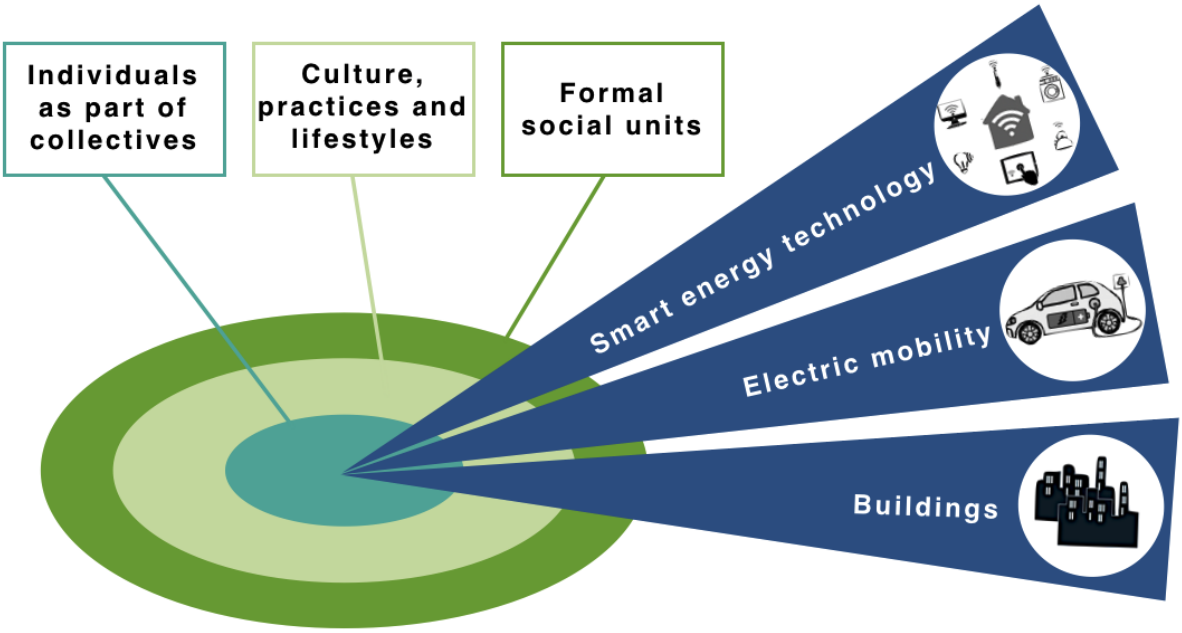

Figure 1 ECHOES levels of analysis and technological foci

1.1 Scope and the corpus of texts

This review covers in total 636 texts, mainly consisting of academic manuscripts, research articles, policy documents, public and business reports. There is some overlap in the sense that some texts are reviewed from multiple perspectives and thus parts of different sections of the report, this is seen as a strength as it allows for central documents to be interpreted from multiple perspectives and thus contribute to the different perspectives.

The overall objective for this review is to provide the foundation for further research in ECHOES, the forthcoming chapters therefore all identify important findings, state of the art, gaps in literature – and by this suggest a direction for future studies in general and how ECHOES will contribute to cover essential research gaps.

As with all the methods applied in ECHOES, the literature review follows a predefined strategy that is described in the box below:

[2] Informal Ministerial Meeting on Urban development and territorial cohesion. Leipzig Charter on Sustainable European Cities, 2007; www.eufunds.bg/document/355

Procedure for the literature review

- Keep a log that tracks all steps taken while performing the literature review
- Choose a topic, define relevant research questions
- Define the scope of the review
- Select the databases to be used for searches
- Conduct searches; keep track of all search words and combination of search words
- Review the literature and fill out the relevant templates according to your findings
- Register the references reviewed on the literature review database
- Store the data in their respective folders on SharePoint

By following this procedure, methodological rigour and verifiability is ensured, while methodological variations linked to different a) professional traditions, b) research objects and c) analytical levels are possible. Procedures and selection processes are presented in more detail in the following sub chapters.

Corpus of text chapter two – micro level

In Chapter 2, the strategies for literature search varied between the different sections, based on the maturity of the research fields. Articles included in sections 2.1.1 Electric mobility and 2.1.3 Energy in buildings were located via ancestry and descendancy searches starting from an initial set of studies the authors were familiar with.[3] The keyword-based search resulted in a total number of 9,150 hits (including duplicate hits). The number of topic-related papers (i.e., not for example methodological papers) included in section 2.1.1 Electric mobility is 40.[4] Number of topic-related papers included in section 2.1.3 Energy in buildings is 44.[5]

Scopus was used for the descendancy search and articles' reference lists were used for the ancestry search. Titles and abstracts of papers located in this way were scanned in order to exclude papers that were clearly not relevant for our purposes. This resulted in the selection of 223 papers (including the initial set of studies). These papers were then read in detail. Their subsequent inclusion in the review was based on their content's relevance. Specifically, to be included, a given study had to focus on one or more of the relevant topics (electric mobility or energy in buildings), and it had to report primary data on one or more predictors from the Comprehensive Action

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[3] Electric mobility: Jansson et al. (2010), Jansson (2011), Klöckner et al. (2013), Schuitema et al. (2013), Bockarjova & Steg (2014), Klöckner (2014), Nayum & Klöckner (2014), Noppers et al. (2015), Barth et al. (2016), Nayum et al. (2016). Energy in buildings: Stern et al. (1983), Clark et al. (2003), Schultz et al. (2007, 2015), Nolan et al. (2008), Göckeritz et al. (2010), Allcott (2011), Ayres et al. (2012), Smith et al. (2012), Sussman & Gifford (2012), Webb et al. (2013), Bator et al. (2014), Dwyer et al. (2015), Korcaj et al. (2015), Van der Werff & Steg (2015), Bergquist & Nilsson (2016), Fornara et al. (2016), Wolske et al. (2017).

[4] These are: Jansson et al. (2010, 2011), Hidrue et al. (2011), Jansson (2011), Leurent & Windisch (2011), Lieven et al. (2011), Franke et al. (2012), Moons & De Pelsmacker (2012), Dimitropoulos et al. (2013), Hackbarth & Madlener (2013), Jensen et al. (2013, 2014), Klöckner et al. (2013), Schuitema et al. (2013), Bockarjova & Steg (2014), Bühler et al. (2014), Klöckner (2014), Nayum & Klöckner (2014), Peters & Dutschke (2014), Petschnig et al. (2014), Wolf & Seebauer (2014), Barbarossa et al. (2015), Lai et al. (2015), Noppers et al. (2015), Barth et al. (2016), Bjerkan et al. (2016), Hardman et al. (2016), Junquera et al. (2016), Kaplan et al. (2016), Mersky et al. (2016), Morton et al. (2016), Nayum et al. (2016), Nordfjærn et al. (2016), Nordlund et al. (2016), Skippon et al. (2016), Zhang et al. (2016), Schmalfuß et al. (2017), She et al. (2017), Smith et al. (2017), White & Sintov (2017).

[5] These are: Macey & Brown (1983), Stern et al. (1983), Clark et al. (2003), Schultz et al. (2007, 2015), Ek & Söderholm (2008), Nolan et al. (2008), Welsch & Kühling (2009), Göckeritz et al. (2010), Ajzen et al. (2011), Allcott (2011), Litvine & Wüstenhagen (2011), Ayres et al. (2012), Smith et al. (2012), Sussman & Gifford (2012), Arpan et al. (2013), Harries et al. (2013), Van der Werff et al. (2013a, 2013b), Webb et al. (2013), Alam et al. (2014), Allcott & Rogers (2014), Bator et al. (2014), de la Rue du Can et al. (2014), Dixon et al. (2014, 2015), Jessoe & Rapson (2014), Yao et al. (2014), Asensio & Delmas (2015), Dwyer et al. (2015), Komatsu & Nishio (2015), Korcaj et al. (2015), Murtagh et al. (2015), Rai & Beck (2015), Van der Werff & Steg (2015), Yang & Zhao (2015), Yun & Lee (2015), Bergquist & Nilsson (2016), Fornara et al. (2016), Ruepert et al. (2016), Testa et al. (2016), Sudarshan (2017), Wang et al. (2017), Wolske et al. (2017).

Determination Model (Klöckner & Blöbaum, 2010; Klöckner, 2013a).[6] In addition, the meta-analysis by Dimitropoulos et al. (2013) was included as well, since it presented secondary analyses of the type of primary data we were interested in (as defined in the previous sentence). The number of citations an article received and article recency were employed as secondary criteria when there were too many articles that could have been included in a given section based on content alone.

For section 2.1.2, it should be noted as a premise that the literature on consumer acceptance and adoption of smart energy technologies is still rather limited. The term has numerous definitions and covers a range of systems. Based on the authors' knowledge of the broader field of technology acceptance in general, our literature search started from common theories employed in studies that aim at explaining the adoption of a new technologies, such as the Theory of Reasoned Action (Fishbein & Ajzen, 1975), and the Theory of Planned Behaviour (Ajzen, 1985), and the Technology Acceptance Model (Davis, 1985, 1989). In the field of smart energy technologies, the Technology Acceptance Model plays an important role because it has been used widely in the area of technology acceptance. The authors deemed the model suitable as a theoretical reference background for the literature research. Thus, based on the authors' knowledge, articles included in sections 2.1.2 Smart Energy Technology were located via backward citation searching starting from two initial studies the authors were familiar with.[7] Articles' reference lists were used for the chain searching. Retrieved references have been screened via Scopus for content's relevance scanning abstracts of papers in order to exclude papers that were clearly not relevant for our purposes.

Articles included in sections 2.2.2 and 2.3 were also located by ancestry and descendancy searches starting from an initial set of studies the authors were familiar with.[8] Additionally, we focused our search on four databases (Science Direct, Sage, PsycInfo, Web of Science) with a number of keyword combinations and articles' reference lists were used for the ancestry search. Titles and abstracts of papers located in this way were scanned in order to exclude papers that were clearly not relevant for our purposes. These papers were then read in detail. Their subsequent inclusion in the review was based on their content's relevance. We also included two recent reviews of the Social Identity Approach and global climate change (Ferguson, McDonald, & Branscombe, 2016; Fielding & Hornsey, 2016) in our ancestry search.

Because of the relatively few number of studies based on the Social Identity Approach (SIA), we did not distinguish between the three technological foci but provided a review on SIA-related studies and environmental behaviour in general. The SIA-related variables included in the review were self-categorization and group identification, group norms, and collective efficacy. For the environmental domain, we included appraisal-related variables (e.g., perceptions of climate change) as well as behaviour-related variables (e.g., future intentions to engage in pro-climate behaviour). Studies were included which had a clear reference to the Social Identity Approach and reported data on at least one of the target variables (social identification, group norms, collective efficacy).

[6] I.e., social norms, personal norms, awareness of consequences, ascribed responsibility, values, New Environmental Paradigm (a measure of pro-environmental worldviews), habits, attitudes, perceived behavioral control, and situational constraints or contextual factors.

[7] These are: Ellabban, O., & Abu-Rub, H. (2016). Smart grid customers' acceptance and engagement: An overview. Renewable and Sustainable Energy Reviews, 65, 1285-1298. Toft, M. B., Schuitema, G., & Thøgersen, J. (2014). Responsible technology acceptance: Model development and application to consumer acceptance of Smart Grid technology. Applied Energy, 134, 392-400.

[8] Abrams et al. (1990), Ayres et al. (2012), Bartels et al. (2010, 2011, 2014), Barth et al. (2016), Bliuc et al. (2007, 2015), Branscombe et al. (1999), Brewer et al. (1991, 2004), Cocking et al. (2004), De Cremer et al. (1999, 2002), Dono et al. (2010), Doosje et al. (1998), Ferguson et al. (2010, 2011), Fielding et al. (2008), Fritsche et al. (2010, 2011, 2012, 2013), Giannakakis et al. (2011), Greenaway et al. (2015), Hamann et al. (2015), Hogg et al. (2007, 2010), Honrsey et al. (2015), Jetten et al. (2004), Jonas et al. (2014), Jugert et al. (2016), Louis et al. (2007), Masson et al. (2014, 2016), McFarland et al. (2012), Murtagh et al. (2012), Postmes et al. (2014), Rabinovich et al. (2012), Reese et al. (2015, 2016), Smith et al. (2007, 2012), Stollberg et al. (2015), Terry et al. (1996, 1999), Thomas et al. (2011), van Zomeren et al. (2008, 2010, 2014), White et al. (2009)

The keyword combinations included:

- ("group norm" AND environment) OR ("group norm" AND "*nvironmental behavi*r") OR ("group identification" AND environment) OR ("group identification" AND "*nvironmental behavi*r") OR ("group efficacy" AND environment) OR ("group efficacy" AND "*nvironmental behavi*r") OR ("social identity" AND environment) OR ("social identity" AND "*nvironmental behavi*r") OR ("collective efficacy" AND environment) OR ("collective efficacy" AND "*nvironmental behavi*r")
- group AND identif* AND *nvironment) OR (group AND identif* AND "*nvironmental behavi*r")
- ("group norm*" OR "group identification" OR "group efficacy" OR "social identity" OR "collective efficacy") AND (car OR electric* OR energy OR recycl* OR transport OR travel)

Corpus of text chapter three – meso level

The ECHOES MESO-perspective concerns collective aspects of energy choices through concepts such as "culture", "lifestyle, and "place attachment", as well the relationship between broader social and historical structures and energy choices. This includes a focus on the material aspects of such structures. In other words, we are interested in how energy choices are shaped and constituted collectively and relationally. Hence, our prime interest has been to review sociological, culturally oriented, practice-oriented and life-style oriented literature that is relevant to understanding the dynamics of energy choices. For the researchers working on the meso-perspectives in ECHOES, it is also a goal to develop a new theoretical concept of energy memories. Hence, we have used this literature review to consider texts that might inform the development of this concept.

There exists a large social scientific community working on energy issues, publishing in a vast number of journals. To cover the breadth of this research we conducted a strategic search in a combination of thematically oriented and disciplinary journals. The key journals probed where *Energy Research and Social Science, Energy Policy, Building Research and Information, Indoor & Built Environment, Journal of Cleaner Production, Environment and Planning A.* These are all journals that tend to publish social scientific articles on energy and environmental issues. Further, we searched disciplinary and more theoretically oriented journals such as *Social Studies of Science*, *Theory, Culture & Society* and *Sociology*. These journals were searched with strings looking for links to the following key words: "energy consumption" + "lifestyle"; "energy consumption" + "social practice"; "energy consumption" + "history"; "energy consumption" + "sociology"; "energy efficiency, buildings, behaviour" and the additional keywords "change" and "transition". Further, the searches such as those above were combined with specific searches to the three ECHOES techno foci: "electric vehicles", "smart energy", and "building".

This produced more than 1,000 potentially relevant articles. Starting from this, we did a strategic selection of articles, where our goal was to cover the breadth of perspectives and results. Here, we have aimed to include both papers that have had a high impact on the academic discourse around such issues, as well as a breadth of thematically oriented articles with different theoretical and methodological approaches. Additional ad-hoc searches have been conducted by the research team in order to include known literature that did not surface in these searches. Google Scholar, ResearchGate and other academically oriented search engines were used. In our view, the result is a relatively even distribution of literature discussing the three different technology focus areas.

The sources address and represent different topics of energy efficiency on a diverse territorial scope and geographical coverage: International; EU 27,EU 27+, EU-28+, EU-28; international with regard to cooperative; 26 European countries, 23 European countries; Sub-Sahara African countries; national (UK, Malta, Estonia, Norway, Italy, Austria, Spain, Germany, Bulgaria, the Netherlands) and federal/state (USA, India), city level (58 cities, London, Paris, Berlin, Istanbul, Leicester); several apartment block buildings in selected EU countries and Chinese cities.

The reviewed papers fall in one of the following categories: Academic manuscripts, research articles etc.; Business reports, case study, private reports etc.; EU reports, directives etc.; Country-specific public reports, targets, strategies etc. Previous project reports (e.g. CONCERTO Premium consortium, 2014, LSE Cities, 2014, ESPON, 2010 (AB - 3)).

Literature search with regard to "Energy Memory"

Due to the novelty of the "Energy Memory" concept, relevant literature that could be found with terms like *"energy memory"* as search words was virtually not existent. Because the concept shares some of its theoretical background with the well-establisheoncept of "Collective Memory" developed by Halbwachs (1950), the search process was initiated with work linked to this concept. Interestingly, some evidence was found that the historical development of the cultural embeddedness of energy use was considered to be relevant from time to time, but no approach explicitly considering that dimension has been developed yet.

Because there is no established tradition of research with an obvious proximity to the aim of "Energy Memory", we could not identify journals or indexes that would promise a high number of hits. The primary search for publications thematically and/or theoretically linked to the aims of "Energy Memory" was therefore, for the major part, done online via *ResearchGate* and *Google Scholar*. The two were often used complementary, especially when we did not have access to a potentially interesting title. Having no quantitative criterion at hand and no well-established theoretical context, the decision if a literature finding was to be included into the corpus of texts or excluded was mainly the based on if it was expected to significantly contribute to a theoretical concept that is to be deployed through empirical research. Thus, decisions regarding inclusion/exclusion were to the major part made by an estimation of how the text would help to meet the aim of developing a new and usable concept. The primary search process was terminated, when we estimated the knowledge gain provided by further research to be only marginal; similar to the idea of *theoretical saturation* that is commonly used in qualitative research. After that, additional literature was only added to the corpus if it was found via citations in the literature selected before and promised to be useful.

Regarding the distribution of literature on the three technological foci in ECHOES, it has to be mentioned, that most publications considered do not have a clear focus on a certain technology. This is because the "Energy Memory" approach will have its theoretical foundation in concepts that practically did not come to use in the energy domain before. Most of the literature relevant for "Energy Memory" are publications from peer-reviewed journals.

The main focus in the review procedure was put on the possible identification of a canon of literature that would form a latent theoretical structure. As the "Energy Cultures" framework by Stephenson et al. (2010) focusses on similar questions in some parts but not explicitly regarding the time-dimension, we gave special attention to work directly or indirectly referring to this concept. Analytically we considered two main aspects: 1) What is the range of existing theoretical work that can potentially contribute to the "Energy Memory" concept? 2) How can such a framework be applied empirically?

The main strength of the review conducted is that the need for a culturally oriented framework that explicitly takes the chronological dimension into account, was confirmed. The main disadvantage is the fact that the number of empirical studies that could be used as a guideline is very limited.

Literature search with regard to "Energy Lifestyles"

Because lifestyle research has quite a long tradition in social science, several studies focussing on energy behaviour have been conducted in the past. The terms "energy lifestyle" and "energy lifestyles" provided an extensive amount of hits on Google Scholar, Google, and ResearchGate. Because the concept of lifestyle is especially prominent in the German speaking/writing research community and many – also international – researchers use the german terminology "Lebensstil", also the German equivalent provided relevant hits in the primary search stage. With the lifestyle part in ECHOES being conducted in 30 countries, we had to clarify especially two questions during the literature search/review:

1) What is the methodological spectrum of lifestyle research?
2) What is the best way to capture lifestyles in ECHOES?

Similar to the process for "Energy Memory", the first phase aimed at reaching theoretical saturation by the use of straight-forward search words. Considering the two central questions, the inclusion/exclusion decision was relatively clear and could be answered after a quick scan of the table of content in most cases. Because the term "lifestyle" is used at many occasions and only a small percentage is related to the identification of "lifestyle groups" by empirical and statistical methods, the great majority of hits were not relevant. Another significant share of literature addressed the ECHOES type of lifestyle research, but in a more theoretical way, which was useful only in some cases.

Concerning the three technological foci, the outcome is the following: The main part of scientifically profound literature about lifestyles aims at analysing the whole "way of life". The number of domain specific studies that is considered in the review is limited, because of our primary focus on the methodological question. The major part of literature with regard to the lifestyle part in WP5 is journal articles, but also a number of books and reports are included.

Because of our primary focus on the methodological dimension, we reviewed the literature with special consideration of how lifestyle research can be conducted in the energy domain. The grade of specificity turned out to play an essential role in this question. Another central question in our analysis was how to reach a maximum of validity in measuring energy related behaviour and behavioural impact.

The main strength of the review of literature regarding lifestyle is that it gives an adequate overview about the methodological spectrum of energy related lifestyle research. However, the number of titles representing each methodological approach is rather limited. This has two reasons: Firstly, the number of studies conducting actual lifestyle research as it is understood in ECHOES (identification and analysis of relevant lifestyle groups in a society), is indeed small. Secondly, the benefit provided by the consideration of additional studies would be marginal in terms of methodological knowledge.

Literature search with regard to "Place Attachment"

A literature search of relevant literature on place attachment related to renewable energy was performed starting from academic research papers by Devine-Wright and colleagues which are considered central in the field investigating social and psychological aspects of siting new energy infrastructure such as wind farms and power lines, including 'NIMBYism' and public engagement. A literature search with Google Scholar was performed to select papers in which place attachment played a role in energy relevant behaviour. Search terms included "place attachment", "renewable energy", and "public acceptance".

In order to complete this part of the review we referred to the theoretical assumption that people's attachment to places provides several opportunities to study human behaviour and it is potentially important in explaining pro-environmental behaviours across a range of settings and contexts. Papers selected and included in this part of review have a common central theme related to social and environmental psychology. An overview of the main results of reported studies and of common arguments is reported in order to clarify and strengthen the concept of "Energy Memory" introduced in ECHOES.

Corpus of text chapter four – macro level

The literature review for the macro level has followed the steps of defining the relevant research questions, defining the scope of the review, selecting the databases to be used for searches, conducting the searches; that is, keeping track of all search words and combination of search words and finally reviewing the literature.

The type of formal social units explicitly addressed in the relevant form (initially analysed and grouped by the column from the table prepared in the 1st part of the literature review for WP6), are: Private users explicitly addressed; Private business explicitly addressed in the category (Producers, Distributors, PX (Power eXchange - Power Exchange Operation (PEO) - pooling companies (POOLCO)); Public institutions explicitly addressed; Various actors addressed.

The two main research questions were identified as: (1) what are the methods and aims of the studies concerning the energy behaviour of formal social units, collective decision making units, and individuals regarding the three technological focii (buildings, electric mobility, and smart energy technologies)? (2) what are the attitude dimensions and variables studies concerning the energy behaviour of formal social units, collective decision making units, and individuals regarding the three technological focii (buildings, electric mobility, and smart energy technologies)? The first question aims at constructing a comprehensive literature review and the second question aims at identifying the behavioural patterns and attitude towards energy technologies.

The sources used in the literature review are mainly selected from studies listed under Web of Science, Science Direct, EBSCOHost and ResearchGate, as well as business and project reports, EU directives and published research from academic institutes, NGOs, international agencies, and EU institutes. On these databases, the main keywords used were

"*energy behaviour, energy efficient buildings, smart mobility, smart energy technologies, smart grid, low-energy buildings, passive houses, smart meter, green building, building energy management, occupant behaviour, electric vehicles, automobility, electric bus, hybrid vehicles, smart charging, e-mobility, eco-driving, low carbon transport, low-carbon electricity, demand-side management, collaborative networks, feed-in, sustainable cities, urban sustainability, ICT, prosumers, electricity consumption monitoring, smart control, power distribution, green electricity, energy self-sufficiency, consumer awareness, energy transition, energy feedback, load management*"

The initial list of references contained around 2,000 sources, and after a pre-process in terms of relevance, more than 431 of them were included for detailed analysis. The reviewed studies utilized a variety of methodologies involving qualitative methods, quantitative methods, or a mixed approach that employs both qualitative and quantitative techniques. These methodologies cover a broad range including, but not limited to, case studies, surveys, scenario analysis, statistical methods, focus group, comparative method and in-depth interviews. The methods that have the highest frequency of implementation were surveys, in-depth interviews and focus group analysis. The foremost advantage of these methods is that through qualitative techniques, they produce fresh, first-hand (primary data). This increases the value and validity of the data and enhances the data to be processed using quantitative techniques in order to generate new results, inferences and to make decisions.

2 MICRO LEVEL: INDIVIDUAL ENERGY CHOICES IN GROUP CONTEXTS

2.1 The Comprehensive Action Determination Model of Environmental Behaviour: A Conceptual Frame of Reference

When analysing individual drivers of energy behaviour in general and within the three technological foci in ECHOES in particular, the literature research reveals a substantial amount of papers from environmental or social psychology that condensate around two major action models, namely the Theory of Planned Behaviour (Ajzen, 1991, 2012) and the Norm-Activation-Theory (Schwartz & Howard, 1981). The first model conceptualizes decisions as following a mandate of rational choice, where rationality is defined within the decision maker's frame of reference and includes more than monetary costs and benefits. The second model outlines the importance of value orientations and moral norms for making decisions that have a dimension of morality to them, such as decisions about behaviours that have an impact on the environment. **Put in simple terms, whereas the Theory of Planned Behaviour highlights the best balance of costs and benefits, the Norm-Activation Theory underlines the importance of doing what feels morally right.**

More recently, empirical research has shown that energy related decisions usually combine both perspectives, which means that models combining the two can be of benefit for creating a more comprehensive understanding of individual energy choices (Bamberg, Hunecke, & Blöbaum, 2007; Bamberg & Möser, 2007). However, both models have been criticized as being of limited use in situations where the behaviour in question is repeated often (Bamberg, Ajzen, & Schmidt, 2003; Klöckner & Matthies, 2004). Whereas rationality or feelings of moral obligation are very relevant for, for example, decisions about making an investment in smart energy technology, these factors will hardly be considered for everyday use of electricity in the house, where the structural conditions, routines and habits take much more control. Furthermore, psychological research on drivers of environmental consumer behaviour has also been criticized for neglecting the role of structural conditions and context, blaming the consumer for bad environmental decisions where he or she is rather locked into conditions that do not allow for more sustainable behavioural solutions (Evans, 2011; Holm, 2003; Shove, 2010). Both lines of criticism have stimulated scholars to rethink the potential array of drivers and barriers to sustainable environmental behaviour, and to open up for more comprehensive models (Klöckner & Blöbaum, 2010; Thøgersen, 2009).

For our analyses in ECHOES we decided to use the Comprehensive Action Determination Model (CADM; Klöckner, 2013a; Klöckner & Blöbaum, 2010) as a structuring framework, since it incorporates most of the frequently used individual predictors of energy behaviour. The model, which is depicted in Figure 2, consists of four main groups of variables: Rational choice variables based on the Theory of Planned Behaviour (intentions and attitudes), routine processes (habits), situational influences (objective constraints and perceived behavioural control), and normative variables taken from the Norm-Activation-Theory and the Value-Belief-Norm Theory (Stern, 2000). The model arranges moral and non-moral processes in a two-step order, indicating that moral processes might motivate the decision-making process, but that they are vulnerable to being overridden by non-moral motivations closer to behaviour. In the following paragraphs, we outline the central variables and assumptions in the model.

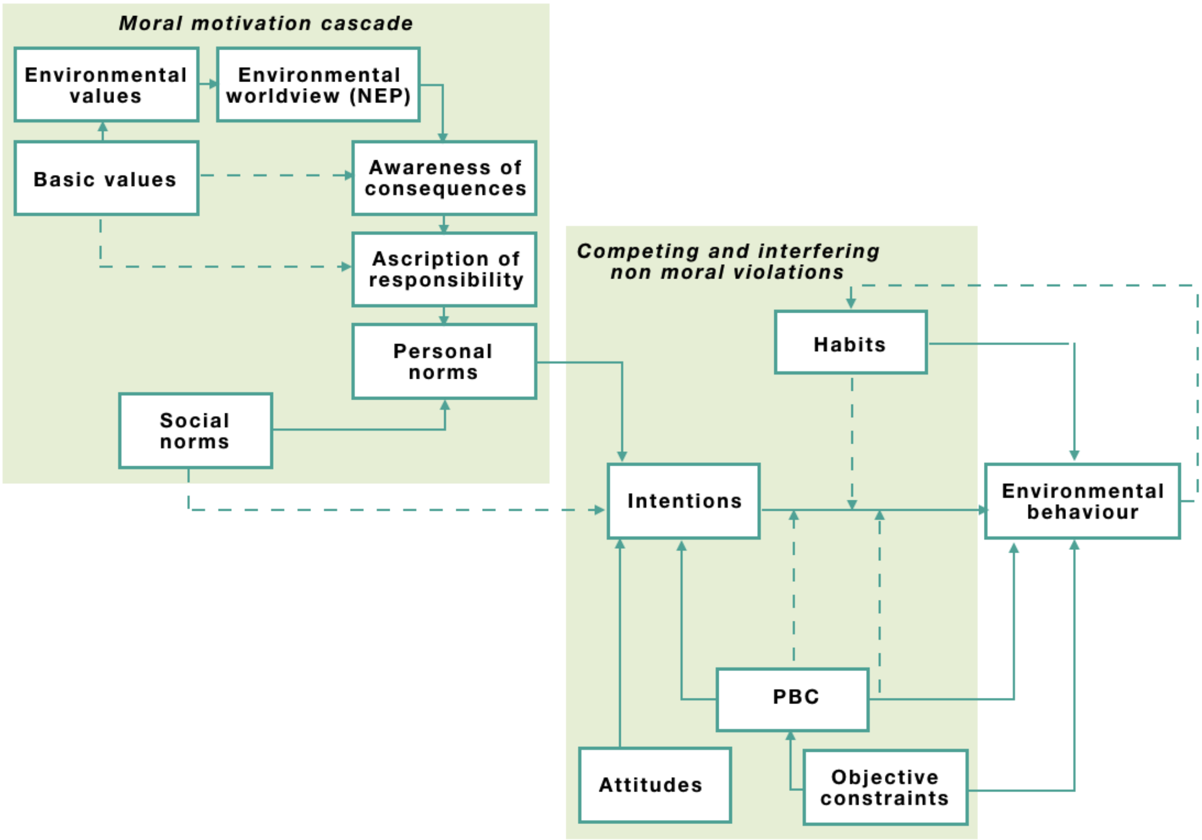

Figure 2 The Comprehensive Action Determination Model (Klöckner, 2013b, p. 462). Used by permission of Springer

The main assumptions of the model are that environmental behaviour in general, and here energy behaviour of an individual, is directly determined by four variables. The strongest variable is often the intention people have to perform the respective behaviour, in other words, the willingness to make an effort to act. In cases where behaviour is repeated often under stable situational conditions, it is assumed that habits develop to perform a certain behaviour. Habits are defined as the automatic performance of a behaviour triggered by the situational conditions (Klöckner & Verplanken, 2012). Some people for example automatically switch off the lights when they leave a room. They do not have to think about this behaviour, but the (habitual) response is triggered automatically by them leaving the room. Developing such habits is highly beneficial as it frees peoples' minds from having to focus on every single decision. The downside is, however, that habits reduce the amount of information that is processed, which might lead to less optimal behaviour in changing situations (Aarts, Verplanken, & Van Knippenberg, 1997; Verplanken, Aarts, & Van Knippenberg, 1997). There is a trade-off between habit strength and the impact that intentions have on behaviour, with strong habits reducing the impact of intentions (Triandis, 1980). This is indicated by the dotted line from habits on the intention behaviour link in Figure 2. Habits themselves are created by repeating behaviour (Klöckner & Matthies, 2012) which is indicated by the dotted feedback loop from behaviour to habits in the figure.

In addition to intentions and habits, situational conditions are assumed to impact energy behaviour. If a behaviour is difficult to perform, the likelihood is high that it will not be implemented, even if intentions strongly favour it. The situational impact is captured in two ways in the model: (1) as objective constraints (or facilitators) and (2) as perceived behavioural control (PBC), which is the subjectively filtered version of the objective constraints. For performance of a behaviour, this subjective representation is often of more relevance than the objective conditions, because what consumers *perceive* as being difficult to do is more important for their decision-making than what they could do from an objective point of view. However, the subjective representation is in most cases related to the objective conditions. In the same way as habits, perceived behavioural control and constraints are also supposed to have an impact not only on behaviour, but also on the link between intentions and behaviour, weakening the link when a behaviour is perceived to be difficult.

Intentions as the main variable integrating many other influences are determined by perceived behavioural control (how subjectively difficult a behaviour is), attitudes, social norms, and personal norms. Attitudes are an overall evaluation of how beneficial it would be to perform a certain behaviour. They consist of a number of salient beliefs about potential outcomes of performing the behaviour (e.g., expected costs and benefits in terms of money, time, effort, etc.), their evaluation (how good or bad would that be), and the likelihood with which they occur.

Personal norms are the main condensation point in the model for moral considerations. They are defined as a feeling of moral obligation to act in accordance to one's values (Schwartz & Howard, 1981). This feeling of moral obligation needs to be activated in a decision situation in order to become a relevant predictor of intentions to act. This norm-activation happens through what the model describes as the moral motivation cascade: If people embrace basic value orientations such as benevolence and universalism, they will be inclined to place high value on environmental protection and sustainability. This will also be expressed in more specific environmental values such as biospheric environmental values (valuing nature for its own sake) or altruistic environmental values (valuing nature for its benefit to other humans) (Stern, 2000). People with such value orientations will have a general worldview that makes them assume that the equilibrium of nature is important and that this might be disturbed by human activity, that resources are limited, and that humans have their place as part of nature. Such beliefs are often referred to as the New Environmental Paradigm, NEP (Dunlap, Van Liere, Mertig, & Jones, 2000). However, even if people embrace values that – on a general note – would tell them to use energy in a sustainable way, they do not necessarily refer to these values in every situation in which they make a decision that has a relevant energy impact. To be relevant, the value orientations first need to be translated into an acute feeling of moral obligation (the personal norm). This only happens if people perceive a situation as being relevant for their values: they need to be aware that their behaviour has negative consequences for something they value, and they need to ascribe responsibility to themselves for (mitigating) these negative effects. If these two preconditions are not fulfilled, personal norms will not be triggered. People with benevolence and universalism values are often more likely to interpret a situation in a way that triggers personal norms, which is indicated in the figure by the dotted arrows from basic values to ascription of responsibility and awareness of consequences.

The final relevant variable in the model are social norms, which are the perceived expectations and behaviour of other people. Social norms are a representation of the social pressure in a given situation, which can be both observing other people's behaviour and inferring what is normal or accepted to do, and being told by other people what should be done. If the individual internalizes social norms, they shape the personal norms (Thøgersen, 2006). Most of the impact of social norms is channelled through personal norms, but sometimes, social norms can also have a direct impact on intentions, indicated by the dotted arrow.

The comprehensive action determination model has been applied to a number of different domains of environmental behaviour, many of them related to the ECHOES technology foci (Klöckner, 2011; Klöckner & Blöbaum, 2010; Nayum & Klöckner, 2014; Sopha & Klöckner, 2011). It also has been tested in a meta-analysis (Klöckner, 2013a) with good results. In the later sections, it will be analysed for each technology focus which of the model variables have been linked to the respective focus behaviour. However, the literature survey has also shown that the comprehensive model is not well enough suited to cover aspects of self-regulation, social identity, and emotional responses as drivers of energy choices. These aspects are briefly introduced in the next section, and will be analysed in more detail in separate sections below.

2.2 Additions to the Comprehensive Action Determination Model: Emotions and Social Identity as Points of Entry for Understanding Environmental Appraisal and Behaviours

2.2.1 Emotions

To date, there is a wide consensus in the scientific community that human information processing is guided by emotion and affect (Loewenstein, Weber, Hsee, & Welch, 2001; Mellers & McGraw, 2001; Weber & Johnson, 2009). In fact, the emotion-as-feedback theory proposes that an anticipated emotional reaction is a direct, proximal cause of behaviour (e.g., DeWall, Baumeister, Chester & Bushman, 2015; Mellers & McGraw, 2001). A recent meta-analysis supporting such an assumption has pointed out that an emotional state is used as information when one is deciding to act (DeWall, Baumeister, Chester & Bushman, 2015). In other words, an individual's ability to appraise an emotional state (e.g., anticipated emotion) enables an elaboration of the potential outcomes of one's behaviour (Panno, Donati, Chiesi, & Primi, 2015). In this review, we assume that emotions can be linked to energy-related human behaviour (and in general to a wider range of pro-environmental behaviour (PEB); see also Carrus, Passafaro & Bonnes, 2008) through a twofold path. First, anticipated emotions can motivate eco-friendly activities by acting on moral norms. For example, guilt represents an emotion that could act in this direction when people are making eco-relevant decisions (Baumeister, Stillwell, & Heatherton, 1994). In fact, anticipated guilt might motivate people to act in an eco-friendly way to avoid such an unpleasant feeling that might occur whenever an eco-unfriendly choice has been made. Second, post-decisional emotions might shore up eco-friendly habits through a mechanism of positive reinforcement. In fact, feelings of pride resulting from eco-friendly behaviours might kick off the process of transforming occasional eco-friendly behaviours into more stable eco-friendly habits. For example, if people feel proud for switching off the lights when they leave a room or for traveling by train rather than by car or airplane, they could have a psychological incentive to adopt such an occasional eco-friendly behaviour in the long run, leading to the development of pro-environmental habits.

Relating these arguments to the Comprehensive Action Determination Model (CADM) by Klöckner and Blöbaum (2010), we claim that anticipated emotions may occur as immediate drivers of the intention at two levels: 1) According to emotion-as-feedback theory, acting as a driver when eco-friendly attitudes, personal norms and intentions go in the same direction; 2) strengthening the relationship between attitudes, norms and intentions when these are not completely pro-environmental. For example, anticipated guilt could moderate the relationship between weak eco-friendly attitudes and eco-unfriendly intentions, thus moving eco-unfriendly intentions to more eco-friendly behaviours. Moreover, post-decisional emotions might act as a positive reinforcement in the loop feedback between eco-friendly behaviour and habits, shoring up such habits.

2.2.2 Social Identity: A "We"-Perspective on Environmental Behaviour

Environmental psychologists are interested in both human consequences of large-scale environmental crises and in how humans contribute to their emergence (Swim et al., 2011). Many psychological models view environmental behaviour as goal-directed action and focus on the determinants of personal pro-environmental decisions and behaviour (e.g., Bamberg & Möser, 2007). These models (e.g., Klöckner, 2013b; Bamberg, 2013) describe people's environmentally significant behaviour as the result of a personal decision-making or action process. On the ground of basic environmental problem appraisal, global personal values, norms, and goals, people consider courses of action that seem promising for reducing environmental problems, expressing their values, or reaching other personal goals, such as feeling comfortable or attaining valued resources (see section 2.1 for details).

What is largely missing in these models of environmental appraisal and action is the *collective* dimension or the dynamics of social identity (Reicher & Haslam, 2010; Tajfel & Turner, 1979). Individualistic models describe environmental appraisals and responses as processes fuelled by cognitions and motivations of *personal* actors. Although some of these cognitions and motivations are conceptualized as being directly or indirectly affected by people's social environment (e.g., influence of social norms or moral values; Nolan et al., 2008), they always relate to a personal, instead of a collective, definition of the self. For instance, approaches based on the Theory of Planned Behaviour (Ajzen & Fishbein, 2005; Bamberg & Möser, 2007) or the Norm-Activation Model (Schwartz & Howard, 1981; Klöckner & Blöbaum, 2010) propose that people direct their pro-environmental behaviour based on personal cost-benefits analyses (in both material and moral terms), the expectations of personally significant others, and their personal efficacy in performing specific behaviours.

This perspective on personal determinants, however, tends to neglect collective-level factors that have an impact upon appraisals of, and reactions to, large-scale environmental problems. Individualistic models usually do not consider the human capacity to incorporate collectives or social in-groups in the self, as outlined in the social identity approach (Fielding, Terry, Masser & Hogg, 2008; Hogg, 2010; Reicher & Haslam, 2010; Tajfel & Turner, 1979; Terry & Hogg, 1996). From this alternative perspective, people often define their self not in terms of their individual person ("I") but as group members ("We"). When they do, appraisals and actions do not emerge out of cognitions and motivations related to the person, but rather people appraise and act on the ground of collective cognitions and motivations. Then, people calculate collective rather than personal costs and benefits of pro-environmental action, adjust their environmental behaviour to in-group norms rather than to the expectations of personally significant individuals, and wonder whether they will be efficacious as a collective (i.e., collective efficacy) rather than an individual to bring about pro-environmental change. In other words, people often think and act as if they were (part of) collectives, and not as individual persons, affected by others. This human mental capacity may be decisive for the global endeavour to tackle large-scale environmental crises effectively.

Social Identity Theory (Tajfel & Turner, 1979) and Self-Categorization Theory (Turner et al., 1987) – jointly called the Social Identity Approach (SIA) – provide a theoretical framework to investigate environmental behaviour beyond well-established person-level predictors. SIA proposes that people derive a significant part of their self-concept from the social groups to which they belong (e.g., gender or ethnic groups). People may define their self on different levels of inclusiveness, ranging from person-level self-definitions to very inclusive collective-level self-definitions, for example identification with all of humanity (McFarland, Webb, & Brown, 2012). SIA investigates how and when individuals come to feel, think and act as group members rather than as unique individuals (van Zomeren, 2014). While group-based behaviour is contingent on self-categorization as a group member (i.e. social identity), interpersonal behaviour is determined by people's perception as a unique person (i.e. personal identity). A social identity approach to environmental (or energy) behaviour thus complements individualistic models of pro-environmental action. Importantly, although such a social identity perspective aims to explain an individual's private behavioural decisions, it differs from personal-level decision-making models by taking into account the effects a collective self-definition has on environmental appraisals and responses. Decisions made under the influence of a social identity are no longer (merely) personal, but depend on collective perceptions and dynamics. The human capacity to define the self in terms of collectives, helps to explain how people appraise and respond to environmental crises, which are often collective rather than personal phenomena. Social identity may even provide a unique route to motivate pro-environmental action.

In the remainder of section 2, we will first review empirical studies on the proposed individual-level and collective-level psychological predictors of energy-related and (general) pro-environmental behaviour. We will then summarize our main findings and highlight possible avenues for future research.

2.3 Review of Research on the Psychological Determinants of Energy Behaviour

2.3.1 Individual-level Predictors of the Behaviours from the Three Technological Foci

2.3.1.1 E-Mobility

Social Norms. Social norms have been shown to influence the adoption of, and the intention to adopt, an electric vehicle (Moons & De Pelsmacker, 2012; Klöckner, 2014; Peters & Dutschke, 2014; Barth et al., 2016; Kaplan et al., 2016; Nayum et al., 2016; Schmalfuß et al., 2017; Smith et al., 2017), and fuel-efficient and alternative fuel vehicles more generally (Jansson, 2011; Nayum & Klöckner, 2014; Petschnig et al., 2014). Consistent with the CADM (see Fig. 2), the impact of social norms on the decision to adopt is mediated by personal norm and, in the final step, by intention (Nayum & Klöckner 2014). Wolf & Seebauer (2014) found that among those who already adopted an electrified means of transportation (an e-bike in this case), people with social norms more supportive of e-bike use had stronger personal norms towards e-bike use, and personal norms in turn predicted actual e-bike use. Thus, social norms did not have a direct influence on behaviour.

Personal Norms. Personal norms have been shown to influence the intention to adopt an electric vehicle (Klöckner, 2014; Nordlund et al., 2016) and adoption of alternative fuel vehicles more generally (Jansson, 2011; Jansson et al., 2011; Nayum & Klöckner, 2014; Petschnig et al., 2014). Consistent with the CADM (Fig. 2), the impact of personal norms on the decision to adopt is mediated by intention in Nayum & Klöckner (2014).

When modelling differences between subjects, Klöckner (2014) finds personal norms and the intention to adopt to be independent of each other, possibly due to low statistical power. On the within-subject level, variation in personal norms over time explains changes in one’s intention to adopt in this longitudinal study. On the between-subjects level, Klöckner (2014) shows personal norms to be predicted by social norms and ascribed responsibility, while responsibility is predicted by awareness of need, consistent with the structuring of influences postulated in the CADM (see the “Moral motivation cascade” portion of Fig. 2).[9]

Studies by Jansson et al. (2010, 2011) have a somewhat broader focus on the adoption of cars fuelled by a variety of alternative fuels – gasoline and electricity (hybrid cars), ethanol, and natural gas and biogas. The authors do not include full battery-electric cars in their study. They find that personal norms increase the willingness to adopt an alternative fuel vehicle (Jansson et al., 2010), as well as actual car uptake (Jansson et al., 2011). In Barbarossa et al. (2015), personal norm affects attitude, which in turn influences the intention to adopt an electric car (see also Fornara et al., 2016 who report the same chain of influences in the context of energy-related investments in the home). This ordering of influences is therefore somewhat different than what is postulated in CADM, although some previous studies have argued for a norm-attitude link (e.g. Kaiser, 2006; see also Terry & Hogg, 1996 who focus specifically on the social norm-attitude link). Thus, partial mediation of personal norms via attitudes might be considered as a possible addition to the CADM.

Awareness of Consequences. Awareness of consequences and other similar variables, such as awareness of need or perceived severity of environmental problems, have been shown to increase the intention to adopt an electric vehicle (Bockarjova & Steg, 2014). Similarly, people with higher awareness of consequences were more likely to adopt an electric car, rather than most types of conventional cars (Nayum et al., 2016). In line with the CADM, awareness of need has been shown to be linked to personal moral obligation to adopt an electric vehicle indirectly via ascribed responsibility (Klöckner, 2014). Similar results are reported in Jansson et al. (2011): awareness of consequences predicts ascription of responsibility, and ascription of responsibility in turn predicts

[9] The social norm-personal norm link also surfaces when attempting to predict variation within person across time, but the awareness-responsibility link and the responsibility-personal norm link do not.

personal norm.[10] Similarly, in Nayum & Klöckner (2014), a chain of influence flowing from awareness of need to awareness of consequences, to personal norm to intention, to the adoption decision is established (based on correlational data).

Ascribed Responsibility. Ascribed responsibility is associated with the decision to adopt an electric vehicle (Nayum et al., 2016), as well as with the adoption of an alternative fuel vehicle more generally (Jansson et al., 2011). Consistent with the CADM (see Fig. 2), ascribed responsibility has been shown to predict personal moral obligation to adopt an electric vehicle (Klöckner, 2014) or an alternative fuel vehicle more generally (Jansson et al., 2011).[11]

In the full model reported by Jansson et al. (2010), ascribed responsibility has no discernible direct effect on the willingness to adopt an alternative fuel vehicle. This is, however, not surprising, as CADM and its predecessors (Schwartz & Howard, 1981; Stern, 2000) assume the effect of ascribed responsibility on behaviour to be only indirect (mediated via personal norm).

Values. Values are considered to be a distal, rather than a proximal predictor of behaviour (see Fig. 2). Consistent with this view, Jansson et al. (2011) show that values predict the New Environmental Paradigm score, awareness of consequences and ascription of responsibility. Similarly, in Nordlund et al. (2016), self-enhancement and self-transcendence values predict the New Environmental Paradigm score.

There is, nevertheless, some evidence suggesting a more immediate influence of values on behaviour. In Jansson et al. (2011), egoistic values have a direct effect on the adoption of an alternative fuel vehicle, and biospheric values have a direct effect on personal norm towards purchasing an alternative fuel vehicle (see also Fornara et al., 2016). Similarly, in Jansson et al. (2010), biospheric values increase the willingness to adopt an alternative fuel vehicle, albeit the direct effect of values, controlling for personal norms, ascription of responsibility and other factors, is weak. Finally, compared to buyers of "compact" conventional cars, electric car buyers scored lower on conservatism values (Nayum et al., 2016).

New Environmental Paradigm. Consistent with the CADM, the New Environmental Paradigm score is predicted by biospheric, altruistic and egoistic values (see Jansson et al., 2011; Nordlund et al., 2016). Also consistent with the CADM, the New Environmental Paradigm score predicts awareness of consequences (see Nayum & Klöckner, 2014) and similar variables, such as environmental problem awareness (Nordlund et al., 2016).

As with values, the New Environmental Paradigm is considered to be a distal predictor of behaviour (see Fig. 2). However, in Jansson et al. (2011), the New Environmental Paradigm score also has a direct effect on adoption of an alternative fuel vehicle. Similarly, in Nayum and Klöckner (2014), the New Environmental Paradigm also influences the intention to adopt a fuel-efficient vehicle relatively directly via its effect on attitude, besides its more indirect influence via the moral motivation cascade (see Fig. 2).[12] In Nordfjærn et al. (2016), the New Environmental Paradigm predicts the perception of electric cars as a viable alternative to conventional cars (but other variables implicated in CADM's moral motivation cascade are not controlled for in the study).

[10] Awareness of consequences also predicts personal norm directly in Jansson et al. (2011). See also Nordlund et al. (2016) in which environmental problem awareness predicts personal norm directly (ascription of responsibility is not measured).

[11] Thus, ascribed responsibility seems to have both a direct and an indirect (via personal norm) effect on adoption in Jansson et al. (2011).

[12] In Nayum & Klöckner (2014), the moral motivation cascade is represented principally by the following chain of influences: New Environmental Paradigm → awareness of consequences → personal norm (→ intention).

Habits. Jansson et al. (2010) find that car habit strength decreases the willingness to adopt an alternative fuel vehicle, i.e. frequent drivers are less willing to adopt. Similar findings are reported by Klöckner et al. (2013) and Nordfjærn et al. (2016). In Klöckner et al. (2013) this is, however, only true for households with a single car. For households owning more than one car, no such link between annual mileage and adoption exists.[13]

Jansson et al. (2010) also report that, compared to non-adopters, current adopters of alternative fuel vehicles are more willing to adopt one in the future. Similarly, current electric vehicle users are more likely to buy an electric car in the future than are most current non-adopters (Peters & Dutschke, 2014). Hardman et al. (2016) report that over 70% of current electric vehicle owners participating in their study intend to buy an electric car as their next vehicle. Tentatively speaking, these tendencies might be in part caused by a habit for driving an alternative fuel or electric vehicle (see, however, our discussion of the distinction between past behaviour and habit in the section on energy consumption in buildings).

Barth et al. (2016), Skippon et al. (2016), and Schmalfuß et al. (2017) study how a brief direct experience with electric vehicles affects people's willingness to adopt one. While it seems unlikely that a brief experience with a new technology will suddenly uproot old habits, under favourable circumstances, it can, nevertheless, contribute to behavioural change (cf. Bamberg, 2006; Verplanken & Roy, 2016). Jensen et al. (2013, 2014) and Bühler et al. (2014) show that participants' perceptions of and preferences for electric vehicles have evolved after being given an opportunity to use one for a trial period of three months or six months. Taken together, these changes nevertheless do not seem to translate into increased purchase intentions.

It should be noted that Jensen et al. (2013, 2014) and Bühler et al. (2014) use within-subject designs without a control group, and so the observed effects cannot be unequivocally attributed to the trial experience. This is a relevant concern, as Skippon et al. (2016) report there were changes in attitudes towards electric vehicles also in the control group subjects, who did not undergo the electric vehicle test drive in their study. An interesting and important avenue for future research is thus to study causal effects of long term experience with an electric vehicle on adoption and on its determinants (including habit formation, which was not investigated in the above studies). Data should be collected at multiple points in time, rather than just pre- and post-intervention, to gain a more in-depth insight into how preferences and beliefs develop (see Bühler et al., 2014; Klöckner, 2014). Also, interactions of experience with other factors should be investigated in detail.

Attitudes. Moons & De Pelsmacker (2012), Bühler et al. (2014), Barbarossa et al. (2015), Kaplan et al. (2016), Morton et al. (2016), and Nayum et al. (2016) report a positive link between favourable attitudes towards electric cars and different adoption indicators (see Jansson, 2011; Nayum & Klöckner, 2014; Petschnig et al., 2014 for similar findings with respect to adoption of fuel-efficient and alternative fuel cars). Klöckner (2014) finds attitudes to be marginally significantly associated with the intention to adopt on the between-subjects level; on the within-subject level this association approaches marginal significance.

Perceived Behavioural Control. Perceived behavioural control has been shown to influence adoption and intention to adopt an electric vehicle (Bockarjova & Steg, 2014; Kaplan et al., 2016; Nayum et al., 2016; Schmalfuß et al., 2017) and fuel-efficient vehicles more generally (including electric ones, see Nayum & Klöckner, 2014). In some studies, however, no such link has been detected (Klöckner, 2014). Consistent with CADM, perceived behavioural control is in part explained by objective constraints, such as income (Nayum & Klöckner, 2014) or

[13] One possible explanation for these observations is self-selection. The self-selection account says that the type of car one purchases is a function of one's driving needs, the number of cars one can afford, and other driver characteristics. For instance, frequent drivers are willing to adopt an electric car only as their second car. And only those who drive very little will buy an electric car as their sole vehicle (see also Mersky et al., 2016).

purchase price (Kaplan et al., 2016). Results in Petschnig et al. (2014) suggest that objective constraints could be partly internalized in attitudes as well. This possibility deserves further exploration.

Situational Constraints. Contextual factors constraining the adoption of electric (and alternative fuel and fuel-efficient) vehicles may include income (Jansson et al., 2010, 2011; Hidrue et al., 2011; Jansson, 2011; Nayum & Klöckner, 2014; Barth et al., 2016; Mersky et al., 2016; Nayum et al., 2016; Zhang et al., 2016; She et al., 2017; White & Sintov, 2017), household size (Jansson et al., 2010, 2011; Jansson, 2011; Nayum & Klöckner, 2014; Nayum et al., 2016; She et al., 2017), policy measures, such as subsidies, toll waivers or bus lane access for electric cars (Hackbarth & Madlener, 2013; Lai et al., 2015; Bjerkan et al., 2016; Mersky et al., 2016; Zhang et al., 2016; She et al., 2017; for an early review see Leurent & Windisch, 2011), as well as a number of monetary and non-monetary cost factors, such as high purchasing price, limited range, long charging time, and underdeveloped charging infrastructure (Hidrue et al., 2011; Lieven et al., 2011; Franke et al., 2012; Hackbarth & Madlener, 2013; Jensen et al., 2013; Schuitema et al., 2013; Bockarjova & Steg, 2014; Noppers et al., 2015; Barth et al., 2016; Hardman et al., 2016; Junquera et al., 2016; Kaplan et al., 2016; Skippon et al., 2016; Zhang et al., 2016; Schmalfuß et al., 2017; She et al., 2017; Smith et al., 2017; White & Sintov, 2017).

Note that findings concerning the impact of contextual factors are often mixed, hence their meta-analytic aggregation can be useful. For a meta-analysis concerning the effect driving range has on people's willingness to pay for an electric vehicle, see Dimitropoulos et al. (2013). They show that this effect is positive, and more pronounced for vehicles with relatively low driving ranges.

2.3.1.2 Smart Energy Technology

Smart Energy Technologies is one of the three technological foci in the ECHOES project. The term includes a range of efficiency technologies that allow to phase in more renewable energy and to consume that energy more effectively, monitoring the production and use by households and providing households with detailed feedback on their energy consumption. In particular, smart grid technologies are very important as they enable several other different renewable energy sources, and demand response provides significant opportunities for both consumers and utilities to save energy. Different studies share the European Technology Platform's (ETP) definition of the smart grid as an "electricity network that can intelligently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies" (Sonnenschein et al., 2015; Ardito et al. 2013; Fang et al., 2012). Often, smart grids aim to influence electricity demand towards more efficient and sustainable patterns of demand by using smart energy technologies (e.g., smart meters). However, the benefits that smart grid technologies can offer and the impact of smart energy systems on the quality of the environment, depends in the first instance on whether consumers actually accept and adopt these alternative energy technologies (Sintov and Schultz, 2015).

Uncertainty exists regarding households' willingness and possibilities to accept smart grids to change consumer demand. According to Verbong et al. (2013), the extent to which users are willing and able to accept and use smart grids determines the likelihood of successful introduction of smart grid technologies. Recently, Van der Werff and colleagues (2016) discussed important findings from psychological studies aimed at understanding and promoting human behaviour in relation to smart grids by both single individuals and households. These authors highlight the role of motivational (notably values) and contextual factors (costs and benefits) influencing behaviour in smart grid adoption, and reaffirm the importance of understanding which factors affect the acceptability of a transition to smart grids. Consistent with the structuring of influences postulated in the CADM, values affect how people evaluate the costs and benefits of behaviours, how important they find different consequences of smart grids, and how they evaluate these consequences.

A recent overview of the literature (Ellabban & Abu-Rub 2016) reveals that the most applied theoretical frameworks for consumers' smart grid acceptance include the Theory of Reasoned Action (TRA), the Theory of Planned

Behaviour (TPB), the Technology Acceptance Model (TAM), and the Value-based Adoption Model (VAM). Although the Theory of Reasoned Action (TRA – Fishbein and Ajzen, 1975) has some limitations, this framework had been used for studies concerning consumers' adoption of innovative technology. The theory of reasoned action proposes that a person's intention to perform a given behaviour is jointly determined by that person's attitude toward the behaviour and the person's subjective norm. Generally, individuals intend to perform a certain behaviour when they evaluate it positively and when they believe that important others approve of it. The Theory of Planned Behaviour (TPB) extends the TRA and adds the dimension of perceived behavioural control, a concept that refers to the perceived ease or difficulty of performing a certain behaviour (Ajzen, 1991). Recently, Perri and Corvello (2015) apply the TPB in order to explain users' intention to adopt smart grid solutions and technologies. Their results show that resistance to change was found indirectly correlated with the adoption intention, through the mediation of attitude. Consumers with high resistance to change may have different intentions and habits in relation to the adoption of smart grid technologies, compared with consumers who have a low resistance to change. Furthermore, resistance to change can be understood as a value dimension, thus confirming assumptions of the CADM.

In general, the literature in this field underlines that studies, which only apply the TPB for understanding the adoption of smart energy technologies, are limited. More studies used and adapted the Technology Acceptance Model (TAM – Davis, 1989) to investigate consumers' perceptions of the innovation characteristics. This model is inspired by the theory of reasoned action (TRA) and is often used to explain the use or intention to use a specific technology. Consistent with the CADM's rational choice variables (intention and attitude), the core part of the model includes only a few factors: perceived usefulness (PU), perceived ease of use (PEOU), attitude (ATT) toward use, behavioural intention to use (BI), and use. Perceived usefulness is defined as the degree of belief that using a specific technology will improve one's work performance. Perceived ease of use is described as the degree of belief that using a particular technology will be easy (Davis, 1989). PU and PEOU would influence the attitude toward using, and this, together with perceived usefulness would in turn predict users' behavioural intention to use. Actual use should thus be affected by a user's behavioural intention in the same way as perceived usefulness is influenced by perceived ease of use. The Technology Acceptance Model has been used to study consumers' acceptance of smart grid technologies. For example, Kranz et al (2010) used an extended TAM model to study household acceptance of smart metering technology. These authors added the construct of subjective control, which is a person's need for control, to capture consumers' concerns about loss of control after installing a smart meter, and the resulting negative emotions that could influence the acceptance of this technological device. The results showed that attitude toward use is the most important determinant of the intention to use, and that subjective control has medium indirect effects on intention to use through attitude. In other research, based on TPB and TAM, Kranz and Picot (2011) investigated the factors influencing consumers' intention to adopt the smart meter technology. Similarly, the results revealed that attitude is the most influential determinant of intention. Besides, intention is also driven by the influence of secondary sources (e.g. media, inspirational public figures), and by environmental concerns, while perceived behavioural control has shown a non-significant effect on intention. Toft et al. (2014) conducted an online survey in Denmark, Norway and Switzerland to capture private consumers' acceptance of smart grid technology. The TAM was employed in the study with the addition of personal norm. The results showed that perceived usefulness and perceived ease of use are significant predictors of the attitude towards smart grid technology in all three countries. Attitude is the most important predictor of smart grid acceptance. Based on the TAM, Park et al. (2014) in their research on factors affecting consumers' acceptance of smart grids, include perceived risk as a major factor affecting the intention to accept the smart grid. Previous studies reported that perceived risk had a negative impact on technology acceptance and intention to use (Wu and Wang 2005; Lee 2009). In this respect, a so called "RITAM" (Risk Integrated TAM) is proposed as a modified model reflecting the assumption that the perceived risk of a new technology has a negative impact on the intention to use (Park et al., 2014). This research shows in fact that the higher the perceived risk of the technology, the lower the perceived usefulness. Furthermore, the higher the usefulness of the technology is perceived, the lower are the concerns about the risk. In addition to these factors, other exogenous variables can be considered. Among these, we could mention factors such as the Perceived Compatibility and Perceived Understanding, which affect the perceived ease of use. Likewise, Perceived Power Supply Reliability, Perceived Electricity Rate Saving, and Perceived Eco-Environment influence perceived usefulness. Finally, perceived Cyber Insecurity, Perceived Fear of Electromagnetic Radiation and Perceived Performance Concerns affect the perceived risk. An important result of this study is related to the necessity of improving consumers' understanding of the smart grid and to offer consumer-oriented education and public relations, because the understanding of the smart grid improves the perceptions of ease of use and usefulness (Park et al., 2014).

TAM and TPB are both extensions of the Theory of Reasoned Action but they have different foci (Chau and Hu, 2002). The TAM has only two distinct beliefs (perceived usefulness and perceived ease of use) predicting a person's intention, whereas in TPB there can be several individual salient beliefs determining attitude towards the behaviour and intention. Compared to TPB, TAM clarifies which specific beliefs may influence acceptance of technology. Other differences are that according to TAM, behavioural intention is the only direct determinant of behaviour, whereas in TPB, both behavioural intention and perceived behavioural control are assumed to predict behaviour. Another difference between the two theories relates to normative influence, such as the concept of subjective norms, included in TPB but not in TAM. Nevertheless, the literature in this field often shows that the choice of theoretical framework turned in favor of the Technology Acceptance Model, compared to other competing models. The model is supported in several studies investigating technology acceptance and was proven to be rather robust (Chen, Li, and Li, 2011). For many authors, the reason for choosing the Technology Acceptance Model is probably related to the fact that it was specifically developed for the particular field of technology acceptance. Moreover, in several studies it has been found to explain more variance compared to the Theory of Reason Action (Davis et al., 1989) and Theory of Planned Behaviour (Chau and Hu, 2002).

The adoption and acceptance of smart energy technology is also related to moral behaviour. Theoretical frameworks that take the moral aspect into account include the Norm Activation Model (Schwartz, 1977; Schwartz & Howard, 1981) and the Value-Belief-Norm Theory (Stern, 2000), which is derived from the Norm Activation Model. The NAM has been successfully applied to predict different kinds of pro-environmental behaviours and prosocial intentions and behaviours (Bamberg & Möser, 2007; Biel & Thøgersen, 2007; Huijts et al., 2013; Abrahamse et al., 2009B), such as choosing environmentally-friendly packaging (Thøgersen, 1999), energy saving (Abrahamse and Steg, 2009), and choosing travel modes alternative to the car (Hunecke et al., 2001). The NAM proposes that performing a behaviour that benefits others or the environment is motivated by a moral self-expectation or personal norm. A personal norm is defined as a feeling of moral obligation to act in a particular way in a particular situation. The Responsible Technology Acceptance Model (RTAM – Toft, 2014), which is a combined framework of the Technology Acceptance Model and the Norm Activation Model, is also worth mentioning here. The RTAM suggests that rational assessments, feelings of a moral obligation or responsibility towards the environment, and a positive contribution to society are important in the acceptance of smart grid technology. People are motivated to see themselves as morally right, and to do the right thing, which may encourage smart energy behaviours (Bolderdijk et al., 2013). The Value-Belief-Norm theory (VBN -Stern et al, 1999) attempted to adjust the Norm Activation model to explain pro-environmental behaviours. According to the VBN theory, a hierarchy of values, environmental beliefs and personal norms explains pro-environmental behaviour. Specifically, the theory proposes a chain model with direct connections between five variables that are antecedents of environmental behaviours (Stern, 2000). These variables are values (either biospheric, altruistic, or egotistic), endorsement of an ecological worldview, adverse consequences for valued objects, perceived ability to reduce the threat, and personal norms (the sense of obligation to take pro-environmental actions).

Lately, van der Werff and Steg (2016) propose the Value Identity Personal norm (VIP) model, in which pro-environmental behaviour is assumed to be influenced by feelings of moral obligation (personal norms). In turn, personal norm should be influenced by one's environmental self-identity, which reflects the extent to which an individual defines her/himself as a pro-environmental person (Van der Werff et al., 2013b). Environmental self-identity is in turn influenced by biospheric values. Comparing the predictive power of the VBN theory and the VIP model, results show that both models explained interest and actual participation in smart energy systems, to a similar extent. According to these authors, it is also important to focus on the benefits for the environment. In fact, when people evaluate these consequences as more important, they are more likely to participate in smart energy systems.

2.3.1.3 Energy in Buildings

It is possible to distinguish three types of actions that influence the type and quantity of energy that is consumed in buildings: curtailment behaviour, investment behaviour, and purchasing green vs. grey energy. Curtailment behaviour means reducing one's energy consumption within one's current structural setting (e.g. one's home or office). This mostly includes simple actions, such as unplugging unused electric devices or cooking with lids on pots. Investment behaviour means investing resources (typically money, but possibly also labour) to change one's current structural setting by improving its energy efficiency. This might include the purchase of energy-efficient electric appliances, isolating one's house, or installing solar panels. Finally, grey energy comes from non-renewable sources, such as coal, while green energy comes from renewable sources, such as wind (Clark et al., 2003). In the following, we summarize existing research on each of these actions. Like in section 2.3.1.1, we structure this section by variables included in the CADM.

Social Norms. There is a growing corpus of studies showing that social norms influence energy related behaviours in buildings. According to Cialdini et al. (1990), there are two types of social norms: descriptive social norms, which are behaviours that are common in a given situation, and injunctive social norms, which are widely shared beliefs of how one ought to behave in a given situation.

First, there is considerable evidence that both injunctive norms[14] and descriptive norms[15] influence curtailment behaviours and intentions. In addition, there is evidence not only for main effects of the two types of norms, but also for an interaction between the two where their effects multiply in case they point into the same direction (Göckeritz et al., 2010; Smith et al., 2012; Bator et al., 2014). Examples of curtailment actions that have been investigated include turning off lights in unused rooms (Sussman & Gifford, 2012; Dwyer et al., 2015; Bergquist & Nilsson, 2016) or switching off unused computer monitors (Bator et al., 2014). Some studies (Schultz et al., 2007, 2015; Nolan et al., 2008; Sudarshan, 2017) measure overall household electricity consumption via meter readings – such a measure therefore potentially compounds curtailment and investment behaviours (see Allcott, 2011; Allcott & Rogers, 2014).

It is worth pointing out that the normative intervention applied in Schultz et al. (2015) had an effect on objectively measured consumption, but not on retrospectively assessed self-reported energy conservation. This suggests that self-reported measures may be too unreliable to register effects of subtle behavioural interventions.[16] For a meta-analytic review evaluating the relationship between objective and self-reported measures see Kormos & Gifford (2014), who show that only a little over 20% of variance in objectively measured pro-environmental behaviours can be predicted by what people say about their performance of these behaviours. Note, however, that Kormos & Gifford (2014) base their analysis on a relatively modest set of 15 articles that met their inclusion criteria. Thus, we need more research into the key issue of self-report validity and how it can be improved. See, for example, Vesely

[14] See Schultz et al. (2007, 2015), Göckeritz et al. (2010), Ajzen et al. (2011), Smith et al. (2012), Sussman & Gifford (2012), Webb et al. (2013), Bator et al. (2014), Dixon et al. (2015), Bergquist & Nilsson (2016). Note that in some studies it is not possible to separate the effect of injunctive and descriptive norms – this occurs when they are measured using a single scale (e.g. Ajzen et al., 2011; Schmalfuß et al., 2017) or when they are not varied independently in an experiment (e.g. Schultz et al., 2015).

[15] See Schultz et al. (2007, 2015), Nolan et al. (2008), Göckeritz et al. (2010), Ajzen et al. (2011), Smith et al., (2012), Bator et al. (2014), Dixon et al. (2014, 2015), Dwyer et al. (2015), Murtagh et al. (2015), Bergquist & Nilsson (2016), Sudarshan (2017). But see Harries et al. (2013).

[16] In the specific case of Schultz et al. (2015), an alternative explanation could be that the objective energy usage reduction under the norms treatment was driven by behaviours other than those elicited in the post-experimental survey. But the validity of self-reports poses a more general problem, as we discuss in the text.

& Klöckner (2017a) who employ an incentivized elicitation procedure to motivate participants to provide accurate responses concerning different aspects of environmental behaviours.

Second, both injunctive norms (Macey & Brown, 1983; Stern et al., 1983; Korcaj et al., 2015; Yun & Lee, 2015; Fornara et al., 2016; Wang et al., 2017; Wolske et al., 2017; but see Rai & Beck, 2015) and descriptive norms (Welsch & Kühling, 2009; Arpan et al., 2013; Korcaj et al., 2015; Rai & Beck, 2015; Fornara et al., 2016) influence investment behaviours and intentions, such as the intention to purchase energy-efficient appliances (Yang & Zhao, 2015; Wang et al., 2017), the intention to install a photovoltaic system (Korcaj et al., 2015; Rai & Beck, 2015; Fornara et al., 2016; Wolske et al., 2017), installation of a solar thermal system (Welsch & Kühling, 2009), and the intention to improve thermal isolation in one's home (Arpan et al., 2013; Fornara et al., 2016).[17] Social norms, however, influence intentions only indirectly through personal norms in Fornara et al. (2016), which is consistent with the CADM (although the model also postulates a possible unmediated influence of social norms on intention, see Fig. 2).

Finally, there is also evidence that social norms play a role in shaping preferences for purchasing green energy. This is again true both for injunctive (Ek & Söderholm, 2008; but see Litvine & Wüstenhagen, 2011) and descriptive norms (Welsch & Kühling, 2009; but see Litvine & Wüstenhagen, 2011; Ek & Söderholm, 2008 report mixed results).

<u>Large field experiments</u>. Seminal field experiments conducted by Schultz et al. (2007) and Nolan et al. (2008) paved the way to the application of normative information in large-scale field experiments, often spanning participant samples of tens and hundreds of thousands (e.g. Allcott, 2011; Ayres et al., 2012; Allcott & Rogers, 2014). Estimated energy savings in these large-scale experiments are in the order of about 2% of baseline energy usage (Allcott, 2011; Ayres et al., 2012). One might therefore expect small, but economically meaningful effects of scalable norm-based interventions. Methodologically, this implies that one needs to work with large samples to be able to detect such subtle effects.[18]

As these large-scale field experiments were primarily intended as program evaluations (Allcott & Rogers, 2014), the treatments augmented normative information with, for example, energy saving tips. This means it is not possible to isolate the unique effect of norms in these studies, although they are assumed to be a key element of the interventions. Harries et al. (2013), nevertheless, suggest that individual consumption feedback could be the key factor. However, their study did not have sufficient power to adequately test this proposition.

We note that there is also a number of smaller experiments, in which one cannot separate the effect of norms from the effect of other variables with which norms co-vary (e.g. Dixon et al., 2014; Sudarshan, 2017). Besides carefully designed experiments, future research can also combine experiments with survey methods to investigate through which specific channels a given treatment influences behaviour (see e.g. Dixon et al., 2014, Jensen et al., 2014; Skippon et al., 2016; Beck et al., 2017; Rai & Beck, 2017; Schmalfuß et al., 2017).

<u>Enhancing norm effects</u>. The impact of normative interventions can be further increased by targeting those who are most receptive to norms, such as people with certain personality traits (Komatsu & Nishio, 2015), people who identify with the norm source (Terry & Hogg, 1996; Terry et al., 1999; Wenzel, 2004; Louis et al., 2007; Masson & Fritsche, 2014; but see Dixon et al., 2015; see also sections II.3.2 and II.3.3 below), heavy energy users (Schultz

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[17] Arpan et al. (2013) include both curtailment and investment behaviours in their behaviour index.

[18] It is telling that Allcott (2011, p. 1090) calls experiments by Schultz et al. (2007) and Nolan et al. (2008) "small sample pilots" (both are in fact fairly large by psychology standards, with 290 and 810 participants).

et al., 2007; Allcott, 2011; Ayres et al., 2012; Komatsu & Nishio, 2015; Sudarshan, 2017; Asensio & Delmas, 2015), or people previously indifferent to conservation issues (Bamberg, 2003; Göckeritz et al., 2010).

Also effective is combining normative interventions with other measures, such as heightened behaviour visibility (people respond more strongly to norms when their behaviour is observable, Vesely & Klöckner, 2017b), or increased energy prices. People respond more strongly to price increases when they are also provided with normative information and individual consumption feedback (Sudarshan, 2017; but see also Jessoe & Rapson, 2014 whose results suggest that individual consumption feedback alone may be what causes the heightened sensitivity to price).

These two strategies (i.e., making use of interactions between norms and various internal and external factors) should be explored in more detail in the domain of energy consumption in buildings, where this type of research has so far been limited.

Personal Norms. Personal norms have been shown to influence curtailment behaviours and intentions (Stern et al., 1983; Van der Werff & Steg, 2015; Ruepert et al., 2016; Testa et al., 2016; but see Schultz et al., 2015), investment behaviours and intentions (Stern et al., 1983; Rai & Beck, 2015; Fornara et al., 2016; Testa et al., 2016; Wolske et al., 2017), and the intention to use green energy (Van der Werff et al., 2013a, Study 1), as well as actual decisions to purchase green energy (Litvine & Wüstenhagen, 2011). Clark et al. (2003) show that a measure of "altruism", which in their study captures personal norms, awareness of consequences, and ascription of responsibility, predicts enrolment in a green electricity program.

Awareness of Consequences. Awareness of consequences and other similar variables, such as environmental problem awareness, have been shown to increase the intention to curtail energy consumption (Van der Werff & Steg, 2015), as well as actual curtailment behaviour in a field experiment (Asensio & Delmas, 2015). The intention to make energy-related investments and the probability of making actual investment decisions is also affected by awareness of consequences (Stern et al., 1983; Wang et al., 2017; Wolske et al., 2017).

In Van der Werff & Steg (2015), the influence of awareness of consequences on the intention to conserve energy is mediated via outcome efficacy and personal norm, broadly consistent with the CADM (see Fig. 2). Similarly, in Wolske et al. (2017), who study interest in installing a photovoltaic system, awareness of consequences is linked to intention via personal norm.

Ascribed Responsibility. In Fornara et al. (2016), ascribed responsibility predicts personal norm towards improving energy-efficiency of one's home. While this is consistent with CADM, the authors also report a direct association of ascribed responsibility with intention. In addition, unlike in CADM, ascribed responsibility is not predicted by awareness of consequences, which exerts an independent influence on personal norm in Fornara et al. (2016). In Ek & Söderholm (2008), ascribed responsibility exerts a direct influence on preferences for green electricity, controlling for social norms, New Environmental Paradigm, price and other factors. Personal norm was not measured.

Values. In the context of improving energy-efficiency of one's home, biospheric values have been shown to predict an environmental worldview (measured by a scale similar to NEP, see Corral-Verdugo et al., 2008). An environmental worldview in turn predicted awareness of consequences, which in turn predicted moral norm (see Fornara et al., 2016). These links are thus very similar to the moral motivation cascade proposed in the CADM (see Fig. 2).

Biospheric values have been shown to predict the intention to conserve energy (Van der Werff et al., 2013b, Study 1), the intention to use green electricity, and the willingness to pay more for it (Van der Werff et al., 2013b, Study 2). In each case, values were linked to intention indirectly via energy-saving self-identity (Study 1) or environmental self-identity (Study 2). Similarly, in Ruepert et al. (2016), environmental self-identity partially mediated the link between biospheric values and energy conservation personal norm. In Wolske et al. (2017), who study interest in adopting a photovoltaic system, values predicted awareness of consequences and personal norm (which was also predicted by awareness of consequences). Personal norm in turn predicted interest in adoption.

That biospheric values, besides their indirect role (see the preceding paragraph), sometimes also have a direct link to variables close to behaviour (for example personal norm, see Fornara et al., 2016; Ruepert et al., 2016), and even to behaviour itself (waste prevention, see Ruepert et al., 2016; adoption of an alternative fuel vehicle, see Jansson et al., 2011) appears to be somewhat at odds with their assumed role as the most distal influence in CADM and other models (Stern, 2000; Van der Werff & Steg, 2016). Nevertheless, it is perhaps plausible that even when values are not fully internalized as part of one's identity or normative beliefs, they may still shape behaviour as a sort of an "external" rule of conduct. This possible role of values is broadly consistent with some previous theorizing (Crawford & Ostrom, 1995; Harland et al., 1999; see also discussion in Ruepert et al., 2016), but it is omitted in the aforementioned action models, including CADM. Exploring how and when values function as a direct influence on behaviour, might be an interesting task for future research.

New Environmental Paradigm. New Environmental Paradigm is considered to be a distal predictor of behaviour (see Fig. 2, see also Fornara et al., 2016). Nevertheless, in Clark et al. (2003), the New Environmental Paradigm score is a direct predictor of participation in a green electricity program (controlling for demographics and for "altruism", which captures personal norms, awareness of consequences and ascription of responsibility). Similarly, the New Environmental Paradigm score directly predicted preferences for green electricity in a hypothetical choice experiment by Ek & Söderholm (2008), controlling for ascribed responsibility, social norms, price and other factors.

Habits. A good understanding of whether and how habits shape energy-related behaviour in buildings is important for designing interventions to discontinue undesirable habits and instill new, better ones. However, research on the role habits play in energy-related behaviour seems to be limited. There is some evidence that past behaviour influences energy conservation (Macey & Brown, 1983; Webb et al., 2013; Schultz et al., 2015) and investment behaviour (Macey & Brown, 1983; Wang et al., 2017; Wolske et al., 2017). However, while – intuitively – past behaviour can be expected to correlate with habits, they are not the same thing (Verplanken & Aarts, 1999; Bamberg et al., 2003; Thøgersen & Ölander, 2003). Past behaviour might be correlated with current behaviour even when stable habits have not been formed – for example when other stable factors (e.g., norms, attitudes, situational constraints) exert an unchanging influence on behaviour over time. Future research should therefore measure habits explicitly using suitable scales (see Verplanken et al., 1994; Verplanken & Orbell, 2003).

Attitudes. Attitudes have been shown to influence curtailment behaviours and intentions (e.g. Macey & Brown, 1983; Ajzen et al., 2011; Smith et al., 2012; Dixon et al., 2015; but not in Webb et al., 2013), investment behaviours and intentions (Macey & Brown, 1983; Korcaj et al., 2015; Rai & Beck, 2015; Yang & Zhao, 2015; Yun & Lee, 2015; Fornara et al., 2016), and the intention to purchase green energy (Litvine & Wüstenhagen, 2011).

Perceived Behavioural Control. Perceived behavioural control has been shown to influence curtailment behaviours and intentions (Ajzen et al., 2011; Smith et al., 2012; Webb et al., 2013; Dixon et al., 2015), investment behaviours and intentions (Korcaj et al., 2015; Rai & Beck, 2015; Yun & Lee, 2015), and intentions to purchase green energy, as well as actual purchase decisions (Litvine & Wüstenhagen, 2011; Alam et al., 2014). Consistent with CADM, perceived behavioural control is in part explained by objective constraints and facilitating conditions, such as the availability of technical support (Yun & Lee, 2015).

Situational Constraints. Situational influences on energy consumption may include weather conditions (Allcott, 2011; Ayres et al., 2012; Asensio & Delmas, 2015), square footage and construction year of one's home (Stern et al., 1983; Allcott, 2011; Ayres et al., 2012), household size (Allcott, 2011; Ayres et al., 2012; Harries et al., 2013; Komatsu & Nishio, 2015), energy prices (Jessoe & Rapson, 2014; Sudarshan, 2017), income (Allcott, 2011; Ayres et al., 2012; Schultz et al., 2015), as well as automatization and other technological factors (Murtagh et al., 2015).

Situational influences on energy-related investment intentions and behaviours may include income (Welsch & Kühling, 2009; Yao et al., 2014; Korcaj et al., 2015; Rai & Beck, 2015; Yang & Zhao, 2015; Wang et al., 2017; Wolske et al., 2017), monetary costs (Korcaj et al., 2015; Wang et al., 2017), household size (Stern et al., 1983; Welsch & Kühling, 2009; Wolske et al., 2017), square footage of one's home (Wolske et al., 2017), and policy interventions, such as subsidies and regulation (Yao et al., 2014; Yang & Zhao, 2015; Wang et al., 2017; see de la Rue du Can et al., 2014 for a thorough overview of different policy measures).

Situational influences on preferences for green electricity may include income (Clark et al., 2003; Ek & Söderholm, 2008; Welsch & Kühling, 2009), monetary costs (Ek & Söderholm, 2008; Welsch & Kühling, 2009; Litvine & Wüstenhagen, 2011; Alam et al., 2014), and household size (Clark et al., 2003; Welsch & Kühling, 2009).

Note that findings concerning the impact of situational constraints are often mixed, and thus aggregating previous results by meta-analytic means is important in this case.

2.3.2 Emotions and General Environmental Behaviour

A review of the literature shows that the most studied emotion in relation to pro-environmental behaviour is guilt, followed by pride. Less attention has been paid to other emotions such as fear and anger, which have also been shown to play a relevant role in the formation of human judgment and habits (Lerner & Keltner, 2000; see also Reese & Jacob, 2015 for more details).

Bierhoff (2002) posits that the formation and activation of moral norms, which are frequently related to eco-friendly behaviour, is likely due to the interplay of cognitive, emotional (e.g., guilt), as well as social factors. Guilt can be considered an emotional reaction arising from the individual internal attribution of a harmful behaviour (e.g., Baumeister, Stillwell, & Heatherton, 1994). Individuals perform or avoid a stunning variety of actions because of the anticipation of guilt. In fact, guilt is a common emotional factor widely investigated in behavioural decision science. This emotion represents an interpersonal phenomenon, which is functionally linked to communal relationships among individuals. Based on this, we can claim that it is an important pro-social emotion as it results in a felt obligation (moral norm) to compensate for the caused damage (Baumeister, 1998). Moreover, feelings of guilt are also closely related to social norms. In fact, Baumeister and colleagues (Baumeister, 1998; Baumeister, Stillwell, & Heatherton, 1994) claim that a perceived mismatch between one's own behaviour and social norms may engender guilt. Social norms give rise to the standard behaviour that a social reference group views as appropriate in a specific context (i.e., what salient groups view and define as right or wrong). If people internalize such a standard, they create the content of their personal moral norms. Thus, the feeling of guilt plays a relevant role in the formation of social and personal norms, which in turn, are widely studied in the field of pro-environmental behaviour. More specifically, Bamberg and Möser's (2007) meta-analysis of the determinants of pro-environmental behaviour suggests that guilt may play a key self-regulatory role in the interplay of cognitive factors (e.g., problem awareness, internal attribution), social and moral norms, as well as attitude and perceived behaviour control when one is deciding to act in an eco-friendly way.

According to Onwezen and colleagues (2013), we can categorize studies that focus on feelings of guilt and pride into three groups.

First, we find studies proposing that the effects of anticipated pride and guilt on behaviour are mediated by personal norms (e.g., Hunecke et al., 2001; Kaiser & Shimoda, 1999). For example, Hunecke et al. (2001) show that personal ecological norms mediate the relationship between feelings of guilt and subway use.

Second, other authors point to a mediating role of guilt in the association between social and personal norms in the prediction of public transportation use (Bamberg et al., 2007). Bamberg et al. point out that the effects of social norms on behaviour are based on social pressure (i.e. fear of social sanctions), whereas the effects of personal norms on behaviour are based upon anticipated emotions (i.e. anticipation of negative self-related feelings). This reasoning implies that personal norms are related to anticipated emotions, which in turn, are associated to ecological behaviour. However, Baumeister (1998) indicates that an observed mismatch between one's own behaviour and perceived social norms gives rise to feelings of guilt, which in turn activate personal norms. In this vein, Bamberg and Möser's meta-analysis supports this statement by showing that guilt is determined by both social norms and awareness of consequences, and that in turn, such a feeling activates personal norms. Then, even a further kind of mediation effect may be identified. A different line of research shows that self-conscious emotions (e.g., pride and guilt) are formed by self-evaluations regarding personal norms and standards. Such emotions in turn influence people's behaviour (e.g., Tracy & Robins, 2004). Accordingly, it could be possible that personal norm is related to behaviour through anticipated pride and guilt.

Third, some studies refer to the moderating roles of anticipated guilt in the association between personal norm and behaviour (e.g., De Ruyter & Wetzels, 2000). These studies posit that "anticipated guilt can motivate an individual to avoid breaking personal norms ("I will behave in line with my personal norms because otherwise I will feel guilty") and that the anticipation of positive feelings of pride can stimulate compliance with personal norms ("If I behave in accordance with my personal norms, I will be proud of myself")" (Onwezen, Antonides, & Bartel, 2013, p. 145). Future studies are needed to investigate these possible mechanisms more deeply, and to disentangle the relationships among these factors.

Reviewing studies that investigate the role of guilt and pride in the environmental psychological field, there are some gaps to be filled. For example, there are some studies that integrate anticipated feelings of pride and guilt into the definition of personal norms, without using an explicit measure of such feelings (e.g., Harland et al., 1999; Vining & Ebreo, 1992). Other research includes feelings of guilt as an item in the measurement of personal norms (e.g., De Groot & Steg, 2009; Steg & De Groot, 2010). These kinds of studies do not differentiate between the constructs, and (more or less explicitly) assume that these emotions are part of a process in which personal norms influence behaviour. Future studies in this field should thus try to measure these constructs as distinct variables. Moreover, previous studies have less frequently included anticipated pride in explaining eco-friendly behaviours (compared to studies on guilt). Thus, guilt has received much more attention than pride in previous research, and future studies should probably aim at filling such a gap.

We performed a systematic search through two relevant multidisciplinary databases (i.e., Scopus and ScienceDirect), where we combined concepts such as "guilt", "pride" or "anger", but also general terms like "emotion" with terms related to the energy domain. We found 444 and 333 articles in the two databases, respectively. This systematic search is a first step in shedding light on whether and how these emotions have been studied in the domain of energy choice. More specifically, to understand a potential mediating and/or moderating role of such emotions in the interplay between cognitive and social factors when referring to energy related behaviour. Finally, another emotion that seems to have emerged in a very specific energy domain is "fear". In fact, this emotion has been investigated in relation to the issue of nuclear energy, and seems to play an interesting role in this field of research (Selimbegović et al., 2016). Scopus and ScienceDirect provide 211 and 181 articles, respectively, when using this keyword in the energy domain. Thus, a deeper investigation of such an emotion could also be desirable, if one wants to understand human reactions in this specific energy domain.

2.3.3 Collective-level (Psychological) Determinants of General Environmental Behaviour

2.3.3.1 The Social Identity Approach: Theoretical Background[19]

Social identity has been defined as "that part of an individual's self-concept, which derives from his [or her] knowledge of his [or her] membership of a social group (or groups) together with the value and emotional significance attached to that membership" (Tajfel, 1978, p. 63). According to the Social Identity Approach (SIA), three basic principles of social identity can be distinguished (Kessler & Mummendey, 2008): ingroup identification and self-categorization, social comparisons, and social identity motives.

Ingroup Identification and Self-categorization. Across situations, people can define their self on different levels of social inclusiveness (Brewer, 1991). Situationally or chronically salient and accessible categorizations of their social environment determine which of these self-definitions people adopt in a situation. A specific self-categorization becomes likely, when at least two social categories (ingroup and outgroup) can be distinguished in a situation, such as environmentalists and non-environmentalists. This is possible when (perceived) similarity among the members of each category is high and similarity between members of different groups is low (e.g., all environmentalists approve of climate change regulations, whereas all non-environmentalists do not) (Turner et al., 1987), and/or the cognitive accessibility of certain in- and outgroups is high (e.g., committed environmentalists are inclined to continuously monitor their social surrounding for environmentalists vs. non-environmentalists, while sexists tend to be highly vigilant for gender group differences). This cognitive perspective on social identity formation via situation-specific categorization of in- and outgroups has been complemented by more recent research showing that social identities often emerge inductively from inter-individual interactions and discussions about common opinions and actions (Postmes et al., 2005; Thomas et al., 2012; Thomas et al., 2016). This research indicates that social identities may form without comparison to outgroups only on the ground of a shared common fate and positive interdependence (Sherif, 1966; see also Gaertner et al., 2006).

Social Comparisons. Social identities do not just tell people where they belong, but also who they are. This is determined by the mental prototype of the ingroup. Although people often have social and personal knowledge about their ingroup's prototype (e.g., perceived ingroup norms and goals or sense of collective efficacy), representations of the ingroup prototype can vary across situations, depending on which social comparisons are salient. If, for instance, Germans compare themselves with the citizens of a developing country in the Sahel, such as Mali, they may perceive their ingroup as a high emission country and rather a perpetrator than a victim of climate change. However, this aspect of the ingroup prototype may markedly change when they themselves with US Americans, whose per-capita emissions are considerably higher (Hertwich & Peters, 2009; see also Rabinovich et al., 2012). In the latter comparison, Germans may construe a rather climate friendly ingroup prototype (regardless of factual climate policies).

Social Identity Motives. Beyond cognitive (self-categorization, social comparisons) and affective (identification) social identity processes, social identity is also shaped by at least four basic social psychological motives (Fiske, 2005; Fritsche et al., 2011; Pittman & Zeigler, 2007) which can be satisfied by membership in social groups. It is argued that processes of social identity are determined by people's desire for (1) *self-esteem* (Rubin & Hewstone, 1998), leading to group-based (e.g., ingroup bias) or personal (e.g., leaving the group) responses to low relative ingroup status. Hogg (2007) added (2) *uncertainty reduction* as a further motive satisfied through identification with

[19] For a more detailed account on a social identity approach to environmental behaviour see Fritsche, Barth, Jugert, Masson & Reese (under review).

ingroups who are distinctive and provide a clear and prescriptive prototype, helping to reduce uncertainty about the self. Castano et al. (2002) integrated social identity theory and (3) *terror management* theory, concluding that identification with continuous ingroups may protect people from the fear of self-extinction. As a fourth motive account, Fritsche et al., (2011, 2013) have proposed that identification with agentic social ingroups and acting in terms of group membership enhances people's *sense of control* and helps people to cope with a lack of personal control (e.g., under conditions of personal helplessness in the face of global environmental crisis). In support of a multi-basic motives perspective on social identity, experimental research has shown that various indicators of social identity-based thinking, such as ingroup identification, ingroup bias, and conformity to ingroup norms (e.g., about pro-environmental behaviour), were increased following certain events. These include a threat to personal self-esteem (Jordan et al., 2005; but see Rubin & Hewstone, 1998), uncertainty (Hogg, 2007; Smith, Hogg, Martin & Terry, 2007), mortality salience (Castano et al., 2002; Fritsche et al., 2010; Giannakakis & Fritsche, 2011), and salient threat to personal control (Fritsche et al., 2013; Stollberg et al., in press). A similar set of social identity motives may explain responses to *collective* threat. Accordingly, threats to ingroup value (Branscombe, Schmitt & Harvey, 1999), ingroup distinctiveness (Jetten, Spears & Postmes, 2004) and existence (Wohl, Giguere, Branscombe & McVicar, 2011), as well as realistic group resources (Riek, Mania & Gaertner, 2006, e.g., when collective natural resources become scarce) increase collective defensive responses (e.g., prejudice towards outgroups).

Self-categorization and ingroup identification, social comparisons, and social identity motives are the primary mechanisms that constitute social identities (Kessler & Mummendey, 2008; Tajfel & Turner, 1979). Further, secondary processes have been described to explain the influence of social norms (Abrams, Wetherell, Cochrane, Hogg & Turner, 1990; Hogg & Turner, 1987), the role of collective emotions (Doosje, Branscombe, Spears & Manstead, 1998; Mackie, Devos & Smith, 2000), and collective efficacy (Mummendey, Kessler, Klink, & Mielke, 1999; van Zomeren, Postmes & Spears, 2008). In sum, SIA describes the determinants and consequences of people defining their self on different levels of social inclusiveness (from person to different ingroups). Which self-definition is salient depends on processes of self-categorization and identification. The prototype of the ingroup (e.g., knowledge about ingroup norms or collective efficacy) is construed on the ground of situated social comparisons. Besides cognitive processes, basic social identity motives determine the formation, adoption, and expression of social identities. Previous research on personal-level predictors does not capture the collective dimension of the self and its effects on the appraisal of and responses to, large-scale environmental crises (see Section 2.2.2; Terry et al., 1999).

2.3.3.2 A Social Identity Model of Pro-Environmental Action (SIMPEA)

Based on our theorizing above, we propose a Social Identity Model of Pro-Environmental Action (see Fig. 3) that describes how environmental crises, as (a set of) external stimuli, elicit people's relevant responses, mediated through environmental appraisal and group-based cognition and motivation. The model centers around three social identity variables that we consider important for understanding environmental-crisis related appraisals (e.g., acceptance of European energy union) and responses (e.g., energy behaviours), and how they are interlinked: ingroup identification, ingroup norms, and collective efficacy beliefs.

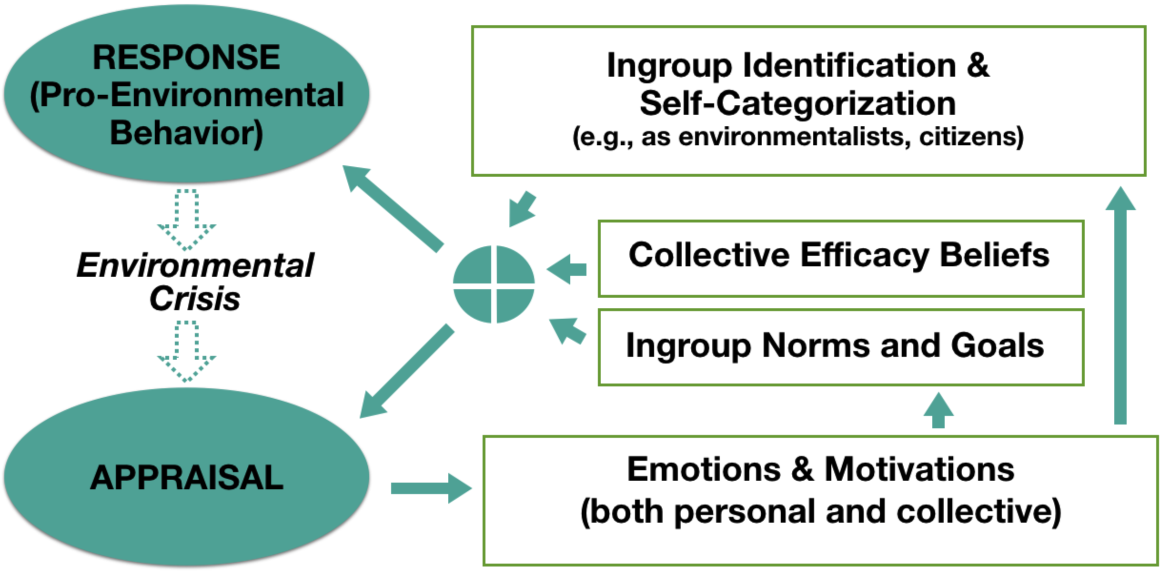

Figure 3 Social Identity Model of Pro-Environmental Action (SIMPEA)

For group-based action to occur, people need to *identify* with a group. That means, they should clearly categorize their self as belonging to a group and feel invested in the group (Leach et al., 2008). These can either be groups that are intrinsically related to environmentalism (Bliuc et al., 2015; Fielding, McDonald & Louis, 2008) or those that are not. What a group stands for is determined by people's perception of the ingroup prototype including *ingroup norms* of thinking and behaviour and specific ingroup goals (Masson, Jugert & Fritsche, 2016). These ingroup norms and goals (e.g., of protecting biodiversity or contributing to the transition to renewable energies) give group members' actions direction and purpose. Pro-environmental norms will increase group-members' inclination to act in a pro-environmental fashion (Nolan, Schultz, Cialdini, Goldstein & Griskevicius, 2008), especially when they are highly identified with the group (Masson & Fritsche, 2014). Acting in line with ingroup norms and goals becomes even more likely when identified people think that the group is able to attain its goals (i.e. *collective efficacy beliefs*; Jugert et al., 2016; van Zomeren et al., 2008).

As indicated by the circled "X" in Figure 3, ingroup identification, environmental ingroup norms, and collective environmental efficacy are supposed to interact in affecting pro-environmental responses. Each of the three critical social identity variables may have unique effects on pro-environmental responses when the other two variables are held constant. However, we expect the effects of each of these variables to be increased given high values on the other two variables. For instance, the effects of pro-environmental ingroup norms or collective efficacy will be catalysed by high levels of ingroup identification. This is because people have to relate norms and efficacy to their (social) self in order to make them a basis for individual action (e.g., "yes, we can" but not "yes, they can"). At the same time, high levels of ingroup identification will only increase people's pro-environmental behaviour intention when environmentalism is a salient ingroup norm and even more so when they perceive their ingroup as effective in reaching its goals.

The three focal social identity predictors (identification, efficacy, and norms) should not only affect pro-environmental behaviour, but the very appraisal of environmental crises as well. Specifically, we assume that the appraisal of environmental crises is the result of information provided by and interpreted in the social context. Social identity processes determine this context. That is, the prototype (e.g., perceptions of ingroup norms and goals or collective efficacy) of a relevant ingroup determines whether and how crises are perceived (Rabinovich et al., 2012).

For instance, identifying with a group that ideologically rejects the existence of climate change (e.g., Dunlap & McCright, 2008; McCright & Dunlap, 2011) will lead members to be sceptical about the very existence of climate change. At the same time, perceptions of collective efficacy will determine to a large part whether people consider climate change as alterable or stable.

Apart from these central processes, we also propose emotions and motivations to mediate the effect environmental crisis appraisal has on group-based processes (see Section 2.2). In general, appraisals of environmental crisis may threaten the satisfaction of basic psychological motives, such as self-esteem or control (Fritsche et al., 2012). When people focus on the personal consequences of climate change they may perceive emotions or self-related motivational states on the personal level, such as personal helplessness, which equals the motivational state of threat (Blascovich & Tomaka, 1996). Focusing on the perceived collective implications of climate change instead will lead to group-based emotions, such as guilt, anger (e.g., when cyclists compare themselves with SUV drivers), or collective threat (e.g., when one's own environmental group is considered ineffective in bringing about change in face of severe crisis). Whereas many group-based emotions are assumed to have directly and deliberately reflected consequences on the level of collective norms and specific goals (e.g., pursuing the collective goal of reparation or pro-environmental action in response to eco-guilt) (e.g. Ferguson & Branscombe, 2010; Harth et al., 2013; see path from emotions/motivations to norms in Figure 1), social identity processes should also be fuelled by an automatic, unconscious, and general ethnocentric responses to both collective and personal threat (e.g., ingroup bias; Fritsche et al., 2011; Jonas et al., 2014; see path from emotions/motivations to ingroup identification). Summed up, collective emotions and resulting general collective motivations should directly affect more specific ingroup norms and goals. At the same time, threats to basic motives on either, or both, the collective and the personal level, should automatically catalyse social-identity based responses.

2.3.3.3 The Role of Social Identity Processes for Environmental Appraisal and Behaviours: An Empirical Review

In the following, we will review existing evidence on social identity processes for general environmental appraisal and behaviours. As researchers have started only recently to apply the social identity perspective to environmental behaviours, the accumulated evidence may be preliminary and some of the reviewed research is not originally framed as social identity research. The review is organized along the three central social identity variables and processes, elaborated above, namely ingroup identification and self-categorization, ingroup norms and goals, and collective efficacy. For each of these variables we review research on first their effects on environmental appraisals and then their effects on pro-environmental behaviour.

Self-Categorization and Ingroup Identification.

Appraisal. Research on climate change scepticism suggests that group membership affects the appraisal of environmental crises. In an analysis of the Gallup Poll 2008, McCright and Dunlap (2008) showed that Republicans were much less inclined than Democrats to believe that effects of climate change had already begun, that most scientists agree climate change is occurring, that it is anthropogenic, and that it is threatening during their life time. At the same time, Republicans more strongly believed that the media exaggerated the seriousness of climate change. Party affiliation was a more substantial predictor of these beliefs than sex, age, income, race and education. McCright and Dunlap's (2011) data also suggest that the more respondents identified as Democrats, and the more they identified with the environmental movement, the less sceptical they were about climate change. A UK representative study (Poortinga, Spence, Whitmarsh, Capstick, & Pidgeon, 2011) as well as an analysis of the EUROBAROMETER (McCright, Dunlap, & Marquart-Pyatt, 2015) come to similar conclusions, finding that conservatives in particular were sceptical of global climate change.

Some research has focused on climate change sceptics and believers as opinion-based groups (e.g., Bliuc, McGarty, Reynolds & Muntele, 2007).[20] The group of climate change sceptics, not surprisingly, is rather reluctant when it comes to pro-environmental behaviour (e.g., Whitmarsh, 2008). Corner and colleagues (Corner, Whitmarsh, & Xenias, 2010) provide an illustrative example for how different groups (i.e., climate change sceptics vs. non-sceptics) appraise information about climate change in line with their dominant attitudinal norm or ideology. In their study, participants were assigned to one of the two groups (based on self-report items), and were asked to evaluate two editorials that were either confirming or contradicting their initial attitude. In line with the authors' expectations, sceptics evaluated the sceptical editorial as more reliable and convincing than the pro-climate change editorial, while the reverse was the case for non-sceptics.

These studies show that both membership in ideological (Corner et al., 2010; McCright & Dunlap, 2008; McCright et al., 2015; Poortinga et al., 2011) or cultural groups (Capstick et al., 2015) as well as the degree to which people self-categorize or identify with their ingroup (Frank, Eakin, & López-Carr, 2011; McCright & Dunlap, 2008) affect their appraisal of environmental crises (or of collective environmental projects), in the direction of ingroup attitudinal norms.

Responses. In its most direct and obvious way, self-categorization and identification affect people's environmental cognitions and behaviours when people identify with groups that are explicitly defined as environmentally friendly. For example, previous studies have found that respondents' identification with the group of environmentalists was positively correlated with their willingness to pay premiums for environmentally friendly products and to participate in collective environmental action (e.g., to sign petitions), as well as with a general willingness to engage as an environmental activist (Dono, Webb, & Richardson, 2010; Fielding, McDonald, & Louis, 2008). Furthermore, identification as an environmentalist was negatively associated with purchase intentions for genetically modified food and with attitudes supporting such food (Cook, Kerr, & Moore, 2002). Focussing on identification with the group of environmentally conscious consumers, Bartels and Hoogendam (2011) showed that high identifiers reported higher spending on organic food as well as more positive attitudes toward eco-brands (i.e. brands that mainly sell organic products; for similar results see Bartels & Onwezen, 2014; Bartels & Reinders, 2010; Gupta & Ogden, 2009). Of importance for ECHOES, identification as a green consumer was found to explain variance in general intentions to behave in a pro-environmental manner over and above other well-established individual-level predictors, such as, perceived behavioural control and biospheric value orientation (Sparks & Shepherd, 1992; van der Werff, Steg & Keizer, 2013; Whitmarsh & O'Neill, 2010). Presumably, constructs like the group of "green" or environmentally conscious consumers are examples of opinion-based groups, that are psychological groups that are "primarily based on shared opinions" (Bliuc et al. 2007; p. 20; although differentiation from personal self-identities is not always straightforward). Previous studies have found consistent support for the effects of membership in opinion-based groups on cognitions, emotions and behaviour across different behavioural domains (Gee, & McGarty, 2013; McGarty, Thomas, Lala, Smith, & Bliuc, 2014; McGarty, Bliuc, Thomas, & Bongiorno, 2009; Musgrove, & McGarty, 2008). Bliuc and colleagues (2007) showed that self-categorization as a member of an opinion-based group increases indicators of salient group membership, such as perceiving goals and identity to be shared among group members (i.e., depersonalized self-perception), thereby providing evidence for the nature of opinion-based groups as genuine social identities. Identification with opinion-based groups) linked to environmental issues should thus not only affect people's perception of but also their responses to environmental problems. For ECHOES, a focus on the "supporters of the transition to renewable energies" as a possible opinion-based group might be a fruitful approach, both theoretically and for the design of intervention campaigns.

However, not only environmentalist identities have an impact on pro-environmental responses. So do those identities that are inherently associated with anti-environmental behaviours. For example, Murtagh, Gatersleben, and Uzzel (2012) primed respondents' motorist identity and found that both measured identity centrality and identity

[20] According to Bliuc, McGarty, Thomas, Lala, Berndsen, and Misajon (2015, p. 226), "opinion-based groups are psychological groups formed around contrasting views about what needs to be done about an issue".

threat reduced their willingness to adopt sustainable modes of mobility. Furthermore, self-categorization and social identification can have tremendous effects on pro-environmental behaviour, even in the case of groups who are not primarily characterized by or founded for pro- or anti-environmental action. For example, Kramer and Brewer (1986) found that participants of a social dilemma game contributed more to the common resource pool (or depleted less resources) when categorized as members of a small (vs. large) group, that is, when social identification was high. Results provided by de Cremer, and van Vugt (1999, 2002) indicate that social identification positively influenced group members' willingness to cooperate in a resource dilemma situation (public goods game), but only when their social identity and not their personal identity was made salient. Social identification thereby encouraged people to make efforts in obtaining outcomes that benefited the group (goal-transformation hypothesis; Simpson, 2006). In a similar vein, Van Vugt (2001) found community identification to prevent overuse of communal water resources, even in the absence of financial incentives.

Finally, social identities do not only differ with regard to their normative content (pro- vs. anti- vs. non-environmental prototype) but may also be structured across different levels of inclusiveness (geographical, social or even temporal, Postmes et al., 2014). Identification on the highest level of social abstraction (i.e., identifying with humankind) has been shown to increase people's endorsement of environmental sustainability (Renger & Reese, in press; Reysen & Katzarska-Miller, 2013; Rosenmann et al., 2016) as well as their concern for climate change (Running, 2013). This may be grounded in a more general care for human (rather than personal) welfare (McFarland et al., 2012; Reese, Proch, & Finn, 2015) and a desire for "environmental justice for all" (Reese, 2016). Similarly, salience of the European (or EU) identity, as opposed to personal-level identities, may increase acceptance of EU-wide energy projects aimed at fostering the transition to renewable energies (e.g., by shifting the focus from personal to group-level gains or by strengthening collective efficacy beliefs, see below).

Although the abovementioned research describes direct effects of self-categorization and ingroup identification on environmental appraisal and response, it has become obvious that these effects are always in line with the norms, goals, and interests of the respective ingroup. That is, ingroup identification should fuel any behaviour considered normative or beneficial to the ingroup (Masson & Fritsche, 2014; White, Smith, Terry, Greenslade, & McKimmie, 2009). This indirectly confirms the assumption that the effect of ingroup identification is contingent on ingroup norms (and collective efficacy beliefs) and that at the same time, identification catalyses the effects of norms (and efficacy). Thus, for ingroup identification (e.g., identification with EU) to foster pro-environmental responses, it has to be assured that pro-environmental behaviour norms are widely shared and salient within the group.

Collective Efficacy.

Groups are for doing. The extent to which people perceive a group to be effective in reaching its goals has been described as collective efficacy (Bandura, 2000; van Zomeren et al., 2008). In fact, research on group entitativity shows that people heuristically perceive groups as homogeneous agents (Brewer, Hong & Li, 2004). Past social identity research has focused on the role of collective efficacy beliefs for collective protest and action (Klandermans, 1997). In their influential meta-analysis, Van Zomeren et al. (2008) identified collective efficacy as one of three major predictors of collective action (among ingroup identification and collective anger). To engage in collective action people have to feel that their group or collective effort can make a significant effect (Mummendey et al., 1999).

Appraisal. SIMPEA predicts collective efficacy to affect both appraisals of and responses to environmental crises. With regard to appraisals, perceiving their own group as likely being capable of dealing with environmental crisis may reduce people's perceptions of threat and turn them into challenge appraisals. In contrast to threat, challenge motivation increases the likelihood that people initiate an effective (collective) response (Blascovich & Tomaka, 1996; Scheepers, 2017). At the same time, perceived inability to tackle environmental crisis even on a collective level may lead to defensive denial. However, we are not aware of any research having tested these assumptions yet. Instead, there have only been initial efforts of investigating collective efficacy as a predictor of people's responses to environmental crises.

Responses. People's pro-environmental action aims to preserve a collective good (Hardin, 1968) which cannot be accomplished by the behaviour of a single individual, but which is the outcome of the behaviour of many. This makes it obvious that considerations of collective efficacy (e.g., are we as a group capable of dealing with this problem?) should play a prominent role in motivating individuals to pro-environmental action. However, despite extensive research on collective protest participation (van Zomeren et al., 2008) very little work has looked at activist or private-sphere pro-environmental behaviour as an outcome of collective efficacy.

Cocking and Drury (2004) used ethnographic methods to show how activist collective action experiences in an anti-roads struggle in Great Britain could increase collective efficacy through newly formed group identities. Their findings also indicate that collective action experiences boost personal efficacy beliefs at the same time, and thus point to an interesting relationship between personal and group efficacy beliefs. As described above, van Zomeren, Spears and Leach (2010) showed that reminders of climate change threat increased pro-climate collective action intentions, such as signing petitions or voting behaviour, mediated through collective efficacy beliefs. This fits with research by Hornsey et al. (2015) who showed that climate change threat increases collective efficacy. Turning to private-sphere pro-environmental behaviours, a recent study (Chen, 2016) found that fear appeals about the likely consequences of climate change were only successful in raising pro-environmental intentions when perceptions of collective efficacy were high, but not when they were low.

Studies that have focused on private-sphere pro-environmental behaviours have typically not considered its collective dimension, and have thus overlooked the role of collective efficacy. In a study among 55 localities of different population size in Spain, Tabernero and Hernández (2011) showed that smaller communities have a greater belief in their collective efficacy to develop pro-environmental action than do larger communities. This finding is in line with the argument that smaller, more particularistic groups may be more efficacious than larger collectives (Kerr, 1989; Vignoles et al., 2006). Their results also show that populations with higher belief in their collective capacity recycle more (see Tabernero, Hernández, Cuadrado, Luque, & Pereira, 2015 for similar findings). In a social identity take on collective efficacy, Morton, Rabinovich, Marshall, and Bretschneider (2011, Study 2) assessed collective efficacy as people's perception of their group being efficacious in preventing, or dealing with the consequences of, climate change. Focus on the possibility of avoiding malicious consequences of climate change (vs. the possibility of these consequences to occur) increased participants' perceptions of collective efficacy, when at the same time, the true likelihood of preventing or experiencing these consequences was uncertain). Collective efficacy, in turn, predicted private-sphere environmental actions (i.e., reducing household waste and non-green energy consumption). Wang (2017) reported similar findings with regard to collective efficacy predicting Chinese consumers' intentions to engage in personal behaviours to mitigate climate change. Finally, Homburg and Stolberg (2006) showed that collective but not personal self-efficacy predicted pro-environmental behaviour (see Chen, 2015 for similar results).

This handful of initial collective efficacy studies shows increased intentions of public or private-sphere pro-environmental action when collective efficacy was increased. This provides first evidence for the role of collective efficacy for pro-environmental action intentions and for the acceptance of collective pro-environmental projects (e.g., energy projects), proposed by SIMPEA. Yet, important questions remain largely unaddressed, for example, the relationship between individual and collective efficacy (Greenway et al., 2015) or methodological issues linked to the measurement of collective efficacy (beliefs).

Ingroup Norms and Goals.

People have a sense of what their group stands for and what the goals of their group are. For that, they construe ingroup norms, which are rules and standards about the positive or negative evaluation of behaviours. The social identity approach offers a parsimonious explanation of why norms affect people, which has been called "referent informational influence" (Abrams, Wetherell, Cochrane, Hogg & Turner, 1990). From this perspective, social norms are markers of social groups and they vary across groups and situations. That is, people can distinguish between groups on the ground of different ingroup norms and infer the ingroup prototype from social norms of the ingroup and a situational comparison outgroup (e.g., members of group X care for the environment, members of group Y do not). The effect of ingroup norms on people's thinking and behaviour can then be explained by self-categorized and identified people adopting the ingroup prototype as a description of their self, which has been illustrated in research on self-stereotyping (Hogg & Turner, 1987). That is, from a social-identity perspective, norm conformity does not necessarily emerge from personal benefits but from people's propensity to define the self in terms of group-membership and to adopt ingroup attributes (e.g. behaviours) as attributes of their self.

Appraisal. A couple of recent social identity studies have looked on how situated intergroup comparisons (i.e., inferred in-group norms) can affect the appraisal of environmental crises. Although perceived ingroup norms have not always been measured explicitly in these studies, they may have been the critical mediating variable. Ferguson et al. (2011, Study 2) found that US undergraduates who compared their ingroup of contemporary students to students in the year 1960 (thus 50 years into the past) reported stronger confidence that climate change is real, harmful and contingent on human behaviour than those who compared with the students from 2060 (thus 50 years into the future). Climate change appraisal fully mediated the effect that comparing to the students of 1960 (vs. 2060) increased participants' willingness to perform sustainable behaviour and their support of climate change taxes. The authors suggest that the salient comparison altered perceptions of who "we" are (i.e., pro-environmental ingroup norm).

In addition to this reflective, cognitive process of adopting comparison results as the ingroup prototype or norm, unfavourable intergroup comparisons on collective contributions to climate change can lead to reactive (i.e., defensive) climate change appraisals as well, for example through a shift in attribution towards non-human causation (Jang, 2013). This protects the ingroup image from harm elicited by the salience of an anti-environmental descriptive ingroup norm (Marques & Paez, 1994). More evidence is needed to determine under which conditions descriptive environmental norms lead to reflective or reactive environmental appraisals.

Responses. Proponents of the social identity approach have stressed the negligence of group-based influence in most individualistic models of pro-environmental action (Terry, Hogg, & White, 1999; White, Smith, Terry, Greenslade, & McKimmie, 2009). Although studies explicitly aimed at studying the role of ingroup norms for pro-environmental conduct are still relatively few, numbers have recently risen. Several studies found ingroup norms to predict recycling intentions and behaviour covering different social groups and countries (Carrus, Bonnes, Fornara, Passafaro & Tronu, 2009; Fornara, Carrus, Passafaro & Bonnes, 2011; Nigbur et al., 2010; Terry et al., 1999; Wellen, Hogg, & Terry, 1998; White et al., 2009).

As a central proposition of the social identity approach, people's perception of what the ingroup norm is, typically emerges out of salient intergroup comparisons. Rabinovich and colleagues (2012) found that British participants who compared their national in-group with an ostensibly less environmentally friendly out-group (US Americans; i.e., downward comparison) perceived their in-group as more environmentally friendly than participants in an upward comparison condition (comparing with Swedes). Importantly, these participants also reported higher willingness to engage in pro-environmental actions compared to participants in the upward comparison condition (conceptually replicating Ferguson et al., 2011 and Jang, 2013). This effect was mediated by perceived pro-environmental ingroup norms (i.e. ingroup prototype): downward comparison moved the normative ingroup prototype towards environmentalism, which in turn increased group members' likelihood of pro-environmental behaviour.

Apart from intergroup comparisons, other comparisons have been shown to affect collective pro-environmental responses, as well, probably because they affected perceived ingroup norms. As noted above, temporal comparisons can be used to compare present behaviour of the in-group to past behaviour (Ferguson et al., 2011). This approach has been employed in a number of studies and it successfully increased recycling behaviour (De

Leon & Fuqua, 1995; Kim, Oah, & Dickinson 2005; Larson, Houlihan, & Goernert, 1995; Schultz, 1999; Young et al., 1995) and sustainable energy use (Carrico & Riemer, 2011). In these studies, whenever participants received any feedback about the ingroups' past performance (e.g., percentage of correctly separated waste at the previous day), sustainable behaviours were shown more often than in conditions were there was no feedback about past group behaviour. It is very likely that the positive effects were the result of normative effects, as information on past group behaviour can certainly set a descriptive norm for future behaviour.

Yet another variant is the comparison of a group member's behaviour to the average behaviour of the group (i.e. descriptive norm). Toner, Gan and Leary (2013) used a bogus carbon footprint calculator to provide feedback about participants' individual environmental impact and that of their ingroup. When they were made to believe that they personally had a worse impact on the environment than their group average, participants reported the highest intentions to act pro-environmentally in the future. The authors propose that people are motivated to change their behaviour when they perceive their behaviour to differ from that of an important ingroup (for correlational evidence see also Onwezen et al., 2014).

Testing the effect of comparative feedback in energy contexts, Staats et al. (2004) combined comparative feedback, information, and social interaction in a team intervention program, allowing for comparisons between team members as well as between teams. This program proved successful in reducing energy use. In another field study, more directly addressing intergroup comparisons, two units of a metallurgical company were either given feedback about their own energy savings only or about their own savings and the savings of other units. Subsequently, energy conservation was measured (Siero et al., 1996). Results revealed that employees in the comparative intergroup feedback condition saved more energy and that this effect was stable six months after the intervention.

Rabinovich and Morton (2012) further scrutinized the processes underlying the effects of individuals comparing to ingroup standards. They gave participants bogus information about Britain's national target for the average individual carbon footprint by 2012, their own carbon footprint (either meeting Britain's national target or missing the target), and the footprint of the average British citizen (either meeting or missing the national target). Results revealed that when receiving negative group feedback, but positive individual feedback, high identifiers considered collective change more important and more strongly intended to behave environmentally friendly than weakly identified group members. This suggests that high identifiers are more invested in the performance of their ingroup and want to minimize discrepancies between self and group (for a review on the effects of group feedback and socially comparative feedback on resource conservation behaviour see Abrahamse & Steg, 2013). These findings further illustrate that pro-environmental ingroup norms emerging out of group-based comparisons guide people's environmental behaviour, especially when they are motivated to affirm group membership.

While there is only preliminary evidence for the effect of ingroup norms on environmental appraisal, the effect of ingroup norms on people's pro-environmental responses seems quite robust and is backed by a multitude of, mostly experimental, studies. As proposed by SIMPEA, the latter effect is particularly pronounced for people who highly identify with the ingroup. For instance, Fielding and colleagues (2008) showed ingroup norms to influence intentions to engage in sustainable agricultural practices among highly identified farmers, but not for those less identified with their local community. Masson and Fritsche (2014) found ingroup norms and ingroup identification to predict intentions to purchase organic food among German students, even after controlling for other well-established predictors (e.g., perceived behavioural control).

2.4 General Discussion: An Agenda for Integrated Research on Energy Behaviour

2.4.1 Summary of the Empirical Findings on the Comprehensive Action Determination Model

Our review reveals that *most of the influences* postulated in the Comprehensive Action Determination Model (CADM) have received considerable attention in past research, especially with regard to research on electric mobility and the use of energy in buildings. Since smart energy technology represents a somewhat more recent technological development, it is understandable that there are fewer studies on this (Sintov & Schultz, 2015). We begin our summary by looking at predictors that describe the "moral motivation cascade" within the CADM. The key mediator through which all the more distal variables included in this cascade operate is personal norm. Previous research confirms that personal norms influence decisions in each of the three technological foci, including the adoption of electric vehicles (Klöckner, 2014), energy curtailment behaviour (Ruepert et al., 2016), energy-related investment decisions (Fornara et al., 2016), preferences for purchasing green electricity (Litvine & Wüstenhagen, 2011), and the adoption of smart energy technology (Toft et al., 2014). In line with the CADM, personal norms thus represent a central predictor of energy-related behaviours across different areas – and a possible point of entry for intervention campaigns. While past studies largely confirm the central role of *personal norms* in predicting the adoption of energy-relevant behaviours, less research is available on intervention aiming to change personal norms.

Our review also highlights the relevance of the more distal predictors within the moral motivation cascade. First, *social norms* are – by now – a well-established predictor for energy-related decisions in each of the areas of research: electric mobility (Barth et al., 2016), energy consumption (Schultz et al., 2007), energy-related investment (Korcaj et al., 2015), green electricity purchasing (Welsch & Kühling, 2009), and smart energy technology (Van der Werff & Steg, 2016). In the wake of seminal field experiments (Schultz et al., 2007; Nolan et al., 2008), conveying normative information to consumers has been recently adopted as a cost-effective and flexible intervention strategy to promote energy conservation (Allcott, 2011; Ayres et al., 2012; Allcott & Rogers, 2014). Although the effects of the provision of normative information observed in natural settings are modest (leading to savings of about 2% of baseline energy consumption), such effects lasted beyond the initial intervention phase (Allcott & Rogers, 2014). Furthermore, the effects of norm-based interventions were found to be particularly strong when the intervention was targeted at those most receptive to it (Göckeritz et al., 2010; Allcott, 2011; Ayres et al., 2012) or when it was combined with other instruments, such as price setting (Sudarshan, 2017). Future intervention campaigns may thus adopt more complex intervention designs (i.e. combinations of information and financial or other incentives) to increase their long-term effects on behaviour.

Besides norms, *awareness of consequences* (of environmental problems) and *ascription of responsibility* (to fight environmental problems) have been shown to play a role in most of the reviewed areas: electric mobility (Klöckner, 2014), energy conservation through curtailment (Van der Werff & Steg, 2015), and through efficiency improvements (Wolske et al., 2017). This also holds true for the adoption of smart technology (Luthra et al., 2014). Finally, existing research also supports the relevance of *values* and *environmental worldviews* for energy-related behaviours. Values were found to influence electric mobility (Nayum et al., 2016), energy consumption in buildings and intentions to use green electricity (Van der Werff et al., 2013b), as well as the adoption of smart energy technology (Ellabban & Abu-Rub, 2016). Environmental worldviews, similarly, impact preferences for green electricity (Clark et al., 2003), and the adoption of electric and alternative fuel vehicles (Nordlund et al., 2016). Strengthening worldviews that stress the interdependency between nature and society (i.e. social-ecological perspective) could therefore represent a fruitful avenue for future research.

With regard to the "non-moral" constraints and motivators (i.e. attitudes, perceived behavioural control, habits, and contextual factors), attitudes and perceived behaviour control, two widely studied predictors of general pro-environmental behaviour, are also of importance for energy-related behaviours. Building on a considerable number of studies, *attitudes*, among others, were shown to influence the adoption of electric vehicles (Barbarossa et al., 2015) and of smart technology devices (Abrahamse & Steg 2009a), energy efficiency improvements (Fornara et al., 2016), energy use curtailment (Smith et al., 2012), and the purchasing of electricity from renewable sources (Litvine & Wüstenhagen, 2011). Similarly, *perceived behavioural control* contributes to decisions to purchase electric vehicles (Bockarjova & Steg, 2014), and green power (Litvine & Wüstenhagen, 2011), and it helps people conserve energy through curtailment (Webb et al., 2013) and investment actions (Korcaj et al., 2015). Consistent with the CADM, perceived behavioural control is partially predicted by objective constraints, such as income (Nayum & Klöckner, 2014) or purchase price (Kaplan et al., 2016). *Habits* are seen as a powerful driver of many pro-environmental behaviours (Klöckner & Matthies, 2004; Klöckner, 2013a). Yet, we did not find much direct evidence for the influence of habits on behaviour in any of the three domains surveyed in this paper, except for a study on elderly people's habits about household smart meters. However, previous research shows that *past behaviour* is associated with the acceptance of electric vehicles. More specifically, past electric vehicle buyers were more likely to buy an electric vehicle again than current non-adopters (Peters & Dutschke, 2014). Furthermore, both short-term (Skippon et al., 2016) and longer-term (Bühler et al., 2014) trial experience with an electric car has a positive impact on attitudes and perceptions, but not necessarily on purchase intentions. Similarly, past behaviour is associated with subsequent energy conservation (Schultz et al., 2015) and energy-related investment behaviour (Wolske et al., 2017). However, as argued for example by Bamberg and colleagues (2003), past behaviour is not necessarily a valid proxy for habit. Future research should therefore evaluate the role of habit more directly, for instance by employing established measures of habit (Verplanken et al., 1994; Verplanken & Orbell, 2003).

Besides psychological determinants, we also identified a considerable number of *situational factors* that possibly influence energy-related behaviour, including prices (Korcaj et al., 2015), income (Ek & Söderholm, 2008), or policy measures (Mersky et al., 2016). Notably, for most of these factors there was no clear pattern of association with the dependent measures. One way of handling this issue is to aggregate the results of individual studies by means of a meta-analysis (see Dimitropoulos et al., 2013, who investigate the importance of driving range for electric vehicle acceptance in their meta-study). Apart from that, future research should also explore in more detail possible indirect effects of situational factors on behaviour, for example through perceived behavioural control (Nayum & Klöckner, 2014; Kaplan et al., 2016) or attitudes (Petschnig et al., 2014).

In sum, our review supports the CADM as a feasible framework to investigate numerous (individual-level) psychological and non-psychological determinants of energy-related behaviour. Methodologically, our review is limited to a narrative presentation of past research; a precise quantification of the surveyed effects is beyond the scope of such work. We therefore intend to submit (some of) the reviewed studies to a meta-analysis, which allows to quantify the associations between the variables proposed by CADM and behavioural outcomes related to energy use across the three technological foci. Additionally, future research on energy-related behaviours based on the CADM may also address the following three issues:

First, *normative influence* has proven to be a cost-effective soft policy measure capable of shifting energy consumption of large groups of people (e.g. Allcott, 2011). Evidence from field experiments shows positive effects of norms on other types of conservation behaviour as well (Goldstein et al., 2008; Hamann et al., 2015; Kormos et al., 2015). Normative influence could therefore possibly represent a suitable approach to promote the adoption of electric vehicles and smart energy technology, the purchasing of green electricity, and investments into energy-efficiency improvements. To avoid an oversimplified adoption of social norms marketing, caution is needed with regard to the specific application of social norms. Previous studies show that, occasionally, the application of social norms may backfire (Schultz et al., 2007), trigger reactance or rebound effects (Sussman & Gifford, 2012; Bergquist & Nilsson, 2016), or give rise to negative emotions (Vesely & Klöckner, 2017b). Thus, it is important to test planned interventions in smaller and theoretically sophisticated research designs, prior to their large-scale deployment.

Second, another avenue for future research is to study the causal effects of *long term experience* with electric cars, smart energy technologies and energy-efficient appliances on subsequent (and repeated) adoption of these innovations. We assume that people who have experienced possible benefits (or downfalls) of technological innovations will be able to make more informed decisions, although experience alone may not necessarily increase the willingness to adopt (Bühler et al., 2014).

Third, a couple of results identified in this review also suggest possible *theoretical developments* pertaining to models such as Stern (2000), Van der Werff & Steg (2016) and CADM. For example, more distal predictors that were expected to influence behaviour only indirectly (see Fig. 2) may also exert a more immediate influence on people's choices. This may pertain to the role of values (Jansson et al., 2011; Fornara et al., 2016; Ruepert et al., 2016), environmental worldviews (Clark et al., 2003; Ek & Söderholm, 2008; Nordfjærn et al., 2016), and ascribed responsibility (Ek & Söderholm, 2008). Similarly, a link may exist between attitudes and personal or social norms (Terry & Hogg, 1996; Kaiser, 2006; Barbarossa et al., 2015; Fornara et al., 2016). In some cases, a seemingly direct effect of a certain theoretically distal predictor may, of course, be a spurious correlation (cf. Ek & Söderholm, 2008; Nordfjærn et al., 2016). Nevertheless, a direct influence of values and other factors on behavioural outcomes seems plausible. This should be tested using appropriate designs.

2.4.2 Emotions and Collective Self-Descriptions as Theoretical Innovations to Research on Energy Behaviour

Emotions. The CADM provides a sound conceptual framework for the analysis of (mainly) individual-level predictors of energy-related behaviours. In the current review, we advance the idea that such a model could benefit from the inclusion of emotions as a further factor improving its predictive power. Moreover, the inclusion of emotions in the CADM might offer insightful stimuli to tailor applied interventions in the energy domain, because emotions play a relevant motivational role driving human behaviour. More specifically, we propose that emotions have a dual function in influencing eco-friendly choices: i) based on the emotion-as-feedback theory, one can posit that anticipated emotions guide behaviour when making eco-relevant decisions; ii) post-decisional emotions can consolidate eco-friendly habits through a positive feedback functioning as a reinforcement mechanism.

Probably the most studied emotion in the pro-environmental field is guilt, followed by pride (Bamberg & Möser, 2007). Guilt has an important self-regulatory function because it might motivate people to act in an eco-friendly way to avoid such an unpleasant feeling in the post-decisional phase that might occur whenever an eco-unfriendly choice has been made. Both anticipated and post-decisional guilt could be relevant mechanisms to be considered in the moral domain included in the CADM. On the post-decisional side, feelings of pride occurring when people behave in an eco-friendly way might initiate a process of transforming occasional eco-friendly behaviours into more stable eco-friendly habits.

With regard to the Social Identity Model of Pro-Environmental Action (SIMPEA), guilt represents an interpersonal phenomenon that could be functionally linked to group membership, social accountability, and communal relationships among individuals. It is an important pro-social emotion, as it results in a felt obligation (moral norm) to compensate for the caused damage (Baumeister, 1998). Likewise, pride can be involved in mechanisms driving ingroup identification and positive feelings of community or territorial membership, bringing about positive consequences for people's local pro-environmental engagement (see for example, Carrus et al., 2005). Thus, we can advance the idea that emotions like guilt, pride or anger can be considered also as group-based emotions, acting at a collective level to motivate eco-friendly habits in the society at large, beyond individual differences.

Collective Self-Descriptions. Recent psychological research suggests that also collective-level (i.e. social identity) variables play an important role in motivating pro-environmental conduct. In the current review, we have introduced the SIMPEA, outlining how social identity processes affect, and are affected by environmental crisis appraisal and drive individuals' responses. The model sketches a number of processes that seem crucial for creating people's collectively shared understanding of the challenges tied to environmental problems and the ways to tackle these challenges, including self-categorization and identification, ingroup norms and goals, as well as perceptions of collective efficacy.

While previous research on energy-related behaviour has often focused on private-sphere behaviour, SIMPEA has a broader conception of collective pro-environmental action, including both public activist and private-sphere behaviour (Stern, 2000). Although on the surface, adopting environmentally friendly modes of transportation or saving energy at home may seem to be merely private decisions, research shows that this is not the case. Instead, personal cost-benefit analyses are accompanied or even outperformed by social identity considerations such as perceived ingroup norms or collective efficacy as predictors of travel-mode choice intentions (Barth et al., 2016), food purchase (Masson & Fritsche, 2014) or private energy-saving behaviour (Nolan et al., 2008; Schultz et al., 2015). Although SIMPEA applies to both private-sphere and activist environmental action and research supports this, it is still an open question whether both kinds of action are predicted equally well by social identity processes.

Given the novelty of the present approach to environmental crises research, SIMPEA provides a network of hypotheses still to be appropriately and sufficiently tested and it may stimulate research in related theoretical and applied fields, including energy-related behaviours (see also Fielding & Hornsey, 2016; Postmes et al., 2014). For instance, whereas much work confirms that salient pro-environmental norms increase respective intentions and behaviour, this research is often unspecific with regard to the process underlying this effect. Do people conform to any more or less "significant" other (Ajzen & Fishbein, 2005) who reminds us of pro-environmental behaviour opportunities or unfolds some kind of social pressure (Cialdini & Trost, 1998), and what is it that determines "significance"? From a SIMPEA perspective, we assume a specific influence process elicited by perceived *ingroup* norms (i.e. referent informational influence, Hogg & Turner, 1987). Obviously, sufficiently testing the determinants and consequences of ingroup norms requires careful analysis or manipulation of these social identity contexts. This, in turn, may help to develop effective interventions targeting the creation of contexts that facilitate behaviour targeted at, among others, reducing energy consumption, such as increasing the salience of pro-environmental ingroups or suggesting social comparisons that highlight pro-environmental norms of chronically important ingroups (e.g., nations). Other social identity processes proposed by SIMPEA still lack extensive consideration. This is particularly true for the effects of social identity variables on environmental appraisal. For instance, comparing the ingroup of the actual world population with future generations may elevate perceived collective controllability of climate change, as present day activities will have higher potential to mitigate climate change than actions in the distant future.

A social identity perspective on environmental attitudes and behaviour may thus inspire a new generation of theory-based interventions for fostering pro-environmental action. Most importantly, it complements the CADM and other individualistic models (e.g., Bamberg & Möser, 2007) by suggesting that successful environmental campaigns (e.g., campaigns to foster the transition to renewable energies) should take into account collective-level factors. In addition, it should teach campaigners that environmental self-efficacy and norms, as critical ingredients of pro-environmental motivation, do not entirely originate from personal attributes or inter-personal relations. Instead, practitioners have to be aware that individuals live in collective realities where group memberships determine to a large degree whether people consider pro-environmental action an appropriate expression of their (collective) self and even whether they think that environmental crises exist at all. This insight should turn campaigners' and policy makers' attention to considering and possibly affecting the three critical social identity processes outlined in SIMPEA (i.e., ingroup identification and self-categorization, collective efficacy, and ingroup norms and goals).

*Ingroup identification and self-categorization***.** Campaigners may affect people's ingroup identifications to change their environmental appraisals and actions. For instance, making people for whom climate change only poses a low personal risk think of themselves as citizens of the world might increase subjective risk to their self, as humanity is and will be affected in the future. In a similar vein, campaigns may highlight membership in generational groups that are ascribed responsibility for pro-environmental action (see Ferguson et al., 2011) or that are inherently characterized by pro-environmental norms ("we, the environmentalists vs. them, the harm-doers"). As a second identification-based strategy, framing environmental action as a collective endeavour should help to overcome barriers to personal action that rest on personal helplessness. For instance, defining the production and use of green energy as a collective project of the ingroup rather than as personal attitudes and individual decisions, may instigate personal actions (e.g., saving energy, using green technology) that people perceive as joining in a collective effort. “Joining in” means that people may not only experience connectedness and validation in line with ingroup norms and goals but also act on a level of their self, which is more appropriate for bringing about relevant changes than the personal self. Besides intragroup consensus, collective distinctiveness facilitates the perception of collective projects. As an example, for Germans, considering “Energy Transition” as a uniquely German project (Germany was the only European state that decided to shut down all of its nuclear power plants after the Fukushima disaster in 2011) should make salient a green energy norm of the ingroup. Although collective projects are most salient when they are unique for the ingroup, that does not mean that collective environmentalism of one group can only be attained at the cost of demolishing the pro-environmental collective self-image of another. Instead, the collective goal of protecting the environment may be held constant while groups or nations can be distinct with regard to the way they pursue it.

Collective efficacy. Global environmental crises can deeply threaten individuals. Although it is true that fear can motivate environmental action intentions (van Zomeren, Spears, & Leach, 2010), in intervention campaigns it needs to be coupled with a sense of collective efficacy to truly increase willingness to act (Jugert et al., 2016; Morton et al., 2011). Thus, campaigns should emphasize possible solutions that can be – and possibly have been – achieved by a group’s joined efforts. At the same time, perceptions of high ingroup effectiveness or agency (Stollberg et al., 2015) might be fostered by highlighting intragroup consensus over autonomously chosen collective action goals (“we as a people decided to go for sustainable energy”), and by ongoing goal-directed collective action (“the country is actually breaking-up towards a sustainable future”). The perception that “We” can make a difference will then motivate individuals to contribute to the collective project, especially those who highly identify as group members.

Ingroup norms. Both laypersons and environmental decision-makers underestimate the impact perceived social norms have on pro-environmental behaviour (Barth et al., 2016; Nolan et al., 2008). Thus, practitioners should be reminded of the effectiveness of group-tailored social norm information campaigns. At the same time, the “invisibility” of normative influence may be used to subtly influence people’s environmental behaviour by directing their attention to descriptive pro-environmental ingroup norms (e.g., to statistics indicating that a clear majority is approving of or actually protecting the environment or respective trend information). These efforts should be accompanied by the promotion of pro-environmental cultural worldviews (e.g., through leaders, Amel et al., 2017) and by avoiding the impression that a majority is failing to conform to prescriptive pro-environmental norms (i.e., ambiguous norms, Cialdini, 2003; Smith et al., 2012).

SIMPEA suggests that referring to pro-environmental norms of a (situationally) self-relevant ingroup instead of norms of some nominal groups or undefined others will catalyse norm salience effects on behaviour (Masson & Fritsche, 2014). It should do even more so when the specific pro-environmental norm in question is presented as distinguishing the ingroup from outgroups, as then conforming to this norm is a distinct expression of group membership (e.g., when identified citizens are reminded that their city is known for its particularly high rate of bike users, biking will become more attractive for them). At the same time, norm information interventions might be less effective when people do not think that the information is specific for their ingroup or may even backfire in case people suspect that it describes an outgroup norm (Oyserman, Fryberg & Yoder, 2007).

3 MESO LEVEL: COLLECTIVE BEHAVIOUR, LIFESTYLES AND "ENERGY CULTURES"

3.1 Theoretical Background

The global oil crisis in 1973 sparked a new scholarly interest in understanding energy demand dynamics or, what we in ECHOES refer to as energy choices or energy behaviour. Throughout the 1980s, the dominant understanding of the phenomena was that a relatively strict model of techno-economic rationality could predict it (Sovacool 2014, Aune 2007, Lutzenhiser 1992). In other words, the consumption of electricity was considered a simple market function, largely determined by available supply, demand and price. At the time, this view was challenged only by a small group of scholars, who highlighted that an eye to the socio-cultural and psychological reveals a much more complex model of decision-making, which significantly broadens what it means to make "rational" energy choices (Wilk and Wilhite 1985, Lutzenhiser 1988). Such ideas have since spawned a significant community of scholars with roots in disciplines like sociology, anthropology, geography, history, and other parts of the humanities, that are particularly well suited to cover the "meso" perspective of the ECHOES-project. This literature review will focus on aspects of that literature, which will help us shed light on features relating to the relationship between culture, social practice, social structures, and energy choices with respect to the ECHOES technological focus areas: electric mobility, smart energy technology and buildings.

At a very basic level, it is possible to say that "culture" links to energy choices, both in terms of enhancing our understanding about how new technologies are acquired, and with respect to how new technologies are used. Moreover, cultural traits affect innovation trajectories and processes of technology development and implementation. As a simple example, comparative studies highlight that what is understood as "cosy" or "comfortable" in terms of lighting, differs between countries. In some countries there is a strong preference for bright, fluorescent light, while householders in other countries prefer warmer tones of lighting (Wilhite et al. 1996). The same is true for thermal comfort, and the way people keep warm at home. In some countries, such as Japan, people "*tend to heat only one room in the house or even just the part of the room they occupy*", while the Dutch typically heat the entire building (Kuijer and De Jong 2011).

Observations like these raise the question of how to explain such differences. While the examples above might seem extreme, as they compare widely different contexts, similar dynamics can also be found in places that are more easily comparable. To wit, large degrees of variability in energy consumption can be observed, also within countries. In some places, consumers at the higher end of the consumption scale use between two and four times more energy than lower consuming households (Santin et al 2009). Social theory has provided several potential explanations for this. A promising route points to consumption as being structured by household composition/dynamics, status-appropriate dwellings and appliances, and lifestyle-based behaviour patterns (Lutzenhiser and Bender 2008). Household electricity use is often strongly, but not solely, related to income levels (e.g. Durckman and Jackson 2008). Gram-Hanssen et al. (2004) show that household size can account for 22–35% of the variation in electricity consumption when homes are grouped into broad dwelling types. However, other socio-economic features of household composition (e.g. age, income, education) only account for a small degree of the remaining variation. Perhaps surprisingly, two thirds of the variation in electricity consumption cannot be explained by socio-economic variables (ibid).

Hence, there is a need to elaborate on the relationship between broad social structures and energy behaviour. An interesting proposal is to think about energy consumption as "social load"; the causal connection between social factors - status, display, sociality, conventionality, security, convenience - with peak and base load patterns in electricity consumption (Wilhite and Lutzenhiser 1999). An important challenge in sociological and anthropological research on energy behaviour, is that it, at times, can become non-specific, describing the relationship between what some scholars have called a "contextual soup" (Aune, 2007, Gram-Hanssen, 2010, Young and Middlemiss, 2011), and specific actions, choices, or behaviours. To avoid the trap of the "conceptual soup", ECHOES departs from the notion of "Energy cultures" in the way that this notion has been conceptualized by Janet Stephenson and colleagues (Stephenson et al. 2010). The next section will discuss this notion more in-depth, including the relationship between the concept and the ECHOES technology focus areas.

3.1.1 Energy cultures

In the early 1990s, the idea that energy choices were embedded in and shaped by broader cultural cues, gained foothold. When developing a cultural model of energy consumption, Lutzenhiser (1992) highlighted that: "*Individual actors ("consumers") make choices, but these are importantly culturally-sensible and collectively sanctioned choices*" (p. 54). Lutzenhiser went on to stress the important relationship between culture and another key term in ECHOES, namely lifestyles: "*Cultural analysis focuses on the group, rather than the individual, as the entity primarily responsible for deploying technologies, practices and meanings in what can be called 'styles' of life"* (Lutzenhiser 1992, p. 54).

A key for Lutzenhiser was to stress that different cultural forms, or different life styles, might hold different potential in terms of changing energy behaviours, e.g. in the direction of increased energy efficiency. As a hypothetical example, he illustrated the difference between "*Retired working class couples - spending most of their time inside modest, well-kept homes in older neighborhoods,[with] limited food habits, [and] short trips in neighborhood*" and "*Young urban families – with a new baby, new car, smaller unit, newer appliances, fast food, frozen food, travel for commuting, shopping and visiting"* (p. 56).

Work on the relationship between culture and energy consumption has continued in the years since the publication of Lutzenhiser's framework, expanding into novel areas termed under various headlines, such as energy humanities, which acknowledge that energy and environment related challenges are not only technical, but are actually entwined with cultural history (Szeman and Boyer 2017). These studies recognize and emphasize a number of complex social and cultural challenges associated with finding a sustainable mix of energy sources, by linking the history of energy to the development of cultural concepts and representations of the psyche, body, society and environment (Buell 2012). These scholarly developments stress the importance of understanding the character of domestic energy consumption, smart energy technologies and (electric) mobility. Much of the subsequent theoretical development in this field has been synthesized by Janet Stephenson and colleagues, who have promoted a framework of energy culture (Stephenson 2017, Stephenson et al. 2015, Stephenson et al. 2010) and mobility cultures (Hopkins and Stephenson 2014).

Stephenson and colleagues' model of energy cultures, take their cue from three distinct bodies of literature. First, they lean heavily on cultural sociology (e.g. Bourdieu 1984) and structuration theory (Giddens 1984). Second, they are inspired by new strands of social practice theory, specifically related to sustainable consumption (e.g. Warde 2005, Shove 2003a, Wilhite et al. 2000, Wilhite and Shove 1998). Finally, they are inspired by certain aspects of Actor-Network-Theory (e.g. Callon 1986, Latour 1987). From this, they build an integrated model, which highlights that "*consumer energy behaviour can be understood at its most fundamental level by examining the interactions between cognitive norms (e.g. beliefs, understandings), material culture (e.g. technologies, building form) and energy practices (e.g. activities, processes).*" Figure 4 depicts the energy cultures elements, as highlighted by Stephenson et al. (2010).

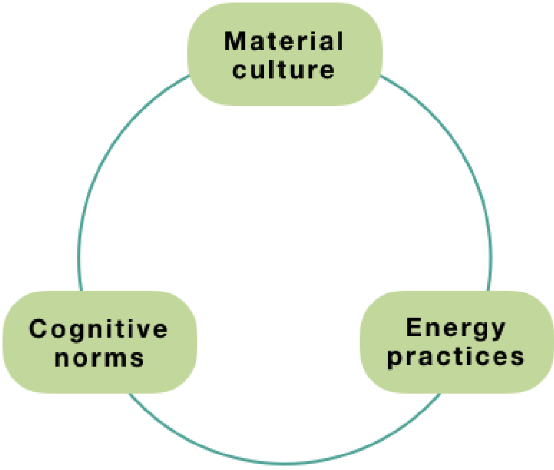

Figure 4 The core concept of the energy cultures framework: the interactivity between material culture, cognitive norms and energy practices (Stephenson et al. 2010, p. 6124)

Sovacool (2014) suggests that a focus on culture in energy studies might allow us to see how conceptions of energy services and the enactment of energy related practices change over time. Elisabeth Shove's work is of particular interest here. Shove highlights how energy consumption is primarily driven by the ways in which humans understand and perform practices related to three themes: convenience, comfort, and cleanliness, while highlighting the culturally contingent nature of these categories (Shove 2003a, b). Comfort is defined as satisfaction with the immediate physical environment. This correlates strongly with controlling indoor temperatures. Cleanliness on the other hand, is a relational concept, which includes distinct ideas of aesthetics, sterilization, and odour (see Jack 2013 for a good example). Convenience involves saving or shifting time, either by helping to coordinate one's lifestyle or by keeping one on schedule. In all such instances, Shove and colleagues typically highlight that specific practices, e.g. ways of washing, ways of heating, and ways of cooking (typical examples of energy choices/behaviours) are comprised of materials, competencies, and meanings (Shove, Pantzar, and Watson 2012), which in sum amount to specific, and often clustered ways of doing things.

Such clustering sometimes shapes distinct lifestyles, but they are not only a matter of individual choice. As Gordon Walker (2014) has pointed out, they are strongly related to the rhythms of society as well as to the distribution of material and elements across society. Thus, where you live, where you work, whether or not you have children, what your age and gender is, who your parents were, and how they raised you, are all parts of shaping a sort of *action space*, a material, cognitive and practical "infrastructure", in which energy related behaviours are enacted.

Hence, when accounting for how energy behaviours look, and why they are enacted in the ways that they are, the energy cultures perspective would lead us to look at links between cognitive, material and practical elements, and the ways that combinations of such elements are clustered between strata of the population, between regions, or between countries. Accounting for this kind of diversity might allow both for firm analysis of how things have become locked into unsustainable patterns, as well as highlight where the potential for changes is the greatest. As an example, Stephenson et al. (2010) highlight how the framework can be used to classify and understand different cultures of heating (see Fig. 5).

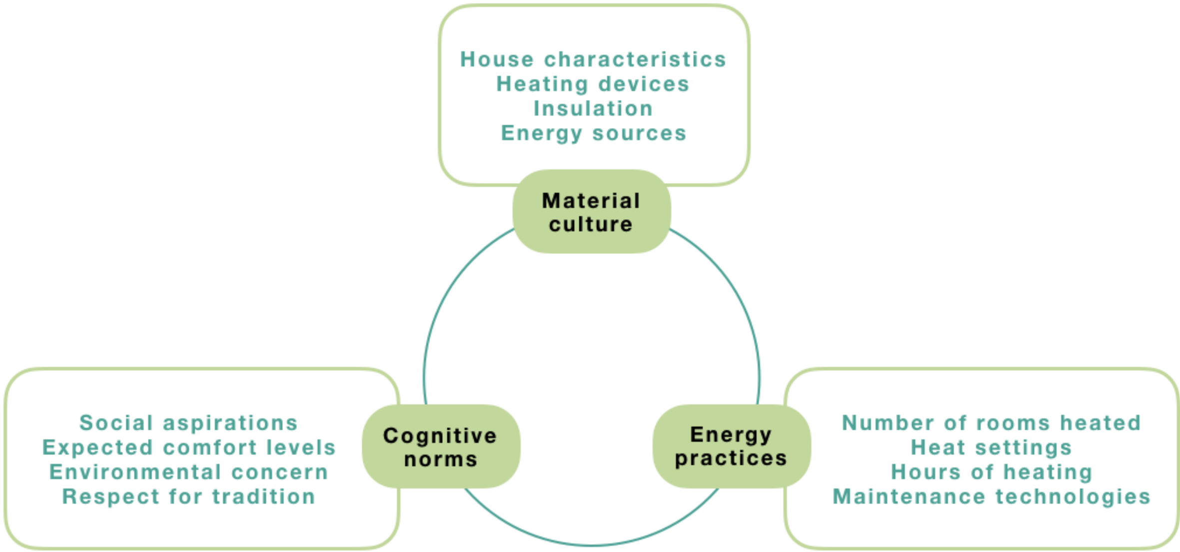

Figure 5 The core concept of the energy cultures framework: the interactivity between material culture, cognitive norms and energy practices (Stephenson et al. 2010, p. 6125)

3.2 Energy cultures, lifestyle and ECHOES technological foci

The three technology foci are intimately linked and oftentimes overlapping. For instance, smart technologies such as smart electricity meters are typically located inside the home (in some instances outside, yet still very close to the household). It measures energy use (and potentially production) in a household unit, whether a freestanding building or an apartment within a building complex. Building-technologies such as heat pumps, ground source heating, residential PV, windmills, or energy storage, as well as other smart home technologies (automation of appliances, electronic monitoring of doors etc.) typically overlap with the category of smart technologies, and are associated with the "smart grid" (explained in the next section). Other, less "smart" building-energy related practices and technologies, such as insulation, double or triple glass windows, practices of indoor heating and temperature level, use of wood-stoves, practices or airing, showering, laundry etc. may not necessarily fit directly into the category of "smart grid" technology. However, as they affect the energy use of a residence/building, they too contribute in one way or another to the energy consumption, which in turn affects the (smart) grid and will read by a smart meter wherever this is available, and displayed on in-home-displays. A number of household appliances are moreover targets for potential smart automation technologies.

In brief, the categories of "smart energy technology" and "energy in buildings" must be seen in connection with each other. The same applies, albeit perhaps to a lesser extent, to smart energy technologies and mobility. Electric mobility typically concerns electric vehicles, oftentimes cars, which in turn are charged either at home or in other locations (place of work, public charging stations, supermarkets). Energy choices related to electric vehicles might be related to why and how they are bought, but importantly, they may also relate to patterns of use, including charging. When and how the EVs are charged is of great importance to the grid, and thus a key goal of some smart energy technologies, are to influence such choices. This means that any practical considerations of the relationship between energy cultures and energy choices related to the three ECHOES technology focus areas should keep in mind that they are all highly related.

Nevertheless, in the following, we attempt to make a distinction between the different technology foci, all the while keeping in mind the necessary interconnections between the three.

3.2.1 Smart Energy Technology

Energy systems across Europe and beyond are changing, and many of the changes tend to be discussed under the umbrella heading as the emergence of a "smart grid". The term has countless definitions. As an example, the council of European energy regulators highlight that a smart grid is:

> *"an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to its generators, consumers and those that do both in order to ensure economically efficient, sustainable power systems with low losses and high levels of quality and security of supply and safety"*[21]

The international research literature on smart grids however, stresses that there is no short and concise definition of the term able to do justice to its many meanings. Rather, the social scientific literature on smart grids tends to stress that the concept is characterized by high levels of interpretative flexibility. This suggests that smart energy technologies can have different meanings and interpretations for various social groups and actors (e.g. Nyborg and Røpke, 2011, Christensen et al., 2013, Skjølsvold and Ryghaug, 2015). Thus, rather than aim for a new and precise definition of what is likely to be a moving and fluid target, we pragmatically focus on some aspects of the smart grid that are of particular relevance for discussing energy choices in an ECHOES context. We focus in particular on smart energy technology for households, as a site where choices are made and life styles are enacted. Households can take on many potential roles within the smart grid (e.g. as consumers, producers or as storage units). In a way that resembles Stephenson's (2010) energy culture framework, Christensen et al. (2013) highlight how householders enact their roles at the intersection of every-day practice, technology, and a broader institutional system (see Fig. 6). Accounting for this is central to the understanding of how energy choices are made in relation to smart energy technologies.

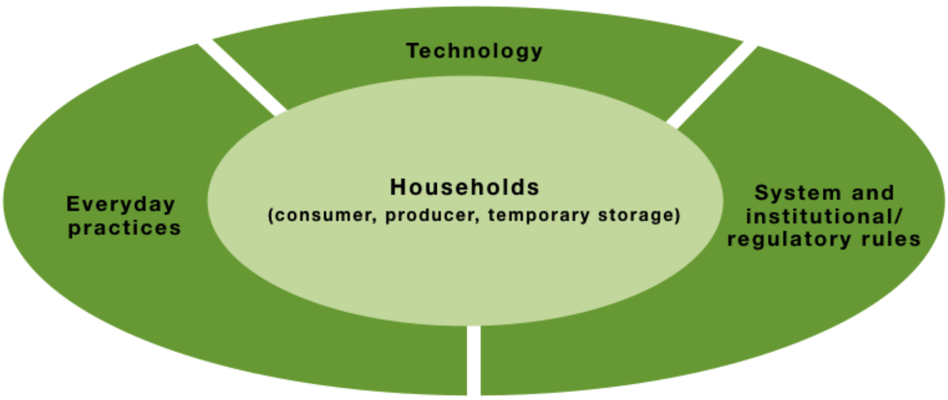

Figure 6 The household in the smart grid as an intersection point between technology, everyday practices and system/regulation (Christensen et al., 2013, p. 2287).

In the ECHOES context, we can think about smart energy technologies as technologies that are meant to stimulate, or enable certain kinds of energy choices. From the perspective of grid managers, or from a market perspective, certain kinds of choices are highly desirable. Both from an economic and technical perspective, it is a goal to stimulate active choices that makes patterns of electricity consumption follow the patterns of electricity production as closely as possible (Throndsen, 2017). For energy system managers this is so important, that the consumers' *non-consumption* of electricity at certain times is highly valued and commodified under the term end user flexibility,

[21] CEER status review on European regulatory approaches enabling smart grid solutions, p. 10 http://www.ceer.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_PAPERS/Electricity/Tab3/C13-EQS-57-04_Regulatory%20Approaches%20to%20Smart%20Grids_21-Jan-2014-2.pdf

as is their higher consumption in times of high production (e.g Strengers, 2013; Skjølsvld, 2014; Ballo, 2015). Another term often used to describe such desired choices through smart technologies is demand-response (e.g. Fell et al 2015), where consumers are expected to actively respond to shifts in the price and availability of energy supply. The expected result from a systems perspective is time shifting, load reduction, or both. In sum, the goal is to produce "*a household action which shifts and/or reduces overall energy use in response to a price signal or other price stimulus"* (Darby and McKenna 2012).

In Europe and beyond there are great expectations for the potential of smart energy technologies to unlock such new modes of energy choices. Up to 2012, there were 281 smart grid projects in Europe across 30 countries (EU-27, Croatia, Switzerland and Norway), accounting for a total investment of € 1.8 billion. 87% of European smart grid projects received some form of external funding. Most funding, 55%, came from national, EC, or regulatory sources. The remaining 45% came from private capital. The UK, Germany, France, and Italy were the leading investors in Smart Grid projects, and there were around 60 multinational projects where the majority of cooperation links could be found between organizations from EU15 countries. More than 50% of all projects take place in seven countries: Denmark, Germany, Italy, Austria, United Kingdom, France and Spain. France, UK, Germany, Spain and Italy are the leading investors in smart grid projects (Colak et al. 2016; Lawrence et al. 2016). Smart homes are one of the EU's 10 priority action areas in its Strategic Energy Technology Plan "Create technologies and services for smart homes that provide smart solutions to energy consumers". Behind this strategic policy objective lies "the Commission's vision for the electricity market [which] aims to deliver a new deal for consumers, smart homes and network, data management and protection" (EC, 2015).

Smart meters and feedback systems

Smart metering is heavily promoted as an essential part of the transition to energy systems that improve the balance between consumption and energy production, and reduces the climate footprint of the energy system. Smart meters, combined with various kinds of feedback technologies, can be considered a kind of infrastructure meant to enable new kinds of energy choices as discussed above, or as highlighted in the integrated roadmap for the European SET-plan, to enhance "*consumers and support their active engagement in the energy system*"[22].

If enough "smart" choices are made, this could translate into macro-level changes, such as carbon emissions reductions along with better supply management. Different countries, or different energy cultures, typically have different patterns of energy consumption, which might lead to the promotion of different kinds of energy choices to through smart energy technologies. Community engagement is considered an important factor in achieving the successful deployment of smart metering. This is sometimes understood as a consultation process that communicates information and educates the public with the intention of empowering the recipients to improve or to achieve desired behaviours (Anda and Temmen 2014). Figure 7 illustrates an example of this, comparing electricity load profiles between Norway, Spain and Denmark on weekdays (Christensen et al 2013).

[22] https://setis.ec.europa.eu/system/files/Towards%20an%20Integrated%20Roadmap_0.pdf, p. 6

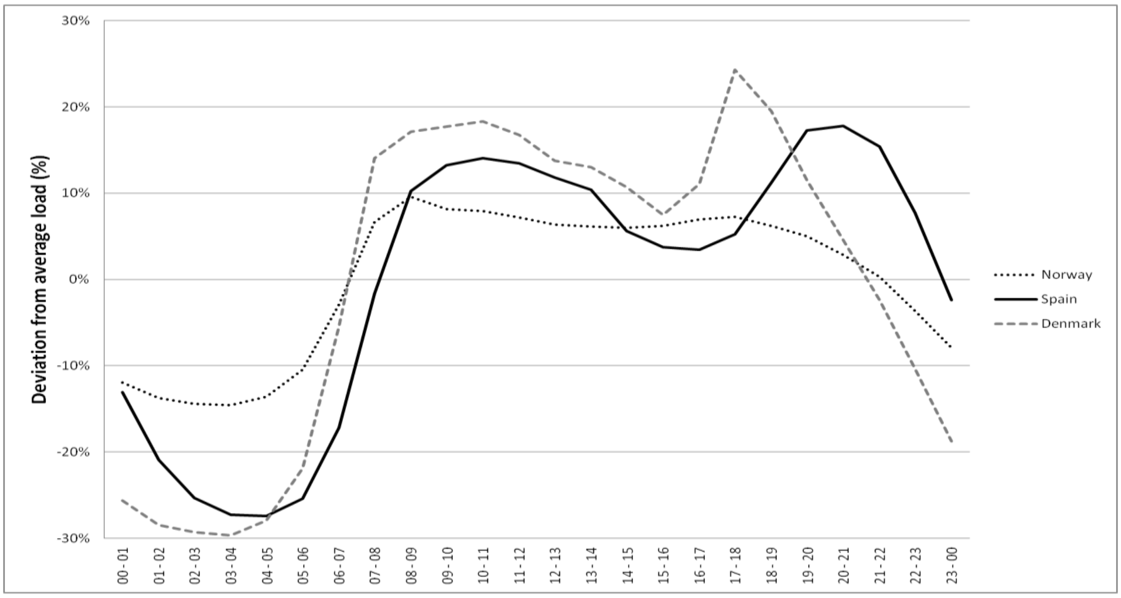

Figure 7 Comparison of load profiles for Norway, Spain and Denmark for weekdays in January 2012. The figure shows the hourly deviation for each country (in per cent) of the electricity consumption (all sectors) from the average consumption

In Europe today, twelve EU Member States have decided to proceed with large-scale smart-metering rollouts by 2020 or earlier (Austria, Denmark, Estonia, France, Greece, Ireland, Luxembourg, the Netherlands, Poland, Romania, Spain, and the United Kingdom). Four Member States (Belgium, Czech Republic, Lithuania, and Portugal) have decided not to proceed at all with a national rollout by 2020, while three member States (Germany, Latvia, Slovakia) have found the rollout of smart meters economically justified only for particular groups of customers. The remaining countries (Bulgaria, Cyprus, Hungary and Slovenia) have not yet reached an official decision. Italy started a national rollout already in 2001. By the end of 2006, about 30 million meters had been installed. In Finland, the smart meter rollout is complete.

At the micro-level, the claim is that smart meters and feedback systems might afford better and more frequent information for householders, leading to demand reduction (i.e. energy savings) and cost reduction, at the same time as they afford the possibility of electrical load micro-management to the utility. At meso-level, there is the prospect of improved customer relations, with the 'smarted' meter acting as a communications hub (Darby 2010: 454). The argument for the implementation of 'smart' metering does however vary according to circumstance and place. In some countries, the business case for establishing an advanced metering infrastructure (AMI) relies in part on improving consumption feedback to customers and assisting in the transition to lower-impact energy systems. There is an expectation that AMI will lead to reductions in both the demand and the cost of serving customers through improved communication. There is an explicit intention to improve customers' ability to manage energy and to encourage time of-use pricing (Darby 2010: 442, 447).

In general, such projects have tended to focus mainly on technology development and implementation as well as economic incentives, while ignoring user involvement and the way that users and systems interact (Verbong, Beemsterboer and Sengers 2013). In other words, technology has largely been designed and developed as non-cultural, neutral objects, of which users are expected to follow very strict scripts, resulting in desired behavioural changes (e.g Strengers, 2013; Strengers, 2014; Skjølsvold and Lindkvist, 2015; Hansen and Borup, 2017). There is abundant literature detailing how increasing information as well as providing basic visual or auditory reminders, can make people behave more desirably and increase energy conservation (Osbaldiston and Schott, 2012; Bekker et al., 2010; Tetlow et al., 2014; Loroz, 2007).

There is however, an increasing trend to pay more attention to the role of users, consumers or citizens in new smart grid projects, and a considerable body of work has been generated from social studies of energy use in domestic contexts, not least regarding smart meters. What can be learned from such studies about energy choices related to energy culture, energy practices and/or life styles?

In terms of facilitating active energy choices, the ability to provide electricity feedback is the main rationale behind the drive for smart metres. They are expected to lead to electricity savings, because they allow consumers to monitor their energy use in real time rather than looking at their electricity bill months later. Indeed, since electricity is invisible, diffuse, and abstract, and in many countries both abundant and cheap, users are represented as being both passive and ignorant regarding their own consumption. Smart meters have been thought to change this. As described by Wallenbornet al., 2011:

> *Users need to be conscious that energy is precious, and they are able to transform their practices accordingly. The development of an advanced metering infrastructure and feedback technologies is then presented as the opportunity to empower to reshape their energy using practices (2011: 147).*

This sums up much of the reason why smart meters combined with in-home displays have been praised, namely because they are believed to provide a feasible way for people to get involved with environmental issues through making energy use tangible (Marres 2009: 117). Alternatively, as coined by Skjølsvold et al. (2017): "the logic behind much of the smart energy roll out … rests on the assumption that personalised, fact-based information enhances energy awareness and allows consumers to modify their behaviour" (2017: 1). Such approaches follow a logic of resource management rather than domestic life (Strengers 2008: 9). Consequently, there is much potential here for the perspective of energy cultures. As Hargreaves, Nye and Burgess write: "*there remains a startling lack of understanding or empirical evidence about how feedback from smart energy meters will be used by householders, how and if it will translate into altered consumption patterns and the duration and lasting effect of potential change"* (2013: 126).

Indeed, providing information, sometimes combined with new price structures, alone, typically proves insufficient to alter behaviour, energy choices, and consumption patterns in a significant way. A key reason for this is that the problematic *peaks* can be considered aggregates of social practices, e.g. *cooking, laundry, dining and home-comings* (Powells et al., 2014). Some practices tend to be more stable than others, e.g. those that typically involve many family members (e.g. dinner), or require synchronization with the world outside the household (ibid.). Further, information, new price signals, and smart energy technologies become parts of highly different household social dynamics, which in term links to the rhythms of society in very different ways (Bell et al. 2015). This suggests both that different social groups and households have very different challenges and opportunities in terms of making new kinds of energy choices, or changing their lifestyles. However, there is a clear lack of studies on this (Nicholls and Strengers 2015), indicating an important opportunity for ECHOES.

Some examples, however, do exist. Barnicoat and Danson (2015) highlights the many difficulties experienced by the elderly population living in rural Scotland in their adoption of smart energy technologies, illustrating how this group tends to lack an interest in the offered technologies, which are poorly aligned with the routines and practices of this group. This image is not clear-cut, however. Others have found that the retired might be more prone to provide flexibility by mobilizing feedback, since they often do not have daily care of children or significant others (Nyborg and Røpke 2013). Nicholls and Strengers (2015) study the potential of families with children when it comes to providing "flexibility" during morning peak hours of peak electricity consumption. They show how an institutionally prescribed need to leave the home at a certain time to ensure family members got to school, childcare and/or work results in high levels of routinized action in this period. Families typically eliminate any non-essential practices from this time, which leads to the conclusion that there is "limited flexibility in the regular disruption or permanent shifting of weekday routines outside the peak period" (p. 123).

While there is a clear lack of studies of different social groups and the general population, one group has been studied extensively. These are the so-called early adopters or front-runners (e.g. Heargreaves et al., 2010; Heargreaves et al., 2013; Wallenborne et al., 2011; Naus et al., 2015; Skjølsvold et al., 2017, but also many others). This group of users tends to be highly educated, highly interested in new technology, and with what has been described as an engineering oriented habitus (Throndsen et al., 2017). There is a clear gender bias in the sense that the overwhelming majority of this group of users across countries are male. This group has a high capacity to engage in new forms of energy choices as individuals. Studies show that they tend to use feedback technologies to do one-off changes in energy consuming infrastructure (e.g. buying less energy intensive equipment), that they try to engage in energy reduction activities, and that they might even try to instigate new rules, or new norms concerning how energy should be used in a household. However, such studies also point to the desperate need to understand the dynamics of energy choices beyond individuals, because this group of highly motivated energy optimizers frequently have to negotiate with their significant others: spouses, partners, children, and pets, who frequently do not share their ambitions as resource managers and system optimizers. Hence, ECHOES might contribute with better and empirically anchored understandings of how energy choices are part of broader cultural and lifestyle dynamics for new and diverse groups of citizens.

Hence, the information-deficit model according to which more data will create active energy citizens rather than passive consumers, and that such data necessarily causes a reduction of and shifting in consumption, has been deemed too simplistic. Neither making nor keeping energy visible through such technologies, is enough (Hargreaves et al. 2013: 132). Unsurprisingly moreover, material structures can form an important barrier to the adoption of smart grid technologies. Concerning smart house technologies, for instance, Wilson, Hargreaves and Hauxwell-Baldwin (2017) show, there is a social risk that these technologies might extend the already existing digital divide associated with ICTs.

Exploring the role of end-users within smart grids requires an understanding of the context in which energy and associated devices are used within the home. Perspectives from STS (science and technology studies), specifically domestication theory, as well as practice theory have contributed to this understanding in different ways. For instance, Skjølsvold et al., (2017) argue that having smart technologies such as smart meters and the effects that this has, must be seen through a lens of four relational rearrangements; knowledge – material - social and routine. There is no one way in which households must engage with, understand, or respond to new technology. Practice Theory, too, situates energy consumption and potential responses (or lack thereof) to new energy technologies within the frame of the mundane, that is, the embedded use of energy in day-to-day life. Practice theory has a number of overlapping formulations, but as applied here, it breaks down practices into four components: materials and infrastructures; rules and knowledge; embodied skills; and engagements and meanings. These are not simply individual. Many of our practices, as well as our knowledge both tacit and explicit, rely or larger social norms, ideals and embodied memories, as past practice continues to shape that of the present through material conditions and infrastructures, as well as ideals of the past.

The role of energy cultures in shaping energy choices with respect to smart energy technologies, might also take on other forms. As an example, several scholars point to trust within a society and between different types of actors as an important, but often neglected element (Gangale et al., 2013). Here, it might for instance be interesting to contrast studies from different countries. The UK, it has been highlighted, is characterized by "deep levels of distrust" between citizens and the traditional energy industry (Parkhill et al., 2013, Goulden et al., 2014), which in terms of energy choices, translates into a deep scepticism towards compliance to smart energy schemes initiated by such actors, as opposed to e.g. more community oriented local initiatives. On the other hand, Döbelt et al. (2015) note how Austrians' belief in their energy providers as trustworthy keepers of data, actually enables certain kinds of smart energy technology oriented choices. However, they also highlight how trust here is not only an individual psychological quality. Rather, it is produced through the concrete relations in smart energy technology projects (see also Gangale et al., 2013). There are similar indications from studies in Norway. Despite being a country with high levels of general trust, participants in smart energy technology pilot- and demonstration projects quite quickly become sceptical if they sense that the electricity company organizing the trial is not honest about *why* participants should adjust their consumption patterns. As an example, there is a tendency amongst trial operators to oversell the economic benefits from participating, while not communicating the more abstract gains of making new types of energy choices (e.g. reduced societal costs on investments, increased security, environmental potential etc.). Focus group studies suggest that many groups would be much more prone to participate if they felt that they contributed to a broader social or environmental cause (Throndsen and Ryghaug 2015). This gives us a clear indication that increased sensitivity towards the role of culture and life styles in shaping action, holds great potential for improving both technology and policy design.

3.2.2 Energy in buildings

Household electricity consumption is steadily increasing in Europe (increase of 21% between 1990 and 2007 in the EU-27). The literature indicates various factors as shaping household energy use. The one hand, the building itself is important, including its year of construction, building type (free standing house, apartment block etc.), apartment size, number and size of rooms (Kane et al, 2015; Engvall et al., 2014; Podgornik et al., 2016; Tuominen et al., 2012; Rotmans et al., 2001; Asensio and Delmas, 2015). The demographic variables of the household are also highly important (Zhao et al., 2015; Steg et al., 2005; Mortensen et al., 2016; Zografakis et al., 2010). These include elements such as the dwellers' age(s), education, and economic status, frequency of use of various appliances, as well as general environmental awareness, values and attitudes (Steg et al. 2005; Doren et al., 2016; Lilliestam and Hanger, 2016; Shrestha and Kulkarni, 2013; Heuts and Renosee, 2016). There are great differences in people's awareness about the potential energy savings implicated in heating, cooling, lighting, windows, and household appliances (Kang et al., 2012; Mortensen et al., 2016; Bigerna & Polinori; 2014, Zografakis et al., 2010). Moreover, physical access to, as well as understanding of and trust in technology, varies (Baborska-Narozny et al., 2014).

The following trends may however explain this general increase in domestic electricity consumption across Europe: A) New appliances (households are increasingly equipped, and the share of small appliances in the total electricity consumption is now higher than 50%.) B) As the average household size drops, the number of households rises, along with the number of appliances used. C) The share of electricity in the household energy budget is increasing, because energy consumption for heating is either stabilizing or decreasing. D) Energy networks are built to add new activities and appliances easily. The general default setting of energy networks is conceived in such a manner that it is easier to consume more than it is to save. E) Consumption and schedule organization are increasingly individualized, depending on personal appliances (Wallenborn et al. 2011).

This illustrates clearly that "buildings don't use energy: people do" (Janda. 2011), and indeed, when it comes to buildings, energy culture is a very useful concept. However, Wallenborn and Wilhite point out: "*a theory of household consumption based on rational choice and methodological individualism has stripped consumption from its grounding in historical processes and has ignored the capacity of the material world, including human bodies to affect consumption*" (2014: 56). They argue that the mainstream theories about energy consumption present consumption as disembodied and decontextualized from social and material worlds. Yet, bodies are repositories of a unique and explicit form for knowledge about the world and this knowledge affects the ways in which we consume. Concrete experiences, involving both body and perceptions are always brought to bear in learning and adapting ourselves to new environments. The escalation of energy consumption can be interpreted as a transformation of bodies. The modern body is increasingly re-equipped and reshaped through new perceptions of comfort." (Wallenborn and Wilhite 2014: 56).

For ECHOES, buildings represent a series of potential "choices", or behaviours. First, there is the buying of a new building – a house or a home, which can be more or less energy efficient. Second, there is the use of a building, what is done inside it. Third, there is a typically constant process of tinkering, upgrading and refurbishing a house. Another aspect complicating the story is the relationship between tenants and house owners, which might differ tremendously within and between countries. Aune (2007) illustrates how one can begin to analyse choice with respect to such issues, principally by understanding what constitutes a "home". A home, she argues, differs between social groups, and how one understands what a "home" is, greatly affects what one does at home, and – following the discussion on smart energy technologies above – affects energy consumption. Aune distinguishes between three understandings: the home as haven, the home as project, and the home as arena for activities. These understandings are culturally rooted, and they point to both elements that challenge active choice, and to elements that might promote it. "The home as a haven" for example, suggests a strong preference for the warm, the light, the cosy – in other words, the energy intensive. The home as a project, on the other hand opens for more active deliberation, e.g. doing more energy efficient retrofits. A different aspect of one's home as a project, however, might also lead to energy intensive behaviours for instance by keeping up with, and installing the latest features and appliances. The European Commission has identified four types of ownerships in blocks of flats with regard to attitude and decision-making processes in energy: *Non-profit housing associations* are regarded as being very towards implementing energy improvements. *Private cooperative flats* relatively so. *Owner-occupied flats* however, are different, as owners are believed to have a stronger focus on individual improvements than on common ones. Lastly, for *private rental flats* the owner must be able to see the benefit of investing in improvements (European Commission, 2011a).

National and geographical differences

Local building practices and traditions have an important influence on energy in buildings (CONCERTO Premium consortium, 2014; European Commission, 2011a), as do transportation capacities and infrastructure (Kurnitski, 2016). Regulations on certification, energy performance monitoring, and white certificates vary across countries (European Commission, 2016b; BUILD UP Skills EU-Italy, 2012), and macroeconomic factors such as real GDP, energy prices, as well as resource capacity and knowledge, will all have an influence on energy in the building and housing sector (Romano et al., 2017; Doren et al., 2016). Educational courses and expert knowledge is more often available in urban areas than in rural settings (BUILD UP Skills EU-Norway, 2012). Barriers to energy efficiency or to the reduction of electricity consumption in buildings are context specific. Although many barriers have national or international origins, the local environment appears to be a promising scale to address barriers (Doren et al., 2016).

Buying a building

Why do we buy (or rent) the buildings that we do? A literature review (Hauge et al., 2011) indicates that energy-efficient houses are bought or chosen mainly for reasons other than the energy profile, such as location or having a balcony. Hauge and colleagues show how cultural preferences e.g. for specific ways of heating might lead certain groups of home buyers to avoid passive or other low-energy buildings, because of a desire to own and operate a wood stove (see also Korsnes, 2017). This illustrates how energy culture configurations might feed into the choice of acquiring a home. For ECHOES, an interesting gap pointed out in the review, is the lack of studies that take into account architectural and aesthetic preferences, which one might reasonably expect to be heavily influenced by historical and cultural situatedness.

Heating and cooling

The questions of residential thermal comfort have been addressed in several studies. Heating and cooling patterns must be seen in connection with climatic conditions, which in turn influence the external threshold temperature, the number of heating periods per day, duration and times of heating, and peak consumption periods (Kane et al, 2015), as well as time of the year in which this takes place (Johansson et al., 2013). We might assume the same of cooling. Importantly, however, comfort standards are 'social constructs which reflect the beliefs, values, expectations and aspirations of those who construct them'. Although there is some evidence that indoor environments are converging around the world, the specification of thermal comfort remains one of the most controversial topics in building science (Chappells and Shove, 2007: 33). Indeed, both culture and technology influence what temperatures are considered comfortable at different times and places. Various studies provide details on how people regulate and use their air-conditioning system. Most users switch off the units manually rather than set the thermostat to control cooling and, contrary to what would be expected from a technical approach, families who controlled their units manually were found to consume less energy than those using the thermostat. These studies included an analysis of how cultural myths about air-conditioning functions influence user patterns. An influential example of the socio-technical approach within comfort studies is the work of Elizabeth Shove, who has shown how preferences and practices of indoor climate have changed historically in response to the scientific and technological development of indoor-climate technologies. A cross-cultural analysis of household energy use behaviour in Japan and Norway compared practices in the two countries to show how cultural differences coexist with technological differences and strongly influence both practices and preferences for space heating. All these studies provide examples of how user practices related to comfort must include an understanding of different social, cultural and material structures. Numerous studies have been made concerning domestic energy and electricity use, and its connection to lifestyle, culture, and demographics (Feng et al. 2016; Yu et al. 2011; Aaen et al., 2016; Santin 2011; Martincigh et al., 2014). For instance, Fell and Chiu conducted a nationwide research on home energy use for UK focused on children and parents (Fell & Chiu, 2014). Another national UK survey (1200 children across England via 60 schools) studied different aspects of current children's lifestyles and factors shaping future generations' attitudes to energy use (Energy Saving Trust, 2007), and Vassileva and colleagues studied electricity consumption and behavioural characteristic of 660 Swedish households in rented apartment in the region of Västerås (Vassileva et al., 2012b).

Recent research in consumer studies and in the socio-technical approach have introduced practice theory to understand how routinized everyday activities are socially structured (Gram-Hanssen 2010: 175-176). We suggest that energy consumption in buildings should be viewed as practices related to, for instance, home-activities. This helps elucidate why it is necessary to investigate and understand such consumption as embedded in a network of socio-cultural and material practices.

Retrofitting

There have been many policy approaches to encourage retrofitting of houses. This concerns refurbishment and renovation of residential buildings in order to improve energy efficiency (Ástmarsson et al., 2013; Friege & Chappin, 2014; Monfils, 2016), major renovations of large buildings (Intelligent Energy Europe, 2008) as well as municipal buildings (Häkkinen et al., 2016). The success of such initiatives, however, has been moderate. The selection of decision-making criteria for house renovations (Monfils, 2016) and the willingness of owners to renovate or upgrade their buildings (BUILD UP Skills EU-Norway, 2012) are of great importance. Nevertheless, in a Swedish study, Persson and Grönkvist conclude that there is no one specific barrier preventing the success of energy-efficient houses. Rather, they argue, barriers are multiple and complex, and (Persson & Grönkvist, 2015). Ástmarsson and colleagues argue that the general awareness of sustainable renovation can stand to be raised (Astmarsson et al., 2013). Crucial for the acceptance of a major renovation, the process and the result, is the relationship between the renovation stakeholders, in particular the housing company and the residents. Involvement from both sides is important (Blomsterberg & Pedersen, 2015). Habits developed in office-buildings can positively affect practices in other sectors (Masoso and Grobler, 2010), whereas the decision-making criteria for the renovation of private homes lacks this potential (Monfils, 2016).

However, despite the increased emphasis, energy retrofitting (including technical and physical improvements) alone does not guarantee low carbon results, even when carried out to a high standard. This is because reducing energy demand in the domestic sector is a characterized by a variety of actors and a range of variables such as climate, build form and age, socio-economic factors, as well as occupant behaviours and motivations often resulting in lower energy savings than expected. Energy retrofitting also has the potential for further unintended consequences, including reductions in indoor air quality, overheating, and health and safety issues such as increased fire risks. Moreover, the actual energy performance of a building can often fall below predicted performance due to a 'rebound effect' whereby energy efficient 'improvements' drive down costs, but encourage greater overall consumption by the occupants (Gupta and Barnfield et al., 2014). A reason why such initiatives fail in their attempts to improve environmental effects may be that they tend to ignore central concerns for the people inhabiting these houses. Gram-Hanssen asks: How can retrofitting be understood in relation to the many other practices that people perform in their everyday life in their homes? What qualities do people want a home to have? What competing desires does retrofitting have to be negotiated against? The human dimension has many quite different approaches, and must be seen in relation not simply to the technological or the financial aspects, but also the social (Gram-Hanssen 2014: 393).

Residential microgeneration

Age, level of education, as well as income level appear to be crucial elements in households' adoption of energy technologies (Mills and Schleich, 2012; Welsch and Kühling, 2009; Noppers, Keizer et al 2015). Early adopters of residential PV panels for instance, prove to be mainly white-collar workers, civil servants, or self-employed. They are relatively wealthy and are well informed about the benefits of solar systems. Regarding the risk taken when implementing energy efficiency measures, an adopter with adequate financial resources will typically view capital risk more favourably than an adopter with poor financial resources (Faiers et al., 2007). A Dutch study suggests that those who have and those who did not have solar panels, in fact evaluate this technology quite similarly with regard to both environmental and instrumental issues. The deciding factor therefore, must lie elsewhere. Geographical location also matters, as within Europe for instance, these concerns appear to be more prevalent in the west than in Eastern European countries. Is this a question of financial possibility, material opportunities, or cultural factors?

Barriers and motivators of energy efficiency in buildings

Regulatory instruments such as the application of standards, mandatory labelling and certification programmes, energy efficiency obligations and quotas might be motivating factors toward energy efficiency in buildings (World Business Council for Sustainable Development (WBCSD), 2007). The European Commission suggests that residents themselves are most likely to implement energy saving measures if these are both visible and contribute positively to a "statement" towards their peers (European Commission, 2011a). Customer education on overall energy consumption and demand response is also highlighted (SGIG, 2014; Šahović & Silva, 2016), moreover there is evidence to suggest that parents view saving energy more positively when framed as educating their child (Fell & Chiu, 2014). Improvements in comfort, indoor environment, and architecture combined with a reasonable project economy can motivate the average homeowner (Mortensen et al., 2016). Accessibility to simple technologies is a central factor to formulating effective policy (Faiers et al., 2007). Engrained social norms, a tendency to 'discount the future' and the use of defaults appear to be significant barriers Cabinet Office Behavioural Insights Team, 2011). Another barrier is a lack of information, as well as tenants' of buildings being unaware of the rights they might have to demand energy efficiency improvements in their home (Hope and Booth, 2014). Unfortunately, practitioners and policymakers seeking to promote energy efficiency and conservation often overlook cognitive biases and motivational factors (Frederiks et al. 2015).

3.2.3 Electric mobility

It is widely held that electric vehicles (EV) have the potential to provide society with many substantial benefits, including reduction of carbon emissions, improvement of public health, increasing national security, and personal savings on fuel and maintenance costs. Despite these benefits, however, electric vehicles have yet to be adopted on a large scale (Noel and Sovacool, 2016). In many countries, EVs have not become the success they were expected to be, and there is a great difference in the distribution of EVs across different countries. This has been attributed in part to high prices, the small size of the car (especially early models), and short driving range – giving rise to the expression "range anxiety" (Pierre and Fulda, 2015), as well as material infrastructures and a lack of institutionalized and consistent national policy and rules. To illustrate this, the relative success of electric mobility in Norway has most likely been prompted by strong financial and regulatory incentives (free access to public parking, toll roads, ferries, and charging stations) in addition to reduced taxes, and the opportunity to utilize bus lanes (Ryghaug and Toftaker, 2014). Barriers may, however, be more than simply institutional. Range anxiety for instance, a widely acknowledged barrier to EV diffusion, Lance and Sovacool (2016) argue, may in fact not be a *functional* barrier to electric vehicle adoption, but rather an excuse offered by consumers to refrain from changing their behaviour, identity, and desires regarding ownership of a vehicle.

Much of the research on electric vehicles has had a techno-centric focus. This is not only the case of electric car use, however. Indeed, in general, the social sciences have paid little interest to the motor car and its tremendous consequences for social life (Sheller, Mimi and Urry, 2000). As Sheller writes: "Cars are above all machines that move people, but they do so in many senses of the word" (2003). Indeed, the car, according to Urry (2006) is not only a quintessential manufactured object, an item for individual consumption, and main avenue of quasi-private mobility. The car also embodies a dominant *culture* that sustains major discourses of what constitutes the good life, and of what is necessary for an appropriate citizenship of mobility. An automobile, regardless of the fact that it is an electric or a conventional one, is a status symbol and a powerful tool to embody the identity of the consumer (Berger, 2001). Therefore, the choice of a particular vehicle is closely related to an individual's understanding of their own self and of their place in society. For instance, while two-passenger coupés had an honoured history in Europe, the American passion for "bigness", coupled with the need for family cars for relatively larger families, shaped a different social perception with regard to what constitutes a better automobile. The availability and accessibility of resources, particularly energy, to operate and maintain a vehicle have also contributed to the social understanding of vehicles. The 1973 oil crisis, for example, had a profound impact in Europe, translating into energy-efficient and environmentally sensitive driving cultures in the decades that followed and enhancing the use of bicycles (Nye, 1999). On the other hand, engine power or type of fuel have always been perceived to symbolize social status in developing countries such as Turkey and India, even at the expense of economic and technical feasibility, and such concerns remain important to date (Gazete and Vatan, 2016). In its most rational sense, a car is a means to an end: getting from A to B. Nevertheless, as Sheller (2004) highlights, people are also emotionally invested in their car, transforming the machine into an object of desire, whose ownership provides the owner with a social status through the connection with ideas such as speed, security, safety, sexual success, career achievement and freedom (Dennis and Urry, 2009, 36). The relationships between car, self, family, and friends create affective contexts that are deeply materialized in particular types of vehicles. This necessitates a deeper understanding of the "car culture" that provides individuals with freedom of mobility at any time and in any direction (Gautama et al 2015).

A stream in previous literature has focused on the values, beliefs, personality traits, lifestyles, and social influences that affect EV preference and consumption (Rezvani et al., 2015). Several studies highlight environmental concerns as a significant indicator, which has been amplified by the social and cultural setting in which the consumers live (e.g., Axsen et al., 2016; Noel and Sovacool, 2016; Sang and Bekhet, 2015). The degree of environmental sensitivities is strongly correlated with pioneering in EV consumption as compared to potential buyers (Axsen et al, 2016). Similarly, social influence and social factors have been identified as important factors in EV preference (e.g., Axsen et al., 2013, Morton et al., 2016. Sang and Bekhet, 2015), concluding that social interactions play an important role in shaping how electric vehicles are perceived and that social influence is very potent in promoting acceptance. The impact of social networks and peer influence also proves quite powerful on buying intentions for electric vehicles (Daziano and Chiew, 2012). For instance, Ryghaug and Toftaker (2014) find that driving an EV appears to be linked to consumption as social performance, as electric vehicle driving seems to be performative of environmental concerns. In this way, driving an EV is also a normative practice. As an increasing number of people drive electric cars, Ryghaug and Toftaker argue, EV driving stands out as a reasonable choice for others (p. 158-160). EV ownership is also linked to other pro-environmental practices, either as part of an already existing scheme, or as a gateway technology spiking interest for other environmental technologies. Whereas automobiles are commonly seen as tangible identity symbols – as we have seen in the previous section – driving itself is typically characterized as a mundane practice. Driving is experienced as trivial and automatic, and a practice where the driver merges with the vehicle generating a hybrid "person-thing", yet without consciously considering this relationship (Ryghaug and Toftaker 2014). Conducting an empirical investigation of Norwegian EV drivers, employing the theoretical perspectives of domestication and practice theory, Ryghaug and Toftaker found that the embodied qualities of electric car driving demonstrate a strong emphasis on comfort, and the experience of driving. This is confirmed by other studies as well. Their study also shows how, due to the material features of the electric car such as driving range and charging needs, driving an electric vehicle seems to make transportation needs and habits more visible to the users.

In short, electric mobility needs to be researched through gaining an understanding of the cultural meanings and practices with which automobility is embedded. We need to understand what a car is, what it is used for, and the symbolic value that owning a car and driving holds for people. Indeed, mobility is not the same as transport, but is composed of a network of entanglements of movement, representation, and practice (Schwaanen in Sovacool 2017: 80). Consequently, there is great potential for research on electric mobility from the point of view of energy culture(s) and energy memories.

3.3 Knowledge gaps

As the discussion of recent and well-established literature shows, manifold aspects of energy culture in general and with focus on certain technological fields in particular, have been studied until today. The majority of work discussed provides genuinely new insights. However, it is noticeable, that many empirical findings, as elaborated as they may be, are extraordinarily pointed to one specific problem, which makes them sometimes hard to interpret and contextualise. Concepts like "energy cultures" (Stephenson et al., 2010) indeed create a systematic view that may help, but one central aspect is not covered by available concepts: the path of development up to the status-quo under consideration of both technological and cultural aspects. The concept of "Energy Memories" that is to be developed in ECHOES seeks to close that gap by combining the potential of energy specific frameworks like "energy cultures" with more general and theoretical concepts like "Collective Memory" (Halbwachs, 1950) and relevant knowledge from historical and empirical research.

The second area that was chosen to be part of the meso level in ECHOES is lifestyle. By understanding lifestyle as an arrangement of all individual and social human action (including corresponding values, norms, attitudes etc.), lifestyle research can also be conducted targeting energy relevant factors. Energy lifestyles' special emphasis on the three technological foci "e-mobility", "smart energy technology" and "buildings" will, in combination with the coverage of people's energy lifestyles in general, provide a high-density, cross-national picture of energy relevant practices on group-level. Available work (as exemplarily discussed in 3.2) outlines the potential of such approaches but also the limitations of lifestyle research in the context of energy experienced so far.

As a consequence of the identified gaps, the meso level of ECHOES, containing "Energy Cultures and Lifestyles", aims to create coherent knowledge based on the two methodological pillars of "Energy Memory" and "Energy Lifestyles". One essential attribute of this work will be the combination of in-depth and cross-sectional analysis. A representative extract of literature, describing the state of the art and crucial challenges for the development and empirical implementation of the two approaches is discussed in the following.

3.4 The ECHOES approach responding to the gaps

3.4.1 "Energy Memory" as constituting element of energy cultures

This concept is developed with the aim of capturing both the path of development up to the status-quo and cultural characteristics on a national level. Therefore, "Energy Memory" has a twofold meaning: On the one hand, it covers the historical dimension and on the other hand it might be understood as the country- (or even group-) specific "background noise" of practices, beliefs and normative ideas that developed from that past.

3.4.1.1 Theoretical background

Maurice Halbwachs shaped the idea that human memory can only function in the context of a social system. Accordingly, social surroundings and individual worldview often go hand-in-hand (Halbwachs, 1950). Thus, "Collective Memory" may act as a powerful construct in the analysis of elementary orientations in societies. The concept of "Energy Memory" introduced in ECHOES therefore widely builds on this perception and its assumptions. The concept of "Cultural Memory" (Assmann and Czaplicka, 1995) broadens the approach of explaining the mechanisms behind collective remembrance and takes "cultural formation (texts, rites, monuments) and institutional communication (recitation, practice, observance)", described as "figures of memory", into account. Confino (1997) strengthened the conclusion that "Collective Memory" is "[…] an exploration of a shared identity that unites a social group, be it a family or a nation, whose members nonetheless have different interests and motivations" (Confino, 1997). Our understanding of "Energy Memory" as a "background noise" that is typical for certain national or cultural context has a clear proximity to that definition, even if we are aware that a collective memory in terms of energy will most probably not cause the specific form of unity discussed by the these authors.

In "Seven types of forgetting", Connerton (2008) discusses seven ideal-typical ways of how cultural memory can be erased (Connerton, 2008). For the concept of "Energy Memory", forgetting is of importance because it seems to be crucial for the adoption of technological innovation as well as for practical and cultural re-orientation.

Frank Uekoetter introduced the term and concept of "environmental sites of memory" in his thesis paper (Uekoetter, 2009). With its clear reference to environmental concerns, it may play an important role in the further development and application of "Energy Memory". The project "Environment and Memory" (Uekoetter, 2011) with its focus on "historical events, limited in chronological and geographical respects, that played an important role in the interaction of man and the natural world", seems to hold manifold links to "Energy Memory". The approach by Uekoetter appears to refer to "figures of memory" by Assmann (see above).

An international comparison by Hadler and Haller showed that private environmental behaviour was quite similar in all 23 analysed countries, while public behaviour is more shaped by the cultural context (Hadler and Haller, 2011). This finding strengthens the assumption that country-specific cultural parameters play a significant role in energy specific behaviour.

Wilhite has argued that energy-consumption should be understood as resulting from the interaction between things, people, knowledge, and social contexts (Wilhite, 2013). Referring to Bourdieu, Wilhite emphasised the fact that human actions are always based on socio-material histories. "Embedded knowledge", discussed in relation to the concept of "enculturation" by Marcel Mauss, is of special relevance for "Energy Memory": The confrontation with standardised praxes of others might play a central role in the explanation of (re-)production and (co-)production of behaviour and is thus a factor to be considered in the development of the "Energy Memory" framework.

Michael Hebbert provides a very concrete example of the question on how collective memory is interlinked with our surroundings (Hebbert, 2005). His work on streets and public space layouts covers the field of interdependencies between the cultural sphere and the physically manifest environment. With streets and public space being important factors of mobility, this dimension might play a role in the analysis and discussion of ECHOES' technological focus on e-mobility.

3.4.1.2 Gaps to be covered

What is the theoretical advantage to be expected from the "energy memories" approach in comparison to existing work and what kind of analytical improvement will it provide?

The concept of "Energy Cultures" (Stephenson et al., 2010) as discussed earlier provides a suitable structure of analysis. The authors introduce and discuss the framework using the example of local initiatives aiming at lower energy demand. However, although such activities bear on factors lying in the past, "Energy Cultures" is a concept that does not explicitly take the past into account. Not properly considering the path of development bears the risk of underestimating or even overlooking such parameters. "Energy Cultures" by Stephenson and colleagues is a solid and promising analytical framework and will play a central role in the development of "Energy Memory".

3.4.1.3 Empirical studies relevant for “Energy Memories” development

Geels discussed technological transition-pathways in the fields of mobility, respectively energy sources. The pathway perspective is essential for developing a systematic understanding of collective memory in the sense of “Energy Memory”. The longitudinal analysis by Geel is one of a number of papers that will serve as empirical basis for the meta-level discussion during the concept development (Geels, 2005).

The spread of electric cars in Norway and the role of policy-measures and expansion of relevant infrastructure is the subject of a case-study that takes up such development processes (Ryghaug and Toftaker, 2014). With its emphasis on e-mobility, this study directly addresses one main technological focus in ECHOES.

The influence of concrete historic events will be discussed using the examples of disasters and public protest. Nuclear power includes both and will therefore be part of that section. Pidgeon et al. examined the public perception of this source of energy in Britain and conducted a quantitative survey of 1,491 respondents (Pidgeon et al., 2008), providing numerous hints that might be of relevance. Another household survey of 1,326 respondents combined with an interview study of 39 participants, both conducted close to the nuclear power stations of Oldbury and Hinkley Point (UK) gives the opportunity to extend the understanding of risk perception to groups living in direct proximity to potentially hazardous sites (Venables et al., 2012).

Klöckner and Matthies (2012) surveyed students’ travel mode choice in two studies with an overall number of more than 4.000 respondents in Germany. They showed that past behaviour is an important mediator between socialisation and habits (Klöckner and Matthies, 2012). Mobility of generation Y is subject to the work of Hopkins and Stephenson. In their paper, they theoretically assess the applicability of the “Energy Cultures” framework on the implied field. The provided discussion presents the framework as a promising basis for the creation of new insights, but also illustrates its limitations concerning the time-dimension (Hopkins and Stephenson, 2014).

Allcott analysed the influence of social norms on energy conservation. The paper especially offers insights into the role of social comparison and feedback. The author showed that consumers significantly altered their energy consumption behaviour after having received information on the energy use of their neighbours (Allcott, 2011). Schultz and colleagues tested the effect of normative messages on changing behaviour in field contexts with a special focus on the so called boomerang effect that occurs when households are already consuming on a low level and are informed about higher rates in their neighbourhood (Schultz et al., 2007).

3.4.2 “Energy Lifestyles” as constituting element of energy cultures

As mentioned, the lifestyle approach of ECHOES will especially focus on the energy related consequences of the way how people conduct their lives. This analysis of different lifestyles and resulting effects on group level will be carried out using a specially developed method that takes the limitations of past work into consideration.

3.4.2.1 Theoretical background – lifestyle research in general

Authors in lifestyle research regularly refer to Pierre Bourdieu’s work “Distinction: A Social Critique of the Judgement of Taste“ (Bourdieu, 1987), first published in 1979. Central in the work of Bourdieu is the idea of habits, behavioural patterns, norms or values as shaping parameters for different societal groups. This assumption is in fact the basis for the vast majority of lifestyle research.

Nevertheless, lifestyle sociology was not only – as is sometimes assumed – introduced in order to analyse the normative dimension of life on the group level in more detail. Its diffusion was also supported by a widespread dissatisfaction with the “vertical” paradigm of social stratification based on socioeconomic parameters, its contributions to a better understanding of sociocultural phenomena and its (often quite memorable) lifestyle and milieu models. By focussing on the form and organisation of practises, it also reconnected the analysis of social structure to the questions of everyday life (Meyer, 2001). Schulze, who discussed “inward orientation” as a central feature of individual life, is a prominent representative of the German tradition of lifestyle theory and research. He identified the “Project of the beautiful life” (*“Projekt des schönen Lebens”, Schulze 2005: 35)* as typical for individuals in our culture. To promote that individual project, *“rationality of experience”* (*“Erlebnisrationalität”*) is deployed, functionalising external circumstances for the inner, emotional life (Schulze, 2005). This connection/interaction between the internal and the external sphere leads to the impression of culturally based lifestyle research being extraordinarily relevant for ECHOES meso-level and its links to the micro-level. However, some papers that are discussed subsequently dramatically restrict the reach of this first appraisal.

Referring to Hartmann (1999), who put the explanatory value of lifestyle models in question, Otte thematised the claim to empirically prove the far-reaching promises of lifestyle-research and presented his own approach, intended to provide a standardised general lifestyle model that matches the mentioned requirements (Otte, 2005). Its stronger focus on the respondents’ action makes the model by Otte and its associated survey tool an important station in the development of lifestyle research. A higher relevance of behaviour instead of norms will quite likely play a role in the lifestyle approach to be conducted in ECHOES.

By a secondary analysis, Hermann showed that lifestyle research using values, norms or attitudes for the identification of lifestyle groups, is not suitable for the analysis of social change, because lifestyles based on such parameters often develop independently or even against expectations from structural change (Hermann, 2004). The limitations of lifestyle models based on values, norms, attitudes etc. will play a crucial role for the energy specific lifestyle model to be developed in ECHOES.

Structuralistic vs. culturalistic models

Hermann (2004) differentiates between structuralistic and culturalistic lifestyle models. In the structuralistic variant, lifestyles are a consequence of social inequality, while in the culturalistic pendant the lifestyle is relatively independent from such external parameters. With the personal lifestyle being an establishing factor for identity, the culturalistic understanding of lifestyle may at a first glance, seem to be the more powerful alternative when it comes to the analysis of energy relevant lifestyle patterns with their manifold expressive practices. This turns out to fall short, when for instance the role of income for climate-relevant action and consumption is taken into account (Kraemer, 2007). Therefore, the lifestyle concept to be developed in ECHOES will have to aim on both the structural and the cultural dimension of lifestyle.

What unites the two alternatives is that both may be general or domain specific in their conceptualisation. This differentiation is at least as important to be taken into account in ECHOES as the coexistence of structuralistic and culturalistic approaches.

General models in energy specific research

Properly speaking, lifestyle includes the whole spectrum of human activity. Therefore general lifestyle models are usually developed with the intention of capturing the way people live their lives as a whole, independent from the question of which parameters primarily shape lifestyles. Many approaches operationalize “lifestyle” as an arrangement of attitudes, values and norms. An example for such a model is the one provided by Schulze (2005), which is based on cultural-sociological theories. A model that is not based entirely on attitudes etc. is the general model presented by Otte (2005). It gives a bit more space to action and personal preferences than concepts solely based on internal factors. What all general models have in common is their specificity for a certain cultural context, which makes them theoretically profound, but of course also limits their applicability in any other context.

This main limitation for the use of general models becomes evident when there is an external criterion that aims to compare quantitatively certain attributes of the identified groups; this is for example the case when the energy demand on group level is to be compared. Bohunovsky and colleagues faced that problem, when the annual per capita energy demand of four identified lifestyle groups in Austria turned out to be more or less the same (Bohunovsky et al., 2011).

This surprising finding was probably caused by the use of a model that has no real connection to the subject of energy. General lifestyle models are mostly intended for capturing and analysing basic attitudes concerning the respondents' whole life. Even if many authors apply such general models in research that aims to explain or predict behaviour in certain fields, the suitability of their use must always be checked critically. For the lifestyle based research in ECHOES, the usage of a general and domain unspecific model will therefore not be the first choice.

Domain specific models

Prose and Wortmann were among the first to conduct research using lifestyle methodology in the field of energy use. Their model included values, norms and attitudes as well as specific items concerning the use of energy, qualifying it as a specific model in this review (Prose and Wortmann, 1991).

In contrast to the results by Bohunovsky et al. (2011) that were achieved by the use of an unspecific lifestyle model, Hierzinger and colleagues identified five different "Energy Styles" in Austria. They referred to the pioneers mentioned above and developed a lifestyle model with a clear focus on energy. They provided a comprehensive characterisation of the identified lifestyles, taking three relevant dimensions into account: Energy specific attitudes/values/behaviour, general attitudes/values/behaviour and sociodemography (Hierzinger et al., 2011). However, even if both studies were conducted in the same country and time proximity, comparing their results is problematic. They discovered a different number of groups by fundamentally different approaches and only one study provided quantitative or quantifiable data concerning energy demand. What limits the knowledge provided by the "Energy Styles" model and study is the fact that all respondents who stated not to believe in climate change were excluded from detailed analysis. This is worth discussing for a number of reasons. Personal readiness to adopt energy saving measures does not necessarily rely on believe in climate change, but may as well be caused by other reasons like economic considerations etc. Most consequences of problematic energy behaviour are shared collectively. Therefore, groups like climate change deniers, if identified in a significant number, need particular consideration precisely because of their noticeable perspective and their potentially negative influence on mitigation strategies.

In their analysis of specific lifestyle factors in US residential electricity consumption, Sanquist and colleagues discovered that *"lifestyle factors appear to account for the correlated variable of household income, and thus better describe how that income is consumed."* (Sanquist et al., 2012) This means that specific lifestyle approaches are in certain borders able to combine both the culturalistic and the structuralistic perspective.

With "housing related lifestyles", Thøgersen recently presented an elaborated study based on lifestyle methodology that also conducts a multi-level analysis of 10 European countries with a sample of 335 respondents each (Thøgersen, 2017). The model of housing-related lifestyle is an adapted version of food-related lifestyle (Grunert, 2006). The understanding both models are based on, sees the domain-specific lifestyle as a partially independent sub-system that is integrated into a *"hierarchical, cognitive-behavioural system that links it to the person's superordinate and trans-situational goals or values.* It *"functions as a mediator, determining how his or her general goals and values are manifested in specific housing related perceptions, choices and actions."* This perspective leads to a theoretically profound model, but also to the problem that with behaviour not being a part of the specific lifestyle, domain specific behaviour is not considered as a constitutive element of the lifestyle. The aspect of actual, specific behaviour is nevertheless a core element for the quantification of lifestyle-specific energy demand, emissions and potentials. The relevance of behaviour is also strengthened by the well-known but still problematic value-action-gap (Moser and Kleinhückelkotten, 2017). In order to capture its magnitude properly, the detailed knowledge of actual behaviour is necessary. Consequently, the model to be developed in ECHOES should, besides the normative dimension, definitely consider energy relevant behaviour as a constituting element.

The representative studies presented point out that the methodological means necessary for energy specific lifestyle research in an international context and the quantification of the behavioural dimension of energy lifestyles are at hand, but need to be recombined in order to develop an approach that meets all requirements. According to that, from the current perspective, the gap to be covered can be defined by the following points:

- The model to be developed should be an energy specific lifestyle model
- The lifestyle model should enable to estimate lifestyle specific energy demand and emissions
- The model should be able to capture both structural and cultural parameters
- The Value-Action-Gap must be considered and the estimation of its magnitude should be part of the empirical process.

3.5 "Place attachment" as constituting element of energy cultures

3.5.1 Theoretical background and empirical studies

The benefits associated with the use of renewable energy sources to tackle climate change appear incontestable. Nevertheless, there is a relevant difference between accepting the appropriateness of renewable energy as a strategy for mitigating the effects of climate change, and accepting the actual fulfilment of renewable energy facilities being built in close proximity to one's home (Botelho et al. 2016; Olsen, 2013). Although empirical data available in psychology and other social sciences are not always consistent, proximity to the proposed site is often associated with higher levels of objection or concern by residents (Venables et al., 2012).

Abbassi and Abbassi (2000) summarize possible adverse environmental impacts of renewable energy sources and their relative magnitudes. For instance, a negative impact of wind energy is the fact that it can interfere with local residents' daily life causing noise pollution or aesthetic degradation. Likewise, the central solar energy systems can have a negative aesthetic impact and other adverse effects such as generation of non-recyclables during decommissioning, permanent use of a large land area, or soil erosion and compaction. Consequently, individuals' perception of these impacts may affect the value given to renewable energy sources, particularly people living in the vicinity of the different facilities could be against the implementation of a renewable energy siting (Wolsink, 2000; Wüstenhagen et al., 2007; Eltham et al., 2008). Public opposition to renewable energy systems has proved to be a significant impediment to encouraging the development of alternative energy sources. Whether the public support for renewables is commonly shared, individuals' attitude does not always turn into a concrete support aimed to contribute to the design and real implementation of a renewable energy project (Olsen, 2013).

The public opposition towards renewable energy developments is often explained by the Not-In-My-Backyard (NIMBY) effect (Burningham, 2000). Dear (1992) define NIMBYs as "*residents who want to protect their turf. More formally, NIMBY refers to the protectionist attitudes of and oppositional tactics adopted by community groups who are facing an unwelcome development in their neighbourhood*" (p. 288). This concept has been questioned for its simplistic description of multifaceted individuals' attitudinal positions (Ellis et al., 2007; Wolsink, 2006). Moreover, it would seem to lack a strong empirical evidence in favour of such an approach (Devine-Wright, 2011). For that reason, in the literature the NIMBY concept is frequently described as inadequate to explain the reasons of negative public responses to renewables. One significant exception is Devine-Wright's work (2009) in explaining NIMBY responses "*as place-protective actions founded upon process of place attachment and place identity*" (p 426). The author proposes a review literature on place and NIMBY concept, highlighting how the literature on place has neglected symbolic and affective aspects of place-related action, while the NIMBY literature is not exhaustive in terms of explanations at the individual level of analysis.

Barry and colleagues (2008), investigating the case of a proposed off-shore wind farm in Northern Ireland, suggest that a key issue in terms of the transition to a renewable energy economy has little to do with the technology itself, but rather factors such as inter-group conflicts and the public involvement in decision-making processes play a relevant role. From a psychological standpoint, opposition or support to renewable implementation may be influenced by the individuals' place relationships. In this respect the study of place attachment, the bonding that occurs between individuals and their meaningful environments (Giuliani, 2002; Low & Altman, 1992), may contribute to a better understanding of public opposition to unwanted local renewable energy developments.

Place attachment is a complex phenomenon described as "*positively experienced bonds, sometimes occurring without awareness, that are developed over time from the behavioural, affective and cognitive ties between individuals and/or groups and their sociophysical environment"* (Brown & Perkins, 1992, p 284). Scannel and Gifford (2010a) review various definitions of person–place bonding synthesizing them into a three-dimensional, person–process–place organizing framework. The person dimension of place attachment refers to its individually or collectively determined meanings. The psychological dimension includes the affective, cognitive, and behavioural components of attachment. The place dimension emphasizes the place characteristics of attachment, including spatial level, specificity, and the prominence of social or physical element. Proshansky and colleagues (Proshansky, 1978; Proshansky et al., 1983) coined the term *place identity*, to refer to the ways in which physical and symbolic attributes of certain locations contribute to an individual's sense of self or identity. The emotional attachment to a place helps to define people's identity that is built upon the physical and symbolic features of the place in which a people live (Bonaiuto et al., 2002; Proshansky et al., 1983; Twigger-Ross & Uzzell, 1996).

Eswarlal et al., (2014) pointed out that community acceptance plays a key role to support local bioenergy projects and, in this regard, practitioners should take appropriate actions to satisfy the needs of such communities in order to foster the acceptance of these sustainable projects. In fact, the implementation of a renewable energy facility in close proximity of community location involves an environmental change and may lead to disruption to place attachments. The literature on disruption to place attachment analyses the consequences of changes to people, processes or places (Brown & Perkins, 1992). It highlights how disruption to place attachments occur when physical changes have a negative effect on place in terms of symbolic meanings (Williams & Patterson, 1996), emotional reaction (Cass & Walker, 2009; Fried, 2000), disruption to social networks (Speller & Twigger-Ross, 2009), and diverse coping responses, including place-protective behaviours (Stedman, 2002).

A small number of studies have focused on the links between place attachment, place identity, and public opposition to renewable energy projects. Most of these empirical studies have consistently observed negative relations between attachment and acceptance suggesting that implementation of an energy siting may lead to disruption to place attachments. For example, Vorkinn and Riese's (2001) research is focussed on local people's attitudes towards a proposed hydropower project in Norway. Their results show that the stronger the local residents' place attachment, the more negative were the attitudes shown, thus suggesting that the renewable energy proposal was perceived disrupting place attachments. Stedman (2002) affirms that place disruption can lead to specific behavioural responses that are related to the strength of place attachment. Furthermore, participants who interpreted the place as being "up north" (in terms of area's wilderness character and distinction from urban life) were more willing to fight against encroachment than those who emphasize its community attributes. The residents' interpretation of the place as "a community of neighbours" revealed less willingness to oppose change by residents. Stedman's work represents an example of a research study in which place attachment and place-related symbolic meanings are used to explain intentions to engage in NIMBY type activities.

Devine-Wright and Howes (2010) evaluated public acceptance of a proposed off-shore wind farm in North Wales, UK in order to deepen understanding of so-called 'NIMBY' responses to renewable energy projects. The research design compared the responses of residents living in two coastal towns situated equal distances from the development site, and the operationalization of emotional responses as an indicator of disruption to place attachments. The findings revealed different patterns of response to the wind farm proposal in the residents of each coastal town. A negative relation between place attachment and acceptance was shown for the residents of one of the towns, where a symbolic lack of fit existed between a wind farm interpreted to "industrialise the area" and a place regarded as "natural". Disruption was suggested by the negative pattern of association between place attachment and positive emotional responses to the wind farm. No relation between attachment and acceptance was shown for the second town's residents, attributed to two factors: the absence of emphasis upon 'naturalness' in place-related meanings, and to a lack of engagement and uncertainty about the wind farm's outcomes amongst the residents of this town. In general, these findings support previous research suggesting links between place attachment and oppositional responses by indicating how the wind farm threatened place identities for those individuals with a strong emotional bond to the place, leading to negative attitudes to the project and oppositional behaviour (Cass & Walker, 2009; Stedman, 2002; Vorkinn & Riese, 2001).

Devine-Wright (2009) proposed a multi-level framework to understand psychological aspects of place change, linking literatures on place attachment with the social psychology of social representations and identity processes in order to describe the dynamic nature of individual and collective responses to place change over time. The psychological response over time to place change includes identification (becoming aware of change), interpretation (making sense of the change by creating and adopting symbolic meanings), evaluation (judging change to be positive or negative, with emotional and attitudinal responses), coping (e.g. denying or accepting change) and acting. The framework does not assume that attachment automatically leads to resistance to change for the reason that the outcome of evaluation can be positive or negative, depending upon whether change is regarded as enhancing or disrupting a place.

Nevertheless, change to places is not inevitably disruptive, but may enhance place attachments in situations of good fit between symbolic meanings associated with both place and project. Based on the Devine-Wright's approach (2009), the role of place attachment and place-related symbolic meanings in explaining public responses to a tidal energy converter are investigated in a case study in Northern Ireland (Devine-Wright, 2011). This study investigated the importance of place attachment, place related meanings and personal variables to explain acceptance of renewable energy, and the degree to which this may vary by context. 281 residents in two different sites completed a questionnaire survey. Results indicated public support for the energy proposal and high levels of community acceptance. In addition, a relevance of place-related meanings and attachments in explaining acceptance of tidal energy emerged. The study supports the value of a place-based alternative to the 'NIMBY' concept (Devine-Wright, 2009) suggesting that by capturing the symbolic meanings associated with places proposed for energy development, it is possible to achieve to a better understanding of public responses.

In summation, the concepts of place attachment and place-related meanings are potentially important variables that have not yet been investigated with respect to energy memories development. Their relevance is related to understanding public responses and place protective behaviours to local energy development proposals. The fulfilment of renewable energy projects may enhance emotional attachments to place. Therefore, it could be necessary that development companies proposing renewable energy projects take emotional bonds and place related symbolic meanings into account, when planning and implementing renewable energy facilities for a more full understanding of the ways in which proposals to land use change and place transformations may lead to diverse local residents' responses.

4 MACRO LEVEL: FORMAL SOCIAL UNITS AND COLLECTIVE DECISION-MAKING

4.1 Introduction

The first phase of the literature review conducted has identified and extracted information from the literature via two templates: (1) literature review (methods, aims etc.) and (2) attitude dimensions and variables, allowing us to map and categorize the sources in an enhanced fashion.

These sources range from peer-reviewed journal articles (mainly from the journals listed under Web of Science, ScienceDirect, EBSCOhost, and ResearchGate) to business and project reports, EU directives and published research from academic institutes, NGOs, international agencies, and EU institutes. Around 2.000 sources were identified. After an initial screening for relevance, more than 431 sources were included for analysis. The reviewed studies utilized a variety of methodologies involving qualitative methods, quantitative methods, or a mixed approach employing both qualitative and quantitative techniques. These methodologies cover a broad range including, but not limited to, case studies, surveys, scenario analysis, statistical methods, focus groups, comparative method and in-depth interviews. The methods that have the highest frequency of implementation were surveys, in-depth interviews and focus group analyses.

The main keywords used for this review were: “energy behaviour”, “energy efficient buildings”, “smart mobility”, “smart energy technologies”, “smart grid”, “low-energy buildings”, “passive houses”, “smart meter”, “green building”, “building energy management”, “occupant behaviour”, “electric vehicles”, “automobility”, “electric bus”, “hybrid vehicles”, “smart charging”, “e-mobility”, “eco-driving”, “low carbon transport”, “low-carbon electricity”, “demand-side management”, “collaborative networks”, “feed-in”, “sustainable cities”, “urban sustainability”, “ICT”, “prosumers”, “electricity consumption monitoring”, “smart control”, “power distribution”, “green electricity”, “energy self-sufficiency”, “consumer awareness”, “energy transition”, “energy feedback”, and “load management”.

The majority of the studies are focused on the European Union and/or its member states and associate countries. Remaining studies cover China, United States, South Korea, Canada, or multiple countries. These reviewed studies cover a range of different levels of decision-making and technologies, but the primary focus is on collective decision-making units listed under the objectives of WP6, with a technological focus on buildings, electric mobility, and smart energy technologies related to ECHOES’ overall objectives.

Accordingly, the second phase of the literature review is completed under three categories related to the following technological foci of ECHOES;

- Buildings
- Electric mobility
- Smart Energy Technologies

For each of these categories, based on a single technology focus, the review follows a set approach. First, rationalizing the reasons and motives for positioning the importance of the related technology as a critical component in Europe's transition towards the decarbonized energy system of the future and completing the European Energy Union, mostly by referring to official documents such as climate and energy packages, EU directives, regulations, reports and papers. Then, based on the reviewed literature, we give a comprehensive summary of what has been done in the EU until 2017, the situation now (what has been achieved), and future prospects and targets.

Next, there is a detailed section focusing on the consumer decision processes with regard to each of the three-decision-making levels listed. In this analysis, we look at how the dynamics of each decision-making level and process contributes and impedes to the progress in achieving objectives. Moreover, available literature identifies dimensions, variables, and factors that affect the decision-making process for target stakeholders.

In addition, there is a separate section at the end of the each category, delineating similarities and differences in decision-making processes on each level.

WP6's focus is on the formal decision-making units acting as policymakers and/or energy providers, collective decision-making units, which are more formally structured and with relatively smaller information and power asymmetries, individuals, and the reasons behind this categorization. Hence, the categories are:

- **Formal Social Units:** Decision-making in units acting as policymakers and/or energy providers
- **Collective Decision Making Units**: Decision-making in more formally structured, collective units
- **Individuals:** small groups or individuals

The literature review primarily establishes the interlink between the three levels of decision-making with respect to the three technological foci, namely, Buildings, Electric mobility, and Smart Energy Technologies. For each category, a state of art review of previous research is presented, particularly with regard to variables and factors that play a role in decision-making at this level. The significance and impact of each variable or factor is discussed in the relevant context, along with the actors; how similar or different are they in their decision-making processes with regard to countries or regions? This is identified along with a summary of methodologies used in previous research. For each level, motivators and barriers that affect the identified variables and factors and the technological foci are also discussed. Finally, gaps for research are identified and a summary of core findings is presented.

4.1.1 Energy transition process in the EU

Each of the three technological foci that is within the scope of this literature review is a significant and integral component of the Energy Union policy of the EU. Therefore, at this point, it is relevant to review the overall conceptual approach and the strategic policy framework of the energy transition process in the EU.

The Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions "Towards a European Strategic Energy Technology Plan" (COM (2006) 847 final) declares that the SET-Plan will address different time horizons and important milestones that have to be met to put the energy system on a sustainable path. It is there it has explicitly been stated that "*the socio-economic dimension, including behavioural changes and social attitudes with an impact on energy use will also be taken into account*".

The updated European Strategic Energy Technology Plan (SET-Plan) (EC, 2015) aims at accelerating the development and deployment of low-carbon technologies. The plan promotes research and innovation efforts across Europe by supporting the most impactful technologies in the transformation to a low-carbon energy system. The SET-Plan proposes to measure progress via overall Key Performance Indicators (KPIs), such as the level of investment in research and innovation, or cost reductions.

The Revised Renewable Energy Directive[23] adopted by the European Commission in 2016 aims at better adapting the framework for renewable energy development to the 2030 perspective and at providing certainty and predictability to investors and address the potential of renewable energy in a number of sectors.

4.1.2 Variables and Factors Regarding Energy Transition Process in the EU

As far as formal units at all levels (EU, national, regional or local) are significant in motivating and leading the energy transition process, a number of policy documents stress the role of the different levels of governance in the energy transition process (Lorenzoni et al., 2007, Semenza, et al., 2008, European Commission, 2015b). They acknowledge the achievements of the Covenant of Mayors and the exemplary role of the public sector (European Commission, 2012b). The next two groups are mostly regarded as part of the more general processes of decision-making. They are mentioned as either contributing to/accepting the overall transition choices (Rijnsoever et al., 2015, Cross et al., 2015), resisting change due to constraints such as legislation barriers, lack of appropriate incentives (Henriques & Catarino, 2016, Poruschi & Ambrey, 2016, European Commission, 2012b, EEA, 2013), no clear obligations or commitments (Lorenzoni et al., 2007, Semenza, et al., 2008, Wüstenhagen et al., 2007), and adopted lifestyles (Rijnsoever et al., 2015, Whitmarsh, 2009).

The factors and variables outlined during the state-of-the-art review on general issues has been structured in three groups related to *energy transition and energy efficiency in general, behaviour* and *changes of attitude/ awareness and lifestyles*.

Regarding **energy transition and energy efficiency** in general, the factors outlined are cost efficiency, technology transfer, environmental issues and regulatory frameworks, economic performance and the potentials for contributing to energy security, industrial competitiveness and environmental effects (Sahzabi et al, 2017).

The effective contribution to the national targets is based on the application of new standards, tax deduction mechanisms, white certificates, incentives, conversion factors, emission factors, power factors, adjustment factors, installed power capacities, generated electric power, and used primary energy resources. In addition, social factors and broader social benefits of energy efficiency need to be explicitly considered (Italian Ministry of Economic Development, 2014; Efficiency First Foundation, 2016; Task Force, 2013). Social acceptance is discussed as a powerful barrier to the achievement of renewable energy targets. This also concerns the socio-political acceptance of effective policies by key stakeholders and policy actors, which would require the institutionalization of frameworks that foster and enhance market and community acceptance (Wüstenhagen et al., 2007). One critical issue here is that perceived system complexity and perceived legal frameworks bear the risk of constituting barriers for energy transition and energy efficiency (Tuominen et al., 2012). Similar barriers exist and vary by sector: for manufacturers they relate to the perceived cost and risk of production disruption, lack of time, the cost of obtaining information, competing priorities for capital investments, and information or incentive gaps. Larger and more energy consuming enterprises face limited access to capital, followed by concerns about technical risk and lack of budget funding, while for small ones, problems are lack of information, limited access to capital, and low priority on energy issues (Engvall et al., 2014). Therefore, policies need to extend beyond the research and development phase in order to support technology deployment. The creation of an enabling environment that includes education and awareness raising, and the systematic development of integrative policies with broader sectors (agriculture, transportation, water management and urban planning) are recommended (Sen & Ganguly, 2016)

The SET plan requires that Member States ensure annual reports. These involve primary energy consumption, total final energy consumption, final energy consumption by sector, gross value added by sector-industry-services, disposable income of households, gross domestic product (GDP), electricity generation from thermal power generation, electricity generation from combined heat and power, heat generation from thermal power generation,

[23] https://ec.europa.eu/energy/sites/ener/files/documents/technical_memo_renewables.pdf

heat generation from combined heat and power plants, including industrial waste heat, fuel input for thermal power generation, passenger kilometres (pkm), as well as updates on major legislative and non-legislative measures towards overall national energy efficiency targets for 2020. There is a special focus on information on the performance of large government owned buildings (EC, 2015a). Such information is also critical in identifying and effectively addressing segment-specific barriers to adoption (e.g., financing, staffing capacity) (Vine et al., 2008).

The significance of *human behaviour* is emphasized by the fact that the implementation of the European Union's Energy Efficiency Directive will require a change in *consumer behaviour* and *energy consumption practices.* Thus, correctly navigating the *interface* between *policymaking* and *human behaviour* is a key factor (EEA, 2013)**.**

Structural factors such as liberalisation, energy mix, dynamic pricing and energy tariff structures should be considered alongside social norms, belief systems and marketing strategies, as well as transparency and constraints and barriers to effective feedback mechanisms. Pricing structure is identified as a barrier to wider engagement of the end consumer through behaviour change alongside barriers to effective feedback mechanisms that hamper consumers in easily getting useful and timely information (EEA, 2013).

Behavioural factors are categorized as internal (beliefs, attitudes, values), external (institutions, regulation, social contexts) and habits/routine (Martiskainen, 2007). Behavioural decision pathways are related to knowledge, needs, values, attitudes, motivations, preferences, energy use patterns, access to financing, and information and trust (Vine et al., 2008). The motivation for employees to engage in energy efficiency behaviours must rely on corporate and social responsibility objectives and reinforcing societal norms. Measures should involve both direct and indirect feedback, in order to increase the consumer's awareness on energy consumption and maintain the motivation to engage actively in energy efficiency actions (EEA, 2013). For investors, participatory planning turns out to be a motivator (Wüstenhagen et al., 2007).

Concerning changes of attitude/awareness and lifestyles, *social acceptance* is considered a constraining factor in the increase of the share of the renewable energy. Factors influencing acceptance are *framework conditions* (e.g. *economic incentives and regulations)* and *local and territorial factors* (e.g., features of the *local economy, the territory, local actors* and *the concrete planning process on-site*; Wüstenhagen et al., 2007). A related set of barriers in this context is defined as *non-awareness barriers* (Itron et al. 2006). They claim that Government policy must eliminate economic, structural, and social barriers to change and advance accessible and economical alternatives (Semenza et al., 2008).

4.1.3 Gaps for Research Regarding Energy Transition Process in the EU

European policy documents identified a number of research gaps, briefly presented in the following paragraphs.

Power generation: Funding of research and development is considered important in all fields of power generation (renewable, fossil and also nuclear), transmission and storage technologies. Increasing use of renewable energies for electricity and also heat production; step by step reduction of the import dependency of EU27+ on fossil energies like gas, oil and coal by a continuous transition to renewable energies (EUREL Task Force, 2013).

*Energy efficiency targets***:** The European Commission (2016d) notes the absence of a defined level of energy efficiency ambition for 2030 in the Energy Efficiency Directive 2012/27/EU ('the EED').

Integrated and sustainable energy efficiency plans: Member States should encourage municipalities and other public bodies to adopt integrated and sustainable energy efficiency plans with clear objectives, to involve citizens in their development and implementation and to adequately inform them about their content and progress in achieving objectives (The Directive on Energy efficiency (Article 17), EC, 2012b).

Deployment of technologies: To achieve a better understanding of the regional energy sector, indicators related to aspects such as available resources, deployment of technologies or legislation has to be considered (JRC, 2016a).

Interface between policymaking and human behaviour: Regarding sustained reductions in energy consumption, the list of reviewed measures puts a major focus on feedback measures; it presents and analyses direct feedback (smart meters and in-home displays) and indirect feedback (enhanced billing, personal goal setting and feedback, energy audits, community-based initiatives). Other measures were also screened, but their impact on reducing energy consumption was neither considered sufficiently proven nor directly related to changing behaviour, so they were not reviewed in detail (EEA, 2013).

Accomplishment of European environmental policies: Economic and environmental estimates for the European countries change if different input or output-oriented models are proposed. It changes mainly in terms of years and technical efficiency versions. While some countries succeeded in terms of National Renewable Energy Action Plans, others observed a ranking decrease through time, thus suggesting that a higher emphasis should be provided in the accomplishment of European environmental policies.

4.1.4 Methodologies Regarding Energy Transition Process in the EU

A set of comprehensive reviews on research concerning theories, models and methods are to be mentioned (EEA, 2013; Martiskainen, 2007). The research methodologies applied are mostly based on literature reviews (Rossi et al, 2016; Rahbauer et al., 2016; Henriques & Catarino, 2016; Sahzabi et al., 2017; Sen & Ganguly, 2016; Lorenzoni et al., 2007; Wüstenhagen et al., 2007), surveys (Poruschi & Ambrey, 2016; Semenza, et al., 2008; Wüstenhagen et al, 2007), interviews (Rahbauer et al, 2016), and comparative analysis of case-studies (Wüstenhagen et al., 2007). Olazabal & Pascual (2015) comprehensively present the implementation of a specific methodology (Q methodology) within a particular case study. Rossi et al (2016) report on an in-depth review of databases covering a 20 year period in peer reviewed articles (database from ScienceDirect, Wiley, Taylor and Francis and Emerald journals), as well as grey literature. The literature review undertaken by (Wüstenhagen et al, 2007) has adopted a case study approach and focused on the best papers presented at an international research conference held in Tramelan, Switzerland in 2006, thus reviewing conceptual contributions and in-depth empirical data analysis based on a variety of research methods and data sources from around the world.

A classification of tool-related and external barriers (Rossi et al, 2016) has been presented, and in order to check change in efficiency rankings in different EU countries output- and input-oriented models have been developed by Madaleno et al. (2017). The inputs used in the input oriented model were capital (K), labour (L), renewable energy (R), fossil fuel (F). The outputs considered in the output-oriented model were GDP/L, GDP/K, F/GDP and R/GDP (share of renewable energy in Gross Domestic Product (GDP), and for both the output considered is GDP per greenhouse gases (GHG) emissions. Wüstenhagen et al (2007) outline three dimensions of social acceptance - socio-political, community and market acceptance. Whitmarsh (2009) discusses attitudes, values and beliefs – relating to the environment, but also to other considerations including comfort, aesthetics, quality, time spent with family, and so on; they identify contextual forces – including social, economic, institutional and political factors; personal capabilities (e.g., knowledge and skills) and resources; and habits. Rijnsoever et al (2015) distinguish between socio-political, market and community acceptance of energy technologies. Poruschi & Ambrey (2016) provide an insight on the connection between income, dwelling type, tenure type and city living (household's energy saving behaviour and residential energy consumption). Lorenzoni et al (2007) define personal engagement by three elements: cognitive, affective and behavioural. Semenza et al (2008) consider changes in energy usage, type of energy source, recycling. Olazabal & Pascual (2015) distinguish four main discourses with regard to the cognitive dimensions of sustainable urban transformation and low-carbon transitions - follower, visionary, pragmatist and sceptic.

4.2 Buildings

The significant reduction of building energy demand is a prerequisite for meeting Europe's GHG emissions reduction targets. The Article 4 of the Energy Efficiency Directive requires member states "to establish a long-term strategy beyond 2020 for mobilising investment in the renovation of residential and commercial buildings with a view to improving the energy performance of the building stock". In order to transpose the Directive and to increase the rates and depth of building renovation, the member states were asked to develop their first renovation strategies and provide them with their third NEEAPs, due by 30 April 2014. The JRC undertook an assessment of 31 national/regional building renovation strategies evaluated them against the compliance with the Energy Efficiency Directive, Article 4. (JRC, 2016).

European Commission, 2016b analyses the 10 years achievements since EU member states (MSs) and Norway started to collaborate in the Concerted Action (CA) EPBD (Energy Performance Building Directive) to find the best ways to implement the EPBD. The report recognizes a huge progress since then and points out that the early efforts are concentrated on the Energy Performance Certificates (EPCs), and especially their form, contents, possible nominees/holders, documentations related to the database of the issued certificates, possible ways to take advantage of them for better informed policymaking.

With the recast Directive 2010/31/EC, new challenges were faced by MSs, the most important of which is estimated to be the cost-optimal calculations for setting minimum requirements and the path towards Nearly Zero-Energy Buildings (NZEBs) by 2020. Along with the effective enforcement and quality control procedures lined with the requirements of Directive 2010/31/EC, new issues gradually emerging during this decade have been identified: the controversy on the pros and cons/goodness and reliability), possibilities to be used for informed decisions for investments, availability of quality control and enforcement by authorities.

4.2.1 Variables and Factors Regarding Buildings Technological Foci

For the technological focus *buildings*, the decision-making units of concern are: the formal decision-making units acting as policy makers and/or energy providers, collective decision-making units which are more formally structured with relatively small information and power asymmetries, and individuals.

Two variables that are strongly related to all three decision-making levels in the buildings technological focus are *energy transition* and *energy efficiency.* The *urban aspects* of energy efficiency have also been identified to be key to this technological focus area (CONCERTO Premium consortium, 2014). On the other hand, *building structure and envelope* are relevant in terms of project/building from design to retrofitting (Hope & Booth, 2014; Masoso & Grobler, 2010).

4.2.1.1 Formal Social Units

From the perspectives of public institutions and/or private business, the aforementioned variables regarding buildings in general depend on endogenous and exogenous factors such as the *level of competence, time frame, prices,* and *level of motivation* (BUILD UP Skills EU-Norway, 2012; Šahović and Silva, 2016; Rotmans et al., 2001). On the formal decision-making unit level, the drivers are *incentives* and *tax deductions*, *public investments, regulations on certification* (Romano et al., 2017; BUILD UP Skills EU-Italy, 2012). The profile variables of the member states such as *energy intensity*, *share of fossil generation*, *electricity consumption, carbon emissions, gas production, oil supply, GDP, electricity prices*, *FDI*, *consumption patterns* and *expert capacity* are also in effect (Romano et al., 2017; BUILD UP Skills EU-Italy, 2012).

Clearly, effective policy instruments and regulatory instruments such as appliance standards, mandatory labelling and certification programmes, energy efficiency obligations and quotas, utility demand-side management programmes promote effective emission reduction and cost effectiveness (World Business Council for Sustainable

Development (WBCSD), 2007). However, poorly aligned incentives may result in the "landlord-tenant split", whereby proprietors under-invest in energy-efficiency because tenants pay energy bills, or tenants do not economise on energy because the proprietor pays the energy bill. Similar misalignments occur among property developers, often due in part to asymmetries of information. Failure to incorporate environmental or other externalities (such as energy security) into energy markets is also included here (Energy Saving Trust, 2007). Such factors are an unwillingness to consider paying for measures that have been subsidised in the past (for example loft insulation) (Accent, Citizens Advice, 2016), or that non-integrated intensive approaches towards changing individual's behaviour, such as education and economic self-interest, are not successful (Anda & Temmen, 2014);

Along with renewable energy in buildings, we see that *intelligent energy* is mostly influenced by the following factors: *Information, awareness and attitude towards energy efficiency adoption and hidden costs* and *risk aversion*, *labels, policy instruments, building codes, energy performance contracting, energy labeling,* and *fuel prices* (Persson & Grönkvist, 2015; Ástmarsson et al., 2013). This applies to both formal and collective decision-making units.

Another crucial aspect for public institutions and private business is the process of *monitoring and measuring* of energy efficiency (BUILD UP Skills EU-Italy, 2012). From the perspectives of public institutions and private business size, scope, and type of buildings are considered as important factors for *changes of attitude / awareness and lifestyle*. The definition of certain *climate mitigation* targets would support decision-makers who design energy service demand reduction measures (Fujimori et al, 2014).

4.2.1.2 Collective Decision Making Units

Factors related to both consumers and providers are: EPC calculation methodology and *EPC control system* (DG Energy, 2015); *feed-in regulation* and *standardized rules* for grid-connection and *tax advantages* (Šahović & Silva, 2016). Various sources stress economic and financial factors that influence energy consumption and provision: development of *loan interest rates* and of *financial incentives* (European Commission, 2016b), the presence of sufficient *investors* with sufficient financial capacities to invest (DG Energy, 2015), and *risks* (Šahović & Silva, 2016). A specific typology of factors is that which affects *ownership costs* of electricity cooperatives and *collective decision cost* (Šahović & Silva, 2016).

These factors are important in terms of overcoming the adverse effects of *economic/financial barriers* and *hidden costs*. High investment costs, market failures, the potentially higher (upfront) costs of energy efficient products, lack of capital, long payback periods, lack of public funds/credits are common examples of economic/financial barriers (UNEP DTIE Sustainable Consumption & Production Branch, 2009; Energy Saving Trust, 2007; CONCERTO Premium consortium, 2014; European Commission, 2011a; Doren et al., 2016). Moreover, costs that are not captured directly in financial flows, such as upfront costs, as well as costs associated with finding reputable providers, time costs of disruption, and the costs of differences in quality of product or service, may all reduce the net benefit derived from efficiency measures (Energy Saving Trust, 2007; UNEP DTIE Sustainable Consumption & Production Branch, 2009; Accent, Citizens Advice, 2016).

The *construction sector* as producer of buildings is a main actor in the process of improvements reflected in energy efficiency (Zhang et al., 2011; Pinkse & Dommisse, 2009; Engvall et al., 2014; Kmeťková & Krajčík, 2015; Heuts & Renosee, 2016; Zhao et al., 2015; Heuts & Renosee, 2016; Shrestha & Kulkarni, 2013; Fossati et al., 2016). The *constraints* faced by professionals, such as investors, architects and contractors need to be considered (World Business Council for Sustainable Development (WBCSD), 2007). Variables related to buildings' *typology* and *ownership*, *size* of *housing stock* (single-family houses, apartment buildings, age), *rates of renovations*, *ownership of dwellings* and *stock indicator* are among such key factors (Tuominen et al., 2012; Rotmans et al., 2001). At this point, political and structural barriers may be in effect. Structural characteristics of political, economic, energy system can make efficiency investment difficult (UNEP DTIE Sustainable Consumption & Production Branch, 2009).

Several related variables worth mentioning here are linked to individual, professional, and institutional capacity: *building tradition*, *training* (European Commission, 2011a; European Commission, 2016b), *expertise,* and the extent of *personal conviction or commitment to sustainable buildings*, *awareness and involvement* (World Business Council for Sustainable Development (WBCSD), 2007). The *establishment of ESCO associations*, *availability of model contracts* (European Commission, 2016b), and *engagement of wide array of companies*, including energy supply utilities, consultants, etc., indicating an *open and competitive market* (European Commission, 2016b).

4.2.1.3 Individuals

From the perspective of private users, factors that relate to energy transition/energy efficiency in buildings are: *psychological* and *contextual* (Wittenberg & Matthies, 2016, Tuominen et al., 2012, Jung et al., 2016; Pyrko & Darby, 2011), *technical* (Wittenberg & Matthies, 2016, Tuominen et al., 2012, Jung et al., 2016, Podgornik et al.; 2016, Doren et al.; 2016, Chou et al., 2015), *economical/financial* (Tuominen et al., 2012, Jung et al., 2016; Podgornik et al., 2016; Doren et al., 2016), *informative* (Tuominen et al., 2012), *social* (Jung et al., 2016, Botelhoa et al., 2016), *demographic* (Botelhoa et al., 2016), *legal urban planning practices* (Ekins & Lees, 2008, Pyrko & Darby, 2011; Doren et al., 2016), *building environment* (Ekins & Lees, 2008; Pyrko & Darby, 2011); *socio-demographic factors* (Šahović & Silva, 2016; Pyrko & Darby, 2011; Doren et al., 2016), *socio-cultural factors* (Rotmans et al., 2001; Podgornik et al., 2016; Doren et al., 2016), and *public awareness and understanding* of the EPC. (DG Energy, 2015)

Although the majority of sources focus on the factors influencing consumers' behaviour, the level of *personal commitment* is also valued (Persson & Grönkvist, 2015). Energy saving potential and profitability of energy efficient renovation measures (Friege & Chappin, 2014) go along with the *risk* that customers take due to outsourcing and the efforts to identify the early adopters, requiring technical knowledge (Pinkse & Dommisse, 2009).

Variables related to perceptions, attitudes and behaviour, such as environmental motivation, energy-saving behaviours, perception and visions of renewable energy perceptions of "sustainable" or "green" buildings, readiness to adopt sustainable building practices (Lilliestam & Hanger, 2016; World Business Council for Sustainable Development (WBCSD), 2007) are also significant on the individual level. At this point, motivational factors (including values, beliefs and attitudes) represent a common thread linking together seemingly diverse behaviours (Energy Saving Trust, 2007; Accent, Citizens Advice, 2016). Therefore, social and emotional motivators (Energy Saving Trust, 2007; Heuts & Renosee, 2016; Fell & Chiu, 2014, education programmes for customers, free seminars, workshops and public lectures; educational tours to regenerative energy (RE) facilities (Fell & Chiu, 2014; SGIG, 2014; Šahović & Silva, 2016)) are of significant use.

On the other hand, lack of information and awareness about smart buildings, energy expenditure, possible savings, lack of familiarity with RE technology, lack of coordination and information flow between the actors in the housing market, and lack of trusted information are important on the individual level. These need to be addressed properly (Energy Saving Trust, 2007; UNEP DTIE Sustainable Consumption & Production Branch, 2009; World Business Council for Sustainable Development (WBCSD), 2007; Šahović & Silva, 2016; Doren et al., 2016).

We should also consider a variety of risks: *Risks and uncertainty* about future energy prices, about whether a households' tenure at a property will be sufficiently long for future savings to repay an initial outlay as well as the risk associated with new (or unfamiliar) products or services (Energy Saving Trust, 2007). Uncertainty about return on investment (Accent, Citizens Advice, 2016); Occupiers' own long-term plans and uncertainty about the future (Accent, Citizens Advice, 2016); discounting the future (Cabinet Office Behavioural Insights Team, 2011), and cost difference linked to lack of awareness (World Business Council for Sustainable Development (WBCSD), 2007).

4.2.2 Gaps for Research

An analysis of research gaps identified by the literature review and on further research needed are outlined below:

The establishment of a methodological framework: A thorough international comparison is needed of baseline laws (cooperative law, renewable energy, electricity markets legislation) and the effects of policy frameworks and measures on citizens' participation in such schemes, including how business models can be modified to encourage stronger cooperative development in areas where they are comparatively less present (Šahović & Silva, 2016). This calls for the development of a unified (reference) procedure a clear guidance on how it is used in the design process, possible approaches for innovations in the procedures (Intelligent Energy Europe, 2008).

Overview and guidance for libraries, including *minimum requirements*: consideration of passive and active renewables in the target values, definitions for high performance buildings (carbon-free, zero energy, passive house, etc), rating of existing buildings (Intelligent Energy Europe, 2008);

Requirements for new buildings: Inter-comparison in the MS, comparison of procedures by using simple buildings (dwellings, offices, schools) (Intelligent Energy Europe, 2008).

Need for sensitivity studies of buildings: influence of system parameters (control, pressure in the HVAC); accuracy of reduced/simplified input values vs. saved inspection and calculation time.

Standards further development for products used: Identification of necessary further product standards (Intelligent Energy Europe, 2008).

Software development: overview of existing software, especially for non-residential buildings; calculation of building service systems (lighting and cooling); experiences with user support; software accreditation procedures, supporting instruments, simplified data collection, practical air change rates.

Private sector and energy efficiency: A qualitative assessment of private sector landlords' attitudes towards improving the energy performance of their tenanted homes can assist policymakers in understanding the motivations that need to be addressed when designing and communicating policy in this area. A new wide-ranging quantitative and qualitative review of the private rented sector and private sector proprietors is required (Hope & Booth, 2014).

Cross-country comparison of participation schemes, business models, different political and institutional frameworks are needed (Šahović & Silva, 2016). A comparative cross-country analysis on drivers and barriers on cultural and institutional characteristics that foster the deployment of cooperatives should be conducted (Šahović & Silva, 2016).

Policy development: It is needed to compare and evaluate the benefits from green buildings instead the energy consumption and energy costs based on the opinion and experience of green buildings' residents and to investigate the rebound effects (Zhao et al., 2015);

Attitudes, habits and experience: Practitioners and policymakers seeking to promote energy efficiency and conservation often overlook the cognitive biases and motivational factors (Frederiks et al., 2015). Human centered methods that might uncover the multidimensional role of attitudes, habits and experience in shaping cooperative actions should be the point of departure for analysis (Šahović & Silva, 2016; Engvall et al., 2014; Fell & Chiu, 2014; Zhao et al., 2015).

4.2.3 Similarities and Differences in Decision Making Processes Related to Each Level

109 sources (106 of which published after 2006) related to the building technological focus were reviewed. The reviewed sources comprise academic papers, policy documents, country-specific public reports, international consumer and producer organizations' reports, and research projects.

Various decision-making units involved or considered as stakeholders have been identified in this literature review. The national level is represented in terms of transposition and implementation of Directive 2002/91/EC- CA – EPBD, production of regulations, and national studies of customer attitudes (outside EU and UK). The utility providers as agents of research are also represented in terms of studying attitudes and consumption patterns on national, regional, city, and neighborhood level. The regional and city level are underestimated in the reviewed sample, though some case studies for different cities are presented. A significant share of the sources focus on the individual level of non-formal decision-making. Few of the sources focus on the behavioural research on energy collectives.

The traditional role of municipalities as an enforcer of national building regulations and mediator of changing energy habits and choices is changing. Municipal actors are involved and responsible for preparing city-level sustainability strategies and action plans that bind the local administration into ensuring the realization of the strategy and the allocation of adequate resources.

Table 1 below summarizes factors that play a role in decision-making process at different levels.

Table 1 Factors that play a role in decision-making process at respective units

Formal Social Unit	Collective Decision Making Unit	Individual Level Unit
Policy Tools (e.g. public investments, incentives, tax deductions, certification)	EPC system and EPC calculation methodology	Demographics (e.g., income, gender, age, household size, and occupation level)
Energy profile (e.g. energy intensity, production, consumption patterns, emissions, electricity prices)	Grid standards and Feed-in regulations	Information, awareness and attitude towards energy efficiency
Level of competence and expert capacity	Existence of an open and competitive market	Environmental motivation
Monitoring and measuring	Financial initiatives and tax advantages	Socio-demographic and socio-cultural factors
Intelligent energy	Economic costs and risks	Regulations, policy practices, incentives
Climate mitigation	Cost of ownership	Perception on risks and uncertainty
Information, awareness and attitude towards energy efficiency	Construction sector	Psychological, contextual factors and personal commitment
	Building tradition, expertise, typology and ownership of building stock	Economic/financial factors
	Establishment of ESCO associations	Building environment

Sustainability can no longer be promoted only in the phases of design and building where the implementation of regulations on materials and construction are strictly applied and building control involved. Methods of consultation, negotiation and involving the various representatives of the private sector are underway, but still challenging and demanding more knowledge and data in order to develop suitable methods and approaches.

Most of the sources stress on the need for competence-raising measures in the energy field, directed at secondary training and education in the building subjects and the impacts of structural measures, as well as the occupier needs and attitudes at all levels - central and local administration, formal and informal decision making units.

4.2.4 Summary of Methodologies

Methods described in the sources relate mainly to behaviour. They include literature reviews (Friege & Chappin, 2014; Faiers et al., 2007; Shafaghat et al., 2016; Häkkinen et al., 2016), policy analyses (BUILD UP Skills EU-Spain, 2012; BUILD UP Skills EU-Italy, 2012; BUILD UP Skills EU-Finland, 2012; BUILD UP Skills EU-Bulgaria, 2012; BUILD UP Skills EU-Norway, 2012; BUILD UP Skills EU-Austria, 2013; BUILD UP Skills EU-Germany, 2012), case studies (Walsh et al., 2017; Zhang et al., 2011; Pinkse & Dommisse, 2009; Monfils, 2016), online surveys (Hope & Booth, 2014; Romano et al., 2017), telephone surveys (Gandalf group, 2014), interviews (Ástmarsson et al., 2013; Zhang et al., 2011), content analysis (Zhang et al., 2011), and cluster analysis (Walsh et al., 2017). More specific single research methods applied are the Granger casuality test (Esso & Keho, 2016), Kano user satisfaction measurement method (Shafaghat et al., 2016), citation network analysis (Friege & Chappin, 2014), bounds test by computing the exact critical values (Esso & Keho, 2016). Although most of the publications are grounded on one single research method, a few of the sources are based on combined methods, such as case studies analysis and cluster analysis (Walsh et al., 2017), literature review and citation network analysis (Friege & Chappin, 2014), scenario analysis (Fujimori et al, 2014), and energy audit (Masoso & Grobler, 2010).

Methods applied in research related to Energy transition/ energy efficiency in general are: Analysis of regulations (Aragonés et al., 2016, DG Energy, 2015), comparative studies and country reports (European Commission, 2011a; European Commission, 2016b), descriptive analysis (Kuusk & Kalamees, 2016), comparative methodology framework (European Commission, 2016b), comparison through indicators (European Commission, 2015), case study (Lilliestam & Hanger, 2016), conceptual analysis and case study (Rotmans et al., 2001), compliance study and mixed-methods approach (DG Energy, 2015), multi-dimensional impact analysis (European Commission, 2016a), basic data mining technique (cluster analysis) (Yu et al., 2011), analysis of life cycle cost in the framework of the building management systems (European Commission, 2016b), online questionnaires (DG Energy, 2015), scenarios analysis (Fujimori et al, 2014), systems approach (Holmgren, 2009), mix of qualitative and quantitative research – questionnaires and structured interviews, focus groups methods (World Business Council for Sustainable Development (WBCSD), 2007), and survey (Marco et al., 2016).

Methods applied in research at National/Regional level are comparative analysis (Jones et al. (eds), 2016), quantitative analyses (ESPON, 2010). Empirical research is used to provide a knowledge-base on urban development, necessary for integrated prospective thinking and open the opportunity for developing scenarios and elaborate a framework for policy options (ESPON, 2010).

Methods applied in research of Urban aspects are: sampling of buildings (CONCERTO Premium consortium, 2014), GIS modelled (static model) heat energy assessment calculation (LSE Cities, 2014), holistic parametric model to estimate the total urban energy use for space heating, embodied building energy, transportation energy, and road infrastructure energy, and how these relate to urban density (Kurnitski, 2016).

Method applied in research related to building structure and envelope as a model targeting non-expert users (future validation by questionnaire survey), i.e. average consumers, on the construction market in Germany (Rochikashvili & Bongaerts, 2016).

The methods applied in research related to interior equipment in buildings are literature review, survey of prominent international intelligent buildings research efforts with the theme of energy saving and user activity recognition. New metrics in order to compare the existing studies have been defined, incl. activities and behaviours, and their impact on energy saving potential for each of the three main subsystems, i.e., HVAC, light, and plug loads (Nguyen et al., 2013).

The methods applied in monitoring and measuring of energy efficiency are literature review (Asensio & Delmas, 2015), survey (Kane et al, 2015), energy modelling (Kane et al, 2015), quantitative analysis of statistics (Johansson et al., 2013), field experiment (Asensio & Delmas, 2015), and correlation (regression) analysis - performed to exploit the relative role of each factors (Feng et al., 2016).

4.2.5 Main Results and Findings

The climate mitigation target was found to be a key determinant of the effectiveness of energy service demand reduction measures. Estimates of the effectiveness of energy service demand reduction measures therefore have a high level of uncertainty under the current climate policy conditions where the ultimate climate mitigation target has not yet been decided. Some measures, such as urban planning or constructing well-designed buildings require long-term perspectives. Therefore, more certain climate mitigation targets would be very useful for the decision makers who are supposed to implement energy service demand reduction measures (Fujimori et al, 2014).

Table 2. Provides an overview of barriers pertaining to the building technology focus. While most of the barriers identified are context-specific, some of the studies underline the importance of applying an integrative perspective when examining barriers to scale-up as such processes require facilitative conditions related to the socio-cultural, market, policy, and built and geographical context (Doren et al., 2016).

Table 2 Barriers regarding buildings

Formal Social Unit	Collective Decision Making Unit	Individual Level Unit
Lack of information and awareness	Economic and financial restrictions, costs	Economic restrictions, costs
Behavioural and organizational barriers	Perceptions on risks and uncertainty	Lack of information and awareness
Lack of participation	Poorly aligned incentives and other regulatory schemes	Lack of trust, perception of risks and uncertainty
Lack of trust in environmental benefits	Lack of participation	Lack of environmental awareness
	Hidden costs	Socio-cultural barriers

There are very different characteristics of buildings, housing policy, building stock and occupiers' behaviour in the different EU member states (Panayiotou et al., 2010; Tuominen et al., 2012; Zografakis et al., 2010; Pyrko & Darby, 2011; Vassileva et al., 2012a; Vassileva et al., 2012b; Engvall et al., 2014; Anda & Temmen, 2014; Doren et al., 2016; Wittenberg & Matthies, 2016; Fell & Chiu, 2014; Bigerna & Polinori, 2014; Mortensen et al., 2016; Steg et al., 2005; Santin, 2011; Ekins & Lees, 2008; Podgornik et al., 2016; Heuts & Renosee, 2016; Kmeťková & Krajčík, 2015). The building envelope primarily affects energy use for heating – that has affected a gradual tightening of building regulations and has resulted today in major investments in low-energy buildings.

Motivators regarding the building technology focus are also significant. These are summarized in Table 3. One question posed is what more we can do to get buildings that are even more energy efficient, and to be able to reach the vision about "close to zero" energy buildings (Engvall et al., 2014). Certain factors, such as building construction materials, construction processes, building design, building orientation, and window design should be investigated in greater detail to further refine the correlation between these variables with energy consumption of Energy Star (ES) or non-Energy Star (NES) homes in USA (Shrestha & Kulkarni, 2013).

Table 3 Motivators regarding buildings

Formal Social Unit	Collective Decision Making Unit	Individual Level Unit
Effective policy and regulatory instruments	Effective incentives	Social factors
Environmental concerns	Environmental concerns	Environmental awareness
Market based factors	Confidence in business	Economic advantages, incentives
	Open market	Educational factors
	Local participation	Individual motivation

With reference to the construction sector, much more training and qualification is needed and will be on demand until 2050 – the building sector has currently employed 20% of the workforce and renewable energy has accounted for 28%; both will be 60% in 2050, so training and qualification of workers is needed (BUILD UP Skills EU-Finland, 2012).

Green building should not only be oriented towards energy performance, but also be user-oriented, the social and human needs model is thus well-established based on Maslow's Hierarchy of Needs. In the life cycle of green buildings, social and human needs are dynamic, which means social processes with consumer engagement and participation needs to be considered in aspects of conceptual design, planning and design, operation and maintenance to improve users' happiness and productivity (Zhao et al, 2015).

Energy efficient behaviour should not be neglected in national energy policies and programs. The most effective tools promoted include an emphasis on the importance of knowledge when energy behaviour is concerned; awareness raising features of feedback; customized information and efficiency indicators for specific household groups with a potential to activate the awareness of established habits and their relevance to energy behaviour (Podgornik et al., 2016).

Three types of intervention could play equally important roles in reducing heat energy demand: behavioural adjustments, technological advancement and design considerations. To explain the up to twenty-fold variation observed for the energy demand of buildings fully, some authors consider whether urban geometry might be the missing factor (LSE Cities, 2014). Some authors outline the value of applying insights from psychology and behavioural economics to inform the effective design and delivery of consumer-focused communication, messages, and other behavioural interventions aimed at encouraging household energy conservation (Frederiks et al, 2015), and report about the identified relationships between occupant behaviour and household characteristics (Santin, 2011).

Climate change has traditionally been framed as an analytical, temporally and spatially distant risk that represents an (uncertain) future loss for society. Yet, psychological research suggests that in order to improve public engagement with the issue, policymakers should emphasize climate change as an experiential, local and present risk. They should define and leverage relevant social group norms; highlight the tangible gains associated with immediate action; and last, but certainly not least, appeal to long-term motivators of pro-environmental behaviour and decision-making (Linden et al, 2015). Support for environmental policies may be enhanced by emphasizing biospheric values, increasing general environmental awareness, increasing the awareness of and responsibility for the problems resulting from high energy consumption patterns, and strengthening personal norms for taking corrective actions (Steg et al., 2005). Green building's sustainable design has an important influence on consumers' decision-making process (Zhao et al., 2015).

Local government can play an important role in supporting informative and cooperative strategies and proactively searching for financial and regulative strategies. Furthermore, some conclusions on how low-carbon urban development can be promoted at the local scale have been proposed (Doren et al., 2016). Municipal actors are also showing increasing interest in preparing city-level sustainability strategies. On the basis of the literature study, there are indications that traditional role of municipalities as a passive enforcer of national building regulations is changing. However, the municipal strategies should be closely linked to the local administration to ensure the realization of the strategy and also the allocation of adequate resources (Häkkinen et al., 2016).

With regard to building design, the process is very much dependent on the standards and methods for EPBD (European Commission, 2010). Some of the identified most significant insights related to behaviour are: (i) our tendency to 'discount the future'; (ii) the power of social norms; and (iii) the use of defaults (Cabinet Office Behavioural Insights Team, 2011).

Community-based social marketing (CBSM) has shown to be very effective at inducing behavioural change due to its pragmatic approach in a large urban electricity meter replacement program (Anda & Temmen, 2014). The effectiveness of the collective learning that takes place in modern housing developments can play a major role in terms of housing performance (Baborska-Narozny et al., 2014).

Based on environmental and cognitive parameters, consumers can be influenced in their moods or desires through communication techniques and will respond, in part, according to their level of 'education' in respect of the product in question. Four categories of consumers are defined: 'initiators', 'early' and 'later' imitators, and finally, 'last' adopters (Faiers et al., 2007). Current user-oriented solutions to green building are always based on a hypothesis that consumers are readily motivated or prefer expensive goods for reducing energy use. To really reflect preference and influenced actions, social acceptance should be analysed to fully gauge the interests and perspective of the people (Zhao et al., 2015). Regarding risk taken when implementing energy efficiency measures, an adopter with adequate financial resources will view any capital risk more favourably than an adopter with poor financial resources (Faiers et al., 2007).

In the field of residential use of energy, occupiers are a crucial parameter of both the problem and its solution (Hong et al., 2015). Homeowners cannot be considered one group, but must be addressed as individuals. The key parameters for determining the motivation factors are related to the homeowner's current position in life: age, presence and age of children, time of ownership, occupation and income. The older generation is hard to motivate, but results nonetheless show that it is possible with the right instruments (Mortensen et al., 2016). Residents' needs must be highlighted, but tenants should also be given the opportunity to understand the housing company's interests and subcontractors' situation in a renovation. Though residents are likely to have dissimilar interests regarding a major renovation and it is not possible to get full acceptance from everyone, the aim should be to satisfy the majority (Blomsterberg & Pedersen, 2015).

Smart cities' authorities need smart citizens, who are aware of their environmental impact, to use smart solutions to their full potential (Hong et al., 2015). Although the public is not familiar with the concept of a green building, the majority of participants would pay more for green buildings as compared to a standard building when they learn the environmental impacts of them (Zhao et al., 2015).

4.3 Electric Mobility

The transport sector is one of the main consumers of fossil fuel and hence contributes a substantial share to the EU's total greenhouse gas (GHG) emission. It is also the only sector that still displays increasing GHG emissions (EEA, 2016; European Commission, 2016; Taefi et al., 2016). This not only increases the fossil fuel dependency but also leads to severe impacts on the environment such as air pollution, noise, resource use and waste, and finally causes climate change (EEA, 2016). To address the issue of climate change, the European Commission has set the goal to achieve emission-free urban passenger transportation by 2050 (i.e., no more conventionally fuelled cars in cities) and emission-free urban freight transportation by 2030 (i.e., CO_2 free logistics) (European Commission, 2011).

However, in order to reach the goals set by the European Commission, there needs to be a shift in the transport sector from fossil fuel dependent vehicles to alternative, less fuel dependent transportation means. Key to this shift is electric mobility and in specific the introduction of electric vehicles (EV) (e.g., Usmani et al., 2015). These vehicles fully or partially operate with electric motors and hence enable to reduce fossil fuel dependency and GHG emissions. However, at present, the acceptance of alternative fuel saving transport vehicles is still marginal and sales volume of EVs in the EU is very low. For example, only countries such as Norway (13.84%), the Netherlands (3.87%), Iceland (2.71%), Estonia (1.57%), and Sweden (1.53%) have reached a market share that is higher than 1% of total new car sales (OECD, 2015). These numbers demonstrate the need for governments and institutions to take action in order to increase the market diffusion of EVs.

4.3.1 Variables and Factors Regarding Smart Mobility Technological Foci

Formal social units can be evaluated on three levels: (1) formal social units that act as policy-makers and/or energy providers, (2) collective decision-making units that are more formally structured and with relatively lower information and power asymmetries, and (3) individual consumers.

Main variables and factors for all three levels are mainly transport-related variables. Transport is responsible for a quarter of Europe's GHG emission and is the major source of air pollution and climate change (European Commission, 2016). Especially light and heavy-duty commercial vehicles contribute to a major extent to CO_2 emissions, air pollution, noise and traffic (Kaplan et al., 2016; European Environment Agency). For example, light and heavy-duty commercial vehicles account for only 13% of the vehicles in Europe. However, their CO_2 emissions contribute more than one third to the total CO_2 emissions in road transport (ICCT Europe, 2015).The electrification of transport (electric mobility) contributes not only significantly to a reduction of energy consumption and GHG emissions but also enhances Europe's energy security. In addition, public health will be improved due to the reduction of air pollution. The shift towards electric mobility also offers many opportunities for European car manufacturers because a new market is established for which they need to modernize their technologies and embrace innovations. Besides car manufactures, also energy companies and service providers can benefit from the shift. With the development of modernized technologies throughout the different sectors, also new jobs will be created (e.g., Haddadian et al., 2015; European Commission, 2016). Electric mobility is hence the focus of discussions concerning sustainable and energy-efficient means of transportation (Peters et al., 2011; Faria et al., 2013).

4.3.1.1 Formal social units

The majority of the articles investigating *operational features* of the electric vehicle such as range, charging time, grid technology, and availability, found significant relationships between these features and EV adaption rates (e.g., Azadfar et al., 2016; Barisa et al., 2016; Haddadian et al., 2015; Kasten and Hacker, 2014; Mahmoud et al., 2016; Sierzchula et al., 2014; Tan et al., 2016). The research in this field reveals that operational features play an important role in decision-making at the formal social unit. The operational features are adversely affected by technical restrictions. Hence, a large amount of studies consider technical restrictions, such as charging time, size of the battery, battery technology or electric battery range, as barriers to effective EV market implementation (e.g., Azadfar et al., 2016; Barisa et al., 2016; Foltyński, 2014; Haddadian et al., 2015; Kasten and Hacker, 2014; Mahmoud et al., 2016; Sierzchula et al., 2014; Tan et al., 2016). The limited model diversity is another barrier hindering successful EV market acceptance (Barisa et al., 2016; Haddadian et al., 2015). The few models on the market and the limited functionalities and operational features do not meet the needs and consumer preferences of the different consumer segments (Haddadian et al., 2015).

Also *charging infrastructure* is found to significantly impact EV market diffusion and is hence considered to be one of the leading factors in decision-making at the formal social unit level (e.g., Azadfar et al., 2016; Bakker and Trip, 2013; Barisa et al., 2016; Barlag, 2015; Foltyński, 2014; Sierzchula et al., 2014; Tan et al., 2016). This knowledge, in turn, enables politicians and governments to better plan future transport systems. Based on these findings, charging infrastructure can be considered a key factor for decision-making at the formal social unit level. Currently, lack of charging infrastructure is considered one of the main barriers to EV market diffusion (e.g., Azadfar et al., 2016; Bakker and Trip, 2013; Barisa et al., 2016; Barlag, 2015; Foltyński, 2014; Sierzchula et al., 2014; Tan et al., 2016). This is especially due to the fact that in case of insufficient charging infrastructure, flexibility and convenience in energy supply is not guaranteed, which in turn makes EV driving less attractive (Haddadian et al., 2015). A sufficient charging infrastructure can however only be realized if extensive information about the drivers and their driving patterns (i.e., travel habits, routs, and EV charging) is available.

Besides operational features and charging infrastructure, the *economic performance* of EVs has been the focus of previous research. Specifically, research investigated aspects such as price, buyer's premiums, costs for maintenance, fuel consumption and Total Cost of Ownership (TCO), including direct but also indirect costs of ownership, such as fees, taxes, depreciation, maintenance, fuel etc. (e.g., Bubeck et al., 2016; Haddadian et al., 2015; Kasten and Hacker, 2014; Liu and Santos, 2015; Sierzchula et al., 2014). Many studies suggest that the economic performance of EVs is also an important indicator that plays a role in decision-making. Economic factors such as reduced fuel costs as well as using night-time rates, benefiting from free electricity at some workplaces, or using public charging can be considered motivating factors to EV market acceptance (Barisa et al., 2016; Haddadian et al., 2015). On the negative side, currently, EV prices are very high as compared to combustion engine cars. That the users of EVs do not receive any compensating benefits for the lower pollution levels that they cause in many countries is also considered a barrier (Barisa et al., 2016; Sierchula et al., 2014), even though the total cost of ownership of electric vehicles is lower than that of conventional vehicles. In addition, many potential EV buyers are not aware of the various incentive programs offered by their government. Sufficient knowledge about these incentives is however key to the successful market acceptance of EVs (Haddadian et al., 2015).

Integral counterpart to economic considerations relate to electricity and raw materials supply. Regarding electricity supply, increased electric mobility calls for a growth in electricity demands. Renewable energy sources are not sufficient to meet the increased energy demand (Kannan and Hirschberg, 2016; Öko-Institut, 2012). Another obstacle is that there is no guarantee that cheap electricity is always available, and at peak loading times, there might be challenges to guarantee a sufficient distribution of energy (European Commission, 2010; Kannan and Hirschberg, 2016; Öko-Institut, 2012). In addition to that, international energy prices are not certain (Kannan and Hirschberg, 2016). Policy decisions in the electric sector are the driving forces affecting the cost efficiency of electric mobility (Kannan and Hirschberg, 2016). Concerning raw materials, the raw materials needed for the production of electric cars are in some cases rare metals (such as lithium and cobalt) or commodities (such as copper) and their supply is not always guaranteed (Öko-Institute, 2012).

The policy implementation counterparts of cost competitiveness for EVs are *incentives, regulations* and/or other *policy practices*. These practices have consequently received a lot of attention in previous research (e.g., Adamou et al., 2012; Colmenar-Santos et al., 2014; Gallagher et al., 2008; Liu and Santos, 2015; Sierzchula et al., 2014). The implementations may range from the combination of subsidies with a raise in gasoline and diesel taxes (Liu and Santos, 2015) to carbon-based tax systems (Adamou et al., 2012). However, policymakers have to assess taxation and the responding consumer reaction carefully in order to avoid losses of public revenues (Adamou et al., 2012, Colmenar-Santos et al., 2014). Policymakers can stimulate the market diffusion of EVs through the aforementioned instruments also by targeting manufacturers (Kiekhäfer et al., 2016).

According to Haddadian et al. (2015) higher taxes and restrictions on conventional vehicles represent motivators for higher EV use. In addition, well-designed incentives can enhance EV acceptance in the transportation sector. The authors suggest that besides federal incentives, also state monetary incentives can have a key impact on EV market acceptance.

Further, publications have investigated *environmental aspects* such as CO_2 emission, noise and air quality (Adamou et al., 2012; Colmenar-Santos et al., 2014; Da Silva and Moura, 2016; Kasten and Hacker, 2014; Mahmoud et al., 2016). Investigating environmental aspects is almost obvious given the fact that the ultimate goal of the European Commission is to achieve emission-free urban passenger transportation by 2050 and emission-free urban freight transportation by 2030. Environmental aspects are hence often the outcome variable in many research studies. Thus, environmental aspects are a prominent factor for the decision-making process at the formal social unit. On the plus side, environmental aspects such as reduction of air pollution, contribution to national climate and energy policy goals, contribution to the "green image" of the formal social unit are becoming more and more vital in the procurement of fleet vehicles (Öko-Institute, 2012; Barisa et al., 2016). However, many potential EV buyers lack sufficient information about electric vehicles and their benefits (Barisa et al., 2016). Besides, electric mobility leads to an increase in power demand, which in turn, increases the CO_2 emissions of the electricity production (Kasten and Hacker, 2014; Öko-Institute, 2012). Potential EV drivers also consider the recycling of used batteries as harmful to the environment, which strengthens the uncertainty towards the greenness of EVs (Haddadian et al., 2015).

4.3.1.2 Collective Decision Making Units

The majority of articles focusing on the collective decision-making units have investigated the *attitude towards electric vehicles*, which is found to significantly impact upon EV adaption rates (e.g., Barlag, 2015; Kaplan et al., 2016; Klauenberg et al., 2015; Matthews et al., 2017; Norland and Ishaque, 2006). In sum, previous research concludes that the attitude is one of the key indicators of EV sales. Hence, this variable can be considered as particularly important in the decision-making at the collective decision-making unit. The attitude towards electric vehicles is affected considerably by further tiers of factors and variables. The technical aspects are among such primary factors. With the increase of the EV market and growing acceptance, EVs increasingly display a better technical performance including a higher range. In addition, a denser network for public charging points will be developed (Quak et al., 2016).

Charging infrastructure is also one of the most investigated aspects at the collective decision-making unit and is considered to highly impact EV market adoption (e.g., Barlag, 2015; Caramizaru and Barlag, 2015; Kiekhäfer et al., 2016; Laurischkat et al., 2016). One of the main findings is that the existence of charging infrastructure significantly affects car manufacturers' incentive to produce electric vehicles (Kiekhäfer et al., 2016). In this context, previous research has also quite often focused on *charging solutions* (e.g., Caramizaru and Barlag, 2015; Kiekhäfer et al., 2016; Laurischkat et al., 2016). Accordingly, charging infrastructure as well as charging solutions are important aspects for the collective decision-making unit and an insufficient charging infrastructure is also one of the most significant barriers at the collective decision-making unit (e.g., Barlag, 2015; Caramizaru and Barlag, 2015; Kiekhäfer et al., 2016; Laurischkat et al., 2016).

The *characteristics of EV use* are also commonly investigated in the context of collective decision-making units (e.g., Ambrosino et al., 2015; Klauenberg et al., 2015; Laurischkat et al., 2016; Noland and Ishaque, 2006). Characteristics such as vehicle use and tour patterns affect the usefulness of switching to EVs (Klauenberg et al., 2015). Based on the characteristics of EV use, collective decision-making units can define specific customer segments and hence better develop respective business models that fit the specific needs of each customer segment (Laurischkat et al., 2016). Therefore, characteristics of EV use can be considered as important in the decision-making at the collective decision making unit.

Economic factors are also significant on the collective decision-making unit level. Several economic factors such as low fuel costs or efficiency of operation can be named as motivators to EV acceptance (Quak et al., 2016). For example, the efficiency of operation can be enhanced by policies that introduce low emission zones, or that enable EVs to use bus lanes or to use special parking spaces. Also decreasing battery prices can be named as potential motivators (Quak et al., 2016). However, high procurement costs of electric vehicles, limited, unreliable and expensive after-sales support, uncertainty about oil prices and energy prices are noteworthy barriers (Quak et al., 2016; Shao et al., 2016; Laurischkat et al. 2016).

Several *operational factors such* as grid issues with large fleet and limited availability of vehicles also represent vital barriers (Quak et al., 2016). In addition, companies aiming to shift their fleet to battery electric vehicles experience an enormous change process, which does not come without challenges (Laurischkat et al., 2016).

The significance of economic and operational factors are even further amplified by conditions of *trust, information* and *knowledge*. On the one hand, the positive acceptance by the public as well as innovative vehicle and battery leasing schemes represent noteworthy motivators for EV market penetration (Quak et al., 2016). *Environmental factors* such as good environmental performance (i.e., low CO_2 emission) and no noise from the vehicle can also turn out as vital motivators to EV acceptance (Quak et al., 2016). On the other hand, potential buyers being unfamiliar with the availability and variety of EVs or sustainability related information regarding EVs, as well as their lack of trust in the marketing campaigns and claims formulated by the manufacturing car companies pose another barrier (Shao et al., 2016). Potential EV buyers also question the environmental performance of EVs, for instance, the battery manufacturing process (Barlag, 2015).

4.3.1.3 Individuals

Most of the related literature focused on *demographics*, such as income, gender, age, household size, socio-economic status, and occupation level, concluded that electric vehicle acceptance is in fact related to demographic factors (e.g., Axsen et al., 2016; Bart et al., 2016; Daziano and Chiew, 2012; Jang, 2016; Peters et al., 2011; Peters and Düschke, 2014; Plötz et al., 2014; Sang and Bekhet, 2015; Ziefle et al., 2014).

A large amount of previous research also investigated the *attitude towards electric vehicles* (e.g., Axsen et al., 2016; Gebauer et al., 2016; Gruber and Kihm, 2015; Moons and De Pelsmacker, 2015; Peters et al., 2011; Plötz et al., 2014; Schmalfuss et al., 2015). Previous research unanimously agrees that a positive attitude towards EVs is a predictor of purchase intentions and plays an important role in decision-making at the individual level.

The attitude towards electric vehicles has its roots in the characteristics and current situation of electric mobility, such as in the case of *economic factors, technical aspects* and *security*. Economic aspects can be considered motivators. For example, some EV users consider the EVs cheap to run and charge (Axsen et al., 2013; Graham-Rohe et al., 2012). Although the initial purchasing price of an electric vehicle is higher than that of a conventional car, in the end, electric vehicles are more cost-saving (Ziefle et al., 2014). In addition, the option to sell battery storage capacity to the grid is another motivating factor (Daziano and Chiew, 2012). On the contrary, currently, the main barrier hindering EV market penetration is the high purchasing price of electric vehicles (e.g., Axsen et al., 2013; Daziano and Chiew, 2012; Graham-Rohe et al., 2012). The unawareness on the charging electricity costs, coupled with the limited battery life span also contribute to this barrier (Graham-Rohe et al., 2012; Daziano and Chiew, 2012).

On the side of technical aspects, the lack of charging infrastructure also represents a barrier to engagement in electric mobility (e.g., Axsen et al., 2013; Daziano and Chiew, 2012; Graham-Rohe et al., 2012). Other technical and security factors such as battery life span and driving range are considered as barriers to engagement (Axsen et al., 2013; Daziano and Chiew, 2012; Zaunbrecher et al., 2014). A further barrier is the perceived immaturity of charging technology (Zaunbrecher et al., 2014). In addition, the much longer recharge time when compared to the refuelling time of a conventional car is also important (Axsen et al., 2013; Daziano and Chiew, 2012; Zaunbrecher et al., 2014). Other technical barriers are the poor acceleration and that electric vehicles are very quiet (Axsen et al., 2013). Many drivers fear that electric vehicles are less secure because pedestrians cannot hear a car approaching and hence more accidents can happen.

The interaction between the demographic factors and the attitude towards electric vehicles result in the so-called *individual factors* and may constitute barriers to engagement such as lack of knowledge regarding reasons and impacts to climate change. In addition, many potential EV users are unable to find relevant information about electric mobility and are often confused by conflicting information or by information that they consider not trustworthy (Lorenzoni et al., 2007). Examples for this are the notions of *functional aspects* and *practicability*. Being able to recharge the electric vehicle at home and not having to go to the petrol station is a motivating factor (Axsen et al., 2013). In addition, smart charging systems for electric vehicles facilitate the charging procedure and enable to balance energy supply and demand (Schmalfuß et al., 2015). Another functional aspect is the lack of noise when driving an EV (Axsen et al., 2013). However, drivers consider the use of electric vehicles as restrictive because they have to plan their journeys in advance (Axsen et al., 2013). Hence, potential EV drivers have to change their lifestyle and to organize their driving habits better (Axsen et al., 2013; Lorenzoni et al., 2007).

Research also considers *environmental values, beliefs,* and *norms* to influence the EV adoption behaviour and/or intentions of individuals to purchase EVs (Rezavni et al., 2015). In line with this, a large amount of articles have investigated values and environmentalism in the context of EV adaption (e.g., Axsen et al., 2016; Cherchi et al., 2015; Flamm and Weinstein, 2012; Graham-Rowe et al., 2012; Krupa et al., 2014; Noel and Sovacool, 2016; Sang and Bekhet, 2015). In conclusion, previous research demonstrates that environmental values, beliefs, and norms play a significant role in decision-making at the individual level and are hence important variables to be considered. Environmental aspects are among the key motivators to purchase an EV by reducing air pollution and greenhouse gas emissions (Axsen et al., 2013; Daziano and Chiew, 2012; Ziefle et al., 2014). However, many potential EV buyers question the lifecycle impact of electric vehicles on CO_2 emissions. Specifically, it is assumed that EVs are not automatically environmentally friendly because the electricity used to charge the electric vehicles is generated from power plants, which in turn may contribute to enormous CO_2 emissions (Axsen et al., 2013; Zaunbrecher et al., 2014).

Social influence and *social factors* have also been the focus of previous research at the individual unit level (e.g., Axsen et al., 2013; Daziano and Chiew, 2012; Krupa et al., 2014; Morton et al., 2016; Sang and Bekhet, 2015). The results of these studies show that social influence and social factors play a key role with respect to decision-making at the individual level and are therefore worthy variables to be considered.

Previous research has also investigated *regulations, policy practices* and *incentives* which are all measures that affect EV market acceptance (e.g., Comodi et al., 2016; Daziano and Chiew, 2012; Kunert and Kuhfeld, 2007; Lieven, 2015; PTV Group 2013; Sang and Bekhet, 2015). These studies reveal that regulations, policy practices and incentives play a significant role in the decision-making process at the individual level, and are even more effective when supported by infrastructural components, and are hence important to consider.

Another important factor investigated by previous research is *experience* with electric vehicles and *general awareness about EVs* (Axsen et al., 2013; Axsen et al., 2016; Barth et al., 2016; Lorenzoni et al., 2007; Schmalfuß et al., 2015). Based on evidence from these studies, it can be concluded that prior experience with EVs also plays an important role in decision-making at the individual level.

Besides the above presented factors, prior research has also focused on the variables *preferences, lifestyle,* and *habits with respect to EV use* (e.g., Axsen et al., 2016; Barth et al., 2016; Fujimori et al., 2014; Noland and Ishaque, 2006; Moons and De Pelsmacker, 2015; Pasaoglu et al., 2013). These variables include buying an EV versus using an EV via car-sharing (Barth et al., 2016), driving and parking patterns (Pasaoglu et al., 2012). A comprehensive understanding of such variables is vital because it enables policymakers, car manufacturers and EV dealers to understand the different customer segments and to hence correspond to the specific needs in each segment better. Thus, preferences, lifestyle, and habits with respect to EV use can be considered to play a significant role in decision making at the individual level.

4.3.2 Gaps for Research

Based on the state of the art analysis, several gaps for research were identified. In the following section, the major gaps for research are outlined below.

Levels of formal social units investigated: The majority of publications investigates the individual level, followed by the formal level and the collective level. A focus primarily on the individual level is problematic, given the fact that there are many actors at different levels playing an important role in the EV ecosystem (Newbery and Strbac, 2015). It is important that future research broadens its perspective and conducts more research at the formal and the collective level to understand the interplay of different levels and to gain a holistic understanding of EV market diffusion.

Country focus of identified articles: The vast majority of studies on electric mobility are at the national level, and mostly concerning Germany and UK. This is striking given the fact that the European Commission's goal of emission-free transportation is a European wide goal, which requires the participation and collaboration of all European countries. There is hence a need to widen this perspective and to conduct more research at the international level.

Levels of attitude investigated: Extant research has investigated several levels of attitude of the respondents. In general, attitude has an affective, behavioural, and cognitive component (e.g., Breckler, 1984). All three components are important predictors of attitude and the simultaneous investigation of these components better predicts the outcome (e.g., Murphy and Zajonc, 1993). Previous research investigating the formal social unit mainly focused on the behavioural aspect, followed by the cognitive and the affective aspect. The latter two however have received very low attention and almost no study investigated the three components simultaneously. Hence, there is need for future research to broaden the perspective of the different components and to investigate all components of attitude.

Total cost of ownership: TCO is an important economic indicator that is not yet fully understood by potential EV buyers. As of today, most car drivers focus on the high initial purchase price of an EV and do not fully consider the savings that arise in the long run. Consequently, diffusion rates of EVs are still low. A fruitful avenue for future research would be therefore to analyse key variables that impact perception of the TCO.

Social networks: Several studies have investigated the impact of social influence on EV perception. Since individuals do not interact in a social vacuum but rather in a society, it is necessary to shift the focus even more from the individual to the social network of individuals. Social contacts shape the perceptions of individuals (e.g., Barth et al., 2016; Daziano and Chiew, 2012). So far, there is not sufficient research investigating this important and realistic research setting. This perspective provides a rich and realistic understanding of social impact on customer preference formation.

Neighbour effect: Looking at a bigger picture, investigating the neighbour effect – which refers to diffusion of visible technology innovations in geographical neighborhoods – might be another fruitful future research avenue. The neighbour effect is considered key with respect to the diffusion of new technologies. In specific, when an innovative technology becomes prevalent in a market, consumers are more likely to change their attitude and preferences in favor of this new technology (e.g., Axsen et al., 2009).

4.3.3 Similarities and Differences in Decision-Making Processes Related to Each Level

In the following section, similarities and differences in decision-making processes related to each level are outlined. Table 4 provides a summary of the variables-factors that play a role in decision-making at the formal social unit level, collective decision-making unit as well as the individual unit. The table allows to gain broad insights into the similarities and differences in the decision making process at the different levels.

Table 4 Factors that play a role in decision-making process at respective units

Formal Social Unit	**Collective Decision Making Unit**	**Individual Level Unit**
Operational features (e.g., range, charging time, grid technology, and availability)	Attitude towards electric vehicles	Demographics (e.g., income, gender, age, household size, and occupation level)
Charging infrastructure	Charging infrastructure	Attitude towards electric vehicles
Economic performance (e.g., price, maintenance costs, fuel consumption, and TCO)	Charging solutions	Environmental values, beliefs, and norms
Regulations, policy practices, incentives	Characteristics of EV use	Social influence and social factors
Environmental aspects (e.g., CO_2 emission, noise, and air quality)		Regulations, policy practices, incentives
		Experience with electric vehicles and general awareness about EVs
		Preferences, lifestyle, and habits with respect to EV use

The table demonstrates that at the formal social unit level operational features, charging infrastructure and economic performance are important drivers of decision-making. Regulations, policy practices and environmental aspects are also relevant. Policymakers and energy providers further have to keep in mind the environmental aspects and goals set by the European Commission.

The formal social units and collective units have in common that availability of charging infrastructure is a key component affecting their decision-making process. In comparison to the formal social unit however, the collective decision-making units also consider the attitude towards electric vehicles as an important aspect. Besides the attitude, also the charging solutions are key factors that influence the decision-making.

Turning to the decision-making at the individual level reveals that the attitude towards electric vehicles is predominant also at this level. Also clear differences can be noticed between the formal social unit, the collective unit and the individual level. For instance, the main aspects influencing the decision-making at the individual level are the following: background of the individuals (e.g., income, age, household size) as well as environmental values, beliefs and norms. In addition, social influence plays an important role. Furthermore, regulations, policy practices and incentive schemes introduced by the formal social unit level impact the decision-making at the individual level.

It is also important to mention, that at the individual level, in comparison to the other two levels, lifestyle and habits with respect to EV use play an important role in the decision-making process.

4.3.4 Summary of Methodologies

An in-depth analysis of previous research reveals that the majority of publications have used surveys to collect their data (e.g., Axsen et al., 2016; Comodi et al., 2016; Kaplan et al., 2016; Klauenberg et al., 2016; Morton et al., 2016; Sang and Bekhet, 2015; Taefi et al., 2016). Kaplan et al. (2016) for instance investigate the intentions of introducing EVs in the commercial sector by surveying a sample of firms in different industrial sectors in Denmark, Germany and Australia. The surveys were administered via email and 24.100 firms were targeted. Morton et al. (2016) investigate consumer preferences towards EVs using a self-administered paper-based household survey in the UK. The authors distributed their survey to 4.000 respondents living in different cities. Taefi et al. (2016) on the other hand use a standardized online questionnaire to investigate the adoption of EVs in urban road freight transport in Germany. For this, the authors surveyed policymakers and freight EV users.

Data collection based on literature reviews has been the second most employed data collection approach (e.g., Mahmoud et al., 2016; Mardani et al., 2016; Noel et al., 2016; Quak et al., 2016; Rezvani et al., 2015). Mardani et al. (2016) for example conducted a literature review among 72 journals related to energy management approaches from 1995 to 2015. Based on their literature search the authors identified and analysed 197 relevant publications. Rezvani et al. (2015) conduct a systematic literature review to investigate drivers for and barriers against consumer adoption of EVs over the period 2007 to 2014. The authors derive their findings based on sixteen publications that they identified using the systematic literature review.

Less attention has been given to interviews (e.g., Bakker and Trip, 2013; Burgess et al., 2013; Graham-Rowe et al., 2012; Wikström et al., 2016). Bakker and Trip (2013) for instance analysed supportive policy options for EVs focusing on seven expert interviews with policymakers from five different European countries (i.e., UK, Netherlands, Belgium, Denmark, and Norway). Burgess et al. (2013) conducted interviews with 55 private EV drivers across the UK. Using interviews the authors assessed the drivers' reports of their interactions with other non-EV drivers. Graham-Rowe et al. (2012) on the other hand conducted semi-structured interviews with 40 UK non-commercial drivers to gain insights into customer preferences and their likelihood of taking up electric vehicles.

A few studies also employed a mixed data collection approach, i.e., using for example surveys and interviews or literature review and interviews to collect data (e.g., Laurischkat et al., 2016; Schmalfuß et al., 2015). Laurischkat et al. (2016) for instance first conducted a literature review to derive a framework to gain insights on e-mobility business models. Then, the authors conducted interviews with a variety of providers from the mobility, energy and infrastructure sectors in order to apply the theoretical framework. Schmalfuß et al. (2015) conducted structured interviews and surveys to investigate the real life experience with respect to smart charging systems and to how EV drivers evaluate these systems. The authors employed interviews to collect data regarding the benefits and the costs of a certain smart charging technology. Variables such as motivation, trust or suitability for the daily routine were measured using a questionnaire. The resulting qualitative data (derived from the interviews) and quantitative data (derived from the surveys) were then combined to the study's findings.

Using surveys to collect data is useful due to the fact that surveys are relatively easy to manage. As can be seen from the presented publications that conducted surveys, surveys can be administered via email, telephone, or online and do not have a geographical dependence. Moreover, using surveys enables to collect a broad range of variables such as attitudes, opinions, values etc. Given the fact that the data gathered is standardized, the analysis of data is also very straightforward. A disadvantage of survey research is however the rigidity. That is, before developing a survey the researcher has to account for all potential answers, otherwise important data might be missing. Survey research is characterized by an inflexible design. The researcher uses the survey from the very beginning and is not able to adjust the survey to new areas of interest that might arise during the survey (Cooper and Schindler, 2013). For many researchers, the advantages outweigh the disadvantages; it is hence not surprising that this research method gained the most attention.

Literature reviews on the other hand, the second most employed data collection method in previous research, are considered as less expensive and time saving, because researchers do not need to get out into the field to collect data (Ghauri and Gronhaug, 2005). In addition, a literature review allows to gain insights on the current state of a certain research field and to identify key research questions that need further analysis. However, a literature review is limited to the aspects studied in prior research and is dependent on the quality of data collected by prior researchers (Cooper and Schindler, 2013). Given the novelty of the topic "electric mobility", it is obvious that many researchers chose the literature review methodology to gain first insights into this research field.

However, to gain a more in-depth understanding of electric mobility, the sole use of survey research and literature reviews is not sufficient. As mentioned above, data collection based on interviews has gained less attention in prior research regarding electric mobility. Interviews for example allow for a more in-depth data collection, where the interviewer can follow-up on responses and gain a deeper understanding of certain aspects that are unclear. Importantly, body language and facial expressions can better be understood and identified. The researcher is flexible and can thus gain a much deeper understanding of the research in question. There are also disadvantages that make interviews less attractive to researchers. For example, interviews are more time consuming, can be expensive and responses may be biased due to the presence of an interviewer during the data collection (Cooper and Schindler, 2013). Also, as can been seen from the examples given above, the sample size is usually much smaller in comparison to survey research. Still, the advantages outweigh the disadvantages and contribute to a much better understanding of the research in question. This is especially important in the case of electric mobility given the fact that market acceptance is still very low and that many barriers still hinder the successful market diffusion of EVs. In addition, as conducted in some cases mentioned above, researchers can strengthen their study findings by employing interviews to derive theories or frameworks and then quantitatively testing these theories or frameworks using survey research.

4.3.5 Main Results and Findings

In the following section, the core findings regarding the variables-factors as well as the barriers and motivators to effective EV market penetrations are outlined.

The majority of the previous research investigates the individual level, followed by the formal level and the collective level. Hence, there is a more comprehensive understanding of individual level aspects that impact the decision-making at this level. The vast majority of previous research is about consumer attitude and perceptions towards electric vehicles as well as socioeconomic and demographic variables. However, according to Anable (2005), it is necessary to focus not only on variables that could affect preferences and choices, but also to focus on an individual's motivation, ability to change and adapt to new things. This is especially important in light of the fact that the use of an EV requires the drivers to change their driving patterns and lifestyle and to plan their driving routes in advance. There is hence a need for future research to expand the focus and to investigate factors that affect an individual's willingness and ability to change.

On the other hand, at the formal social unit level, operational features such as range and charging time, as well as charging infrastructure and economic performance of the electric vehicle are key drivers affecting EV purchasing decisions. Besides these aspects, regulations, policy practices and incentives as well as environmental aspects (e.g., CO_2 emission, noise, etc.) seem to be noteworthy influencing factors at this decision-making level. Despite the broad focus on the formal social unit by prior research, it is however surprising those important aspects such as supply and security of raw materials are not considered as affecting factors in decision-making. As outlined above, with increasing electric mobility more raw materials will be needed for the production of electric cars.

However, the supply of certain raw materials is not always guaranteed (Öko-Institute, 2012). Therefore, the supply and security of raw materials need to be taken into account when making decisions towards EVs at the formal social unit level.

Finally, at the collective decision-making level, the attitude towards EVs seems to be a significant influencing factor towards EV adaption. Charging infrastructure, charging solutions as well as characteristics of EV use are considered relevant at this decision-making level. It is important to note that the collective decision-making level has received rare attention in prior research, compared to the individual and formal social unit level. Hence, valuable aspects that might affect the decision-making at this level are missing. For example, it might be of interest to investigate how collective decision-making at the collective unit level influences the purchase intentions of EVs. In particular, there are many pitfalls and limitations that have an impact on the decision-making process at the collective level. According to Shaw (1976), decisions made by groups are likely to be more risky than decisions made by the individual group member. This behaviour is due to the fact that group members perceive their personal responsibility in case of negative consequences to be lower in such a group decision scenario (Forsyth, 1990). In the case of EV purchase intentions, it would be of great interest to investigate in how far group decision-making facilitates or hinders the procurement of electric vehicles.

The analysis of barriers and motivators along the three different levels of the formal social unit (see Table 5) reveals that there are many different barriers hindering the successful market penetration of EVs. On the other hand, the number of motivators is unfortunately limited. This imbalance of barriers versus motivators is also reflected in the low diffusion rate and acceptance of electric vehicles. Given this discrepancy, there is a need for governments, cities and car manufacturers to take action and to invest in practices and technologies that strengthen the benefits and hence the motivators for using electric vehicles.

Table 5 : Barriers to EV market acceptance

Formal Social Unit	Collective Decision Making Unit	Individual Level Unit
Lack of charging infrastructure	Lack of charging infrastructure	Lack of charging infrastructure
Economic restrictions (e.g., purchase price of EV)	Economic restrictions (e.g., purchase price of EV, limited loading capacity, uncertain oil prices and energy prices)	Economic restrictions (e.g., purchase price of EV, replacement costs of batteries)
Technical restrictions (charging time, battery technology, electric battery range)	Operational restrictions (grid issues with large fleet and limited availability of vehicles)	Technical restrictions / Security of technology (e.g., battery life span, driving range, poor acceleration, noise)
Lack of trust in environmental benefits	Lack of trust, information and knowledge	Lack of trust in environmental benefits
Electricity supply		Individual aspects (e.g., lack of knowledge regarding reasons and impacts to climate change, climate change considered as distant threat)
Raw materials supply		Other aspects/ practicability (e.g., change of lifestyle, driving habits)
Limited availability of models		

Across all decision-making levels, actors almost unanimously agree on the barriers that hinder EV market diffusion. Lack of charging infrastructure for example is a prominent barrier mentioned throughout the different decision-making levels. In order to overcome this barrier, policymakers and energy providers have to ensure that a sufficient charging infrastructure is build. For this, international collaboration throughout the European Union is indispensable to guarantee a European wide charging grid.

The majority of studies evaluated the high purchasing cost as main barrier to EV acceptance. Although these studies agree on this aspect, research is missing that provides in-depth information on the cost in the long run, i.e., the total cost of ownership. A few researchers argue that the TCO is smaller compared to conventional vehicles (e.g., Haddadian et al., 2015; Bubek et al., 2016). The TCO could even be enhanced when taxes for fossil fuel as well as conventional vehicles are increased. This increase is according to Da Silva and Moura (2016) one of the most effective policies to boost EVs diffusion. However, few studies have investigated the TCO and there is still insufficient understanding about this significant indicator. There is hence a need for future research to more often investigate the TCO of electric vehicles and to provide a better understanding to potential EV drivers on how to calculate the TCO.

In addition to that, actors across the three decision-making levels mention the lack of trust as a barrier. This lack of trust is mainly with respect to environmental benefits. Here, policy makers, energy providers and car manufacturers have to provide more information that is easily accessible and understandable for the public. Only with sufficient and transparent information, lack of trust in environmental benefits can be prevented.

Specific barriers that primarily affect the formal decision-making level are the supply of electricity and raw materials. These barriers affect the entire success of electric mobility and are hence significant obstacles to be mitigated. In order to overcome these barriers, policymakers as well as energy providers worldwide have to collaborate and develop strategies that guarantee a secured electricity and raw material supply.

On the other hand, barriers that primarily affect the individual level unit are aspects such as climate change to be considered as a distant threat or aspects such as the need to change one's lifestyle. These barriers can be addressed by educating the public about the constant and increasing threat of CO_2 emissions and by providing transparent and trustworthy information on how each individual can contribute to a low CO_2 emission environment.

Table 6 Motivators to EV market acceptance

Formal Social Unit	Collective Decision Making Unit	Individual Level Unit
Environmental aspects (e.g., reduction of CO_2 emissions)	Environmental aspects (e.g., reduction of CO_2 emissions)	Environmental aspects (e.g., reduction of CO_2 emissions)
Economic aspects (e.g., reduction of fuel costs)	Economic aspects (e.g., low fuel costs or efficiency of operation)	Economic aspects (e.g., reduction of fuel costs, selling surplus energy to the grid)
Taxes, incentives and regulations	Technical aspects (e.g., better technical performance)	Functional aspects (e.g., charge the EV at home)
	Other aspects (e.g., positive acceptance by the public)	

The main motivating aspect to engage in electric mobility across all the decision-making levels is driven by environmental reasons. This is, however, striking given the fact that most potential EV drivers claim that they have insufficient trust in the environmental performance of EVs. It is therefore of utmost importance to more effectively clarify the environmental advantages of EVs and to provide more accessible information on the benefits that arise with the purchase of an EV.

Economic aspects such as the reduction of fuel costs are unanimously mentioned as a motivator to EV market acceptance. This perception is important and a first step towards better understanding the total costs of ownership. That is, while the purchase price of an EV is higher compared to a conventional car, the operating costs including fuel costs are lower, and hence positively affect the TCO.

As mentioned, the barriers outperform the motivators. Consequently, market acceptance of electric mobility is relatively low. Therefore, as elaborated above, there is a need for researchers, practitioners and governments alike to take action in order to strengthen the motivators and eliminate the barriers.

4.4 Smart energy technology

The term “Smart grid” is a complex and still evolving concept. Consequently, even on the EU level, there is no one single definition of the concept and there exist several understandings of what the smart grid is and what it does. It may however be considered ‘*an upgraded electricity network, to which two-way digital communication between supplier and consumer, intelligent metering and monitoring systems have been added*’ (Zgajewski 2012: 7). An alternative definition by EPRI (Electric Power Research Institute) is '*the overlaying of a unified communications and control system on the existing power delivery infrastructure to provide the right information to the right entity*' (Camarinha-Matos, 2016). The smart grid concept also incorporates Information Communication Technology (ICT) tools.

The utility market is changing and according to predictions, the European electricity sector will have to deal with huge challenges in the decades to come. Developing smart grids and putting in place smart technology solutions is seen as an important priority across Europe, in order to reduce carbon emissions, achieve future goals of sustainability, and assure electric stability to cities and their citizens (European Technology Platform Smart Grids, 2012; Schleicher-Tappeser, 2012; Zgajewski, 2015; Giordano, 2013; Colak et al., 2013; Gangale et al., 2013; Giardano and Fulli, 2012; Hamilton and Gulhar, 2010). However, developments have been slow and there is uncertainty as to what exactly smart grids or smart technologies are (Zgajewski, 2015).

Smart Grids can contribute to sustainability objectives of EEU by facilitating the reduction of CO_2 emissions, enabling the integration of large-scale renewables, and increasing energy efficiency in the power sector. New business models and business practices, new regulations, as well as more intangible elements like consumers’ behavioural changes and social acceptance play a key role in this project. Initiatives across Europe and across the world are involved in research activities, the goals of which are to create the basis for a high quality, economically affordable and sustainable electricity supply transition. The EEGI (European Electricity Grid Initiative) and other SET plan initiatives work towards the energy and electricity system for the year 2035, with the aim of a CO_2 free electricity system by 2050.

Decision-making levels

The following section provides a state of the art review of previous research. The focus is on the following three levels of formal social units: (1) formal social units, which act as policy-makers and/or energy providers, (2) collective decision-making units that are more formally structured and with relatively lower information and power asymmetries, and, (3) individual consumers.

4.4.1.1 Formal Social Units

Governance, supply, networks, smart controls, demand response, environment, and energy behaviour are identified as crucial dimensions of the transition to a low carbon economy (Hammond, 2013; Good, Ellis and

Mancarella, 2017). Specifically, *government support*, *consumer engagement*, *organizational structure* and *entrance of new players* are important motivators. *Trust, national economics* and *environmental impact* are also crucial.

*Public policies and regulations (*such as *incentives* and *dynamic pricing)*, *reconstitution of energy generation, market, usage* and *information flow* are identified to be key to the success of smart grids (Iquityanilham et al., 2016; Clastres, 2011). Policymakers can play a coordinating or facilitative role with the smart home technology industry in developing *transparent standards*, best practice *guidelines*, or quality control *procedures* and *rights of recourse* for installations. However, the literature provides evidence that smart energy implementations suffer from the inadequacy of generic and common actions for all the schemes (Colmenar-Santos, Rosales-Asenio, Borge-Diez, Mur-Péres, 2015). It is also necessary to consider member states individually and adopt actions that respond to the casuistry of each Member State (Kuzemko et al. 2016). In this context, the electric and hybrid vehicles *industry* is also an important player in the smart grid transition. In order for a breakthrough of battery-electric vehicles argue, *strong governance measures* aimed at fostering technological development, cost reductions (through implementation of *taxes and subsidies*), as well as building consumer knowledge and confidence in the industry is necessary (Nilsson and Nykvist, 2016).

Infrastructure and development of *innovation* systems around renewable energy technology are crucial in order to accelerate the diffusion and implementation of smart grids (Negro, Alkemande and Hekkert, 2012). This could be hindered by the *lack of resources***.** Electricity firms could be hesitant to deploy smart grid tech because they lack the required time and capital. Small enterprises also suffer from a lack of personnel dedicated to researching energy efficiency and opportunities (Trianni et al., 2013). The effects of these factors increase due to the presence of *risks and uncertainty.* Companies are affected by the risks of moving away from centralized generation and changing their established business models. The perceived need to guarantee the continuity of the business leads to a fear of possible hidden costs related to production hassle or disruption, as well as technical risks. (Trianni, Cagno, Thollander and Backlund, 2013). The uncertainty about the profitability of smart grids has created resistance and hindered diffusion (Shomali and Pinkse, 2015). On a related aspect, short-term *financial criteria* may undermine possibilities of change (Karakosta and Psarras, 2010; Carafa, Firsari and Vidican, 2015).

Industrial enterprises may also be seen as energy providers in addition to consumers. Energy efficiency may improve the overall energy performance of a region by having heat production, electricity production, cold production and storage facilities of industries cover residential needs, thus, converting companies into *prosumers* (Karner et al., 2016).

4.4.1.2 Collective Decision Making Units

Community acceptance of infrastructure is crucial, and whereas *community involvement* in investment in renewables is favouring community and market acceptance, the inclusion of it in a *co-operative* micro grid is likely to increase acceptability as well. Community acceptance, in turn, is affected by a variety of factors and variables. *Confusion*, for instance, may play an important role in this regard. The public's beliefs about energy networks are rather detached from reality, and it is crucial to gain trust and acceptance from communities as a whole (Tobiasson and Jamasb, 2016). For instance, concerns about climate change often do not translate into behavioural changes. This is due to both individual and social reasons, such as a perceived lack of knowledge, no desire to find info, information overload, confusion about the links between problems and possible solutions, and difficulty in interpreting information and data (individual). There may also be a lack of infrastructure to support environmentally friendly behaviour, and environmentally friendly items (e.g. food) are generally more expensive (monetary and social) (Lorenzoni et al., 2007). Another related factor is represented by *habits*. Older patterns of behaviour have become engrained through *social acceptance*. Therefore, there is a need for policies and governance structures to initiate a systemic shift to a low consumption paradigm in order to move people out of their comfort zone of carbon-intensive living (Lorenzoni et al., 2007).

Studies show that *material structures* also contribute to community acceptance. Poruschi and Ambrey (2016) find that in Australia, living in a large city is associated with being less likely to engage in eight different energy saving actions and with being less likely to use solar electricity. Indeed, renters and people living in non-detached dwellings face significant impediments to engage in energy-saving behaviours (Hatzl et. al., 2014).

The *changing nature of the energy industry*, *public and community awareness* in energy and environment are identified as the main reasons behind increased involvement of the public and local communities in grid developments (Tobiasson, Jamasb, 2016).

Direct compensation and *benefit sharing methods*, might play a role in reducing opposition to the introduction of smart grids and the establishment of renewable energy sources (Tobiasson, Jamasb, 2016).

On the level of the collective decision-making unit, *energy self-sufficiency* becomes an important motivator**.** Striving for energy self-sufficiency in municipalities has become a noticeable trend, which can be supported or steered by policymakers (Engelken et al (2016). The main benefits are increasing tax revenues, environmental awareness and the desire for greater independence from private utility companies. In addition, there is the *political power* and access to more *financial resources* is a plus for local governments. At this point, initiatives aimed at promoting *local energy production* are also important and usually undertaken by volunteering actors whose backgrounds vary and include political parties, commercial ventures, energy cooperatives, and village working groups. (Stirling, 2014).

On a related field, an active and growing number of *local community energy initiatives* in cities, towns and villages occasionally put together ambitious visions to achieve 100% *sustainable energy, energy neutrality, zero carbon emission,* or *zero-impact* of their communities (Van der Schoor and Scholtens, 2014). *Community energy initiatives* is an emergent phenomenon that in the present stage provides a useful grassroots approach for citizens to engage in the transition to a sustainable energy future.

4.4.1.3 Individuals

Citizen and consumer acceptance is highlighted as an important prerequisite for the success of smart grids, both on the community and on an individual level (Huijts, Molin, Steg, 2012). *Citizen acceptance* is the behavioural response to situations in or close to one's home, whereas *consumer acceptance* reflects the public's behavioural response to the availability of technological innovations, that is, the purchase and use of such products.

Unfortunately, the current state of citizen and consumer acceptance suffers from *lack of focus on users* in smart energy measures**.** There is an increasing trend to pay more attention to users in new smart grid projects. However, in general, such projects have tended to focus mainly on technology and on economic incentives while ignoring user involvement and the way users and systems interact (Verbong, Beemsterboer and Sengers 2013). On the user side, the dimensions of *social acceptance* are influenced by *personal (demographics), social-psychological (perceptions and experience), and contextual (siting, type of development)* factors (Cohen, Reichl, Schmidthaler, 2014). *Demographic factors* such as education, age, and job status affect the adoption of smart technologies and environmental action (Stigka et. al., 2014). *Economic* and *cognitive factors* (income, estimated price premium, level of information on environmentally friendly goods), *consumption patterns* of reference persons (friends, neighbours, relatives), and one's own consumption patterns in the past are important (Welsch and Kühling, 2009). *Household characteristic*s and *country* of residence are also shown to affect residential energy efficient technology adoption, energy conservation behaviour, and attitudes towards energy savings (Mills and Schleich, 2012). Unsurprisingly, material structures become an important factor regarding adoption of smart grid technologies and to adoption of environmental action (Wilson, Hargreaves and Hauxwell-Baldwin, 2017). In several different studies, older age groups and people from lower socio-economic backgrounds being generally less willing to engage in low-carbon behaviours (Bertsch et al., 2016; Mills and Schleich, 2012). In the context of Western lifestyles and socio-culturally driven consumption patterns, changes in energy consumption will rather demand opening up 'energy policy' (as currently conceived) to consider complex and fundamentally political questions about the role of consumption and energy in everyday life.

Furthermore, the acceptance and active adoption of *smart environmental technologies* are related to *environmental motivation*. *Environmental concerns* and environmental self-identity may be important factors promoting positive spillover to other pro-environmental behaviours (van der Werff and Steg, 2016; Hahnel, Ortman, Korcai and Spada, 2014). Activating environmental values alters the internally represented price-thresholds towards sustainable products such as electric vehicles. Although concerns about environment and climate change are present, this often does not translate into behavioural change because of a *lack of knowledge* (Lorenzoni et al, 2007; Ponce, Polasko and Molina, 2016).

Trust is an associated element for smart grid technologies (Ponce et al., 2016). However, users of smart grid technologies are not entirely confident in the intelligent technology. The development of smart technologies depends on measures aimed at fostering, not only technological development and cost reduction, but consumer knowledge and confidence in the industry as well (Raimi, 2016; Lopes, Antunes, Jandad, Peixotoe and Martins, 2016; Parag, 2016; Nilsson and Nykvist, 2016). Hence, devising procedures to facilitate quick and efficient *negotiations between infrastructure developers and local groups* is becoming particularly important (Cohen et. al., 2014).

4.4.2 Gaps for Research

We identify several gaps for research in the body of literature reviewed. These are outlined in the following paragraphs.

Country focus: There appears to be little research on the rollout of, acceptance rate of, and policy framework regarding smart technologies and smart grids in many European countries. Several countries in Europe were not covered or mentioned at all in the reviewed research. Moreover, as smart grids and the implementation of smart technologies and the rollout of the smart grid is an EEU wide priority, it is surprising that very little research appears to have been done on collaborations between European countries.

Methods: Most of the empirical data gathered in the literature results from quantitative studies, such as surveys and questionnaires. Surveys are a well-suited method in many regards. They may be administered via email, telephone or online and thus have little geographical limitations. Moreover, a broad range of variables may be gathered and standardized, using more or less sophisticated software. Nevertheless, there is a need for further research of a more qualitative nature, not the least with regard to smart technologies in the home and the everyday life setting. Qualitative research methods such as in-depth interviews, focus groups, or ethnographic observation, are less rigid than surveys, and have the ability to take into account new information that arises during data collection. These methods capture body language, tone of voice and expressions, and give respondents a chance to emphasize what they believe to be important, as there are fewer external constraints to their utterances. A downside to such methods of course, is that qualitative research cannot be replicated in the same way as quantitative data can.

Levels of formal social units investigated: There is a need for more research on collective social units as well as research, which takes into account the necessary interplay between the formal, collective, and individual levels. Although much of the literature is critical of this, the research on the rollout of smart grids or similar technology has tended to be top-down, and to focus on the end-user through a conventional lens of the “passive consumer”. Future research should aim to study the impact and acceptance of smart grid technologies from a bottom-up perspective, looking at the ways in which the technologies and people interact, rather than simply identifying which qualities makes a person more or less likely to accept or adopt smart technologies.

4.4.3 Similarities and Differences in Decision-Making Processes Related to Each Level

Next, an overview of similarities and differences in decision-making processes related to each level is given. Main factors that are in effect in the decision-making processes of the three levels are provided in Table 7.

Table 7 Factors that play a role in decision-making process at respective units

Formal Social Unit	Collective Decision Making Unit	Individual Level Unit
Governance, public policies and regulations	Community involvement and community acceptance	Demographics (e.g., income, gender, age, household size, and occupation level)
Supply networks and infrastructure	Co-operative grids, compensations and benefit sharing methods	Citizen and customer acceptance
Reconstitution of energy generation market	Charging solutions	Environmental motivation
Transparent standards, guidelines, procedures	Public and community awareness in energy and environment	Socio-psychological, economic and cognitive factors
Smart controls, innovation	Energy self-sufficiency and local energy production, local community energy initiatives	Household characteristics (e.g. consumption patterns)
Environmental considerations	Zero carbon emission, zero-impact	Communication between local groups
Energy profile	Changes in energy industry	Trust
Prosumers	Material structures	Country of residence

Considering the formal social units, the factors that are the most important turn out to be the governance and policy related ones. The energy profile and energy supply infrastructure and the market structure are also key factors for formal social units. That is, the operating environment and the constraints for the formal social units are defined by the market, and the infrastructure; governance and policies need to be designed and implemented within these boundaries.

Collective decision-making units, on the other hand, are dependent on factors related to both formal social units and individuals. To begin with incentives, compensations and other regulations are critical. Moreover, community involvement and community acceptance are also important. These require public and community awareness. Co-operation among collective decision-making units is becoming a key factor.

For the individuals, naturally, demographics, socio-psychological factors, economic factors and environmental concerns are inevitable drivers. It is worthwhile to note that communication and consumption patterns become outstanding factors that deserve more attention.

4.4.4 Summary of Methodologies

Considering the academic articles included in this section of the review, the majority employ a form of first-hand empirical data, mostly surveys or questionnaires, that is, they use quantitative analysis.

A high number of the studies also employ an extensive literature review, and a selection of articles are reviews. Some sources use a mixed-methods approach, incorporating qualitative data in addition to quantitative analysis, whereas only two rely on quantitative approaches only, such as case study, in-depth interviews, semi-structured interviews, and/or field observations.

4.4.5 Main Results and Findings

In the following section, we discuss the core findings regarding the variables, as well as the barriers and motivators to effective smart technologies rollout. The focus of the ECHOES project is on Europe, specifically the European union plus Turkey and Norway. Of the reviewed documents, the 81 concern the European context as a whole, a specific European country, or indeed a comparison between two or more European countries. The remaining articles deal with India (1), China (4), Taiwan (1), Thailand (1), Hong Kong (1), Japan (1), South Korea (1), North America (USA 4) Mexico (1), Israel (1), and Morocco (1).

A vast majority of the articles investigates the individual level, followed by the formal and the collective levels. However, much of the literature does not concern smart technologies, but environmental actions and attitudes in a broader sense. Moreover, it should be noted that smart technologies or the smart grid is a very wide field, and the findings from research on electric vehicles, solar panels, and smart home technologies for instance, may not be directly comparable. Furthermore, we see a clear tendency to investigate and to write about the rollout of smart energy technologies and the smart grid under an a priori normative assumption that this is the future and that this is a good thing.

The rollout of smart grids in Europe has been slower than expected. The reasons for this are identified as pertaining not to the technologies themselves, but to policy and social structures. Industries require more financial incentive to render their production more energy efficient, as well as more knowledge and possibly designated personnel. The energy industry is weary of increasingly decentralized production, and a transition to a more service based economy. Smart grid demo-projects have tended to have a top-down structure and a technology-only (or almost only) focus. This tendency is criticized in the reviewed literature as a barrier in itself, as indeed the transition to smart grids is considered a political and cultural change, which necessitates the active participation of citizens. An important impediment to smart grids and smart technologies is the confusion surrounding its very nature. Smart grid projects are very unevenly distributed throughout Europe, with only a handful of countries representing the vast majority of initiatives. On the community level, organizations are emerging, ranging from politically motivated ones to loosely formed collectives. Table 8 below depicts these barriers to smart energy technologies.

Table 8 Barriers to Smart Energy Technologies

Formal Social Unit	Collective Decision Making Unit	Individual Level Unit
Lack of acceptance of policies	Confusion	Lack of focus on users
Restrictions with the industry	Material structures	Lack of trust, information and knowledge
		Demographics

People in Europe appear to be concerned with the environment; however, there is a lack of information concerning how smart technologies can contribute, and a lack of trust in public institutions and the "market" when it comes to managing energy shifts. People want to contribute, but know relatively little about which efforts and actions yield the most notable results. Moreover, those tasks that are easier to perform and that contribute the least to a perceived loss of comfort and quality of life tend to be more popular. Demographic factors appear to be rather crucial to the acceptance of and engagement with renewable energy sources, energy efficiency, and the adoption of smart technologies. Motivators for the acceptance of smart energy technologies are represented in Table 9 below.

Table 9 Motivators for Smart Energy Technologies

Formal Social Unit	Collective Decision Making Unit	Individual Level Unit
Governance and organizational structure	Energy self-sufficiency	Environmental concerns
Consumer engagement		Demographics
Environmental impacts		
Trust		
New players in the market and industry		
Electric and hybrid vehicles industry		

4.5 Conclusion for Section 4

The literature review analysed the three technological foci of ECHOES, namely, Buildings, Electric mobility, and Smart Energy Technologies.

Each technological focus is critical to the achievement and completion of the European Energy Union and a critical component in Europe's transition towards the decarbonized energy system of the future. This significance is reflected by the official documents such as climate and energy packages, EU directives, regulations, reports and papers.

Regarding the technological focus Buildings, the significant reduction of building energy demand is a prerequisite for meeting Europe's GHG emissions reduction targets. The Article 4 of the Energy Efficiency Directive requires member states "to establish a long-term strategy beyond 2020 for mobilizing investment in the renovation of residential and commercial buildings with a view to improving the energy performance of the building stock."

A similar comment also holds for Electric mobility: Since the transport sector is one of the main consumers of fossil fuel and hence contributes to the most part to the EU's total greenhouse gas (GHG) emission, as well as fossil fuel dependency and environmental impacts such as air pollution, noise, resource use and waste, and climate change (EEA, 2016). To address the issue of climate change, the European Commission has set the goal to achieve emission-free urban passenger transportation by 2050 (i.e., no more conventionally fuelled cars in cities) and emission-free urban freight transportation by 2030 (i.e., CO_2 free logistics) (European Commission, 2011).

Smart energy technologies defines an equally important and complementary counterpart of the two other technological foci. Smart grids can contribute to sustainability objectives of EEU by facilitating the reduction of CO_2 emissions, enabling the integration of large-scale renewables, and increasing energy efficiency in the power sector. The EEGI (European Electricity Grid Initiative) and other SET plan initiatives work towards the energy and electricity system for the year 2035, with the aim of a CO_2 free electricity system by 2050.

Clearly, there are differences among the member states, also with respect to the technological foci in terms of the achievements versus EEU and country targets. Concerning buildings, according to the EC report (European Commission, 2016b), the 10 years achievements of EU member states in implementing the EPBD (Energy Performance Building Directive) reflects a considerable progress. Regarding electric mobility on the other hand, the acceptance of alternative fuel saving transport vehicles is still marginal and sales volume of EVs in the EU is very low. There is also a considerable difference between countries; only Norway (13.84%), the Netherlands (3.87%), Iceland (2.71%), Estonia (1.57%), and Sweden (1.53%) have reached a market share that is higher than 1% of total new car sales (OECD, 2015). Developing smart grids is an important priority across Europe, however developments have been slow (Zgajewski 2015), there is often little knowledge among the population, uncertainty as to what exactly smart grids or smart technologies are.

The analysis for the three technological foci is structured around three levels of decision-making units. These are the formal decision making units acting as policy makers and/or energy providers, collective decision making units which are more formally structured and with relatively lower information and power asymmetries, and individuals.

An analysis of the variables-factors that play a role in decision-making at different decision-making levels demonstrates key similarities and differences. Typically, the variables concerning formal decision-making units are related with policies and incentives, the variables concerning collective decision-making units involve infrastructural and environmental aspects. The variables for individuals are more related to demographic, social, economic and environmental drivers.

Table 10-12 below present comparisons of key variables across technological foci.

Table 10 Factors that play a role in decision-making process for formal decision-making units

Technological Focus **Factor/Variable**	**Buildings**	**Electric Mobility**	**Smart Energy Technologies**
Effective policy and regulatory instruments	X	X	X
Transparency (standards, guidelines, procedures)			X
Environmental concerns	X	X	X
Market based factors	X		
Economic performance		X	X
Infrastructure		X	X
Operational features		X	
Smart controls, innovation			X
Energy profile			X
Prosumers			X

The table shows that different technological foci have common key variables such as policy and environmental concerns, whereas there are also technology-specific key variables such as smart controls for smart energy technologies.

Table 11 Factors that play a role in decision-making process for collective decision-making units

Technological Focus **Factor/Variable**	**Buildings**	**Electric Mobility**	**Smart Energy Technologies**
Effective incentives	X		X
Environmental concerns	X		X
Confidence in business	X		X
Open market	X		
Local participation	X	X	X
Infrastructure		X	X
Charging solutions		X	X
Characteristics of use		X	
Changes in energy industry			X

Among the variables that are significant for the collective decision making units, local participation is common to all three technological foci. The buildings and smart energy technologies foci have matching variables such as incentives and environmental concerns, whereas variables such as infrastructure and charging solutions are common to electric mobility and smart energy technologies.

Table 12 Factors that play a role in decision-making process for individual decision-making units

Technological Focus / Factor/Variable	Buildings	Electric Mobility	Smart Energy Technologies
Social factors	X	X	X
Environmental awareness	X	X	X
Economic advantages, incentives	X	X	X
Educational factors	X	X	
Individual motivation, attitude, trust	X	X	X
Demographics (e.g., income, gender, age, household size, and occupation level)	X	X	X
Household characteristics (e.g. consumption patterns)			X
Communication between local groups			X

Most of the key variables for individual decision-makers are common across technological foci. These are mainly social, environmental, economic, individual and demographic factors. Consumption pattern and communication emerge as of specific importance for smart energy technologies.

An analysis of motivators and barriers yields a similar result: Policies and attitude may pose barriers or motivators for formal decision-making units. For collective decision-making units, effectiveness of policies define barriers or motivators. Risks, uncertainty and costs define barriers; environmental concerns and local participation are important motivators. For individual decision-making units, social, environmental, individual and demographic variables have potential to form barriers as well as motivators. However, currently, these usually act as barriers for the individual decision-making unit level.

Tables 13-15 below present comparisons of barriers across technological foci. Although many of the key variables are common for the three technological foci, the barriers do not coincide very much. This is also justified by the varying levels of progress for the achievements of the targets regarding different technological foci. The buildings technological focus is affected by more information and attitude related barriers whereas smart mobility is adversely affected by the current state of the market offerings and technology.

Table 13 Barriers for formal social units

Factor/Variable — Technological Focus	Buildings	Electric Mobility	Smart Energy Technologies
Lack of information and awareness	X		
Behavioural and organizational barriers	X		X
Lack of participation	X		
Lack of trust in environmental benefits	X	X	
Lack infrastructure		X	
Economic restrictions		X	
Technical restrictions		X	X
Electricity supply		X	
Raw materials supply		X	
Limited availability of models		X	

Table 14 Barriers for collective decision-making units

Factor/Variable — Technological Focus	Buildings	Electric Mobility	Smart Energy Technologies
Economic and financial restrictions, costs	X	X	
Perceptions on risks and uncertainty	X	X	X
Poorly aligned incentives and other regulatory schemes	X		
Lack of Participation	X		
Lack of infrastructure		X	
Operational restrictions		X	X

Regarding the collective decision making units, this level is affected in common perceptions of risks and uncertainty. Related economic and financial factors also stand out as barriers for the buildings and the electric mobility technological focus. Operational restrictions are in effect for electric mobility and smart energy technologies.

Table 15 Barriers individual decision-making units

Factor/Variable — Technological Focus	Buildings	Electric Mobility	Smart Energy Technologies
Economic restrictions, costs	X	X	
Lack of information and awareness	X	X	X
Lack of trust, perception of risks and uncertainty	X	X	X
Lack of environmental awareness	X	X	X
Lack of infrastructure		X	
Technical restrictions		X	

Lack of trust, information and awareness as well as risk and uncertainty concerns affect collective decision-making units. Economic barriers are common to the buildings and electric mobility foci. Infrastructure and technical restrictions demonstrate the current problems of the electric mobility.

Tables 16-18 below present comparisons of motivators across technological foci:

Table 16 Motivators for formal social units

Technological Focus Factor/Variable	Buildings	Electric Mobility	Smart Energy Technologies
Effective policy and regulatory instruments	X	X	X
Environmental concerns	X	X	X
Market based factors	X	X	X
Consumer engagement			X
Trust			X
Electric and hybrid vehicles industry			X

Regarding formal social units, effective policy and regulatory instruments, market based factors and environmental concerns are in effect for all three technological foci. Smart energy technologies are sensitive to consumer engagement, trust and electric vehicles industry, which is the core industry for the electric mobility focus.

Table 17 Motivators for collective decision-making units

Technological Focus Factor/Variable	Buildings	Electric Mobility	Smart Energy Technologies
Effective incentives	X	X	
Environmental concerns	X	X	
Confidence in business	X	X	
Open market	X		
Local participation	X	X	X
Energy self-sufficiency			X

For collective decision-making units, local participation is a motivator for the three technological foci. Important common motivators for the buildings and electric mobility are incentives, environmental concerns, confidence in business and local participation. Smart energy technologies has a rather different outstanding motivator, which is energy self-sufficiency.

Table 18 Motivators for individual decision-making units

Technological Focus Factor/Variable	Buildings	Electric Mobility	Smart Energy Technologies
Social factors	X		X
Environmental awareness	X	X	X
Economic advantages, incentives	X	X	
Educational factors	X		
Individual motivation	X		X
Functional aspects		X	

Environmental awareness is a common motivator for individuals. Rather individual factors such as demographics and social factors are motivators for buildings and smart mobility technological foci. Motivators concerning functional aspects are important for smart mobility.

5 CONCLUSIONS

This report forms the basis for further research in ECHOES and gives at the same time an overview about the state-of-the-art. Based on a literature review with an initial screening of several thousand sources (and 597 sources reviewed), research from all three ECHOES research perspectives and technology foci is mapped and research gaps are identified which will be addressed in ECHOES. One overall conclusion is that there is a considerable amount of research that deals with specific technologies, problem areas, or research perspectives, but there are shortcomings related to more comprehensive and integrated analyses. The existing literature identifies factors playing a role in decision-making on the household level with respect to all of the listed issues in relation to all three foci, i.e. micro-, meso- and macro-level. However, it does so in a fragmented and disciplinary siloed way. Thus, there are gaps to fill in describing the decision-making processes from a comprehensive standpoint and with a multilevel perspective. The research identified does not allow to predict decisions in a satisfactory way, nor does it derive integrated policy or market recommendations. Hence, the literature review has confirmed the need for the type of comprehensive and integrated analysis that will be conducted in ECHOES. Based on these findings, the ECHOES project will focus specifically on how to predict *decision-making* at different levels (from the individual to small groups, collective decision-making units, and formal social units) and on *deriving recommendations* using the identified research gaps as starting point.

Nevertheless, the comprehensive literature study has uncovered a number of relevant factors and starting points for the work in ECHOES. Figure 8 shows the main reviewing concepts and findings as an overview, distributed by analytical levels and technological foci. At the macro level, the main concept is to map motivators and barriers for each technology and for the three different sub-levels defined as different formal units. This produced an interesting overview of which factors are relevant for one specific decision-making level or technology, and which factors are of overarching importance. At the meso level, the main contribution of this report is to review literature on the socio-cultural aspects of energy use through the analytical lens of the concepts *energy culture*, *energy lifestyles* and *energy memories*. These place the decision-making units into a cultural and historical context and tap into explanations of energy use behaviour that go unnoticed by by the individual or societal focus. At the micro level, a comprehensive review of the individual centred approach is provided, which shows how commonly used concepts such as values, worldviews, personal and social norms, attitudes, habits and routines, objective and subjective constraints and facilitators interact to determine decisions in the three technology focal areas of ECHOES. The comprehensive action determination model (CADM, Klöckner, 2013) is used as a point of departure for the analyses and the literature was researched for indications of the relevance of these concepts and their relations to each other. The CADM received good support by the literature review, though the concepts of emotion (most importantly guilt and pride) as a driver of energy and social identity/identification were found as missing in the model. Thus, a model of social identity model of pro-environmental action (SIMPEA) is proposed as a complementing approach and suggestions are made for where and how to integrate emotions into both models.

			
MACRO Motivators and barriers at formal, collective and individual levels	**Motivators** **Formal** Effective policy & regulatory instruments, Environmental concerns, Market based factors **Collective** Effective incentives, Environmental concerns, Confidence in business, Local participation **Individual** Social factors, Environmental awareness, Economic advantages, Incentives, Educational factors, Individual motivation, Attitude, Trust, Demographics	**Motivators** **Formal** Effective policy & regulatory instruments, Environmental concerns, Market based factors **Collective** Effective incentives, Environmental concerns, Confidence in business, Open market, Local participation **Individual** Social factors, Environmental awareness, Economic advantages, Incentives, Functional aspects	**Motivators** **Formal** Effective policy & regulatory instruments, Transparency, Environ-mental concerns, Economic performance, Infrastructure, Smart controls, Innovation, Energy profile, Prosumers **Collective** Local participation, Energy self-sufficiency **Individual** Social factors, Environmental awareness, Individual motivation
MESO Energy culture, lifestyles and memories	Car as a status symbol, embodies identity, driving culture, EV preference, EV as a normative practice, role of history on Energy memories	Home definition influence on energy practices, National and geographic differences, Buying a building, Heating and cooling, Retrofitting, Residential microgeneration, Social comparison and energy conservation	Smart metering rollout by 2020, provides information and changes consumer energy practices, Place attachment
MICRO CADM and SIMPEA	Use CADM and SIMPEA Distal factors may also play a closer role to influencing behaviour and attitudes NEP influences intention to adopt fuel-efficient vehicle via its effect on attitude Egoistic values have a direct effect on adoption of alternative fuel vehicle Objective constraints include: Household size, Income Policy measures, Toll waivers, Bus lane access, Number of cost factors, Purchasing price, Range, Long charging time, Charging infrastructure	Use CADM and SIMPEA Objective/situational constraints: Availability of technical support, Weather, Construction year, Square footage, Household size, Energy prices, Income, Automatisation, Other technological factors Social and personal norms influence curtailment, investment and purchasing behaviours. Emotions such as guilt and pride are mediators between social and personal norms Guilt results from mismatch between behaviour and social norms For increased response, combinine normative interventions with behaviour visibility or increased energy prices and consumption feedback	Use CADM and SIMPEA Several models and theories used for technology acceptance studies. The higher the perceived risk, the more negatively it affects acceptance of technology and intention to use The higher the usefulness, the lower are the concerns about risk The consumers´understanding of the smart grid is necessary due to its influence on PEOU and PU TAM as the most robust model in considering technology acceptance VBN and VIP both underline the importance of focusing on the benefits to the environment Media and pulic figures as secondary sources influencing intentions Perceived risk as major factor to accepting smart grid Attitude is most influential on intention

Figure 8 Levels of analysis and technologies

In the following sections the main findings from the different perspectives are summarized in more detail. Figures 9-11 shows the main findings at the micro level when using the CADM model as a reference framework but integrating factors that the review showed may play an important role but were not included in the original model. The darker green background highlights the predictors appearing often in the literature for the specific technology. The grey arrows show the relationship of the predictors and the target behaviour. The text boxes that have dark green borders are those mentioned in the literature and are found in the CADM. The text boxes with grey borders are predictors or factors that are not found in the CADM model but were found in the literature review. The other lines in the CADM model were not shown in order to make the key research on the specific technology more visible. Dotted boxes show specific types of predictor sub-category (for example, injunctive and descriptive are two types of social norms) that were specifically mentioned in the literature. At the micro level for the buildings, social norms and environmental behaviour were highlighted in blue to show that a mismatch between them will result in an emotion (circle).

In general, the review shows that most of the influences postulated have received considerable attention in past research, with some differences between the technologies in focus here. However, it remains unclear if the differences are substantial or rather circumstantial, due to a specific study advocating for a particular effect selecting only one of the three technology foci. It is for example likely that the emotion reaction resulting from mismatch between own behaviour and social norms (a feeling of guilt or shame) is not specific to the building focus, but will in the same way be found in the other technological foci. It is also interesting to note that for some technology foci, a modelling tradition related to the CADM is rather common (energy in buildings, electric mobility), whereas for adoption of smart energy technology, technology adoption models (TAM) are more common in the literature, although also energy choices in buildings and electric mobility can be framed as problems of technology adoption and smart technology can be analysed from the perspective of the CADM.

Figure 9 shows the findings related to smart energy technology, which shows that:

- Several models and theories are used for technology acceptance studies, some related to the CADM, some with roots in technology adoption studies.
- The higher the perceived risk, the more negatively it affects acceptance of technology and intention to use
- The higher the perceived usefulness, the lower are the concerns about risk
- The consumers´understanding of the user related aspects of the smart grid (and a basic understanding of its functionality) is necessary due to its influence on perceived ease of use and perceived usefulness
- The technology acceptance model (TAM) is the most robust model in considering technology acceptance
- However, extensions of the TAM with moral / normative aspects appear to strengthen the approach

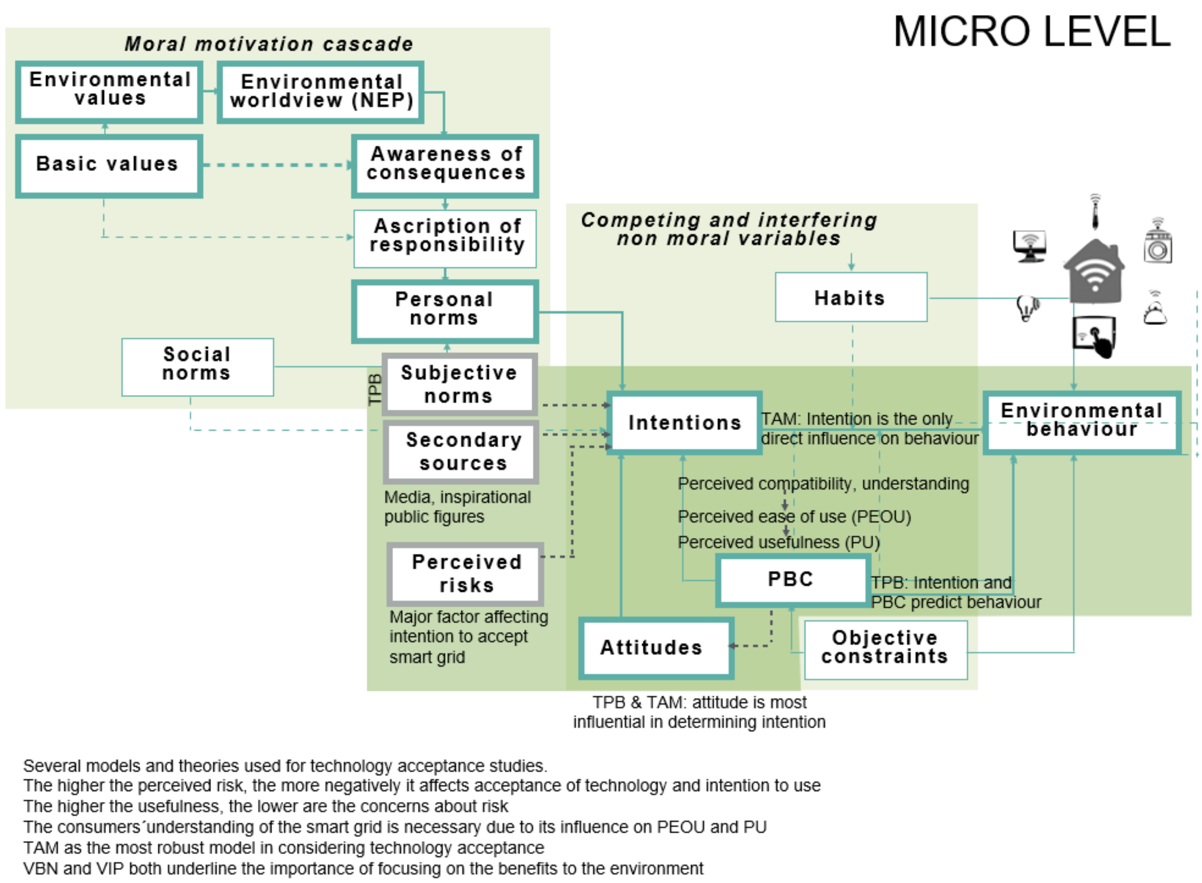

Figure 9 Individual level – technology focus "smart energy technology"

Figure 10 displays the main findings related to electric mobility, which shows that there are research gaps in the study of causal effects of long-term experience with e-vehilcle on adoption and on habit formation (especially continued purchase of electric vehicles after the first EV), in the attitude-internalized objective constraint, and that distal factors may play a closer role to influencing behaviour and attitudes for electric mobility which basically is a big investment decision for the customers.

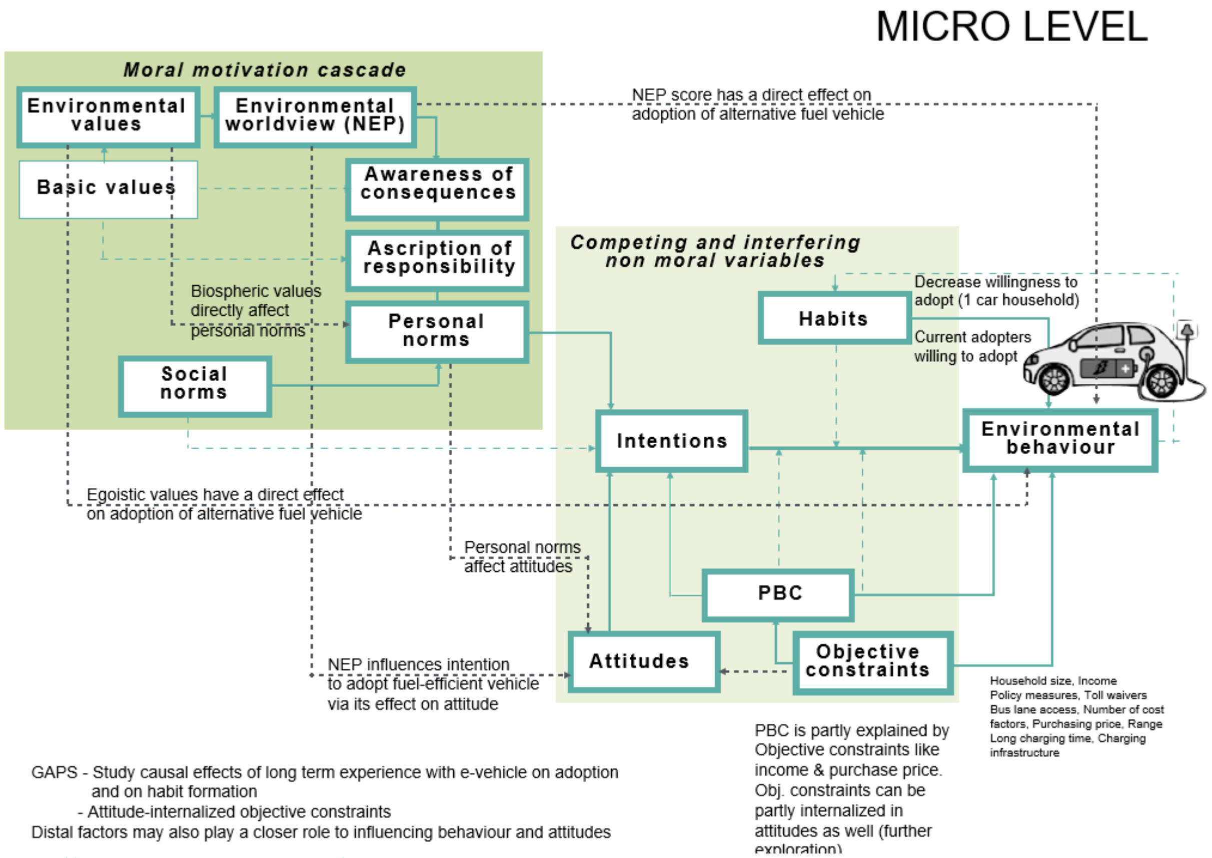

Figure 10 Individual level – technology focus "electric mobility"

Figure 11 shows the main findings related to buildings. First, social norms influence curtailment, investment & purchase intentions & behaviours. Second, normative interventions should target the most receptive: certain personality traits, identify with norm source, heavy energy users or previously indifferent. Third, combining normative interventions with behaviour visibility or increased energy prices and consumption feedback for people to respond more. Finally, if there is a mismatch between social norms and behaviour feelings of guilt result which may activate personal norms.

Gaps identified are:

- Research on interventions combining norms and internal/external factors
- Values as a direct influence on behaviour
- Role habit plays in energy-related behaviour
- More consistent use of a suitable scale for habit measurement
- Emotions (fear, anger, guilt, pride) and role in human judgment and creation of habits
- Role of guilt and pride as activating forces of personal norms and behaviour
- Anticipated pride as a stabalizing factor in explaining continued eco-friendly behaviour

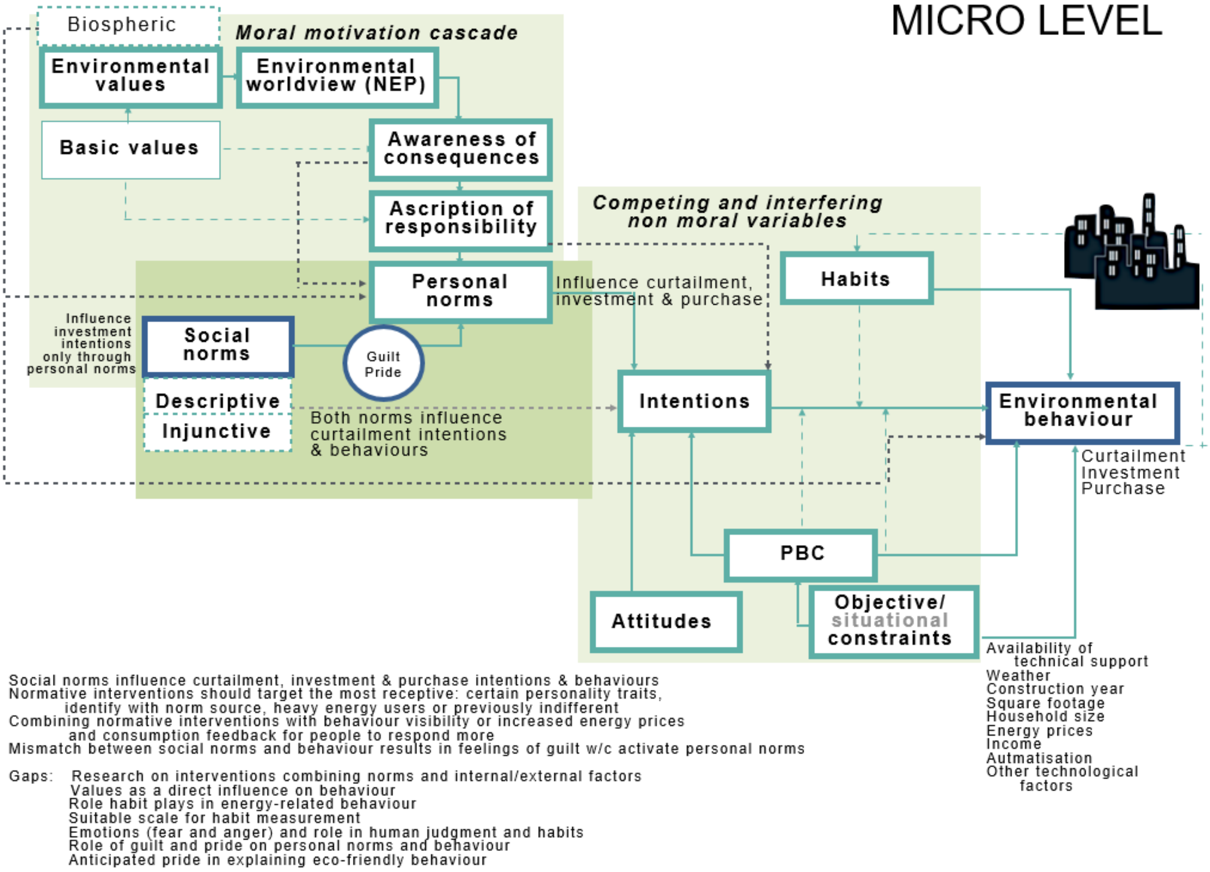

Figure 10 Individual level – technology focus "buildings"

As the (extended) CADM is only one of the two micro-perspectives taken in ECHOES, figure 12 shows the main findings using the SIMPEA model. The model proposes that identification with a group (e.g., citizens of a city, a country or the EU) leads to activation of a "we" thinking rather than an "I" thinking. If ingroup norms and goals of that group propose energy saving behaviour and if the decision-making individual perceives the group as capable of solving the problem together (collective efficacy), energy saving behaviour is more likely and situations are more likely interpreted as relevant for the topic.

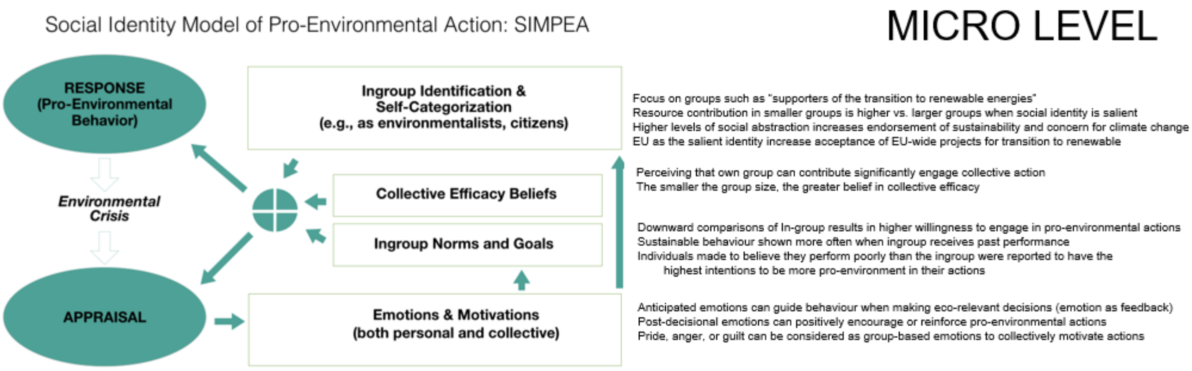

Figure 11 Main findings regarding social identity and energy choices.

At the meso level, the key conceptual approach for reviewing the literature has been through the lens of the theoretical concepts 1) energy culture, 2) energy memories (which is a new development in the ECHOES project), 3) energy lifestyle and 4) place attachment. Here, the social and historical embeddedness of energy decisions regarding the three technology foci was the core of the analysis. Important gaps identified at the general level are that 1) there are advantages and analytical improvement of using the energy memory approach over the related concepts of energy culture and energy lifestyles because energy memories not only include the cultural and contextual rooting of the behaviour, but also the temporal/historical dimension, and 2) place attachment and place-related meanings are not investigated with respect to the energy memories development. At the technology-specific level, the main findings are presented in figure 12.

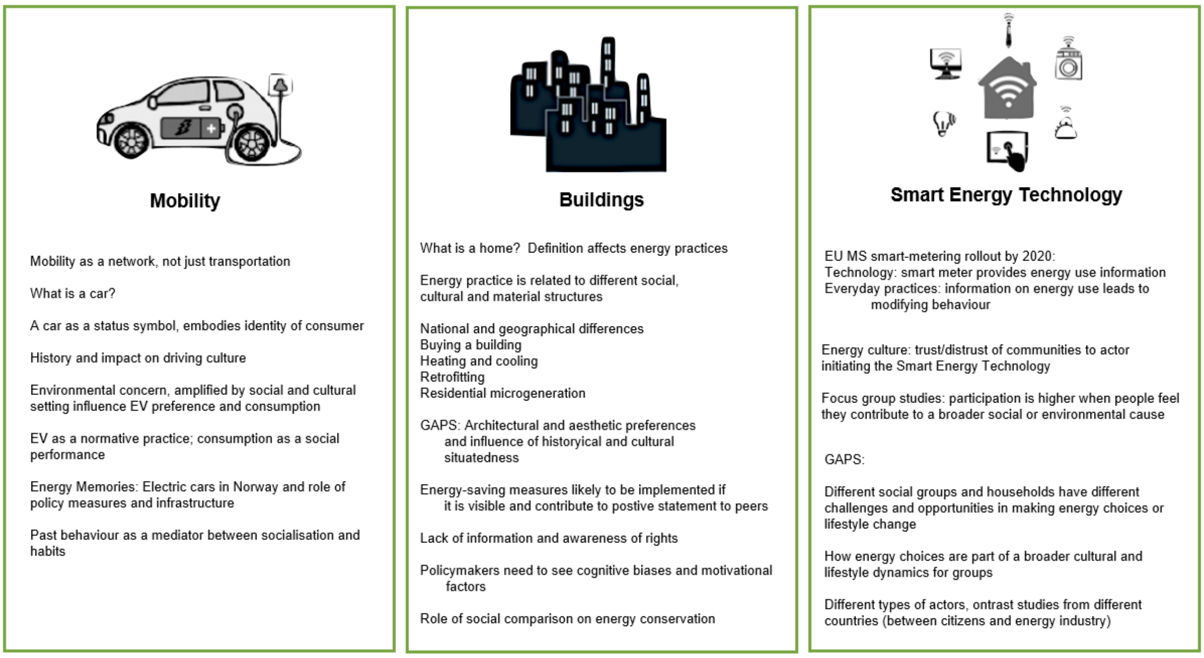

Figure 12 Main findings meso level

Figures 14-16 shows the main findings at the macro level. As the review at this level has been completed by distinguishing three sub-levels that all focus on the three technological focuses, mapping 1) factors important in decision-making, 2) barriers, 3) motivators and 4) research gaps, the figures present the results within each technology. An important general finding is that there is a need for more research on energy choices in collective social units as well as research, which takes into account the necessary interplay between the formal, collective, and individual levels. For the main results distributed by technologies, see the figures below. The final Figure 17 summarizes the research gaps identified in the three technology foci and the three ECHOES perspectives.

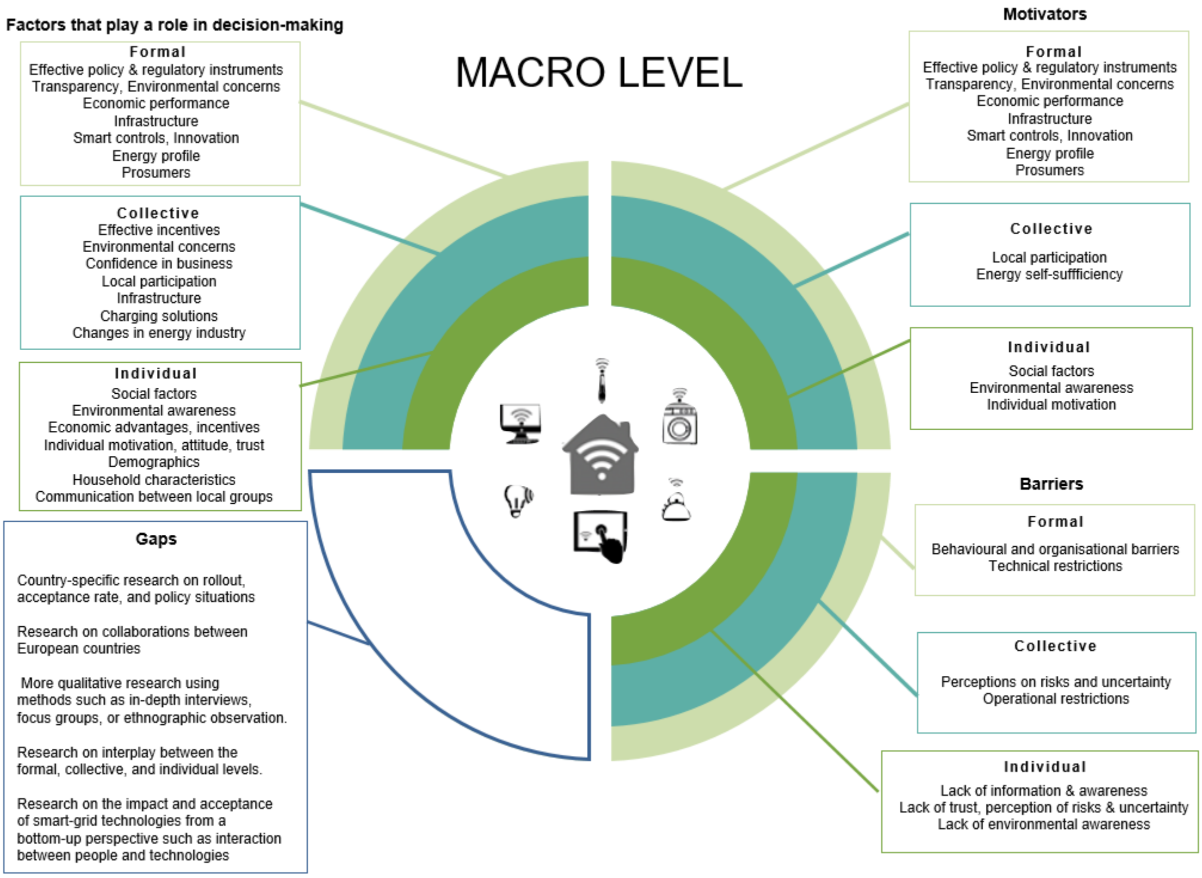

Figure 13 Main results macro level, smart energy technology

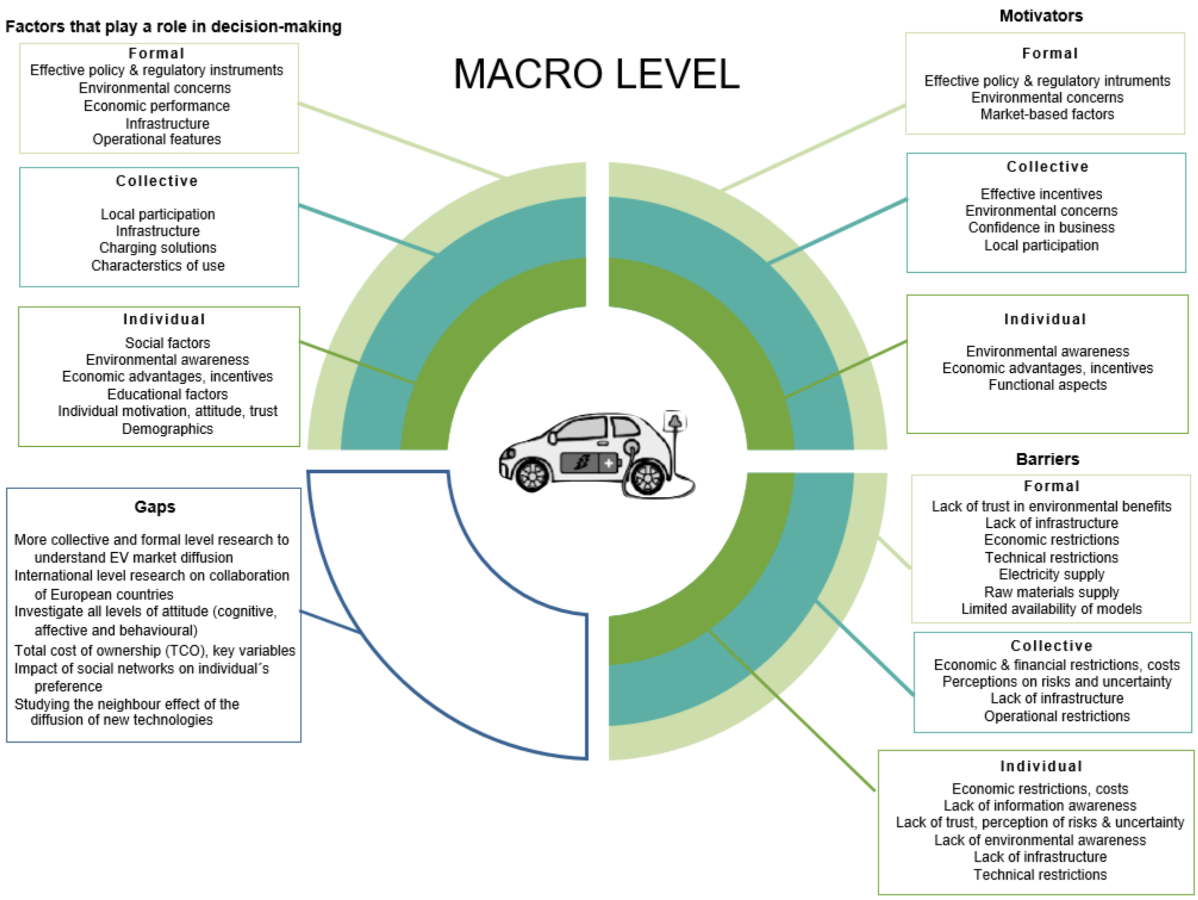

Figure 14 Main results macro level, electric mobility

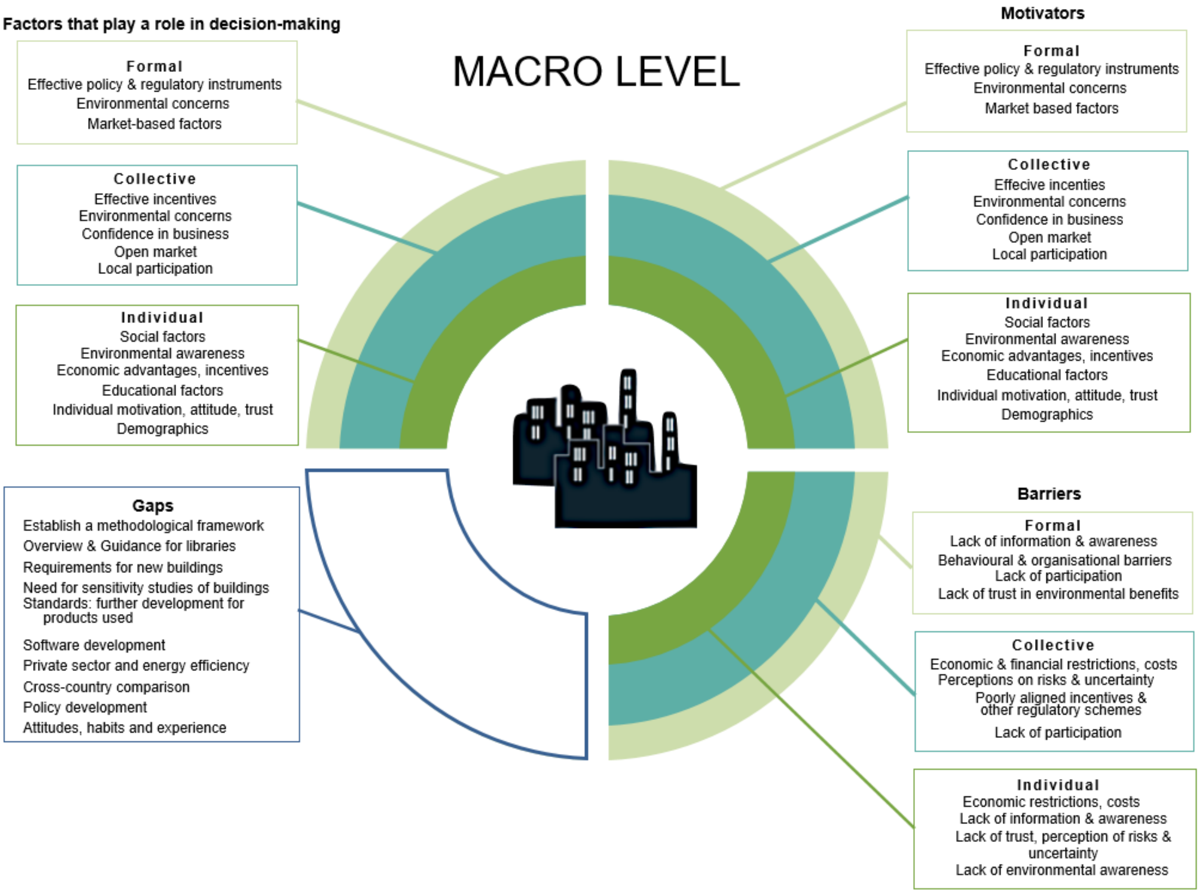

Figure 15 Main results macro level, buildings

			
MACRO	More collective and formal level research to understand EV market diffusion International level research on collaboration of European countries Investigating all levels of attitude (cognitive, affective and behavioural) Total cost of ownership (TCO), key variables Impact of social networks on individual´s preferences Studying the neighbour effect of the diffusion of new technologies	Establishing a methodological framework Overview & Guidance Requirements for new buildings Sensitivity studies of building standards: further development for products Software development Studies on private sector and energy efficiency Cross-country comparisons Policy development Exploring attitudes, habits and experience	Country-specific research on rollout, acceptance rate, and policy situations Research on collaborations between European countries More qualitative research using methods such as in-depth interviews, focus groups, or ethnographic observation Research on interplay between the formal, collective, and individual levels More research on the impact and acceptance of smart-grid technologies from a bottom-up perspective such as interaction between people and technologies
MESO	Mapping of advantages and for making analytical improvement of using the Energy memory approach Place attachment and place-related meanings investigations with respect to energy memories development Research on mobility as a network Definition and meaning of car as a concept History and impact on driving culture EV as a normative practice; consumption as a social performance Electric cars in Norway and role of policy measures and infrastructure Past behaviour as a mediator between socialisation and habits	Mapping of advantages and for making analytical improvement of using the Energy memory approach Place attachment and place-related meanings investigations with respect to energy memories development Architectural and aesthetic preferences and influence of historical and cultural situatedness Exploring the role of social comparison on energy conservation	Mapping of advantages and for making analytical improvement of using the Energy memory approach Place attachment and place-related meanings investigations with respect to energy memories development Exploring advantages and analytical improvement of using the Energy memory approach Exploring place attachment and place-related meanings with respect to energy memories development Exploring how energy choices are part of a broader cultural and lifestyle dynamics for groups Studies on different types of actors, contrast studies from different countries (between citizens and energy industry)
MICRO	Studies on causal effects of long term experience with e-vehilcle on adoption and formation of habits Exploring attitude-internalized objective constraints Exploring the role of distal factors in influencing behaviour and attitudes	Research on interventions combining norms and internal/external factors Studying values as a direct influence on behaviour and the role habit plays in energy-related behaviour Finding a suitable scale for habit measurement Exploring emotions (fear and anger) and their role in human judgment and habits Role of guilt and pride on personal norms and behaviour Exploring anticipated pride in explaining eco-friendly behavior	Further studies of human understanding of smart grids and smart energy technology (meters, et cetera) Further exploring and testing of choices and priorities and the role of technologies in relation to this (energy feedback)

Figure 17 Main research gaps per technology focus and ECHOES research perspective.

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