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A Conceptual Framework to Understand Households' Energy Consumption

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Abstract: Households' energy consumption has received a lot of attention in debates on urban sustainability and housing policy due to its possible consequences for climate change. In Europe, the residential sector accounts for roughly one third of the energy consumption and is responsible for 16% of total CO_2 emissions. Households have been progressively highlighted as the main actor that can play a substantial in the reduction of this energy use. Their behavior is a complex and hard to change process that combines numerous determinants. These determinants have already been extensively studied in the literature from a variety of thematic domains (psychology, sociology, economics, and engineering), however, each approach is limited by its own assumptions and often omit important energy behavioral components. Therefore, energy behavior studies require an integration of disciplines through interdisciplinary approaches. Based on that knowledge, this paper introduces a conceptual framework to capture and understand households' energy consumption. The paper aims at connecting objective (physical and technical) with subjective (human) aspects related to energy use of households. This combination provide the answers to the 'what', the 'how' and most importantly the 'why' questions about people's behavior regarding energy use. It allows clarifying the numerous internal and external factors that act as key determinants, as well as the need to take into account their interactions. By doing so, we conclude the paper by discussing the value of the conceptual framework along with valuable insights for researchers, practitioners and policymakers.

Keywords: households; energy consumption; pro-environmental behavior; conceptual framework

1. Introduction

Households' energy consumption has received a lot of attention in debates on urban sustainability and housing policy due to its possible consequences for climate change [1–3]. The residential sector is responsible for 17% of global CO_2 emissions in the world and constitutes the third-largest major energy consumer worldwide [3]. According to Brounen et al. [1], about 20% of total global energy demand originates from the requirements to heat, cool, and light residential dwellings. In Europe, the residential sector stands for roughly 30% of the energy consumption and is responsible for 16% of total CO_2 emissions. According to the Environmental Investigation Agency (EIA) [2], households in Europe accounted for 21% of the world's total residential energy consumption in 2012. Space heating is responsible for the most important part of energy used by households. In accordance with recent literature highlighting the strong relationships between building energy consumption, location,

transportation and urban form [4–7], individual mobility is considered in this paper as part of the energy uses at the household level. Transportation indeed represents a significate part of households' energy consumption [8,9]. Last but not least, transportation in the sole sector, at the European level, in which energy consumption and related emissions of greenhouse gases is increasing.

Reducing domestic energy uses is necessary, especially to achieve the international and national commitments to significantly reduce carbon emissions. By 2050, the European Union should cut greenhouse gas (GHG) emissions to 80% below 1990 levels. The milestones to be achieved are 40% cuts by 2030 and 60% by 2040 [10]. Still according to this low-carbon economy roadmap [10], emissions from the building sector (houses and offices) could be cut by around 90% in 2050 by improving drastically three strategies: passive housing technologies for new building; refurbishing old buildings and substituting electricity and renewables for fossil fuels in heating, cooling and cooking. In this search for more energy efficiency in the domestic sector, three main strategies have been the focus on extensive review in the current literature and are namely summarized within the "Trias Energetica concept" developed by TU Delft [11], consisting in three consecutive steps:

(1) Reducing demand for energy by avoiding waste and implementing energy-saving measures
(2) Using sustainable sources of energy instead of finite fossils fuels (renewable energy)
(3) Producing and using fossil energy as efficient as possible

This framework, as well as recent research [5,12,13] put the focus on the crucial need to reduce energy demand as the first and most efficient way toward a sustainable future. As far as regulations and policies are concerned, there are numerous local, national and also international regulations and policies aiming to reduce energy demand by strict technical requirements. For buildings characteristics, the European directive on the energy performance of buildings came into force in 2002, and was progressively strengthen to impose, by 2018 for public buildings and by 2020 for all new buildings to be nearly zero energy buildings. Retrofitting the existing building stock has also been highlighted as the main target to achieve [10], especially in Europe where the renewal rate of buildings is low [14–17]. Regulations on maximum CO_2 emissions for private vehicles are also periodically strengthen whereas initiatives focused on changes in consumption patterns, and the use of energy in a greener way remain more limited.

In energy efficiency research, households have been progressively highlighted as the main actor that can play a substantial in the reduction of this energy use [18–20]. Households' energy consumption is a complex and hard to change process that combines numerous determinants. It is made up by different characteristics of the building and the neighborhood in which the household live, by the energy-using appliances and heating/cooling systems, but more importantly by a variety of internal and external factors, such as households' beliefs, values and attitudes, other people's behaviors, and various economic incentives.

For example, Jones et al. [21], based on Wei et al. [22] and a review of the literature summarized key determinants (here for space heating) into four main categories, as follows:

(1) Environmental factors: indoor and outdoor climate, wind pressure, etc.
(2) Building and system related factors: dwelling type, dwelling age, insulation level, type of heating system, fuel, control, etc.
(3) Occupant related factors: age, gender, education level, socio-economic classification, household size, etc.
(4) Others factors: occupancy, heating prices, awareness of energy use, and attitudes about energy use.

Each determinant considered alone, or some combinations, of determinants within the same category, has already been extensively studied in the literature and research on household energy consumption has mainly focused on the economic and technological aspects of this issue, while most of the policy action has aimed at reducing information barriers and providing financial incentives (see the literature overview for overview of the key literature that identify the factors affecting housholds'

energy consumption). In this perspective dominated by neoclassical economics, a growing body of research in behavioral sciences and sociology showing that household energy consumption is far more complex than the assumptions made in cost-benefit analyses has largely been overlooked. Actually, it is formed by a combination of factors, not only individual factors but also contextual factors are of importance. Due to this complexity, household energy consumption is often studied using a more fragmented and disciplinary studies from a variety of thematic domains such as psychology, sociology, economics and engineering. While technological approaches focus on quantifying energy consumption as a support for decision-making, approaches in the social sciences focus on understanding and explaining actual energy behavior. Nonetheless, each approach is constrained by its own assumptions and it often omit important energy behavioral components. Therefore, energy behavior studies require an integration of different disciplines by using an interdisciplinary approach.

In this context, the aim of this paper is to introduce a new conceptual framework to capture and understand the households' energy consumption. The paper aims at connecting objective (physical and technical) with subjective (human) aspects related to energy use by households. This combination aims at providing the answers to the 'what', the 'how' and most importantly the 'why' questions about people's behavior regarding energy use. In order to underhand how households' energy consumption work, Section 2 firstly provides the methodology followed by review of exiting behavioral change theories analyzing and identifying strengths and weaknesses of the models (Section 3). Such analysis combines technical and behavioral determinants of energy consumption as well as environmental influence constituting a set of aspects which leads to develop a differentiation of the main aspects of households' energy consumption. Then, Section 4 proposes a new comprehensive conceptual framework concerning determinants of the external and internal context. Finally, Section 5 summarizes our main findings and highlights new insights and perspective for future research in households' behavior and energy efficiency.

2. Methodology

The first part of this research is a literature review in order to define more clearly what is to be examined, with the intention of having a sufficient outline for determining what data to collect and how to analyse the data in practice [23]. The literature review consists of 4 steps: (1) selection of papers; (2) preliminary analysis; (3) detailed analysis; and (4) framework development.

Step 1: Selection of papers

The literature were searched on Scopus and Web of Science online databases due to their ability to allow fast and customized searches. The basic terms for the review were identified as "energy efficiency" and "behavior", the first search on the database was performed using the "energy eff*" which included both "energy efficiency" and "energy efficient". Next, the search was limited to journal articles in English only. A further filtering based on title reviewing was carried out and we determined the articles relevant enough to be included in the analysis. The criteria used for the inclusion of the articles were the following:

- Studies where the energy efficiency concept is the main topic
- Publications that are focused on households' energy consumption / households' behavior
- Studies that offer a contribution to the social science and humanities
- Papers which are published in peer reviewed journals

The literature review included a broad range of scientific literature: action determination models; environmental behavior models; the social practices approach. This search of literature resulted in a total of more than 150 peer-reviewed studies.

Step 2: Preliminary analysis

We have grouped the papers according to different main lines: terminology; pro-environmental behavior models; and drivers and barriers. In doing so, this review aims also to complement and update previous reviews on households' energy consumption and other pro-environmental behavior models.

Step 3: Detailed analysis

A detailed analysis on both categories of energy reductions in households: the technical and behavioral energy saving measures is carried out. Followed by an overview of the most influential and commonly cited behavioral models or frameworks developed in socio-psychological research in order to provide a comprehensive explanation of energy consumption of households are described in detail, including the strengths and the weaknesses. The research topic of drivers and barriers has gained a lot of the attention of the academic community, as understanding the nature of these drivers and barriers is essential for the success of energy related policies that might encourage efficiency investments of households.

Step 4: Framework development

Based on this overview (step 3) it became clear that little research is available on what individual and social factors might influence the adoption of novel energy consumption and investment practices in households' and there is a stringent need to understand the barriers to and drivers of involvement in these. These insights and guidelines were used as a basis to build our conceptual framework on how to improve our understanding and knowledge of households' energy consumption. The framework should provide a deeper understanding in the 'what' (what factors are associated with households energy consumption, e.g., financial costs or visibility), the 'how' (how can these factors be influences, e.g., technical solutions or public policy initiatives) and the 'why' (why different types of households' are likely to behave in different context e.g., certain choices can be explained by income) in order to promote and sustain conserving practice.

3. Literature Review

3.1. Energy Efficiency in Households: Key Definitions

Various terminologies are used in the literature to describe the reduction of energy use in households. Many terms start with "energy", (energy savings, energy conservation, energy consumption, energy efficiency), while others stress more the attention on "behavior" (efficiency behavior, energy usage behavior, curtailment behavior, energy related behavior) or on the "measures" (energy saving measures, technical energy saving measures, energy efficiency measures, energy conservations measures, behavior energy saving measures) [24–27].

In order to reduce energy use in households, two broad categories of actions can be identified: "once-off actions" to save energy and "ongoing day-to-day actions" to reduce energy consumption. Once-off actions are related to efficiency behavior realized through technical energy saving measures (or energy efficiency measures). Less energy is used for a constant service, for example, an older equipment (washing machine, vehicle, etc.) replaced by a more energy efficient model (energy-efficient appliances) or investing in home improvements like insulating the roof or replacing the glazing but more efficient one. These technical measures can significantly reduce households' building and transportation energy uses and save energy and costs over long periods of time. However, they are seen as an expensive way to reduce energy consumption as they often require an initial investment. In this debate, it is also worth mentioning that, despite a growing trend to energy vulnerability of some low-income households, in Europe, energy prices (for gas, coal but also fuel for vehicles) remain relatively cheap [28,29], which led to longer return on investment for hard works such as insulation. The shift from fossil fuel to renewable energy needed to complete the international targets on CO_2 emissions should however lead to an increase in energy prices to finance this shift [30].

Day-to-day actions refer to the reduction of energy consumption through using less of an energy service as part of people's lifestyles. Turning the thermostat down a degree or two in the wintertime

for example, switching off the lights, or modal shift from car to bike for short trips, etc. However, these measures are often associated with additional effort or a decrease in comfort. These behavior energy saving measures or energy conservations measures refer curtailment (energy conservation) behavior. Table 1 summarizes the main characteristics of the two previously highlighted categories of actions toward households' energy consumption.

Table 1. Energy consumption of households.

	Category 1	**Category 2**
Actions	Once-off actions	Day-to-day actions
Energy savings	Energy efficiency (Efficient energy use)	Energy conservation
Behavior	Efficiency behavior	Curtailment behavior
Strategy	Technical improvement	Different use of products and shifts in consumption
Measures	Technical energy saving measures;	Behavior energy saving measures;
	energy efficiency measures;	energy conservations measures
Amount of savings	Large energy savings	Small energy savings
Examples	Investing in home improvements e.g., insulation, energy efficient appliances, energy efficient car	Setting thermostats, switching off lights, limiting use of heating systems or car

Researchers have not been able to quantify whether efficiency behavior or curtailment behavior is more effective [24]. Some researchers have argued that curtailment behaviors initiate actual behavioral changes and sustain them for long-term [31], while others has suggested that efficiency behavior is in fact generally more effective in obtaining actual energy savings [24]. The success of the latter (efficiency behavior) may be counteracted by the "rebound-effect" (reduction in expected gains from new technologies that increase the efficiency of resource use through behavioral responses) [32].

Considering these aspects, this paper considers both categories of energy reductions in households: the technical and behavioral energy saving measures, the latter seeming somewhat overrepresented even with the knowledge that the energy saving potential of the technical measures is considered equal. The interplay between macro-level (e.g., technological innovations) and micro-level factors (e.g., use of technological innovations) will be studied in detail.

3.2. Theoretical Framing

Several behavioral models have been developed in socio-psychological research in order to provide a comprehensive explanation of energy consumption of households. The most influential and commonly cited frameworks are described in this section.

3.2.1. Action Determination Models

Many approaches could be categorized under the generic term of action models or action determination models. One of them is the Theory of Planned Behavior (TPB), a classical framework that has proven to be successful in explaining behavior intention and attitude in the field of household energy consumption. The TPB developed by Ajzen [33] proposes that behavior is preceded by the formation of behavioral intention. This behavioral intention depends on attitudes towards the behavior, social norms, and perceived behavioral control (the belief on whether one is capable of performing the behavior). TPB suggests that, for a specific behavior, the more active Behavioral Intention (BI) is, the more intense Subjective Norms (SN) and feel the less difficulties, individuals will be more likely to implement this behavior.

Behavioral research suggests that, values are the basis of attitude formation and it could predict behavior in a more stable and durable way than attitude [33]. In the field of environmental behavior,

the Value-Belief-Norm (VBN) theory proposed by Stern et al. [34] and Stern [35] is the classical theory to study how environmental values affect the behavior. Stern divided environmental values into three dimensions: self-interest values (SV) is the belief that environmental problems will affect self-interest; altruism values (AV) is the belief that environmental issue affect others and long-term interest; biosphere values (BV) focus on natural environment intrinsic values, suggest human could not destroy the nature. The theory of VBN suggests that, environmental values are the primary antecedents to inspire public responsibility consciousness and further implement eco-environmental behavior. Another similar framework in the same line of research is the Norm-Activation Model (NAM) [36,37]. Both theories (VBN and NAM) are rooted in the thought that energy is conserved when people feel a moral obligation to do so. The VBN-theory further assumes that awareness of the problems is rooted in environmental concern and values. Thus for explaining low-cost energy curtailment behaviors, the NAM and VBN theory appeared to be successful.

However, the explanation of pro-environmental behavior is incomplete if only internal factors are considered. Guagnano, Stern et al. [38] suggest the ABC model, which incorporates the relationships of contextual factors (C), attitudes (A) and behavior (B). The ABC model involves the strategies for integrating internal processes and external conditions. Behavior is formed through the combination of personal attitudinal variables and contextual factors. Attitudinal variables include internal factors such as specific attitudes, beliefs, norms, values, information and a tendency to act in certain ways, whereas contextual factors include external factors such as physical capabilities and constraints, social institutions, legal factors and economic forces like monetary incentives and costs. The ABC model postulates that the corresponding behavior is associated with both attitudes and external conditions suggesting that behavior is an interactive product of personal-sphere attitudinal variables and contextual factors [35].

3.2.2. Social Practice Theory

Social practice theory (SPT)refers to "a routinized type of behavior which consists of several elements interconnected to one other: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge" [39]. It is increasingly being applied to the analysis of human behavior, particularly in the context of energy consumption. Nowadays, this theory is used as an umbrella approach under which various aspects of theory are pursued rather than a single (or specific) theory. Here the work of Shove (Lancaster University) on consumption and the group around Spaargaren (University Wageningen) on change processes is of particular relevance. The primary insights focusses not on individual behavior but on social practice and on the interaction of people's practices and in particular their material contexts. This leads towards reflecting upon why certain practices are done, and how and why other practices are prevented. Shove stresses the importance on how social practice have changed over time, how it becomes normal and what the consequences on sustainability are. She is doing this using the concepts of cleanliness, comfort and convenience [40,41]. Spaargaren uses Shove's theoretical approach and place the social practices into a conceptual model, which has a strong emphasis on sustainability of existing lifestyles and on the ecological modernization of the society [42].

3.2.3. Integrated Perspectives

Nowadays, the conducted studies seem to focus more on the interaction of multiple factors, the integrating of different theories/perspectives and the multiplicity of forces underpinning energy consumption and conservations. Venkatesh [43] proposed the Unified Theory of Acceptance and Use of Technology (UTAUT), a synthesis of eight existing models of technology acceptance. The model integrates elements from Theory of Reasoned Action (TRA), Motivational Model (MM), Theory of Planned Behavior (TPB), Technology Acceptance Model (TAM), a combined Theory of Planned Behavior/Technology Acceptance Model (C-TPB-TAM), Model of PC Utilization (MPCU), Innovation Diffusion Theory (IDT), and Social Cognition Theory (SCT).

Turaga et al. [44] integrated for example the moral considerations of VBN with the rational framework of TPB and Bamberg [45] combined the TPB and the NAM. Abrahamse et al. [24] proposed that both micro-level factors and macro-level factors can influence household energy consumption. And, some researchers have investigated different types of energy consumer profiles in order to pinpoint what specific factors are associated with energy-saving behavior, e.g., Guerra Santin [46] and Gaspar and Antunes [47].

Table 2 summarizes the main behavior change models used in energy research. The name of the model and its principal proponent is given in Table 2, followed by some strengths and weaknesses. Due to the restricted length of this paper, it will not have been possible to describe every single facet of each model.

Table 2. Strengths and weaknesses of behavior change models.

Constructs	Main Concept and Strengths	Weaknesses	Empirical Evidence
Attitude-Behavior-Context Model (ABC model)—Stern & Oskamp [48]			
Attitude; Behavior; Context	Behavior (B) is an interactive outcome of personal attitudinal variables (A) and contextual (C) factors.	Does not take into account the influence of habits.	[49]
Consumption as Social practice theory—Spaargaren & Van Vliet [42]			
Social practices; Lifestyle; System of provision; Consumption	Describes a mutual dependency between domestic consumers and external systems that provides domestic goods where consumers are unable to engage in environmentally sustainable lifestyles unless external systems provide facilitative goods and take into account consumers' domestic practices	Difficulty of defining exactly what a practice is.	[50]
Diffusion of Innovation (DI)—Rogers [51]			
Innovation; Communication channels	Explain the process by which people adopt a new idea, behavior or object. It specifies numerous mechanisms through which adoption is achieved, and factors that influence the choices an individual makes.	The theory does not consider the possibility that people will reject an innovation even if they fully understand it. Does not take into account that adoption of new technologies is constrained by situational factors (lack of resources or access to these technologies).	[52–54]
Goal-Framing Theory—Lindenberg & Steg [55]			
Hedonic goals; Gain goals; Normative goals	Propose that goals direct the iformation and cognitions that people attend to. It proposes three types of goals (hedonic, gain and normative), an states that activation of each type directs people's attention to different sub goals, cognitions and information	The three goals are not equal of strength	
Model of pro-Environmental behavior—Kollmuss & Agyeman [56]			

Table 2. *Cont.*

Constructs	Main Concept and Strengths	Weaknesses	Empirical Evidence
Internal and external factors; Barriers;	This theory is composed by internal and external factors that can contribute to environmentally friendly behavior, alongside a number of barriers to pro-environmental behavior.		
Norm Activation Theory (NAT)-Schwartz [36]			
Activation of norms; Perception of need and responsibility; Assessment, evaluation and reassessment; action or inaction response	Explain the decision making process underlying altruistic and environmentally friendly behavior.	Intention, past experience and habit as factors influencing altruistic behavior are not considered.	[57–59]
Self-Determination Theory—Deci & Ryan [60]			
Intrinsic and extrinsic motivation	Comprising 5 theories and provide a broad framework to study motivation, personality and behavior.	Only when individuals are intrinsically motivated towards an activity is the behavior considered to be fully self-determined.	[61]
Social Learning Theory—Miller & Dollard [62]			
Drive; Cue; Response; Reward	Explains how imitative learning takes place, with four factors instrumental to the learning process.		
Stage model of self-regulated behavior change—Bamberg [45]			
Self-regulating process; Goal intention; Behavioral intention; Implementation intention	The perception of individual responsibility and negative effects of personal behaviors activate social norms and thus could lead to behavioral change.	Not include external factors and past experience.	[63,64]
	It describes the behavioral change process and the individual intention or willingness to change behavior toward a pro-environmental behavior by four stages.	Based on the assumption that it is possible for people to move up the ladder of sustainable behavior.	
Theory of Interpersonal behavior—Triandis [65]			
Behavior intention; Habits; Social factors	Intentions, and habits, influence behavior, which are also affected by facilitating conditions (external factors).	Has not been as widely used in empirical	[57]
Theory of Reasoned Action (TRA)—Ajzen & Fishbein [66]			
Attitude; Subjective norms; Intention; Behavior	Relationship between attitudes and behaviors within human action.	Issues such as cognitive deliberation, habits and the influence of affective or moral factors are not addressed.	[67]
		Unable to account for behaviors not under volitional control.	
Theory of Planned Behavior (TPN)—Ajzen [33]			

Table 2. *Cont.*

Constructs	Main Concept and Strengths	Weaknesses	Empirical Evidence
Attitude; Subjective norms; Perceived behavioral control; Intention; Behavior	Builds on the TRA model and includes a new determinant of perceived behavioral control to predict behavior - person's belief on how difficult or easy a behavior will be influences his/her decision to conduct that behavior.	Experience is not included in the model, so the measurement of actual behavior is missing. Personality characteristics, demographic variables and factors such as social status are excluded from the model.	[57,68–70]
The Social Practice Theory [40,41]			
Comfort; Cleanliness; Convenience	Introduces three domains of everyday life, those of comfort, cleanliness, and convenience (CCC). By using these concepts, Shove explores the questions of how new conventions become normal, and what the consequences are for sustainability	A group of individuals is seen as one single actor instead of all the individuals represented as such	[71]
Value Belief Norm Theory (VBN)—Stern et al. [34]			
Personal values; New ecological paradigm; Awareness of consequences; Ascription of responsibility; Personal moral norms;	Explains environmentalism and conservation behavior. It proposes a casual chain of values, beliefs and norms that leads to support for a social movement	Each variable in the chain affects the next and may variables more than one level down the chain. Thus all variables have to be analysed to identify the most influential factors. Values often fail to predict specific behaviors and weak correlation between personal norm and indicators of pro-environmental behavior	[72]
UTAUT 1,2,3—Davis; Venkatesh and& Davis [73,74]			
Perceived usefulness; Perceived ease of use; Intention; Subjective norm	It reviews eight models. Describes the factors that influence the acceptance/usage of technology, and the mechanisms underlying these influences. Central to the model is the proposal that acceptance is determined by two factors, namely perceptions of ease of use and perceptions of usefulness.	It is considered a less parsimonious theory	[74,75]

For some behavior change models we do not have indicated any weaknesses or relevant empirical evidence (see empty cells in the table).

The diversity and variety of the behavioral models or theories have shown that pinpointing the right type of constructs/indicators to achieve behavioral change is not straightforward. Jackson ([49]) sums up this problem in his discussion of consumer behavior. *"Beyond a certain degree of complexity, it becomes virtually impossible to establish meaningful correlations between variables or to identify causal influences on choice. Conversely,... simpler models run the risk of missing out key causal influences on a decision, by virtue of their simplicity... this means that there will always be something of tension between simplicity and*

complexity in modelling consumer behavior. More complex models may aid conceptual understanding but be poorly structured for empirical quantification of attitudes or intentions (for example). Less complex models may aid in empirical quantification but hinder conceptual understanding by omitting key variables or relationships between key variables".

Behavior is a complex combination of different constructs/indicators (values, norms, habits, social factors) and changing any of these can be challenging. Last but not least, it is worth mentioning that there is not a framework that is universally accepted by scholars as providing a comprehensive explanation of households' energy consumption and conservation.

Although the overview provided in this paper does not intend to be exhaustive and the selected models vary in purpose and context, the following insights and guidelines can be highlighted and used as a basis to build our conceptual framework:

- Consistent terminology for key constructs, some models used different terms interchangeably for the same construct
- Focus on current behavior rather than generating behavior change, given that most models use static data
- The importance of considering motivation, ability and barriers arising from the physical and social environment as important factor
- Concept of social norms was brought in the models in slightly different ways, in some models differentiations were made between different types of social norms
- Behavior change involves going through a series of stages (stage-based approaches), however, we have not found an advantage over other (more dynamic) models

3.3. Households' Energy Consumption: Key Determinants

Much research has been conducted over the years to clarify the key determinants that influence households' energy consumption. They may have been differing motives as to why research has looked at this domain, however, the overarching aim has been the focus on the reduction of energy consumption. Whether it is considered from an economic perspective (household's energy consumption linked to and have monetary impacts) or from a perspective related to environmental impacts does not matter. This section provides an overview of recent developments in the literature with regard to factors influencing households' energy consumption. Non-residential buildings are out of the scope of this paper and therefore literature in this field is not considered.

A classification of the identified influencing factors underlying this behavior in the residential sector is proposed to identify the determinants affecting households' energy consumption. Gärling et al. [76] argued that in order to change people's environmental behavior there is a need to consider both macro and micro-level factors. Jackson [49] divided all the influencing factors into internal factors (including attitudes, beliefs and norms) and external factors (including regulations and institutions). This paper follows his classification line and examines the following classification for the factors as possibly affecting energy-saving behavior: internal level factors, external level factors and social factors. Regarding the latter, previous research [41,49] has come up with useful conclusions that the social embeddedness/ social context is understudied. More in detail, how individual choices are continually being shaped and reshaped by the social contexts is important to consider in this research.

3.3.1. Internal Level Factors Influencing Household Energy Consumption

Various internal level factors influence household energy use and energy savings. Steg and Vlek [77], one of the most relevant publications on residential energy behaviors, identified motivational factors, contextual factors and habitual behavior as the most important factors in environmental behavior.

Motivational factors are defined as subjective individual characteristics that may influence how people perceive and rate the acceptability of objective characteristics of energy alternatives. *Habitual*

factors refer to individual factors habitual and guided by automated cognitive processes rather than being preceded by elaborated reasoning. How these habits are formed, reinforced and sustained is important for designing effective interventions to modify this behavior. *Contextual factors* refers to the objective characteristics of energy alternatives determined by its own context for example the energy price.

3.3.2. External Level Factors Influencing Household Energy Consumption

The second group of identified influencing factors place behavior as a function of processes and characteristics external to the individual, these include amongst other fiscal and regulatory incentives, and institutional constraints. In the literature, the term 'institution´ can play different roles in transition trajectories/ innovations and various authors [78–80] do not mean the same things when using this term. More in detail, Lundvall consider institutions as 'things that pattern behavior' (such as norms, rules, and laws), while Nelson and Rosenberg institutions consider as 'formal structures with an explicit purpose' (often called as organizations) [79]. In this research, the term institutional factors are used to describe the rules, regulations, standards and so on that shapes the behavior of households in terms of perceptions and actions. Institutional change can therefore greatly influence how households perceive and respond to uncertainties in the energy usage.

3.3.3. Social Factors Influencing Household Energy Consumption

The effect of social interaction on energy-saving behavior is also emphasized in some studies [81–86]. Social norm and social identity studies in the energy domain have generally looked at their influence on consumption patterns and have showed their effectiveness when used in intervention studies to reduce energy consumption. As social norms signal what the members of the communities we live in do, as well as what they approve or disapprove off, they are an important determinant of individual behavior both at home and on the road.

Furthermore, the importance of considering the group membership as an indicator of the importance of cultural contexts and social influences on consumer behavior has also been identified in previous research [87–90]. Individuals with a strong sense of group membership (i.e., with a high group identification), typically express positive evaluations, display the tendency to act in favor, and strive to maintain a positive image of their in group, even at the expense of an out-group. Social psychological studies showed social identity as one of the main psychological factors leading to voluntary cooperation to solve commons problems or dilemmas by postponing their narrow self-interest and to act on behalf of their group, community or place.

Table 3 gives an overview of the most commonly identified influencing factors correlated with household energy consumption, both energy efficiency and energy conservation.

Table 3. Overview of the key literature that identify the factors affecting households' energy consumption.

Category	Characteristics	Literature
Internal context	Socio-demographic, Contextual factors, Attitudes, behaviors and habits (implicit behavior)	[19,24,26,31,58,59,72,82,88,91–120]
External context	Incentives, institutional, and infrastructures	[24,67,101,121–130]
Social context (internal and external factors)	The role of social norms, social identity and social practices (incl. social systems)	[59,69,81,82,94,131–136]

The concepts of "day-to-day actions" and "once-off actions" presented in Chapter 2 are particularly used in this vision. Household's energy saving behavior indeed includes a wide range activities from habitual day-to-day actions to sophisticated and costly once-off actions [27]. That is why it should be

noted that the above determinants of household's energy conservation behavior affect these various types of activities in different ways depending on type of behavior and involvement with the product and behavior and have different psychological properties [99].

While once-off actions are one-time purchase decisions characterized though initial financial expenses and the potential for future savings, curtailment behaviors or ongoing day-to-day actions are considered to be routinized or habitual in the sense that it spares individual's time and effort of decision-making on issues that re-occur regularly [90,119]. In comparison to one-time purchase decisions that might have the side effect of increasing consumer's comfort, day-to-day actions implicate additional effort or decreased comfort.

Psychological factors including values, beliefs, attitudes and norms have been identified to be successful in predicting curtailment behavior [117,137]. For example, personal norms affect both curtailment behavior and involvement in purchase decisions through feeling a moral obligation to do so. This is also the case for environmental beliefs in the form of ascription of responsibility [118]. Eriksson et al. [138] and Nordlund and Garvill [139] have shown in their research on car use that there is a strong influence of personal norms for the willingness to curtail personal car use.

In general, Gatersleben et al. [137] and Whitmarsh [117] delivers an empirical evidence that daily energy saving actions are more likely to be influenced by internal factors, while actions which require considerable monetary costs (energy efficiency investments) are more dependent on guided circumstances. However, Jansson and Marell [118] shows in their empirical research that for both high involvement once-off actions and ongoing day-to-day actions biospheric values and personal norms have a strong influence on their energy reduction.

Regarding socio-demographic factors such as age, living status and gender, existing literature provides evidence both for and against hypothesis in either direction. Lee et al. [140] show that there are some gender differences in adoption of energy-efficient lighting at home in the sense that women are more likely to adopt energy-saving practices and were more willing to pay a higher price for energy-efficient light sources. Poortinga et al. [26] show that couples and families found technical efficiency measures more acceptable than singles did. According to Sardianou [112], energy saving investments are less likely to be made by older households since these households believe in shorter stream of benefits from energy improvements than other age cohorts. Another explanation is that younger households prefer an up-to-date technology which is most of the time also more efficient, while older households accept their older appliances and replace them only when necessary [114]. Carlsson-Kanyama et al. [114] also prove that households with younger head of the family are more likely to adopt energy-saving measures. However, Guerin et al. [120] show that age and the energy saving curtailment behavior is positively correlated. Poortinga et al. [26] also provides empirical evidence for the hypothesis that energy efficiency measures are more acceptable for households with a high income, while behavioral energy saving measures aimed at reducing direct energy costs were the least acceptable for high incomes. This might be explained, as seems to be straightforward, by the fact that energy efficiency measures (technical measures) often require an initial investment, which seems to be less problematic for households with a high income [112]. Another possible explanation for this phenomenon is the fact that day-to-day actions implicate a decrease in comfort while one-of actions might even increase consumer's comfort. Stern and Gardner [141], show that the home ownership also causes differences between households, energy efficiency investments is meaningful for homeowners whereas curtailments might be the only option for renters.

3.3.4. Discussion

A number of key determinants have been identified in the literature, ranging from situational factors in the external environment (e.g., contextual, structural and institutional factors) through to more person-specific attributes of consumers themselves (e.g., socio-demographic, psychological factors). Despite an expanding literature, empirical evidence of the impact of the latter two broad categories of variables that have been identified, socio-demographic factors (e.g., income, employment

status, dwelling type/size, home ownership, household size) and psychological factors (e.g., beliefs and attitudes, motives and intentions, perceived behavioral control, cost-benefit appraisals, personal and social norms) has not been consistent and conclusive to date. However, a common finding that has been well documented by behavioral economists, psychologists and other social scientists is that individuals do not always behave more sustainably despite having positive attitudes or behave logically to favorable economic choices in order to reduce household energy consumption.

Another common identified finding, combining financial incentives with program components (like energy assessments, information, education, appeals, informal social influences, convenience and quality assurance) reduce the transaction costs of targeted/ desired actions and have shown synergistic effects greater than the additive effects of individual interventions or policy. Furthermore, previous research has shown the importance of the full range of consistent knowledge of the environmental, economic and social impact for policy makers and financing institutions to decide whether or not to support new business models. For example, smart metering has been widely pushed, despite little knowledge on the environmental impacts as well as social impacts such as data security.

But both strands of action (one-off investment action or continuous action) require important and coordinated changes in household practices that go beyond passive assumption of energy-efficient technologies and acceptability of traditional policy measures. Efforts to change household energy use through information campaigns have proven very limited [24,129,142] and recent trends in diversification of energy generation and changing consumer roles have underlined the potential for smarter transformation potentials in harnessing the active households [143–145]. Nevertheless, little research is available on what individual and social factors might influence the adoption of novel energy consumption and investment practices in households and there is a stringent need to understand the barriers to and drivers of involvement in these. The challenge is to understand the internal, social and external level factors that threaten the energy use in household, so that energy-saving behaviors could be facilitated. Furthermore, the effects of contextual factors on energy usage behavior need to be studied in more detail, as well as how these factors might be affect various environmental and motivational factors. This in turn should lead to an extension of the existing methodological and/or theoretical models.

4. A Framework to Understand Household's Energy Consumption

Based on the literature review provided in the previous section, the identified key influencing factors are summarized as possibly affecting energy-saving behavior in a conceptual framework, presented on Figure 1. Whether household energy consumption is based on a one-off investment action or continuous actions, behavior is influenced by the external as well as by the internal context. External context such as institutional factors, technological developments, economic growth, cultural developments influence behavior at the broader level, while attitudinal and personal factors such as demographic factors and motivations shape behavior at the individual level. To illustrate the framework, the dimension of the external context, the internal context-attitudinal factors and the internal context-personal factors is connected. In order to differentiate between determinants of a different nature, a distinction between contextual, economic and social variables is proposed. These have different positions in the model and operate at different levels of influence. Regarding these levels of influence, personal (household) factors at the level of internal context have the biggest influence on the energy-saving behavior of households in contrast to the factors at the level of external context. A personal level economic factor can be altered relatively quickly, for example by a change in income, while the introduction of a subsidy program for all households in a country is often over the course of a few years.

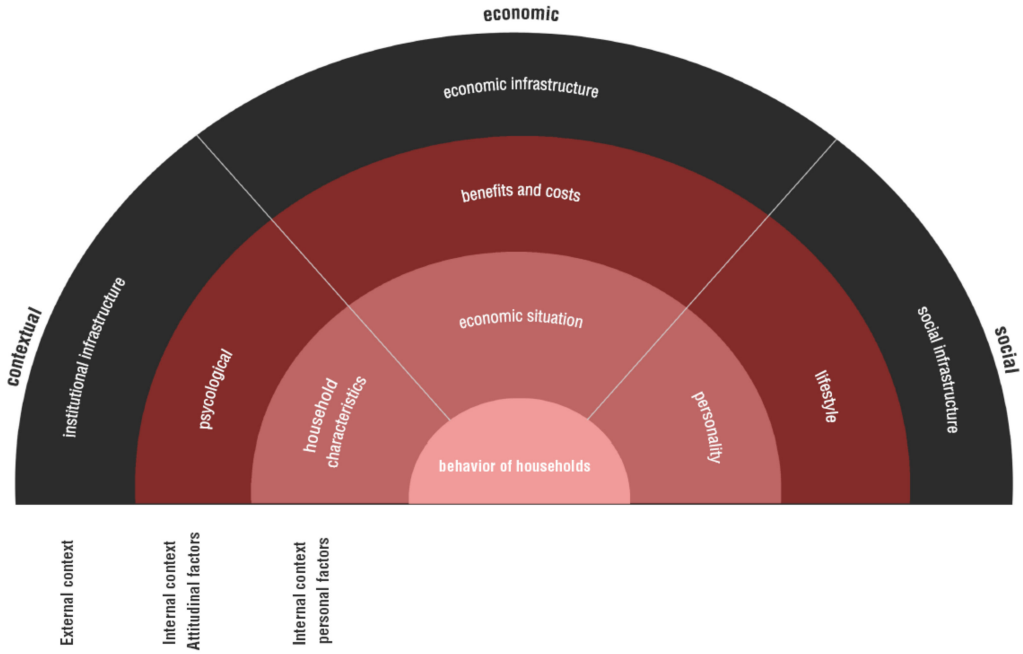

Figure 1. Conceptual framework to understand households' energy efficiency behavior.

Internal Context—Personal Factors

As already explained, the characteristics of each household have a direct impact and the biggest influence on the behavior of households. Their characteristics reflect the attitude and experiences from a descriptive angle (e.g., ownership, size and type). The availability of the requirements necessary to adopt technical and behavioral measures (economic situation) is also an important issue. This obviously affects what a household can afford, but the perspective on money and the level of importance of price in certain purchasing decisions does not belong to personal factors but has to do with the attitude people have. The personality of the people is clustered in the social context, however, it is composed by role and status, age or gender which represents a strong connection for certain behavior.

Internal Context—Attitudinal Factors

Attitudinal factors include factors held by the individual that affect the choices and the behavior people undertakes. These include an individual's motivation (e.g., pro-social, altruistic), perception, beliefs and attitudes which are part of the contextual process affecting the individual intentions. It includes also calculations which people make before acting, including personal evaluations of costs and benefits. Thus in spite of the advantage of adopting more efficient appliances, the cost of that decision has to be in concordance with the perceived benefits. Even when energy-saving measures are affordable, the balance between costs and benefits could represent a major barrier due to the uncertainty. For instance, the fact of thinking about long-term benefits when costs are immediately perceived has a direct effect in the attitudinal factor regarding to the intention behavior (especially in the case of the adoption of photovoltaic panels, as shown in [99,146,147].

The lifestyle of people such as group membership, normative social influence and family are also important factors. The indirect commitment with society makes behavior to be on the same line with the others tended to follow social system flow. Also one has to cooperate with other household members.

External Context

The external environment comprises situational opportunities and dependence of other. It can be interpret as set of regulations, system of laws, political environment and governance structure which interrelated control the distribution and consumption of energy adopting new measures in households.

At the social context for example, one has to obtain correct information about the most effective ways of reduction in order to reduce household energy consumption.

Table 4 provides an overview of the three categories of potentially important variables that have been identified for explaining variability in energy reduction of households: contextual, economic and social variables. These variables are divided over different levels with an explanation of the determinants of household energy behavior.

Table 4. Determinant of household energy consumption.

Level of Factors	General Determinants	Detailed Determinants
External environment		
Contextual	Institutional infrastructure	Laws, regulations and policies Availability technology Built environment (Infrastructure)
Economic	Economic infrastructure	Pricing (tariffs, rebates and subsidies)
Social	Social infrastructure	Information, mass media and advertising Neighborhood factors (community spirit and community norms) Broader public norms
Internal environment—Attitudinal factors		
Contextual	Psychological factors	Motivation Perception Beliefs and attitudes Knowledge and awareness (learning)
Economic	Benefits and costs	Energy consumption pattern Financial cost Benefit appraisal (potential impact of cost)
Social	Lifestyle	Group membership Normative social influence Family
Internal environment—Background factors		
Contextual	Household characteristics	Size and type Dwelling (ownership, age, size) Geographical locations (region, rural-urban, climate)
Economic	Economic situation	Income Employment status Education
Social	Personality	Role and status Age Gender

In summary, the conceptual model shows that energy consumption of households is based on a complex interaction between contextual, economic and social influence. This interaction has been structured into three categories implying a multilevel division of factors to shape the process of households' behavior and its transition to assume and adopt new insights affecting their day-to-day actions. The conceptual framework suggests a range of determinants for energy-saving behavior at different levels. However, it should be noted that an important point of attention is which specific label to be used in the conceptual framework and where the specific labels should be placed. This could be related to the disciplinary angle from which one approaches the framework. This is especially the case along the boundary of the social context. Although all the determinants are presented separately, from a practical approach are working synergistically and interrelated influencing the behavior and their current performance in households.

The framework is not only interesting for researchers, but also for policymakers (at the national and local level), practitioners (energy providers and engineers), as well as for social energy networks. First, it is interesting for policymakers in the area of energy provision for households, at national and local levels. At a national level, the gained insights into the "what", the "how" and the "why" provides handholds to formulate an appropriate policy or service view that can help the government to transform the current energy system into a more sustainable one. In order to motivate these

households, 'education and communication' is an important issue. Education on the interrelated issues of energy, climate change, and sustainability, and communication of strategies for reducing consumption and emissions (ranging from energy efficiency and conservation to more sustainable energy technologies). At a local level, households (and communities) can start participating more in bottom-up energy initiatives, thereby increasing the share of more sustainable energy technologies in the energy market. These results are also helpful for local governments and their planners as they have an important role to play in promoting more sustainable energy technologies. But, for both, national and local policymaker, these insights stresses the importance of creating policies that are transparent and easy to take advantage of. Second, we find that trustworthy information about the contextual (e.g., performance) and economic (e.g., costs) dimension is an important factor influencing interest in speaking with practitioners like energy providers and engineers. And finally, that households may seek such information from the experiences of personal connections in their neighborhoods and social networks (social dimension).

5. Conclusions and Perspectives for Further Research

Our intention in the paper has been to introduce a new conceptual framework to capture and understand households' energy consumption, efficiency behavior and curtailment behavior. Households have been progressively highlighted as the main actor that can play a substantial potential in the reduction of this energy use. Their behavior is a complex and hard to change process that combines numerous determinants. These determinants have already been extensively studied in the literature from a wide range of thematic areas each by its own assumptions and often neglect important energy behavioral components, therefore, energy behavior studies require an integration of disciplines through an interdisciplinary approach. Based on that knowledge, this paper aims at connecting objective (physical and technical) with subjective (human) aspects related to energy use of households in one framework. This combination should provide the answers to the 'what', the 'how' and most importantly the 'why' questions about people's behavior regarding energy use. This proposed framework allows clarifying the numerous internal and external factors that act as key determinants, as well as the need to take into account their interactions. Moreover, it would re-form demand as one of the result of interactions in and between the contextual, economic and social contexts in which households' lives. It would, however, not obviate the individual household nor research that intended to track changes in how individual households think and act. The framework proposed in this paper opens avenues for the integrated study of households' energy consumption and has further potential policy implications to better capture and take into account behaviors in policies, incentives and regulations still often focused on technical aspects.

Further studies are suggested to use the proposed framework for explaining households energy behavior focusing on identifying the specific factors that influence household energy usage (e.g., consumption) and changes in energy use over time (e.g., curtailment and efficiency behaviors). The framework has to be applied to an increasing set of empirical cases (for example PV and LED) carried out in a way as to systematically explore the opportunities and barriers, which in turn can enhance our understanding of how determinants interact as part of a larger explanatory framework.

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