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From a Techno-Economic towards a Socio-Technical Approach—A Review of the Influences and Policies on Home Energy Renovations' Decisions

Maria Isabel Abreu [1,*], Andreia Pereira [2] and Helena Gervásio [2]

[1] Instituto Politécnico de Bragança, Campus de Santa Apolónia, 5300-253 Bragança, Portugal
[2] Institute for Sustainability and Innovation in Structural Engineering, Universidade de Coimbra, 3030-788 Coimbra, Portugal
* Correspondence: isabreu@ipb.pt

Abstract: Over the past decades, the debate on how to encourage energy efficiency in existing homes has been guided by a technic-economic model that has a strong focus on technologies and cost savings, in which human behavior has been devalued to a narrow behavioral economics overview. While this specific area of behavioral science enabled to capture of the dimension of energy renovations as a problem of homeowners' individual choice, the collective and social aspects of energy efficiency are still largely overlooked on the energy policy agenda. With its emphasis on how social structures interpenetrate individual actions, social sciences offer additional insights that go beyond the identification of barrier-drivers underlying investment choices and also help to identify positive opportunities for renovation within the conditions of domestic and social life. Until recently, comprehensive behavioral aspects and the social dimension of home energy renovation have been ignored in policy initiatives, and the integration of complementary disciplines is only in its early stages. Based on a broad literature review, this paper aims to provide an up-to-date interdisciplinary perspective of the theoretical evolutionary background, which has been the support to gradually redefine and address the problems associated with energy improvements in homes.

Keywords: energy renovations; energy policies; decision-making; behavioral science; social science; influencing factors; homes; homeowners; interdisciplinary

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1. Introduction

Buildings account for 43% of the final energy consumption in the European Union (EU) [1], with roughly 75% being energy inefficient (35% of the building stock is over 50 years old). According to current statistics, the household sector consumes more than 25% of total energy and accounts for two-thirds of building consumption [2]. This sector, consisting mostly of owner-occupied housing [3], represents about 74% of the European building stock, which enables untapped opportunities regarding energy renovation practice, particularly in the owner-occupied subsector [4]. One specific case is the considerable stock of single-family houses, which are responsible for more than half of the heating energy consumption [5]. Furthermore, living in such types of houses is in contradiction with climate mitigation goals as they are responsible for larger emissions of CO_2 when compared to multifamily buildings [6]. On the other hand, on average, single -family houses have a larger potential to save energy than multifamily ones [7], and their renovation has more chances to be operationalized [8]. Bearing in mind that achieving energy and climate goals in the EU is considered of upmost importance, private household investment in renovation is undoubtedly critical to the future of effective policies [9].

If all of this was already a great concern in the past, now it represents even a major one [10]. The current energy crisis has resulted in a drastic increase in the wholesale price of gas and electricity. This suggests that the world is maybe at the beginning of a period where cheap energy will no longer be available, and people need to get used to huge price variability. Even if prices come down, future events will probably cause prices to increase again. An energy-inefficient private building is now a very expensive one if minimum comfort is to be achieved. Considerable changes to our habits and the way we use energy in buildings are needed to reduce the impact of future energy shocks.

Thus, achieving a step change in energy efficiency behaviors will require enhanced knowledge of behavioral drivers and the translation of this knowledge into successful intervention programs. The knowledge of these drivers has been depicted in different models of decision-making [11], which have been the support for policies. Being that energy improvements necessary for energy transitions in private houses [12], homeowners are a key group to be tickled by policy schemes [13–15]. Several energy policy measures have been implemented over the last decade, aiming to encourage them to make energy improvements in single-family homes. Unfortunately, so far, current governmental policies have brought only little success in increasing these renovation practices [16–18].

Primarily, policy-makers have been trying to convince homeowners to be deep renovate their houses under single and direct top-down instruments and establishing rules that are frequently very strict and demanding [19]. Secondly, the argument of sustainability does not seem to be enough to persuade homeowners [20], and even when relevant technical means are available, often economically viable, it remains hard to make them positively involved [21]. Third, research on homeowners' decisions to perform energy renovations was firstly rooted in neoclassical economics and technology adoption theories [11]. Where market failures are the main explanations for less-than-logical human decisions [22]. It is assumed that people always choose the most profitable possibility for themselves [22]. After it was recognized that these economic theories were insufficient to fully explain human behavior, behavioral economics theories were brought into the policy discussion [19]. Behavioral economics emerged from bringing some understandings from psychology to be connected to economic behavior, thereby predicting and explaining complex cognitive decision failures that conduct individuals to make suboptimal decisions that could not be anticipated by standard economic models [23]. Thus, based on these theories, the major arguments that sustain energy efficiency (EE) policies approaches have been built up to now on the narrow idea that homeowners decide to renovate in order to save energy and money but are prevented from doing so because of market failures and cognitive biases about which they are largely unaware. Financial constraints and doubts regarding energy savings, financial return, and reliability of the professionals are still examples of the most pointed reasons for policy failure [19]. Their focus has been on costs and savings analyzes [24] depicting homeowners as single rational decision-makers (that may behave irrationally from time to time) [19]; passive recipients [21] and; an homogeneous group [25]. In fine, energy policies are still largely planned based on insights from technology, engineering, economics and mathematics [26].

There is a growing body of literature that pinpoints the key role of other non-economic and technology-related factors that affect energy-related decisions [27]. One of the contributions came from the introduction of social and environmental psychology paradigms on domestic energy research [28], which brought to light that a sustainable energy transition in owner-occupied houses involves more wide-scale changes in human behavior than the ones represented by behavioral economics [29,30]. Because these aspects play a part in economic rationality whenever a decision process is involved [31], many behavioral-related insights, undervalued in the pass, are now increasingly got in relevance to provide a rich body of evidence to explain the underlying complexity of energy policies [27].

Despite the valuable accomplishments achieved through the application models derived from the above-mentioned behavioral-related theories, they often take individuals in isolation from social contexts, such as daily life activities and other social structures [32]. They neglect or even ignore a diversity of social and cultural determinants householders share in relation to home improvements [33–35]. The integration between the meanings that a home represents for its occupants, which differ significantly between individuals and the elements of domestic practices have been progressively exposed by social scientists as a way to explain homeowners' decisions [36]. Thus, social science was brought into domestic energy research [37], highlighting new perspectives on energy enhancements in private houses. They relate continuous home improvement with several mundane and shared aspects involving many levels of socio-cultural influence [16,19,35,38–40]. Unfortunately, these novel contributions are still much undervalued by policy makers [41].

Despite that we are still in an evolving understanding of the role of people and society in low-carbon energy transitions, it is already acknowledged that energy efficient behaviors are with great certainty the "co-constitutive outcomes of technical, economic, psychological, social and cultural elements" [42] which configures a need to address the problem of multiple interpretations of 'behavior' [43]. Thus, behavioral and sociological theories, as complements to techno-economic-related sciences, are the new settings for a socio-technical approach to be introduced in energy-related research on houses [44,45]. This requires a cross-disciplinary and integrative research framework of multiple domain-specific issues, which calls for behavioral, social, and technical experts to carry out together in-depth research on people and society [26], providing alternative ways of re-thinking actual policy strategies. This shaped the understanding of private buildings' heterogeneity [27], not only the heterogeneity measured by dwelling characteristics but also by householders' characteristics and by house renovation styles [42].

In sum, there is already a history of research attempts to offer multidisciplinary integrated models of energy behavior. For stronger policy coherence and to increase its impact, a comprehensive approach to research and on policy strategies should be embraced [12]. However, integrating multiple disciplines can be a workable task for researchers but quite a more challenging one for policy makers [46]. This study intends to contribute to closing the information gap that still exists among policymakers on how to best apply energy policies [46]. Because the scientific literature is rapidly growing and through a review of the body of existing research, the aim is to make a cross-disciplinary and concise perspective about the developments in different areas of research that attempt to explain homeowners' behaviors regarding energy improvements. At the same time, it has the aim to give a contribution to highlighting the importance of novel complementary approaches to the behavioral and sociological domains as emerging areas in domestic energy research [22].

The remainder of the paper is organized as follows: in Section 2, the research method used in the study is presented; Section 3 provides an overview of the actual EE scenario in the household sector in the EU; Sections 4–6 present the body of existing research on the different theoretical models that have been used to understand homeowners' behaviors on domestic energy activities. Section 4 starts by unveiling the current models, the conventional policy instruments implemented, and their effectiveness. Section 5 discusses the contribution of other behavioral-related areas beyond the behavioral economics domain and their related policy-making tools. In Section 6, the novel understandings on a sociological perspective about energy home improvements are introduced, as well as the main outputs. Section 7 presents a cross-disciplinary examination of the different theoretical models presented previously and outlines the main findings. A concluding remark finalizes the study.

2. Research Method

A narrative review approach was selected for this study. Narrative reviews are used to appraise, critique, and summarize the available research, not necessarily following systematic procedures [47]. They can be read as a general and accurate guide to what is already known about a given topic [47]. The review structure was designed to synthesize the different areas of research drawn upon their temporal evolution.

In order to gather, filter and select the relevant literature, more than one search strategy was selected. Taking advantage of the research carried out before this study, a list of references was already available before. It was the result of previous author's experience working in this field. Among other academic works, these references were, in great part, formed by ground-breaking studies (studies that are the first to advance new knowledge), also called "seed references" [48]. A collection of relevant journals, topics, studies, and authors on domestic energy research domains were the starting point. Two goals were established: (a) to improve, as much as possible, the initial list and (b) to search for the newest developments. Therefore, a citation tracking method (sometimes referred to as snowballing) [48,49] was selected to search for more literature. Both backward and forward citation tracking [49] was used. They allowed the creation of a citation network to see who has cited whom and whether their work was convenient. Scopus and Web of Science were the databases selected to search for peer-reviewed articles, although some highly referenced books and official reports were also considered.

In backward citation tracking, experts within the authors' team identified the most important papers from the list, and their cited references were examined for other articles that could be relevant (along with their references) and so forth [50]. The references that seem relevant and more often cited among the articles were highlighted as significant to the research. Then, a citation management software (Mendeley Desktop) was used to organize them into categories and remarked when they were already read or not. Because the process seems to never end, if the same citations were repeated on a regular basis for a certain research subject or approach, it was considered that some saturation was reached. Backward citation tracking also allowed us to see whether there was a gap in the literature and how each author was working through the analyzed concepts. It was also a tool to search for a comprehensive list of relevant previous reviews, which were established as instrumental for this review.

Forward citation tracking was used to find the newest studies. Based again on foundational studies, recent articles that have cited those studies where identified [50]. In order to do this task, the aforementioned databases were used. This method was also a way to see or confirm how influential the author of a certain work was and be aware of relevant research that was following a specific topic (this was particularly relevant for recent behavioral and social science developments). For best results, the relevant research works based on which the forward citations process was made were at least a couple of years old to give time for scholars to incorporate them into their own articles.

As a complement to forward citation methods for tracking new developments or emerging subjects, the above-mentioned databases, supported additionally by Google Scholar, were directly consulted to find some supplementary relevant articles restricted to the last three years. In order to take this search in hand, some strategies were used. Many significant keywords were already known from the authors' previous experience in other research. "Indexed keywords" from database platforms also helped to collect keywords for search. Different combinations of these keywords were used. Within the same keyword category, the search attempts were designed to use the Boolean operator *OR*. The *AND* operator was used between different keyword categories. For a coherent search method, the same combinations of search phrases were used in both databases.

Other strategies for search took advantage of databases' tools. With the introduction of relevant academic works or authors in the databases' platforms, it was possible to obtain access to the documents that shared the same keywords or topics. For example, keyword-based search allowed to bring to light topics/subject headings. In turn, using these relevant topics to do a search, it was also possible to easily extract the most representative publications or top publishing authors for those topics. Other complementary strategies used to gather references were: (a) activating database system alerts for new publications (authors' alert was used to stay notified of new related research studies) and (b) following the publications' list suggested in databases related with a selected article.

Initially, with the support of the citation management software referred to above, cross-checking was done on titles for screening and to remove duplicates. Then, analyzing in more detail abstracts' contents allowed filtering the collected references for each thematic. Consequently, a collection of relevant references was shortlisted following the criteria of being reviews, ground-breaking studies, or giving innovative/relevant outputs. The next step was full-text reading to in-depth content analysis. After some exclusions, mainly because they were overwhelmed by others, a noteworthy list was ready for final detailed content analysis.

3. An Overview of the EE in the EU Household Sector

3.1. The Energy Efficiency Gap Definition

Despite improvements year after year, the rates of EE measures in private houses are obstinately lower than instrumental drivers of renovation decisions would suggest [19]. A EE or energy-performance gap between techno-economic potential (built upon the level of EE that appears to make economic sense) and the actual level of EE in houses due to market adoption has long been documented [51]. Cases of such a gap have been reported for existing buildings, building renovations, and new constructions [52]. For building renovations in particular, the slow diffusion of energy-efficient technologies, was, for a long time, explained by the fact homeowners are capable of recognizing the EE attributes but they fail to take effective actions due to market failures, transaction costs, behavioral failures, uncertainties and miscalculations of energy savings [53,54].

3.2. Energy Renovation Market Specificities

It is worth noticing that the majority of information on national and European official databases is related to deep building renovations, although there are clear definitions for different renovation depths—deep, medium, light, and bellow threshold (EU Building Stock Observatory) [55]. Despite the efforts of the Energy Performance Building Directive recast and the positive implementation of building energy certifications schemes in EU countries [16], the findings signpost that deep renovations are not at the necessary level (neither in terms of speed nor terms of structure and investment costs) to achieve a climate-neutral building stock by 2050 [55]. Other studies signpost that house owners perform major renovations of their houses once or twice in their lifetime [56]. In practice, deep renovations only occur sporadically, while gradual over-time renovations are the dominant feature [55], one of the many signs that there exists a gap between technical and market potential [5]. Homeowners are indeed willing to spend money for energy investments but seem to be not so willing to spend too much to reach maximum levels of EE. Policy initiatives need to strike a balance between deep, one-off, and step-by-step home upgrading.

The most striking feature of the literature review is, perhaps, the fact that more than 90% of residential energy renovations take place in combination with other utility renovations, the latter experiencing significantly higher rates than the former in most EU member states [57]. This brings into the discussion the renovation works in their entirety. The main types of renovation works vary among different countries [19,58,59], but some results point out that the renovation works favored by homeowners are visible and aesthetics improvements [31,59]. Aesthetical and indoor renovations seem to be a priority to homeowners in several EU countries, followed by the building envelope and outdoors [21].

4. Neoclassical and Behavioral Economics and Technology-Adoption—Theories, Models, and Current EE Policies

4.1. The Neoclassical Economics Model

Because an economic rationale for EE policy subsists, some theoretical explanations for the EE gap were framed by empirical and experimental economic models. Neoclassical economics is a broad theory that focuses on supply and demand as the driving forces behind the production, pricing, and consumption of goods and services [54,60]. Through this theory it is assumed that investment is a discrete choice and is guided by a monetary cost-benefit analysis [11]. Discrete choice models represent individuals choosing between different alternatives characterized by a number of attributes [11]. Utility theory is a widely used microeconomic model of consumer choice that explain individual behavior based on the assumption that perfectly rational individuals make choices based on preferences. They behave and make decisions under risk adopting the most rational option available [22] and these same individual preferences provide criteria for the rationality of choice [11]. The decision outcome preferred will be the one that provide the most utility for their given preferences [60]. Because utility-based decisions are guided by an individual's evaluation of outcomes [11], EE attributes (theoretically, energy and cost savings, profitability, additional comfort, and environmental benefits) are perceived by economic scientists as the main low-cost approaches to save consumers´ money and reduce carbon emissions through energy-efficient technologies [19]. Additionally, because investing in EE is considered a pro-environmental behavior, policy makers have been assuming that homeowners are, in general, carriers of pro-environmental preferences and that displaying environmental arguments would convince them to invest in EE. Actually, research suggests that values that reflect a concern with others (i.e., altruistic and pro-social values), and particularly values that reflect a concern with nature and the environment (i.e., self-transcendent and biospheric values), are most likely to predict consistent sustainable energy behavior and induce more willingness to invest in energy solutions [12,22].

Hence, any deviations from these rational-orientated behaviors are mainly explained by market failures, environmental externalities and information difficulties [11,22,60] (e.g., imperfect markets, limited access to capital, misaligned incentives, regulatory-based failures, organizational barriers, lack and problems in collecting information, imperfect information). It is assumed that due to these failures, consumers, despite being rational, produce a deviation between what are socially optimal and private decisions [53].

Closely linked with the market failures, intangible costs or nonfinancial costs are also determinants to the EE gap. They are characterized mainly by transaction costs (TC) which are related to the several burdens on time and efforts homeowners face to find information, credibility, and support along the decision journey [27]. For example, minimizing the timeframe within which a feeling of fatigue with the renovation can be developed is one of the explanations why gradual renovations are favored [61]. The same happen with the miscalculations of energy savings which is an usual failure to understand and consider all the supporting influences of energy-consuming behavior in energy calculations [8,52].

4.2. The Behavioural Economics Model

Behaviors require, in general, an advanced cognitive involvement [62]. After evidence-based standard economics theories were unable to model entirely human behavior on energy-related decisions, the introduction of behavioral economics opened a "window of possibilities" for the integration of a more robust psychological understandings of decision-making in EE policies [22]. Behavioral economics draws on aspects of both psychology and economics. It explores failures that may stem from systemic cognitive biases, which are anomalies in decision-making (from the energy economists' perspective) that often prevent people from making rational decisions, despite their best efforts [53]. This is explained, in part, by the fact that humans base their decisions on their limited knowledge and cognitive capacity (bounded rationality) and often use shortcuts (they simplify decisions), also named heuristics [22]. Cognitive biases involve [22,60]: (a) non-standard preferences (e.g., loss and risk aversion; debt aversion; limited ability to plan ahead; subjectively weight probabilities when faced with uncertainty); (b) non-standard decision-making (e.g., 'status quo' bias; limited attention) and (c) non-standard beliefs (e.g., incorrect beliefs over future benefits and efficient technology). With the introduction of behavioral economics, policy interventions could rely no longer only on simple economic paradigms to correct market failures but also on cognitive psychology theories to try to solve cognitive failures when decision are made. Nevertheless, this formal discipline still tends to emphasize failures somehow around the financial, market, and technical-based concerns [25]. Notwithstanding some achievements in understanding energy-related behavior in homes, applying basic principles of cognitive psychology to economic paradigms failed to give accurate explanations about energy-related behavior [63].

4.3. The Technology Adoption Model

Technology adoption theories are also used to explain energy-related decisions. Technology adoption is explained, in great part, by diffusion of innovation decision models. Social networks (interpersonal and impersonal) [64] and technological attributes [11] are considered key influences for the success of innovations' diffusion and produce results on homeowners' attitude formation. The main attributes that are used to explain the majority of the variance in adoption rates are: relative advantage over the mandatory technology; compatibility with the existing situation; complexity; trialability (e.g., whether innovations can be tested prior to adoption), and observability (e.g., whether innovations are highly visible) [11]. It is with this attributes that policy makers rely on if they want EE technological innovations be positively disseminated and adopted. Additionally, another theory used to reinforce the diffusion of innovations model is the theory of cognitive dissonance. Individuals will actively make decisions or behave so as to reduce dissonance between their knowledge, attitudes, and actions [11]. Thus, actual policy makers believe that more information and knowledge result directly in more homeowners' action. Failures in the rate of diffusion, to understand the role of social networks on diffusion, and in the design of suitable communication channels are seen as contributing to a low engagement in EE technologies [11].

4.4. The Decisional Drivers and Barriers Framework

Once identified which behaviors need to be changed, it is fundamental to understand which factors underlie different types of behaviors and decisions and what influences affect the acceptability of changes. The above-mentioned models establish the core of what is currently named as techno-economic approach [19,25,40]. Due the dominance of this approach, influences on renovation decisions have been entrenched mostly in economic issues related to EE "win-win" attributes (drivers), technology adoption theories, and market barriers that slow the diffusion of energy-efficient technologies [53]. In the beginning, several scholars made an effort to assist policies toward energy renovation investments in order to identify potential barriers and drivers to recommend the adoption of proper energy policies and packages [65]. Thus, there has been a dominant use of a "drivers and barriers" framework in energy research. Firstly, it was very customary for drivers and barriers to be classified generally into two main categories: economic and non-economic [17,31] due to the dominance of standard and behavioral economic models (Table 1). Afterward, a broader categorization of drivers and barriers started to be used in several pieces of literature [22,66–72], whose main categories are summarized in Table 2. These categorizations represent discrete analysis models that have been widely used to express households' preferences or rejection for EE attributes [17] with a strong emphasis on market, technical, environmental, and behavioral economics issues.

Table 1. Examples of influencing factors on renovations' decisions in a mainstream economic and non-economic perspective.

	Drivers	Barriers
	Energy renovations:	Homeowners may:
Economic	Pay back (profitable); Increase the property value; Reduce energy bills and volatility against energy prices; Reduce supply problems and dependency on classical suppliers; Benefit from funding possibilities	Give up because high upfront costs; Not have the financial resources (capital availability); Be unwilling to raise a loan; Not be sure the investment will pay off (delay on gains)
Non-economic	Examples: Increase resilience against climate change; Reduce energy demand, environmental impact, risk for future problems and dependency of fossil fuels; Increase comfort; Embellishes the buildings appearance; Increase convenience and status	Examples: Think no renovation is needed; Have no time to deal with; Think the process is to complex; Be not interested to make more than necessary; Have fear of increase in dampness; Be worried that causes much dirt and stress; Have fears about quality and work of craftsmen

Table 2. Influencing factors on homeowners' renovation decisions based on market, economic, technical and environmental concerns.

		Based on EE market and technology adoption attributes
Drivers	EE qualities	Cost savings; Comfort; Environmental benefits; Air quality and health; New aesthetics and appearance; Profitability; Maintain or increase house value; Self-sufficiency
	Policy incentives	Availability of financial support mechanisms; Easy access, timing and salience; Energy consulting; Diffusion of innovations on technology
		Based on market and technology adoption failures
Barriers	Financial	Higher initial investment costs; Financial limitations and capital availability; Unwillingness to raise a loan and apply for financial mechanisms; Complexity of funding schemes; Disregard for the life-cycle-cost perspective; High-risk investment; External risks; Risk aversion; Energy performance less valued than investment costs, Uncertain long-term economic returns/payback periods; Delayed gains; Insufficient economic incentives; Difficulty to access financing; Financial crisis/economic stagnation; Lack of data related to costs and benefits
	Informational	Uncertain cost savings, comfort and health outcomes; Misperception of energy use; Low salience of energy; Imperfect or asymmetric information; Lack of accessible information; Inadequate distribution of information; Difficulty to gather information; Lack of credibility and trust in information sources; Lack of awareness/knowledge on information gap of technologies
	Regulatory	Complex and insufficient regulations, policy, and implementation efforts; Lack of regulatory provision/change of legislation for local/regional administrative division; Complex/inadequate regulatory procedures; Inefficient codes and standards; Unclear definition and uncertainty in policy action; Legislative issues regarding renewable energy schemes; Complex certification procedures
	Technical and market-based	Lack of technical competence and prior expertise (skilled professionals, trusted information, knowledge, and experience); Lack of awareness/knowledge on the information gap about technologies; Supplier capacity risks; Lack of stakeholder involvement and collaboration; Lack of adequate research and development; Fragmented market; Split incentives; Inadequate current business models; Lack of efficient marketing strategies; Lack of substantial market demand; Limited knowledge of market potential
	Technological	Inadequate advanced technologies; Unreliability and uncertainty of current technologies; Misadjustments between planned and real systems performance; Difficulty in integrating technologies in renovation works; Negative perception regarding the economic viability, function, and aesthetics of renewable technologies; Lack of technological standards
	Institutional-organizational	Lack of institutional support; Inadequate implementation of policy measures; Poor policy coordination across different institutional levels; Bureaucracy
		Based on behavioral failures and transaction costs
	Decision-making oriented	Cognitive burden; Bounded rationality; Non-standard preferences (time; loss, risk and debt aversion; Limited ability to planning ahead; Subjective weighted probabilities when faced with uncertainty); Non-standard decision-making (*status quo* bias; limited attention); non-standard beliefs (incorrect beliefs over future benefits and efficient technology) Transaction costs (time and effort—information search, apply to financial support; reliability/quality of experts and advisor); Complexities in acquiring knowledge and skills; Dissatisfaction with past experience; Perception as not essential (other priorities and inertia); Disruption of the ordinary life; Hassle factor; Sensitivity to the complexity of the renovation process; Lack of knowledge about the start point

4.5. The Dominant Techno-Economic Arguments to Encourage Energy Investments

Political efforts have been made over the last few decades to convince house owners to improve their homes, assuming rational individuals would always choose to invest in EE [22]. Because the arguments that sustain actual policies emerged from the techno-economic and pro-environmental approaches discussed above [73], formal models have most often emphasized the advantages of EE in houses. Thus, providing information about all these advantages, turning energy efficient technologies available on the market, and ensuring funding schemes opportunities to overcome financial difficulties were the main policy strategies adopted (Figure 1) [19,22,74,75]. Policy makers followed the assumption that homeowners would overcome market failures and behavioral biases and be more willing to invest in EE if more information, EE technologies, and financial resources were provided [22]. Energy policies at the EU level, and consequently at the national level, have been encouraging better building design and technological developments [76] to solve the EE gap. Policy makers tend to interpret houses as technical constructions created by skilled architects and engineers for people who need to adapt to their plans [25]. This results from their propensity to see houses as technical constructions apart from the people that live in them [77] (Figure 2).

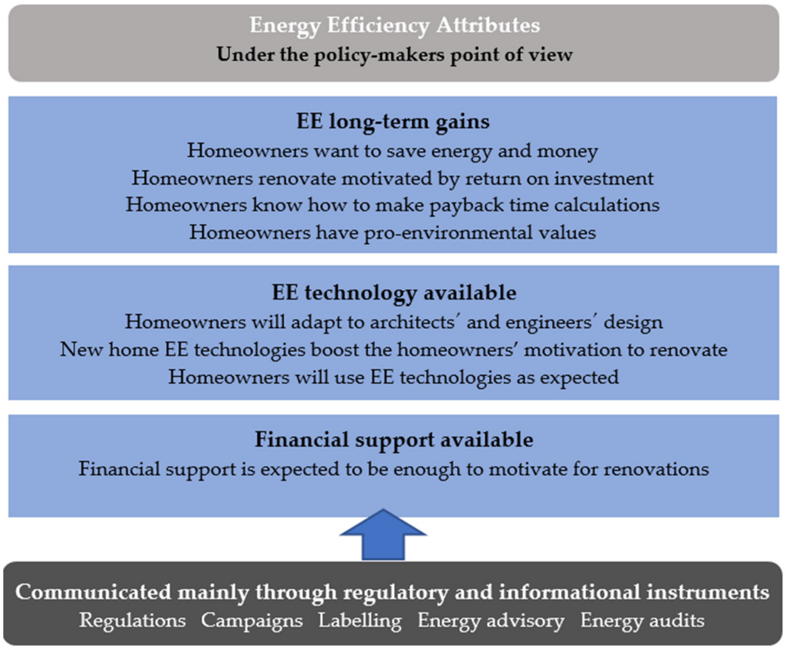

Figure 1. Main arguments used by mainstream policies that aim to encourage low-carbon renovations among homeowners.

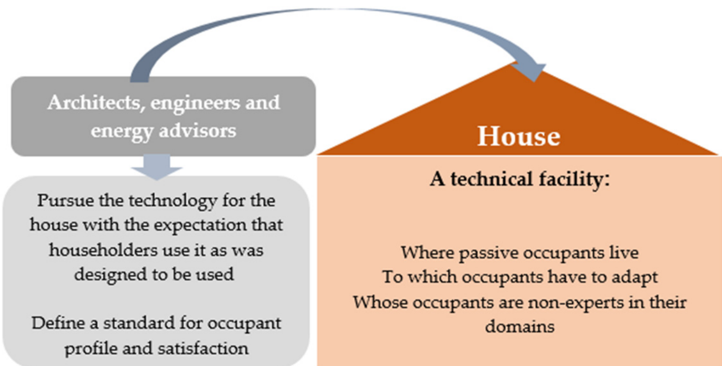

Figure 2. The perspective of architects and engineers about houses.

4.6. Energy Policy Instruments in the EU

A number of EE policies and policy packages [78,79] have been adopted to remove barriers to optimal EE informed by evidence-based models and through the consultation of stakeholders [22]. The process normally starts with the definition of medium-term targets and is followed by the launch of top-down instruments which are progressively reinforced. Although there are slight differences, there is a broad agreement about the comprehensive categories and instruments spread across EU countries [66,80–84]. Even though instruments vary in design and implementation (Table 3), the findings revealed the dominance of financial, fiscal, and regulatory measures in EU27 [84,85], where 43% of all undergoing measures are financial, and 25% are regulatory, followed by informational campaigns [2]. At the EU level, the policy package normally includes frameworks to set national building codes, EU Regulations for efficiency requirements for energy systems, directives for the removal of barriers to investments in EE, and supporting financial tools. Regulatory instruments work as product standards in order to set a minimum level of EE [22]. These standard levels have remained at the decision of each Member State, leading to large discrepancies in ambition among them [73]. Beyond the aforementioned instruments, voluntary schemes are also policy instruments reported to be implemented in countries such as Finland, Netherlands, Sweden, Slovenia, and France [2,83,85]. There are also small steps for some innovative policy measures taken by some frontrunner countries [15,16,21,58,86,87]. Sweden, Germany, Denmark, France, Slovenia, and the United Kingdom are examples. They are also displayed in Table 3. Some of the instruments presented in this table have a direct impact on homeowners' decisions. Others intend to reach them indirectly.

Table 3. Energy policy instruments categories implemented to foster household energy improvements in the EU.

Categories	Sub-Categories
Financial/fiscal	Financial incentives and capital support; Funds; Subsidies; Tax alleviations and credits; Free or low interest loans (mainstream) Feed-in tariffs; Carbon taxes; Eco-pack renovations incentive; Energy contracting; Community or neighborhoods renovation schemes
Regulatory	Building codes; Minimum energy performance standards; EE standards for appliances, lighting & equipment (mainstream) Renovations obligations; Procurement regulations; Phase-out of inefficient equipment; Progressive EE standards; Building carbon allowances; Building Renovation Passports
Informational and awareness	Energy labelling; Marketing and information campaigns; Energy audits (mainstream) Free personalized consultation at home; Local offices for free advice; Initial energy assessment offered by energy agencies; Smart meters and smart billing; Demonstration programs; Local workshops/exhibitions with the participation of opinion leaders to share experiences on renovation; Group tours; Living lab housing renovation programs; Thermographic actions at homes; Governing by example
Voluntary action	Voluntary certification; Voluntary and negotiated agreements.
Training	(mainstream) Professional certification and training; Vocational education; Quality standards
Market-based	Business models for full service energy renovation—One-stop-shop concept; Energy Efficiency Obligation Schemes (EEOSs); Third Party Financing/ESCOs, White certificates; Incentives for the producers of innovative technologies; Technology deployment schemes; Public-private partnerships with local companies
Technological	Partnerships governments/research institutions and industry; Financed R&D for new technologies development
Infrastructure	Energy supply infrastructures; Smart meter rollout

4.7. The Effectiveness of the Current EE Policy Models and Interventions

4.7.1. A Brief Introduction to Energy Policy Assessment

The real challenge for energy policy design and evaluation lies in developing assessments under real-world constraints [53]. The literature on policies assessment has been growing [81,84,88–95], which are often performed at the request of policy makers and regulators [53]. Some databases are also freely available to consult [82,96]. Notwithstanding a range of policies adopted in the last years to eliminate, overcome or reduce barriers to investments in EE technologies [97], assessments reveal that a potential mismatch between current policies assumptions and the homeowners' actual needs exists. Identifying the obstacles for EE improvements in houses but then merely providing single, top-down direct, and one-fits-all instruments have limited impact on the renovation investment decision [98].

4.7.2. Constraints of the Neoclassic and Behavioral Economics Models

Firstly, a salient mismatch between householders' and energy economists' points of view is clearly identified in the neoclassic economics models [99] (Table 4).

Table 4. A mismatch between household consumers' and energy economists' perspectives about domestic energy consumption.

Energy Economists	Homeowners/Householders
Contextualize the household energy consumption in terms of economic theory	Have complex and broad considerations when consume energy, incorporating personal and other mundane issues

Additionally, policies designed to solve market failures cannot be sufficiently accurate for solving the biases created by behavioral failures [53]. When behavioral economics was introduced, people have finally been more widely recognized as important determinants for energy transitions in homes. However, this only enabled energy researchers to capture the dimension of EE as a problem of individual choice and rationality [100]. These behavioral disciplines represent individual homeowners making reasoned decisions subject to some personal and contextual influences in order to achieve certain outcomes, which are frequently analyzed in isolation from domestic life [19]. It ignores the fact that energy use occurs in places in which complex webs of social relations already exist [101]. The decisions are also seen as limited to the decision moment rather than the process preceding or the context from which renovations emerge [19]. Actually, the standard models of decision making are dichotomous. They assume individual behaviors (i.e., demand) can be modified without altering the physical and social contexts that shape both market supply and demand sides [102].

4.7.3. Deconstructing the Techno-Economic and Environmental Policy Arguments

Like many other fields of research, domestic energy research has a history of support coming initially from positivist science, engineering, technology, and mathematic backgrounds, where the EE gap is explained as a failure in design [103]. If the modeled demand does not match the actual performance of the house, the response of policies has been to adapt the building design rather than engage householders [25,102]. Thus, there is research and industry work done on developing even better design, energy-efficient products, and building energy performance calculation methods and tools [31], which have increased the technical capability of the market for deep renovations. However, householders' behaviors and everyday practices at home are still not included in these energy calculations methods [103] despite buildings occupants being recognized as paramount to domestic energy management [104]. People have been framed as an afterthought to technology-centered plans [100].

Despite all these technical achievements and all the efforts made for the diffusion of these innovations via media channels, homeowners are not adopting these technologies as expected. Technologies and behaviors are not adopted simply through awareness and favorable attitudes [11]. A homeowner may have well-informed and positive attitudes to EE measures as well as the necessary resources but may not translate these into action even though the outcomes are clearly beneficial [11]. In fact, engagement in technologies is nowadays seen as an intersection between people, energy, and technology at multiple levels [105]. The attributes of technological innovations may not be sufficient to boost their adoption [11] and homeowners are also very attentive to innovations´ diffusion through social networks´ channels [64]. In sum, energy renovations cannot continue to be considered as a mere exercise of integrating technology into buildings [100].

The idea of convincing homeowners to renovate their houses based on EE investment payback arguments due to potential energy savings is not fruitful [31]. Economic considerations are undoubtedly important for the decision but mostly within everyday life situations [106] when opportunity moments or triggers occur [31,91]. Saving energy and money is commonly not the main renovation rationale [4,13], but many times an added additional benefit in the whole building renovation determinants [21]. Financial issues can be decisive arguments when the amount of money that the house owner is interested in or able to spend on renovations is limited. However, this does not imply that house owners generally make monetary calculations regarding the payback period. Profitability argument is a "black box" to homeowners and they do not perform profitability calculations previous to a renovation as energy advisors would expect [31]. The ones that are more informed about it stay overwhelmed by payback periods above 15 years because these periods do not fit into manageable timeframes [31]. In fact, most house owners wait until building components are approaching the end of their useful life before considering options for renovation, and then they assess whether or not the additional costs for EE improvements are affordable [53]. Feasibility is the main concern for the homeowners. Actually, comprehensive renovations may occur and not be economically viable [31]. This behavior can be seen as very reasonable from the house owners' (decision makers) perspective but not so much from the policy-makers perceptive, so the focus of policies should not be only on the cost side and how homeowners benefit financially from EE measures.

Financing support instruments for EE are also often credited with a smaller positive impact [107] and are more likely subject to misevaluation [53]. Nevertheless, they can be helpful in kick-starting new technologies or encouraging homeowners that are willing but not financially able to go beyond the mandatory standards [58]. Energy renovations usually need high upfront costs, so an important threshold exists, and higher amounts might demotivate the homeowners [61]. Surprisingly, the vast majority of consumers use their own capital to finance renovation works (which increases with the homeowners' age [108]), suggesting that: (a) consumers undertake energy renovations when they have sufficient capital [108]; (b) there is a significantly negative attitude towards loans (grants are preferable over loans) [107,108] and (c) the application to public funds is considered time consumer [31].

Finally, there are also recognized deviations to pro-environmental behaviors. These deviations can deconstruct the effectiveness of the environmental benefits´ message used in informational policy initiatives. One of the reasons suggested by research is the great heterogeneity of what underlies homeowners' self-interest in the environment [22]. This heterogeneity was recognized as related to environment-related value orientations of egoism and altruism which may prompt different concerns about the climate change issue [109]. There are two types of altruism that shape human behaviors: "warm glow" (an emotional reward of giving to others drives house investment decisions rather than environmental concerns) and prosocial orientation (individuals really care about the actual level of environmental protection) [109]. Heterogeneity is also related with the influence of personal norms (individuals are willing to protect the environment to be in line with the structure of their personal identity) and social norms (individuals think that their social group considers that protect the environment is the appropriate thing and will disapprove any deviation) [22]. The other reason for deviations on pro-environmental behaviors is because the environmental concern (e.g., CO_2 reduction) is rather EE side-effect than a motivation for several homeowners [31], in part explained by the fact that they have difficulty combining the demands of everyday life with sustainable practices [4]. Although homeowners express concern about the environment, they also communicate other priorities, which are exhibited in the renovations, and reflect wider homeowner expectations [4]. If there is a rationality conflict between the homeowners' needs, aspirations, and preferences and broader societal and environmental concerns, what they prioritize for themselves (such as comfort, cleanliness, and convenience) tend to prevail [110].

In sum, the common assumption that information and financial support should result in significant EE diffusion proved to be wrong. Figure 3 makes a summary of all the above-mentioned arguments.

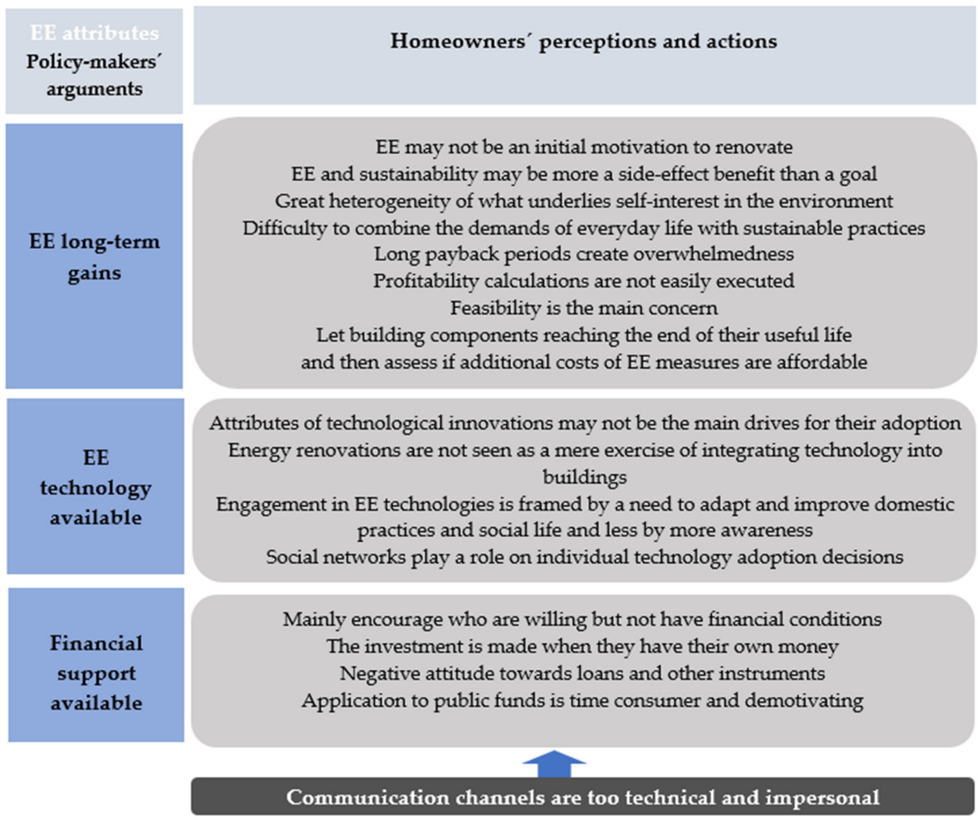

Figure 3. Homeowners' perceptions and actions about EE arguments used in energy policies.

5. The Behavioral Perspective—Theories, Models, and Innovative Policies

5.1. Novel Contributions from Social and Environmental Psychology

The short-handing of reducing people's roles to their "behavior" is a disservice to energy transition understandings [100]. Recent outputs pinpointed that sciences committed to home energy research need to be better in identifying "social desire paths", individuals' preferences but sensitive to their context, considered at the time of the choice but that may change across circumstances and time [5,111]. Human behaviors need to be distinguished by their psychosocial characteristics for a complete understanding of the situation [11]. Thus, empirical and experimental evidence under the social and environmental psychology fields has helped to identify the pro-environmental homeowners' preferences as motivations for EE uptake [112]. Social and environmental psychology disciplines examines transactions between individuals and their built and natural environments [28]. The attention is then shifted to the role of psychological constructs (values, attitudes, norms) but framed by environmental concerns [11].

Under the guidance of these disciplines, some models to explain the pro-environmental behavior were suggested by some foundational studies [11]. One of these models, modeled by the Theory of Planned Behavior, examines antecedents driving behavior [22]. This theory is based on individual psychology, were personal attitudes about energy decisions in the context of social norms are studied [5,113]. One of these antecedents is the intention to act which is a driver for behavior ruled by: (a) attitudes (relatively enduring organization of an individual's beliefs and evaluations of consequences that predisposes his or her actions toward an object, person, event, or idea [11]); (b) subjective norms (perceived approval of behavior by relevant peers) and (c) perceived behavioral control (perceived difficulty to engage in a certain behavior) [11,22]. Positive evaluations of EE consequences, perceptions of an executable task, and positive feed backs from their peers can lead to more willingness to invest in EE [22]. In fact, a behavior change result sometimes from the house no longer be compatible with homeowners' self-identity (what people think of themselves and how people would like others to think of them) or with their actual household´s living standards [106].

Another model of pro-environmental behavior distinguishes personal and contextual domains that explain behavior, recognizing that there are interactions between these two domains [11]. The personal domain comprises not only attitudes but also habits, current practices, and experience. However in this case, attitudes are not only exclusively a result of beliefs but also of personal values, morals, and norms [114,115]. This interconnection is explained by the Value-Belief-Norm Theory, which proposes a causal chain from the stable essentials of personality [11]. Recent achievements in research challenge behavioral science in domestic energy research to be even better at identifying the basic values of a person, defined as "desirable trans-situational goals" [116] in order to properly target homeowners´ behavior. They are basic values that are organized into a coherent system relatively stable across time and place that serve as guiding principles in the life of an individual [116]. Also within the personal domain, individuals displaying moral obligations towards the environment, which are interlinked to their personal values, are more willing to invest in EE [22]. In turn, the contextual domain of this pro-environmental model comprises the capabilities of the individuals (e.g., acquired skills and know-how, socioeconomic status or resources) and other variables shared by many individuals (e.g., social norms and interactions, market actors, regulations, technologies, or economics) [11].

Despite being a less tangible issue, houses are also physical spaces imbued with attached and symbolic meanings. "The multidimensional meanings of home and home-as-ideal may be useful to track since these may influence energy demand" [25]. These meanings represent an emotional, and representative connection householders attribute to their homes which they use when they think about house improvements they want to carry out [19,25,39,40]. They change according to time and are formed through ordinary life experiences performed at home and around the home [117]. Usually, there is a practical motive behind the appropriation of different parts of a house but through a process of integration, a symbolic meaning will become more significant [106]. Thus, houses should not be envisioned by policy makers as a material frame but also as the symbolic image they represent for their inhabitants [106].

Emotional connections are also constitutive elements of decisions acting as a filter [118], and if an information about EE in homes prompts positive emotions, it is likely that an engagement EE improvements can happen [22]. Renovating is, above all, a decision grounded in hidden emotions, individual dispositions, and less gut instinct [31]. This is in line with the fact that is common energy advisors be requested to validate the already made emotional decisions about the house [31].

These and other efforts of a growing literature on behavioral sciences applied to domestic energy research have resulted in some progresses. In one of the recent studies sponsored by the European Commission [55], the barriers were split into: (a) technical; (b) financial; (c) regulatory; (d) personal efforts (transaction costs); (e) attitude (own and peers) and (f) awareness/knowledge. The drivers were subdivided into: (a) trigger moments; (b) motivations, and (c) incentives. The motivations were subdivided into: (a) environmental; (b) comfort & health benefits; (c) knowledge about renovation works, and (d) ability to do things (DIY). The Maslow's Hierarchy of Needs (a motivational theory in psychology) is also mentioned for the first time to examine homeowners' motivations.

5.2. Behavioural-Oriented Policy Instruments

Behavioral science insights are increasingly shaping the design, implementation, and evaluation of energy policies [27,119]. Despite research has been offering valuable outputs about homeowners' behaviors, policy makers are still resistant to widespread their implementation despite their potential to enrich the policy toolbox. Two main types of instruments are considered as being behavioral-oriented: nudges and boosts [120].

Nudges enable to directly address the behavioral failures by altering the decision process structure or by assisting the decision [53,111,121]. In practice, they have the propose to change the context of decision without restricting any alternative. In general, these behavioral interventions with regard to energy are framed by four major areas: (a) convenience (easy and ready); (b) information (to justify behavior and to give guidance on changing behavior); (c) monitoring (feedback and rewards); and (d) social influence (social modelling, commitment and setting goals) [54,60]. Taking account of behavioral biases when designing effective environmental and climate change policies is recognized as being crucial [60]. The actual policies have been working mainly with a narrow segment of informational programs (e.g., campaigns, energy labels, energy audits) and some feedback instruments (e.g., smart meters). In fact, providing transparent information stimulates energy saving behavior among households, and giving feedback can considerably reduce the energy bills of households [122]. However, traditional interventions can be augmented with a broad consideration of behavioral insights [60] that result in interventions that explore convenience, social influence and other models of information and monitoring to cover behavioral biases. Working with convenience is to assist decision implementing behavioral instruments that: promote easy and effortless changes; avoid inessential complexity and sensory overburden or provide reminders. Working with behavioral-oriented information tools is to: use clear, concise and comprehensible format messages; emphasize cost/loss reductions of taking EE solutions; underline the low-risk, safe, stable, and secure of EE measures and investments; provide information from a high-credibility sources or display other EE options consequences rather than only the EE attributes. Other behavioral-related instruments work with psychological factors such as normative social influence, cognitive dissonance, non-monetary rewards, and social and professional network trust factors [60].

Boosts are interventions that do not target behavior, but competencies, with the aim of empower individuals to make complex decisions [22]. Competencies can be achieved by improved know-how and skills or by acquiring capabilities to interpret information clearly (to reduce cognitive costs). A positive renovation experience [123,124] and EE related know-how and skills [125] foster more comprehensive energy-related renovations to happen. This brings people's DIY and astute project management propensities [126] to policy agenda discussion, which configures lifestyle determinants that has been undervalued by policy-makers [127]. It also brings to the discussion the need for training schemes to be implemented to improve homeowners' well-informed decisions. All these competencies play a significant role in the depth of the technological solution achieved with the renovation [128] and in the degree of owner involvement in the creation of technological solutions, which also has an impact in the homeowners' involvement to reduce energy use in the post-renovation phase [128].

Some examples of innovative behavioral-related measures can be found in Table 5 [22,58,60,66,129]. Inside the EU context, Sweden, Germany, Denmark, and the United Kingdom are some of the forerunner countries that did experimental research and attempted to introduce these types of instruments in the policy agenda.

Table 5. Policy instruments based on behavioral-oriented insights (nudges and boosts).

Categories	Behavioral-Oriented Strategies/Instruments	
Financial/Fiscal	Reduce the effort to select options	Pack incentives; Interventions framed by the level of loss aversion (for tax credits/alleviations); Target people based on motivations (for subsides); Mechanisms to reduce loss perceptions (for loans); Decrease financial efforts (e.g., enabling to pay EE measures with savings; third party financing); Community/neighborhoods renovation schemes (collective procurement, support for vulnerable or low income households); Energy performance contracting
	Diversify EE options' consequences	Fiscal benefits for certain measures (Feed-in tariffs)
Regulatory	Reduce the effort to select options	Accounting for time preferences; Building Renovation Passports; Energy efficient solutions implemented as default
Informational and awareness	Reduce the effort to select options	Free personalized consultation at home; Public or independent offices for free advice; Business models for full service energy renovation—One-stop-shops; Initial assessment offered by energy agencies
	Diversify EE options' consequences	Address alterative consequences for EE measures (social status, up-to-date technology at home, property value);
	Reduce cognitive costs	Clear, concise and comprehensible formats; Focus on low-risk, safe, stable, and secure EE measures and investments; Emphasis on the cost/loss reductions achieved with EE measures; Emphasis on the costs of inefficient investments; Simplifying and making relevant policy information; Use of graphical ways (in energy labeling); Thermographic actions at home; Demonstration programs; Local exhibitions
	Provide reminder	Reminders about property age, carbon footprint for inefficient solutions
	Provide feedback	Smart meters and smart billing
Social influence	Promote commitment and reward	Non-monetary rewards mechanisms (praise, recognition, social approval)
	Promote social modelling	Diffusion of renovation practices; Group tours to see renovations' cases; Employment of high-credibility sources for information
Training	Promote competencies	Training on energy-financial literacy; Living lab housing renovation programs; Local workshops (for information exchange and share of experiences)

6. The Sociological Perspective—Theories and Models

6.1. Domestic Energy Consumption as a Social Issue

First place, energy use has a social nature [130]. It provides useful services allowing the functioning of normal social activities, which are part of individuals' home life [131]. In fact, most energy-intensive activities in homes are quite mundane and diversified: dining, socializing, entertaining, heating rooms and water for washing, and running appliances to froze food or dry clothes. When it comes to everyday life in homes, people do not think of themselves as energy consumers, but they consume in an unconscious way while carrying out their usual practices and routines [132,133]. Nevertheless, when questioned, they are able to associate customary actions with aspects of EE [134].

Hence, there is a complexity in home energy consumption [14] which seems to require a scope of action on EE that emphasizes the social nature of energy use. Regarding the complex interplay between energy requirements, personal behaviors, societal objectives, and environmental considerations [135,136], there is a move of the research apparatus toward more sociological understandings of energy issues [26].

6.2. Home vs. House

As mentioned previously, techno-economic rational dominates energy-related studies for private buildings, and this has, in part, happened because of a lack of comprehensibility about the difference between "house" and "home" [25]. The question is whether homeowners and policy-makers have different views about private buildings.

For policy-makers, a private building is a "house", a physical and envelope structure, a setting they use to formulate their theories [40]. For owner-occupiers, the "home" is the scenery where everyday life activities are performed, the focal point of private life, and a place to provide feelings of privacy and identity, comfort, company, and safety [19,106]. Homes are places to live, to make plans, to adapt and improve domestic practices and social life. Thus, homeowners are continually involved in a process of keeping their home habitable, improving or changing it gradually [40] in a process named as the "practice of dwelling" [137]. In fact, they domesticate the house "turning it into a home by constructing and negotiating a network of occupants, activities, technologies, and values" [106]. The materiality (house) and people (householders) interact mutually, shape each other and evolve together [25,40]. Through these "home" theories, existential and not only physical qualities of living inside a house are highlighted (Figure 4).

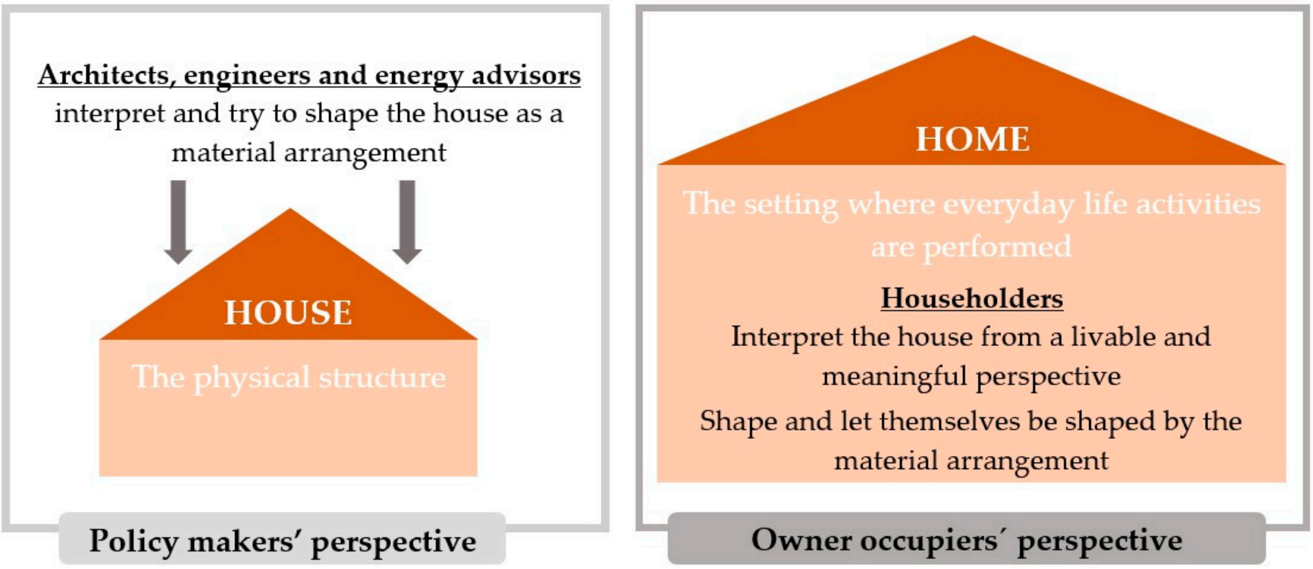

Figure 4. Homeowners vs. policy-makers´ understandings about the "house".

Additionally, "house" and "home" connect different perspectives in domestic energy research. The concept of the "house" is sloped to work with positivist research approaches, passive users, definable occupant satisfactions and technical interventions whereas the home concept favors interpretive approaches, active building users, complex occupant satisfaction, and social intervention strategy [25] (Table 6). The positivist approach refers to a philosophy of science that sustains that natural science methods (e.g., hypothesis testing, experimental controls, falsifiability) are preferable for explaining social phenomena [25]. The interpretive approach maintains that the methods of natural science are not adequate to study the social world since social phenomena are fundamentally distinct from the physical reality studied by natural scientists. It includes the researcher's subjective analysis and integrates human interest [25]. Summarizing, translating the concept of "house" into "home" brings interesting insights to the study of domestic energy consumption and interventions [25,106]. It is time to "home-in" on domestic energy investigation [114].

Table 6. Insights from the "house" vs. "home" approach in energy home issues and interventions.

	Approach	Intervention	EE Experts' Role	Occupants' Role
House	Techno-economic	Just improving design, technologies, or other physical aspects of domestic buildings	Architects and engineers, typically employ quantitative and applied methods (large quantitative surveys, modeling, and statistics) based on local climate and building features	Householders Passive Definable by experts
Home	Socio-technical	Understand the comfort, identity, security, privacy issues as connected to emotions and relationships as well as to social and cultural expectations	Trained experts to carry out qualitative and quantitative methods altogether exploring also social science methods and skills	House owners Active Complex occupant needs

6.3. The Socio-Material Approach in Domestic Energy Research

As demonstrated above, by targeting the house apart from the people that live inside, the potential of altering cultural norms and ways of doing everyday activities with influence on energy consumption is underestimated and may actually justify and perpetuate increasingly energy-demanding expectations [25]. On the other hand, targeting only individual behaviors apart from the physical structures (the house) or from the social structures is to underestimate that people's choices are affected by the context around [19,31,40]. In social sciences, the focus is on socially-related physical structures because they influence individuals' choices and actions [25]. Individuals are affected by places to which they are accustomed (houses) [22]. An example is that householders' energy perceptions, expectations of comfort, and their related consuming habits can vary with changes in the EE of the house [138,139]. If an energy efficient technology shapes the habitual householders' practices and plays a role in changing what is perceived as normal ways of doing things inside the house, energy savings can happen [42]. If the consumers actively appropriate this technology and assimilate it into existing regimes and frames of living at home [85,86], it is likely the energy consumption be higher than planned [79], and optimal expected savings do not happen as it was anticipated.

Social science has arisen as a complementary theoretical framework to understand more deeply home occupiers' behaviors. Its focus is less on individual choice but more on social structures and how these interpenetrate individual actions [16]. Households are social structures such as are the habitual practices, social classes, culture, or laws [22]. In fact, society and technology shape each other in multiple dimensions [70], and this requires additional conceptual development to capture the complexity of interaction between both physical and socially-related drivers, named as a socio-technical approach. Through this theory, homeowners' behaviors can be characterized by the "soft elements" coming from economic, psychological, and social fields, and by the physical/technical systems, which include the house characteristics, house equipment and appliances, and renovation measures [70].

6.4. Social Theories

Social theories seem to represent the proper theoretical backgrounds to model the energy improvements activities in homes [33]. There are relevant theories to be mentioned. The socio-technical theory explore humans and technology interaction and how they mutually influence and determine each other [5]. The habitus theory relate different socioeconomic groups, gender, and ethnic groups (and their preferences) with energy issues [5,21]. The structuration theory focuses on the rules, formal and informal, that govern or influence energy-related behavior [5]. The theory of habitual behavior, explores the connection between habitual behaviors and energy consumption and help to understand and find ways of supporting consumers in establishing new energy-saving habits [5]. And finally, the social practice theory links energy-related practices to consumers acting in accordance with them [5,76]. From a practice theory framework, home practices need to be analyzed and understood using four constitutive elements: material-structure (house), competencies to perform the practice (knowledge and skills), meanings associated with the practice [140], and institutionalized knowledge and explicit rules [141]. These elements need to be considered together for a total explanation of certain circumstances [141].

6.5. The Socio-Material Approach Explaining Home Energy Improvements

Subsequently, to all that was discussed, a socio-material approach discloses and adds a global challenge to conventional theoretical models used to disclose householders' behavior regarding energy issues. This challenge is to consider important social dimensions of houses with impact on energy interventions: (a) houses are settings for mundane practices; (b) houses are part of homeowners' life cycles and personal events [142]; (c) houses are frameworks for social relations [101]; (d) houses are markers of social values [16,40] and (e) houses are makers of the cultural setting around [42]. The following chapters define better each of these dimensions.

Social scientists recognize that practices are social structures, and houses are places for habitual practices and routines [140]. They also know that home renovations are interlaced with everyday energy-consuming practices and also embrace continuing practices of improvement for living or doing home maintenance [134,143]. Opportunities to improve a house's energy performance present themselves in the course of other home renovations [144]. One possible motive is because that the adoption of EE measures is often cost-effective together with other renovations [145]. Another possible reason result from the normal chain of renovation interventions since adaptations to the physical elements of the home can prefigure one another [67]. Therefore, energy improvements are seen, through a sociological perspective, as other types of home improvement with which the homeowners engage continually as result of the dynamics of their domestic life. They have the goal to put homes more efficient to manage energy that householders use daily to meet their everyday needs in order to perform energy consuming practices that support wider practices of dwelling (Figure 5) [134,146]. Karvonen [35] argued: "domestic retrofit is not an activity of changing a house from poor energy performance to exceptional energy performance, but an intervention into the rhythms of domestic occupancy." The engagement in energy renovations tends to be framed by the needs of dwelling [147] and by other mundane social aspects, which often weighted more than the operated by market logic [13,147]. In sum, incentivizing home improvements, in general, makes a positive contribution to boost the market of energy renovations. Opportunities are lost when aspirations of homeowners beyond the energy-related goals are not taken into consideration by policies. This highlights the importance of implementing policy instruments to target energy renovations indirectly [98] because non-energy benefits of energy renovations might be even higher to the owners than direct energy benefits [148]. In consequence, the first two challenges to the conventional models that inform EE policies are that energy renovations should be seen as a social practice and as any other mundane improvement at home.

Houses being settings for mundane practices also highlights that too great a focus on large energy renovation projects and decisions may miss the opportunity to influence the many gradual and smaller changes in the house that are continually performed by the "practice of dwelling". Small changes can conduct up to larger projects [143]. Therefore, recent studies recommend energy policy-makers to put their focus also on the minor improvements made in homes because increasing the rate of low-cost measures can help to achieve higher EE targets earlier in time [148]. Thus, a second challenge to the conventional models is that policy interventions should address the renovation rate of existing buildings rather than be obstinately focused on the renovation depth [148].

The house as part of homeowners' life cycles and personal events represents the improvements and adaptations in the house as a consequence of homeowners' positioning in a particular stage of life or in the beginning or at the end of a life cycle which have consequences in their willingness and capacity [40]. Homeowners experience specific life events that have major impacts on their willingness and often create a need to change the house [142]. Social scientists named these "windows of opportunity" [142]. Everyday routines and consumption patterns change somehow during these life-course transitions, being decisive for these changes in routine not only the specific life moments but also all the preparation phases preceding them and a rather short period after it [142].

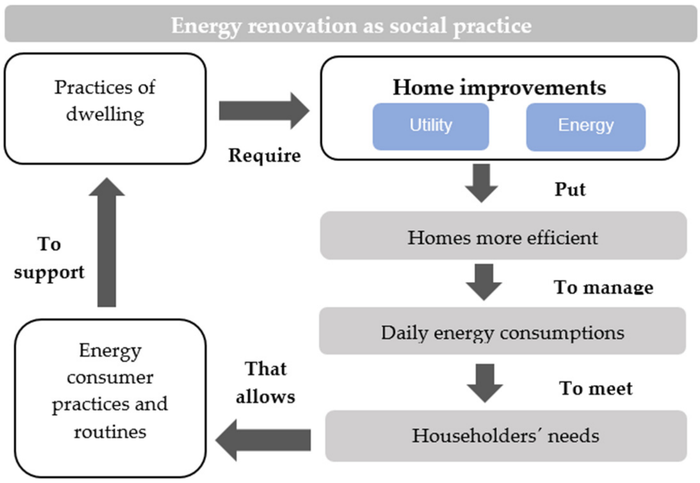

Figure 5. Energy renovations are conceptualized as a social practice.

The house as framework for social relations and their activities means the house is a reflex of the interaction between householders and their understandings of livability, socialization [134], and indoor environment improvement [7]. People have different patterns of social relations, which differ between societies, groups of people, and individuals and these social relations shape how people respond to interventions on energy use at home [101]. This brings to light the roles and relations within the family dynamics, such us the gender roles or the hierarchy roles [88].

Houses as markers of social norms represent people being more susceptible to social norms than they think, both descriptive norms, which is what others do, and injunctive norms, which is what others expect [127]. This is much related to social classes, determined mainly by householders' resources (capital), and that induces a character that produces certain behaviors [22]. The house is a reflex of the social identity homeowners wish to display to others to enhance social standing [40] and to respond to how others (the community in general or specifically a social class) consider a house should be [16,31,40,149]. Social class is a prominent social structure rooted in high and low capital or status concerns [22]. Lower classes individuals use visible measures and adopt certain practices to ascend to a higher class, and less-visible measures tend to be diffused within the same class or social network [22]. Thus, even an economically unattractive energy-efficient measure could still be attractive, whereas an economically reasonable EE measure might not be the obvious choice if it does not send a signaling effect for the community [101]. This justifies, in part, the fact that visible [31,40,59] and aesthetic renovations come first in the priorities [125,150,151], even if they are not suggested by energy advisors (e.g., roof tiling, replacement of windows). Aware of this, the European Commission will launch the New European Bauhaus to nurture a new European aesthetic that combines performance with inventiveness, aesthetics, and design [57].

And finally, houses are markers of the cultural environment around the householders [42,152,153]. A culture-based approach to behavior, through an "energy cultures" conceptual framework, suggests that energy behavior is as influenced by the material culture as by cognitive norms and energy practices [43].

6.6. The Techno-Economic Model Gaps Revealed by the Socio-Technical Approach

Drawing from the literature and through a socio-technical perspective about energy improvements in homes, it is possible to unveil the gaps produced by the techno-economic perspective (Table 7).

Table 7. Techno-economic model gaps informed by a socio-technical perspective.

Techno-Economic Approach	Insights from a Socio-Technical Perspective
Buildings as physical structures	Dwellings imbued with attached meanings [25,39,40]
EE improvements	EE improvements as part of other types of improvements and adaptations inside the dwelling [31,55,123,126,134,144,146,147]
On time renovation (single event)	Step by step renovations [55,143]
Renovations as building physical changes	Activity for all days involving shared objects, skills and understandings [16,25,40,154]
Financial, saving energy and environmental benefits	Other significant qualities of home renovation [19,40,127,154]
Universal standards concerned with comfort in relation to EE	Comfort in terms of standout social expectations and adaptive strategies [25]
Decisions as a one-time moment	Process that precedes the decision and domestic context from which emerge [19,143]
Homeowners as a homogeneous group	Differentiated dwellers [19,31,55,126]
Homeowners as single players in the decision-making	Multiple decision-makers inside the household domestic life and negotiation between them due to their interaction in home organization [19,25,154]
Household as an isolated unit apart from social context	Social values and norms around the household are paramount with interpersonal contacts having a great influence [16,19,22,31,40,125,150,154]

6.7. Towards a Comprehensive Influences' Framework on Decision-Making

A drivers and barriers framework or a polarized personal vs. contextual characterization of influences reduces the problem of the EE gap to a technical analysis under the assumptions of individual decision-makers [19]. Within a newly situated approach, an important distinction is made between isolable influences and those influences, which are deeper fundamentals of renovating. This requires the best possible realistic representation of the decision process and a fuller account of specific onsite householders' needs and capacities [5]. Actually, decisions can be understood as embedded in the "practice of dwelling", and the readiness for decisions regarding renovation is created, or not, in this practice [143]. Thus, to identify those deep influences, navigating between behavioral research on EE to its sociological critique is required [19].

In an attempt to understand what is underlined in the initial homeowners' intentions to renovate, Gram-Hanssen [21] argued there is tension in the early stages. Four areas define this tension, as depicted in Figure 6. The majority of policy efforts so far are focused on the bottom left part of the figure: renovations done out of necessity (mainly for repair and maintenance—"wear and tear") and renovations done because of an interest in the result (product) of the renovation (mainly comfort, energy savings, CO_2 reduction). However, owners can also aspire to do something new because of changes in their personal taste or to follow new trends (lifestyle), or even because they enjoy working on the project itself (*project*). In fact, recent scholarships pinpointed that these intentions are frequently the main drivers for many of the renovations that happen in homes [16]. If energy renovations are processes that are connected to a wide variety of influences and background conditions, shifting the focus from the outcome of decisions to attention toward the process that leads to readiness for making the decision seems necessary. Thus, there is a need to be better cognizant of the lived experience of households, their multiple perceptions, their housing aspirations, and their daily routines. This creates a comprehensive perspective where behavioral and sociological factors determine the renovations' undertaking interweave with techno-economic factors [76]. Table 8 summarizes the influences on homeowners' decisions from a comprehensive perspective of decision [16,17,19,31,34,35,40,86,126,127,134,147,154–156].

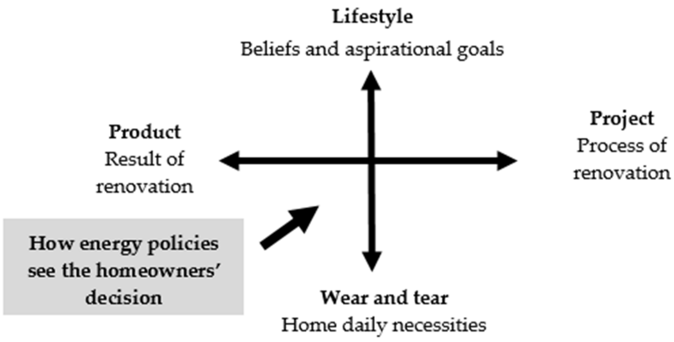

Figure 6. Four main areas of decision define the tension in the early stages of decision (adapted from [21]).

Table 8. Decisive factors on homeowners' decisions informed by a socio-technical perspective.

Usually Identified	Sporadically Identified
Cognitive awareness and information	
Expert advice, Energy audits, Expected cost savings	Availability and creditability of information; Social learning; Peer advice (interpersonal and impersonal trust); Trust towards installers and advisers; Information source type
Personal norms, values and attitudes (attitude towards the result)	
Pro-environmental preferences; Comfort concerns; Aesthetic concerns and improvements	Cozy home; Quality of life enhancement; Perceptions about renovating and homes; Time preference; Stage of life course beliefs; Taste preferences and affinities (Low carbon and smart technologies -tech-savvy, house design, redecoration); Use of technology in living area; Worldviews (altruistic or egocentric); Perceived behavior control about renovating; Moral obligations towards the environment; "Warm glow" effect; Social-ecological values; Environment-related pessimism; Uncertainties about climate change; Independency in energy supply
Experience and skills (attitude towards the process)	
	Past experience; DIY propensities, technical skills and know how; Astute project management skills; Innovativeness; Perceived capabilities and confidence to search info and act
Household characteristics and dynamics	
Age, education, income and employment, ethnicity; Size, composition (number of children)	Occupation; Gender; Decision-making roles; Routines and habits (maintain or change); Room occupancy profiles; Competing needs for spaces inside the home; Fluctuations of household composition; Family comfort patterns; Safety and easy-use of home facilities; Adaptation to dwellers' physical abilities; Number of people at home in midday hours; Number of parties living in the house; Location (rural or urban)
Salient events and life cycles (triggers)	
Moving home	Disruption of routine (new born, children leaving home, retiring, heating system failure, tenants moving, personal/family event); Anticipate family events/phases and future house practice; Beginning or end of a new life cycle

Table 8. *Cont.*

Usually Identified	Sporadically Identified
Beliefs about renovations consequences	
Reduction in energy costs, House value, Good investment; Immediate benefits; Up-to-date technologies; Technical problem repaired	Functional requirements and the quality of living; Aspiration related to aesthetics; New lifestyle, status or prestige aspiration; Self- sufficiency; Preserving environment; Doubts about work going wrong (not be done on time or at all; properly or to a high standard); Uncertainties about financial benefits; Doubts about desired effects achievements; Concerns about damage to the structure (e.g., mildew); Uncertainties on cost and energy savings; Societal benefits
Social influences (lifestyles and social norms)	
	Descriptive norms (what others do) Injunctive norms (what others expect); Perceived social influence; Perceived disapproval of behavior by relevant persons; Indoor conditions to socialize; Enhance social standing; Fashion and trends created by society and products industry; Building identity and self-identity mismatch; Systems used by reference persons; Positive experiences by peers; Social support; Social comparison in saving energy; Social networks influence, Peer-to-peer marketing; Neighborhood attachment
Subjective perceptions, attached meanings and emotions	
	Perceived comfort and livability; Worth of investment; House appropriateness; Emotional and symbolic connection to the home; Interests after heritage
Physical property characteristics	
Size, age, construction period, type, insulation, heating system	Number of different types of rooms; Living spaces arrangements; Infrastructure availability in the urban zone; Physicality of house ageing; Renovation necessity, Insufficient adaptability; Renovations since construction; State of energy performance; Regional characteristics
Home tenure	
Ownership, mortgage	Duration of tenure

6.8. The Role of Heterogeneity in Understanding Decision-Making

The contributions gathered so far highlight the importance of considering heterogeneity as a factor to understand underlying reasons within the distinctive behaviors on energy improvements. It is not recently that homeowners' archetypes have been adopted; however, it was more frequently considered in terms of socio-demographics (educational background, age), socio-economics (occupation, income), and house type [59,157–159]. Introducing a socio-technical approach provides the theoretical background to understand the several ways homeowners see and foresee their houses: (a) as a project (linked to DIY skills) [106,160]; (b) as a pleasure/haven (linked with comfort, luxury, and quality) [106,160]; (c) as a step up (linked to property value); (d) as a home (linked to updating decor, furniture, and appliances); (e) as a necessity (linked to pressures of life) [160]; (f) as a shelter (linked to safety and security) [106,160]; (g) as a place to live (linked to functionality, convenience, and environmental issues) and (h) as an arena for activities (linked to simple and environmentally conscious lifestyles) [106]. In practice, they represent different images and practical constructions of the home as well as different awareness and knowledge backgrounds. They underline also how households' emotional and symbolic connections with their homes impact on their expectations of comfort and subsequent actions [106]. Thus, the home seen with a specific meaning communicates a material and symbolic expression of the inhabitants, their tastes, priorities, relationships, and social context, which are constantly subject to new requirements over time (e.g., changes in taste, new products available or personal economy improvement) [106]. Understand houses through this perspective gives useful insights to categorize homeowners in several possible groups or at least in two major groups, such as, the motivated and unmotivated or simply the experienced and non-experienced (Table 9).

Table 9. Recent attempts to create homeowners' archetypes for understanding home renovation decisions.

Studies	Homeowners' Architypes		
[7]	Motivated		Unmotivated
[161]	Adopter		Non-adopter
[74]	Renovator		Potential renovator
[162]	Experienced		Non experienced
[15]	Energy group		Standard group
[163]	DIY owner	Well-kept house owner	Aesthetic owner
[13]	The conscious The self-confident (informed, unaware or handy)		
[127]	Technology enthusiast (normally is a tech-savvy)		
[160]	The Idealist Restorer The Pragmatist (functional or aesthetic) The Affluent Service Seeker The Stalled (lack of finance or pressure of life) The Property Ladder Climber		
[88,126,164–166]	(by gender) Woman		Man

These taxonomies also depend, to a higher degree, on whether homeowners consider themselves as individuals or as part of a group. Inside a group, social identity represents people acting based on the identity that is prominent [63]. These groups can be formed at the administrative (e.g., citizens of a country, neighborhood/village) or at the personal and social level (technology enthusiasts, interior design followers, etc.) [127].

Some salient issue in the literature linked with the heterogeneity subject is gender. Gender studies play today a central role to understand heterogeneity [31,40], noticeable by the growing number of studies. Both feminine and masculine understandings of energy consumption, technology, and practices are paramount to be considered to discuss renovation behaviors [164]. Because women play a major role in home daily energy consumption practices, and tend to be more interested in visible measures and aesthetic choices [164], harnessing their interest in energy improvements can be imperative [126]. On the opposite hand, technologies emerge within inherited masculine domains through what men express their self-expression, technical know-how, and their dominion on energy monitoring and management [164]. Therefore, also masculine roles influence, to some extent, energy choices inside the house [165]. Gender issues are also present when additional coordination and change of practices is needed to deal with new EE technologies. Studies revealed that this can exacerbate gender inequalities in the division of household labor [167].

In sum, these categories still do not provide the complete picture. However, they convey an understanding of the complexity of energy decisions that are far from rational [106]. However, in response to the socio-technical challenges of energy renovation, a differentiated renovation approach with house owners grouped according to similar behavioral patterns together with dwelling and household characteristics can significantly improve energy-saving potential compared with the conventional methods (that tend to standardize occupant behavior) [42,159,160]. For example, a possible shift in policy strategies for non-adopters or unmotivated owners, could be to consider barriers as the main focus to understand in more detail the influences that hinder their interest [161]. On the contrary, for adopters or potential renovators, disclosing the drivers can be more noteworthy [161]. When trying to approach specific groups, several challenges can be faced when it comes to motivation. As an example, improving coziness and aesthetics, rather than energy saving economy is more important for the ones that see the house as a project, a pleasure, or a home [106]. Practical systems and financial factors are more significant than following new technology trends for the ones that see the house as a place to live and to do activities [106].

7. Discussion

Neoclassical economics and, more lately, behavioral economics were the first theoretical frameworks used to explain homeowners' decisions with regard to energy improvements in private buildings. Drawn from these theories, policymakers established their interventions to change energy behaviors in houses based economic and pro-environmental-related arguments and on building technology development. However, these assumptions would provide limited effectiveness to achieve sustainable goals for houses [19]. These models, still underpinning much of today's building EE policy instruments, programs, and research, reflect an automatic and sometimes unrealistic view of people with respect to why and how they decide about energy issues [130]. In fact, these approaches were useful in a first stage to identify decisional barriers and drivers for EE but insufficient to fully explain the underlying process of decision [22]. They largely omit consideration of larger scale and more intricate behavioral issues, social contexts, and many other homeowners' expectations that shape the habits and practices behind energy use [130]. Thus, rethinking current models to explain people's behaviors regarding energy activities in homes became critical for policies, programs, and research.

One of the most relevant contributions from several intellectual resources suggests that motivational policy instruments should be more attentive to factors that precede energy-related decisions. It is not only a question of giving the homeowners the right techno-economic information, they already carry with them a personal "baggage" they use routinely when making decisions (e.g., beliefs, values, norms, established habits, know-how, experience). Additionally, contextual domains are also involved, which comprise variables specific to each individual (e.g., technical skills, know-how) and variables shared by multiple individuals (e.g., social norms). Thus, working with social and environmental psychology and not exclusively with cognitive psychology is already possible due to the ground-breaking research that is already available to be used by policy makers.

To better understand the interactions between context and behavior, many of the latest developments in research also embrace a sociological perspective on energy improvements in private houses [12]. Social potential is a formulation that complements and transcends technical and behavioral potential [130]. Social structures interpenetrate individual actions, and a dynamic relationship between behavioral change and social norms exists [168]. These norms are, in fact, instrumental drivers of personal norms and values [169]. Social scientists are very aware that looking through the lenses of individual choice is not enough to explain behaviors and that socially shared practices that constitute domestic life play an important role in shaping decisions [19]. This social point of view on energy decisions helps to account for the often conflicting issues people have to deal with when making decisions [170].

This sociological perspective also envisions energy improvements in a way that is rarely considered in current policy models. It is framed as a social practice comparable to many other home improvements as reproduced activities over time. A shift needs to be made in policy making to address the small and progressive renovations that are implemented in existing private buildings rather than be exclusively focused on target deep renovations to happen.

Another great challenge to conventional policy models brought by social perspectives of behavior is that they need to include the social dimensions that houses represent to their inhabitants, which have an ultimate impact on the way differentiated homeowners implement energy improvements. These social dimensions symbolize the several personal meanings and social conveniences, and practicalities that householders attribute to their homes.

These socio-behavioral perspectives about people and their choices brought to light the importance that heterogeneity has for future policy making. Although more research is needed, valuable insights are already available for the categorization of house owners' in groups represented by similar behavioral patterns and renovation styles. Drawn from this, it is salient the great research developments that are happening about gender roles on energy decisions within the household domain.

Hence, new perspectives were brought by recent research about the close examination that needs to be made to the manifold interrelation between techno-economic issues and behavioral and sociological factors. In fact, several pieces of the literature highlight that people, society, and technology shape each other in multiple dimensions, and this should not be underestimated by policy makers. An "energy cultures" framework suggests that consumer energy behavior 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 design) and energy practices (e.g., activities, processes) [43].

Home energy research has made important developments during the last decades, becoming gradually more behaviorally and socially comprehensive, which comprises to be further problem, interdisciplinary and heterogeneous-oriented. These approaches enlightened policy makers on how to: target homeowners' groups, expand the scope of energy renovation, consider existing energy socio-cultural elements on their agendas, or convince homeowners to shift unsustainable energy practices to match policy goals [42]. Further cross-disciplinary studies are needed where qualitative methods and citations to social science and humanities studies need to be enlarged [14] as well as discrete models, based on context-sensitive empirical data, should also be implemented [171].

Although multiple search methods have been adopted to try to obtain all relevant literature for this narrative review, two main study limitations can be identified. The first is that the literature on domestic energy research is rapidly growing, and probably new developments can be released in a shorter time. The other limitation is that although narrative reviews are evidence-based, they are much more prone to selection bias because they are less systematic than others [172]. They are more descriptive, and they offer authors' subjective perspectives on a focused but broader topic [172]. Thus, the resulting findings could be biased towards the lenses of the author's experience, and some concepts or viewpoints on the topic could eventually not be mentioned. Other research methodologies should also be adopted to enable a more in-depth coverage of the interdisciplinary character of this subject which could include interviews with homeowners and representatives of different of the mentioned disciplines.

8. Conclusions

Over the last decades, energy researchers have been offering valuable outcomes for energy policymakers to be able to make scientifically valid and socially relevant decisions. However, these outcomes evolved over the years. Researchers started by developing EE technologies and standard economics frameworks to explain influences on decisions (assuming only a rational-economic energy behavior). Shortly after, behavioral economics theories were also introduced into domestic energy research (recognizing that irrationality also exists in energy decisions). Until now, these models have nurtured energy policy programs. After significant criticisms pointed to these models, the research agenda has gradually been re-directed to approaches based on other behavioral disciplines in an attempt to better understand individual behavior. This individual behavior is not only linked with the circumstances of the decision moments and their outcomes but also with the conditions and process that lead to readiness for making the decision. Ultimately, investigating social structures, such as the household domain, the social network, or even cultural-related issues, is the newest complementary contribution. Thus, this review aimed to "draw a big picture" on the evolution of these different theoretical models used to inform policies, and synthesizing their main outcomes. Many of these achievements represent opportunities to vastly improve the robustness of policy models and, ultimately, increase their suitability to inform policy design.

The literature review revealed that creating an energy-efficient building stock is actually an urgent societal mission that requires the collaboration of people and society [102], not exclusively advanced technologies and economic resources. Although the integration of human factors into energy policies is still in the early stages, the first studies on the subject have been important in pointing the way for policymakers and encouraging their critical thinking. Understanding human behaviors involves working with cross-disciplinary knowledge between different disciplines. Therefore, in the last decade, the research agenda has been gradually moving towards a socio-technical approach to energy use and interventions in homes. "Soft elements," coming from economics, psychology, social and cultural fields, and physical/technical systems, which include house characteristics and renovation measures, have gradually been examined. They are progressively providing possible answers to solving the EE gap and being a step change in the paradigm of current policy agendas. Despite that traditional discrete energy models will undoubtedly continue to be used to inform policy making, a shift from looking to householders as merely rational energy consumers towards seeing them as parts of a complex socio-technical system is now in progress. What is necessary is that institutional actors stop "turning a blind eye" to these novel insights. Actually, from the literature review, it is noticeable that policy agendas are gradually distancing from technological determinisms to reorganize concepts of innovation not only as a technological undertaking but also as a societally driven enterprise. Findings also revealed two key concepts that characterize domestic energy research: interdisciplinarity and heterogeneity.

This review also highlighted that behavioral and social scientists have been contributing to the home energy research field, providing excellent examples that offer new visions and practical recommendations for topics traditionally addressed by building technology researchers. In the particular case of domestic energy research, attention needs to be given to cross-disciplinary collaborations between researchers of different disciplines to promote the inclusion of societal perspectives. The problem is that the number of writers that reported training in any behavioral and social science disciplines and related areas, such as history, psychology, anthropology, and communication studies, is very low when compared to those who work in the technology and mainstream economics fields [14]. However, specialized behavioral and social experts for home energy issues are emerging in the research and policy network, some of them engineers/building technologists and others already entitled environmental psychologists, sociologists, and anthropologists. However, to effectively inform policies, behavioral and social experts need to develop the ability to provide clear and effective advice to both engineering professionals and policy-makers who are not so much used to working with these topics. The exchange of knowledge to bridge the existing informational gap between them and policy-makers needs to be improved. This way, appropriate communicational channels favoring socio-behavioral insights may develop their potential to inform policies. More formally developed models and methods are needed for engineers, behavioral and social scientists in a shared venture. Without claiming that the task is easy, this paper attempted to provide an optimistic view of how continuing advances in socio-behavioral endeavors may lead to new insights and improved policy making in the near future. Other in-depth undertakings are the subject to further development.

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References

1. Rousselot, M.; Pinto Da Rocha, F. Energy Efficiency Trends in Buildings in the EU. ODYSSEE-MURE Policy Brief. 2021. Available online: https://www.odyssee-mure.eu/publications/policy-brief/buildings-energy-efficiency-trends.pdf (accessed on 3 March 2023).
2. Bukarica, V.; Pešut, A.K.L.D.; Zidar, M. Renovation in Buildings. ODYSSEE-MURE. 2017. Available online: https://www.odyssee-mure.eu/publications/policy-brief/renovation-building.html (accessed on 3 March 2023).
3. Eurostat Distribution of Population by Tenure Status, Type of Household and Income Group, EU-SILC Survey. Available online: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc_lvho02&lang=en (accessed on 22 November 2022).
4. Judson, E.P.; Iyer-Raniga, U.; Horne, R. Greening Heritage Housing: Understanding Homeowners' Renovation Practices in Australia. *J. Hous. Built Environ.* **2014**, *29*, 61–78. [CrossRef]
5. Galvin, R.; Sunikka-Blank, M. Ten Questions Concerning Sustainable Domestic Thermal Retrofit Policy Research. *Build. Environ.* **2017**, *118*, 377–388. [CrossRef]
6. Karpinska, L.; Sławomir, S. Shadow of Single-Family Homes: Analysis of the Determinants of Polish Households' Energy-Related CO_2 Emissions. *Energy Build.* **2022**, *277*, 112550. [CrossRef]
7. Azizi, S.; Nair, G.; Olofsson, T. Analysing the House-Owners' Perceptions on Benefits and Barriers of Energy Renovation in Swedish Single-Family Houses. *Energy Build.* **2020**, *198*, 187–196. [CrossRef]
8. van den Brom, P.; Meijer, A.; Visscher, H. Actual Energy Saving Effects of Thermal Renovations in Dwellings—Longitudinal Data Analysis Including Building and Occupant Characteristics. *Energy Build.* **2019**, *182*, 251–263. [CrossRef]
9. Kerr, N.; Winskel, M. *Private Household Investment in Home Energy Retrofit: Reviewing the Evidence and Designing Effective Public Policy*; ClimateXChange: Edinburgh, UK, 2018; pp. 1–21.
10. Zakeri, B.; Paulavets, K.; Barreto-gomez, L.; Echeverri, L.G.; Pachauri, S.; Boza-kiss, B.; Zimm, C.; Rogelj, J.; Creutzig, F.; Ürge-vorsatz, D.; et al. Pandemic, War, and Global Energy Transitions. *Energies* **2022**, *15*, 6114. [CrossRef]
11. Wilson, C.; Dowlatabadi, H. Models of Decision Making and Residential Energy Use. *Annu. Rev. Environ. Resour.* **2007**, *32*, 169–203. [CrossRef]
12. Steg, L.; Perlaviciute, G.; Sovacool, B.K.; Bonaiuto, M.; Diekmann, A.; Filippini, M.; Hindriks, F.; Bergstad, C.J.; Matthies, E.; Matti, S.; et al. A Research Agenda to Better Understand the Human Dimensions of Energy Transitions. *Front. Psychol.* **2021**, *12*. [CrossRef]
13. Risholt, B.; Berker, T. Success for Energy Efficient Renovation of Dwellings—Learning from Private Homeowners. *Energy Policy* **2013**, *61*, 1022–1030. [CrossRef]
14. Sovacool, B.K. What Are We Doing Here? Analyzing Fifteen Years of Energy Scholarship and Proposing a Social Science Research Agenda. *Energy Res. Soc. Sci.* **2014**, *1*, 1–29. [CrossRef]
15. Stieß, I.; Dunkelberg, E. Objectives, Barriers and Occasions for Energy Efficient Refurbishment by Private Homeowners. *J. Clean. Prod.* **2013**, *48*, 250–259. [CrossRef]
16. Bartiaux, F.; Gram-Hanssen, K.; Fonseca, P.; Ozoliņa, L.; Christensen, T.H. A Practice-Theory Approach to Homeowners' Energy Retrofits in Four European Areas. *Build. Res. Inf.* **2014**, *42*, 525–538. [CrossRef]
17. Friege, J.; Chappin, E. Modelling Decisions on Energy-Efficient Renovations: A Review. *Renew. Sustain. Energy Rev.* **2014**, *39*, 196–208. [CrossRef]
18. Bergquist, P.; Mildenberger, M.; Stokes, L.C. Combining Climate, Economic, and Social Policy Builds Public Support for Climate Action in the US. *Environ. Res. Lett.* **2020**, *15*. [CrossRef]
19. Wilson, C.; Crane, L.; Chryssochoidis, G. Why Do Homeowners Renovate Energy Efficiently? Contrasting Perspectives and Implications for Policy. *Energy Res. Soc. Sci.* **2015**, *7*, 12–22. [CrossRef]
20. Ebrahimigharehbaghi, S.; Qian, Q.K.; De Vries, G.; Visscher, H.J. From Collective to Individual Decision-Making: Barriers and Opportunities to Improve the Success Rate of the Energy Retrofits in the Dutch Owner-Occupied Sector. In Proceedings of the CLIMA 2022 The 14th REHVA HVAC World Congress, Rotterdam, The Netherlands, 22–25 May 2022; pp. 1–8.
21. Gram-Hanssen, K. Existing Buildings—Users, Renovations and Energy Policy. *Renew. Energy* **2014**, *61*, 136–140. [CrossRef]
22. Della Valle, N.; Bertoldi, P. Promoting Energy Efficiency: Barriers, Societal Needs and Policies. *Front. Energy Res.* **2022**, *9*. [CrossRef]
23. DellaVigna, S. Psychology and Economics: Evidence from the Field. *J. Econ. Lit.* **2009**, *47*, 315–372. [CrossRef]
24. Geels, F.W.; Sareen, S.; Hook, A.; Sovacool, B.K. Navigating Implementation Dilemmas in Technology-Forcing Policies: A Comparative Analysis of Accelerated Smart Meter Diffusion in the Netherlands, UK, Norway, and Portugal (2000–2019). *Res. Policy* **2021**, *50*, 104272. [CrossRef]
25. Ellsworth-Krebs, K.; Reid, L.; Hunter, C.J. Home -ing in on Domestic Energy Research: "House," "Home," and the Importance of Ontology. *Energy Res. Soc. Sci.* **2015**, *6*, 100–108. [CrossRef]
26. Ingeborgrud, L.; Heidenreich, S.; Ryghaug, M.; Skjølsvold, T.M.; Foulds, C.; Robison, R.; Buchmann, K.; Mourik, R. Expanding the Scope and Implications of Energy Research: A Guide to Key Themes and Concepts from the Social Sciences and Humanities. *Energy Res. Soc. Sci.* **2020**, *63*. [CrossRef]
27. Mundaca, L.; Zhu, X.; Hackenfort, M. Behavioural Insights for Sustainable Energy Use. *Energy Policy* **2022**, *171*, 113292. [CrossRef]
28. Gifford, R. Environmental Psychology Matters. *Annu. Rev. Psychol.* **2014**, *65*, 541–579. [CrossRef]

29. Steg, L.; Perlaviciute, G.; van der Werff, E. Understanding the Human Dimensions of a Sustainable Energy Transition. *Front. Psychol.* **2015**, *6*, 805. [CrossRef] [PubMed]
30. Nielsen, K.S.; Clayton, S.; Stern, P.C.; Dietz, T.; Capstick, S.; Whitmarsh, L. How Psychology Can Help Limit Climate Change. *Am. Psychol.* **2021**, *76*, 130–144. [CrossRef]
31. Baginski, J.P.; Weber, C. A Consumer Decision-Making Process? Unfolding Energy Efficiency Decisions of German Owner-Occupiers. *SSRN Electron. J.* **2017**. [CrossRef]
32. Ptashnyk, I. Advancing Energy Policy. Lessons on the Integration of Social Sciences and Humanities. *J. Contemp. Eur. Stud.* **2019**, *27*, 127–128. [CrossRef]
33. Sovacool, B.K.; Ryan, S.E.; Stern, P.C.; Janda, K.; Rochlin, G.; Spreng, D.; Pasqualetti, M.J.; Wilhite, H.; Lutzenhiser, L. Integrating Social Science in Energy Research. *Energy Res. Soc. Sci.* **2015**, *6*, 95–99. [CrossRef]
34. Gram-Hanssen, K. Retrofitting Owner-Occupied Housing: Remember the People. *Build. Res. Inf.* **2014**, *42*, 393–397. [CrossRef]
35. Karvonen, A. Towards Systemic Domestic Retrofit: A Social Practices Approach. *Build. Res. Inf.* **2013**, *41*, 563–574. [CrossRef]
36. Wang, X.; Ghanem, D.A.; Larkin, A.; McLachlan, C. How the Meanings of 'Home' Influence Energy-Consuming Practices in Domestic Buildings. *Energy Effic.* **2021**, *14*. [CrossRef]
37. Malone, E.L.; Betsill, M.; Hughes, S.; Kemp, R.; Lutzenhiser, L.; Moezzi, M.; Preston, B.L.; West, T.O. Chapter 6: Social Science Perspectives on Carbon. In *Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report*; Cavallaro, N., Shrestha, G., Birdsey, R., Mayes, M.A., Najjar, R., Reed, S., Romero-Lankao, P., Zhu, Z., Eds.; U.S. Global Change Research Program: Washington, DC, USA, 2018; pp. 264–302.
38. Vlasova, L.; Gram-Hanssen, K. Incorporating Inhabitants Everyday Practices into Domestic Retrofits. *Build. Res. Inf.* **2014**, *42*, 512–524. [CrossRef]
39. Maréchal, K.; Holzemer, L. Unravelling the 'Ingredients' of Energy Consumption: Exploring Home-Related Practices in Belgium. *Energy Res. Soc. Sci.* **2018**, *39*, 19–28. [CrossRef]
40. Tjørring, L.; Gausset, Q. Drivers for Retrofit: A Sociocultural Approach to Houses and Inhabitants. *Build. Res. Inf.* **2019**, *47*, 394–403. [CrossRef]
41. Köhler, J.; Geels, F.W.; Kern, F.; Markard, J.; Onsongo, E.; Wieczorek, A.; Alkemade, F.; Avelino, F.; Bergek, A.; Boons, F.; et al. An Agenda for Sustainability Transitions Research: State of the Art and Future Directions ☆. *Environ. Innov. Soc. Transitions* **2019**, *31*, 1–32. [CrossRef]
42. Liu, G.; Tan, Y.; Huang, Z. Knowledge Mapping of Homeowners' Retrofit Behaviors: An Integrative Exploration. *Buildings* **2021**, *11*, 273. [CrossRef]
43. Stephenson, J.; Barton, B.; Carrington, G.; Gnoth, D.; Lawson, R.; Thorsnes, P. Energy Cultures: A Framework for Understanding Energy Behaviours. *Energy Policy* **2010**, *38*, 6120–6129. [CrossRef]
44. Galvin, R.; Sunikka-Blank, M. The UK Homeowner-Retrofitter as an Innovator in a Socio-Technical System. *Energy Policy* **2014**, *74*, 655–662. [CrossRef]
45. Buser, M.; Carlsson, V. What You See Is Not What You Get: Single-Family House Renovation and Energy Retrofit Seen through the Lens of Sociomateriality. *Constr. Manag. Econ.* **2017**, *35*, 276–287. [CrossRef]
46. Axon, S.; Morrissey, J.; Aiesha, R.; Hillman, J.; Revez, A.; Lennon, B.; Salel, M.; Dunphy, N.; Boo, E. The Human Factor: Classification of European Community-Based Behaviour Change Initiatives. *J. Clean. Prod.* **2018**, *182*, 567–586. [CrossRef]
47. Siddaway, A.P.; Wood, A.M.; Hedges, L. V How to Do a Systematic Review: A Best Practice Guide for Conducting and Reporting Narrative Reviews, Meta-Analyses, and Meta-Syntheses. *Annu. Rev. Psychol.* **2019**, *70*, 747–770. [CrossRef] [PubMed]
48. Ewald, H.; Hirt, J.; Nordhausen, T.; Appenzeller-Herzog, C. Citation Tracking for Systematic Literature Searching: A Scoping Review (CINAHL). *searchRxiv* **2023**. [CrossRef]
49. Bakkalbasi, N.; Bauer, K.; Glover, J.; Wang, L. Three Options for Citation Tracking: Google Scholar, Scopus and Web of Science. *Biomed. Digit. Libr.* **2006**, *3*, 7. [CrossRef]
50. Hu, X.; Rousseau, R.; Chen, J. On the Definition of Forward and Backward Citation Generations. *J. Informetr.* **2011**, *5*, 27–36. [CrossRef]
51. Jaffe, A.B.; Stavins, R.N. The Energy-Efficiency Gap What Does It Mean? *Energy Policy* **1994**, *22*, 804–810. [CrossRef]
52. Mahdavi, A.; Berger, C.; Amin, H.; Ampatzi, E.; Andersen, R.K.; Azar, E.; Barthelmes, V.M.; Favero, M.; Hahn, J.; Khovalyg, D.; et al. The Role of Occupants in Buildings' Energy Performance Gap: Myth or Reality? *Sustainability* **2021**, *13*, 3146. [CrossRef]
53. Gillingham, K.; Keyes, A.; Palmer, K. Advances in Evaluating Energy Efficiency Policies and Programs. *Annu. Rev. Resour. Econ.* **2018**, *10*, 511–532. [CrossRef]
54. Gillingham, K.; Palmer, K. Bridging the Energy Efficiency Gap: Policy Insights from Economic Theory and Empirical Evidence. *Rev. Environ. Econ. Policy* **2014**, *8*, 18–38. [CrossRef]
55. Esser, A.; Dunne, A.; Meeusen, T.; Quaschning, S. *Comprehensive Study of Building Energy Renovation Activities and the Uptake of Nearly Zero-Energy Buildings in the EU*; EU: Luxembourg, 2019.
56. Mainali, B.; Mahapatra, K.; Pardalis, G. Strategies for Deep Renovation Market of Detached Houses. *Renew. Sustain. Energy Rev.* **2021**, *138*, 110659. [CrossRef]
57. European Commission. *A Renovation Wave for Europe—Greening Our Buildings, Creating Jobs, Improving Lives*; European Commission: Brussels, Belgium, 2020.

58. Weiss, J.; Dunkelberg, E.; Vogelpohl, T. Improving Policy Instruments to Better Tap into Homeowner Refurbishment Potential: Lessons Learned from a Case Study in Germany. *Energy Policy* **2012**, *44*, 406–415. [CrossRef]
59. Bravo, G.; Pardalis, G.; Mahapatra, K.; Mainali, B. Physical vs. Aesthetic Renovations: Learning from Swedish House Owners. *Buildings* **2019**, *9*, 12. [CrossRef]
60. Ebrahimigharehbaghi, S.; Qian, Q.K.; de Vries, G.; Visscher, H.J.; De Vries, G.; Visscher, H.J. Application of Cumulative Prospect Theory in Understanding Energy Retrofit Decision: A Study of Homeowners in the Netherlands. *Energy Build.* **2022**, *261*, 111958. [CrossRef]
61. Jakob, M. The Drivers of and Barriers to Energy Efficiency in Renovation Decisions of Single-Family Home-Owners. *CEPE Work. Pap. Ser.* **2007**, *18*, 1–30.
62. Galvin, R. Why German Households Won't Cover Their Roofs in Photovoltaic Panels: And Whether Policy Interventions, Rebound Effects and Heat Pumps Might Change Their Minds. *Renew. Energy Focus* **2022**, *42*, 236–252. [CrossRef]
63. Ekambaram, A.; Gorantonaki, E.; Von der Leyen, B.S. Learning and Energy-Efficient Renovation of Residential Buildings: The User Perspective. *Eur. Conf. Knowl. Manag.* **2022**, *23*, 352–354. [CrossRef]
64. de Wilde, M. The Sustainable Housing Question: On the Role of Interpersonal, Impersonal and Professional Trust in Low-Carbon Retrofit Decisions by Homeowners. *Energy Res. Soc. Sci.* **2019**, *51*, 138–147. [CrossRef]
65. Howarth, R.B.; Andersson, B. Market Barriers to Energy Efficiency. *Energy Econ.* **1993**, *15*, 262–272. [CrossRef]
66. Bertoldi, P. Policies for Energy Conservation and Sufficiency: Review of Existing Policies and Recommendations for New and Effective Policies in OECD Countries. *Energy Build.* **2022**, *264*, 112075. [CrossRef]
67. Mandel, T. Policy Design for Energy Efficiency First: Taking Stock of Measures for Moving from Principle to Practice. *ECEEE Summer Study Proc.* **2021**, 285–296. [CrossRef]
68. Reddy, A.K.N. Barriers to Improvements in Energy Efficiency. *Energy Policy* **1991**, *19*, 953–961. [CrossRef]
69. Palm, J.; Reindl, K. Understanding Barriers to Energy-Efficiency Renovations of Multifamily Dwellings. *Energy Effic.* **2018**, *11*, 53–65. [CrossRef]
70. Ohene, E.; Chan, A.P.C.; Darko, A. Prioritizing Barriers and Developing Mitigation Strategies toward Net-Zero Carbon Building Sector. *Build. Environ.* **2022**, *223*, 109437. [CrossRef]
71. Blomqvist, S.; Odlund, L. Understanding Energy Efficiency Decisions in the Building Sector—A Survey of Barriers and Drivers in Sweden. *Clean. Eng. Technol.* **2022**, *9*, 100527. [CrossRef]
72. Dolšak, J. Determinants of Energy Efficient Retrofits in Residential Sector: A Comprehensive Analysis. *Energy Build.* **2023**, *282*. [CrossRef]
73. Economidou, M.; Todeschi, V.; Bertoldi, P.; D'Agostino, D.; Zangheri, P.; Castellazzi, L. Review of 50 Years of EU Energy Efficiency Policies for Buildings. *Energy Build.* **2020**, *225*, 110322. [CrossRef]
74. Ebrahimigharehbaghi, S.; Qian, Q.K.; Meijer, F.M.; Visscher, H.J. Unravelling Dutch Homeowners' Behaviour towards Energy Efficiency Renovations: What Drives and Hinders Their Decision-Making? *Energy Policy* **2019**, *129*, 546–561. [CrossRef]
75. Ebrahimigharehbaghi, S.; Qian, Q.K.; Meijer, F.M.; Visscher, H.J. Homeowners' Decisions Towards Energy Renovations - Critical Stages and Sources of Information. *E3S Web Conf.* **2019**, *111*, 03014. [CrossRef]
76. Galvin, R. Why German Homeowners Are Reluctant to Retrofit. *Build. Res. Inf.* **2014**, *42*, 398–408. [CrossRef]
77. Shirani, F.; Sullivan, K.O.; Hale, R.; Pidgeon, N.; Henwood, K. From Active Houses to Active Homes: Understanding Resident Experiences of Transformational Design and Social Innovation. *Energies* **2022**, *15*, 7441. [CrossRef]
78. Bergman, N.; Foxon, T.J. Reframing Policy for the Energy Efficiency Challenge: Insights from Housing Retrofits in the United Kingdom. *Energy Res. Soc. Sci.* **2020**, *63*, 101386. [CrossRef]
79. Wiese, C.; Larsen, A.; Pade, L.L. Interaction Effects of Energy Efficiency Policies: A Review. *Energy Effic.* **2018**, *11*, 2137–2156. [CrossRef]
80. Sterner, T.; Robinson, E.J.Z. Selection and Design of Environmental Policy Instruments. *Handb. Environ. Econ.* **2018**, *4*, 231–284. [CrossRef]
81. Economidou, M.; Labanca, N.; Castellazzi, L.; Serrenho, T.; Bertoldi, P.; Zancanella, P.; Paci, D.; Panev, S.; Gabrielaitiene, I. *Assessment of the First National Energy Efficiency Action Plans under the Energy Efficiency Directive*; Synthesis Report Title; European Commission: Brussels, Belgium, 2016.
82. International Energy Agency Policies Database. Available online: https://www.iea.org/policies?sector=Buildings (accessed on 13 November 2022).
83. ADEME; Enerdata; Fraunhofer ISI; EASME; EnR Mure Database. Available online: https://www.measures.odyssee-mure.eu/energy-efficiency-policies-database.html#/ (accessed on 13 November 2022).
84. Economidou, M.; Labanca, N.; Serrehno, T.; Castellazzi, L.; Panev, S.; Zancanella, P.; Broc, J.-S.; Bertoldi, P. *Assessment of the Second National Energy Efficiency Action Plans under the Energy Efficiency Directive*; EUR 29272 EN; Publications Office of the European Union: Luxembourg, 2018.
85. Segurado, P.d.A. *Energy Renovation of Buildings in Spain and the EU. Lessons Learned and Main Recommendations*; Background: Retrofitting as a Key Element of the Energy Planning; SSRN: Rochester, NY, USA, 2021.
86. Nair, G.; Gustavsson, L.; Mahapatra, K. Owners Perception on the Adoption of Building Envelope Energy Efficiency Measures in Swedish Detached Houses. *Appl. Energy* **2010**, *87*, 2411–2419. [CrossRef]

87. Sesana, M.M.; Salvalai, G. A Review on Building Renovation Passport: Potentialities and Barriers on Current Initiatives. *Energy Build.* **2018**, *173*, 195–205. [CrossRef]
88. Wilhite, H. *Gender Implications of Energy Use and Energy Access*; Energy and Economic Growth; UC Berkeley: Berkeley, CA, USA, 2017.
89. Economidou, M.; Todeschi, V.; Bertoldi, P. *Accelerating Energy Renovation Investments in Buildings—Financial and Fiscal Instruments across the EU*; European Commission: Brussels, Belgium, 2019; ISBN 978-92-76-12195-4.
90. Bertoldi, P.; Rezessy, S. Voluntary Agreements for Energy Efficiency: Review and Results of European Experiences. *Energy Environ.* **2007**, *18*, 37–73. [CrossRef]
91. Bertoldi, P.; Economidou, M.; Palermo, V.; Boza-Kiss, B.; Todeschi, V. *How to Finance Energy Renovation of Residential Buildings: Review of Current and Emerging Financing Instruments in the EU*; John Wiley and Sons Ltd.: Hoboken, NJ, USA, 2021; Volume 10.
92. Bertoldi, P.; Mosconi, R. Do Energy Efficiency Policies Save Energy? A New Approach Based on Energy Policy Indicators (in the EU Member States). *Energy Policy* **2020**, *139*, 111320. [CrossRef]
93. Boza-Kiss, B.; Bertoldi, P.; Della Valle, N.; Economidou, M.; European Commission. *One-Stop Shops for Residential Building Energy Renovation in the EU: Analysis & Policy Recommendations*; European Commission: Brussels, Belgium, 2021; ISBN 9789276401001.
94. Palermo, V.; Rybak, E.; Sukhodub, I.; Bertoldi, P. *; European Commission. CoM EAST: Overall Assessment and in-Depth SECAPs Analysis*; European Commission: Brussels, Belgium, 2022; ISBN 9789276519720.
95. Rivas, S.; Urraca, R.; Palermo, V.; Bertoldi, P. Covenant of Mayors 2020: Drivers and Barriers for Monitoring Climate Action Plans. *J. Clean. Prod.* **2022**, *332*. [CrossRef]
96. RenoWiki, an Initiative of the BUILD UPON Project. Available online: https://buildupon2.eu/initiatives/ (accessed on 3 March 2023).
97. Giraudet, L.G. Energy Efficiency as a Credence Good: A Review of Informational Barriers to Energy Savings in the Building Sector. *Energy Econ.* **2020**, *87*, 104698. [CrossRef]
98. Petkov, I.; Knoeri, C.; Hoffmann, V.H. The Interplay of Policy and Energy Retrofit Decision-Making for Real Estate Decarbonization. *Environ. Res. Infrastruct. Sustain.* **2021**, *1*, 035006. [CrossRef]
99. Aune, M.; Godbolt, Å.L.; Sørensen, K.H. Mismatch or Misunderstanding? Calculation and Qualculation among Economists and Consumers in Their Framings of the Electricity Market. *Acta Sociol. (United Kingd.)* **2016**, *59*, 347–361. [CrossRef]
100. Moezzi, M.; Lutzenhiser, L. Beyond Energy Behaviour: A Broader Way to See People for Climate Change Technology Planning. In *Energy and Behaviour: Towards a Low Carbon Future*; Academic Press: Cambridge, MA, USA, 2019; pp. 89–106. ISBN 9780128185674.
101. Hargreaves, T.; Middlemiss, L. The Importance of Social Relations in Shaping Energy Demand. *Nat. Energy* **2020**, *5*, 195–201. [CrossRef]
102. Foulds, C.; Royston, S.; Berker, T.; Nakopoulou, E.; Bharucha, Z.P.; Robison, R.; Abram, S.; Ančić, B.; Arapostathis, S.; Badescu, G.; et al. An Agenda for Future Social Sciences and Humanities Research on Energy Efficiency: 100 Priority Research Questions. *Humanit. Soc. Sci. Commun.* **2022**, *9*. [CrossRef] [PubMed]
103. Kelly, S.; Crawford-Brown, D.; Pollitt, M.G. Building Performance Evaluation and Certification in the UK: Is SAP Fit for Purpose? *Renew. Sustain. Energy Rev.* **2012**, *16*, 6861–6878. [CrossRef]
104. Gram-Hanssen, K.; Georg, S.; Christiansen, E.; Heiselberg, P. What next for Energy-Related Building Regulations?: The Occupancy Phase. *Build. Res. Inf.* **2018**, *46*, 790–803. [CrossRef]
105. Tirado Herrero, S.; Nicholls, L.; Strengers, Y. Smart Home Technologies in Everyday Life: Do They Address Key Energy Challenges in Households? *Curr. Opin. Environ. Sustain.* **2018**, *31*, 65–70. [CrossRef]
106. Aune, M. Energy Comes Home. *Energy Policy* **2007**, *35*, 5457–5465. [CrossRef]
107. Murphy, L.C. Policy Instruments to Improve Energy Performance of Existing Owner Occupied Dwellings: Understanding and Insight. *A+BE Archit. Built Environ.* **2016**, *17*, 1–242.
108. Esser, A.; Dunne, A.; Meeusen, T.; Quaschning, S. Determinants for performing energy renovations. In *Comprehensive Study of Building Energy Renovation Activities and the Uptake of Nearly Zero-Energy Buildings in the EU*; EU: Luxembourg, 2019.
109. Stern, P.C.; Dietz, T. The Value Basis of Environmental Concern. *J. Soc. Issues* **1994**, *50*, 65–84.
110. Anker-Nilssen, P. Household Energy Use and the Environment—A Conflicting Issue. *Appl. Energy* **2003**, *76*, 189–196. [CrossRef]
111. Michalek, G.; Meran, G.; Schwarze, R.; Yildiz, Ö. *Nudging as a New "Soft" Tool in Environmental Policy–An Analysis Based on Insights from Cognitive and Social Psychology*; European University Viadrina: Frankfurt, Germany, 2015; 40p.
112. Steg, L.; Vlek, C. Encouraging Pro-Environmental Behaviour: An Integrative Review and Research Agenda. *J. Environ. Psychol.* **2009**, *29*, 309–317. [CrossRef]
113. Michelsen, C.C.; Madlener, R. Homeowners' Preferences for Adopting Innovative Residential Heating Systems: A Discrete Choice Analysis for Germany. *Energy Econ.* **2012**, *34*, 1271–1283. [CrossRef]
114. Noguchi, K.; Kamada, A.; Shrira, I. Cultural Differences in the Primacy Effect for Person Perception. *Int. J. Psychol.* **2014**, *49*, 208–210. [CrossRef]
115. Ajzen, I. The Theory of Planned Behavior. *Organ. Behav. Hum. Decis. Process.* **1991**, *50*, 179–211. [CrossRef]
116. de Groot Judith, I. M; Thøgersen John Values and Pro-Environmental Behaviour. *Environ. Psychol.* **2018**, *28*, 111–133.
117. Hand, M.; Shove, E. Orchestrating Concepts: Kitchen Dynamics and Regime Change in Good Housekeeping and Ideal Home, 1922–2002. *Home Cult.* **2004**, *1*, 235–256. [CrossRef]
118. Damásio, A. *Descartes' Error: Emotion, Reason and the Human Brain*; Random House: New York, NY, USA, 2005.

119. Sibony, A.; Alemanno, A. The Emergence of Behavioural Policy-Making: A European Perspective. In *Nudge and the Law: A European Perspective*; Bloomsbury Academic: London, UK, 2015.
120. Osbaldiston, R.; Schott, J.P. Environmental Sustainability and Behavioral Science: Meta-Analysis of Proenvironmental Behavior Experiments. *Environ. Behav.* **2011**, *44*, 257–299. [CrossRef]
121. Carlsson, F.; Gravert, C.; Johansson-Stenman, O.; Kurz, V. Nudging as an Environmental Policy Instrument. *SSRN Electron. J.* **2019**. [CrossRef]
122. Ayres, I.; Raseman, S.; Shih, A. Evidence from Two Large Field Experiments That Peer Comparison Feedback Can Reduce Residential Energy Usage. *J. Law, Econ. Organ.* **2013**, *29*, 992–1022. [CrossRef]
123. Kerr, N.; Gouldson, A.; Barrett, J. Holistic Narratives of the Renovation Experience: Using Q-Methodology to Improve Understanding of Domestic Energy Retrofits in the United Kingdom. *Energy Res. Soc. Sci.* **2018**, *42*, 90–99. [CrossRef]
124. Bobrova, Y.; Papachristos, G.; Fong, L.; Chiu, L.F. Homeowner Low Carbon Retrofits: Implications for Future UK Policy. *Energy Policy* **2021**, *155*. [CrossRef]
125. Baumhof, R.; Decker, T.; Röder, H.; Menrad, K. Which Factors Determine the Extent of House Owners' Energy-Related Refurbishment Projects? A Motivation-Opportunity-Ability Approach. *Sustain. Cities Soc.* **2018**, *36*, 33–41. [CrossRef]
126. Sunikka-Blank, M.; Galvin, R.; Behar, C. Harnessing Social Class, Taste and Gender for More Effective Policies. *Build. Res. Inf.* **2018**, *46*, 114–126. [CrossRef]
127. Klöckner, C.; Andres, J.; Chebaeva, N.; Dimitrova, E.; Frieden, D.; Koksvik, G.; Koljonen, T.; Lofstrom, E.; Qiu, X.; Royrvik, J.; et al. *An Analysis of the Potential of Advanced Social Science Knowledge in Policymaking—Report No ECHOES 3.3–D3.3 Policy Potential Analysis*; ECHOES: Derio, Spain, 2020.
128. Bobrova, Y.; Papachristos, G.; Cooper, A. Process Perspective on Homeowner Energy Retrofits: A Qualitative Metasynthesis. *Energy Policy* **2022**, *160*. [CrossRef]
129. Gillingham, K.; Tsvetanov, T. Nudging Energy Efficiency Audits: Evidence from A Field Experiment. *J. Environ. Econ. Manag.* **2018**, *90*, 303–316. [CrossRef]
130. Moezzi, M.; Janda, K.B. From "If Only" to "Social Potential" in Schemes to Reduce Building Energy Use. *Energy Res. Soc. Sci.* **2014**, *1*, 30–40. [CrossRef]
131. Walker, S.L.; Lowery, D.; Theobald, K. Low-Carbon Retrofits in Social Housing: Interaction with Occupant Behaviour. *Energy Res. Soc. Sci.* **2014**, *2*, 102–114. [CrossRef]
132. Shove, E.; Walker, G. What Is Energy For? Social Practice and Energy Demand. *Theory, Cult. Soc.* **2014**, *31*, 41–58. [CrossRef]
133. Gram-Hanssen, K.; Georg, S. Energy Performance Gaps: Promises, People, Practices. *Build. Res. Inf.* **2018**, *46*, 1–9. [CrossRef]
134. Judson, E.P.; Maller, C. Housing Renovations and Energy Efficiency: Insights from Homeowners Practices. *Build. Res. Inf.* **2014**, *42*, 501–511. [CrossRef]
135. Süsser, D.; Martin, N.; Stavrakas, V.; Gaschnig, H.; Talens-Peiró, L.; Flamos, A.; Madrid-López, C.; Lilliestam, J. Why Energy Models Should Integrate Social and Environmental Factors: Assessing User Needs, Omission Impacts, and Real-Word Accuracy in the European Union. *Energy Res. Soc. Sci.* **2022**, *92*. [CrossRef]
136. Lopes, J.; Oliveira, R.; Abreu, M.I. The Sustainability of the Construction Industry in Sub-Saharan Africa: Some New Evidence from Recent Data. *Procedia Eng.* **2017**, *172*, 657–664. [CrossRef]
137. Ingold, T. The Perception of the Environment: Essays in Livelihood, Dwelling, and Skill. *Technol. Cult.* **2021**, *43*, 401–402. [CrossRef]
138. Hansen, A.R.; Gram-Hanssen, K.; Knudsen, H.N. How Building Design and Technologies Influence Heat-Related Habits. *Build. Res. Inf.* **2018**, *46*, 83–98. [CrossRef]
139. Madsen, L.V. Materialities Shape Practices and Notions of Comfort in Everyday Life. *Build. Res. Inf.* **2018**, *46*, 71–82. [CrossRef]
140. Shove, E.; Pantzar, M.; Watson, M. *The Dynamics of Social Practice: Everyday Life and How It Changes*; Sage: Thousand Oaks, CA, USA, 2012; ISBN 9781446250655.
141. Gram-Hanssen, K. Understanding Change and Continuity in Residential Energy Consumption. *J. Consum. Cult.* **2011**, *11*, 61–78. [CrossRef]
142. Schäfer, M.; Jaeger-Erben, M.; Bamberg, S. Life Events as Windows of Opportunity for Changing Towards Sustainable Consumption Patterns? *J. Consum. Policy* **2012**, *35*, 65–84. [CrossRef]
143. Fyhn, H.; Baron, N. The Nature of Decision Making in the Practice of Dwelling: A Practice Theoretical Approach to Understanding Maintenance and Retrofitting of Homes in the Context of Climate Change. *Soc. Nat. Resour.* **2017**, *30*, 555–568. [CrossRef]
144. Kerr, N.J. The Rationale for Retrofit: A Multi-Level, Interdisciplinary Perspective on the Energy Efficient Retrofit of Existing Residential Buildings. Ph.D. Thesis, University of Leeds, Leeds, UK, 2018; pp. 1–443.
145. Janson, U. *Passive Houses in Sweden Experiences from Design and Construction Phase*; Lund University: Lund, Sweden, 2008; ISBN 9789185147243.
146. Lutzenhiser, L. Through the Energy Efficiency Looking Glass. *Energy Res. Soc. Sci.* **2014**, *1*, 141–151. [CrossRef]
147. Fyhn, H.; Søraa, R.A.; Solli, J. Why Energy Retrofitting in Private Dwellings Is Difficult in Norway: Coordinating the Framing Practices of Government, Craftspeople and Homeowners. *Energy Res. Soc. Sci.* **2019**, *49*, 134–142. [CrossRef]
148. Reiter, U.; Palacios, A.; Weinberg, L.; Lienhard, L.; Schmid, J.; Jakob, M.; Mathiesen, B.V.; Ilieva, L.S.; Maya-Drysdale, D.W. Energy Efficiency and Refurbishment Strategies in Buildings. 2022. Available online: https://vbn.aau.dk/ws/portalfiles/portal/478191212/sEEnergies_Factsheet_WP1_Buildings.pdf (accessed on 3 March 2023).

149. Abreu, M.I.; de Oliveira, R.A.F.; Lopes, J. Housing Energy-Related Renovations from a Lifestyle and Social Standards Perspective:Insights from Portuguese Homeowners. *E3S Web Conf.* **2022**, *347*, 02011. [CrossRef]
150. Sunikka-Blank, M.; Galvin, R. Irrational Homeowners? How Aesthetics and Heritage Values Influence Thermal Retrofit Decisions in the United Kingdom. *Energy Res. Soc. Sci.* **2016**, *11*, 97–108. [CrossRef]
151. Pardalis, G.; Mahapatra, K.; Bravo, G.; Mainali, B. Swedish House Owners' Intentions towards Renovations: Is There a Market for One-Stop-Shop? *Buildings* **2019**, *9*, 164. [CrossRef]
152. Sovacool, B.K.; Griffiths, S. Culture and Low-Carbon Energy Transitions. *Nat. Sustain.* **2020**, *3*, 685–693. [CrossRef]
153. Piselli, C.; Pisello, A.L.; Sovacool, B.K. From Social Science Surveys to Building Energy Modeling: Investigating User-Building Interaction for Low-Carbon Heating Solutions in Europe. *Energy Reports* **2022**, *8*, 7188–7199. [CrossRef]
154. Liu, G.; Ye, K.; Tan, Y.; Huang, Z.; Li, X. Factors Influencing Homeowners' Housing Renovation Decision-Making: Towards a Holistic Understanding. *Energy Build.* **2022**, *254*, 111568. [CrossRef]
155. Klockner, C.A.; Nayum, A. Specific Barriers and Drivers in Different Stages of Decision-Making about Energy Efficiency Upgrades in Private Homes. *Front. Psychol.* **2016**, *7*. [CrossRef] [PubMed]
156. Strengers, Y.; Nicholls, L.; Maller, C. Curious Energy Consumers: Humans and Nonhumans in Assemblages of Household Practice. *J. Consum. Cult.* **2016**, *16*, 761–780. [CrossRef]
157. Mortensen, A.; Heiselberg, P.; Knudstrup, M. Identification of Key Parameters Determining Danish Homeowners' Willingness and Motivation for Energy Renovations. *Int. J. Sustain. Built Environ.* **2016**, *5*, 246–268. [CrossRef]
158. Schleich, J. Energy Efficient Technology Adoption in Low-Income Households in the European Union – What Is the Evidence? *Energy Policy* **2019**, *125*, 196–206. [CrossRef]
159. Ben, H.; Steemers, K. Assessing the Impact of a Differentiated Retrofit Approach in UK Domestic Buildings. *J. Phys. Conf. Ser.* **2019**, *1343*, 012173. [CrossRef]
160. Haines, V.; Mitchell, V. A Persona-Based Approach to Domestic Energy Retrofit. *Build. Res. Inf.* **2014**, *42*, 462–476. [CrossRef]
161. Broers, W.M.H.; Vasseur, V.; Kemp, R.; Abujidi, N.; Vroon, Z.A.E.P.; Urban, S.; Box, P.O.; An, H. Science Decided or Divided ? An Empirical Analysis of the Decision-Making Process of Dutch Homeowners for Energy Renovation Measures. *Energy Res. Soc. Sci.* **2019**, *58*, 101284. [CrossRef]
162. Maciosek, B.; Farsi, M.; Weber, S.; Jakob, M. *Impact of Complexity and Experience on Energy Investment Decisions for Residential Buildings*; IRENE Working Paper22-07; Université de Neuchâtel: Neuchâtel, Switzerland, 2022.
163. Risholt, B.; Time, B.; Hestnes, A.G. Sustainability Assessment of Nearly Zero Energy Renovation of Dwellings Based on Energy, Economy and Home Quality Indicators. *Energy Build.* **2013**, *60*, 217–224. [CrossRef]
164. Mechlenborg, M.; Gram-Hanssen, K. Masculine Roles and Practices in Homes with Photovoltaic Systems. *Build. Cities* **2022**, *3*, 638–652. [CrossRef]
165. Bartiaux, F. Gender Roles and Domestic Power in Energy-Saving Home Improvements. *Build. Cities* **2022**, *3*, 824–841. [CrossRef]
166. Anditi, C.; Musango, J.K.; Smit, S.; Ceschin, F. Addressing Gender Dimensions in Energy Innovations: A Gender Analysis Framework for Informal Urban Settlements in Africa. *Energy Res. Soc. Sci.* **2022**, *88*, 102476. [CrossRef]
167. Aggeli, A.; Christensen, T.H.; Larsen, S.P.A.K. The Gendering of Energy Household Labour. *Build. Cities* **2022**, *3*, 709–724. [CrossRef]
168. Creutzig, F.; Callaghan, M.; Ramakrishnan, A.; Javaid, A.; Niamir, L.; Minx, J.; Müller-Hansen, F.; Sovacool, B.; Afroz, Z.; Andor, M.; et al. Reviewing the Scope and Thematic Focus of 100 000 Publications on Energy Consumption, Services and Social Aspects of Climate Change: A Big Data Approach to Demand-Side Mitigation. *Environ. Res. Lett.* **2021**, *16*, 033001. [CrossRef]
169. Cialdini, R.B.; Reno, R.R.; Kallgren, C.A. A Focus Theory of Normative Conduct: Recycling the Concept of Norms to Reduce Littering in Public Places. *J. Pers. Soc. Psychol.* **1990**, *58*, 1015–1026. [CrossRef]
170. Nielsen, K.S.; van der Linden, S.; Stern, P.C.; Van Der Linden, S.; Stern, P.C. How Behavioral Interventions Can Reduce the Climate Impact of Energy Use. *Joule* **2020**, *4*, 1613–1616. [CrossRef]
171. Walker, L.; Hischier, I.; Schlueter, A. Does Context Matter? Robust Building Retrofit Decision-Making for Decarbonization across Europe. *Build. Environ.* **2022**, *226*, 109666. [CrossRef]
172. Booth, A. *Systematic Approaches to a Successful Literature Review / Andrew Booth, Diana Papaioannou, Anthea Sutton*, 3rd ed.; Papaioannou, D., Sutton, A., Eds.; Sage Publications: Thousand Oaks, CA, USA, 2012.