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Review

Energy Conservation at Home: A Critical Review on the Role of End-User Behavior

Lia Marchi and Jacopo Gaspari *

Department of Architecture, University of Bologna, 40136 Bologna, Italy; lia.marchi3@unibo.it
* Correspondence: jacopo.gaspari@unibo.it

Abstract: The recent literature emphasizes the significance of occupants' behavior in shaping home energy demand. Several policies have been defined and tools and technologies have been developed to raise people's awareness and encourage energy-saving practices at home, but households' energy demand keeps rising. The thesis is that the fundamentals on this topic are still unclear and that available tools, strategies and measures should be approached in a more integrated way, as they are not now effective enough to encourage energy savings. How these could be successfully combined is still a major knowledge gap. Thus, this article proposes a critical review of the literature to discuss the potential role of end users in energy conservation at home, preparing the ground for truly effective engagement strategies and tools to encourage behavioral change. To that end, a systematic literature review is performed, including over 130 relevant articles. According to the critical interpretation of their content, after years of technologically driven strategies, the most promising approaches capable of overcoming the intention–action gap are those more user-centered. However, relying solely on the social aspect is not effective. Synergistic integration of the two main clusters of studies has been identified as a promising field of research for the future.

Keywords: smart metering; behavioral implications; energy efficiency; energy savings; intention–action gap

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1. Introduction

Reducing the energy demand of the building sector is key to cutting carbon emissions, tackling climate change, and, thus, achieving sustainable development at the global level [1,2]. Several United Nations Sustainable Development Goals (SDGs) are indeed connected with energy use in the built environment, from Goal 7 'Ensure access to affordable, reliable, sustainable and modern energy for all' to Goal 11 'Make cities and human settlements inclusive, safe, resilient and sustainable' and Goal 13 'Take urgent action to combat climate change and its impacts' [3,4]. Over 17% of the SDG targets are directly dependent on construction, and 27% are indirectly dependent on this sector's activities [5], most of which are highly energy-consuming.

Indeed, according to the latest estimations, over one-third of global energy consumption and emissions are attributed to the building sector, which includes energy used to build, heat, cool, and light either living or working spaces, including equipment and appliances [6]. Space and water heating account for about half of these, which largely depend on building energy performance and system efficiency [6–8]. The type of fuel energy also matters in this regard: even though the market share of fossil fuel-based heating systems is declining, gas boilers continue to be the most sold and used in a variety of global markets, and cleaner alternatives are scarcely increasing [9]. Therefore, at least in Europe, significant efforts have been made in the last decade to achieve extensive renovation of the building stock by reducing the envelope thermal flows, upgrading heating and cooling systems, and shifting to renewable energy sources [2,6,10–14].

In recent decades, in addition to technical factors, increasing attention has been paid to social factors relevant to buildings' energy efficiency, in particular in relation to occupants' behavior. For example, one of the key elements of the Clean Energy for All Europeans package is to empower end users to change their passive behavior and make their home energy demands more flexible [15]. This is estimated to potentially contribute a 4% to 30% saving in home energy consumption [16].

One of the biggest energy and carbon-saving behavioral shifts in buildings deals with lowering heating/raising cooling set points or introducing smart and/or user-centered technologies to manage systems and appliances' schedules. However, their implementation and effectiveness are highly dependent on personal circumstances that are difficult to predict and are determined by a series of technical, economic, and social factors that still require a significant amount of work [17].

Rising energy prices and growing inflation rates after the COVID-19 pandemic and the Russian–Ukrainian conflict have contributed somewhat to raising awareness of this topic at all levels. Lockdown events also have led to diverse home occupancy patterns—typically for longer periods during the day. Consequently, changes in energy consumption have emerged. Energy use in buildings can indeed affect households' economic stability, especially that of the most economically vulnerable consumers who struggle daily to cover basic living expenses [18–21].

Consumers have become more interested in both flexible energy contracts and retrofit interventions. Discontinuous energy demand during COVID-19, and later gas shortages from Eastern Europe, have driven utility organizations towards new demand response (DR) programs and clean energy sources. These, combined with the overarching goal of a just and clean energy transition, have pushed policymakers to more seriously consider households' behavior, energy nudging, and economic incentives for deep retrofitting. At the European level, for example, the program Repower EU [22] includes the EU 'Save Energy', plan which stresses the importance of short-term and long-term measures to reduce the energy consumption of both households and industries by pushing voluntary habit changes and structural retrofitting measures in combination: changes to our lifestyles and behavior can help significantly lower our energy consumption. Choosing to reduce heating temperatures, [. . .] use household appliances and air-conditioning more efficiently and switch off the lights can deliver substantial, short-term savings [23].

As buildings become smarter and more energy efficient (towards net zero or positive energy), it has been estimated that the role of end-users in shaping the energy demand will also increase [24]. Accordingly, the topic has been progressively researched and considered in a variety of sectors [25–27]. Energy conservation options and user energy profiles are increasingly studied to drive the development of policies, strategies, and tools more effectively. However, great uncertainty on the actual role and weight of home occupants in energy conservation is still observed in the literature, which partly depends on what behaviors are considered (e.g., only those dependent on routines, or also one-shot investments in energy-saving appliances) [28] and partly on the fact that the determinants of user behavioral change are still unclear. Also, the effectiveness of energy monitoring and management tools, which have been long considered as a solution to this issue, is now an open debate [29–32].

Overall, it seems that the main research gap is how to make available means and tools work together effectively, as the topic is so complex that environmental, economic, social and institutional factors are all relevant and should be considered together. However, it is still uncertain which drivers and leverages of the system are more promising to be studied further because most studies tend to focus on one aspect at a time.

This paper presents a critical State-of-the-Art review to investigate the role of users' behavior in shaping home energy demand and the opportunities for energy savings that are recurrent in the literature, along with strategies that might encourage users to adopt such behaviors. In addition, possible gaps to be filled by future research, intersections between the diverse categories of end-users contributions, and frontiers of the topic will be identified.

Future research could build on this knowledge and evolve practical strategies for accelerating the energy transition at home and thus contribute to global sustainability targets.

2. Materials and Methods

According to the research workflow presented in Figure 1, a systematic literature review was performed in Web of Science (WoS) and Scopus (stage 1). Science Direct, Research Gate, and Google Scholar were also considered, but then not included as the first is very similar to Scopus; the second is a voluntary repository which might not be fully updated; and the third is not properly structured with filters to scan and select the wide number of expected records. The two selected electronic databases are widely used in bibliometric analysis and considered highly authoritative and credible in academia as they include peer-reviewed records and are managed by third-party entities [33–36].

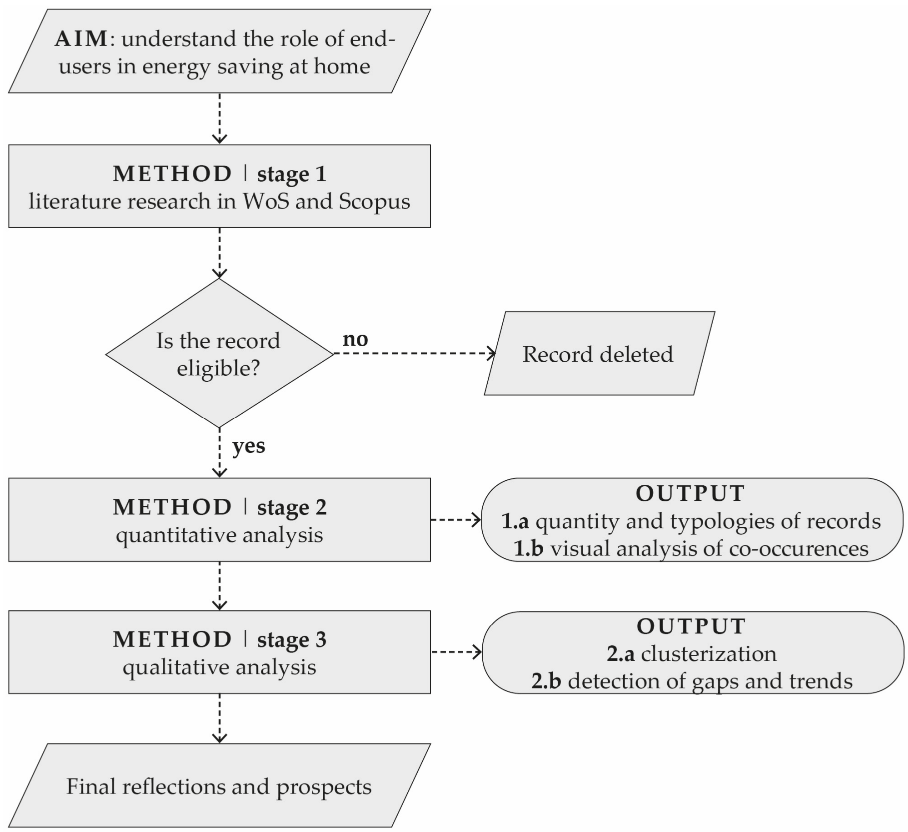

Figure 1. Literature research workflow.

Articles were searched by title and keywords. A 3W criterion was used to build the keyword string:

- *What*: Energy AND (conservation OR saving* OR reduction OR consumption OR use* OR behavio*)
- *Who*: User* OR Occupant* OR Household* OR Tenant*
- *Where*: Home* OR House* OR Resident*

Accordingly, the complete search string in each database is: (Energy AND (conservation OR saving* OR reduction OR consumption OR use* OR behavio*)) AND (User* OR Occupant* OR Household* OR Tenant*) AND (Home* OR House* OR Resident*).

The following filters were applied:

- Years: 2013–2023, assumed as a reasonable time during which the issue has evolved considering the recent energy challenges.
- Language: English

- Types of work: reviews, articles, and book/book chapters, to ensure the quality of contribution and homogeneity of data.
- Research area in WoS: Engineering; Construction Building Technology; Energy Fuels; Environmental Science Ecology; Architecture; Urban Studies; Behavioral Sciences. Subject area in Scopus: Engineering; Energy; Environmental Science; Social Sciences.

The search was conducted between May and August 2023, with regular updates (the last search was on 29 August 2023). Once the search was completed, records were screened according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) diagram [37], as shown in Figure 2.

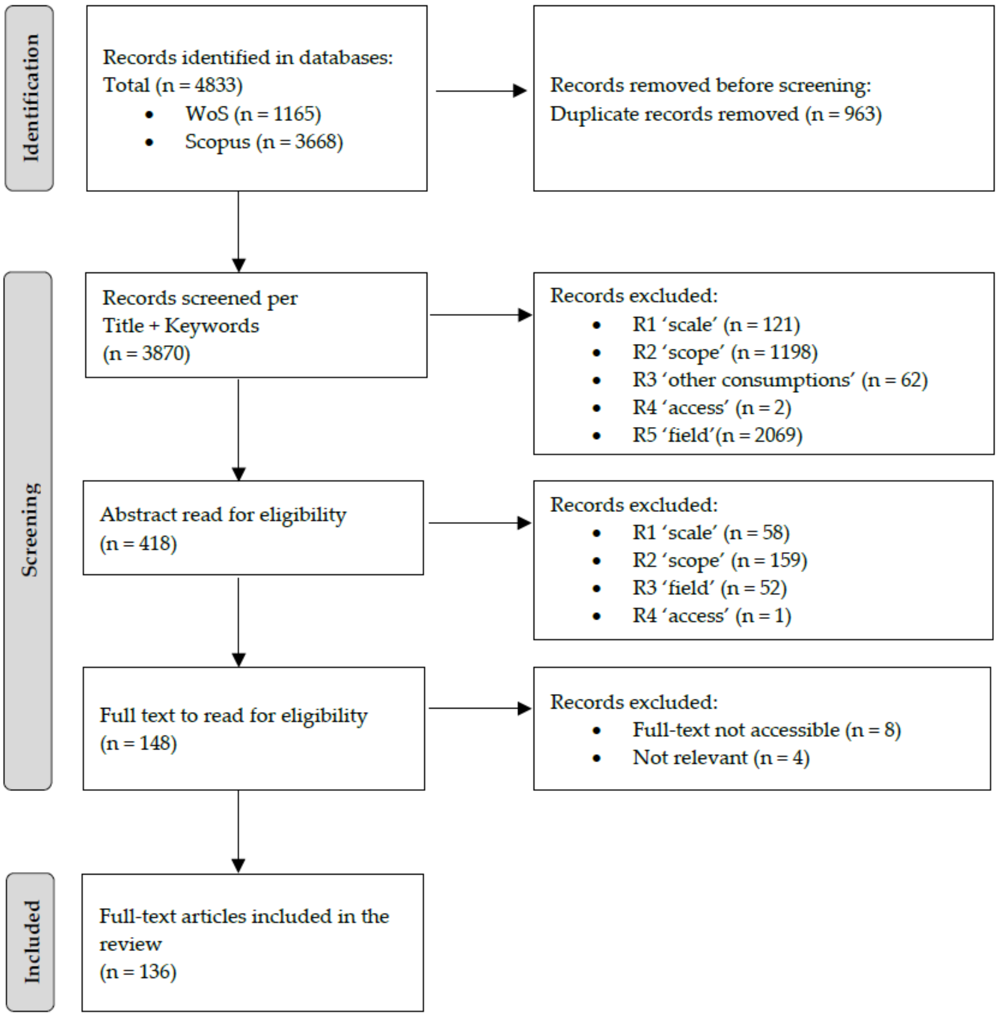

Figure 2. PRISMA workflow with the number of records processed per stage.

The identified 4833 records were imported into an Excel file and duplications excluded through automatic detection by title (963). Accordingly, 3870 records were selected for the screening process.

The first consistency screening was by title and keywords. In the Excel file, the records were categorized as "consistent" or "not consistent" by the following reasons for exclusion:

- Reason 1, the scale of the study is too large (e.g., city or regional level) or limited (e.g., specific appliances).
- Reason 2, the study is out of scope, e.g., focused on the Internet of Things, fuel and energy systems, building energy retrofitting, green purchasing, energy literacy, energy poverty, etc.
- Reason 3, the study addresses households' consumption other than domestic energy use (e.g., transport, food, clothing).

- Reason 4, content not retrieved, including abstract and keywords.
- Reason 5, the content is from another field/discipline.

At the end of the first screening phase, 418 records were selected for the following stage. The second screening phase consisted of reading the abstract to check for other excluding reasons. The identified ones were nearly the same as in the previous step:

- Reason 1, the scale of the study is too large or limited.
- Reason 2, the study is out of scope.
- Reason 3, the content is from another field/discipline.
- Reason 4, the abstract is not retrieved.

The third phase of screening regarded the full text of the resulting 148 records, 8 of which were discarded as the file was not fully accessible and 4 were deemed as not relevant to this study. A total of 136 records were included in this study.

The second stage of the review consisted of the quantitative analysis of the selected records (output 1.a), per time distribution, source, and type of document. Then, the open-source tool VOSviewer was used to find the co-occurrence of terms (output 1.b). The tool is indeed particularly useful to identify and visualize trends, patterns, and clusters of recurrent topics in bibliometric networks [38], which can be of help for the following stage. A Research Information System file (.ris) was exported from Mendeley (reference software, version Desktop 1.19.8) with titles and abstracts and used in VOSviewer v. 1.6.19 to obtain maps of terms. The counting method was set as binary, which means that a term was accounted for once in each document. The minimum number of occurrences in the database was set to 5 to register only frequent terms.

The authors' critical interpretation of clusters, trends, and gaps—which was derived from reading articles—was combined with this visual finding to form the basis of the qualitative analysis of records (outputs 2.1 and 2.2).

3. Results

Quantitative Analysis

The first output of the quantitative analysis is the time distribution of detected records for both stage 1 (including duplicates, divided per database) and stage 3 (articles included in the review) (Figures 3 and 4). In addition, top-ranking journals where the included articles were published are shown in Table 1.

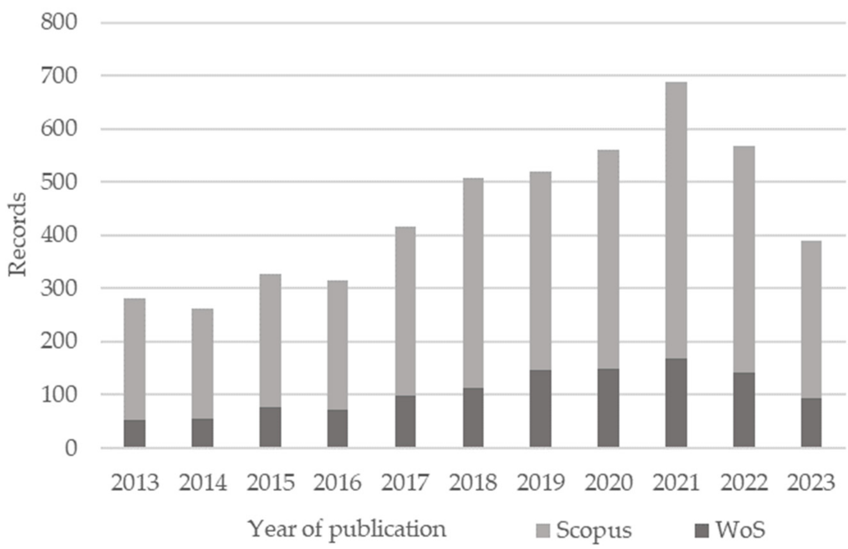

Figure 3. Time distribution of records per database, duplicates included.

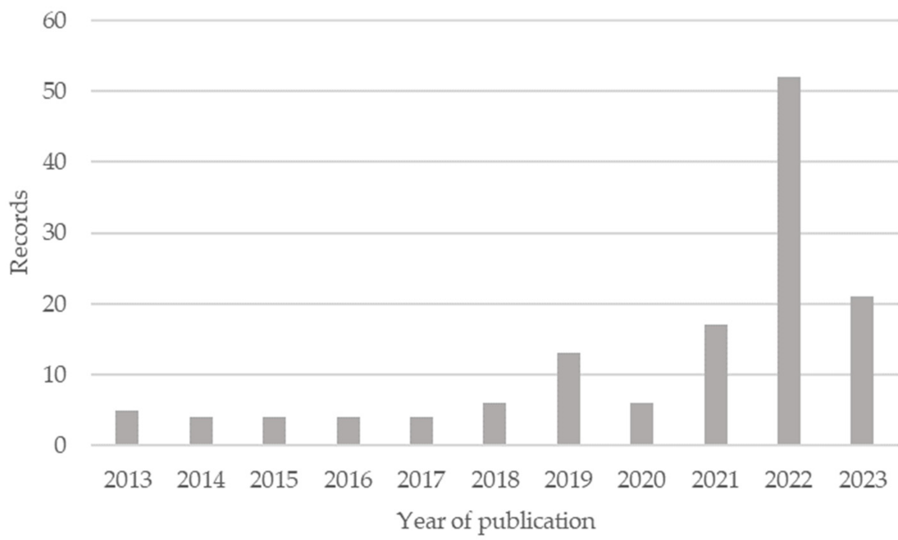

Figure 4. Time distribution of articles included in the review.

Table 1. Top-ranking journals where selected articles are published.

Source Title	Number of Articles
Energy Policy	13
Energies	12
Energy and Buildings	10
Energy Efficiency	10
Renewable and Sustainable Energy Reviews	6
Journal of Cleaner Production	5
Energy Research and Social Science	5
Sustainability	4
Energy	4
Sustainable Cities and Society	4
Energy Economics	4

The graphs show a significant increase in records during the last 3 years (2021–2023), with a peak in 2022 which demonstrates the increasing interest the topic has gained in several scientific and nonscientific sectors. This can be partly explained by contextual factors such as the rise in energy prices, while the 2023 apparent decrease might be related to the time period considered for this review (the end of August).

As for the document type, 122 are 'Articles', 13 are 'Reviews', and 1 is a 'Book chapter'. The first map created in VOSviewer was made by selecting the most relevant terms, which are obtained by default as 60% of the total co-occurrences detected. So, 113 terms were included in the map shown in Figure 5, where the software has grouped the items into four clusters (red, green, blue, and yellow).

The first two groups are significantly bigger than the others and contain the top five cited terms, which are: use (50 occurrences), model (34), efficiency (31), user (29), and role (29). The distance between the terms here represents the thematic distance in the research topics: while red and green clusters are quite homogeneous and compact, the other two groups contain quite scattered items suggesting that they are more heterogeneous.

The red cluster refers to terms pertaining more to the technological/physical dimension of energy conservation, such as: 'use', 'feedback', 'efficiency', and 'system'. However, a strong user-center approach emerges in this group by terms such as 'user', 'preference', and 'profile'. The green cluster is more related to social sciences/intangible aspects and behavioral theories, being the mainstream items 'model', 'role', 'attitude', 'determinant', and 'intention'. The blue cluster deals more with methodological aspects of the research in this field, with terms such as 'question', 'barrier', 'target', and 'subject', while the yellow one contains the remaining and less related terms.

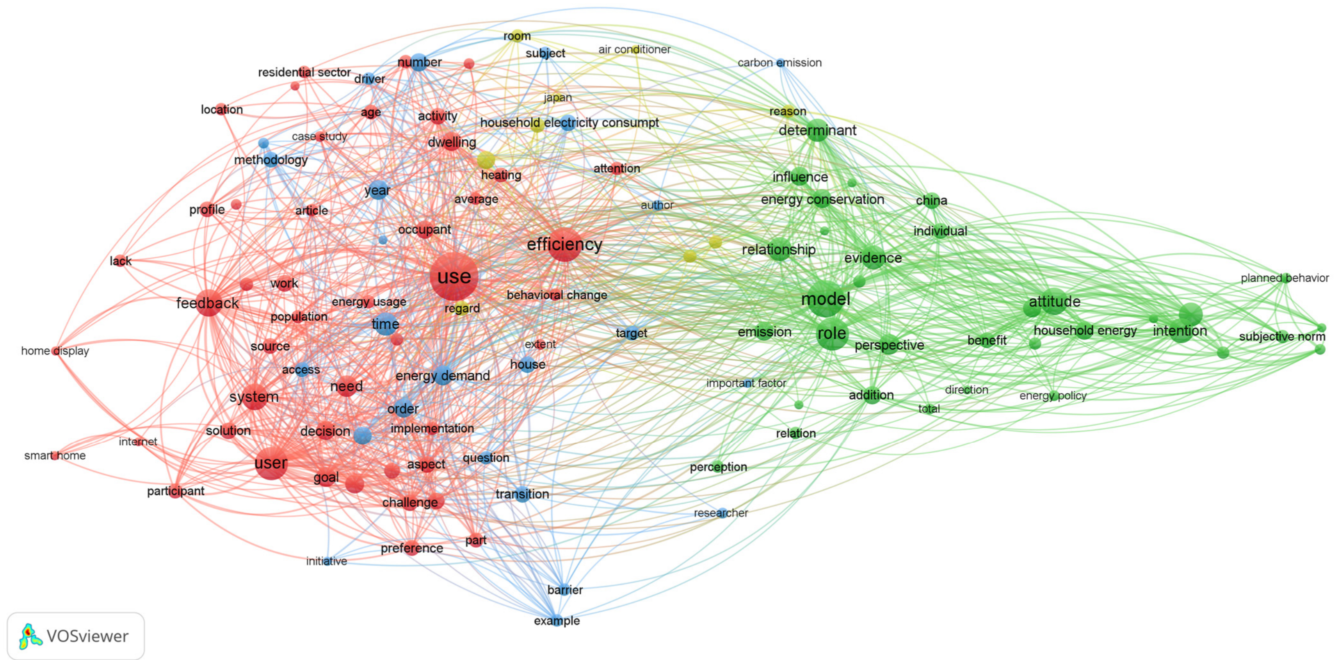

Figure 5. Co-occurrence of terms in the selected records, grouped per cluster and linked to each other. Diagram processed through VOSviewer.

Figure 6 visualizes the same clusters and terms in another way, giving more emphasis to the time distribution of the terms in recent years.

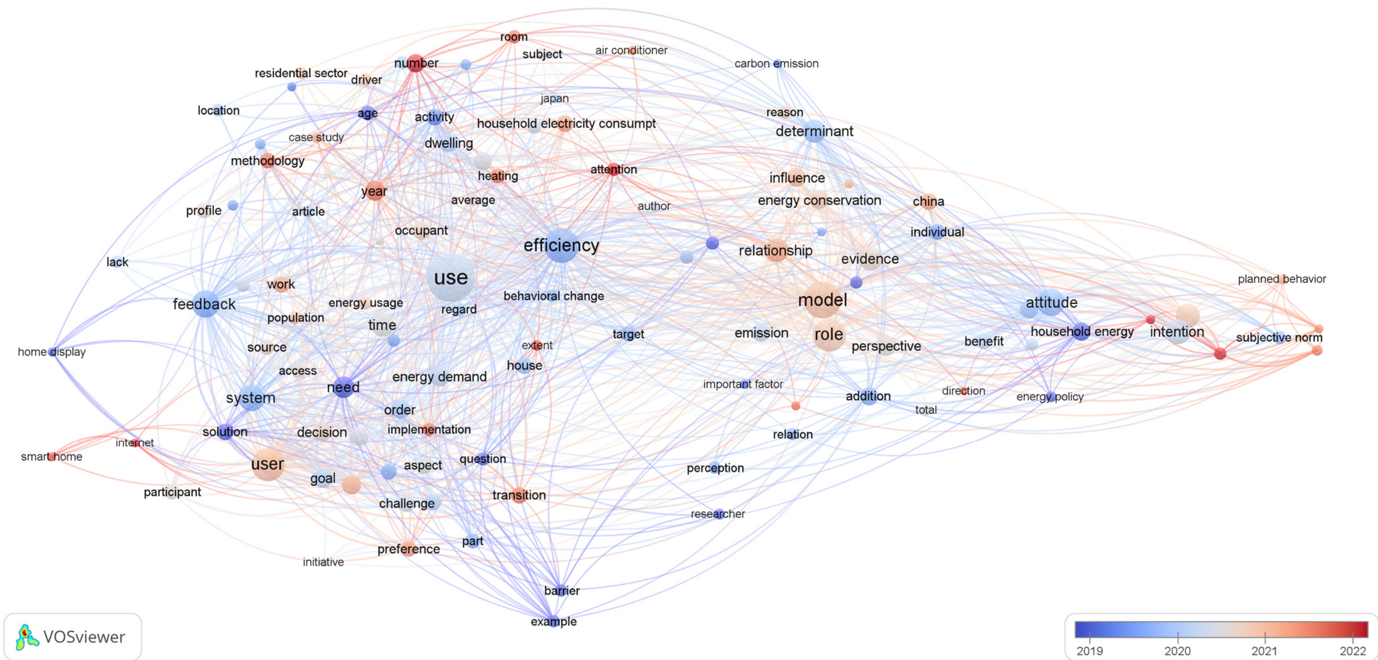

Figure 6. Visualization of recurrent terms as hot topics (in red) during the last 4 years. Diagram processed through VOSviewer.

Figure 7 focuses on the term 'use' (the most recurrent) and its over 110 links (represented by the curved lines). As the term is quite general, in this diagram it is more interesting to observe the connection between the item and the other ones.

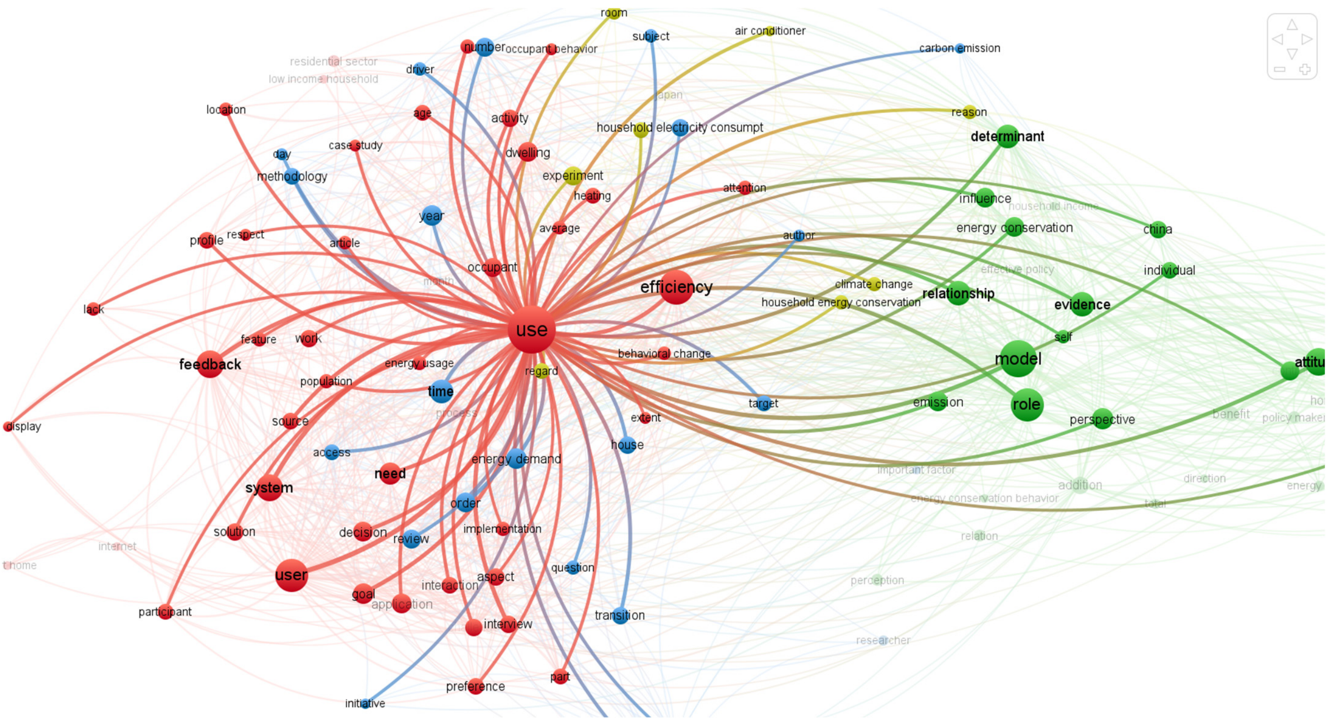

Figure 7. Extract of the network map focused on the term 'use' and its links. Diagram processed through VOSviewer.

4. Discussion

The screening of records in the two selected databases demonstrated that the topic is highly relevant. It has been progressively and increasingly investigated in the literature in attempts to address the environmental, societal, and economic concerns associated with energy conservation in the residential sector. The time distribution of records clearly illustrates that the research interest has been growing towards the topic, with a peak in 2021 (Figure 3, records not screened) probably due to changes in residential energy consumption patterns induced by the COVID-19 pandemic and the increasing harshness of climate change effects in cities.

From the over 3600 records identified at first, only 136 were selected in the end for the full-text reading (screening step 3). However, before discussing the latter, it is worth briefly reflecting on the discarded records. Although some were removed as not consistent, most of them were related to the general challenge of household energy transition and can help to frame the general discussion.

The most frequent and relevant research lines observed in the deleted records were:

Technical aspects

- Studies on information and communication technology (ICT) or the Internet of Things (IoT) for the management of either energy networks or smart homes.
- Studies on the impact of the primary energy type on the energy demand or, on a larger scale, on the national energy mix/energy market.
- Studies on the energy sources and network efficiency.
- Studies on the effect of photovoltaics and energy storage systems on the energy demand at home.
- Studies on the impact of urban morphology and/or pattern on residential energy use.
- Studies on the efficiency of cooling/heating systems.

- Studies on statistical methods for energy use trend predictions
- Studies on the efficiency of cooling/heating systems and/or the increased use of cooling to cope with global warming effects.
- Studies on statistical methods for energy use trend predictions.
- Studies on the performance gap between energy efficiency simulations of buildings and real consumption due to the human factor (occupancy patterns).
- Studies on other energy and carbon-saving practices for households, including food, mobility, and clothing choices.

Economic aspects

- Studies on the impact of the energy market or energy price on energy consumption and home system choices.
- Studies on the optimization of demand response programs and/or their effect on energy bills and user comfort.
- Studies on home appliances green purchasing and/or household energy-saving options (HESO), including preferences and motivation for their adoption.

Social aspects

- Studies on the role of energy consumption on the occupants' comfort and living standards.
- Studies on the human factors that may influence energy or fuel poverty.
- Studies on the preference, diffusion, or acceptance of electric vehicles rechargeable at home.
- Studies on the change induced by the COVID-19 pandemic in occupancy patterns on the energy demand.

Although it includes discarded records (due to scale, scope, etc.), this list suggests that when searching for households' energy saving, the mainstream topics are related to the technical dimension of the issue, from the efficiency of the energy network to the improvement in the technical performances (thermal insulation, system upgrading or shift, etc.). In addition, a significant number of discarded records were related to the economic dimension of households' energy transition, implying that the problem requires not only multidisciplinary but also multi-scale approaches and solutions across the market. Even though the subjects of the discarded studies were diverse, the marketing strategies and behavioral sciences issues identified suggest further investigation could help point out whether there is a spillover potential for approaches and tools used in different sectors.

As for the selected records, the observations of the VOSviewer maps (Figures 5–7) solicit some relevant reflections. It strongly emerges, as confirmed by the literature investigation, that there is a limited connection between the topics social and technical dimensions in existing studies. This has largely been identified as a significant barrier to effective advancements in the field, as well as a clear prevalence of technologically driven approaches to users' energy savings at home. Nonetheless, the hot topic visualization in Figure 6 shows a slightly promising shift in recent years toward social aspects. Terms such as 'solution' seem now to be outdated as it was largely proven to be ineffective in solving such a complex and multifaceted issue, that is the adoption of energy savings in the residential sector. An abundance of terms can be observed, such as 'feedback', 'preference', and 'role', supported by 'smart home' and 'internet'.

These general reflections are strengthened by a detailed analysis of the records, which is addressed in the thematic discussion that follows and whose main thematic clusters are displayed in Table 2.

Table 2. Distribution of records per thematic cluster, corresponding to the breakdown of the discussion sub-sections.

Clusters	Relevant Records
Chance for savings and role of users' behavior	
Energy saving practices and behaviors	Bouktif et al., 2022 [39]; Karahan et al., 2021 [40]; Khani et al., 2021 [41]
Energy price and energy savings link	Nahiduzzaman et al., 2023 [42]; Sloot et al., 2022 [43]; Al Mamun et al., 2022 [44]; Xu et al., 2021 [45]; Wang et al., 2021 [46]; Deumling et al., 2019 [47]
Efficiency investments and curtailment practices	Matsumoto et al., 2022 [48]; Never et al., 2022 [49]; Gajdzik et al., 2023 [50]
Energy efficiency paradox	Wester 2022 [51]; Aydın et al., 2023 [52]; Moeller et al., 2022 [53]
How to mobilize the adoption of energy conservation practices	
Intention–action gap	Gaspar et al., 2017 [54]; Yue et al., 2023 [55]; Zhang et al., 2021 [56]; Frederiks et al., 2015 [57]
Determinants of energy behavior	Al Mamun et al., 2022 [44]; Hori et al., 2013 [58]; Belaïd et al., 2016 [59]; Stikvoort et al., 2018 [60]; Hagejärd et al., 2023 [61]; Jakučionytė-Skodienė et al., 2023 [62]; Han et al., 2022 [63]; Owusu-Manu et al., 2022 [64]; Duong et al., 2022 [65]; Chen et al., 2022 [66]; Yixuan et al., 2022 [67]; Żywiołek et al., 2021 [68]; Wang et al., 2021 [69]
Nudging and behavioral interventions	Streimikiene 2023 [70]; Sudarmaji et al., 2022 [71]; Williams et al., 2022 [72]; Ruokamo et al., 2022 [73]; Henry et al., 2019 [74]; Sohre et al., 2022 [26]
Impact of social factors and comparison on savings	Fraser 2023 [75]; Bohdanowicz et al., 2021 [76]; Vassileva et al., 2014 [77]; Mukai et al., 2022 [78]; Hafner et al., 2019 [79]; Schneider et al., 2023 [80]; Jorgensen et al., 2020 [81]
Effect of smart energy management devices and apps	Chen et al., 2022 [66]; Caldera et al., 2023 [82]; Mostafa et al., 2022 [83]; Hess et al., 2022 [84]; Wood et al., 2019 [85]
Effectiveness of feedback and user engagement	Hagejärd et al., 2023 [61]; LaMarche et al., 2014 [86]; Pombeiro et al., 2019 [87]; Kendel et al., 2017 [88]; Nilsson et al., 2018 [89]; Geelen et al., 2019 [90]; Dalvi et al., 2016 [31]; Straub et al., 2018 [91]; Paneru et al., 2023 [92]; Garg et al., 2023 [93]; Madsen et al., 2023 [94]; Kim et al., 2023 [95]; Mataloto et al., 2023 [96]; Al-Kababji et al., 2022 [97]; Chatzigeorgiou et al., 2021 [98]; Song et al., 2020 [99]; Csoknyai et al., 2019 [100]; Méndez et al., 2022 [101]; Méndez et al., 2023 [102]; Papineau et al., 2022 [103]; Koasidis et al., [104]
Contextual and user differences in energy savings	
Geographic impact on energy patterns	Johansson et al., 2019 [105]; Iwata et al., 2015 [106]; Long et al., 2018 [107]
Socio-demographic features and dwelling characteristics impact	Karahan et al., 2021 [40]; Chen et al., 2022 [66]; Sudarmaji et al., 2022 [71]; Zhao et al., 2019 [108]; Spandagos et al., 2020 [109]; Kumar et al., 2023 [110]; Lei et al., 2022 [111]; Sen et al., 2022 [112]; Wang et al., 2022 [113]; Jareemit et al., 2019 [114]
Age factor in energy use	Pais-Magalhães et al., 2022 [115]; Dai et al., 2021 [116]; Lv et al., 2022 [117]
Income level and energy consumption	Vassileva et al., 2014 [77]; Malama et al., 2015 [118]; Podgornik et al., 2016 [119]; Romero-Jordán et al., 2022 [120,121]; Kaplowitz et al., 2022 [121]; Matthies et al., 2022 [122]; Perez-Bezos et al., 2023 [123]; Godoy-Shimizu et al., [124]
Genre or ethnicity effect on saving attitudes	Jareemit et al., 2019 [114]; Shrestha et al., 2021 [125]; Leslie et al., 2022 [126]
Ownership status and energy use	Taneja and Mandys 2022 [127]; Boudet at al. [128]
Household archetypes and related energy use profiles	Gaspar et al., 2017 [54]; Bedir et al., 2017 [129]; Ben et al., 2018 [130]; Ortiz et al., 2019 [131]; Mi et al., 2021 [132]; Akbari et al., 2021 [133]; Lu et al., 2022 [134]; Heinrich et al., 2022 [135]; Chen et al., 2022 [136]
Intersection with environmental and societal issues	
Energy consumption and environmental awareness nexus	Żywiołek et al., 2021 [68]; Rosak-Szyrocka et al., 2022 [137]; Kaplowitz et al., 2022 [121]; Kopsakangas-Savolainen et al., 2013 [138]; Sapci et al., 2014 [139]; Zhang et al., 2021 [140]; Jaciow et al., 2022 [141]; Chen et al., 2023 [142]; Du et al., [143]; Lam et al., [144]
COVID-19 effects on energy consumption patterns	Mataloto et al., 2023 [96]; Ueno 2022 [145]; Khalil et al., 2022 [146]; Balest et al., 2022 [147]
Research methods, gaps, and frontiers	
Literature reviews and meta-studies	Bouktif et al., 2022 [39]; Krishnan et al., 2022 [148]; Composto et al., 2022 [149]; Hu et al., 2022 [150]
Survey as research tool	Gaspari et al., 2021 [28]; Zhang et al., 2021 [56]; Hori et al., 2013 [58]; Johansson et al., 2019 [105]; Iwata et al., 2015 [106]; Zhao et al., 2019 [108]; Godoy-Shimizu et al., [124]; Kopsakangas-Savolainen et al., 2013 [138]; Chen et al., 2023 [142]; Venkatesh et al., 2020 [151]
Studies on technology impact on savings	Zhang et al., 2021 [140]; Kim et al., 2022 [152]; Andrade et al., 2022 [153]; Bastida et al., 2019 [154]; Qin et al., 2022 [155]; Pothitou et al., 2017 [156]
Studies that apply behavioral theories	Wang et al., 2018 [157]; Xu et al., 2021 [158]; Yue et al., 2019 [159]; Qalati et al., 2022 [160]; Webb et al., 2013 [161]; Conradie et al., 2023 [162]; Le-Anh et al., 2023 [163]; Nguyen et al., 2022 [164]; Fatoki 2022 [165]
Need for an integrated approach	Gaspari et al., 2021 [28]; Dietz et al., 2013 [166]; Gram-Hanssen 2013 [167]; Savvidou et al., 2020 [168]

4.1. Chance for Savings and Role of Users' Behavior

Nowadays, the majority of researchers in the field agree that occupants can strongly affect the energy demand, either acting on the physical features of the building or changing energy use practices [39,40]. Accordingly, energy-saving opportunities emerging from the selected articles can be grouped into two main clusters:

- Investments to reduce operational energy use (e.g., system replacements/upgrades, envelope thermal retrofit, replacement of appliances with new efficient ones).
- Change in energy consumption routine (i.e., conservation) or one-shot energy-saving actions. The change can involve either a different time or spatial use of energy [41].

As for the first category, the discussion can be extended on a larger scale to the shift in energy sources. In fact, end-users can have a role in energy savings by shifting to local renewable energy sources (e.g., photovoltaic panels) or entering DR programs which allow energy providers to optimize energy generation and distribution, with positive effects on both the energy market and the household's bill. There is indeed a strong correlation between energy price/tariff and user savings [42–45]. To this end, Al Mamun et al. proposed applying energy incentives to low-energy users—who are those using less energy than their peers—as a motivation for curtailment, even if Wang et al. observed that savings are more affected by occupants' attitudes than the energy price itself [46]. Nevertheless, Deumling et al. suggested that low-energy users should be further studied to understand how they became "virtuous" and thus how they can act as pilot cases for others to follow [47].

Interestingly, a positive nexus can be frequently observed between energy efficiency investments and energy curtailment practices [48,49]: in general terms, this means that those who spend their money on energy retrofitting are more likely to implement conservation or saving behaviors/actions. This attitude can be reinforced by the environmental awareness of the household, but it is not always true. Gajdzik et al. argues that being a prosumer frequently leads to the adoption of pro-environmental behaviors [50]. Others note a controversial relationship between clean or energy-efficient homes and the adoption of energy use practices (i.e., the energy efficiency paradox) [51–53]: sometimes it appears that using clean energy or living in an energy-efficient home makes the occupant feel legitimized to care less about energy conservation measures.

4.2. How to Mobilize the Adoption of Energy Conservation Practices

Despite the consistent body of work in the literature and knowledge about the role of the end user in shaping the energy demand, and specifically in the range of saving practices that can be implemented, researchers all agree that there is a great discrepancy between willingness to change a certain energy consuming behavior and its actual uptake. This is usually called the knowledge–action, value–action, or intention–action gap and it represents one of the major challenges for this research field [54–57].

Therefore, many scholars have investigated how to overcome this gap and how energy-saving potentials related to users' behavioral change can be mobilized. Nonetheless, there is still great uncertainty about the leverage of this complex system (i.e., households' behavior). Determinants for occupants for the adoption of energy-saving practices can vary from values to knowledge, from personality traits to income, from subjective norms to age, up to dwelling ownership and features. Regardless of the determinants that are detected and examined in specific studies, all agree that several concurring factors may lead to a change in household behaviors [44,58–69].

Among these, social factors play a major role, which is why many authors have focused on the advantages or disadvantages of nudging (i.e., gently encouraging someone to do something) and behavioral interventions [70–74]. For instance, Sohre and Schubert have contended that top-down interventions, which are typical of these approaches, are ineffective in this field because they deal with users' preferences at home and their private behaviors, which can be challenging to control from the outside [26]. Even if nudging alone is not enough, it can be combined with other strategies and policy measures to overcome the traditional financial and social barriers of the energy transition, for which economic and financial means put in place in the last decade have been demonstrated as not being fully effective [70].

In addition, other scholars discuss how social comparison, competition among peers, and goal setting for energy conservation can become more effective means to mobilize the potential for households' energy transition at home [75–79]. Contrasting opinions emerge also on this point: while Schneider et al. illustrate the role of individual energy coaches for this purpose [80], Jorgensen et al. argue that group-targeted interventions are more successful than individualistic approaches [81].

Technology emerges as a powerful supporting tool for this purpose. Therefore, great effort has been put into developing digital and/or smart tools to support the optimization of energy demand in the last decades. Home energy management systems (HEMSs) have been extensively discussed in the literature, as well as the potential of utility apps and feedback in energy bills to enable or activate users' conservation practices [66,82–85]. However, up to date, most of the experts in the field agree that effective feedback from such devices is essential not only to activate one-shot changes but especially to engage users in the long run [31,61,86–99]. To this end, gamification is frequently mentioned as an effective means for the use of smart meters and other energy consumption feedback supports [100–103]. In connection with gamification, others suggest monetization of pro-environmental behaviors, as in the case of the study of Koasidis et al. [104].

Overall, it can be observed that a balanced mix of behavioral interventions, financial support, and technology-driven feedback can be good at motivating users' energy conservation, while none of them is enough by itself. Indeed, on the one hand, the effectiveness of smart devices for energy monitoring or management might be prevented if the building occupants are not properly engaged. On the other hand, a collective versus individual momentum towards energy transition at home is claimed, suggesting that behavioral interventions can be truly effective only if capable of engaging users as a community with a shared responsibility.

4.3. Contextual and User Differences in Energy Savings

Besides the attitudes and values of specific users, many authors agree that energy-saving behaviors can derive from cultural, geographical, or other contextual factors. Johansson et al., for example, discussed the different approaches and attitudes of users' energy conservation practices between developed and developing countries [105]. Similarly, Iwata et al. argued that behavioral interventions that are effective in the US might not be in Japan [106]. According to Long et al., the perception of each role in climate change—which is affected by the cultural background, among other factors—demonstrates diverse attitudes to energy savings in the US and Germany [107].

Several authors discuss the role of both users' background and dwelling features in shaping the energy demand [40,66,71,108–114]. In this regard, Spandagos et al., for example, have argued that socio-demographic factors impact less than value beliefs [109].

Some records then examine the effects of one or very few specific factors at a time. More specifically, the age of users seems to strongly affect energy saving practices: elders, for instance, need more energy for heating and cooling because they are more sensitive to thermal discomfort but use fewer digital devices so that this share of consumption is less than in the younger generation or adults working from home [115,116]. So, retirement may also imply a reduction in consumption [117].

In particular, the relationship between income and energy consumption in the residential sector is also investigated [77,118–122], with special concern for social housing occupants [123]. The income–energy use relationship is often examined along with other contextual factors, such as age and employment status, as is the case of the research of Godoy-Shimizu et al., who found that according to statistical analyses, high electricity use is significantly correlated with social class, large household size, unemployment, and middle age, while low electricity use is significantly correlated with single-person households, small homes, and retirement [124].

Genres also seem to affect energy consumption patterns at home [114,125]: generally speaking, it is found that women are more prone to save energy than men when dealing with air conditioning in bedrooms or other home activities. Some also discuss how ethnicity can impact energy consumption patterns [126], arguing that some groups tend to save more energy because of religious principles or cultural values.

Interestingly, the ownership status of the dwelling can also have an impact on whether to encourage the adoption of energy-saving actions or not. That is why both policymakers and energy providers are recommended to take this into account: Taneja and Mandys, for instance, found that in the UK, renters are more sensitive to changes in electricity and gas prices than homeowners [127], but less interested in energy-saving investments, as pointed out by Boudet at al. [128].

Based on these differences in user backgrounds, many researchers are attempting to define household profiles/archetypes related to energy use patterns to support policy targeting [54,129–136]: some try to profile users and associate energy use profiles with them; others discuss the barriers and drivers behind the adoption of energy saving practices in certain occupants' archetypes. However, it is also noted that determinants of users' behavioral change in the residential domain are so individual that generalization does not help lead to effective change.

4.4. Intersection with Environmental and Societal Issues

Energy consumption in the residential sector is strongly linked with some transversal topics which are mainstream in the literature, such as climate change (CC) and the effects of the COVID-19 pandemic on daily life.

The correlation between CC awareness and the adoption of energy-saving practices at home is indeed a hot topic in the literature. Despite the general increase in the first, some authors point out that there is limited knowledge of conservation behaviors and changes that can be implemented at home [68,137]. Others state that there is a positive link between increasing environmental awareness and energy saving at home (i.e., the climate–energy consumption nexus), but the intention to adopt certain practices is not always translated into real actions [121,138–142].

On the other hand, the increasing harshness of CC effects is leading to a rise in energy demand for cooling, especially in dense urban environments. A growing number of studies have been performed to this end: such as that of Du et al., who examined the combined effect of CC and COVID-19 on energy use especially for cooling [143], and Lam et al. who discussed the determinants of behavioral change in this regard [144]. So, even though energy saving for heating is still mainstream in the literature, the number of research projects addressing cooling-related energy conservation behaviors is increasing.

Regarding COVID-19, several authors have investigated how various occupancy patterns and the economic crisis brought on by the pandemic have either temporarily or permanently changed energy use at home [96,145–147], which was typically increased during the lockdown and reduced in the recovery phase to cope with resource shortages of low-income families.

4.5. Research Methods, Gaps, and Frontiers

Energy conservation in the domestic environment has been largely studied in its multiple facets, as proven by the available reviews and meta-studies [39,148–150]. It emerges that due to the complex nature of the topic, the survey is the most widely used research means [28,56,58,105,106,108,124,138,142,151].

As it is evident from both the co-occurrence visualization and the specific content of included articles, up to now, studies in this field have focused on the technological or the behavioral facets of the energy transition at home in a separate way.

Regarding the first, existing research is mostly focused on tools or methodologies to assess and encourage the energy-saving potential of users' behavior [152,153]. Overall, a controversial role for technology emerges in energy savings. Overall, ICT, smart meters, apps and home energy management systems (HEMSs) drive users to save energy either automatically or by encouraging them to change their behavior [154]. To a certain extent, sole access to the Internet can help save energy by allowing users to search for information about related practices and investments [155]. However, on the other hand, the growing use of ICT work or entertainment devices is accounted to drive an increase in the energy demand [156]. Additionally, it should be noted that a purely technological approach to managing home energy savings runs the risk of encouraging the energy efficiency paradox, which occurs when energy demand is reduced because of energy efficiency interventions, household income rises, and as a result, the residents tend to take fewer conservation measures [140]. Therefore, studies focused on digital tools alone appear outdated.

Regarding the social dimension, it can be observed that an increasing number of studies try to apply well-established behavioral theories to the topic to overcome existing research and action gaps. Among these, the theory of planned behavior (TPB) recurs the most, followed by the goal framing theory (GFT) [157–165]. It is frequently observed that intentions are the most direct contributors to actions and behaviors, and that they can be predicted by attitude, social norms, and especially perceived behavioral control (a feeling that one can act successfully). Without this perception, any top-down behavioral interventions would be ineffective because people will not change their behavior or spend money on something that does not directly affect major issues or give them a sense of empowerment. Thus, it is widely held that knowledge about energy-efficiency measures is insufficient to promote the transition (which explains, in large part, why smart devices or apps that only provide quantitative feedback are ineffective).

Overall, despite the expected potential, an integrated approach between technology and social sciences has been only occasionally implemented in this field. Therefore, in light of the discussed gaps, many authors recommend considering more seriously the interconnection between the different perspectives of the issue in further research [28,166–168].

5. Conclusions

This article reported the outcomes of a literature review about the role of end users in implementing energy saving practices at home. It emerged that studies in the field of energy transitions are progressively shifting from a technological-driven approach alone to a perspective including behavioral theories and tools, with particular implications in institutional and social-normative terms.

Traditionally, actions taken in this field have focused on and promoted energy-efficient technologies and infrastructure, which have proven to yield less energy savings than expected due to rebound effects or significant knowledge–action gaps. Most of the included records mention energy efficiency interventions as the first and most important measure to conserve energy in the long term (i.e., structural measures), even if the focus of this article is the behavioral change in households towards energy. It is indeed widely acknowledged that while the effects of the first type of measures are higher, and permanent once implemented, the second type are more unstable as they rely on the user's willingness to maintain virtuous practices in the long run. Notably, while data and figures related to the benefit of structural measures have led to wide recognition of their importance, there is still a large disagreement about the actual effect of user behavior on demand reduction. This is indeed recognized to contribute from less than 1% to over 50% of the whole energy demand of the house. Such a large span suggests that not only are the determinants of behavior unclear, but also terms and a shared understanding of energy-related user behavior are lacking. As a result, it is difficult to compare multiple studies across the world and from diverse disciplines, according to common and shared elements.

Nevertheless, the majority of authors of the included records agreed that along with designing new efficient buildings and retrofitting those that are already in use, the active role of end-users in shaping energy demand is becoming increasingly important to achieve sustainable development and carbon neutrality targets. However, the determinants of households' energy conservation behaviors are still being debated, making generalization difficult.

The analysis of both mainstream topics in discarded records and the detailed investigations of the selected ones suggests that the issue is highly multifaceted and there are no simple solutions. It can be deduced that more holistic and multi-scale approaches must be assumed to address it successfully.

Designing and targeting policies can be highly challenging, which is why many scholars suggest that additional research in the field is needed. The effectiveness (or not) of available policies and behavioral interventions to this end should also be considered, as well as the impact of pilot experiences, such as carbon-neutral districts, neighborhoods or communities. Institutional and community-based normative levels can indeed have a crucial role in shaping individual attitudes and behaviors, although these were out of the scope of the present review.

As for the building-user scale on which the review was focused, this article has outlined the most relevant studies that can be used for future research in the field to bridge the gap that is preventing both individual and collective efforts to achieve a rapid energy transition in the residential sector.

Overall, technical tools have largely proven to be ineffective alone. The same goes for the sole social (behavioral) sphere of individuals. This fact was claimed in more than 50 records included in the cluster about how to mobilize energy conservation practices and beyond. The most recent and promising studies then move in the direction of a combination of the two main domains. However, this does not ensure success and further studies should be performed to understand effective integration mechanisms, as suggested by at least four articles included in the cluster on research methods, gaps and frontiers.

In this regard, the few research projects that have tried to interlace several aspects still lack a wide implementation as they were mostly surveys taken on a case-by-case basis. This prevents academics and policymakers from making broader considerations: systematic or meta-studies could help knowledge advancement in this field.

In addition to methodological and general considerations, some interesting hints about specific aspects emerged.

Among the many considered factors and determinants, users' socioeconomic background seems to have a minor impact on the role of end-users in energy conservation. Rather, social norms and peers' comparison appear as strong drivers. This is understandable in the era of social media and networks, and both policies and energy app/device developers should consider it more carefully. In this regard, useful suggestions might come from the observation of "low energy" users, to better understand what, why and how they adopted virtuously to be potentially replicated by others. Instead, at present, very few articles focus on this.

Nonetheless, a consistent number of records (more than 14) indicate energy price as a strong determinant in shaping households' energy demand in the short term. When this is especially studied in relation to low-income families, it becomes an even more important driver. Unfortunately, when it comes to energy poverty—largely recurrent also in discarded records—social and subjective norms lose their positive relevance. Vulnerable consumers face an actual need to curtail their energy bills to face more vital expenses (e.g., food), at the expense of comfort and health. In these situations, public support for structural improvements to the dwelling energy performances is vital, but it also becomes crucial to increase awareness of the role that users' energy-saving actions can play. In other words, targeted feedback, and energy education (or literacy) can be more valuable than is deemed nowadays for such a specific share of the population.

Lastly, an interesting connection of the topic emerged with contextual factors that have strongly featured in the last five years, which are the COVID-19 pandemic and awareness raising toward climate change. Interestingly, both have had an impact on the way people use energy at home, in many cases positively affecting conservation attitudes. However, the effects related to the pandemic seem mostly to have disappeared with the end of the health crisis, but small seeds of change persist and deserve to be studied further. Environmental awareness and its complex socio-economical implications are also worth investigating more deeply, as, despite the general interest of citizens, the intention–action gap here is greater than elsewhere.

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