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Review

Climate Change Mitigation Policies Targeting Households and Addressing Energy Poverty in European Union

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Received: 20 June 2020; Accepted: 30 June 2020; Published: 1 July 2020

Abstract: Climate change mitigation measures linked to households' energy consumption have huge greenhouse gases (GHG) emission reduction potential and positive impact on energy poverty reduction. However, measures such as renovation of residential buildings or installation of micro generation technologies based on renewable energy sources have not realized their full energy saving and GHG emission reduction potentials, due to the energy efficiency paradox and other barriers. These climate change mitigation policies targeting the households' sector can deliver extra benefits such as energy poverty reduction and implementation of the energy justice principle; therefore, they require more attention of scholars and policy makers. The aim of this paper is to analyze the energy poverty and climate change mitigation issues in EU households based on a systematic literature review, and to provide future research paths and policy recommendations. Based on the systematic literature review, this paper develops an integrated framework for addressing energy poverty, just carbon free energy transition and climate change mitigation issues in the EU. Additionally, we argue that more targeted climate change policies and measures are necessary in the light of the shortcomings of current measures to reduce energy poverty and realize climate change mitigation potential linked to energy consumption in households.

Keywords: climate change mitigation; households; energy renovation; renewable energy sources; energy poverty; energy justice

1. Introduction

Energy poverty is currently among the key policy issues in the European Union (EU) due to various challenges linked to energy sector transition. This problem is especially problematic in East European countries, with energy consumers trapped in inefficient residential housing stock without the ability to change heat suppliers or regulate energy consumption in their homes, sometimes named as energy degradation problem [1]. A few studies showed the intensity of energy renovation being linked with the age of households: willingness to engage in energy renovation is much lower for those over the age of 70 than that of the younger population [2,3]. Retired homeowners face an additional hurdle with high heating and maintenance costs of under-occupied apartments since grown kids have left the country and do not have plans to return [2,4–7]. By contributing to fuel poverty, the areas with the least energy-efficient building stock and the highest heat consumption levels often correspond with

elderly, retired, low-income and vulnerable households [8–10]. There is another problem, linked with collective decision making in multi-apartment buildings as this process becomes very complex when owners inadvertently depend on each other or have diverse and sometimes conflicting interests due to age, education, awareness and income differences [4]. This is a significant problem for policies and measures aiming to modernize and enhance energy efficiency multi-apartment buildings as current schemes often fail to solve such type of issues.

Energy efficiency improvement in households by deep energy retrofitting of residential buildings has the highest energy saving and climate change mitigation potential in households. Although energy efficiency improvements are the most efficient win-win solution to achieve climate change mitigation in households, the so-called energy efficiency paradox was revealed by scholars [11]. It indicates that the real energy efficiency improvement level is lower than the optimal or desired level. Due to important barriers related to energy efficiency improvements in the residential sector, the energy efficiency paradox is obvious.

Though there are studies dealing with the energy efficiency paradox and climate change mitigation measures as well as energy poverty and energy justice challenges, there is a lack of studies analyzing these issues together and providing policy recommendations on how to avoid the main barriers and increase the effectiveness of these climate change mitigation policies by delivering additional benefits linked to energy poverty alleviation and promotion of social justice.

So far, the existing literature has not yet attempted to synthesize the existing body of literature focusing on both energy poverty and climate change mitigation measures in households linked to energy consumption. Therefore, the framework that takes on the perspective of energy poverty and climate change mitigation measures targeting households' energy consumption is missing. To contribute to better understanding of linkages between energy poverty and climate change mitigation measures in households, this paper aims to present the state of the research field and to provide insights into present and future directions. In order to do this, a review of studies that fall within the scope of the research field is performed. This will allow us to map existing concepts and empirical findings and contribute to a better overview and critical evaluation of the body of literature and to present future research paths. The main focus is the European Union, due to the fact that climate change mitigation policies vary significantly among countries and energy poverty issues are also country specific and closely linked with economic and social development level.

Based on a systematic review of the literature, the paper identifies the main barriers of climate change mitigation of energy poor households linked to energy refurbishment of multi-apartment buildings and other energy efficiency improvements. The current EU climate change mitigation policies and measures used to promote energy efficiency and use of renewable energy sources in the household's sector are critically discussed, with regards to their ability to deal with the main barriers of energy refurbishment, energy efficiency improvements and use of renewable micro-generation technologies. Finally, the idea of a new approach for developing climate change mitigation policies to overcome the main hurdles of energy efficiency improvement and use of renewable energy sources in energy poor households is developed.

The main contribution of this work is the presentation of the integrated framework for development of an innovative climate change mitigation policies in households aiming at removing the behavioral barriers of climate change mitigation actions in energy poor households in EU. This is very important in terms of moving to carbon free economy and ensuring energy justice in this transition. The scholars and decision makers were concentrated on economic and financial barriers of energy efficiency improvements in energy poor households; however, the overcoming of economic barriers is restricted by behavioral and psychological barriers of energy poor households. Therefore, the paper focuses on behavioral barriers of climate change mitigation in energy poor households in order to define innovative policies to tackle these barriers and ensure just transition to low carbon economy.

The following second section of the paper presents methods; the third section provides a literature review on energy poverty, energy vulnerability, and energy justice; the fourth section critically discusses

the main drivers of energy poverty; the fifth section presents an analysis of the main barriers of climate change mitigation measures in energy poor households; the sixth section provides an analysis of climate policies impacts on energy poverty and energy justice; the last section concludes.

2. Methods

This section presents research method, data collection, phases of analysis.

2.1. Research Approach

In order to review and consolidate the literature across the field of energy poverty and climate change mitigation measures targeting energy consumption in EU households, a systematic, evidence-informed literature review was performed. This method is characterized by a well-documented, replicable and transparent search process, which is driven by a deep understanding of both phenomena—energy poverty and climate change mitigation measures in households, and improves the quality of the review process [12].

2.2. Data Collection and Analysis

For identification of the most relevant publication in the scope of this research, the following search terms and their combinations: "energy poverty", "climate change mitigation in households"; "EU" were applied. To cover the most important scientific articles, the following main databases for studies published during 1990–2020 were searched: Science Direct, Web of Science. The search strategy yielded an initial sample of 455 peer-reviewed papers which were manually screened and 200 papers were collected. The final 40 relevant sources for analysis were collected after reading all abstracts of identified 200 collected papers. Since peer-reviewed journal papers are considered the most valid, the books, book chapters, discussion papers were excluded from systematic review [12]. Based on the snowballing approach, the references of 40 selected papers were reviewed. Through this method, 75 additional papers were snowballed from 40 different publications.

After reading these publications, the main topics were identified and publications were grouped according four main areas: delineating energy poverty, analyzing the main drivers of energy poverty; dealing with the main barriers of climate change mitigation of energy poor households and addressing climate change mitigation policies impacts on energy poverty.

In the next sections of the paper results of review in four areas is provided.

3. Delineating Energy Poverty

Energy poverty is an important problem throughout Europe, and especially East Europe suffers from this problem. Households living in scarcity conditions are often forced to decide to reduce their heat comfort for cutting their energy expenditures and saving money for other necessities, or they are not able to afford other necessities due to relatively high energy, especially district heating prices in East European Countries. As already mentioned, the problems of energy degradation and heat traps exist in East European Countries, and low-income households living in energy inefficient buildings do not have the opportunity to regulate heat consumption or change heat supply sources, as disconnection from district heat systems and switching to other heating sources is complicated due to the legal environment. It is also necessary to stress that the increase in energy prices does not have an impact on consumption levels, due to low price elasticity and energy being defined as a necessary good. In East Europe and other EU member states, energy prices have been increasing faster than the net incomes of lowest income households, creating more risks of energy vulnerability and energy poverty danger.

There is no universally agreed definition of the term 'energy poverty', but usually in scientific literature it means that households are spending a perversely high share of their real income on their energy needs or that households cannot meet their basic energy needs such as heating comfort due to insufficient income and high prices [13]. Though the existence of energy poverty or problems of energy affordability are quite known around the world, there are still many discussions among scholars in

defining energy or fuel poverty. There are only a few approaches used to define energy poverty levels as well, and they can be distinguished as either based on physical energy requirements or energy expenditures measurements. There is a popular way to estimate energy poverty level by assessing energy expenditures as a share of total household expenditures [14]. Energy poverty in less developed countries is also assessed by the types of energy used by households or based on expenditure poverty line already evaluated for a specific country [15].

The main approaches to outline energy poverty are systematized in the following way:

- The amount of physical energy which is necessary to satisfy the necessary energy requirements for households such as heating; lighting; cooking etc.;
- The certain percent of expenditures spent on energy in total households' expenditures;
- The amount of physical energy or the specific type of energy carriers that are being possessed by households at the poverty line;
- The certain level of income below which it is supposed that energy consumption and/or energy expenditures do not change, indicating that the bare minimum energy consumption level is reached.

These four main approaches to energy poverty definition have their advantages and limits [15]. The roots of the definition of energy poverty according to the first defined approach is based on the tactic applied in defining the minimum amount of necessary food consumption for living a healthy life. By converting this approach to energy, it is necessary to define the minimum amount of energy, which is critical to ensure the cooking, lighting, and heating needs of households. However, the description of the exact minimum level required for daily inevitable energy services is very difficult due to differences in local conditions. Due to differences in culture, habits, climate or geographical conditions, energy supply infrastructure and availability of natural resources, countries apply completely different cooking and heating practices. Consequently, households possess different energy requirements.

The second methodology in defining energy poverty is linked to the idea that energy poverty assessment can be performed according to the percentage of households' income spent on satisfying their energy needs. The low-income families usually devote a higher share of their income to satisfy energy needs than high-income families do. Empirical studies provided a range from 5% to 20% of income spent on energy by households [16,17]. Based on the UK approach, when spending on energy is above 10% of income, then it has an impact on the general welfare of households. Therefore, if households need to spend 10% or even more of their income for satisfying basic energy needs, they are experiencing the lack of other basic goods to sustain a healthy life. The main limit of his approach is that 10%, as in the case of methods based on physical measures of energy, cannot be applied universally to measure energy poverty due to specific local conditions. Country-specific thresholds based on twice median energy expenditure share (2M indicator used by European Energy Poverty Observatory) allow avoiding the limitations of using the same 10% threshold in different countries. However, such an approach fails to reflect energy poverty impacts of increasing energy prices: if prices for different energies increase by the same rate, median energy expenditure share increases as well, while the number of households whose energy expenditure share is above the national median as well as the energy poverty level remains stable.

The third way of outlining the energy poverty is linked to the assessment of households' energy consumption level, which is below the established poverty line for expenditure or income in the specific country. These expenditures linked poverty lines are well established in most countries. Household energy surveys can be applied for defining the average energy consumption level in the country, which is below of established poverty line. This method also has shortcomings, as the poverty line is not linked to the energy and climate change mitigation policies of the country, and it is difficult to control and target it by these policies. Assessing energy poverty in this way is similar to assessing general poverty rates in the countries.

The fourth approach addresses the level of energy demand linkages with household income. It is assumed that after reaching a certain level of income, households start to use more and more

energy. In terms of poor households, it implies that their energy consumption does not increase with the increase of their income. This approach is complicated and requires a lot of data and analysis of household surveys. The main advantage of this method is that it assesses energy poverty considering actual energy use based on local conditions, implemented policies, and available energy prices in the country [15].

There are many studies [16–23] dealing with the main reasons of energy poverty, which is multifaceted ranging from low incomes, poor quality inefficient residential housing, lack of energy efficient appliances, poor energy infrastructure, high energy prices etc. Additionally, high energy poverty rates associate closely with high at-risk-of-poverty rates, high share of elderly people in society; inabilities to satisfy basic food, high rates poor health incidences etc. Studies provided evidence that high rates of energy poverty are linked to poor health outcomes. The countries having high energy poverty rates demonstrate low self-reported health indicators. Of course, poor health is a result of various drivers, including unhealthy life choices, medical services in the country, environmental, especially air, quality, etc. Nevertheless, households experiencing energy poverty usually live in colder homes and do not afford other necessary goods, such as food, and do not afford medical services and decent living conditions as well [24–26].

There is a common situation that when national energy poverty rates are below 5%, the at-risk-of-poverty rates are usually less than 25%, and thereafter both rates can increase substantially [27]. For low incomes households, the problems of paying energy bills is becoming harder, as rising energy prices multiple further income constrictions making impossible to collect funds for energy renovation of poor-quality homes and install energy efficient appliances, causing the waste of expensive energy, and in this closing the energy poverty cycle [28]. Simcock et al. [29] discussed fuel poverty understanding in the UK. Annual statistics provide a sharp increase in the number of deaths during winter months in the UK [30]. The important fact is that this increase is significantly larger than in other countries having colder climates. Therefore, it was found that this problem in the UK is linked to the low energy efficiency of residential buildings, making heating of their homes very expensive and not affordable for low income, older and disabled households. This statistic about the 'excess' deaths has been denoted as a 'national scandal' in the UK (Johnson, 2009) claiming that lives of old and disabled matter less than for other segments of population. In the UK, concerns about the affordability of heating was always on the agenda of state policies, first of all because of worries about the public health outcomes due to cold homes. Brenda Boardman [16,17] was the first who publicized this problem by defining the fuel poverty concept. According to Boardman [16], 'fuel poverty' is the incapability of a low-income household to afford necessary heating comfort levels together with other energy services if they have to spend above 10% of their income for energy needs. The line of 10% was set based on the findings of the study indicating that deprivation is occurring when energy costs burden exceeds the national median twice [31]. This indicator was adjusted in 2013 and new 'low incomes high costs' term was introduced to define fuel poverty. The main idea of the new definition is that fuel poor households live in energy inefficient buildings and experience income poverty due to paying too high fuel bills in order to heat their home to achieve inside temperature necessary for a healthy life [32]. Therefore, UK policies are now oriented in increasing energy affordability through direct payments to older and low-income people to increase heating affordability during winter months, but putting more emphasis on energy efficiency improvements. These main negative effects of fuel poverty were defined in the UK context: poor health and inability to satisfy other needs due to high energy expenditures. Some other studies have also investigated energy poverty [33,34], however, just after the publication of a review by John Hills [32] this subject was explored very deeply. The study by Hills [32] provided the term 'low cost high income'. The consequences of fuel poverty are not only linked to insufficient warmth and have an impact on the physical and mental health of people [32], but also hamper the satisfying of other necessary needs due to household budget restrains or situations such as 'heat or eat'. In this situation, low-income people are forced to choose between paying energy or food bills [35]. According to the definition by Sen [36,37], fuel poverty influences the capability of people to achieve

important daily functions, and has negative impacts on the freedom to make decisions in regarding health, education, budgeting, etc.

Another study by Moore [38] investigated energy poverty further, and energy poverty has also been addressed by using other terms, such as non-payment for energy services or cold homes etc. [39,40]. It is necessary to stress that the UK's policies and research on 'fuel poverty' had impact on various studies across the world countries. Scholars in New Zealand have also analyzed problems of energy efficiency in residential buildings and heating affordability for low income and elderly households, by linking these issues with the peak in deaths and hospitalizations during the winter months [41–43]. The study by Bouzarovski and Petrova [13] tried to develop a universal term to define energy poverty, concentrating on the fact that low-income households suffering because of energy poverty are in some way restricted from taking part in practices and customs delineating the membership of society—to a level that is necessary for maintaining a healthy life and is socially habituated.

Thomson et al. [44] stressed the need for a common energy poverty definition in the EU due to the urgency of tackling this problem by policies. The common EU definition of energy poverty would enable the recognition of this problem and enhance its political visibility. It will help to solve problem of terminological misunderstanding and provide necessary clarification of this problem. The relationship with other policy domains can also be achieved by enhancing policy synergy. Nevertheless, other studies such as Deller [45] were opposed to such a position and provided evidence that a common EU definition of fuel poverty is very challenging, as there are different energy affordability issues and country specific problems in EU Member States. Deller [45] and Dubois [46] and argued that 'different metrics, and the concepts can be applied for different tasks' in dealing with the energy poverty phenomenon. In general, energy poverty in the EU Member States has been investigated by applying the EU survey data on households' ability to heat the home, occurrence of damp and mold housing, and energy bill arrears [47,48].

Other scholars in post-soviet European countries analyzed the affordability of district heating, by providing linkages between the poor quality of housing and energy poverty [1,49,50]. According to Bouzarovski [19] and Dheret and Giuli [51] in Central-Eastern European countries, energy poverty is frequently associated with the privatization of energy sector, inherited low housing stock, limited energy infrastructure access, inability to change energy supplier of energy carrier, high energy prices and low income of people as well as aging and shrinking community. Therefore, the East European countries having a high stock of low-quality residential housing are usually facing higher risks of energy vulnerability and energy poverty. In addition, residents living in low-quality, poorly insulated homes are spending larger portions of their disposable income on heating due to energy inefficiency at their homes. Usually, these households are already vulnerable due to their in general low income. It is obvious that countries having high energy poverty rates also encounter high at-risk-of-poverty rates. One can guess that high poverty rates are linked to the range of issues such as unemployment, age, health status, economic situation of the country, public support availability, and that the high cost of heating is important contributor to energy poverty of low-income households. In Lithuania, energy poverty is even a universally spread problem affecting various income households' groups. Numerous studies in the energy poverty field have indicated that high levels of energy poverty in former communist countries were related to an increase in energy prices due to the unbundling and liberalization of energy sectors. Scholars provided evidence that energy prices have increased during the 6-year period since 2006 by 22% in the Czech Republic, by 33% in Poland and by 69% in Hungary [22]. So, energy poverty in post-communist countries is affected by sharply increased energy prices by other drivers such as housing conditions and low levels of social support due to the low budgets of countries [22].

The study by Droutsa et al. [52] analyzed energy poverty problems in post-crisis Greece and defined main reasons of energy poverty as result of austerity policy. In Ireland, with similar climatic conditions and housing stock as the UK, the energy poverty is defined as incapability to ensure adequate heating of homes due to income restrictions, or incapability to achieve adequate heating due

to the poor energy efficiency of housing stock. The main concerns of energy poverty in Ireland are also related to negative health outcomes due to energy inefficient and cold homes [47,53]. In France, the term of 'energy precariousness' is used in order to define households having difficulties in energy affordability to satisfy their basic energy requirements due to the lack of necessary financial resources or due to the poor housing conditions [54]. Though this term emphasizes less the heating problem, this allows for better consideration of dwelling and heating efficiency and affordability problems in France [46].

It is necessary to stress that most of the studies dealing with energy poverty in the European context were concentrated on heating issues in households. Therefore, according to some authors, energy poverty is first of all related to the problem of peaking winter deaths, and the evidence that these deaths happen in the older segment of the population [55,56]. As older people are more vulnerable to the cold climate, such households need more heating services than other population segments. Older people spend most of their time at home in comparison with employed people; therefore, these problems have a more significant effect on their health and quality of life. Recognizing differential need of older and disabled households [57] or people having chronic illness as well as households having small kids, the special attention should be paid to energy poverty alleviation in these population segments as they are socially and politically marginalized as they have difficulties to force governments and politicians to recognize their needs. The problem of overestimating of disability or age in a counter-productive manner was also highlighted in studies [58]. Nonetheless, putting more emphasis on certain social groups offers better understanding of this problem. Without recognition of differences between social groups and energy poverty relevance for them precise needs and vulnerabilities can be overlooked in developing policies and measures to tackle energy poverty.

The other approach for the diagnosis of energy poverty based on the energy services accessed was provided by scholars [59,60]. This tactic does not provide any statements about the necessary amount of energy to provide adequate energy services. The indicator of multi-dimensional energy poverty (MEP) was developed by Nussbaumer et al. [61], which integrates the indicators of having modern cooking fuel, a fridge, TV/radio, phone, access to electricity for lighting, etc. The total energy access indicator was also developed by other institutions, assessing households' affordability of minimum standards for access to lighting, cooking, space heating, space, food cooling services [62]. These indicators also assume that one household should not spend more than 30 min per day collecting fuel necessary to satisfy energy needs. These energy service orientated measures are probably the most comprehensive approaches for defining and measuring energy poverty [62].

4. Drivers of Energy Poverty

The main driving forces of energy poverty in Europe were addressed in several studies. Traditionally, scholars investigating energy poverty deal with the mixture of energy prices growth, decreasing household incomes, and energy-inefficient homes. Energy inefficient houses, having poor thermal insulation, use of obsolete domestic appliances, and low-efficiency heating installations result in high energy bills causing energy poverty. Scholars usually agree that low residential energy efficiency is a key reason for energy poverty, as it causes low thermal comfort, high humidity and mold in homes. Altogether, the main consequences of such a situation are bad health indicators and diverse forms of social segregation [9,25].

The main drivers of energy poverty are low incomes, high energy prices, and low energy efficiency. Therefore, it is necessary to stress that energy poverty is a situation of material deprivation extending beyond income poverty. The importance of the mentioned drivers is country and household specific. Even in rich countries having low energy poverty rates, low-income households experience energy poverty problem [63]. In Finland, for example, having a high energy consumption per capita level and a cool climate, the portion of low-income people that live in poor quality and low heat comfort homes and that have energy bill debts is twice higher than the country average. According to Bouzarovski [19], in Eastern European countries, the high level of energy poverty is linked to inadequate investment in

energy efficiency improvements and inadequate social support levels since the collapse of socialism. In the UK and Ireland, the overlapping of low income and energy inefficient housing stock provided to high rates of energy poverty, though these countries' have quite mild climates [64,65]. In Italy, energy poverty is related to low level of energy affordability due to high energy prices, and in Austria, energy poverty is attributed to energy-inefficient homes causing drastic energy bills increase with energy price increase [66].

Scholars have defined supplementary factors having impact on energy poverty. Households such as families with children, pensioners, disabled people higher risk of energy vulnerability and energy poverty [65,67,68]. The studies also have revealed that the most vulnerable households in post-communist countries such as Hungary, Lithuania etc. are 'trapped' in low energy efficiency homes with poor inflexible heating systems without no abilities to regulate heating or to switch to other forms of energy supply [1,22,49]. The lack of adequate energy services lead to broader inequalities in the housing stock governance [20,69]. Maxim et al. [63] showed in his study that tenants without regulated rents and owners with mortgages experience energy poverty because of financial restrains for improving energy efficiency of their apartments as compared to the tenants having regulated rents or homeowners without mortgages. Besides that, studies indicated that people living in detached houses are more disposed to energy poverty than those living in multi-flat buildings due to the impact of external walls. Additionally, it was found that people living in rural areas have more struggles to heat their houses adequately [48]. The main reasons are the restricted energy supply options and high deprivation rates in rural areas. The lack of adequate state support is also an important issue [22].

The main drivers of energy poverty are addressed in Table 1.

Table 1. The main drivers of energy poverty in the EU.

Main Drivers	Description
Limited access	Limited availability of energy supply options to meet household needs.
Low affordability	High energy prices and low income of households, including high taxes and inadequate social support schemes. Lack of investments in new energy infrastructure development.
Low flexibility	Restrictions of choice of energy supply options or service providers to satisfy household needs.
Low energy efficiency	High energy losses during energy conversions in households
Needs	Discrepancies between energy needs and available energy services due to social, cultural, economic or health reasons.
Lack of practices	Lack of knowledge and awareness about energy efficiency support programs or energy-saving behaviors in households

Sources: Created by authors based on [21,22].

The drivers of energy poverty are rooted in country-specific cultural, social, political, and environmental conditions.

Capability theory was proposed as a useful framework for defining energy poverty as well. Capability theory was discussed in several works [13,61,70,71], but without providing systematic review and development of a clear theoretical concept. The important input of capability theory to address energy poverty issues was provided by Sovacool et al. [72]. This study has provided important arguments for understanding of energy affordability in terms of justice. In another study [73] the energy use was conceptualized from a capabilities perspective, based on the works of (indicatively) Sen and Nussbaum. The linkages between energy and human wellbeing was addressed, and energy deprivation was conceptualized based on these relationships. Understanding energy poverty and vulnerability in terms of capabilities allows finding multiple spaces for policies and measures in order to achieve synergy. This also allows to analyze energy poverty issues in the context of climate change and moving towards carbon-free future of mankind.

In Table 2 the main concepts of energy poverty are given.

Table 2. Energy or fuel poverty concept.

Authors	Energy Poverty Definitions
Boardman [16,17]	Fuel poverty is the incapability of a household to afford heating and other energy services at their homes, if they are required to spend more than 10% of income for satisfying their energy needs.
Foster, et al. [15]	Energy poverty is assessed based on the portion of households living at or below the poverty line established in the country based on the overall expenditure of households.
Hills [32]	Energy poverty is associated with low income and high energy costs issues, assuming that household should live in energy inefficient homes, therefore energy poor households are left in residual income poverty (below the official poverty line) due to covering they energy bills assuming that they are heating their homes to the recommended level.
Barnes [14]	Energy poverty is assessed based on energy poverty line, defined as minimum end-use energy. In this case, energy poverty is understood as the line at which households consume the bare minimum energy necessary to maintain good health. Beyond this line, energy provides for higher economic welfare levels.
Thomson et al. [44]	Energy poverty is a situation where households are forced either to use a disproportionately high proportion of their income to satisfy their energy needs at the cost of having adequate food intake, etc., or they are forced to reduce their spending on energy needs by tolerating the decreased living standards or are enforced to do both.
Day et al. [74,75]	Energy poverty is the incapability to fulfill households needs due to direct or indirect consequences of insufficient access to affordable, reliable, and safe energy services, also addressing available options for fulfilling these capabilities.
De Quero and Lapostolet [54]	An energy precariousness situation is a situation when households are facing various important difficulties in accessing the necessary energy provision services to fulfill their basic needs, due to lack of financial resources or of poor housing conditions.
Bouzarovski and Tirado Herrero [22]	Energy poverty is a situation when households are 'trapped' in poor residential housing stock distinguished with poor inflexible district heating systems, reinforced by the prohibited switch to other forms of energy supply.
Bouzarovski and Cauvain, [20]	Energy poverty is lack of households' possibilities to afford necessary warmth in their homes due to low income or low energy inefficiency of residential housing.
Clinch and Healy [64] Thomson and Snell [48]	Fuel poverty is households' inability to heat adequately their homes, linked to damp and mold housing, and energy bill arrears.
Frank et al. [35]; Rademaekers et al. [76]	Energy poverty is a situation when households must make a choice between to heat or to eat, where households are put in a situation to choose between paying either energy or food bills.
UN [77]	Energy poverty means the lack of access to basic energy provision services such as electricity, heating, food cooling, cooking, etc.
Pye et al. [78]	Energy poverty is the situation where individuals are not able to adequately heat (or provide necessary energy services) in their homes at affordable cost.
EC [79]	Energy poverty occurs where a household finds it difficult or impossible to ensure adequate heating in the dwelling at an affordable price and having access to other energy-related services, such as lighting, transport or electricity for use of the Internet or other devices at a reasonable price.
Bouzarovski [19]	Energy poverty is a situation in which a household cannot achieve necessary and socially desirable energy services in their homes.

Sources: created by authors.

Summarizing all the main definitions of energy poverty, they can be divided into two main categories: disproportionally high share of household's income spent on energy and inability to consume enough energy services to satisfy the household's needs due to unaffordable cost or other restrictions. A good illustration of the latter case is insufficient heating comfort in multi-apartment buildings of post-communist countries due to poorly insulated buildings and apartments lacking energy regulation or ability of switching to another energy supply option. Therefore, one can notice that energy poverty is a multifaceted and broad topic involving economic, social, behavioral, policy, etc., dynamics and country-specific conditions [48].

5. Climate Change Mitigation Barriers in Energy Poor Households

The authors [80–82] pointed out that GHG emission reduction measures in households brought only little success due to energy efficiency or GHG emission reduction paradox. The popular explanation about the main reasons of these paradoxes provided in scientific literature is the fact that all these policies and measures do not adequately address the behavioral and psychological as well organizational barriers in household's decision making. Authors agree that traditional GHG mitigation policies in households have mostly focused on fiscal and financial incentives, i.e., subsidies and tax allowances and did not provide expected results [83]. Several scholars recommend in addition to financial incentives to implement information dissemination and environmental awareness rising policies, providing more understanding about renewable energy source (RES) technologies and benefits of energy renovations of multi-flat buildings as well as to ensure middle actors activities in the market by increased assignment of energy efficiency renovation specialists [83,84].

Scholars have not acknowledged the kinds of barriers that exist to energy efficiency in energy poor households' groups. There is a general understanding that low income households are prohibited from making necessary investments for energy efficiency improvements and they live in rented apartments, therefore facing market failure linked to the landlords and tenant's dilemmas. Some studies identified what savings are inevitable for a range of different energy efficiency investments and how much these costs should be reduced in order to overcome financial barriers for implementing energy efficiency measures. Some studies showed that energy expenditures of households even tend to increase following energy efficiency improvements due to a rebound effect. Having perfect understanding of the behaviors of energy poor households in terms of returns to investments from energy efficiency measures in the form of increased comfort and reduced energy bills would allow the addressing of the main barriers, and to propose facilitators of their behavioral changes. It is also necessary to stress that behavioral theory in this area has not focused on households that are in energy poverty but on more general issues of adoption of responsible or sustainable behaviors. Nevertheless, the findings from this broader literature on shaping sustainable behavior can be also applied to energy poor households. It is especially important to address the changing social norms in context of energy poor households. Such measures as constant energy metering, collective purchasing, etc., allow some certainty level of reductions in energy expenditures or increased thermal comfort associated with making behavioral changes [83,84]. Therefore, more understanding is necessary about the main drivers of changes to habitual behavior to increase energy efficiency in energy poor households. There are studies dealing with changing habits in the behavioral and psychological literature, however, with no focus on specific behavior of the energy poor consumer groups.

This expected utility theory (EUT) formed the basis for decision making, as it provides the list of the main tools which are helpful to achieving main policy targets. EUT considers that households' behavior and decisions are grounded by comparison of the costs and benefits of alternatives. Therefore, the EUT assumes that behavioral changes can occur only due to economic incentives and provision of necessary information [85]. Based on these main assumptions of EUT, policy makers first of all deal with the economic or financial barriers of peoples' behavior and pursue to establish taxes, subsidies and other incentives, including restrictions and regulations and awareness rising measures or campaigns, in order to encourage behavioral changes.

Therefore, EUT permits straight-forward predictions about behavioral changes. However, behavioral economics insights [86,87] provided proof that individuals systematically demonstrate examples of decision-making pattern constantly deviating from EUT [88]. Behavioral economics analyses of these irrational behaviors have provided explanations for that, allowing us to have a more realistic understanding of individuals decision-making processes. It also allows us to develop new policy tools and effective collective behavioral changes, and to make more accurate forecasts of policies impacts [89].

According to Khaneman and Tverskly [89], individual decision-making is made based on the dual system (System 1 and System 2). The first system centers on intuitive decision making, and the

second system provides for more controlled and analytical decision making. However, due to the limited cognitive capacity of humans [86], more decisions are being made based on intuitive premises of first system. This leads to irrational decisions and errors and confronts the EUT principles of rational choice theory [89]. According to behavioral economists, the context has crucial impact on observed behavior [89]. Therefore, the main implication of behavioral economics is that individuals are rational, but important factors linked to specific situations force them to make mistaken decisions having impact on such phenomena such as energy efficiency paradox [86].

Several scholars provided evidence that individual decisions are less rational when people are experiencing high cognitive load or are performing tasks requiring a lot of mental effort [90]. Many other factors linked to the surrounding environment such as music, light sleep or stress and bad mood [91] have impact on the cognitive capacity of individuals, leading to irrational decisions. A fundamental environmental situation having impact on the cognitive capacity of energy poor households is living in poverty and scarcity. Scholars have provided evidence that when individuals face problems linked to inability to satisfy their needs due to lack of income, they have even less cognitive capacity to make rational decisions. Therefore, the vulnerable individuals due to poverty context have limited cognitive capacity. This also be affected by other situational factors such as long-lasting stress, unsafe neighborhoods, fragile social relations, etc. Additionally, all these problems may affect other irrational decisions, requiring further mental efforts [92].

The prospect theory analyzes the issue of loss aversion [89]. The loss aversion and framing effect have impact on irrational decisions of people in energy poverty. Loss aversion is the trend to perceive losses as more hurting than comparing with possible equivalent gains in the future. Prospect theory allows us to explain irrational decision-making processes based on this phenomenon. Therefore, the individual decision is affected by the presentation of options in terms of gains or losses, named as a framing effect [93]. Therefore, the important implication of framing effect is that individuals tend to take more risks in order to avoid losses, instead of possible gains. This framing affect is also strengthened by situational factors. The energy poor households being under constant stress take more risks in order to avoid possible losses [94]. If the choice of energy inefficient or renewable energy technologies is presented as the option to avoid losses, the individuals will make decisions to implement these technologies rather than doing this if the choice is presented as possible gains. Energy poverty situations can even strengthen the tendency to react on possible future losses [92]. Vulnerable individuals might forego switching to new energy suppliers or implementing energy renovation due to the fear of receiving high energy bills in the future. Therefore, in order to overcome the framing effect and loss version barriers the guarantees for vulnerable households should be provided that they will not encounter extra costs in their energy bill, if they decide to implement measures to increase energy efficiency or switching to a new energy supplier, new tariffs etc. Nudging policies can be useful in this case [83].

Important contextual factors making impacts on the rationality of decision making is present in bias. According to behavioral economists, individuals experience behavior to put more attention on short term goals and do not take into account those that are distant in time. It means having the preference of immediate low benefits rather than higher benefits in the future [95]. However, options that provide higher future benefits can have better outcomes in peoples' lives, such as investments in education; still, people select other short-term benefits [69]. Scholars have provided evidence that households with higher incomes and lower liquidity constraints usually prefer larger benefits in the long-term future to smaller immediate benefits, and this is an important contextual factor indicating that households experiencing energy poverty tend to be more effected by the present bias phenomenon. Therefore, households living in constant stress have higher preferences for earlier rewards [96]. This situation has impacts on irrational financial decisions, such as not saving money for investments in energy efficiency improvements in order to get rewards of energy savings and reduced energy bills in the future, and impacts on even more worsening situations of energy poverty. Vulnerable households can be put in to conditions of cutting energy consumption to save expenditures

to satisfy other more important needs such as food [97]. Therefore, energy poor households do not make decisions to install energy efficiency measures or energy efficient renewable energy technologies because of these constraints. Therefore, nudging polices might be even more helpful for low income inhabitants' group [83].

Rational choice theory (RCT) considers that households' decisions are not affected by the neighboring environment or social context. Nevertheless, behavioral economics provided a lot of evidence that decisions of individuals are affected by others behavior patterns. Due to limited cognitive capacity, individuals apply simplifying heuristics in information procession [89]. Social norms are very important drivers to act or not act by expecting approval or disapproval of other people [98]. Social norms can provide for effective collaboration in small groups [99] and they have impacts on behavior on a large scale. Social norms have impact on energy consumption behavior of households as well. Therefore, the social norms can be effectively applied to solve many challenges that societies are facing today [99]. Nevertheless, it is necessary to consider the fact that social norms are specifically based on the context of a situation [100]. They can also influence undesirable behaviors, such as situations where vulnerable households do not take necessary action to save energy, because they think that such behavior is not socially accepted. Therefore, social norms can be applied to avoid inefficient energy consumption behavior such as leaving lighting on, if this is disapproved by social norms.

In addition, there is huge heterogeneity in individuals' values, preferences and risks, which is replicated in their decisions on investments in energy savings or renewable energy technologies, therefore such a type of heterogeneity should be addressed by developing policies targeting specific households' groups. As investments in renewable energy generation technologies or large-scale energy renovation decisions are a risky decision, there are many aforementioned behavioral barriers including loss aversion, framing effect, status quo and present bias, social norms etc. The organizational problems such as apartment owners' limited abilities to reach common decisions on renovation should be also taken into account, as households have different preferences due to having different incomes, age, education, environmental awareness etc.

The behavioral barriers linked with changes of status quo are also important for energy poor households, as this behavioral barrier can lead to inaction or limited behavior in a situation that requires moving from the status quo, for example registering for a subsidy program, initiating energy renovation of home or engagement in an energy service company (ESCO) or other scheme for energy efficiency improvement.

There are also important information failures which are overlapping with other behavioral barriers by even strengthening them. Gifford [101,102] proposed a comprehensive outline of behavioral barriers by allocating them to seven groups: limited cognition, perceived risks, ideologies, social norms, sunk costs, discredence in state policies and limited behavior. It is necessary to stress that low income also means that households have limited control over the life outcomes of families, an experience the lack of power as well as decrease in perceived self-efficacy. The nonexistence of control activates three main features of the poverty mindset, in turn leading to mistaken economic decisions which negatively affect the long-term welfare of energy poor households. In addition, constant stress, and its subsequent increase in stress hormones, triggers even stronger will for short-term benefits over potential higher rewards in the future. The use of limited mind resources for everyday poverty concerns provides for a cognitive overload and inability to make the right decisions and in turn even more increases heuristics and biases risks. In the long run, however, it provides for such negative consequences as poverty trap.

Policies to promote climate change mitigation at households should aim to reduce the perceived risk of these measures and provide options such as possibilities to avoid losses. One of the best ways to mitigate perceived risk is to stipulate apartment owners with guaranteed future incomes due to energy and associated costs savings. The best way to achieve this to provide obvious short-term benefits as well. Governments can support energy renovations and installation of RES micro generation technologies in residential buildings by sharing the costs and also the future benefits from potential energy and resource savings. The effect of social norms should be properly addressed and employed

to achieve better results on stimulating climate change mitigation actions on the household's level. Information provision and awareness rising can allow to spread social norms faster in the society. Energy saving behavior should become an important social norm in everyday life. In order to achieve that responsible or sustainable behavior become social norms more efforts are necessary from state policies. The boosting instead of nudging can be applied in this case of developing climate change mitigation policies [83]. For example, municipalities can play important role in development of such social norms and boosting. An ESCO model can be applied for contracting on energy renovations to mitigate financial risks of apartment owners. Similarly, policies can provide "early benefits" for apartment owners renovating their homes in order to ensure less future oriented households to be more willing to renovate their homes [97]. In addition, scholars confirmed, that the reluctance in energy renovation investments is not only individual energy efficiency or GHG mitigation gap but also a replication of household's environmental and social preferences, risks and time constrains [103]. Therefore, very important behavioral barriers of climate change mitigation actions need to be addressed by state policies especially targeting energy poor households, which are the most vulnerable and requiring more targeted policies to overcome these barriers. Energy poor households are experiencing limited cognitive, loss aversion, framing and current time bias effects even more strongly due to their specific situation of living in scarcity and constant stress.

Decision makers can apply effectively the main insights from behavioral economics by developing specific "choice architecture for individual's everyday decisions making or nudging approach [104]. Especially, they can develop energy poverty reduction measures in order not to create additional burden for energy vulnerable individuals' cognitive capacity since life under scarcity settings requires many additional mental efforts in everyday life. It is important to unlock energy poor households mental potential to make decisions long-term rational decisions resulting in their better future and reduction of energy poverty.

Behaviorally informed climate change mitigation policies should aim to reduce the factors having negative impact on depleting cognitive capacity, and to form better conditions for making rational decisions such as engaging in energy saving and other rational energy-related decisions and programs. Such nudging policies and measures can use default options for households, establishment of automatic enrolment to available energy renovation subsidies programs, and then refusal is necessary not to be included in this program. The commitment devices used for paying the bills including publicly announcing commitments, or sending the reminders to save money or to pay energy and other bills. Such boosting policies, such as promotion of social norms and community engagement and development of trust between community members allows the development of new socially accepted norms of household's energy saving behavior.

Especially useful are behaviorally informed interventions, but they can be encouraged only if they are planned and implemented in transparent ways and reach the targeted households. Therefore, it is necessary to know household's goals and needs and to prevent the development of manipulative measures by the private sector. Some companies can use the cognitive biases of households to promote decisions having impact on increase of their profits. This result will have impact on discredence and mistrust to state policies and promote self-defeating behavior of households, such as not investing in a deal that is being treated to be too good to be true. This effect is called "sludging". Some companies apply aggressive marketing tools for vulnerable households to endorse decisions not in line with the interest of households, such as the buying of various destructive mortgages and fast short-term loans with extremely high interest. Consequently, policy makers should apply knowledge and evidence from behavioral economics in order to create improved consumer protection measures, in order to prevent private companies from using limited cognitive capacity of vulnerable households.

During recent years, behavioral economics was applied in shaping many state policies such as public health, however there is limited application of the insights of this research in climate change mitigation. Therefore, considering that energy poor households' decisions constantly deviate from that of perfectly rational or optimal ones, public policies should try to address these behavioral

shortcoming [81–83]. Considerable research is still required to reconcile many issues such as how behavioral barriers and failures affect deployment of energy efficiency and renewable energy technologies in energy poor households, how behavioral and or barriers relate and reinforce each other in vulnerable households, and how all these barriers can be overcome by policies and measures.

6. The Climate Change Mitigation Policies and Energy Poverty

Several scholars were dealing with the energy performance of buildings and analyzed energy conservation interventions in residential buildings in order to ensure sustainable urban development. In the energy poverty context these studies are important as they provide insights in energy planning at different scales [73,82,105] and evaluate and map the energy performance of various building stocks [52,81,105,106]; evaluating uncertainties linked to energy performance certificates use in the building stock [107–109] and assessing the energy performance certificates effect on energy renovation of buildings [80]. Many governments have implemented policies and measures to combat the energy poverty of low-income inhabitants. There are different policy approaches undertaken by governments to alleviate energy poverty. The most common approach to tackle energy affordability problems is to provide subsidies, however these are mainly short-term policies as they do not provide proper incentives to implement energy efficiency measures or energy renovation of homes, and are usually environmentally harmful and just provide distorting price effects in the energy market.

Therefore, other policies and measures are necessary to combat energy poverty. The long-term policies should be to developed targeting energy efficiency increase and use of renewable energy sources in households. Therefore, new climate change mitigation policies and measures are necessary which are targeting efficient energy consumption choices in households, and provide for the increase the quality of life and ensure energy efficiency improvements such as energy renovation of residential buildings having long-term energy poverty alleviation effect. Such measures can include financial subsidies and regulatory efficiency or renewables portfolios or standards for energy renovation and renewables in households however need to be properly shaped to address the behavioral barriers especially relevant to low income population groups.

Behavioral barriers such as status quo or present bias can be overcome by ensuring "smart default" options for energy poor households [110]. In this way households will be connected for an energy renovation subsidy program, or switching to another energy supplier or more useful utility contract and implementing energy saving energy measures as default options without asking them to do this. This allows energy poor households to overcome barriers linked to information searching to change the status quo. This allows also to diminish individuals' cognitive burden, as decision makers offer the "right" default decision instead of them. This makes the enrollment in an energy efficiency program easier, and access to energy renovation schemes or switching to a better contract or energy supplier. Sometimes these schemes were being criticized as being paternalistic and reducing free choice of people or allowing manipulations [89]. Therefore, it is necessary to provide clear information for households about the possibility to opt-out easy from the default option.

The present bias behavioral barrier can be overcome by commitment devices and reminds. Commitment devices were proved to be an effective tool to overcome behavioral barriers of energy savings for vulnerable households by providing the aid for them to implement their plans properly according to the deadlines, by showing the negative outcomes of not meeting deadlines such as social or financial sanctions [84]. Based on scientific evidence, low-income households committed to save money, generally apply very expensive schemes for their savings. Reminders are also efficient tools encouraging households to continue the previously adopted plan. Reminders are effective for promoting attention to the long-term benefits of energy savings. A simple reminder to save energy using SMS or e-mails were proved to be an effective measure. In general, households usually do not apply efficient behaviors, as they are convinced that such behavior is deviation from the socially acceptable behaviors, the provision of information about what most individuals do (such as use of fluorescent bulbs instead of a traditional bulbs) can be a very efficient policy to ensure energy saving

behaviors in energy poor households, though these bulbs are slightly more expensive however they are much more efficient and in the end will provide for electricity costs savings.

It is clear that energy efficiency improvements in households allows the addressing of energy poverty issues. Though there are many energy subsidies to help vulnerable households to deal with energy poverty, however these measures allow to short-term results in combating energy poverty. However, policies aiming to increase energy efficiency in homes, provides for long-term results and provides for increase of the quality of housing and reducing the burden of energy expenditures for low-income group of people. This also allows to safely state budget money by reducing energy subsidies which are usually environmentally harmful. It is evident that increasee in energy efficiency in homes of residents provides for significant country level benefits such as climate change mitigation, helping to increase economic growth and employment due to large scale energy retrofits and increase in energy supply security [78]. It is necessary to highlight that energy efficiency improvements positive impact on a fiscal situation in the country by dropping expenditures on energy-related subsidies, allowing more spending for needed public investments. Diminished expenditures for energy subsidies can allow to accumulate financial resources for support of energy renovation, education and public health and to make households not to make trade-off between heating and eating. These expenditures allow to provide new educational opportunities and increase usage of other goods that enhance quality of life and reduce long-term energy poverty risks.

Therefore, energy efficiency improvements in households allow the decrease of energy consumption and expenditures for paying energy bills for low income households and also deliver enhanced welfare due to mitigation of health risks linked to mortality and morbidity during winter seasons, with reduction of long-term negative health impacts such as cardiovascular, allergies and improving mental wellness. Increases in energy efficiency can also deliver benefits for the increase of employment, income growth and the overall welfare in the country. Furthermore, having a more energy efficient home will decrease the cost of transition to renewable micro generation technologies for low income households. RES can also contribute to energy poverty reduction as well as renewable micro-generation technologies, which are developing very fast and with installed capacity growth, the marginal costs of these technologies are decreasing further making them a competitive alternative with traditional energy carriers in residential sectors, including multi-apartment buildings. The transition to use of micro generation renewable energy-based technologies in households will positively affect energy bills reduction for low-income residents. In general, the cost of producing energy from renewables is higher than the cost of energy produced from traditional energy sources due to the problem of not integrated externalities linked to energy supply. In any case, the costs were diminishing for renewable energy sources, especially solar as these micro generation technologies have low long-term marginal costs, this will provide for lower energy prices in the future. Most of RES, such as solar energy are variable generation sources, as they can operate just if the sun input is physically available. Therefore, RES cannot meet base load, daily variation and peak demands currently, but renewable energy sources will play very important role in the future due to upgrading transmission system and development of smart metering and smart grid systems [111,112].

With the increase of use of renewable energy sources, their costs will constantly decrease. For example, with solar generation capacity increase in Germany, the solar installations costs decreased significantly [113]. As renewable energy sources have almost zero marginal operation costs and therefore lower market clearing prices [113]. The fossil fuels and biomass-based power plants have higher fixed costs and energy costs therefore, this has impact on higher biomass and fossil fuel-based energy generation costs [114]. Therefore, renewable energy sources are becoming cost-effective energy supply option. Numerous scholars provided clear evidence that renewable energy sources have already reached cost parity with conventional energy sources and will even overcome them in the future as they capacities will continue to develop by providing low cost advanced solar photovoltaic or wind mills designs [115]. Therefore, moving towards low carbon future from the point of view of costs burden for low income, energy poor and vulnerable households will not make any problems,

but just allow the use of cheaper and more effective clean energy sources in the future to reduce energy poverty. Additionally, prices of renewable energy micro generation technologies are sharply affected by governmental support provided to renewable energy sources. There are different policies and measures to promote use of renewable energy sources, ranging from fiscal-based incentives, quota obligations, feed-in premiums etc. [116]. In many states specific vulnerable consumer groups are excluded from obligation to pay for fiscal based incentives created to promote renewable energy sources. The feed in tariffs rates are currently being reduced in many states, due to the decrease of energy generation costs of renewable energy [117]. Many EU Member States are undertaking regular adjustments of their support schemes for renewable energy sources with the development of renewable energy technologies [116]. With the increase of state support for renewables, the final price is dropping all of the time because of lower variable costs and the almost zero marginal costs of renewable energy.

Therefore, the decarbonization of energy systems and fast penetration of renewables allows solutions for the problem of energy poverty during low carbon energy transitions. So, these processes can have positive impact on vulnerable consumers if the costs of low carbon interventions are not fully and equally covered by end-consumers through energy bills.

There scholars provided evidence that impacts of low carbon energy transitions are linked with location, consumption behavior and household size, but less with income [22]. Some studies showed that energy efficiency measures in residential buildings in Germany were unsuccessful to provide for stable energy prices, and that adequate compensation mechanisms were not provided for low-income vulnerable households [118,119]. There is evidence that low-carbon energy transitions implications depend on the taxing policy applied for fuel and energy carriers. The increase of taxes on diesel and petrol has less negative effect on energy poor households, when comparing with increased taxes on electricity and heat, as those affect poorer households [120]. This is especially pertinent to Central and Eastern Europe having lower incomes, widely developed centralized heat supply systems and more severe climate conditions in comparison with Western Europe. Problems in these countries are linked to the restricted possibilities to switch to alternative energy carriers as disconnections from centralized supply systems are prohibited.

Bouzarovski [18] provided many arguments stating that various energy price subsidies are not effective tools for redistribution of income, as high-income population groups typically use more energy in comparison to low income energy vulnerable households that are prone to be directed to RES of local interest and availability [121,122]. Therefore, many scholars agree that well-targeted income support for low income population groups via the social welfare system is more socially optimal and desirable. Other measures are linked to support of public transportation, and systemic energy renovation of old housing stock. Scholars furthermore highlighted that low-carbon energy transitions can be better, if low income vulnerable households will be funded by reduced income taxation rather than via introduction of support for covering their energy bills.

The energy justice concept can also help to develop climate change mitigation measures to ensure just low carbon energy transition. Energy poverty is linked to distributive injustice linked to limited access to energy services which is obtained due to other inequalities connected to energy prices, housing quality and income level. Three interlinked energy justice elements need to be addressed, as distributional injustice is framed also by the inadequate recognition of the energy poverty problem and procedural injustice. When addressing fuel poverty in policies, it is necessary to take into account the requirements of vulnerable households and to ensure the procedural justice by providing access to information, transparent legal process, and impact on effective decision-making. In this way the lack of procedural and recognition justice is interconnected with distributional inequalities in energy services. In such a typical policy the effectiveness of decision-making among vulnerable households has been investigated through a typology of clustering regional units by using the multivariate statistical method of cluster analysis, regarding installed power of RES plants for the production of electricity [123]. In a similar study, the new ecological paradigm scale (NEP) has been used as a uni-dimensional measure of

the overall relationship between humans' environmental attitudes and their willingness to pay for renewable energy expansion [124].

7. Synthesis of Review Results

To synthesize existing research on energy poverty and climate change mitigation in households and to advance the development of this research field, the integrated framework for addressing energy poverty issues through climate change mitigation measures in households for EU is proposed in Figure 1.

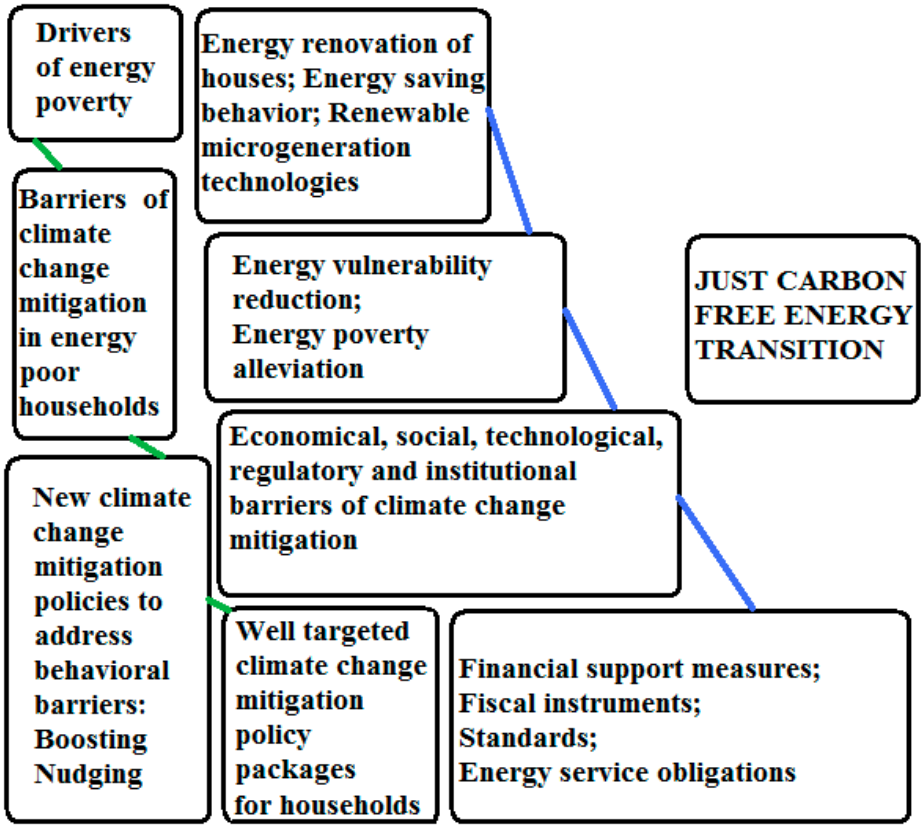

Figure 1. Integrated framework for addressing energy poverty issues through climate change mitigation measures in households for EU Member States.

Based on Figure 1, the integrated framework for addressing energy poverty issues through climate change mitigation measures in households for EU Member States should be levelled to three scalable levels, from the left to the right, as follows:

Level-1 is a four-steps and green-colored branch that contains policies that can be undertaken to climate change mitigation, while considering the drivers and the barriers of the "just carbon free energy transition".

Level-2 is a four-steps and blue-colored branch that contains the economic, social, technological, and environmental (built-environment: housing renovation; natural-environment: renewable energy sources) dimensions to be considered towards the "just carbon free energy transition".

Level-3 is the (in capital lettering) research target of the aforementioned framework, towards the "just carbon free energy transition".

The conducted systematic literature review allowed us to develop the framework and to identify the main research topics to be addressed in analyses of the most important carbon just energy transition issues and developing main recommendations.

As one can notice from the conducted systematic review of scientific literature and developed integrated framework for addressing energy poverty and climate change mitigation issues in EU households, the most important factor to achieve carbon free energy transition of EU in 2050 is to develop well-targeted climate change mitigation policies packages. These climate change policies and measures are necessary to overcome not only interlinked economic, financial, social and regulatory barriers but also to address behavioral barriers of climate change mitigation in households. Especially, it is relevant to energy poor households, as these barriers are also among the most important drivers of energy poverty in European Union countries. Therefore, the proposed framework shows the most important future research paths, and these paths first of all are related with the preparation of well-targeted climate change mitigation packages in households.

8. Conclusions and Policy Implications

Energy poverty is one of the most important problems to be addressed, followed by developing climate change mitigation policies that influence the EU towards carbon free energy in 2050. However, the existing scientific works have not yet succeeded in synthesizing the existing body of literature focusing on both energy poverty and climate change mitigation measures in EU households linked to energy consumption.

The main result of the systematic literature review provided in this paper is the developed integrated framework, linking energy poverty and climate change mitigation policies in EU households. The proposed framework shows the most important future research paths and these paths are related with the preparation of well-targeted climate change mitigation packages in households. New climate change mitigation policy packages need to be developed to overcome interlinked economic, financial, social, regulatory and behavioral barriers affecting climate change mitigation in households. Traditional climate change mitigation instruments target the economic and financial barriers of climate change mitigation actions in households. However, behavioral barriers are more important for the energy poor, as they also overlap with the most important drivers of energy poverty in European Union countries.

There are several climate change mitigation measures linked to energy consumption in households able to address the structural roots of energy poverty, such as energy renovation, energy efficiency improvements and use of renewable energy microgeneration technologies in households, however due to important behavioral barriers of energy poor households, these measures have delivered very limited results in GHG reduction. Well-shaped climate change mitigation policies can contribute to educating consumers, helping households to make right decisions, creating initiatives to improve the quality of homes, to save energy and, in turn, to reduce their energy poverty. There are two main approaches developed by behavioral economics insights: boosting and nudging. Both can address important behavioral barriers of climate change mitigation.

Therefore, energy poverty can be tackled in the EU by determined, continued, and multifaceted actions, by promoting responsible behavior patterns and discouraging environmentally harmful and wasteful energy consumption and, at the same time, reducing income inequalities on energy consumption. However, there is a lack of evidence on the behaviors and attitudes of energy poor households, and it is necessary to investigate them in order to address these main behavioral barriers of energy vulnerable households and to develop well-shaped policies and measures targeting them. It is very important to define the most important causes of why households do not take up the initiatives designed to help them to get out of energy poverty, especially linked with energy efficiency improvements.

The conducted analysis and assessment suggests that additional research is necessary to address policies and measures designed to target energy vulnerable households by incorporating relevant non-economic issues in the decision making of the households, especially those linked to behavioral change, which is not adequately addressed by current climate change mitigation measures.

Author Contributions: All authors contributed equally to the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by a grant S-REP-20-3 from the Research Council of Lithuania.

Conflicts of Interest: The authors declare no conflict of interest.

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