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Focus article

Bringing fuel poverty forward from post-intervention evaluations to design and decision-making stages

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The growing threats of climate change and the necessity of a sustainable energy transition are now well underway across the world (York and Bell, 2019). Different societies have implemented different measures to drive improvements in their energy system and meet sustainable development goals. In this context, the building sector -as one of the major contributors to the climate crisis- has a key role in the decarbonisation of the energy systems (Röck et al., 2020). At the European Union (EU) level, buildings account for around 450 Mtoe (million tonnes of oil equivalent) of the final energy consumption, making up 43 per cent of total EU energy use in 2019 (Rousselot and Rocha, 2021). Buildings in the EU are also responsible for 36 per cent of total direct and indirect greenhouse gas emissions (European Environment Agency, 2021). The figures clearly show the need for fully exploiting the potential for energy conservation and carbon reduction in the building sector. The unique importance of sustainable transition in this sector has been a point of consensus in recent years (Wang et al., 2018).

However, sustainable transitions involve more than a simple shift to less carbon-intensive technologies. They are tied up with societal regimes and have the potential to negatively impact upon the wellbeing of people and communities if end-user needs are not carefully considered (Rösch et al., 2018; Sareen and Haarstad, 2018). Increasing discussion around these social aspects of transition strategies has led to a renewed focus on discourses of "just transition" in recent years. Just transition pays attention to the fact that transition policies should not reinforce existing inequalities and vulnerabilities within society, whilst supporting economic and industrial transitions (Kortetmäki and Järvelä, 2021). The notion of just transition is more challenging in the domestic sector where transition policies could directly influence the health, comfort and behaviour of end-users (Abbasi et al., 2021; Sovacool et al., 2019). Alleviating societal risks such as reducing fuel poverty, improving thermal comfort and promoting pleasant residential districts, is crucial for driving just and sustainable transitions in the residential sector. The term "sustainable" is used to underline the necessity of attending to environmental, social, and economic aspects in a balanced way (Nielsen et al., 2016). While transition strategies within this sector are increasingly being pursued, the perception of social sustainability is still vague among the stakeholders (Atanda, 2019; Sierra et al., 2018). Despite the well-established frameworks for environmental and economic assessments, social factors are less prominent within the main categories of sustainability assessments (Fatourehchi and Zarghami, 2020). This is likely due to the lack of a compelling set of social criteria, as well as the lack of a solid systematic framework for measuring human interactions with the built environment (Atanda, 2019; Atanda and Öztürk, 2020). As a result, practitioners and decision-makers have rarely incorporated social factors into the planning and design stages of real-world projects (Hashempour et al., 2020; Pombo et al., 2016). Fuel poverty alleviation is one example of a matter of social sustainability that is often overlooked at the early stages of building projects (Siksnelyte-Butkiene et al., 2021).

The gap confirms the need for more comprehensive and inclusive approaches which can bridge economic, environmental and social factors in the context of the building sector. This paper focuses on fuel poverty, arguing that it is one of the most important social indicators of sustainability in the residential building sector and which must be taken into account at the design and planning phases of energy and building interventions. It is argued that fuel poverty can be addressed by a preventive approach before it arises as a result of implementation. Incorporating fuel poverty as a decision making factor into Multi-Criteria Decision Analysis (MCDA) and Sustainability Assessment (SA) frameworks is proposed in this study, allowing fuel poverty to be investigated in conjunction with other environmental, economic and technical factors. This could enhance understanding of interactions between fuel poverty and its driving factors, leading to well-informed and sustainable decision making.

Fuel poverty, a missing factor in pre-intervention analyses

Fuel poverty, also referred to as energy poverty or energy vulnerability in the literature with slight differences in definitions, is recognised as a significant systemic problem within the energy development landscape (Bouzarovski and Petrova, 2015). Based on the 2019 data from Eurostat, nearly 34 million people, 6.9 per cent of all households, were unable to access or afford adequate indoor thermal comfort in their homes in the EU (Eurostat, 2021) and this situation will have worsened as a result of the pandemic and current energy price crisis. The magnitude of the problem has made fuel poverty a major challenge and consequently, a political priority for the EU and member states (Rodriguez-Alvarez et al., 2021). In recent years, many different initiatives have been designed and launched, aimed at alleviating fuel poverty both at the national and EU level (Sareen et al., 2020). Tackling fuel poverty could converge with decarbonisation goals, accelerating the transition away from fossil fuels while decreasing the social disparities. Previous research has suggested that building and energy improvements in the existing stock are one of the simplest and most effective ways of alleviating fuel poverty and its associated impacts on well-being and health (Grey et al., 2017). However, capturing the synergies between fuel poverty alleviation and intervention measures requires more holistic approaches to better understanding the underlying factors, drivers and impacts of fuel poverty (Ürge-Vorsatz and Herrero, 2012).

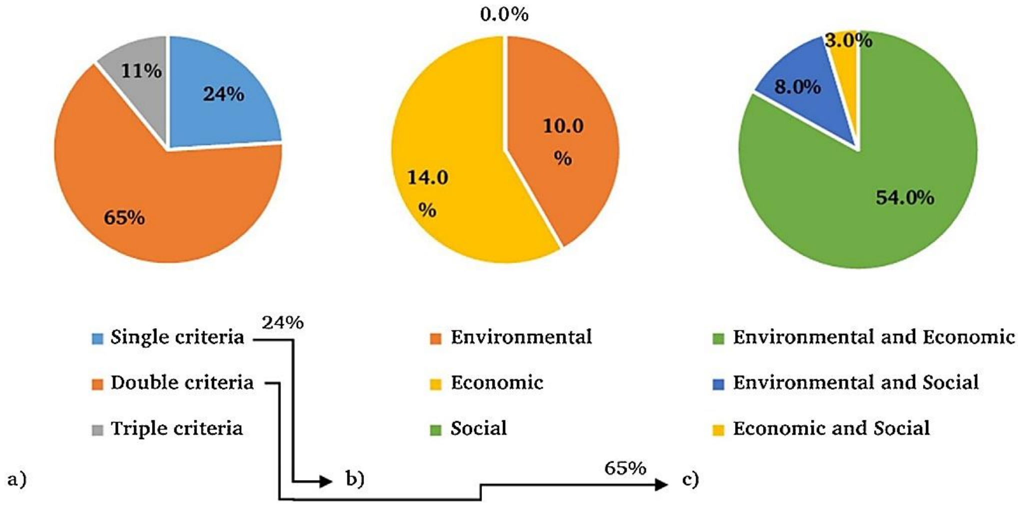
Fuel poverty is typically driven by building efficiency, energy prices, and households' income (Robinson et al., 2018), resulting in either low indoor temperatures or a trade-off effect, where households have to choose between warmth and other essentials such as food (Grey et al., 2017). This has been linked to detrimental effects on households and society, including excess winter deaths in most countries. Perhaps the most substantial impact is on physical health with a close correlation between excess winter deaths, respiratory problems and cardiovascular disease (Koh et al., 2012). Fuel poverty also causes and exacerbates mental health issues and social isolation, more severely in children and the elderly (Thomson et al., 2017). Social health is another affected health factor, as fuel poverty alleviation could reduce anti-social behaviour and dysfunction within families (Koh et al., 2012).

In recent years, fuel poverty has gained increasing recognition and prevalence among politicians and academics (Thomson et al., 2017). This paper seeks to contribute to the existing literature in two main ways. Firstly, a review of the literature reveals that a large body of fuel poverty studies are based on a diagnosis of the existing status of domestic energy deprivation (Pérez-Fargallo et al., 2018). Most of the relevant efforts over the last decade have been aimed at quantifying the extent and intensity of fuel poverty at various scales (Herrero, 2017). Fuel poverty is often measured and investigated using various subjective (household-reported perception) or objective (measurement-base) methods (Robinson et al., 2018). Likewise in research related to energy and building interventions, fuel poverty is often investigated with a diagnostic approach in post intervention phases (Sovacool et al., 2019). These studies provide valuable insights on understanding the current conditions but limit scope to predict the potential risks of future initiatives in relation to fuel poverty. That is probably why fuel poverty has not often translated into national-scale policies, except in a few places like Northern Ireland (Robinson et al., 2018). Only a few studies have adopted a predictive approach to estimate the risk of fuel poverty in dwellings not yet built or policies not yet implemented (Bienvenido-Huertas et al., 2021; Pérez-Fargallo et al., 2018). Using such methods, fuel poverty can be addressed in a preventive manner rather than the prevalent remedial approach currently taken.

Secondly, looking at the driving forces of fuel poverty, the role of technical parameters (namely the building's energy efficiency) and the energy technologies are always highlighted, along with the social parameters such as households' income (Middlemiss, 2017). However, it is noticeable in the literature that fuel poverty and its impacts are less prominent within engineering discourses and are consequently less directly represented in a variety of relevant design and decision-making processes (Bouzarovski et al., 2014; Walker and Day, 2012). In the authors' opinion, this represents a significant gap that needs to be bridged by expanding the traditional boundaries of fuel poverty scholarship. This gap is recognised in some previous studies, acknowledging the division between recognition of fuel poverty and understanding of its driving forces, as well as highlighting the key role of technological aspects of energy poverty in future developments (Bouzarovski and Petrova, 2015). In other words, fuel poverty cannot be precisely understood in solely social terms, but rather requires hybrid approaches to include technological and engineering perspectives. The need for such comprehensive approaches which could analyse fuel poverty within the complex composition of environmental, economic and technical parameters of buildings, energy systems and households is emphasised in the literature (Bouzarovski and Petrova, 2015; Pérez-Fargallo et al., 2018). By adopting these approaches, fuel poverty can be considered as a design or decision making factor for future building renovations or energy intervention strategies.

The extensive research on fuel poverty to date has made significant advances in understanding and addressing problems of energy deprivation and inequity and associated well-being and health impacts (Bouzarovski and Petrova, 2015). However, fuel poverty is less directly incorporated into design and decision-making processes associated with building intervention. To support this proposition, as well as laying the ground for a new approach, some evidence from the literature is presented in this article. Hashempour et al. (Hashempour et al., 2020) have conducted a comprehensive review of multi-criteria frameworks used for analysing energy retrofit and renovation measures in existing buildings. In investigating 51 recent publications, they found social dimensions still considerably underdeveloped compared to economic and environmental criteria. Figure 1 shows the balance of sustainability criteria in the investigated studies. Not surprisingly, none of the few studies with a social dimension have included fuel poverty and it associated vulnerabilities in their frameworks.

Fig. 1: Percentage of studies reviewed with single, double and triple sustainability criteria consideration; b) Sustainability dimensions in single-criteria assessments; c) Sustainability dimensions in double-criteria assessments (Hashempour et al., 2020)



In a similar article by Pombo *et al.* (Pombo et al., 2016), only three studies out of the 42 reviewed have incorporated social dimensions in the multi-criteria assessment of sustainable renovations, none of which have considered fuel poverty as one of the social indicators. Where social sustainability is attended to, the focus is on indoor air quality, functionality, employment, thermal comfort, and cultural aspects (Nielsen et al., 2016). It is therefore argued in this paper that multi-criteria analysis or decision-making frameworks do not take sufficient account of the potential impacts of interventions on fuel poverty, instead aiming at cost minimisation and reducing emissions. Although important in their own right, reducing energy costs and increasing energy efficiency does not necessarily lead to mitigation of fuel poverty (Sovacool et al., 2019). This could be due to the complex nature of fuel poverty or the potential 'rebound effect' that is well documented in the literature (Poortinga et al., 2018). Thus, it is sought in this article to propose an approach that allows fuel poverty to be observed at the early stages of designing building interventions, aiding decision-makers to address fuel poverty with a preventive approach.

Proposed approach

In this paper, we argue that a better understanding of fuel poverty and its drivers and determinants at the early stages of development and retrofit projects provides a sounder basis for the design of effective energy and building interventions. It is attempted to defend the view that fuel poverty should hold equal weight to other economic, ecological and technical factors in decision-making processes, helping to untangle the synergies and trade-offs between fuel poverty and other influential factors relevant to intervention scenarios and leading to better-informed, more reliable, and accurately targeted solutions.

In this respect, MCDA and SA are identified as useful and reliable approaches that have been increasingly used in building design processes to explore the trade-offs between various criteria (Pombo et al., 2016). These methods take account of the complexities within the systems, including social aspects. Essentially, these methods are multi-dimensional appraisal methods that provide quantitative measurement of the costs and benefits of different scenarios to enable comparisons across them (Munaro et al., 2020). Considerable research can be found around the theme of SA and MCDA methods and their application to energy and building improvement scenarios (Pombo et al., 2016). However, reviewing these studies shows that the most frequently assessed objectives have been investment cost, CO_2 emissions, technical efficiency, and operation and maintenance cost (Bhardwaj et al., 2019). In contrast, the considered social factors have been usually limited to public impacts, such as job creation and social acceptance, and indoor environment (i.e. thermal comfort) (Antunes and Henriques, 2016).

This article proposes that the risk of fuel poverty can be quantitatively estimated and weighted, and therefore incorporated into multi-criteria analyses. Fuel poverty can be defined as a decision variable in an MCDA or as a sustainability indicator in an SA, allowing fuel poverty to be evaluated along with other factors through a unified multi-criteria analysis. In doing so, the probability of fuel poverty or its severity should be calculated using predictive methods which are not frequently used in relevant studies. To date, only limited predictive methods have been developed, namely using the logistic regression models in (Belaïd, 2018) and the Fuel Poverty Potential Risk Index (FPPRI) in (Pérez-Fargallo et al., 2018; Pérez-Fargallo et al., 2017). These methods allow us to calculate how a change in a known building characteristic affects the probability of being fuel poor. This can also be done using one of the existing expenditure-based methods to measure fuel poverty such as the 10 per cent indicator, provided that required energy expenditure is used instead of actual energy costs. These methods can estimate the extent of domestic energy deprivation for the household with a certain range of income using the ratio of household income to the required energy expenditure.

Within these predictive measures, in contrast to the prevalent fuel poverty measurement procedures, fuel poverty calculations are made using required energy cost, instead of actual energy expenditure. This approach is supported in the literature, confirming that required energy expenditure could better represent fuel poverty as it is not affected by some unpredictable factors like households' individual behavioural and psychological mechanisms. Thus they avoid the influence of individual preferences or customs such as "households' self-rationing and self-disconnection" in vulnerable households or extensive energy needs of families with infirm members (Castaño-Rosa et al., 2020; Herrero, 2017). Thus, as the first step, the energy demand and expenditure of the dwellings after implementing an intervention should be predicted using one of the energy modelling tools and methods. Presently, several energy simulation tools, such as IES Virtual Environment, DesignBuilder, and EnergyPlus are available to facilitate the complex calculations of buildings' energy performance. Computer simulations can take account of a wide range of factors in calculations to produce accurate and reliable predictions. Crucial parameters like thermal and physical characteristics of dwelling components, energy systems specifications, household characteristics, and spatial parameters can be modified to achieve a more realistic estimation of building energy performance, which could lead to a more meaningful prediction of fuel poverty. Depending on these parameters, simulation tools predict the energy performance of a house, a group of houses, or a district. Then they obtain the energy cost based on the current energy tariffs for business-as-usual analyses or based on the projected future prices. Through such approaches, decision-makers will improve the potential for building interventions to positively impact fuel poverty metrics through mathematical predictions. This will enable them to directly observe fuel poverty in their design and decision-making, instead of interpreting energy efficiency or demand as the basis for understanding likely future scenarios.

Concluding remarks and recommendations

Sustainable transitions in the building stock could have significant benefits for climate stability and green economic development. However, sustainability is a multidimensional issue composed of a wide diversity of social, economic and environmental factors that need to be evaluated before implementing any policy and interventions within buildings. While multi-criteria approaches have facilitated the study of sustainability factors in a holistic and integrative way, social factors form lesser of a consideration in design and decision-making stages. As a result, low-income families have been under-represented in some intervention projects and have faced worsened social inequalities as a result. This article argues that fuel poverty is one of the most important social factors which needs to be observed at the early stages of intervention projects. Implementing building and energy efficiency strategies without considering their impacts on fuel poverty could potentially expose more households to the risk of energy deprivation. Therefore, the importance of utilising predictive approaches which allow fuel poverty to be incorporated in designing and planning energy interventions in the building stock is emphasised here. Such methods could give precedence to fuel poverty in research and practice, enabling building interventions to move from a remedial to a preventive approach.

The proposed approach could potentially address some of the critiques and flaws of existing approaches set out earlier in this paper. Through a predictive approach, the risk of fuel poverty that future interventions may pose to the households can be predicted using the households' income and the modelled energy expenditure. Energy modelling simplifies the way fuel poverty is often measured in the literature. Utilising energy simulations to predict the energy demand of households could minimise the need for complex building assessment tools, robust databases, and household surveys. Energy models can take multiple factors, such as buildings, energy systems, dwellers and spatial parameters, into calculations to produce more accurate and reliable predictions. They also avoid misrecognition of the households with special needs or individual preferences. Furthermore, the proposed approach allows fuel poverty to be incorporated into decision-making, rather than be investigated in post-implementation phases. It enables exploration of the synergies and trade-offs between fuel poverty and a range of criteria that aids selection of the optimal measures for a building or a group of buildings. As a result, households will be offered upgrades in their buildings which are informed by their needs and circumstances and do not exacerbate disadvantages.

In terms of application, this new approach may not be able to precisely predict the risk of fuel poverty that each intervention scenario could have on the dwellers. Several uncertainties and external factors that influence fuel poverty experience, such as households' individual behavioural and psychological mechanisms, cannot be modelled using computers. Such factors could probably only be captured through in-depth surveys and long-term interactions with households. Furthermore, considering multiple correlated factors and conducting individual or group simulations requires extensive time and effort that is not practically feasible for studies at a regional or national scale. These are the limitations of the proposed approach which may make it difficult to adopt in national scale policymaking. However, as a predictive index at the household to district levels, the new method could provide insight into possible fuel poverty challenges that future low-carbon measures could impose.

Finally, as an insight for future research, this study suggests that some uncertainties about the social implications of low-carbon transition measures can be predicted and alleviated to some extent through simulation models. Focusing on fuel poverty, the authors hope this new approach will contribute to the scholarship in this field by paving the way for fuel poverty to be assessed in the design and planning stages. However, the predictive approach needs to be applied to real-world projects to demonstrate its effectiveness in preventing or reducing vulnerabilities associated with energy upgrades in buildings. This forms the basis for further research to investigate the effectiveness of the proposed approach, as well as developing new models for other social implications of low-carbon transitions. Furthermore, compatibility of the proposed approach with the new fuel poverty indicators such as the Low Income Low Energy Efficiency (LILEE) measure needs to be considered in future research.

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