1. Introduction

Climate change is internationally acknowledged as one of the most significant challenges of our time, representing a global threat to both society and the environment. Globally, energy consumption is predicted to grow as a result of population growth, urbanisation, ownership of personal appliances, and changes in home occupancy profiles and behaviours (Nejat et al., 2015) and this will consequently impact on global carbon emissions. Many governments are “seeking to address” this challenge (Mulliner and Kirsten, 2017, p.183) through implementing strategies to mitigate climate change and its effects, whilst maintaining quality of life and meeting future energy demand (Wrigley and Crawford, 2017).

Carbon dioxide (CO_2) emissions from energy use globally accounted for 70% of total CO_2 emissions in 1990, growing to 74% in 2015 (International Energy Agency, IEA, 2018). With up to 40% of energy consumption attributable to buildings (Marino et al., 2017), the energy performance of buildings is one of the EU’s climate change priorities (Pasichnyi et al., 2019) reflected in regulations such as the Energy Performance of Buildings Directive (Willan et al., 2020). Improving the energy efficiency of buildings has recognised benefits including mitigating climate change (Wrigley and Crawford, 2017), improved occupant wellbeing (Boomsma et al., 2017; Maidment et al., 2014) including thermal satisfaction (Grey et al. 2017), and reduced utility bills (Lilley et al., 2017).

The private rented sector (PRS) accounts for around 20% of the UK housing stock (Office for National Statistics, 2019) and has been identified as having a large proportion of poor energy performance certificate (EPC) ratings (Ministry of Housing, Communities and Local Government, 2018b). The government has introduced legislation that makes it unlawful to lease property that fails to achieve minimum energy efficiency standards (MEES) based on a property’s EPC rating. This viewpoint paper presents a discussion on whether, based on the primary criticisms of the EPC, the UK’s MEES requirement is an appropriate, transparent and reliable method for improving the energy efficiency in the PRS housing stock. It draws on the existing literature to guide the discussion in addition to the author’s own observations in industry and aims to stimulate debate and further research.

This paper will provide a background on the UK housing stock, and the EPC and its principal criticisms. It will then outline concluding remarks and suggestions for future developments for policy and research.

2. Background

The UK's Climate Change Act 2008 set the world's "first legally-binding target to reduce the UK's greenhouse gas emissions by 80% by 2050, from a 1990 baseline" (Mulliner and Kirsten, 2017, p.183). By 2018, the UK had achieved a 39% reduction in CO_2 emissions compared with 1990, and a 44% reduction in greenhouse gases overall (BEIS, 2019a).

UK housing is the second largest producer of national CO_2 (BEIS, 2018a) and it is estimated that 75% of this current housing stock will exist in 2050 (Jones et al., 2017; Booth et al., 2012). Home space and water heating account for 25% of the UK's total energy consumption and 15% of its total carbon emissions (Committee on Climate Change, CCC, 2019). Therefore improving the energy efficiency of the housing stock is considered to represent an effective, inexpensive opportunity to reduce carbon emissions (Amecke, 2012) and mitigate climate change (Nejat et al., 2015). However, whilst the existing housing stock is viewed as an important component for achieving the UK's climate change policy targets (Bergman and Foxton, 2020; Booth et al., 2012), Ahern et al. (2016) argues that the energy saving potential of the existing housing stock is overestimated.

The overall improvement in home energy efficiency has slowed (Department for Business, Energy and Industrial Strategy, 2019; Gillich et al., 2019) and carbon emissions are not decreasing at the rate required (CCC, 2019). The lack of adoption of energy efficiency retrofits across the UK and the challenges of lower actual carbon savings than predicted following the adoption of measures means there is a risk that the UK emission reduction targets will not be achieved (Hamilton et al., 2016). The deceleration of energy efficiency activity is interpreted by Gillich et al. (2019) as a result of policy changes, which has traditionally driven improvements. Such energy efficiency policies are, Shove (2018) argues, framed to perpetuate unsustainable ways of life by delivering the same or more services with less energy, whilst maintaining the current standard of living. There needs to be a societal transformation to a more sustainable model of living rather than relying on energy efficiency improvements. Whilst beyond the scope of this paper, this need for a societal change will rely on, in part, intrinsic motivations of individuals and their social networks.

2.1 Housing

Owner-occupied housing accounted for 62% of housing in England in 2018, with PRS housing contributing to 20% and social housing to 17% (Office for National Statistics, 2019). Under the European Union's (EU) 2002 Energy Performance of Buildings Directive (Mulliner and Kirsten, 2017), residential buildings in EU member states are required to implement an EPC system (Mangold et al., 2015) and accompanying report. In the UK, the EPC provides a rating calculated by an accredited professional (Liu et al., 2018) using the standard assessment procedure (SAP). Ratings range from A (the most efficient) to G (the least efficient) "based on the energy efficiency of the thermal envelope and installations" such as heating (Murphy, 2014, p.664). EPCs are "regarded as a cornerstone of the effort to reach the EU's emission reduction target in the building sector" (Amecke, 2012, p.4) by reducing energy consumption (Frankie and Nadler, 2019).

Despite owner-occupied housing accounting for the greatest proportion of England's housing stock, the PRS has been identified as having an 'overrepresentation' of the worst EPC ratings (with 28% of all F and G rated housing in England based in the PRS (Ministry of Housing, Communities and Local Government, 2018b). This is not unique to England, with similar issues present internationally (Ambrose, 2015). In addition to the higher proportion of low EPC ratings, the PRS also has the greatest proportion of fuel poor households (19.4%) (BEIS, 2019b; Rosenow et al. 2013) and older dwellings (35% constructed pre-1919) (Ministry of Housing, Communities and Local Government, 2019), although an older construction date does not necessarily determine energy efficiency.

Under the Warm Homes and Energy Conservation Act 2000, fuel poverty is defined as 'a person [who] is a member of a household living on a lower income in a home which cannot be kept warm at reasonable cost' (BEIS, 2019c). Previously considered to be where a household spends 10% or more of their income on fuel bills (Swan et al., 2017; HM Government, 2015), fuel poverty is currently measured using the Low Income High Costs indicator (LIHCI). The LIHCI considers a household to be 'fuel poor' where their fuel costs are above the national median level and, were they to spend the amount required to heat their home to adequate temperature, "they would be left with a residual income below the official poverty line" (RSM, 2019, p.10) (c.f. Robinson et al., 2018 for a discussion of the implications of moving to the LIHCI). Policy is in place which aims to reduce the number of fuel poor households in England by raising the EPC rating of fuel poor houses by 2030 to at least Band C where possible (BEIS, 2019d).

Residing in a home with inadequate warmth has been shown to have a detrimental impact on physical and mental health (Collins and Dempsey, 2019; Thomson et al., 2017), particularly vulnerable groups including the elderly, children and those with chronic health conditions (Public Health England, 2014). Based on the World Health Organisation's (WHO, 2018) analysis of evidence, currently 'adequate warmth' is defined as 18˚Celsius for all rooms, and 21˚Celsius for living rooms and these are the temperatures assumed in SAP calculations. The WHO recognise that, whilst there is limited evidence on absolute indoor temperatures below which adverse health conditions are likely, increasing the temperature of colder homes is likely to have a positive impact on occupant health. This includes a reduced risk of health issues relating to cardiorespiratory conditions.

Whilst Shove (2019) suggests reflecting on the current temperature assumptions, and whether lower temperatures or heating for single rooms should be considered, Grey et al. (2017) highlights that heating only certain parts of the home can limit occupant use of cooler parts of the house and place a strain on social interaction within the home, and therefore occupant enjoyment of their home. Evidence reviewed by Public Health England (2014) suggests that negative health conditions start at around 18˚Celsius for healthy adults who are sedentary and wearing minimal clothing. This indicates that there may be scope to reduce minimum temperature standards if a behavioural change in the wider healthy adult population can be facilitated such as encouraging dressing for the season alongside improvements in home energy efficiency.

2.2 Private Rented Sector regulations

UK regulations have been introduced to accelerate energy efficiency improvements in PRS housing, contributing to carbon emission and fuel poverty reduction targets. This includes the Energy Act 2011 and, under the Landlord and Tenant Act 1985, the Homes (Fitness for Habitation) Act 2018. The Homes (Fitness for Habitation) Act 2018, came into force on 20th March 2019. It has ten principal considerations against which the courts will consider whether a property is fit for human habitation, including assessment against the Housing Health and Safety (England) Regulations 2005. One provision under the Homes (Fitness for Habitation) Act is the requirement for private and social landlords to provide a reasonable degree of thermal comfort (Wilson, 2018) in relation to efficient heating and effective insulation as defined by the Department for Communities and Local Government (2006).

The Energy Act 2011 provided for energy efficiency regulations targeting private rental property in the commercial and domestic sectors. Effective from 1st April 2018, under the Energy Efficiency (Private Rented Property) (England and Wales) Regulations 2015, it is unlawful to lease property failing to attain the MEES unless eligible for exemption (Muliner and Kirsten, 2017). Failure to comply with the MEES can result in local authorities issuing a compliance notice, the publication of the breach and issuing a penalty (BEIS, 2017a). The maximum amount a landlord can be fined is £5,000 per property (BEIS, 2017a).

Based on a building's EPC rating, the aim of the MEES is to encourage landlords to improve building energy efficiency (Royal Institution of Chartered Surveyors, n.d.). Domestic and non-domestic buildings in England and Wales must meet a minimum EPC E rating (Montlake and Gelb, 2018), rising to a minimum EPC C by 2030 (House of Commons, 2019). The aim is for the MEES to drive improvements in energy efficiency across the PRS, with a clear trajectory for sector professionals to follow. This addresses previous criticism from authors such as Ambrose (2015) regarding the lack of a regulatory driver to improve energy efficiency in the PRS. It has also attempted to mitigate the landlord-tenant split incentive, in line with the revised EPBD 2018 Paragraph 9 (EU Directive 2018/844/EU).

Also known as the 'principal-agent' problem, the split-incentive issue is where "the person making the investment to increase energy efficiency (landlord) is not the same person who benefits from it by the reduced energy costs (tenant)" (Weber and Wolff, 2018, p.681). In their study in Aberdeen, Liu et al. (2018) found that tenants were willing to pay 2 – 11% higher rents for more energy efficient properties, thus negating the split-incentive barrier by benefitting landlords with more energy efficient housing. However, this willingness was reduced during economic recession. This potential to charge a rental premium did not address other barriers identified in the study such as insufficient funding to undertake energy efficiency improvements (Liu et al., 2018).

To negate the split-incentive issue, the MEES was originally designed for improvement measures to be financed through subsidies and 'no cost' funding mechanisms such as the Green Deal. In the context of commercial buildings, McAllister and Nase (2019) suggest that issues over the Green Deal and financial incentives to support the adoption of energy efficiency measures and technologies has resulted in the upfront costs being incurred by landlords. For domestic properties, in the Energy Efficiency (Private Rented Property) (England and Wales) (Amended) Regulations 2018, a cost cap of £3,500 was introduced. Based on this, exemptions of five years could be secured where the cost of improving the energy efficiency of a PRS home to meeting the minimum EPC rating exceeded this cap. The regulations do not consider any spending prior to 1st October 2017 as contributing to the cap, potentially penalising landlords who have been in the process of improving the energy efficiency of their properties prior to this date, as highlighted in a letter to the Government from the Residential Landlords Associate (2018). The cap does not apply where there is third party funding available such as local authority grants, Green Deal finance or Energy Company Obligations to cover the full costs of the improvements identified in the EPC report (BEIS, 2017a). The UK's Green Homes Grant, which provides grants of up to £5,000 for building energy performance improvements, may present an opportunity to reduce costs incurred by landlords. Under MEES, exemptions require three quotes from different installers to demonstrate that the cost of the cheapest EPC recommendations exceeds the cost cap. In the non-domestic PRS, the Better Buildings Partnership (2020) argues this is a cumbersome requirement. It also raises the question about whether such a requirement has the potential to exploit contractors who may have a diminished chance of successfully winning improvement works where the cost exceeds the cost cap, and landlords are intending to apply for exemption.

3. Energy Performance Certificates

3.1 Background

EPCs are reported to be one of “the most important sources of information on the energy performance of the EU’s building stock” (Charalambides et al., 2019, p.2) and can be viewed as informing government policy regarding energy efficiency and assessing national improvements. The EPC was expected to drive change through market transformation (Murphy, 2014) by “informing actors in the building sector (building owners, occupants, real estate agents, etc.) about the energy performance of buildings” (Pasichnyi et al., 2019, p.486). However, conflicts exist regarding whether EPCs influence sale and rental prices (Charalambides et al., 2019; Olaussen et al., 2017) and the decision-making processes of renters and owners (Frankie and Nadler, 2019). Crucially, property value and decision-making processes are complex and, therefore, identifying the actual effect of the EPC rating amongst the multiple factors within this complex is problematic.

There are wide-ranging criticisms in the academic literature relating to EPCs. These criticisms vary depending on the country on which the study is focused. An attempt to address a number of these criticisms was made through the 2010 Energy Performance of Buildings Directive recast (Frankie and Nadler, 2019). However, some criticisms and issues remain, with the primary criticisms discussed below.

McAllister and Nase (2019, p.715) state there are a number of “major and minor potential sources of policy failure”, including that the EPC rating could be an inappropriate standard on which to base a minimum energy policy. This is echoed by the Better Buildings Partnership (2020) report on non-domestic properties. As Jenkins et al. (2017) highlight, if building owners are being encouraged to invest in the energy efficiency of their property based on EPC ratings using their own capital, the validation of the model behind the EPC and related advice is of great importance. If, as Jenkins et al. (2017) suggest, the current system of validation for EPCs and the associated recommendations is insufficient, this calls into question the robustness of the MEES.

3.2 EPC methodological approaches

A national building energy performance classification system should be credible, accurate, applicable to a wide range of buildings, reproducible, transparent, cost-effective, and clear for users to understand both the overall result and effect of choices (Ahern et al., 2016). The methodological approach will impact on a number of these desirable outcomes. Implementation of EPC systems across EU Member States can considerably differ (Amecke, 2012). Cozza et al. (2019) emphasise that due to this difference between countries, research findings on EPCs in a specific county cannot be assumed to be generalisable to other countries. Broadly there are two primary methodological approaches to produce an EPC: (1) the estimation method and (2) the measurement method (Crawley et al., 2019; Zirngibl and Bendžalová, 2015). Countries also include different data requirements, for example some incorporating cooling needs and plug loads (Kelly et al., 2012).

The estimation method is based on identifying the physical properties of a building's envelope and heating systems. It uses data from standard tables for the required energy performance calculation and average values from similar types of buildings to substitute missing information. Theoretical energy consumption represents the energy use of a building under standard conditions of occupation and normal climatic conditions (Collins and Curtis, 2018). This methodology is adopted in the UK, using SAP. For the assessment of the energy performance of existing housing, the Reduced Data Standard Assessment Procedure (RdSAP) method is used. RdSAP is used to guide EPC assessors "towards suitable input data" for running the model in the absence of complete information (Jenkins et al., 2017, p.480).

The application of a standardised calculation procedure has the advantage of being able to more effectively compare multiple buildings under standard conditions. It does not base the information on existing utility bills and therefore the final rating should not be affected by occupant behaviour, which has been shown to be variable. Indeed, occupant energy behaviour has been studied for at least four decades (e.g. Socolow, 1978) and has been identified as resulting in large variations in energy. In Gram-Hanssen's (2013) study of Danish households it was identified that energy consumption could differ by as much as a factor of three. Sunikka-Blank and Galvin (2012) report that previous research has found differences in heating energy consumption by more than a factor of 6. In a small case study research project on retrofitted social rented housing in South Wales, Jones et al. (2017) found overall little difference between monitored and actual gas consumption (10 – 21%) following the retrofit works. However, a greater difference between predicted and actual consumption was noted for electricity consumption (Jones et al., 2017). The estimation method avoids this variability and enables comparison of the energy efficiency of buildings under standard conditions. However, Cozza et al. (2019, p.6) argue that this approach should be used by policy "only to evaluate the entire building stock" and not to use these theoretical results as a reference for actual performance.

In contrast to the estimation method, the measurement method uses actual data on energy consumption to estimate building energy performance. It is quicker, less expensive to undertake and more closely reflects actual energy consumption and expenditure. The advantage of more closely reflecting actual energy consumption is that, with information more closely reflecting reality, occupiers can potentially make better informed choices about renting or purchasing properties. However, for this method the energy performance rating can be "adversely affected by occupant behaviour" and this lack of standardisation between properties means that it is not possible to compare the energy efficiency performances of properties (Kelly et al., 2012, p.6870).

Neither method is free from disadvantages. Kelly et al (2012) suggest that a combined approach could be more suitable. This is supported by Jones et al. (2017) who recommend a combination of energy modelling and actual measurements to provide greater understanding and accuracy.

One important consideration is that by EU Member States adopting different methods and data input, it demonstrates that we do not have consistency and therefore are not able to draw accurate comparisons between EU countries. This is supported by Cozza et al. (2019) and Pasculal Pascuas et al. (2017). Pasculal Pascuas et al. (2017) suggest that any cross-country comparisons of EPC should be treated with caution.

Additionally, the strength and suitability of each of these approaches depends on what the desired outcome is. Whatever the intended outcome of the EPC, Jenkins et al. (2017) highlights that we now have a good opportunity to review the current EPC, what it is used for now and in the future, and increase the accuracy and validity of the methodology.

3.3Accuracy and consistency

There have previously been issues reported relating to EPC data quality (Mangold, et al., 2015). The 2010 and 2018 EPBD call for "additional requirements to strengthen and improve the quality of" EPCs (Li et al., 2019, p.1; (EU Directive 2018/844/EU), and the EPBD 2018 requires increased transparency and consistency, including the parameters for calculations (EU Directive 2018/844/EU). To ensure quality control, EPBD recast 2010 (EU Directive 2010/31/EU) requires member states to introduce independent quality control systems for the verification of results and recommendations (Arcipowska et al., 2014), this being reaffirmed by the 2018 EPBD (EU Directive 2018/844). Despite these amendments to the 2002 EPBD, Hardy and Glew (2019) estimate between 36% and 62% of logged EPCs to be inaccurate, and Mangold et al. (2015, p.329) stating that the accuracy of the EPC across Europe "is estimated to be 35%".

There have been changes to the SAP and RdSAP calculation methodologies following periodic consultations, most recently in 2016 (BEIS, 2017b). Crawley et al. (2019) suggests that whilst there have been changes to the RdSAP calculation methodology, these have not significantly affected the overall distribution of EPC ratings. However, in conjunction with other sources of variation, uncertainty regarding EPC ratings persist. In their study of homes across England and Wales, Jenkins et al. (2017) found that multiple EPC assessors have been found to produce different results and recommendations for the same property. This is despite the introduction of verification processes under the EPBD recast 2010, training and improvements to UK software. A lack of accuracy can erode confidence in EPC ratings (Collins and Curtis, 2018), but also challenges their use to underpin minimum energy standards.

Regardless of the level of accuracy, there needs to be a consistent output of ratings, not just to enable a fair approach and to foster public trust, but to also ensure useful comparisons can be made between properties. Further, consistent ratings support the overarching aim of the EU – for market transformation. If renters and homebuyers are to make meaningful comparisons between properties, and for energy performance to contribute to their decision-making, EPC ratings must be consistent and rigorous. However, the research by Jenkins et al. (2017) identified that EPC ratings can vary by at least two energy bands, with an average difference of 11.1 points, pre-1919 dwellings experiencing the greatest difference in EPC rating for the same properties.

The question posed by Crawley et al. (2019) of how large an uncertainty is acceptable for an EPC to be useful remains pertinent here. This depends on the intended application of the EPC rating. In the case of the MEES, uncertainty of a whole energy band may be unacceptable where such a difference straddles the minimum required theoretical performance. The enormous potential difference in EPC ratings is a significant issue, particularly in light of the MEES, where the same property has the potential to either pass or fail the minimum requirement under the MEES as a consequence of the data input by the energy assessor. A lower EPC rating means the property becomes potentially unlettable until improvements are made, and this has financial implications for the landlord. Jenkins et al. (2017) identify the main reason for the variation in the scores to be individual error or differences in judgement. Indeed, they highlight that any assessment requiring some level of choice or judgement from an assessor is likely to result in variations in the potential energy rating (Jenkins et al., 2017). Further, it is possible that this is also a reflection of previous differences in training and experience amongst EPC assessors as well as pressures to be competitive, thus reducing the time spent at each property (BEIS, 2018c). According to Stone et al. (2014, p.736) 75% of the variance in EPC rating can be accounted for by errors in “geometry, heating system efficiency and external wall U-value”.

Reducing these risks alongside the potential for individual error or differences in judgement (Jenkins et al., 2017) is likely to contribute to a reduction in rating variability.

The issue of rating discrepancies is not restricted to the domestic sector, Mulliner and Kirsten (2017) identifying differences in EPC ratings for the same non-domestic building where assessments are undertaken by different professionals. In response to this, the Government and EPC accreditation bodies have implemented improvements in EPC software, assessor training, and the auditing process (BEIS, 2018c). Auditing is based on detailed records from the EPC assessments, including site notes, and auditing is performed on 2% of an assessor's lodged EPCs (Quidos, 2019). EPC assessors are also randomly audited on 1% of their reports, and the first lodged EPC for new assessors (Quidos, 2019). Auditing will also occur for EPCs which are selected based on a risk-based criteria, based on customer complaints, or failure of another audit (Elmhurst Energy, 2018).

To reduce potential errors, mobile applications are being used by some assessors and accreditation bodies, enabling 'smart defaults' being input in some fields in the software (BEIS, 2018c) but the effectiveness of this is currently unknown. There will need to be some degree of user input into such software, and therefore, whilst 'smart defaults' may help to reduce the extent of EPC rating discrepancy, the potential for differences will persist. Indeed, where input values are fixed for assessors to select between, the potential for output variance is reduced (Stone et al., 2014).

Although historically there has been a "strong association" between dwelling age and energy efficiency, this is diminishing as a result of refurbishment work (Ahern et al., 2016, p.269). Therefore, whilst default U-values may help in reducing variations between EPC ratings, care must be taken not to be overly pessimistic where standard U-values are adopted. Indeed, research has previously indicated that modelled U-values for solid walls have generally been lower than on-site measurements (Li et al., 2015; Watson, 2015; Hulme and Doran, 2014; Rhee-Duverne and Baker, 2013; Stevens and Bradford, 2013; Rye and Scott, 2012), erroneously affecting the thermal rating of solid walled buildings. To reflect the findings of research, the Building Research Establishment (2016) updated the U-values used in its RdSAP calculation. However, average U-values cannot accurately reflect all of the heterogeneous housing stock with its wide range of construction types and materials. Therefore, without undertaking on-site U-value measurements – thus increasing the time and cost associated with producing an EPC rating, a degree of uncertainty regarding the energy rating of a building will persist.

In addition to the variability of the calculated ratings, there is a large body of evidence indicating an energy performance gap between modelled and actual energy use.

3.4 The Energy Performance Gap

The energy performance gap refers to the phenomenon whereby there is a difference between predicted values and actual energy performance (Pasichnyi et al., 2019; Zou et al., 2018). Whilst it is a broad topic with varied causes (Gillich et al., 2019) there is a broad consensus in the extant literature that buildings with a poor energy performance rating consume less energy than predicted, and high energy efficiency rated buildings consume more than predicted (Cozza et al., 2019).

Research has suggested multiple factors to explain the energy performance gap. Based on a systematic literature review, Zou et al. (2018) proposed three primary categories for the root causes of this energy gap: (1) the design stage; (2) the construction stage and; (3) the operation stage. Each category encapsulates factors such as model assumptions (design stage), poor quality workmanship or design changes (construction stage) and occupant behaviour (operation stage). These categories proposed by Zou et al. (2018) broadly reflect findings of the wider literature. Factors identified by the existing literature include aspects such as the assumptions used for the algorithms to calculate predicted energy use (Sunikka-Blank and Galvin, 2012) relating to building fabric U-values, expected air change rate and internal temperatures (Cozza et al., 2019). There can be uncertainties regarding actual specification or the lack of information on the components installed (van Dronkelaar et al., 2016) leading to inaccurate data input into the energy performance software. Indeed, Cozza et al. (2019) suggest that standards overestimate for inefficient buildings and underestimate for efficient buildings. Differences can also exist between design and actual construction resulting in an energy performance gap (Sunikka-Blank and Galvin, 2012).

Occupant behaviours can have a significant impact on energy consumption. Van Dronkelaar et al. (2016) suggests that heuristic uncertainty can have an effect of 70% or more on energy usage. Home energy behaviours are highly variable because these are influenced by aspects such as occupant culture, upbringing and education (van Dronkelaar et al., 2016).

In addition to variable heating behaviours, the prebound effect has also been identified as having an impact. This is where occupants in buildings with a poorer energy performance behave more economically with their space heating (Sunikka-Blank and Galvin, 2012).When retrofitting a home with a poorer energy performance, this can result in the rebound effect whereby, rather than a decrease in energy consumption, the average internal temperature increases (Sunikka-Blank and Galvin, 2012). This is also known as 'Jevons Paradox', whereby the increase in energy efficiency lowers the implicit cost of energy which becomes more affordable and leads to greater energy consumption or the savings are spent on other services with negative environmental implications such as increased travel (Shove, 2018). Therefore, when making allowances for the rebound and prebound effects, the current estimated carbon emission reductions from the housing stock is likely to have been overestimated. However, as Crawley et al. (2019) highlight, the EPC is not intended as a method of predicting operational energy consumption, and care should be taken with any approach using it as such.

3.5 EPC Recommendations

As required by the Energy Performance Building Directive (Kelly et al., 2012), EPCs must be accompanied by "recommendations showing what energy efficiency improvements are possible and in some cases what corresponding cost savings can be expected" (Murphy 2014, p.664). Research in Norway has, however, suggested that EPC recommendations are too generic and fail to sufficiently take account of "cost-effectiveness, technical compatibility or historic character". This can result in a lack of adoption or adoption of inappropriate improvement measures (Berg and Donarelli, 2019, p.231). Further, EPC recommendations fail to provide guidance on the implementation of appropriate measures phased over time (Gonzalez Caceres, 2018). Indeed, a phased approach has been identified by Fawcett (2014) in owner-occupied homes as a way of spreading the cost and disruption.

Generic recommendations were found by Gonzalez Caceres (2018) to be common across Denmark, Germany, Norway, Poland, Spain and Sweden, as tailoring recommendations for each property would increase the cost of the EPC. However, recommendations that are too generic can be viewed as irrelevant (Berg and Donarelli, 2019), which risks fostering a lack of credibility, applicability or trust amongst the public. Further, considering the potential inaccuracies present in EPC ratings, whether it is possible to generate accurate generic recommendations is called into question. In the context of Danish owner-occupiers, Christensen et al. (2014) note the importance of EPC recommendations not telling individuals what they already know, or providing too general or trivial recommendations, supporting Gonzalez Caceres (2018) and Berg and Donarelli (2019). Although it is not clear whether such findings would extend to the UK and to landlords, such findings should not be overlooked.

Previous research states that although EPCs have reportedly resulted in the adoption of measures such as loft insulation, in relation to the number or types of energy efficiency measures adopted, there has been little or no statistical significance detected between groups with an EPC and groups without an EPC (Murphy, 2014). Further, in Christensen et al.'s (2014) study of Danish homeowners, EPCs alone do not encourage the adoption of energy efficiency improvements.

3.6 Unintended consequences

In non-domestic buildings, the Better Buildings Partnership (2020) argue that there is a risk of unintended consequences as a result of generic EPC recommendations, particularly in heritage buildings. This is not unique to non-domestic properties. Improving the thermal performance of a building is likely to alter the way it performs and inadvertently lead to unintended consequences. Particularly in historic buildings, a reduction in ventilation can result in increased condensation, and incompatible materials can lead to damage to the building fabric and trapped moisture (Agbota, 2014), leading to cold bridging and black spot mould (Watson, 2015). Further, potential negative effects from improving dwelling energy efficiency and airtightness have been identified by Collins and Dempsey (2019) as including indoor pollutants, mould growth, radio signal attenuation (i.e. mobile phone and wireless internet signal) and overheating. Preliminary research has indicated a possible connection between hospital admissions for respiratory conditions and increased home energy efficiency in the research area (Sharpe et al., 2019).

Greater consideration is needed about how best to improve the energy performance of historic buildings to reduce the negative effects of unintended consequences. This is likely to require the application of reasoned professional knowledge and judgement about the building type and the impact of specified measures, and the possible use of energy models rather than the use of generic EPC recommended measures. This includes consideration of ventilation systems, which are not currently included as part of the EPC recommended measures (Sustainable Traditional Buildings Alliance, STBA 2018) despite increased airtightness of buildings having the potential to increase issues with the building fabric and indoor air quality. Further, much better tailoring of measures is needed or clearer indication of the suitability of the measures for a property, particularly for historic buildings to provide sufficient information to the building owner and/or occupants.

4. The purpose of the EPC

SAP and EPC ratings are used for multiple purposes. The question that arises is what is the principal aim of the EPC and, as a tool, whether it meets construct validity? Is it intended to raise awareness, thus reducing the impact of the information deficit? Is it intended to provide an accurate indication of energy costs to help homebuyers and renters make informed choices, addressing what Kelly et al. (2012) call 'information asymmetry' between buyers and sellers? Is it to facilitate comparison and provide a measure of improvements nationally? Should it support the identification of energy efficiency improvements, as required by the EPBD? Is it a tool to inform policy and to support possible segmentation of the population to receive incentives?

4.1 Market transformation through information

The aim of implementing an EPC system across EU Member States was to drive market transformation. Through the provision of energy labels indicating energy costs, individuals are expected to be able to make informed choices regarding purchasing or renting a property. In turn, the expectation is that energy ratings will affect property rental and sale prices (Fuerst et al., 2016). With the addition of recommendations accompanying the EPC, owners can make further decisions about how to improve the performance of a property. This relies not only on the provision of accurate EPC ratings and relevant recommendations, but it is underpinned by the concept of information deficit.

4.2 Theoretical concept: information deficit

EPCs are a form of eco-labelling, aligning with the information deficit concept. This concept assumes that by reducing information asymmetry through education and awareness-raising, individuals will make rational choices (Owens and Driffill, 2008). Indeed, Cajias et al. (2019) suggest that the EPC has had some success in reducing information asymmetry in the German rental market. By providing building eco-labels, it is expected that objective comparisons can be drawn between buildings in relation to their calculated energy use and performance (Frankie and Nadler, 2019). However, research in Denmark – one of the forerunners in the adoption of EPCs, has shown that homeowners do not lack knowledge regarding home energy efficiency and how to improve it (Christensen et al., 2014), challenging the notion that knowledge and awareness of energy efficiency is a primary barrier to action.

Although there has been a persistent emphasis in UK government policy on the concept of information deficit, the effectiveness of housing eco-labelling has not been unequivocally demonstrated in practice. Further, eco-labelling has been criticised for its oversimplification and "naïve conceptualisation of human behaviour" (Murphy, 2014, p.665), failing to consider heterogeneity of populations and the socio-cultural and institutional contexts in which individuals act and the range of barriers to action.

In the context of PRS housing, Hope and Booth (2014) suggest the knowledge of 'casual' private landlords regarding energy efficiency is generally poor, but that such landlords considered the energy performance of their stock to be good. Whilst Hope and Booth's (2014) study surveyed just 53 landlords with SAP scores equivalent to EPC F and G ratings, there may be parallels with owner-occupiers – in Murphy's (2014) study of Dutch householders, lack of adoption of energy efficiency measures amongst participants without an EPC was reported to be because they *believed* their home to be sufficiently energy efficient. Therefore, EPCs may be able to inform such 'beliefs'. Conversely information presented in an EPC may be rejected for conflicting with those beliefs as part of 'confirmation bias', as explored in the areas of medicine, psychology and social science.

Whilst the EPC may not be sufficient in driving energy efficiency improvements, it can aid awareness in calculated energy efficiency performance. Research conducted in New Zealand noted that landlords had varying knowledge about the energy efficiency measures within their properties with lower knowledge levels overall than owner-occupiers, but better than tenants (Phillips, 2012). However, Ambrose (2015) found private landlords in the North of England were aware of the poor energy efficiency performance of their properties, but accepted this as normal within the local context. Whilst the EPC is available at the point of a new lease, it may also indicate the need for increased visibility of EPCs more generally to facilitate greater local benchmarking and competition.

Although the front cover of the EPC states that it is based on standard assumptions and may therefore not reflect actual energy consumption, the placement of this text is suggested by STBA (2018) as likely to be missed by the reader. However, if the drive is to provide prospective renters and homebuyers with greater, more accurate information to facilitate decision-making and an indication of energy costs, calculating the EPC using the measurement method may prove more useful than the estimation method. If the EPC is intended to provide a way of comparing similar properties, the use of an estimation model based on standard occupancy assumptions would be more effective but unlikely to provide occupants with an accurate indication of energy costs. Where actual energy costs deviate from those predicted, trust in and relevance of the EPC is potentially reduced. This diminishes its effectiveness in driving market transformation.

Information alone will not drive action, highlighting the importance of the EPC forming part of a mixture of policy tools and a need to recognise socio-contextual and institutional factors. The MEES has a role in driving improvements in the PRS, and may help to diminish a lack of willingness-to-pay as reported by Ambrose (2015).

4.3 Benchmarking

The EPC is a benchmarking tool rather than a tool to provide an accurate indication of anticipated energy costs. The UK EPC is based on SAP, which is more of a measure of economic performance, with the outcome significantly affected by fuel type (Kelly et al., 2012). Thus Kelly et al. (2012) argue that SAP, and therefore the EPC, is a more useful measure for policies aimed at reducing fuel poverty. Kelly (2013) further argues that SAP is inadequate for estimating the cost-effectiveness, energy efficiency or environmental performance of housing, as required for policy objectives. If the EPC is not adequate for estimating home energy efficiency, this raises the question of whether it is suitable for the MEES. Where EPCs are attempting to measure energy performance and indicate appropriate improvement measures rather than simply indicating anticipated economic performance, this questions the construct validity of the current EPC. However, doubt is also cast on its ability to accurately anticipate economic performance, Jenkins et al. (2017) suggesting that RdSAP may not be a suitable tool for estimating energy bills. It would therefore be inappropriate for estimating potential savings following energy efficiency improvements. This supports findings by Ingram et al. (2011). Whilst identifying EPC recommended measures based on a low, medium and high capital cost and their respective savings may be beneficial in informing owners of the potential tangible benefits such measures represent, such theoretical savings do not represent a useful indicator if it has the potential to undermine public trust for failing to deliver similar real-world savings.

5. Manipulating the system

The UK government recognises that variability in EPC results exists and that this is likely to be as a result of 'unintentional discrepancies' (BEIS, 2018c). However, they recognise that "deliberate manipulation of the results may also occur" (BEIS, 2018c, p.23). On behalf of the Scottish Government, Craigforth's (2017) analysis of the responses to the consultation on *Energy Efficiency and Condition Standards in Private Rented Housing* highlighted the need to ensure that the EPC system is not manipulated to achieve the required minimum rating. Indeed, in their research on energy rating 'bunching', Collins and Curtis (2018) state that there is a risk of manipulating the EPC result by adjusting the data input in the energy software to produce a more desirable energy rating. As a consequence, a perverse incentive can be created whereby raising the performance of properties that should be below an energy performance rating 'band' may result in the stagnation of the properties above the threshold, leading to the 'bunching' of energy ratings (Collins and Curtis, 2018). In their analysis of the national EPC dataset for England and Wales, Crawley et al. (2019) estimate that 24% of properties rated EPC D or above should be EPC E, but that 19% of properties rated EPC D or below should be rated EPC C. This indicates that not only is there a potential for poorly performing properties to be misclassified resulting in them passing the MEES threshold, but that there is also the potential for properties that should meet the minimum threshold to be misclassified and not meet that minimum threshold. This has the potential to create a disproportionate system that advantages landlords with properties that should be below the EPC minimum threshold, and penalises others below the threshold, creating an unacceptable level of uncertainty, and potentially skewing the overall national results, obscuring the results to provide a distorted impression of the national housing stock's energy efficiency.

To avoid unintentional mistakes and manipulation of the information to produce a more desirable energy rating, Geissler and Altmann (2015) suggest that energy software needs more clearly defined data input. They also suggest that quality control measures need to be implemented to identify professionals who consistently upload inaccurate EPCs, sending these individuals back to training to improve their knowledge and, in more extreme cases for repeat offenders, issue sanctions and disqualifications (Geissler and Altermann, 2015). This partially supports the verification requirement introduced by the EPBD 2010.

6. Closing remarks and implications for policy and research

This viewpoint paper set out to identify the primary criticisms of the EPC in the UK and whether these call into question the suitability of its use to underpin the MEES. The PRS includes a large proportion of older housing and the greatest proportion of poor energy performance. With the government drive to improve the energy efficiency of the housing stock and attenuate fuel poverty, against a background of policy driving energy efficiency improvements generally, there is an unequivocal need for legislation to drive energy efficiency improvements in the PRS. Therefore, the introduction of the MEES and the Homes (Fitness for Habitation) Act 2018 are appropriate in the context of a PRS. However, the current state of the EPC is complex and, depending on its intended purpose, it does not necessarily meet construct validity in relation to energy efficiency.

There is a clear need for EPCs, although the principal aims of the EPC in the UK appear to be multiple. This, therefore, has the potential to dilute and obscure its purpose. One argument is that, rather than energy efficiency performance, the EPC is most suited to measure fuel poverty due to the underlying calculation being significantly affected by fuel type. However, EPCs are particularly important in measuring and monitoring progress in energy efficiency in housing locally, regionally, and nationally, in addition to drawing comparisons between housing and tenure types. It is not, however, possible to draw accurate international comparisons due to the adoption of different EPC calculations across EU Member States.

The MEES is based on EPC ratings, but the EPC system has a number of criticisms levelled against it. These particularly relate to clarity over its purpose and construct validity; the assumption that market transformation can be facilitated through information; inaccuracy, consistency and the energy performance gap; the potential for rating manipulation and misclassification; and the appropriateness of the EPC recommended measures.

The first principal criticism is the apparent multiple and divergent aims against which EPCs are used, and the underlying calculations do not complement some of these aims. That is, for some applications of the EPC, the construct validity of the underlying methodology is not met.

The methodological approach for the EPC adopted in the UK is theoretical and, whilst this enables comparisons to be more easily drawn between properties, it does not necessarily reflect energy costs in reality or, therefore, the most effective improvement measures. This has implications for public trust in the EPC as an information source. A combined approach which includes theoretical information as well as actual energy prices has the potential to increase usefulness, relevance and foster trust. In implementing such an approach, in parallel with smart meters, this could contribute to 'nudging' home energy behaviour to reduce consumption. This, of course, depends on what the EPC is intended for – if it is to analyse the energy performance of the national housing stock over time, the estimation calculation approach would be more appropriate. Policy makers should review the primary purpose of the EPC to ensure a clear aim and that construct validity is met, avoiding applying the EPC for other purposes which can obfuscate and dilute the usefulness and appropriateness of the EPC. If the estimation method is retained with the use of standard occupancy assumptions, this should be more prominently displayed on the certificate.

Second, the overarching conceptualisation of the EPC as a way of facilitating market transformation is based on the outdated information deficit model. Information alone will not drive the adoption of energy efficiency improvements, and therefore EPCs should be one component of a suite of policy initiatives to expedite the energy efficiency of the housing stock. In the PRS, the MEES is a good example of policy aligning to deliver this. It likely to require support from incentives and more needs to be done to better support the delivery of improvements in the PRS. This should be recognised in future government policy and initiatives.

Third, EPC assessors' ratings are not consistent using the current system. Although there have been developments in training and the software to reduce the extent of rating differences, the issue is indicative not only of human error inherent in all social inputs, but also is a symptom of the current system in place. In an attempt to ensure EPCs remain cost-effective, attempts to streamline processes have been undertaken and improvements have been implemented. However, more needs to be done to reduce the potential for these deviations in assessed ratings between assessors, particularly when faced with a number of unknown characteristics in existing housing. This could indicate the potential for the research and development of more effective on-site tools and measurements. For example, to perform effective on-site measurements of actual U-values and air changes, without the need for time consuming, costly instruments and measurements. Even where this is achieved, it will not resolve the energy performance gap which will continue to be influenced by additional factors such as occupant behaviour and uncertainties regarding the actual specification of a number of components. A rating displayed as a range or stating data confidence could be alternative methods of presenting the likely energy efficiency of a property.

Fourth, despite systems having been implemented to deter assessors from logging inaccurate EPC ratings and improve consistency through verification, the potential exists for the manipulation and misclassification of EPC ratings. This not only introduces unacceptable levels of uncertainty, but can lead to a distorted impression of the real energy efficiency of the national housing stock. An argument might be that, at a national scale, high rated misclassified properties balance the lower rated misclassified properties. However, in the context of the MEES, for individual properties it has a palpable risk of unfairly penalising some landlords whilst unfairly advantaging others. Further, it places landlords and tenants into potentially vulnerable positions: landlords may become unable to lease a property and therefore miss rental income unnecessarily if the rating calculated is lower than reality; tenants may reside in a property that is calculated to have a higher rating than reality and should be a candidate for improvements. Until the accuracy of the EPC is improved, the MEES is not an appropriate method to deliver the actual improvements required in the PRS. The current EPC approach results in insufficiently accurate, consistent and reliable ratings and therefore undermines the MEES.

Fifth, assessors should be required to liaise with building users and owners in addition to undertaking measurements for software calculations to better inform measure recommendations. This, in conjunction with empowering assessors with greater control over the recommended measures, would address the criticism of recommended measures being too generic or inappropriate for the context (e.g. historic buildings). This has the potential to improve the usefulness of the EPC and recommendations, whilst attempting to maintain a cost-effective approach. Recommendations that are perceived as generic or not applicable has previously contributed to a lack of adoption of recommendations and a lack of public trust in the information presented. EPC recommendations should also include directions to further guidance on implementation of improvement measures, including a phased approach and the incorporation of ventilation. There needs to be more consideration about how the recommended measures can be applied whilst avoiding negative unintended consequences such as increased condensation and black spot mould, and poor indoor air quality.

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