Decarbonising Real Estate: The Evolving Relationship Between Energy Efficiency and Housing in Europe

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1.0 Introduction

Decarbonisation is a global issue affecting all classes of real estate. 27% of total UK carbon emissions is attributed to housing; however great potential to decarbonise this sector rests with the adoption of energy efficiency technologies (Nejat et al, 2015) as the energy savings realised will lower greenhouse gas (GHG) emissions. Three main approaches exist to achieve this. The first is to take a mandatory approach in which minimum high level energy efficiency standards are set, enforced and applied to both new and existing buildings by enforcing compliance through retrofits of substandard stock (Wilkinson et al, 2015; Patrick et al, 2014). Option two is a voluntary approach, using mechanisms such as Energy Performance Certificates (EPCs) or other rating tools that classify performance to stimulate awareness and action. Third, financial measures, both incentives and taxes, can be applied to 'nudge' behaviours. With most westernised countries wedded to neo-liberal governance paradigms, the voluntary fiscal approaches have prevailed over the last 30 or so years. The argument is the market will value more energy efficient properties through increased prices (RICS, 2011. Warren-Myers, 2016). It follows that a premium for energy efficient properties should be apparent (Fuerst et al, 2015. Ferlan et al, 2017). As the time available to take effective climate action diminishes, evaluation of the effectiveness of this approach is imperative.

Given the implementation of measures, both voluntary and mandatory over the last three decades, this paper reviews academic literature and case studies of a selection of large-scale consortia projects conducted in Europe. Most of the research reviewed is based on hedonic pricing analyses which have sought a relationship between Energy Performance Certificates and either capital, or rental residential values across Europe. The research sought to gain a deeper understanding of the relationship between energy efficiency and the value of residential property over time. Secondly, this study sought to determine whether more action is required to realise decarbonisation in new and existing residential property in Europe. Finally, the research sought to identify whether other approaches need to be considered to accelerate the rate of change.

2.0 The case for energy efficient residential real estate

2.1 A need to meet climate change targets

The issue of climate change and the urgent need for all sectors of society and industry to act is widely acknowledged (United Nations Climate Change, 2015). Whilst previous emphasis focussed on how to mitigate against climate change; there is recognition now that this will not be enough: adaptation is required. The 2018 Report of the Intergovernmental Panel on Climate change (IPCC) confirmed that, at best, the climate is on a trajectory for a 1.5 degree global temperature increase (IPCC, 2018[b]). Many EU countries will experience increased days with intense heat, but still with cold winters (EEA, 2012). A reduction of 80% of carbon emissions from a 1990 base was agreed in the 2015 Paris Climate Conference COP21 (UNCC, 2015), but recently public pressure is leading several countries to increase to more ambitious targets[1].

Yet climate change predictions mean that demand for energy to heat and cool property will increase, unless action is taken to increase the efficiency of the stock. Whilst energy efficiency is not a substitute for changing the source of energy away from fossil fuels, the reduction of demand for energy is a key component of any decarbonisation strategy.

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[1] Both the Netherland and the UK are planning for net-zero by 2050. Whereas this is non-statutory so far in the Netherlands, In June 2019 UK government announced legally binding net-zero emissions target for 2050 https://www.edie.net/news/11/Prime-Minister-Theresa-May-agrees-legally-binding-net-zero-emissions-target-for-2050/;

2.2 the need for increased energy efficiency in the housing sector.

The need for energy efficiency in the building stock has never been greater. The bulk of Europe's housing stock, however, is old and energy inefficient. The Buildings Performance Institute Europe (BPIE) estimates only 3% of total stock is constructed or improved to the highest energy standards (BPIE, 2017). Further, the energy efficiency of stock is correlated closely to age; and rented stock is likely to have a lower efficiency than owner-occupied stock (WGBC, 2018). Despite large strides having been made in decarbonising grid supplies, [2] in many countries a major source of energy is still sourced from fossil fuels, resulting in residential emissions accounting for a significant percentage of a country's carbon emissions; some 27% in the UK, for example (Nejat et al, 2015).

A compounding factor is the slow replacement rate of stock, which rarely exceed 1% per annum and less during periods of economic slowdown (see Balaras *et al.* 2007). Although some improvement in adoption of higher energy efficiency standards has been noted, a much faster rate and level of upgrade is needed (Artola *et al.,*2016). The 2018 IPCC report (IPCC, 2018[a]) noted building adaptation is critical to achieving climate change targets and stated rapid, far-reaching transition based on reduction in energy use demand is necessary, as well as transition from fossil fuels to clean electricity; and, greater thermal insulation of envelopes to lower heating and cooling demand. Therefore, increasingly, policies and regulations are targeting the speeding up of building adaptations and altering occupier behaviours to change the supply/demand relationships between old and new stock. This, it is argued, should lead to value differentiation between efficient and non-efficient buildings (IPPC, 2018. Artola et al, 2016).

2.3 Measuring energy efficiency: a pre-requisite to stimulating demand

If reliance on market demand for energy efficient dwellings is the preferred policy option, a reliable trusted measure of what constitutes an energy efficient building would appear to be a pre-requisite; yet no universal measure of building energy efficiency exists. The common European Union (EU) metric used is the Energy Performance Certificate (EPC) first mandated by the Energy Performance of Buildings Directive (EPBD) in 2002 and revised with increased standards in 2010 and 2018. The Directive applies across member states, however technical measurement is a matter for individual jurisdictions (Sayce & Wilkinson, 2019). All European countries require valid EPCs to be produced as part of advertising material when a building is to be let or sold, to alert buyers or tenants to the energy efficiency standards of the property (BPIE, 2019). Concerns about EPC quality, reliability and consistency between countries were acknowledged and the 2018 revision of the EPBD now requires member states to express EPCs in ways that allow cross-country comparison (BPIE, 2019).

The original EU directive required that, over time, new buildings should be constructed to Nearly Zero Energy Building Standards (NZEB) by 2020. This was defined as having; "*a very high energy performance with the nearly zero or very low amount of energy required covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby*" (European Commission 2013). Individual EU member states apply the definition differently according to local conditions including climate and much progress has been made in relation to new buildings. The 2018 EPBD (European Performance of Buildings Directive) revisions state that upgrading existing buildings is vital to achieving energy and carbon targets (BPIE, 2019). The revisions, recognising the slow pace of building replacement, require member states to develop strategies for upgrading buildings to higher energy standards with an obligation to put in place long-term renovation strategies aimed at decarbonising the existing building stock by 2050 (BPIE, 2019; Sayce & Wilkinson, 2019). These strategies have a financial component; however the means of delivery is a matter for individual member states.

There is little consistency between EU member states regarding the ways EPCs are calculated (Sayce & Wilkinson, 2019). Some countries base the EPC on KWh output; whereas for others, it is a design calculation which may, or may not, account for fuel cost. Further, in Germany and Spain, there are in-country variations that further cloud consistency and comparison. Critically, there is evidence that some EPCs, particularly those produced during the early years, may not have provided consistently accurate information (European Commission, 2013).

[2] In the UK, the contribution of non-fossil fuels has risen to approximately 50% in 2019 https://www.nationalgrid.com/britains-clean-energy-system-achieves-historic-milestone-2019

But, if market participants are to appropriately differentiate between levels of energy efficiency in buildings, accurate information is essential; further this should be trusted and readily available both to buyers and the valuers who advise in terms of market values, especially for purchases financed through secured lending. Often the only information available to the valuer to assess the level of energy efficiency of a dwelling is that which is visually accessible (for example, the qualities of doors and windows and, often less obvious heating/cooling systems) and the EPC. Therefore, if there is variability in calculation and inconsistency in results of EPCs as has been found in some countries, the EPC will not be a useable tool to help to establish comparative value (RICS, 2018).

Valuers, however, do need to be cognisant of current and published regulations and national 'road maps' towards achieving increased energy efficiency measures (RICS 2018). RICS (2018) advises that they will need to consider the impact such regulatory shifts may have on value and, in particular, the risk of value decline for non-resilient stock.

Further, where recognition has taken place that voluntary measures are not working, mandation should be based on accepted reliable measures, However, across Europe, where mandated measures (option one outlined above) are under consideration or have been introduced to assist in meeting international targets, these have been generally been based on the EPC. For example in the UK, minimum standards for investment stock have been, or are in the process of being, introduced under the overarching provisions of the Energy Act, 2011 (see for example Patrick et al, 2018).

2.4 A social as well as climate-related agenda

The principal case for trying to achieve an energy efficient housing stock lies primarily in the climate change arguments. However, it is not the only reason: there are socio-economic arguments as well. Willand et al., (2014) linked energy efficiency with occupant health and well-being. Whilst it is acknowledged that the relationship is complex, research points to energy upgrades providing social and health benefits which include psycho-social factors, better air quality and reduction of damp conditions (Fisk, 2000; Roulet et al, 2006). Further, a meta-analysis (Maidment, *et al.,*2014) found that household energy efficiency interventions typically led to small, but significant, improvement in the health of residents.

An efficient stock by reducing the need for energy consumption any supply issues will, at least in part, protect occupiers against future increases energy prices which affects those with poor purchasing power most, leading to fuel poverty, negative health outcomes and; at worst, fatalities (Basham et al.2004; Willand et al, 2015; Kholodilin et al, 2017).

Another consideration is the impact of the tenure in the case for energy upgrades. The so-called 'split incentive' (Kholodilin et al, 2017) means that, unless tenants will pay more for enhanced energy efficiency, there is no incentive, other than the 'soft' benefits, to the landlord. It follows from this, that policies which assume that financial return in the shape of enhanced market values may underplay the complexity around the drivers for improving energy efficiency in homes.

Bearing in mind the criticality of tenure patterns, the challenge to improving homes across Europe is variable, but, although within Europe owner-occupation is the most common, there is a trend towards renting (Pittini *et al.,* 2017). Critically, with the exception of social rented stock, many residential portfolios are small and in some countries often consist of less than four units (Scanlon and Whitehead, 2016), although this varies considerably across countries. These units also tend to be those most in need of upgrade, but may be owned by those with the least financial ability so to do (Shelter, 2014).

3.0 Research design

The paper seeks to review whether, to date, there is sufficient evidence that reliance on the 'nudge' approach of the EPC to incentivize energy efficient upgrades is producing a market incentive through price or other drivers, sufficient to support a non-mandatory upgrade strategy. Therefore, it was considered important to review the extant evidence linking value and energy efficiency through a literature review, but to augment this through the use of case studies, all of which have had the market value and energy efficiency relationship at their heart. The

research underlying the evidence reviewed falls into two main approaches: quantitative evidence obtained from statistical analyses and qualitative evidence gathered from literature The former reports relationships but can seldom explain them; the latter provide interpretative findings but lack the scale of the former.

To augment these reviews, the findings from a series of large-scale consortium projects seeking to support market transformation are included as they present deep insights into the issues and move towards solutions. Case studies are an acknowledged means of gain a deeper understanding of how policies are applied in practice (Yin, 2011). The results, detailed below, provide a deeper knowledge of the relationship between energy efficiency and value. The projects do not represent a comprehensive list of work recently undertaken to support market transformation; they are chosen for the size of their potential impact (Yin, 2011).

4.0 Findings

4.1 Quantitative evidence

An extensive desktop study of secondary sources gathered evidence in respect of the relationship between energy efficiency and the value of residential property over time. Secondly, the type and scope of initiatives adopted to promote and encourage energy efficiency in the residential stock were analysed to determine whether more action is required to realise decarbonisation in new and existing residential property in Europe. The research design gained insight into stakeholders views and perspectives of residential energy efficiency, evidence of premiums paid for energy efficiency when properties are sold, and sought to identify whether other approaches need to be considered to accelerate the rate of change.

For the quantitative component, twenty-one studies on the relationship between capital and/or rental values and energy efficiency in the owner-occupied, private rented and social housing sectors were reviewed. Most were large-scale studies using the hedonic pricing model developed by Rosen (1974). This model seeks to isolate the impact on value of one variable (here, energy efficiency – measured in terms of ratings); the chief intent in most studies has been to isolate the impact of the EPC within the assessment of either transaction, or rental, prices achieved.

The results of any hedonic study are dependent on researchers accurately identifying, quantifying and eliminating the impact of other variables (Rosen, 1974). In the case of these studies the other variables claimed to be eliminated, included factors known to influence residential values as location, age and condition. However, results need to be considered in context, as the presence of short-term financial incentives or changes to energy rating systems, and the extent of their adoption, can make it difficult to interpret the evidence from the academic studies meaningfully (Sayce & Wilkinson, 2019). Specifically, most studies relate to the relationship between EPC ratings – introduced in 2008 under the EPBD 2002/91/EC and altered in 2012 – and rental or capital values achieved. Some are based on valuations, while others recorded market prices.

Only studies relating to EU member states were included and the selection sought to present a balanced picture of findings. All the studies have been researched during changing regulatory, economic and social contexts and in which, in some member states, various fiscal or grant incentives have been in place. They also span countries in differing climatic zones. Table 1 summarises the studies published to 2020, but it should be recognised that most studies are based on data collected some years previously; there is therefore, an inbuilt lag on market behaviours. Almost all provide observational evidence of a positive link between energy efficiency, normally measured in terms of the EPC, and transacted prices (rental or capital), although some provide only limited evidence, or in some cases, none. Over time, the papers are more likely to report a stronger 'brown' discount than a green premium. Collectively, the studies provide strong trend data; however, they do not explain *why* value differentiation is occurring, nor can they give evidence to assist Valuers commissioned to value a specific property in a specific location, on a specific date.

Insert Table 1 here

As evidenced in Table 1, Most studies concentrate on a single member state; however, one large cross-country study conducted, as part of the EU-funded REVALUE project considered below, (Chegut *et al.,* 2016; REVALUE, 2019), comprises a regression analysis of social housing across four member states. Over 5,000 valuations of residential social housing in the UK, the Netherlands, Sweden and Germany were analysed in respect of their

reported assessed value, against both their EPC rating and standard assessment procedure (SAP) indexes, as well as components affecting energy performance (such as provision of double-glazed windows). The results revealed a slight value premium in some locations, but also increasing evidence over time of a 'brown discount', where properties with poor energy ratings decreased in value relative to the mean (REVALUE, 2019). In all cases, while it was possible to see that energy efficiency had an influence on reported capital values, particularly in the Netherlands, this was small (approximately 1 per cent) compared to the 79 per cent explained by traditional value drivers and 20 per cent that could not be explained via the model. However, supporting the findings of Feige et al (2013) and conclusions of Davis *et al.* (2015), the impact of individual components was important; indeed, within the analysis of a large housing portfolio in the UK, the quality of the glazing was found to be a significant value driver.

The implication of these results is that visible components, that in themselves contribute to energy efficiency, may be more influential in terms of value determination than actual certification. For example, purchasers can see double, or triple, glazing but not insulation placed in walls and roof spaces. This finding has importance for policy makers because, whilst they show a trend of values towards value differentiation, is this a conscious market response to energy labels, or are they indicative of other factors which influence home buying decisions? On the basis of the quantitative evidence, It may be difficult to assess, on a fine-grained level, that the policy options are working, although it does give some comfort. For this purpose, qualitative data could provide richer data as most of the quantitative studies cannot, and do not, provide this level of data.

4.2 Qualitative evidence

The quantitative evidence is large-scale, trend-based data. However valuable this is, it does not represent, and cannot be used as a basis for valuing, an individual property or portfolio or fully understanding market decisions. There are far fewer qualitative studies that seek to link energy efficiency and residential values. The research selected major qualitative research studies conducted in EU countries for this review. Of those qualitative studies, the literature search revealed two surveys of real estate professionals, notably Valuers, and a series of funded projects, which are detailed below as case studies.

4.2.1 Questionnaire surveys

The first of the two questionnaire surveys, Michl et al (2016), was a large-scale study examining sustainability and the perceptions of value held by Valuers in respect of commercial and residential instructions across a range of European countries,. It was sent by the professional body to consultant qualified valuers. The responses were primarily from the, UK, Germany and Switzerland.

It concluded that there was very little evidence that sustainability factors in general were influencing real estate values, either residential or commercial, although Valuers were collecting some data sets as advised by the professional body in their guidance. Importantly, it highlighted that those commissioning valuations were seldom requesting specific information regarding energy or other sustainability characteristics. However, Valuers reported that where the instruction was to provide an estimate of investment worth – rather than market value – this would be more likely to reflect some element of sustainability characteristics; this was mainly due to levels of certification (both mandatory and voluntary) (Michl et al, 2016). Given that other literature would suggest that it is the large commercial portfolio investors who are more likely to have adopted environmental and social governance reporting, Michl *et al.*, (2016), which did not differentiate between residential and commercial, does not support value differentiation. However this paper was based on evidence from 2012, so may not represent current practices, particularly as the professional body has made stronger recommendations to valuers within their mandatory standards.

A more recent study by Ferlan *et al.* (2017) of factors influencing residential values in urban units in Slovenia underscored a lack of significance of energy efficiency among value drivers. Ranking factors impacting residential values, they found that energy efficiency ranked 15th of 26 identified drivers, although they argued that, implicitly, it was included in the 9th ranked maintenance costs. However, overwhelmingly, traditional factors such as location, accommodation and configuration and the immediate neighbourhood characteristics, including noise and pollution levels affected value more (Ferlan *et al*., 2017).

4.3 Case studies

The third strand of the research analysed the findings from three consortia research projects, all UK government or EU funded, to ascertain different ways they drive market transformation and promote demand for more energy efficient stock. Two studies (REVALUE and EeMap) were EU funded and cross European in nature; one was a UK consortium (the LENDERS project).' Of the three, one was multi-stranded and concerned primarily motivations towards energy efficiency and the role of the Valuer (REVALUE); the remaining two were fundamentally about the role of private finance. All help to enhance understanding of the emerging relationship between energy efficiency and the residential sector in Europe.

They all point to the involvement of many major market players and a determination to drive changes in market demand and supply of energy efficient dwellings. Collectively they do not find a 'tipping point' has been reached at which energy efficiency is a key market price driver, but they point to key factors critical for policy makers.

4.3.1 REVALUE

REVALUE was a four-year EU funded project which had a stated aim of leading the "*development of appraisal norms and standards that recognise the value of energy efficiency in social and private residential real estate.*" [3] Undertaken by a consortium of organisations, it operated through several work packages, each of which used a differing research instrument. Whilst the focus was primarily on social housing and a limited number of European countries, the strands of work collectively provide insight across a number of aspects of the residential markets. Underlying the initial bid was that valuers, working within their professional standards were not differentiating between energy efficient stock and that which was not.

One strand comprised a regression study of reported valuations of social housing in the Netherlands and UK using data between 2010 and 2015. The results were therefore not of realised prices, but of valuations undertaken primarily for accounting purposing and mainly using discounted cash flow techniques, rather than analysis of comparable sales. The results reported in Chegut *et al* (2019) showed that over the study period, a relationship between reported values and EPC labels began to be discernible, both in the form of a 'brown discount' for stock with lower than average ratings and, notably in the Netherlands, an enhanced value for higher rated stock. Not reported in Chegut *et al.* (2019), but as part of the findings from the regression study reported in Sayce and Wilkinson (2019) and on the project website[4], the analysis showed that the EPC label was of lesser importance to value than specific physical attributes, notably visual aspects such as window insulation; conversely, less visual factors which influence energy efficiency such as boilers or heating systems were not associated with valuation differentials.

Another strand of empirical work was a series of roundtables conducted with Valuers across four European countries (England, Germany, Spain and the Netherlands) (REVALUE, 2019). These workshops, conducted in 2017, confirmed that EPCs were not considered to be drivers of residential value, partly due to lack of trust in their accuracy and partly due to the perceived lack of significance as part of the transaction of letting process. However, visual 'signals' such as windows were considered important to value. What also came through was that, partly due to a lack of technical training in energy matters of real estate advisers in some countries, energy investigations did not tend to form a significant part of the due diligence process (REVALUE, 2019). The conclusion of all workshops was that within residential markets, traditional values drivers dominated; energy efficiency *per se,* represented only a very small direct consideration for most buyers or tenants.

The third strand of the empirical work comprises interfacing with social housing providers to investigate their motivations for energy upgrades.[5] Two major findings emerged. First, the data held by even large scale investors on their residential portfolios was limited both by quality and quantity, which makes comparative analysis difficult and second, the motivation for energy investment lies less in anticipation of capital returns and more in their social responsibility aspirations, notably in protecting the health and well-being of their tenants, reducing fuel poverty and enhancing tenant satisfaction. This did not mean that economic arguments were unimportant;

[3] REVALUE introduction available at https://www.buildup.eu/en/practices/publications/revalue-project-final-report-value-energy-efficiency

[4] Deliverable 3.3 available at https://revalue-project.eu/wp-content/uploads/2019/08/D3.3-Regression-Analysis.pdf

[5] Deliverables D2.5 and D2.6 available at

they were, but this related more to reducing default rates and voids and supporting an ability to borrow against the security of the portfolio and protection of long-term value, than measurable rental of capital value increases. It was recognised that the business case for social landlords is not the same as for those in the private rented sector, partly due to their social purpose and partly due to the legislative constraints upon them which, notably in the UK, impacts their ability to recoup investment via increased rents.

Collectively the findings from REVALUE point to a complex picture in terms of value drivers; whilst some linkage to EPC was observed in the quantitative study, the EPC is a short-hand for energy efficiency; it was not universally accepted as a reliable measure and motivation for investment stems from a series of other considerations. Even visual signals, such as well-insulated windows may relate to the comfort (by way of protection from draughts), the security they provide against intruders and the aesthetics as much as thermal quality (Sayce and Wilkinson, 2019). The project pointed to a need for Valuers to work with energy experts and develop greater knowledge around renewable energy sources and technologies; further it provided policy makers with insights into the decision-drivers for energy efficiency retrofits; these were not necessarily value driven.

4.3.2 EeMAP (the Energy Efficient Mortgage Action Plan)

Led by the European Mortgage Federation and the European covered Bond council (EMF/ECBC), EeMAP set out to "*create a standardised 'energy efficient mortgage'*", according to which building owners are incentivised to improve the energy efficiency of their buildings or acquire an already energy efficient property by way of preferential financing conditions linked to the mortgage[6]". The contention underlying the project was that private finance has a real role to play in providing the mechanism by which existing houses can be retrofitted to energy efficient standards and to 'reward' those buying a highly efficient building. The project was predicated on the assumptions that investing in energy efficient measures could enhance capital value, thus reducing the effective loan to value ratio of the loan, and that more efficient dwellings are cheaper to run, reducing the risk that the borrower could not keep up the mortgage payments. Both assumptions underpinned the claim that lending on an energy efficient mortgage is inherently less risky than lending on an inefficient building. As with REVALUE a further premise was that valuers were not sufficiently reflecting elements of energy efficiency in their reported values.

As with REVALUE, the EeMAP project was arranged in work packages, collectively aimed at supporting the development of a European network of lenders committed to supporting 'green mortgages' and energy retrofits. The main research instruments used were qualitative including; workshops, interviews and questionnaires. Although a larger-scale quantitatively analysed review into the demand for green mortgages and into an analysis of credit risk for banks was undertaken. A major initial finding of the project was most lenders did not hold information on their loan books as to the energy efficiency of the stock against which they were lending, although there was a desire to improve this level of data.[7] From a valuation perspective, a review of the relationship between mortgage lending practice and valuation practice revealed that, whilst the aims of the project were worthy, there was no guarantee within the residential, owner occupied sector that investing in energy efficiency improvements would necessarily yield enhanced capital values. However, it would potentially assess value preservation, ensure saleability and reduce risks of obsolescence, thus reducing risk to lenders. Further, supporting some of the REVALUE findings, default risk could be lower. What it did underscore was that for the banks to fully understand risk, relating lending policies to the EPC alone would be insufficient as EPCs were thought to be "*less than a robust tool for correlation with value"* (Hartenberger *et al.* 2017:4).

Yet, at the time the research took place, most banks were asking either for no sustainability data or, at most, the EPC. Subsequent to this, a valuation 'checklist' was produced, piloted and further refined with the aim of supplying targeted information to lenders as to whether a property subject to a loan application carried a risk of 'brown discount' over and above that of an 'average' dwelling, or, alternatively whether the property presented a lower risk due to superior energy efficiency characteristics. Whilst it was reported that the checklist offered such potential, Hartenberger *et al.*(2018:1) concluded that "*only if and when energy efficiency and wider*

[6] As quoted on the EeMap website https://eemap.energyefficientmortgages.eu/services/

[7] Parallel and connected to EeMap was another project EeDapp exploring not just data issues, but how they could be overcome.

sustainability aspects are positively reflected as risk factors, will an energy efficiency mortgage product find market acceptance" and by implication, impact buyer behaviours.

Since 2017 the number of banks who have signed up to the initiative has steadily grown and, as at October 2019, nearly 50 banks have agreed to pilot the initiative[8]. Data remains an issue, as does the extent to which the valuation instruction protocols will alter to enable more sophisticated lending criteria to be adopted. In conclusion, success in terms of altering buyer demand towards more energy efficient stock and the retrofit to achieve such standards is likely to be dependent on the valuation instruction and on the internal processes of credit risk assessment EeMAP, 2019).

Going forward, the success of energy efficiency mortgages depends on two things. One is clearly the consideration of energy efficiency indicators in valuation routines; this in turn requires enhanced data. The other concerns internal risk management procedures within banks. The conclusions of the EeMap project present another important market 'nudge' related to finance. Where residential markets are dominated by mortgage-dependent buyers, the ability to access more attractive funding packages for energy efficient homes or to support such improvements is likely to be influential. In time this could drive enhanced efficiency among some residential stock, but potentially, non-qualifying stock will be at greater risk of 'brown' discounting or could potentially become 'stranded'. The inference for policy could be that support for 'green finance' might help to stimulate action – independent of actual energy retrofits.

4.3.3 The LENDERS project

The Lenders Project was a UK initiative led by the UK Green Building Council with industry and academic partners and funded by Innovate UK (Lenders, 2017). Like EeMAP, the project aimed to support borrowers and encourage them to purchase a property with greater energy efficiency, as measured through the EPC. The project did not "*aim to demonstrate a link between property valuations and energy performance, nor to the related sales values or speed of property sales* …but to provide "*a more accurate means of forecasting a homebuyers' future fuel cost"*. (LENDERS, 2017 p:13). Therefore unlike EeMAP, LENDERS viewed the challenge of stimulating demand for 'greener' stock through the position of the borrower's ability to support the loan. The premise was that borrowers who purchased a property with a high EPC rating would experience lower running costs and therefore, taking their total outgoings into account when assessing the amount they could borrow, the banks would be able to offer bigger mortgages as they would be secured against lower operational costs and more efficient dwellings.

Therefore, the project was set up *to 'analytically examine the link between property energy efficiency and fuel bills'* (LENDERS, 2017, p:3). When the project was undertaken, it was required practice for lenders to consider whether the borrower could support the intended loan. Normally this discussion takes place at an 'in principle' stage prior to the intended borrower finalising their house search, to avoid abortive time and effort on all those involved in the lending chain. Part of this calculation was undertaken by reference to official government household spending calculations. For these, costs of heating/lighting etc were calculated on a 'normalised' basis which ignored the characteristics of the property offered as security.

The LENDERS project investigated the impact of the energy efficiency of the dwelling against the EPC label. Whilst accepting the EPC is not a totally accurate measure of energy efficiency, the team constructed a model of affordability based on developed a model that predicted a property's annual fuel bill based on: the number of residents intended to live in the property; a simple categorisation of the dwelling by type and size; and the EPC band of the property (LENDERS, 2017 p:13). This they claimed provided improved data from which to make lending 'in principle' decisions, prior to the proposed purchaser agreeing an offer price on a property.

The project team, which included two mortgage lenders, were thus able to demonstrate lower fuel costs for more energy efficient dwellings in a much more 'nuanced' way than simple use of average data and such that the advantages of an energy efficient home could be passed on as a tangible benefit to homebuyers. The end project produced a working calculator through which homebuyers can access, with the provision of limited property and household information, estimates of their likely bills and can feed this into discussions in principle

[8]See news item at https://eemap.energyefficientmortgages.eu/garanti-bbva-mortgage-joins-the-lending-institutions-of-the-energy-efficient-mortgages-pilot-scheme/

about mortgage finance[9]. To date no details regarding the take up of the tool are publicly available, but the concept has received recognition by UK Government (BEIS, 2018 p:48) who wish "*to see the project recommendations implemented, including improving mortgage affordability assessments on energy bills.. to encourage consumers to purchase more efficient homes or to improve their efficiency.*"

4.3.4 RentalCal

RentalCal[10] was another EU funded project undertaken by a German-led consortium of industry organisations and universities. It developed a tool to provide investors with a tool to enable informed decisions about residential energy retrofitting based on country level analysis of building types, energy costs, subsidies and grants and potential rental value returns. The resultant tool, which is based on data from several European countries, is available for free download. This research was unique in that it sought to integrate within the tool the costs of work, the likely financial savings in relation to the energy improvements and to take full account of the rental contracts prevailing for each country. It does not claim to provide firm evidence as to whether any scheme of work will be appropriate in a particular case; instead it gives ex-ante guidance.

Unsurprisingly it concluded that *residential energy efficiency analyses are far from straightforward (*Brounen *et al.,*2018 p: 4). Nonetheless the tool does integrate a range of elements to enable an estimate as to whether it would be financially feasible to upgrade a residential building, although in its policy report it recognises that such decisions are not necessarily dependent on finance alone: such upgrades can provide 'soft' benefits such as were found in the REVALUE study.

As part of the RentalCal project, a literature review of the value implications of energy efficiency was conducted (Adan *et al.* 2016 [a]) together with four empirical studies (Adan *et al.* 2016 [b]). The findings of these studies, which include some of those listed in Table 1, confirm the findings in 4.1 above. However, the most unique contribution to the decarbonising debate, it is suggested, lies not in the tool, but in the policy recommendations (Brounen *et al.* 2018) concerning the efficacy, or otherwise, of grants and subsidies to support investor action. Critically among these it calls for financial interventions to comprise "t*ransparent and consistent long lasting funding programmes…* and to clear and stream line the *"programme jungle"* (Brounen *et al.* 2018 p:17).

4.4 Case study summary

The case studies reported above provide insights into both the barriers towards the enhancement of energy efficiency in residential units and a belief that creating a shift in demand towards energy efficient stock is essential in ensuring the delivery of low carbon homes. Whilst REVALUE was focused on rented, primarily, social rented markets, EeMap and LENDERS addressed the owner-occupation market. RentalCal was different in that it was focused on helping investors determine whether improvements would be cost effective – but in recognising the need for subsidies, it implicitly accepted that the business case was not necessarily proven: improved efficiency might lead to raised rental values – but not necessarily produce an acceptable financial return on investment.

All projects, except RentalCal, started from the premise that stimulation of demand for energy efficiency was critical; all also saw that the role of the Valuer was important. What comes through from REVALUE was that whilst, observationally, the markets are moving towards a differentiation related to energy efficiency, the rationale is primarily based, not on the often adduced argument of cost saving to the occupier or enhanced value increase, but additionally on comfort, well-being, security and, for social landlords, protection of long-term asset values.

EeMap and LENDERS were both concerned with finance; EeMap from the banking perspective in which energy efficient buildings are viewed as presenting lower credit risk due to value protection against obsolescence and lower risk of default; LENDERS on the enhanced ability to support a mortgage due to lower outgoings. Collectively, the studies show that, whilst value matters, the prospects of capital gain or investment return are only one of a complex set of decision tools and "*to pin a case for retrofitting on financial returns may be*

[9] The tool is available at https://www.epcmortgage.org.uk/

[10] For full information and the RentalCal tool see http://www.rentalcal.eu/home

misguided … other arguments may be more compelling" (Sayce and Wilkinson, 2019 p:23). RentalCal, as outlined above, was accepting of the need in many cases for fiscal breaks or/and subsidies.

However, through their empirical work, all consortia came to recognise that shifting demand is not purely about seeking a 'value add'; in particular there is a growing recognition that lenders have a key role to play in differentiating their financial offer by reference to energy efficiency and policy makers may need to continue to offer support. Whilst the role of finance for mortgage lending connected to owner-occupation, is clear, REVALUE also considered finance for social housing portfolio owners. Here the energy characteristics of individual dwellings did not have a direct relationship to the ability to borrow. Most social landlords, the research revealed, raised money for enhancements, not through secured lending but through corporate borrowing and a well-managed portfolio, with a programme for building enhancement, was perceived lower risk.

Finally, the case studies all pointed to a continuing issue with both data collection and the use of data within decision making. This was apparent within social housing portfolios, where data sets were incomplete and varied from organisation to organisation. Further in terms of lenders, the collection of energy data is in its infancy, though projects such as EeMAP and LENDERS have added visibility to the issue and RentlCal has sought to provide a decision support tool .

5.0. Conclusions

This paper sought to gain a deeper understanding of the relationship between energy efficiency and the value of residential property in Europe and by so doing to determine whether stronger policies are required to realise decarbonisation in existing residential property. It did this through an examination of the literature which sought to make a connection between energy efficiency and value and by detailing three specific projects. Underlying policy across Europe has been that market demand for energy efficient buildings, both to buy and rent, will occur through greater knowledge and realisation of cost savings that investment in energy efficiency can bring. The argument is that these cost benefits should be revealed through the pricing mechanism and emergence of a green premium. However, the only public required metric for energy is the EPC which does not measure consumption – and hence energy costs in use. Fundamentally, if the EPC is to be a transformative tool, a decade after its introduction, research should demonstrate that change is occurring.

Therefore, this paper has reviewed a range of evidence, both large-scale academic studies and more practical, consortia-led investigations. What was revealed, at first reading, could be seen to be contradictory results.

The quantitative evidence points to the emergence of a 'green premium' for residential values when prices achieved, or rent achieved, are regressed against EPC data. As a caveat to these collective findings is that the basic measure of the EPC may not be accurate and, as acknowledged by many of the authors, the state of the market, presence of incentives and other factors could have been influential; some recognise that it is the visual signals, rather than the label which may be important. There is no doubt, however, that they provide strong trend data and reveal a price differentiation, although, as with all hedonic studies they cannot offer other than a tentative explanation as to why such price differences are occurring. In contrast, valuers dealing with individual commissions report that EPC do not generally influence pricing decisions of buyers or renters and as such, are not value drivers. Writing in respect of the Australian commercial market, Thanh-Le and Warren-Myers (2019) concluded that valuers had insufficient knowledge of sustainability matters to adequately reflect sustainability in market values. On the evidence from the consortium studies discussed in this paper, such a claim would not appear to be valid in the European residential sector. These suggest that any price differentiation due to energy efficiency arise, not due to the EPC, but to visible property factors that are observable during inspection and to the overwhelming dominance of traditional value drivers.

Collectively the studies point to a continued lack of data on which to evidence market movements accurately. Importantly, however, they point to the emerging role that finance is likely to play in decision making. If energy efficient stock is deemed to be less risky to lenders and is cheaper to borrowers, this could be a more potent change agent than a business case built on possible value increase, especially as the evidence is that visual appeal, and security and well-being are also part of the decision matrix.

In conclusion, do the studies show that low or zero carbon homes can be achieved with current policies? Market pricing is moving towards brown discounting with some green premiums; social landlords are seeking to support

their tenants by refurbishments but still face barriers and lenders are only at the start of their moves to link credit risk and energy performance. Further, although there is evidence that in some cases 'green' value can emerge for energy retrofitted work, the returns may not be fully economic and rely on subsidies of fiscal breaks. As such the 'value add' argument is insufficient to drive significant change; more potent may be the value loss in not investing in the continued upgrade of the asset, especially as newer, more efficient stock becomes more readily available. On this evidence, progress exists but not at the rate that is likely to deliver against targets. For this more radical solutions, based on financial support or mandated retrofitting, as those being introduced to energy inefficient investment properties, in the UK and the Netherlands, are looking increasingly necessary. In this, valuers have a part to play, but only where they adopt a strategic advisory role: by themselves they cannot shift markets- they only reflect them.

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Table 1

Country (alphabetical)	Author(s)	Date of Publication	Sample size	Valuation (V), Price (P) or Asking Price (AP)	Method	Owner-Occupied (OO); Social Housing (S) or private rented (PRS)	Headline Findings
Denmark	Jensen *et al.*	2016	117,483	P	Multiple regression	OO	Longitudinal study of detached family house compared the period sold between before/after mandatory production of EPC ratings. Before, there was no market impact; afterwards the greater transparency showed that not only did more energy efficient dwellings gain more value relative to the 'norm' but to a greater extent less efficient dwellings lost value
Finland	Fuerst, Oikarinen *et al.*	2016	'Several thousand'	P	Hedonic regression	OO	Apartment sales prices were tested for relationship between label and price and allow for benefits other than cost saving. Premium 3.3% apartments, adjusted to 1.5% to exclude neighbourhood characteristics but only for high value units. Noted that Finland could be atypical due to high buildings standards adopted throughout.
France	Baumont *et al.*	2019	2, 549	P	Hedonic regression with spatial Durbin Model	OO	homes Using the Diagnostic de Performance Energetique (DPE) rating, Transactions of apartments and houses in Dijon revealed a low level of green premium of up to 9.75% for highly rated houses but higher levels of discount for worst low rated flats (6.8 to 11.5%) and more so for houses (16.5 to 30%). It is

							acknowledged that this also relates to age and condition.
Germany	Amecke, H. *Energy Policy*, 46, pp.4-14	2012	Not stated	P	Hedonic regression	OO	EPCs not found to influence purchaser decisions to any extent – other traditional factors held sway.
	Cajias, M. and Piazolo, D.,	2013	2,630	V	Theoretically modelling	Investment/ PRS	IPD performance data and tenant energy consumption data from 2008- 10 modelled to see if superior rents or returns achieved. Data showed return premiums of 3.15% and 0.75 €/m² rental) Energy efficiency was significantly correlated with rental levels but not with vacancy or maintenance costs.
	Kholodilin *et al.*	2017	Not stated	AP	Hedonic regression	PRS	Price premiums for investment sales exist based on future expectations, but less so than in the OO market. Explanations are proffered but it is concluded that investors place less emphasis on energy efficiency that do owner occupiers
	Cajias *et al.*	2017	570,239	AP	Hedonic regression	PRS	Significant evidence of premium rents general, but less so in major cities where stock is short. Some evidence that time to rent is reduced.
Hungary	MacLean *et al.*	2013	1,399	P	Difference in Differences model	OO	Premium 9.42% for retrofitted apartments; however, price increases were less than the cost of improvement work, implying a need for subsidy.
Ireland	Hyland *et al.*	2013	40,568	P	Hedonic regression	OO PRS	Relative to D-rated properties, A-rated properties had asking rents that were 1.8% higher, but discounts for F/G rates of 3.2%. In the capital market, the spread was far wider, with premiums of up to 9.3% for A-

							rated properties and F/G rate discounts of 10+%. It was concluded that market conditions were a critical factor not necessarily sustainable over the cycle
	Stanley *et al.*	2015	2,792	P	Hedonic regression	OO	A 50-point improvement in the Building Emission Rate (BER) had a 1.5% higher list price. Using this metric a 1-point improvement in the 15-point scale from G to A1 yielded list price increases of 1%.
	Davis *et al.*	2015	3,797	P	Hedonic regression	OO	EPCs found to exert a small positive influence on property values across various housing types in Belfast. However, attributes such as double-glazing, heating type, and loft/cavity wall insulation improve energy efficiency are more important drivers of market behaviour; therefore it is not surprising that there is a positive relationship between price and the EPC.
Italy	Fregonara *et al.*	2017	879	P	Hedonic regression	OO	Study of older apartments showed that the EPC rating made no real difference to the sales price of the unit.
Netherlands	Brounen and Kok	2011	32,000	P	Heckman 2-step	OO	A first attempt to investigate the impact of energy efficiency on dwellings' sales prices. Premiums of 3.2% were found among the stock with EPCs. They conclude that EPCs had added transparency and acted as a price signal.
	Chegut *et al.*	2016	17,835	P	Hedonic regression	SH	Sales of Social housing units demonstrated a premium of between 2.0 and 6.3% for units which had EPC ratings A-B when compared with those at D or below.

	Aydin *et al.*	2017	30,036	P	Hedonic regression	OO	Using data on energy efficiency and investigating houses with/ without EPCs they conclude that residential energy efficiency improvements affect transaction prices, regardless of the provision of an energy label. The actual efficiency matters more than the label and is priced in
Portugal	Evangelista *et al.*	2019	256,000	P	Hedonic regression and Quartile analysis	OO	Sales price premiums of up to 13% for flats and 6% for houses were found for A/B rated buildings during a depressed market period but no real discount for lower grades.
Romania	Popescu *et al.*	2012	64	P	Price comparison	OO	Price premium 2–3% for apartments with thermal retrofits, producing a value payback of some 60% of the costs at transaction.
	Taltavull *et al.*	2020	16,443	P	Hedonic Regression and Spatial Diffusion	OO	Properties in Bucharest retrofitted to 'green' showed price premiums of between 2.2% and 6.5% but only in some areas of the city; elsewhere no price impact felt
Spain	de Ayala *et al.*	2016	1,507	V	Hedonic regression	OO	Owner's own value estimation premium between 5.4% and 9.8%, compared to those with the same characteristics but a lower energy efficiency level.
Sweden	Högberg	2013	1,073	P	Hedonic regression	OO	Found that a 1% decrease in standard energy consumption led to an increase in selling price by an average of 0.044 p. Where EPCs showed improvements were recommended, buyers sought a discount.
	Cerin *et al,*	2014	67,559	P	Hedonic regression	OO	Inconclusive, but early indications show that actual energy performance is associated with house prices premiums in some subsectors of the market, low value stock; in high value housing there was no reward for energy efficiency

	Wahlström	2016	77,000+		Hedonic regression	OO	There was no conclusive evidence that EPC labels were associated with premium pricing. However, transaction prices were affected by visible elements, such as triple glazing and heating systems, than with EPC labels.
Switzerland	Banfi *et al.*	2008	305	V	Survey for Stated preference Willingness to pay/regression	PRS and OO	Tenants and owners show through willingness to pay methodology, a preference for a range of sustainability factors, including, but not restricted to, energy savings. A regression analysis showed a negative correlation with rents, possibly due to the inclusive rent structures in Swiss leases, but a positive relationship with water efficiency and 'soft' criteria such as health, comfort and security
	Feige *et al*	2013	2,453	P	Hedonic Price Analysis	PRS	Data used was not labels but a list of 5 sustainability features. Three (energy and water efficiency, safety and security and health and comfort) had a positive effect on rents obtained. The others (accessibility and flexibility) did not. Energy and water showed the most marked results
England	Fuerst *et al*	2015	333,095	P	Hedonic Price Analysis	OO	Sample was of twice sold houses/flats. Compared to D rated units, EPC bands A and B sold for a 5% premium, C band properties had a 1.8% premium with discounting for E/G rated dwellings. The study period commenced prior to the introduction of EPCs with stronger findings after the introduction.

	Adan and Fuerst; and *Fuerst* et al.	2016; 2020	Approximately 4,000	P	Hedonic Regression	PRS	Houses sold and then let were analysed. Rental premiums of 5.3 (houses) and 8.7% (flats) for A/B over D found but 6% discount for F/G houses with no discount for flats. Further analysis confirmed evidence of a negative relationship between time-on-market and energy efficiency rating
Wales	Fuerst, Mcallister *et al.*	2016	191,544 with 47,158 being repeat sales	P	Hedonic Regression	OO	Price premiums of up to 12.8% for top-rated properties against the price of average (band) dwellings (band D), with discounts of 6.5% for those below the average. Significant regional and tenure variation. Less conclusive results on repeat sales. High percentages may relate to low average values.

Decarbonising Real Estate: The Evolving Relationship Between Energy Efficiency and Housing in Europe

1.0 Introduction

Decarbonisation is a global issue affecting all classes of real estate. 27% of total UK carbon emissions is attributed to housing; however great potential to decarbonise this sector rests with the adoption of energy efficiency technologies (Nejat et al, 2015) as the energy savings realised will lower greenhouse gas (GHG) emissions. Three main approaches exist to achieve this. The first is to take a mandatory approach in which minimum high level energy efficiency standards are set, enforced and applied to both new buildings and existing buildings by enforcing compliance through retrofits of substandard stock (Wilkinson et al, 2015; Patrick et al, 2014). Option two is a voluntary approach, using mechanisms such as energy performance certificates (EPCs) or other rating tools that classify performance to stimulate awareness and action. Third, financial measures, both incentives and taxes, can be applied to 'nudge' behaviours. With most westernised countries wedded to neo-liberal governance paradigms, the voluntary fiscal approaches have prevailed over the last 30 or so years. The argument is the market will value more energy efficient properties through increased prices (RICS, 2011. Warren-Myers, 2016). It follows that a premium for energy efficient properties should be apparent (Fuerst et al, 2015. Ferlan et al, 2017). As the time available to take effective climate action diminishes, evaluation of the effectiveness of this approach is imperative.

Given the implementation of measures, both voluntary and mandatory over the last three decades, this paper reviews academic literature and case studies of a selection of large-scale consortia projects conducted in Europe; most of the research reviewed is based on hedonic pricing analyses which have sought a relationship between Energy Performance Certificates and either capital, or rental residential values across Europe. The research sought to gain a deeper understanding of the relationship between energy efficiency and the value of residential property over time. Secondly, this study sought to determine whether more action is required to realise decarbonisation in new and existing residential property in Europe. Finally, the research sought to identify whether other approaches need to be considered to accelerate the rate of change.

2.0 The case for energy efficient residential real estate

2.1 A need to meet climate change targets

The issue of climate change and the urgent need for all sectors of society and industry to act is widely acknowledged (United Nations Climate Change, 2015). Whilst previous emphasis focussed on how to mitigate against climate change; there is recognition now that this will not be enough: adaptation is required. The 2018 Report of the Intergovernmental Panel on Climate change (IPCC) confirmed that, at best, the climate is on a trajectory for a 1.5 degree global temperature increase (IPCC, 2018[b]). Many EU countries will experience increased days with intense heat, but still with cold winters (EEA, 2012). A reduction of 80% of carbon emissions from a 1990 base was agreed in the 2015 Paris Climate Conference COP21 (UNCC, 2015), but recently public pressure is leading several countries to increase to more ambitious targets[1].

Yet climate change predictions mean that demand for energy to heat and cool property will increase, unless action is taken to increase the efficiency of the stock. Whilst energy efficiency is not a substitute for changing the source of energy away from fossil fuels, the reduction of demand for energy is a key component of any decarbonisation strategy.

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[1] Both the Netherland and the UK are planning for net-zero by 2050. Whereas this is non-statutory so far in the Netherlands, In June 2019 UK government announced legally binding net-zero emissions target for 2050 https://www.edie.net/news/11/Prime-Minister-Theresa-May-agrees-legally-binding-net-zero-emissions-target-for-2050/;

2.2 the need for increased energy efficiency in the housing sector.

The need for energy efficiency in the building stock has never been greater. The bulk of Europe's housing stock, however, is old and energy inefficient. The Buildings Performance Institute Europe (BPIE) estimates only 3% of total stock is constructed or improved to the highest energy standards (BPIE, 2017). Further the energy efficiency of stock is correlated closely to age; and rented stock is likely to have a lower efficiency than owner-occupied stock (WGBC, 2018). Despite large strides having been made in decarbonising grid supplies, [2] in many countries a major source of energy still stems from fossil fuels, resulting in residential emissions accounting for a significant percentage of a country's carbon emissions; some 27% in the UK for example (Nejat et al, 2015).

A compounding factor is the slow replacement rate of stock, which rarely exceed 1% per annum and less during periods of economic slowdown (see Balaras *et al.* 2007). Although some improvement in adoption of higher energy efficiency standards has been noted, a much faster rate and level of upgrade is needed (Artola *et al.,*2016). The 2018 IPCC report (IPCC, 2018[a]) noted building adaptation is critical to achieving climate change targets and stated rapid, far-reaching transition based on reduction in energy use demand is necessary, as well as transition from fossil fuels to clean electricity and greater thermal insulation of envelopes to lower heating and cooling demand. Therefore, increasingly, policies and regulations are targeting the speeding up of building adaptations and occupier behaviours in order to change the supply/demand relationships between old and new stock. This, it is argued, should lead to value differentiation between efficient and non-efficient buildings (IPPC, 2018. Artola et al, 2016).

2.3 Measuring energy efficient: a pre-requisite to stimulating demand

If reliance on market demand for energy efficient dwellings is the preferred policy options, a reliable trusted measure of what constitutes an energy efficient building would appear to be a pre-requisite; yet no universal measure of building energy efficiency exists. The common European Union (EU) metric used is the Energy Performance Certificate (EPC) first mandated by the Energy Performance of Buildings Directive (EPBD) in 2002 and revised with increased standards in 2010 and 2018. The Directive applies across member states, however technical measurement is a matter for individual jurisdictions (Sayce & Wilkinson, 2019). All countries require valid EPCs to be produced as part of advertising material when a building is to be let or sold, to alert buyers or tenants to the energy efficiency standards of the property (BPIE, 2019). Concerns about EPC quality, reliability and consistency between countries were acknowledged and the 2018 revision of the EPBD now requires member states to express EPCs in ways that allow cross-country comparison (BPIE, 2019)),although it is acknowledged that occupational demand in the residential sector is likely to be very location specific.

The original EU directive required that, over time, new buildings should be constructed to Nearly Zero Energy Building Standards (NZEB) by 2020. This was defined as having; " *a very high energy performance with the nearly zero or very low amount of energy required covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby*" (European Commission 2013). Individual member states apply the definition differently according to local conditions including climate and much progress has been made in relation to new buildings. The 2018 EPBD (European Performance of Buildings Directive) revisions state that upgrading existing buildings is vital to achieving energy and carbon targets (BPIE, 2019). The revisions, recognising the slow pace of building replacement, require member states to develop strategies for upgrading buildings to higher energy standards with an obligation to put long-term renovation strategies aimed at decarbonising the existing building stock by 2050 in place (BPIE, 2019. Sayce & Wilkinson, 2019). These strategies have a financial component; however the means of delivery is a matter for individual member states.

There is little consistency between EU member states regarding the ways EPCs are calculated (Sayce & Wilkinson, 2019). Some countries base the EPC on KWh output; whereas for others, it is a design calculation which may, or may not, account for fuel cost. Further, in Germany and Spain, there are in-country variations

[2] In the UK, the contribution of non-fossil fuels has risen to approximately 50% in 2019 https://www.nationalgrid.com/britains-clean-energy-system-achieves-historic-milestone-2019

that further cloud consistency and comparison. Critically, there is evidence that some EPCs, particularly those produced during the early years, may not provide accurate information (European Commission, 2013).

But, if market participants are to appropriately differentiate between levels of energy efficiency in buildings, accurate information is essential; further this should be trusted and readily available both to buyers and the valuers who advise in terms of secured lending. This variability in calculation and inconsistency in results has led some countries, to regard EPCs as unhelpful as a measure to analyse in terms of use to establish comparative value (RICS, 2018).

Valuers, as a result of EPBD requirements, need to be cognisant of current and published regulations and national 'road maps' towards achieving increased energy efficiency measures (RICS 2018). RICS (2018) advises that they will need to consider the impact such regulatory shifts may have on value and, in particular, the risk of value decline for non-resilient stock.

Further, where recognition has taken place that voluntary measures mandation should be based on accepted reliable measures, However, across Europe, where mandated measures (option one outlined above) are under consideration or have been introduced to assist in meeting international targets, these have been generally been based on the EPC. For example in the UK, minimum standards for investment stock have been, or are in the process of being, introduced under the overarching provisions of the Energy Act, 2011 (see for example Patrick et al, 2018).

2.4 A social as well as climate-related agenda

The principal case for trying to achieve an energy efficient housing stock lies primarily in the climate change arguments. However, it is not the only reason: there are socio-economic arguments as well. Willand et al., (2014) linked energy efficiency with occupant health and well-being. Whilst it is acknowledged that the relationship is complex, research points to energy upgrades providing social and health benefits which include psycho-social factors, better air quality and reduction of damp conditions (Fisk, 2000; Roulet et al, 2006). Further, a meta-analysis (Maidment, *et al.,*2014) found that household energy efficiency interventions typically led to small, but significant, improvement in the health of residents.

Further, an efficient stock by reducing the need for energy consumption any supply issues will, at least in part, protect occupiers against future increases energy prices which affects those with poor purchasing power most, leading to fuel poverty, negative health outcomes and at worst, fatalities (Basham et al.2004; Willand et al, 2015; Kholodilin et al, 2017).

Another consideration is the impact of the tenure on the case for energy upgrades. The so-called 'split incentive' (Kholodilin et al, 2017). means that, unless tenants will pay more for enhanced energy efficiency, there is no incentive, other than the 'soft' benefits, to the landlord. It follows from this, that policies which assume that financial return in the shape of enhanced market values may underplay the complexity around the drivers for improving energy efficiency in homes.

Bearing in mind the criticality of tenure patterns, the challenge to improving homes across Europe is variable, but, although within Europe owner-occupation is the most common, there is a trend towards renting (Pittini *et al.,* 2017). Critically, with the exception of social rented stock, many residential portfolios are small and in some countries often consist of less than four units (Scanlon and Whitehead, 2016), although this varies considerably across countries. These units also tend to be those most in need of upgrade, but may be owned by those with the least financial ability so to do (Shelter, 2014).

3.0 Research methodology

The paper seeks to review whether, to date, there is sufficient evidence that reliance on the 'nudge' approach of the EPC to incentivize energy efficient upgrades is producing a market incentive through price or other drivers, sufficient to support a non-mandatory upgrade strategy. Therefore, it was considered important to review the extant evidence linking value and energy efficiency through a literature review, but to augment this through the use of case studies, all of which have had the market value and energy efficiency relationship at their heart. The

research underlying the evidence reviewed falls into two main approaches: quantitative evidence obtained from statistical analyses and qualitative evidence gathered from literature The former reports relationships but can seldom explain them; the latter provide interpretative findings but lack the scale of the former.

To augment these reviews, the findings from a series of large-scale consortium projects seeking to support market transformation are included as they present deep insights into the issues and move towards solutions. Case studies are an acknowledged means of gain a deeper understanding of how policies are applied in practice (Yin, 2011). The results, detailed below, provide a deeper knowledge of the relationship between energy efficiency and value. The projects do not represent a comprehensive list of work recently undertaken to support market transformation; they are chosen for the size of their potential impact (Yin, 2011).

4.0 Findings

4.1 Quantitative evidence

An extensive desktop study of secondary sources gathered evidence in respect of the relationship between energy efficiency and the value of residential property over time. Secondly, the type and scope of initiatives adopted to promote and encourage energy efficiency in the residential stock were analysed to determine whether more action is required to realise decarbonisation in new and existing residential property in Europe. The research design gained insight into stakeholders views and perspectives of residential energy efficiency, evidence of premiums paid for energy efficiency when properties are sold and sought to identify whether other approaches need to be considered to accelerate the rate of change.

For the quantitative component, twenty-one studies on the relationship between capital and/or rental values and energy efficiency in the owner-occupied, private rented and social housing sectors were reviewed. Most were large-scale studies using the hedonic pricing model developed by Rosen (1974). This model seeks to isolate the impact on value of one variable (here, energy efficiency – measured in terms of ratings); the chief intent in most studies has been to isolate the impact of the EPC within the assessment of either transaction or rental prices achieved.

The results of any hedonic study are dependent on researchers accurately identifying, quantifying and eliminating the impact of other variables (Rosen, 1974). In the case of these studies the other variables claimed to be eliminated included factors known to influence residential values as location, age and condition. However, results need to be considered in context, as the presence of short-term financial incentives or changes to energy rating systems, and the extent of their adoption, can make it difficult to interpret the evidence from the academic studies meaningfully (Sayce & Wilkinson, 2019). Specifically, most studies relate to the relationship between EPC ratings – introduced in 2008 under the EPBD 2002/91/EC and altered in 2012 – and rental or capital values achieved. Some are based on valuations, while others recorded market prices.

Only studies relating to EU member states were included, the selection sought to present a balanced picture of findings. All the studies have been researched during changing regulatory, economic and social contexts and in which, in some member states, various fiscal or grant incentives have been in place. Table 1 summarizes the studies up to 2018. Almost all provide observational evidence of a positive link between energy efficiency, normally measured in terms of the EPC, and transacted prices (rental or capital). Collectively the studies provide strong trend data; however, they do not explain *why* value differentiation is occurring, nor can they give evidence to assist valuers commissioned to value a specific property in a specific location, on a specific date.

Insert table 1 here

As evidenced in Table 1, Most studies concentrate on a single member state; however, one large cross country study conducted as part of the EU-funded REVALUE project (REVALUE, 2019), comprises a regression analysis of social housing across four member states. Over 5,000 valuations of residential social housing in the UK, the Netherlands, Sweden and Germany were analysed in respect of their reported assessed value, against both their EPC rating and standard assessment procedure (SAP) indexes, as well as components affecting energy performance (such as provision of double-glazed windows). The results revealed a slight value premium in some locations, but also increasing evidence over time of a 'brown discount', where properties with poor energy ratings decreased in value relative to the mean (REVALUE, 2019). In all cases, while it was possible to see that

energy efficiency had an influence on reported capital values, particularly in the Netherlands, this was small (approximately 1 per cent) compared to the 79 per cent explained by traditional value drivers and 20 per cent that could not be explained via the model. However, supporting the findings of Feige et al (2013), the impact of individual components was important; indeed, within the analysis of a large housing portfolio in the UK, the quality of the glazing was found to be a significant value driver.

The implication of these results is that visible components that in themselves contribute to energy efficiency may be more influential in terms of value determination than actual certification. This finding has importance for policy makers as, whilst they show a trend of values towards value differentiation, is this a conscious market response to energy labels, or are they indicative of other factors which influence decisions? On the basis of the quantitative evidence, It may be difficult to assess, on a fine-grained level, that the policy options are working, although it does give some comfort. For this qualitative data could provide richer data.

4.2 Qualitative evidence

The quantitative evidence is large-scale, trend-based data. However valuable this is, it does not represent, and cannot be used as a basis for valuing, an individual property or portfolio or fully understanding market decisions. There are far fewer qualitative studies that seek to link energy efficiency and residential values. Of those that do, the literature search revealed two surveys of real estate professionals, notably valuers, and a series of funded projects, which are detailed below as case studies. The first of the two questionnaire surveys, Michl et al (2016), was a large-scale study examining sustainability and the perceptions of value held by Valuers in respect of commercial and residential instructions across a range of countries, notably, UK and Germany.

It concluded that there was very little evidence that sustainability factors in general were influencing real estate values, either residential or commercial, although Valuers were collecting some data sets. Importantly, it highlighted that those commissioning valuations were seldom requesting specific information regarding energy or other sustainability characteristics. However, Valuers reported that where the instruction was to provide an estimate of investment worth – rather than market value – this would be more likely to reflect some element of sustainability characteristics; this was mainly due to levels of certification (both mandatory and voluntary) (Michl et al, 2016). Given that other literature would suggest that it is the large portfolio investors who are more likely to have adopted environmental and social governance reporting, Michl *et* al., (2016), which did not differentiate between residential and commercial, does not support value differentiation. However this paper was based on evidence from 2012, so may not represent current practices.. A more recent study by Ferlan et al (2017) of factors influencing residential values in urban units in Slovenia underscoreds a lack of significance of energy efficiency among value drivers. Ranking factors impacting residential values, they found that energy efficiency ranked 15th of 26 identified drivers, although they argued that, implicitly, it was included in the 9th ranked maintenance costs. However, overwhelmingly, traditional factors such as location, accommodation and configuration and the immediate neighbourhood characteristics, including noise and pollution levels affected value more (Ferlan et al., 2017).

4.3 Case studies

The third strand of the research analysed the findings from three consortia research projects, all UK government or EU funded, to ascertain different ways they drive market transformation and promote demand for more energy efficient stock. Two studies (REVALUE and EeMap) were EU funded and cross European in nature; one was a UK consortium (the LENDERS project).' Of the three, one was multi-stranded and concerned primarily motivations towards energy efficiency and the role of the Valuer (REVALUE); the remaining two were fundamentally about the role of private finance. All help to enhance understanding of the emerging relationship between energy efficiency and the residential sector in Europe.

They all point to the involvement of many major market players and a determination to drive changes in market demand and supply of energy efficient dwellings. Collectively they do not find a 'tipping point' has been reached at which energy efficiency is a key market price driver, but they point to key factors critical for policy makers.

4.3.1 REVALUE

REVALUE was a four-year EU funded project which had a stated aim of leading the "*development of appraisal norms and standards that recognise the value of energy efficiency in social and private residential real estate.*" [3] Undertaken by a consortium of organisations, it operated through several work packages, each of which used a differing research instrument. Whilst the focus was primarily on social housing and a limited number of European countries, the strands of work collectively provide insight across a number of aspects of the residential markets. Underlying the initial bid was that valuers, working within their professional standards were not differentiating between energy efficient stock and that which was not.

One strand comprised a regression study of reported valuations of social housing in the Netherlands and UK using data between 2010 and 2015. The results were therefore not of realised prices, but of valuations undertaken primarily for accounting purposing and mainly using discounted cash flow techniques, rather than analysis of comparable sales. The results reported in Chegut *et al* (2019) showed that over the study period, a relationship between reported values and EPC labels began to be discernible, both in the form of a 'brown discount' for stock with lower than average ratings and, notably in the Netherlands, an enhanced value for higher rated stock. Not reported in Chegut *et al.* (2019), but as part of the findings from the regression study reported at Sayce and Wilkinson (2019) and on the project website[4], the analysis showed that the EPC label was of lesser importance to value than specific physical attributes, notably visual aspects such as window insulation; conversely, less visual factors which influence energy efficiency such as boilers or heating systems were not associated with valuation differentials.

Another strand of empirical work was a series of roundtables conducted with Valuers across four European countries (England, Germany, Spain and the Netherlands) (REVALUE, 2019). These workshops, conducted in 2017, confirmed that EPCs were not considered to be drivers of residential value, partly due to lack of trust in their accuracy and partly due to the perceived lack of significance as part of the transaction of letting process. However, visual 'signals' such as windows were considered important to value. What also came through was that, partly due to a lack of technical training in energy matters of real estate advisers in some countries, energy investigations did not tend to form a significant part of the due diligence process (REVALUE, 2019). The conclusion of all workshops was that within residential markets, traditional values drivers dominated; energy efficiency *per se,* represented only a very small direct consideration for most buyers or tenants.

The third strand of the empirical work comprises interfacing with social housing providers to investigate their motivations for energy upgrades.[5] Two major findings emerged from this. First, the data held by even large scale investors on their residential portfolios was limited both by quality and quantity, which makes comparative analysis difficult and second, the motivation for energy investment lies less in anticipation of capital returns and more in their social responsibility aspirations, notably in protecting the health and well-being of their tenants, reducing fuel poverty and enhancing tenant satisfaction. This did not mean that economic arguments were unimportant; they were, but this related more to reducing default rates and voids and supporting an ability to borrow against the security of the portfolio and protection of long-term value, than measurable rental of capital value increases. It was recognised that the business case for social landlords is not the same as for those in the private rented sector, partly due to their social purpose and partly due to the legislative constraints upon them which, notably in the UK, impacts their ability to recoup investment via increased rents.

Collectively the findings from REVALUE point to a complex picture in terms of value drivers; whilst some linkage to EPC was observed in the quantitative study, the EPC is a short-hand for energy efficiency; it was not universally accepted as a reliable measure and motivation for investment stem from a series of other considerations. Even visual signals, such as well-insulated windows may relate to the comfort (by way of protection from draughts), the security they provide against intruders and the aesthetics as much as thermal quality (Sayce and Wilkinson, 2019). The project also pointed to a need for Valuers to work with energy experts and develop greater knowledge around renewable energy sources and technologies; further it provided policy makers with insights into the decision-drivers for energy efficiency retrofits; these were not necessarily value driven.

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[3] REVALUE introduction available at https://www.buildup.eu/en/practices/publications/revalue-project-final-report-value-energy-efficiency

[4] Deliverable 3.3 available at https://revalue-project.eu/wp-content/uploads/2019/08/D3.3-Regression-Analysis.pdf

[5] Deliverables D2.5 and D2.6 available at

4.3.2 *EeMAP (the Energy Efficient Mortgage Action Plan)*

Led by the European Mortgage Federation and the European covered Bond council (EMF/ECBC), EeMAP set out to "*create a standardised 'energy efficient mortgage'*", according to which building owners are incentivised to improve the energy efficiency of their buildings or acquire an already energy efficient property by way of preferential financing conditions linked to the mortgage[6]". The contention underlying the project was that private finance has a real role to play in providing the mechanism by which existing houses can be retrofitted to energy efficient standards and to 'reward' those buying a highly efficient building. The project was predicted on the assumptions that investing in energy efficient measures could enhance capital value, thus reducing the effective loan to value ratio of the loan, and that more efficient dwellings are cheaper to run, reducing the risk that the borrower could not keep up the mortgage payments. Both assumptions underpinned the claim that lending on an energy efficient mortgage is inherently less risky than lending on an inefficient building. As with REVALUE a further premise was that valuers were not sufficiently reflecting elements of energy efficiency in their reported values.

As with REVALUE this project was arranged in work packages, collectively aimed at supporting the development of a European network of lenders committed to supporting 'green mortgages' and energy retrofits. The main research instruments used were qualitative including workshops, interviews and questionnaires, although a larger-scale quantitatively analysed review into the demand for green mortgages and into an analysis of credit risk for banks. A major initial finding of the project was most lenders did not hold information on their loan books as to the energy efficiency of the stock against which they were lending, although there was a desire to improve this level of data.[7] From a valuation perspective, a review of the relationship between mortgage lending practice and valuation practice revealed that, whilst the aims of the project were worthy, there was no guarantee within the residential, owner occupied sector that investing in energy efficiency improvements would necessarily yield enhanced capital values, although it would potentially assess value preservation, ensure saleability and reduce risks of obsolescence, thus reducing risk to lenders. Further, supporting some of the REVALUE findings, default risk could be lower. What it also underscored was that for the banks to fully understand risk, relating lending policies to the EPC alone would be insufficient as EPCs were thought to be "*less than a robust tool for correlation with value."* (Hartenberger *et al.* 2017:4).

Yet, at the time the research took place, most banks were asking either for no sustainability data or, at most, the EPC. Subsequent to this, a valuation 'checklist' was produced, piloted and further refined with the aim of supplying targeted information to lenders as to whether a property subject to a loan application carried a risk of 'brown discount' over and above that of an 'average' dwelling, or, alternatively whether the property presented a lower risk due to superior energy efficiency characteristics. Whilst it was reported that the checklist offered such potential, Hartenberger *et al.*(2018:1) concluded that "*only if and when energy efficiency and wider sustainability aspects are positively reflected as risk factors, will an energy efficiency mortgage product find market acceptance*" and by implication impact buyer behaviours.

Since 2017 the number of banks who have signed up to the initiative has steadily grown and, as at October 2019, nearly 50 banks have agreed to pilot the initiative[8]. Data remains an issue, as does he extent to which the valuation instruction protocols will alter to enable more sophisticated lending criteria to be adopted. In conclusion, success in terms of altering buyer demand towards more energy efficient stock and the retrofit to achieve such standards is likely to be dependent on the valuation instruction and on the internal processes of credit risk assessment EeMAP, 2019).

Going forward, the success of energy efficiency mortgages depends on two things. One is clearly the consideration of energy efficiency indicators in valuation routines; this in turn requires enhanced data. The other concerns internal risk management procedures within banks. The conclusions of the EeMap project present another important market' nudge' related to finance. Where residential markets are dominated by mortgage-

[6] As quoted on the EeMap website https://eemap.energyefficientmortgages.eu/services/

[7] Parallel and connected to EeMap was another project EeDapp exploring not just data issues, but how they could be overcome.

[8]See news item at https://eemap.energyefficientmortgages.eu/garanti-bbva-mortgage-joins-the-lending-institutions-of-the-energy-efficient-mortgages-pilot-scheme/

dependent buyers, the ability to access more attractive funding packages for energy efficient homes or to support such improvements is likely to be influential. In time this could drive enhanced efficiency among some residential stock, but potentially, non-qualifying stock will be at greater risk of 'brown' discounting or could potentially become 'stranded'. The inference for policy could be that support for 'green finance' might help to stimulate action – independent of actual energy retrofits.

4.3.3 The LENDERS project

The Lenders Project was a UK initiative led by the UK Green Building Council with industry and academic partners and funded by Innovate UK (Lenders, 2017). Like EeMAP, the project aimed to support borrowers and encourage them to purchase a property with greater energy efficiency, as measured through the EPC. The project did not "*aim to demonstrate a link between property valuations and energy performance, nor to the related sales values or speed of property sales* …but to provide "*a more accurate means of forecasting a homebuyers' future fuel cost"*. (LENDERS, 2017 p:13). Therefore unlike EeMAP, LENDERS viewed the challenge of stimulating demand for 'greener' stock through the position of the borrower's ability to support the loan. The premise was that borrowers who purchased a property with a high EPC rating would experience lower running costs and therefore, taking their total outgoings into account when assessing the amount they could borrow, the banks would be able to offer bigger mortgages as they would be secured against lower operational costs and more efficient dwellings.

Therefore, the project was set up *to analytically examine the link between property energy efficiency and fuel bills* (LENDERS, 2017, p:3). When the project was undertaken, it was required practice for lenders to consider whether the borrower could support the intended loan. Normally this discussion takes place at an 'in principle' stage prior to the intended borrower finalising their house search, to avoid abortive time and effort on all those involved in the lending chain. Part of this calculation was undertaken by reference to official government household spending calculations. For these, costs of heating/lighting etc were calculated on a 'normalised' basis which ignored the characteristics of the property offered as security.

The LENDERS project investigated the impact of the energy efficiency of the dwelling against the EPC label. Whilst accepting the EPC is not a totally accurate measure of energy efficiency, the team constructed a model of affordability based on developed a model that predicted a property's annual fuel bill based on: the number of residents intended to live in the property; a simple categorisation of the dwelling by type and size; and the EPC band of the property (LENDERS, 2017 p:13). This they claimed provided improved data from which to make lending 'in principle' decisions, prior to the proposed purchaser agreeing an offer price on a property.

The project team, which included two mortgage lenders, were thus able to demonstrate lower fuel costs for more energy efficient dwellings in a much more 'nuanced' way than simple use of average data and such that the advantages of an energy efficient home could be passed on as a tangible benefit to homebuyers. The end project produced a working calculator through which homebuyers can access, with the provision of limited property and household information, estimates of their likely bills and can feed this in to discussions in principle about mortgage finance[9]. To date no details regarding the take up of the tool are publicly available, but the concept has received recognition by UK Government (BEIS, 2018 p:48) who wish "*to see the project recommendations implemented, including improving mortgage affordability assessments on energy bills.. to encourage consumers to purchase more efficient homes or to improve their efficiency.*"

4.4 Case study summary

The case studies reported above provide insights into both the barriers towards the enhancement of energy efficiency in residential units and a belief that creating a shift in demand towards energy efficient stock is essential in ensuring the delivery of low carbon homes. Whilst REVALUE was focused on rented, primarily, social rented, EeMap and LENDERS addressed the owner-occupation market.

All three projects started from the premise that stimulation of demand for energy efficiency was critical; all also saw that the role of the Valuer was important. What comes through from REVALUE was that whilst,

[9] The tool is available at https://www.epcmortgage.org.uk/

observationally, the markets are moving towards a differentiation related to energy efficiency, the rationale is primarily based, not on the often adduced argument of cost saving to the occupier or enhanced value increase, but additionally on comfort, well-being, security and, for social landlords, protection of long-term asset values.

EeMap and LENDERS were both concerned with finance; EeMap from the banking perspective in which energy efficient buildings are viewed as presenting lower credit risk due to value protection against obsolescence and lower risk of default; LENDERS on the enhanced ability to support a mortgage due to lower outgoings. Collectively, the studies show that, whilst value matters, the prospects of capital gain or investment return are only one of a complex set of decision tools and "*to pin a case for retrofitting on financial returns may be misguided … other arguments may be more compelling*". (Sayce and Wilkinson, 2019 p:23)

However, through their empirical work, all consortia came to recognise that shifting demand is not purely about seeking a 'value add'; in particular there is a growing recognition that lenders have a key role to play in differentiating their financial offer by reference to energy efficiency. Whilst the role of finance for mortgage lending connected to owner-occupation, is clear, REVALUE also considered finance for social housing portfolio owners. Here the energy characteristics of individual dwellings did not have a direct relationship to the ability to borrow. Most social landlords, the research revealed raised money for enhancements, not through secured lending but through corporate borrowing and a well-managed portfolio, with a programme for building enhancement, was perceived lower risk.

Finally, the case studies all pointed to a continuing issue with both data collection and use within decision making. This was apparent within social housing portfolios, where data sets were incomplete and varied from organisation to organisation. Further in terms of lenders, the collection of energy data is in its infancy, though [projects such as EeMAP and LENDERS have added visibility to the issue.

5.0. Conclusions

This paper sought to gain a deeper understanding of the relationship between energy efficiency and the value of residential property in Europe and by so doing to determine whether stronger policies are required to realise decarbonisation in existing residential property. It did this through an examination of the literature which sought to make a connection between energy efficiency and value and by detailing three specific projects. Underlying policy across Europe has been that market demand for energy efficient buildings, both to buy and rent, will occur through greater knowledge and realisation of cost savings that investment in energy efficiency can bring. The argument is that these cost benefits should be revealed through the pricing mechanism and emergence of a green premium. However, the only public required metric for energy is the EPC which does not measure consumption – and hence energy costs in use. Fundamentally, if the EPC is to be a transformative tool, a decade after its introduction, research should demonstrate that change is occurring.

Therefore, this paper has reviewed a range of evidence, both large-scale academic studies and more practical, consortia-led investigations. What was revealed could at first reading be seen to be contradictory results.

The quantitative evidence points to the emergence of a 'green premium' for residential values when prices achieved or rent achieved are regressed against EPC data. As a caveat to these collective findings is that the basic measure of the EPC may not be accurate and, as acknowledged by many of the authors, the state of the market, presence of incentives and other factors could have been influential. There is no doubt, however, that they provide strong trend data and reveal a price differentiation, although, as with all hedonic studies they cannot offer other than tentative explanation as to why such price differences are occurring. In contrast, valuers dealing with individual commissions report that EPC do not generally influence pricing decisions of buyers or renters and as such, are not value drivers. Writing in respect of the Australian commercial market, Thanh-Le and Warren-Myers (2019) concluded that valuers had insufficient knowledge of sustainability matters to adequately reflect sustainability in market values. On the evidence from the consortium studies discussed in this paper, such a claim would not appear to be valid in the European residential sector. These suggest that any price differentiation due to energy efficiency arise, not due to the EPC, but to visible property factors that are observable during inspection.

Collectively the studies point to a continued lack of data on which to evidence market movements accurately. But they also point to the emerging role that finance is likely to play in decision making. If energy efficient stock

is deemed to be less risky to lenders and is cheaper to borrowers, this could be a more potent change agent than a business case built on possible value increase, especially as the evidence is that visual appeal, and security and well-being are also part of the decision matrix.

In conclusion, do the studies show that low or zero carbon homes can be achieved with current policies? Market pricing is moving towards brown discounting with some green premiums; social landlords are seeking to support their tenants by refurbishments but still face barriers and lenders are only at the start of their moves to link credit risk and energy performance. On this evidence, progress exists but not at the rate that is likely to deliver against targets. For this more radical solutions, based on financial support or mandated retrofitting, as now beginning to be introduced to energy inefficient investment properties, both in the UK and Netherlands, are increasingly looking to be required.

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Table 1: Selected European studies evaluating energy efficiency and residential value

Country	Sample size	Dates	Value effect (+/-)	Sector (OO, PRS, SH)	Premiums
Finland	7000	2015	+	OO	Premium 3.3% apartments. adjusted to 1.5% to exclude neighbourhood characteristics.
Germany	2630	2008-2010	+	OO PRS	Premium up to 3.15% 0.76 euros/m^2 rental Energy efficiency was significantly correlated with rental levels but not with vacancy nor maintenance costs.
Berlin	not stated	2011-2014	+	PRS	Investor purchasers anticipated future capital growth related to energy efficiency. Whilst Tenants paid a small premium their willingness to pay was less that the asking price increase
Hungary	1399	2012	+	OO	Premium 9.42% for retrofitted apartments; however price increases were less than the cost of improvement work implying a need for subsidy.
Ireland	40,568	2011	+	OO PRS	Relative to D rated properties, A rated properties had asking rents 1.8% higher, but discounts for F/G of 3.2%. In the capital market, the spread was far wide with premiums of up to 9.3% for A and F/G discounts of 10+%. It was concluded that market conditions were a critical factor. Premium of 1.5%
Dublin	2,792	2009-2014	+	OO	A 50-point improvement in the Energy Performance Indicator had a 1.5 % higher list price. Using the BER metric, a 1-point improvement in the 15-point scale from G to A1 yielded list price increases of 1 %.
Netherlands	17,835	2008-2013	+	SH	Price premium between 2.0% and 6.3% compared to those with the same characteristics but lower EE level (social housing) although unobserved differences in quality could not be ruled out. They could not conclude whether retrofit costs would be covered by value increases.
	14,451	2012-2015	partial	SH. PRS	Rental premiums were observed in the regulated part of the rental market for energy efficient dwellings, but not in the unregulated, indicated an unwillingness to pay additional money by some tenants.
Romania	64	2011.	+		Price premium 2-3% for apartments with thermal retrofits, producing a value payback of some 60%. .

Spain	1,507	2015	+	OO	Owner's own value estimation premium between 5.4% and 9.8% compared to those with the same characteristics but lower EE level.
Sweden	67,559	2009-2010	?	OO	Inconclusive but early indications that actual energy performance is associated with house prices in some sub-sectors of the market such as low value and some highly energy efficient stock.
	77,000+	2009-2010	+	OO	Premium values were associated more with visible elements, such as triple glazing and heating systems than EPC labels.
Switzerland	305	2007	n/a	PRS	Tenants and owner show through WTP methodology, a preference for a range of sustainability factors including, but not restricted to, energy savings.
	2,453	2009	-	PRS	A regression analysis of rents showed a negative correlation with rents, possibly due to the inclusive rent structures in Swiss leases, but a positive relationship with water efficiency and 'soft' criteria such as health .comfort and security.
England	333,095	1995-2012	+	OO	Price premium dwellings in EPC bands A and B sold for 5% premium, C band property had a 1.8% premium. Discounts for lower rated dwellings.
Wales	191,544	2003-2012	+	OO	Price premiums up to 12.8% against Band D with discounts of 6.5% for lower rated. Significant regional and tenure variation. Less conclusive results on repeat sales.

Key: OO =Owner-occupied, PRS= Private rented, SH = Social Housing.
(Source: Sayce and Wilkinson, 2019 p: 15