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Article

Passive House and Low Energy Buildings: Barriers and Opportunities for Future Development within UK Practice

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Abstract: This paper describes research carried out to understand better the current and future emphases emerging from practice for the design and development of "Passive House" and low energy buildings. The paper initially discusses the extant position, particularly with regards to the UK and considers how regulation and assessment systems have changed in recent years, as well as projecting ideas forward taking account of contemporary political situations. Relevant previous research into Passive House and low energy design and construction is then reviewed. The need for greater understanding of professionals and their communication/collaboration with clients were identified as important factors impacting development. Those involved in the design and construction practice therefore have key roles in the process of enhancing energy efficiency. Five industry/practice based professional organizations were interviewed in-depth to gain insights into their experience of current low energy design, and to extrapolate the outcomes to future scenarios. The method employed used a structured interview technique with key question areas to lead the discussion. The anonymized responses discussed are grouped around key themes. Evidence suggests there has been a move towards the adoption of voluntary high level standards because of potential limitations with mandatory regulations and because of perceived additional benefits of higher quality design. This change is now more than previously, being driven by informed clients, design professionals, and the industry, with regulation taking a secondary role. New opportunities and barriers are becoming evident and these require further consideration.

Keywords: Passive House; low energy; construction; practice; design

1. Introduction

Dealing with global climate change and ensuring the efficient use of resources are continuing requirements for sustainable human life on planet Earth. The use of energy in buildings results in both significant emissions of carbon dioxide (associated with the causes of global climate change) and also a major demand for the consumption of precious energy resources. The Intergovernmental Panel on Climate Change (IPCC) has frequently signaled in its reports the importance associated with reducing energy demand in buildings. It stated in its fifth and latest report in 2014 that "recent improvements in performance and costs make very low energy construction and retrofits of buildings economically attractive, sometimes even at net negative costs" [1].

Issues around the development of low energy design are very complex and vast resources and research time have been expended over several decades in investigating heat transfer, energy supply systems, and energy demand in buildings. A very important feature that runs alongside the increasing understanding of science and technologies is the implementation in practice. The setting of regulations often creates the development of standardized approaches to design and detailing which "just meet" the requirements. However, aspirations ought to be: to exceed regulation standards in order to prepare for future upgrades to standards; to meet the broader global challenges; and also to provide consumers/occupants and other stakeholders with higher quality and more energy efficient alternatives.

In such circumstances, the author proposes that the key to effective implementation in practice of more advanced standards is the need for designers (architects, engineers, etc.) to have appropriate knowledge and skills, as well as motivation towards engaging with low energy design. These professionals are also the same people who come into regular contact with potential clients and other stakeholders involved in building procurement/refurbishment, and thus are the people who are able to provide evidence to encourage the most efficient and cost-effective improvements. The research described here therefore explains the current situation in which such aspects of design development could be lacking and then focuses on a select, but knowledgeable and influential, small group of experts, and on their views and opinions about how to further advance low energy design. The research also questions the required support measures and the hurdles to be overcome.

As part of this research, this paper takes the opportunity to examine current views on the status of "Passive House" (sometimes referred to as Passivhaus) and more general low energy design, particularly in the UK. There is potential to re-focus on the ways that building energy use improvements might be encouraged, and to secure sufficient future improvements to meet climate change obligations.

Passive House is a design and performance standard initially devised in Europe in the 1980s by Wolfgang Feist from Germany and Bo Adamson from Sweden. A prototype exemplar was produced in 1991 and the Passivhaus Institut was established in 1996, both linked to the development of design guidance and an exacting standard for building performance. Buildings certified under the standard are assumed to have a strong likelihood of exhibiting very low energy demand evidenced by the evaluation against technical specifications and performance testing. Key parameters include energy use per unit floor area and air-tightness. Approximately 4000 schemes have been assessed under the certification system with many more in the process of development, and since numerous schemes have multiple units (some running into the hundreds) the number of Passive House buildings is therefore likely to exceed 50,000. There is no difference between the definitions of "Passive House" and "Passivhaus", though the latter is the phrase commonly used in Germany which is closely associated with the Passivhaus Institut.

The research described below has been driven by the conjunction of several considerations relevant to building energy performance:

- the potential importance of energy efficiency legislation for buildings in driving standards and performance;
- the changes in legislation (particularly in the UK) which have modified commitments and timescales to address energy efficiency in buildings;
- the potential implications arising from the UK electorate's vote in June 2016 to leave the European Union;
- a background in which the energy efficient design of buildings now has great penetration in the minds of designers and increasingly in the general public; and
- the need to assess the future priorities for energy-efficient building design.

Some important elements in determining the potential to achieve energy efficiency in buildings are the attitudes and knowledge of those involved in delivering them.

As previously mentioned, it is important to note at the outset that several changes to national policies have occurred in the period since May 2015 in the UK. One of the most significant has been the withdrawal of the Code for Sustainable Homes (CfSH) as a system for assessing and effectively encouraging improvements in the environmental design of dwellings [2]. This has meant the abandonment of the scheme which gave a framework of levels of achievement, which had been set up within the Code, and to which low energy designers could aspire to meet or surpass.

Energy conservation legislation still exists as it did previously within the Building Regulations [3], however there is something of a vacuum regarding suitable standards that exceed basic regulatory needs, and as a result the Passive House Standard has the potential to expand its influence and impact. Some of these issues are discussed in the sections which follow.

The aims of this paper are several: firstly, to examine building energy related standards and how they have developed; secondly, to consider the current standards and assessment methods and how changes might affect their practice; thirdly, to research how low energy design is currently developing/evolving in practice; and finally, to determine and examine some of the hurdles and difficulties that may impact the improvement of energy efficiency applications. The last two elements are specifically addressed through the interviews.

2. Development of Standards

The current UK Building Regulations energy-efficiency standards trace their roots back to the 1960s when they were first introduced to replace byelaws set at local level. Though this change set national levels of conformity, a drawback was the omission of ventilation requirements which subsequently produced an increase in moisture and condensation problems. As a result, the 1974 regulations introduced substantial improvements in thermal insulation standards though these still lagged far behind those of many other countries such as Sweden. In the 1980s, thermal standards were increased again (partly as a reaction to the oil price increases of the 1970s), and the 1985 regulations were the first to use the more flexible "approved document" route of enforcement. However, it was not until the 1990s that comparisons with other European countries indicated a need for substantial change, which was eventually taken on board by the Government [4]. With key revisions came new regulations in 1995; in particular, they began to insist on new and more robust calculation techniques for heat transfer, and raised the profile of thermal bridges and their impact on overall heat transfer and upon condensation risk. Calculation techniques have continued to evolve over time and are now relatively sophisticated and may need specialist input and analysis if standard forms of detailing are not employed.

From the late 1990s onwards, development of UK regulations began to be influenced by European programmes and legislation, notably the Energy Performance in Buildings Directive (EPBD) originally set in 2002 [5] and then recast in 2010 [6]. These directives provided a framework under which individual national governments would introduce regulations to limit energy use and provided for: minimum standards; methods of calculation; certification systems; and checks on equipment performance. Although there were variations in the implementation between countries, the directives introduced a base standard and a European-wide focus. For the UK, these directives helped frame the technical directions that building regulations and assessment systems would follow. From these flowed the notions of "zero-energy" and "zero-carbon" buildings, and the technologies and technical understanding underpinning the aims set within the directives. One of the problems was the difference between the concepts of the two phrases (zero-energy and zero-carbon) and the subsequent concept of "nearly zero carbon" buildings, and also the identification of which building energy uses came within the scope of the phrase.

Taking a broader view, there have been many initiatives and opportunities to develop the environmental and energy performance of existing buildings in the UK, not just "new build"; indeed the greatest challenges are acknowledged to lie in the difficulties of upgrading existing building stock. These retrofitting initiatives were initially linked to providing basic decent homes and later to encouraging upgrades that improved comfort and well-being, as well as producing more energy efficient buildings with lower running costs [7]. Opportunities were also sought to address the problems associated with fuel poverty; that is, the occupants of poor energy performance buildings also had such low incomes that they were unable to afford to keep homes comfortable or to pay for upgrading of the fabric or systems [8]. In the early part of the current decade, an incentive based on predicted energy cost savings (the "Green Deal") was developed in the UK, however this proved to be flawed and had very low uptake. This outcome further supports the need to have other encouragements to pursue higher standards of environmental as well as low energy design—see for example, Dowson [9].

Despite some changes made in recent years, the UK Government is still committed by the Climate Change Act (2008) [10] to legally binding obligations to reduce carbon dioxide emissions by 2050 compared to a 1990 baseline. Over a period of approximately 15 years (1995–2010) significant advances in designated building energy standards took place and funding was provided from a number of sources to support the research and development of solutions (both technical and non-technical).

Some relaxation in approaches began in 2010 with a decision by the UK Government to avoid "goldplating" standards [11]; in other words, a decision not to go beyond the basic requirements, and this signaled some intentions for the future. In mid-2015, the target of zero-carbon buildings was set aside/delayed as part of the incoming new government's first budget. Many other incentives for low carbon solutions and energy production were also changed with several consequences which continue to impact on industry and practice. An eventual but not unsurprising impact was the closure of the Zero Carbon Hub at the end of March 2016; it had initially been established in 2008 to support, amongst other things, the reduction of building energy use, but could not continue with lack of support [12]. An interesting review of recent changes in policies and practice was produced by the UK Green Building Council in mid-2016 [13] which also indicated some potential future directions that policy might take.

It now appears that the main and perhaps only legislation and encouragement to be applied to help improve the efficient use of energy in buildings still supported by the UK Government will be the Building Regulations themselves. It further seems that the links to European Directives and targets is in doubt as a result of the UK referendum vote to leave the EU in June 2016. This means that the main pressure for improvements in the short to medium term will have to come from designers, developers, clients, and the marketplace. Some may argue that this is in any case a more appropriate route to success; however, it does bring a significant level of upheaval in processes, systems, and expectations. It is therefore a research necessity to understand better how new mechanisms might operate and evolve for the future.

3. Differences between Standards

In the UK, a number of assessment tools or standards have been available for the energy and environmental performance of buildings. As in many countries there have been mandatory basic levels with which all buildings were obliged to comply and also a range of alternative or additional standards or assessments. Although the current situation in the UK has seen the recent removal of a number of previous standards and assessment systems, it is worth considering the range of opportunities which they offered, and continue to offer in some cases. The following paragraphs provide a brief overview in order to set a background against which some of the areas of discussion found in the professionals' interviews can be examined.

As a result of long term variations as well as more recent devolution within the UK, different legislation has applied in Scotland and in Northern Ireland as compared to England and Wales, although all have some common features. More recently the Welsh Assembly was also allowed to set its own building standards (from 2011), so that although all four countries are aligned in some ways, there is now greater potential for variation within the UK than in the past. Each regulatory authority approves methods of calculating energy demand in buildings, and dwellings are normally classified differently to other building types. Also, there are differences applied to the procurement of new buildings as compared to the upgrade or renovation of existing buildings. In Scotland, Building Standards [14] are used which are generally regarded to be in advance of those elsewhere in the UK. This paper is primarily concerned however with the regulations and attitudes currently found in England (in which almost 85% of the UK population resides), and for which the relevant primary standards are the Building Regulations Part L, concerned with the conservation of fuel and power.

In the recent past in England, the energy regulations were also integrated into a version of the Building Research Establishment Environmental Assessment Method (BREEAM). For dwellings, this evolved from the "EcoHomes" assessment method (which had been introduced in 2000) to become the CfSH [15] which began to be defined in 2006. Where EcoHomes had credits which achieved grades on the BREEAM scaling, a new methodology using "code levels" was used for CfSH. The Code (as with BREEAM) embraced a number of different components of environmental design, not just energy conservation. Themes considered were: energy and carbon dioxide emissions; water; materials; surface water run-off; waste; pollution; health and well-being; management; and ecology. Minimum mandatory performance standards were created for some of the categories of assessment, and in the cases of carbon dioxide emissions and water consumption, mandatory increases in standards were specified to occur over several years.

CfSH complemented the EPBD and other aspects of environmental and energy assessment. Levels of attainment which showed advances over building regulation compliance (not just in terms of energy but other environmental design issues) could be awarded credits up to level 6 compliance. The original intention (expressed in 2007 [16]) of the changes to regulations and assessment procedures was the proposed achievement of "net zero carbon dioxide emission" dwellings by 2016 (the target date for zero carbon non-dwellings being 2019). The expectation was that staged advancement of building regulations in 2010 and 2013 would lead development and that in the meantime, designers and developers would be encouraged to produce buildings with performance levels above the regulatory minimum, rewarded by certification.

The CfSH was not without problems and criticisms, though during its lifespan it did offer a framework for improvement; however, in 2014 the government indicated its intention to withdraw the Code and consolidate it into the main building regulations; a process finalized in 2015 with its formal withdrawal from use with new developments [17]. The withdrawal not only suggested a lessening of the commitment to environmental standards but also a delay in the implementation of regulatory levels of performance. A concise history of policy developments as mentioned earlier was provided by the UK Green Building Council [13].

One of the alternatives to the original BREEAM assessment procedures was created by the U.S. Green Building Council in its Leadership in Energy and Environmental Design (LEED) scheme, which has now reached its fourth version [18]. LEED is a voluntary system with variations according to building type. Overall it embraces the following categories of assessment: location and transportation; sustainable sites; water efficiency; energy and atmosphere; materials and resources; indoor environmental quality; innovation; and regional priority. It thus has a number of similarities with the CfSH, except that it was voluntary, and perhaps this now indicates the direction of any future development for CfSH. However, there is potential for confusion since the Building Research Establishment has launched a new standard (the Home Quality Mark); apparently because the Code for Sustainable Homes was a government (not BRE) owned standard, which will be maintained for use in certain circumstances.

Another professional group within the UK which offers standards is the Association for Environment Conscious Building (AECB). Its Gold Standard has been closely aligned with Passivhaus certification for some time [19]; however, also of interest in this context is its Silver Standard which offers an opportunity to meet a lower than Gold, yet still significant, level of achievement [20], through tools designed as part of the CarbonLite Programme.

The Passive House standard itself is well described within documentation and procedures to be followed by designers, in particular the Passive House Planning Package (PHPP) [21,22]. Passive House is also a voluntary standard and one in which the focus is on reducing space heating and cooling energy requirements to a minimum through the adoption of very high thermal performance. This is achieved though ensuring appropriate design and construction techniques for the envelope of the building, with testing in the post-construction phase. Many would argue that the strength of the standard comes from the rigour with which it is applied. There are five main elements in the standard:

- High thermal insulation values in all components of the building envelope (typical U values between 0.6 and 0.15 W/m^2K);
- Minimisation of "thermal bridging" (that is of the critical thermal weaknesses in construction)
- Airtight construction with air flow no more than 0.6 air changes per hour at a pressure difference of 50 Pa;
- Controlled mechanical ventilation using heat recovery in the heating season;
- Optimum use of solar heat and internal gains whilst avoiding overheating.
- The application of the above principles should allow the following criteria to be met:
- Annual space heating demand not to exceed 15 kWh/m^2 of net living space or 10 W/m^2 peak demand (and in climates where active cooling is required, approximately the same values apply for the cooling component);
- Renewable primary energy demand for all appliances should not exceed 60 kWh/m^2 treated floor area;
- Air tightness (as above) set at 0.6 air changes per hour at 50 Pa pressure difference;
- Thermal comfort standards to be met for summer and winter operation including maximum of 10% of hours in a year exceeding 25 °C.

In addition to these regulations, standards, and assessment methods, many others have now been developed around the globe including in new geographical areas and in developing countries (see for example [23]).

It is also appropriate at this point to draw attention to differentiations in the definition of certain standards which impacted for a time the development of regulations. Because the UK's original framing of climate change legislation was formulated in order to restrict carbon dioxide emissions, the requirements set within regulations aimed to produce zero carbon buildings. The European approach however based on the EPBD focused on reducing energy requirements to zero, or rather "nearly zero" [24,25].

Zero energy buildings are not buildings which need no energy to function, but rather buildings which produce sufficient renewable energy on site (or nearby) to cover requirements. Sometimes this definition can include the energy balance over a year so that excess energy produced at one time can compensate for energy required at another point in the year, so "zero net energy" might be the more appropriate phrase to be used. The EPBD defines a term "nearly zero energy" in which the energy consumption was based upon primary energy requirements and in the expectation that buildings would be designed to require minimum energy, and that the energy could be supplied by on-site or near to site renewables. However, this resulted in a significant variation between counties in terms of energy use per m^2 (up to about 10:1 ratio) depending on the amounts of renewable energy available and also upon the building energy uses included in the total (for instance variations in the appliances incorporated).

Zero carbon buildings focus on emissions of carbon dioxide rather than energy use, with a degree of flexibility occurring depending on the energy source; also, in the UK the definition of the uses and systems from which carbon emissions would be counted was wider than EPBD. Despite attempts to create clear and tight definitions there were protracted discussions and consultations over this terminology resulting in delays and ultimately opportunities for adjustments to be made at a later date. It was perhaps disappointing that such adjustments have been able to reduce significantly some aspects of the energy and carbon saving potential, and also to reduce confidence in what standards would be applied and when they should be applied.

Recent and somewhat rapid changes to standards and assessment techniques in the UK, whilst potentially reducing red tape and time delays, have also extended the degree of uncertainty over design and construction requirements; and this situation has not been helpful to designers and building developers who wish to demonstrate energy efficient design. Consequently, there is now an opportunity, and in fact a need, for substantial changes in the way energy efficient buildings are procured in practice. In particular, changes are needed to accommodate the switch from the imposition of mandatory advanced regulations to a situation of perhaps only basic requirements being imposed, with optional higher level awards and standards being merely voluntarily adopted.

4. Review of Previous Research

The low energy design of buildings has been considered an important goal both to encourage resource efficiency and to reduce the potential for global climate change associated with the consumption of fossil fuels.

It can be difficult to compare not only standards for different countries/locations but also for different climates. Some standards use quite different factors and also some are not only concerned with energy use. A review paper concerned with comparing the varying international standards [26] in the USA and Europe determined that the most frequently used comparator, (that of thermal transmittance of fabric components), whilst very often included in standards, was not in fact a good choice as it neglected other important factors. It also concluded that the Passivhaus standard was perhaps the best reference energy consumption indicator; thus confirming its role and relevance to the research in this paper. It is not the choice in this paper to replicate such cross-comparisons of standards because the frequent use of sub-types and variations in definitions in the documentation reduces clarity and is also difficult to perform accurately and comprehensively. The choice has been rather to focus on outcomes in terms of delivery of low energy use potential. The following paragraphs give background and justification to the research direction.

The low energy design of buildings has been considered an important goal both to encourage resource efficiency and to reduce the potential for global climate change associated with the consumption of fossil fuels. These altruistic aspirations are not the only concerns however, and studies taking an economic focus [27,28] can have significant value if the prime concern is that of cost. In addition to energy saving and cost assessments, occupants/clients/users are likely to be interested in the wider performance of a building, particularly when it is their own place of residence. Information on a range of factors ought to be more readily available to aid effective decision making for the procurement of such buildings, as they are for instance when making other major purchases/choices for motor vehicles and significant household goods.

The historical development of the interest in, and the need for, higher levels of energy efficiency in the design of buildings are relatively recent considerations as indicated by Ionescu and colleagues in their review [29]. Their view was that as a subject, building energy performance has moved from relative obscurity in 1900 to a situation of virtual solution/conclusion by 2000. Their review also identified four key moments of change in the 20th century, one of which was the design and construction at the beginning of the 1990s of the first Passive House in Darmstadt, Germany.

Passive House dwellings can now be seen to form an important sub-division of the more general typology of low-energy homes and have been the subject of broad spanning studies by some research teams. A number of comparators can be used for performance evaluation such as: on-site or off-site energy sourcing; primary and delivered energy use; air-tightness and ventilation; carbon dioxide production; and energy label comparisons. One study [30] that considered standards across six countries (UK, France, Germany, Norway, Sweden and Denmark) reflected a view that embodied energy in design was less often taken into account than it ought to be. The same study concluded however, that the Passive House standard, with its focus on the building itself, produced real quality in the envelope design and construction and thus longer term benefits for "economy, comfort and environment".

The benefits of the Passive House design have indeed been established by many researchers and are particularly associated with increased occupant satisfaction [31]. Merely improving energy consumption is not always sufficient but improved comfort adds to the positive occupant evaluation of changes needed for design and construction, and of course of the potential additional costs and complexity; additional benefits should therefore be well-communicated. A comparison of monitored apartment blocks in Vienna in which low energy design and Passive House standards were used showed that both versions performed well, but that the Passive House block was rated slightly better and that the effects of the controlled ventilation system was a contributory factor [32] to occupant opinions.

Over the period when changes to definitions of zero carbon homes were proposed in the UK (2010–2015), research supported the view that in order to obtain clear and consistent reductions in long-term energy demand, that the most viable option would be to rely on Passive House or an equivalent standard [33]. This has also been confirmed by other studies which indicated that the development of techniques using such standards could effectively help deliver energy saving and also satisfy client requirements [34].

Developments to the Passive House standard have occurred over an extended period of time and research has been able to evaluate outcomes and show other non-energy benefits for occupants. The role of ventilation control and the use of mechanical ventilation with heat recovery systems (MVHR) has been found to be an important aspect that contributes to the overall benefits package [35]. A number of other research investigations have attempted to evaluate a range of additional beneficial outcomes for end-users of low energy buildings. These have stretched beyond energy performance to include winter and summer thermal conditions experienced, indoor air quality, and comfort in general [36]. Such research determined that whilst energy costs were important, these other comfort factors were key necessities for user satisfaction. They also found however an unmet need for quality assurance systems and this naturally leads to the identification of the importance of the role of design and support development practices for low energy buildings. One could infer that the contact between designer/builder and client/user and the transfer of knowledge and understanding would be valuable in increasing the potential number of low energy buildings.

Some researchers have investigated how to actively engage clients/client groups in developing and defining the low energy standards they wish to use [37]. Their findings indicated substantial value in such stakeholder involvement, and also that the use of the Passive House standard seemed to provide appropriate outcomes to support the process. Such research also encouraged the procedures used and reported upon later in this paper to examine the perceptions of designers and builders with detailed knowledge of low energy design and Passive House.

Occupant behaviour has long been recognized as an important determinant of energy performance of dwellings and consequently it is also related to the failure to meet predicted design outcomes in constructed buildings. The difference is often referred to as a "performance gap" and has been the subject of much research in recent times though some case studies [38] have found that in Passive House development the performance in-use is much closer to that predicted than for other types of new housing. Of course, the very low energy requirements associated with Passive House dwellings means there is an even greater expectation of high performance from occupants/clients and research has been conducted to examine these and their link to behavioural factors [39]. Outcomes from this suggest occupants to have relatively less impact on building performance in very low energy design than other types (though this may also be due to better user understanding of the principles of operation). Results of recent research involving a new Passive House development showed that occupants might also alter their use and ownership of household appliances and therefore affect associated electrical energy consumption as a result of moving to low energy homes [40].

Some researchers have more directly evaluated wider performance issues of buildings based on occupant experience [41] rather than simply relying on energy use. This indicated that user-centred approaches could not only result in development of better evaluation techniques but could in the future lead to better matching of occupant needs to outcomes. Again, this would indicate that a good rapport and interaction between designers/builders and their clients are necessary for the best results.

Research has shown concerns however over a lack of knowledge amongst more general groups of building designers and construction professionals about low energy design, and this has highlighted the need for better assured labeling systems. For this to be supported, designers must adhere to procedures and prove matching to specifications, and the Passive House standard has seemed to provide such assurance but must also be well understood for its success [42]. There have also been studies of the potential additional costs for low energy design: such costs are variable but can be broadly identified and calculated when associated with a specific technology or technique. Such knowledge enables cost-benefit analyses and choices to be made: for example, in one recent study the costs were calculated in the range of an additional 4%–16% for Passive House retrofitting [43]. However, in the same research which was carried out in Sweden, so-called "transaction costs" were considered be a more significant barrier because they were less predictable and could have added an additional 20% to investment costs. These transaction costs arise for example: in searching for technical information and suitable suppliers; from the additional complexities of making contractual arrangements which may not be straightforward because low energy buildings are less common; from larger cost allowances for unknown factors; and from other contingencies introduced into the process. All this adds additional barriers and uncertainties which can restrict development of low energy buildings but these barriers have the potential to be significantly reduced through the transfer of knowledge and information, and in the confidence built through the communication process itself within a project.

Researchers have attempted to use modeling of green building investment decision processes [44] to find ways to reduce uncertainties and thus reduce the additional costs. Four issues were identified through this process by the researchers, all of which might be addressed in some way by improving understanding between design and construction teams and user/clients:

- that the benefits of green building development were generally undervalued by societies;
- that developers were prone to exaggeration of difficulties, risks, and uncertainties associated with green buildings which resulted in higher transaction costs;
- that governments could have incentivized processes that would reduce uncertainties (which would also reduce transaction costs) and thus have increased likely investment by end users in green buildings; and
- that better information flows and awareness would, along with other changes, be likely to increase demand for green buildings.

A significant change currently being experienced by the construction industry is the increase in the use of Building Information Modeling (BIM). This has the potential to reduce transaction costs as well as to provide much more confidence and efficiency in the design and construction process, and also to provide an effective way to communicate outcomes to clients and end-users. Some researchers have therefore identified a need to link better BIM and low energy design software [45] and have tested simplified building design geometries that were used alongside the Passive House Planning Package.

One of the stimuli to the writing of this paper was to draw together and focus on ways forward, prompted by the special issue of the journal *Sustainability*, which addressed the topic of Passive House and low energy design. The papers presented therein provide an interesting cross-section of views and research areas relevant to the overarching debate. Four of the papers dealt with Passive House and three were broader in their focus on energy issues. In terms of regional location, four could be said to be European and three were from outside Europe.

The research of point thermal bridges in the design of advanced ventilated facades linked to the performance of Passive House and high energy performance was considered through detailed modeling by one team [46]. This indicated that substantial increases in heat transfer could occur and that knowledge of the details could improve heat transfer understanding and accuracy in predictions. Another paper was concerned with heat transfer through windows (and window to wall ratios) in hot humid climates [47]; the analysis which it presented was largely focused on predicted occupant comfort and shows the increasing concern with comfort impacts on choices for low energy design. The extension of Passive House approaches to the hot climates found in the Arabian Gulf region was examined by researchers using a combination of simulation techniques and future climate predictions [48]. The outcomes suggested that Passive House standards would result in lower energy cooling costs and that Schneider comfort charts could be used as an analysis technique in such a climate to also demonstrate benefits.

An important research issue pertinent to all aspects of the Passive House design is whether the predicted outcomes can be delivered in practice. Surveys of a modest sample of Passive House buildings were carried out in-situ [49] and supported the conclusion of research identified earlier that the Passive House standard was robust and gave predictable savings. Research has also shown however that some Passive House dwellings have exhibited some more marginal outcomes [50] and that there is some lack of information in published sources about performance. The study examined five dwellings in Scotland and indicated concerns in the areas of indoor air quality, comfort and occupant health. A particular issue identified was the potential for imbalances in the ventilation system.

The Passive House design is now becoming more prevalent in other parts of the globe (Qatar as featured above [48]) and also in the world's most populous country: China. The research featured in [51] however was of a different building technological focus—making use of solar energy in rural rather than urban areas. Although supporting principles of low energy design, this research did not contribute specific advancement in relation to Passive House or very low energy dwellings, but did indicate potential for prefabricated off-site construction. The expansion of research facilities devoted to low energy design was also described in the remaining contribution [52] to the journal issue. The laboratory installation aimed to provide opportunities for the study of future developments including autonomous buildings and Passive House standard dwellings.

It is clear from even such a simplified analysis that the range of circumstances in which low energy design issues for buildings might now be considered relevant is very wide, and is not being led in a particular way by adherence to minimum standard building regulations. The majority of the papers referred to above were concerned with practical implementation and Passive House/low energy design development rather than theoretical analyses or concerns with the social, political, or economic issues in detail. This practice-based emphasis is one which could be said to characterize Passive House and enable it to be the driving force for more general low energy design. As such, research into the understanding and implementation of low energy design by practitioners is a needed area of investigation.

The outcomes of the review of research into low energy buildings and into changes in the UK led to the directions of the investigation presented here. Key considerations were:

- low energy building design benefits are often wider than simple reductions in energy costs and include higher quality in design and improved/more stable environmental conditions and comfort;
- transaction costs including those associated with poor information flows and lack of awareness reduce the attractiveness to clients/end-users;
- there is great potential to use certifiable and defined standards to encourage the uptake of low energy design, and Passive House is a product with a well-researched and high standard in terms of delivery;
- regulation and legislation relating to energy use in buildings in the UK (and particularly in England) has changed, partly as a result of changes in government policy, partly because of changes to support systems, and partly as a result of uncertainties with respect to European led directives given the vote of the UK to withdraw from the EU.

In order to advance the low energy design of buildings, it is necessary to understand better the knowledge, issues, relationships, and other considerations uppermost in the minds of designers/construction professionals. From this it may be possible to extrapolate both future research needs and also the methods that can encourage future low energy design from knowledge of some of the opportunities and barriers that exist. Researchers in Norway [53] who examined energy performance and Passive Houses also considered that the role of architecture (and thus the influence of designers) could be increased to help provide better end-user control and adaptability but also saw the importance of adequate information transfer.

5. Method of Investigation

The research upon which this paper is based was initiated in 2014 with the holding of broad workshop/symposium discussions with practitioners of sustainable and low energy design. This exercise indicated a need to understand in depth some of the barriers and also the support mechanisms that impacted the procurement of low energy buildings in practice. It had been noted that the surveys of industry opinion have often shown that those questioned were in favour of low energy design, but nevertheless did not implement it. In some cases, respondents found it more difficult to use advanced technologies and techniques in practice, particularly where other stakeholders were less aware of the process. It was felt therefore that responses from those with current involvement would produce more insightful and valuable outcomes that might suggest how to encourage greater update and dissemination.

A group of 12 key potential contributors was selected and this was followed by exploratory discussions. This resulted in the formulation of question and themes within which there was a clear lack of published understandings. Further discussion led to the planned research now embodied in this paper and also prompted the reviews included in Sections 2–4. It was clear from following these reviews and also the information from practitioners that additional research was required in order to deliver more specific information and understanding. At this point it was decided to focus on a small number of key stakeholders and the participants from the earlier study were contacted and from them emerged the process of greater in-depth interviews with a selected sub-set.

Question themes were identified under the following headings:

- The general knowledge and skills background of the interviewee.
- Professional situation of the interviewee and what caused them to become involved with Passive House and low energy design.
- Identification of differences in the approach between Passive House design and more general low energy construction techniques.
- The value of "Passive House" to the interviewee's business and differences, if any, to those of low energy design (potentially considering the "branding" value).
- The motivation for undertaking Passive House and low energy design.
- Issues around the setting of a standard and the form it ought to take (and discussion of alternatives).
- The attitudes encountered in practice to Passive House and low energy design from the interviewee's professional and client relationships.
- Issues around retrofitting/refurbishment to achieve improved energy efficiency.
- The impact of relationships between the UK and Europe.
- Identification of key issues/concerns/barriers that exist.
- What directions future development might take.

A selection process determined the key characteristics and knowledge/skill base required and five interviewee participants were identified to give the greatest coverage from initial design to completion and also to cover a range of scheme sizes. It is recognized that had time and resources permitted, a larger group could have been consulted at the detailed interview level.

The interview process involved making detailed notes which were then grouped and focused around key reporting themes. From this, some outcomes arose as findings were extracted. It should be stated that the choice to focus on a small group, rather than to attempt to survey a larger group of professionals by questionnaire, was driven by the need to obtain specific and detailed answers, and also to allow for progression in the discussion in an interactive way. Institutional ethical procedures were used in determining the process and in its performance; additionally, no individuals have been directly identified in the text.

The selected participants were: an architect working as the leader of a small practice who has substantial knowledge of delivering Passive House and low energy design (I1); an architect leading a larger practice making use of the latest BIM technologies in support of a strong commitment to high quality design incorporating low energy features (I2); representatives of a company producing products and components for low energy buildings as well as involvement in their design and construction (I3); an architect with experience of a variety of commercial projects over their career (more than 30 completed) who had later developed interest in low energy design (I4)—he also had experience overseas as well as in the UK; and a research consultant with long term interest in low energy design and with experience of constructing or advising on a number of low energy housing projects (I5). The detailed analysis of their views follows in Section 6.

The underlying research approach is qualitative in nature, gathering empirical data as part of an inductive process through observation of patterns of understanding, outcomes, and behaviour. Ontologically, both idealist and realist views impinge on the issues, and whilst epistemologically the solution to the overriding concerns for energy efficient design spring from positivism, the work described in this paper could be considered an interpretivist activity through the interviews. There is clearly some value bias in the research both from the researcher point of view and also from that of the participant. Despite some of the limitations, the author is confident that the information will be of value for future development.

6. Results: Interviews and Outcomes

As previously mentioned, interviews were conducted with representatives of five expert stakeholders. Interviews took place either at the office of the interviewee or at the University—in both cases, quiet rooms without telephones or other distractions were used.

The following sections of the paper collate responses from those interviewees under a number of headings. Clearly the modus operandi and the requirements for outcomes from the research meant that a more discursive approach to reporting the findings was necessary. The headings evolved as part of the structured interview process and represent the directions the conversations took within that overall structure and are those collated outcomes rather than answers to specific questions.

Interviewees are identified as I1, I2, I3, I4, and I5. To help preserve anonymity, all interviewees are referred to as male and in the singular.

6.1. Attraction of Low Energy Design

In each of the interviews, one of the initial areas of discussion concerned the perceptions about the attractiveness of low energy or Passive House design. The information sought partly related to the interviewees themselves and their views, but primarily to their understanding of and interpretation of the views and requirements of their clients and other associated parties.

The reasons and routes for becoming involved in low energy buildings varied amongst the interviewees. I1 is involved because he likes to "help clients achieve what they want" and through that gains a sense of satisfaction in the successful realization of outputs which were something of a challenge, and he also mentioned that the outcomes would be products to excite and interest him. I1 did not like clients who wasted money on decoration when they could have spent it on higher quality components helping to achieve the Passive House certification standard. Nevertheless, although he wanted clients who wished for low energy design he would also take clients who, for good reasons, were satisfied with "approaching" the Passive House standard.

I2 considered that his role was to support the client to achieve the best design possible and that although he did not carry out a "hard sell" of low energy design, it would be something in the nature of his designs, and that clients would be approaching him because of his practice's reputation in that field. He stated that his practice did not advertise their services very much as they found clients sought them out from their reputation. The types of projects he found himself most often involved in working on consisted of hotels, one-off "high-end" houses, and social housing schemes and their associated and specific issues. I2 also found that though these building types were quite diverse, that there was potential for much knowledge transfer between the types. He felt that speculative new-build and developer–led housing was less appropriate because of external and third party pressures, and that those developments often involved a short-term focus which was not complementary to low energy because of the longer time scale over which the benefits might accrue.

I3's clients split approximately half and half into small or large. He felt that the real value lay in meeting standards such as Passive House rather than aspiring to the more broad term of "low energy design". His mix of clients meant he often supplied components and systems, and for a smaller group of customers he was more involved with the construction of buildings; the design work was more limited to specific components or details. His clients had usually already made some commitment to low energy or environmental design and in a number of cases they could be acting intermediaries driven by end client requirements. I3 would also directly interface with a range of clients himself. Obtaining good publicity such as in newspapers helped raise the company profile and increase business enquiries. Having said this, he did not find clients coming from any specific background such as wanting to "save the planet"; just as likely was the need for comfort at minimum energy costs. Two of the interviewees also found some commercial clients were also influenced by the potential to advertise their green credentials by adopting recognizable low energy design.

I3 discussed different types of clients and also some single larger clients who were unable to adopt Passive House on all properties in their portfolio, but who nevertheless tried to use it in some projects to leverage future development They felt there was a gap between Building Regulations Standard and Passive House which at present was only being filled by the AECB Silver Standard [26]; but because this was a self-certification scheme, some clients were nervous about using it for fear of lack of independent verification. At least he felt CfSH had previously offered a range of standards (code levels) giving some flexibility and also independence to the certification. In the absence of CfSH, these issues now seemed to be leading certain clients to the more likely adoption of Passive House.

I3 also felt that television programmes, in which owners/occupiers had built or redeveloped their own properties, had raised the profile of low energy design to a point where it was becoming a normal requirement from the clients he met. On the other hand, "sustainability" was thought by I2 to be not always the best phrase to use with clients as it sometimes had variable impacts and connotations; other phrases might be used to explain the same approach, demonstrating it was the "smart" thing to do. This also offered opportunities to focus on other terminology such as Passive House.

As a result of I4's experience with another country in the developing world, he felt that low energy was important for clients to reduce costs and improve comfort but he also recognized the financial limitations experienced by some. He also had concerns for overheating in warm climates but recognized the broader needs for reducing energy consumption where possible.

The underlying reason for I5's interest had originally sprung from a sense of trying to reduce environmental damage to the earth from resource depletion and pollution. However, as his career had developed, he felt that there were strong economic arguments to favour low energy design and particularly from a sense of trying to "future-proof" dwellings for the longer term.

6.2. Specific Importance of Passive House

Passive House is one of the standards that can be used to assess building performance specifically related to energy. Some questions were put to the interviewees regarding the value and positioning of Passive House and the extent to which clients might request or make use of it.

I3 recognized that Passive House was gaining a reputation as a mark of quality or indeed caché. Two interviewees mentioned that in some parts of the world the term Passive House was not used directly in marketing but rather the focus was on the improved attributes of design quality that accrued through using it. I5 felt that Passive House had recently grown in stature as a standard and was now beginning to be used in a wider range of countries and climates. He recognized that it would not be suited to all circumstances but that its value was increasing though visibility with some clients was still limited.

I2 was however a little uncertain about the value of focusing on the branding of low energy designs as "Passive House" and he would normally ask clients exactly what they wanted (that is Passive House or "near to" Passive House). I3 however felt that the time and effort of pursuing a low energy design that was merely "close to Passive House" was wasteful as it was relatively easy to follow the full specification and to achieve it. I4 held some similar views but felt that clients usually had a range of concerns and that adherence to a firm Passive House Standard might not always be their priority.

It was clear that there were some differing viewpoints on the importance of pursuing Passive House certification, and perhaps outcomes in the future will ultimately depend on whether a client wants particular design features. Certain design features would impact on costs and construction methods if attempting to meet the full standard, particularly considering clients requests to use elements such as stoves (and chimneys/air flow routes) which could reduce the airtightness of the envelope, and thus make it more difficult to achieve the Passive House standard.

I2 wondered if the client's wish to achieve the certification was dependent on their country location, believing he detected different attitudes in the UK compared to Germany and Austria. He also thought that it might depend on the commitment of a client to a palate of materials/options before the design process commenced; he was prepared to discuss issues with the client and whether they could be persuaded to modify their requirements, but ultimately he thought it came down to "analyzing what it is the client wants to achieve". He also mentioned that for some clients there was a distinction between the "end product" and the "journey" or process of making, as some clients wanted to be involved to a greater degree in the details of procurement and construction and gain satisfaction from that. This could lead to challenges but as with I1, it seems to be something his practice would relish.

A general view from the interviewees was that Passive House clients "know what they will get", and thus have more certainty in the end product. Two also felt that Passive House represented design at the leading edge and thus added value. They agreed that designers should aim for the highest standards and that this would naturally lead towards Passive House if undertaken in a systematic manner. I1 and I3 felt the costs of getting close to Passive House were almost as high as meeting it so there was no real reason not to aim for the award of the standard.

There was some discussion about perceptions of the phrase "Passive House". I3 felt it was often viewed as a "brand" and was seen as more relevant and legitimate to follow through with active and interested builders compared to previous experience with the CfSH. This was not to disrespect the CfSH or the BREEAM with which CfSH is closely associated, but rather that the reality of loss of the CfSH as a measure of performance now led people to other standards, and that Passive House provided something both "specific and stringent".

Three interviewees also felt that comfort was substantially enhanced from their experience of built examples through the adoption of Passive House, and that it had produced even more environmental conditions with small variations in temperature between the head and feet. They also felt that Passive House meant that ventilation and detailing issues would have had to be confronted and resolved in a more organized way compared to non-Passive House design, thus leading to better construction.

In practical terms, two of the interviewees mentioned how it seemed much easier to achieve Passive House with larger scale buildings; this they considered was because the surface area-to-volume ratio was lower in such buildings and thus impacted air change rates, making it easier to meet airtightness requirements. This therefore made them more likely to encourage clients who were considering constructing larger buildings to look into the Passive House standard as an option.

All interviewees had some agreement with the notion that clients were often convinced to go down Passive House routes once they understood the potential of both reducing costs and also improving comfort levels.

6.3. Financial Costs and Benefits

One of the contentious areas of discussion with regards to the use of low energy design and technologies is the perceived additional costs associated with the required technologies and techniques. This can sometimes act as a deterrent to specification and use. Questions were therefore raised to try to elicit information from the interviewees based on either their own perceptions and knowledge, or those factors/issues picked up from their clients and associates.

I3 thought that for architects and associated designers, the use of the PHPP [49] enabled those professionals to see and to demonstrate value in their designs, and thus provide a reason to expend money achieving it. PHPP was an aid to support the businesses of recognized low energy designers as well as to others with a passing interest trying to understand what was required. I5 considered that with sufficient information available, many interested clients could be persuaded to undertake low energy and Passive House schemes.

I2 thought it was beneficial to explain to clients how good, if slightly more expensive, initial design decisions taken at the commencement of a project, yielded much more benefit (claiming a 1:60 cost ratio between doing things right at the beginning rather than rectifying them at the end). He frequently used academic papers and industry published material to show how to optimize costs and his practice regularly constructed full computer-aided design (CAD)/simulation models from which running costs could be estimated early in the project cycle.

I1 thought the main additional costs were not in meeting insulation standards but rather in meeting airtightness requirements, and noted the importance this would have for more exposed locations because of increased air pressure differentials.

I4 thought that clients still required greater assurance on costs and that more evidence in the public domain could help build the case for more development. He thought that perhaps better use could be made of the methods of communication that used terminology that had a broader understanding in the population.

It was also discussed by I3 that in high property price areas (such as capitals or major cities) that the additional costs of Passive House were small compared to the overall building costs, where high value specification might already be expected. In discussing whether this might mean Passive House was something only for the more affluent, he also suggested (based on experience) that for large scale multi-dwelling schemes (often in the social housing sector) that economies of scale helped keep any cost increase to a minimum, and thus it was available to a wider market. I3 (echoed by I1) noted that certification costs per unit would be lower if building multiple units on the same site to Passive House levels.

All interviewees mentioned or alluded to the fact that lower energy running costs ought to be something more frequently publicized in trying to encourage clients to ask for, or invest in meeting, Passive House standards. This was also something that would (over a longer term) enable less affluent occupants to cope better with energy running costs and so help release funding to maintain the fabric of their dwellings more easily. Another practical issue mentioned by one was that by using low energy design there was a reduction in costs for sophisticated heating/controls systems which could further enhance the cost-benefit analysis in favour of Passive House and low energy design.

There was also some reporting of comments made by developers that they would not conform to high standards if they were not required to as this could save money (apparently "up to £10,000 per dwelling"), however the interviewees felt few such developers were able to justify where the figures came from. There was a sense that careful detailing could reach the low energy standards for close to the same construction cost if using skilled/experienced designers and trades-people.

I2 also mentioned his discussions with developers indicated they had to be prepared to drop prices to be competitive with nearby developments, and thus needed a wider cost-price margin. The interviewee thought that developers should perhaps more fully consider trying to market low energy designs based on saving potentially £600 per year in energy running costs as a way of gaining an advantage as an alternative.

6.4. Government and Regulatory Issues

The financial circumstances of almost all countries changed and went through rapid periods of adjustment arising from the financial crises between 2007 and 2009, and subsequent readjustments still evident in the present day. Changes to environmental and energy policies in the UK have been numerous since 2010 and the change of government that occurred at that point. These factors have had impacts on the perceived priority given to energy saving investments and upon regulations that might increase costs for both businesses and individuals in the short-term.

There was widespread concern from all about changes to regulations and assessments relating to low energy design. All interviewees thought there had been impacts on proposed improvements to low energy design and enthusiasm/support offered by the government. This effect was also mentioned in relation to the changes to planning regulations which have changed substantially (a large number of policies and guidance documents have been abandoned) and this has made it difficult for areas outside London to apply more rigorous environmental and energy standards. I5 was specifically concerned that changes were undermining the basis on which decisions might be made—almost as if professional and expert opinions were being diminished in influence and replaced by opinion and conjecture.

Three interviewees felt although the UK government is still committed by law to carbon dioxide reductions, the exit from the EU might mean some redefinition of things such as "Nearly Zero Energy Buildings" and that this could lead to further gaps in policy and practice. Despite this it was recognized that planning officers and building inspectors still had significant impacts on building development and one interviewee talked at some length about the need for a good and co-operative arrangement with such officials in order to properly advance low energy design.

One interviewee thought that the loss of CfSH meant there was less certainty about what the phrase "sustainable homes" meant with regards to planners and planning activity. I3 pointed out that there needs to be more discussion about the difference between new build and retrofit and considered it was rather more difficult to meet certain standards, but pointed out this was in his view a missing element of government policy and leadership.

All interviewees felt to some degree that the absence of development in policies and regulation led by the government in the UK at this point, meant there was a greater need for professionals, and the industry more broadly, to encourage a change in attitude amongst stakeholders. I4 felt in particular that communication around these issues needed to be improved.

6.5. Issues from Practice

A number of comments related to how low energy design might be approached from practice. From the discussions, it was clear that each of the interviewees had quite different ways of working, and these basically reflected the size of the group within which they operated and also their flexibility and other calls on their time. I1 and I5 were quite clear that their main professional interests were better orientated to dealing with issues of single buildings rather than larger developments. This was in contrast to the other three, who although not necessarily focused on larger projects would be happy to be involved at that scale; although one of them felt that many developers were not interested yet in true low energy design "at scale".

The value of the Passive House Planning Package and associated training was mentioned particularly by I1, I3, and I5 in terms of supporting the practice of low energy design and construction. They also thought of it as a practical way of guiding clients and designers to a successful outcome which also had the advantage of Passive House certification.

I2 thought the use of a BIM as a means to offer wider choice to clients was worth the investment at the beginning of a project. This interviewee also thought it was beneficial to be able to show that tenants/occupants would also experience lower running costs and that savings could be used to offset any additional construction costs. He also suggested that better low energy buildings attracted more knowledgeable tenants who would be more likely to maintain the building to a good standard.

I2 was also prepared to produce more detailed materials at the practice's expense in order to create attractive drawings and materials to give to potential clients as an enticement. He was not too concerned that his ideas might be appropriated without payment by the potential clients or third parties as they "would only do it once" and might also have difficulty interpreting the detail of the architect's work. His projects did not always make substantial profits but they often provided a valuable addition to their website enabling them to attract new clients. He also felt that the experience gained from engaging in new projects, whether or not they were completed, helped develop expertise for the next client or to grow longer term commercial relationships. I5 was of a similar mind and was often prepared to offer advice at no or low cost in order to develop understanding and future potential.

Two interviewees thought it important to work with their client to establish the environmental strategy and the things that were wanted from the design at the outset. For instance, whether the focus ought to be on thermal comfort, or perhaps daylight, or that the building was known for being of an ecological design.

All interviewees mentioned the need to work collaboratively with other professionals or advisors. They saw this as a way of getting the building physics and engineering correct; in other words, knowing the limits of their own expertise. However, in one case there was a concern that using engineers who were not known to them, might encourage the engineers to over-complicate the design when Passive House should allow them to stick to basics.

The work and publications of exemplar architects or designers were mentioned by all interviewees as having helped them develop their practice. I1 mentioned the impact of the Hockerton Housing Scheme [54] which he considered to be very close to a Passive House building. Also mentioned by two interviewees was the influence of Robert and Brenda Vale and their book The New Autonomous House [55]. I5 had also been influenced by these architects and also their contemporaries.

The development and changing attitudes over a period of years of like-minded professionals working with specific design practices was mentioned by four of the five interviewees as one key supporting element that has enabled Passive House understanding and skills to grow in the UK design workforce.

All interviewees noted the importance of design detailing as one of the key necessities for success. I1 also commented that when he starts designing a project he "automatically begins to think about how elements will fit together" in an efficient and successful way. He also commented that he would "push boundaries" to meet the requirements of a particular project and relished the challenge of "doing something different in each project". He also felt there were benefits for someone to take a reviewing role for projects.

6.6. Technical Issues

All interviewees were of the opinion that putting "fabric first" was the best way to design and as such were also disappointed by the means some designers employed to meet standards in other ways. This seemed to be a criticism of compensatory measures (or technical fixes) that could be used to overcome basic flaws or inadequacies in the fabric design or detailing. Two also mentioned the way in which Passive House led more directly to low energy end products when adherence to standard building regulations allowed a degree of "fudging". In relation to this, there were also some criticisms of the former CfSH in the way that the use of non-building fabric components/systems allowed some poorer performing designs to meet certain code level standards. This was particularly focused upon by one interviewee in relation to those elements which gained credits under CfSH which could potentially be removed or switched off after the assessment period. One interviewee thought that even if more sophisticated engineered systems might be used in low energy buildings, fabric should always be considered as the first stage.

I4 felt that suppliers should be encouraged to develop products that made it easier (and cheaper) to incorporate low energy and Passive House outcomes—he had a sense that for some products there was a sense of mystique and specialism. He thought that an effort to reduce perceived barriers would bring benefits.

I2 thought that "good design will provide a controlled and measurable airtightness" which had value more broadly. The need to take care of choice of heating system and its design/operation was highlighted by two interviewees particularly, because of the likely required size of systems (smaller than normally expected in the UK).

6.7. Barriers

The take up of energy efficient design often relies on the use of new technologies and techniques which can introduce difficulties and problems because of their innovation. This can create technical barriers and risks, but there are also a number of social, cultural, and economic non-technical barriers. Queries were raised with the interviewees to record their various perceptions of barriers to low energy design and Passive House.

Some underlying concerns were expressed by one interviewee that certain designers, even in relatively well-known architectural practices associated with low energy design, were reluctant to fully embrace the Passive House methods either because of pride or perhaps overconfident self-belief in their own abilities. Another interviewee expressed sadness that some of the leading architects in Europe, who were producing designs close to Passive House compliance, did not want to be seen as concerning themselves with such a technical standard when their main reputation lay in more aesthetic fields. Another interviewee felt that more openness was required alongside an ability to be honest about potential difficulties.

Whilst the costs of meeting Passive House certification were considered by all to be reasonable nevertheless there were also two areas in which several interviewees felt that sometimes insufficient funds were allocated from the construction budget. The first was to materials such as sealing tapes used for air tightness, which at hundreds, if not thousands, of £UK, could be an area for ill-advised subsequent cost cutting. The other main area was that of MVHR design and installation, with concerns that cheaper, sometimes off-the-shelf systems, were being used and this was giving Passive House a bad name when not matched to the design. It was also clearly felt by two interviewees that the building ought to be designed to go hand in hand with the MVHR design and detailing.

A concern of four of the interviewees was the potential for overheating which they felt was being addressed in Passive House techniques and assessment, but that perhaps further opportunity for development still existed, as in their experience, there were still concerns expressed by clients. There was also some concern that Passive House essentially reflected a central European approach to design and construction; an approach which did not quite align with their experience in the UK, and thus created a non-technical barrier across country boundaries.

Two interviewees thought there was a tendency of inexperienced designers not to design sufficiently precisely in order to deliver a product that would facilitate meeting Passive House standards. This indicated a need for more widespread knowledge about the techniques and also for the use of training courses. The impression given by all interviewees was that in traditional UK site practice, the approximations allowed in typical specifications and drawings were too large to match Passive House requirements, particularly where gaps might occur between components affecting airtightness or where condensation risk might increase.

One concern about the PHPP related to how it dealt with certain site influences and two interviewees thought there was greater scope for additional site analysis and incorporation into design recommendations.

A significant concern for the future expressed by I2 was the impact of the exit of the UK from the European Union ("Brexit") as his practice already worked on a number of multi-national projects in a collaborative mode. He had also found it beneficial to collaborate in order to "cross-fertilize" and develop ideas drawing on a wider group understanding. I3 mentioned the Brexit issue with regards to fluctuating currency exchange rates and how this made for some business difficulties when using products from different countries. This issue was also a concern for I5.

I3 felt that UK industry could "do the fabric" but could not deliver the required ventilation systems on a sufficiently large scale to meet the exacting standards at the moment. This he thought arose from several causes: the building industry had not yet "grasped the nettle" and was still trying to do things too cheaply, particularly with regards to MVHR. He felt that there was some expense in designing it correctly including the need to provide acoustic attenuation in the system to avoid getting complaints of noise transfer. He felt that cutting costs in the design could lead to the industry and the standard "getting a bad name". He further felt there should be more emphasis on designing and installing ducts correctly, involving: correct sizing; correct routing; the use of suitable connection fittings; and the use of suitable filters and having the means of cleaning/maintenance access; the need to use large enough ducts and connections fitted correctly; the need to use correct filters; and having the means of cleaning.

Detailed discussion with I3 also considered where other problems might arise: airtightness was the prime issue and he felt that information gleaned from others in the industry suggested risks came 80% from the design and 20% from the on-site construction. One area he specifically mentioned was the need for accurate, precise suitably scaled drawings that could be interpreted by builders; in other words that the design had to be "buildable", without recourse to too much on-site interpretation.

I3 also felt that once a project began to use a plethora of subcontractors that the technical cohesion required for Passive House might be lost and was often the cause of failure to meet testing standards. He suggested getting a good builder was essential and that if they were smart enough and had an open mind they could develop the skills needed. He also mentioned the need for good management and planning to ensure "the right information was in the right hands".

Another major hurdle according to I3 and I5 was the area of retrofitting technologies used for existing buildings, but this needed much more open discussion than is currently taking place. They would have significant concerns about how to achieve Passive House for interconnected dwellings (terraces, apartments, or even semi-detached) unless neighbours were also going down the same route. This can be more complicated when the ownership varies from property to property between owner occupiers to social rented to private rented. Further difficulties might result if health and safety risks result from the installation of inappropriate retrofit measures. Potential for litigation was raised by one interviewee who considered it may deter retrofit at the present time in some building types. Therefore, there is a need for industry to upgrade its knowledge base and increase its skill-sets.

There is a version of Passive House for retrofit (EnerPHit [56]) but knowledge of it and its methods of application are not as widespread. It is a standard for buildings when it would be impossible, because of original construction limitations, to meet the Passive House standard in full. EnerPHit can be used when the components and approach used is matched to Passive House but giving some relaxation in the energy use definition as well as airtightness.

6.8. Future Developments and Opportunities

I1 thought the priority for the future would lie in legislation rather than education and training. He considered this was the only viable means in the future to ensure adherence and development of low energy building design. I5 disagreed with this believing there would be some time before legislation (at least at the national level) moved to support Passive House standards, and that in the meantime, education was the prime way forward.

I3 and I5 felt the rigor of the certification process should be maintained as this was something which continually kept the focus on build standards and detailing. They felt this was something which would encourage the longer term adoption and use of Passive House. Three interviewees expressed the need for continuing the focus of the standard in order to provide stability and confidence.

Areas outside the UK were mentioned as good exemplars by all the interviewees areas of Germany, Belgium, Ireland; but also some areas of the UK which are trying to support development, such as in Exeter and Bristol, were identified as offering examples of good practice. Interviewees felt that the better examples within the UK which could be quoted and shown to potential clients, the better the uptake would be of low energy and Passive House design. As such, this was seen as an essential future development area which could be enhanced by good publicity. I4 also mentioned the recent increase in knowledge and application of Passive House in China.

All interviewees felt that there was large untapped potential to have many more Passive House buildings, provided designers paid enough attention to the detail. They also welcomed the application of the standard to a wider range of building types such as schools.

One interviewee thought that the process of parallel manufacturing with construction offered scope for development. Related but not the same was the view from I2 that much greater use should be made of off-site construction.

I2 thought one positive way forward that would encourage low energy design overall was to try to focus on "clients rather than projects" and to try to develop longer term links with repeat clients or their representatives. He stated that between projects the architectural practice would be willing to work on other technologically related questions and to perhaps jointly seek consultancy type funding for the ongoing research and development activities which might well address an industry-wide problem or issue. He thought the sequence "predict, iterate, monitor, calibrate" expressed one of his underlying philosophies and helped him deal better with the next project and maintain a position at the cutting edge. I5 supported this line of reasoning.

I2 also summarized three key focus areas for the future:

(1) Information—provision of good building information could help improve design and bring down costs with less waste. The information was "helping to know": what is there now, what is possible, and how to achieve it. He also linked this philosophy to the idea of working in partnerships.
(2) Human approach—this he believed kept people engaged and allowed them to understand what they wanted and how they could optimize their use of buildings.
(3) Policies—these he felt needed to be long term and driven by the need to achieve specific goals, and to be outside the scope for regular intervention by changing governments; he suggested policy timeframes that last 7 years.

Three of the five interviewees discussed in some detail the appeal and advancement that might be associated with the AECB approach, and in particular, their Silver Standard (Gold effectively being Passive House). They felt that some thought should be given to development which might allow the Silver Standard to provide a clearer link leading up to Passive House, allowing an intermediate route to achieve low energy design.

Looking forward, I3 and I5 noted that new build was easier than retrofit to design and for which to find construction solutions; and also that retrofit was a major challenge not yet confronted if the UK is to meet its longer term carbon reduction targets which will necessarily involve improving the existing housing stock.

These interviewees also felt there was a need to clarify legislation and to educate designers to understand the large gulf between specifying trickle ventilators and MVHR. They felt that both might be specified with the same depth of thought and failed to recognize that they were so different in practical impacts. Understanding of ventilation and airtightness were recurring themes discussed by the interviewees as something that needed more education and skills in the industry. I3 particularly mentioned that all forms of ventilation have some issues or difficulties, the main one being a frequent lack of consistency in performance.

I3 and I5 mentioned the changes in planning system in the UK which meant it was more difficult for local authorities to set standards and had limitations on their powers. It was therefore necessary to be more proactive in persuading developers and others likely to commission new buildings. I3 and I4 thought different groups including housing associations and other clients as well as Passive House suppliers ought to work more collaboratively. There was a perceived gap at the national policy level, and encouraging the building of some exemplars would be very useful.

It was also felt by four of the five interviewees that if the right things were in place and that potential clients had access to good information, that there would be in the future a good market for pre-selling of multiple Passive House units "off-plan" as well as the current routes.

Overall all five interviewees maintained a positive and enthusiastic view of low energy design in the future, albeit linked to cynicism about certain current policies in the UK.

7. Discussion

The author recognizes that the use of five contributors/organizations is a small sample size, however each organization and their representatives had a high level of knowledge and experience as well as skills in relation to Passive House and low energy design in the UK. They were also known to be well-connected to a wide range of other stakeholders and therefore able to relate experience and understanding from beyond their own projects. The depth of interviews used also gives additional credibility. Table 1 attempts to give a summary of key views and opinions. The final column indicates on the basis of the recorded views, if the interviewee considered that aspect to be a positive issue or not in terms of supporting their own development. Several of the responses indicated a conditional view—that is no clear outcome yet understood.

The quality of discussion in the interviews was at a high level—the interviewees were very knowledgeable and experienced and this came through in their measured and appropriate responses to the topics raised.

Table 1. Summary of interviewee views and responses.

Interviewee Number	Topic	Summary of Response	Overall View
I1	Attraction of low energy design	Helps clients get what they want	Positive
	Importance of Passive House	Very enthusiastic/worthwhile	Positive
	Financial costs and benefits	Good case to be made	Positive
	Government/regulatory issues	Very concerned by recent change	Negative
	Issues from practice	Strong underlying practice theme	Positive
	Technical issues	Focus on fabric	Positive
	Barriers	Relishes solving problems	Positive
	Future developments/opportunities	Supports more legislation	Conditional
I2	Attraction of low energy design	Aim for best design—not hard sell	Positive
	Importance of Passive House	Seen as branding	Conditional
	Financial costs and benefits	Needs explaining to clients	Positive
	Government/regulatory issues	Changes worrying but potential	Uncertain
	Issues from practice	Practice can exploit opportunities	Positive
	Technical issues	Focus on good design	Positive
	Barriers	UK/EU changes a concern	Negative
	Future developments/opportunities	Focus on clients	Positive
I3	Attraction of low energy design	Yes, but real value is P.H.	Conditional
	Importance of Passive House	Gaining in reputation	Positive
	Financial costs and benefits	Value should be demonstrated	Positive
	Government/regulatory issues	Worried about changes	Negative
	Issues from practice	Practice can carry on with PH	Positive
	Technical issues	Fabric first and exploit potential	Positive
	Barriers	Understanding of MVHR and sub-contractor issues	Conditional
	Future developments/opportunities	Certification and rigour important	Positive
I4	Attraction of low energy design	To reduce costs/improve comfort	Positive
	Importance of Passive House	Needs development/support	Conditional
	Financial costs and benefits	More evidence needed	Conditional
	Government/regulatory issues	Case can still be made	Conditional
	Issues from practice	Needs more support	Negative
	Technical issues	Suppliers need to support	Conditional
	Barriers	Concern for inexperienced staff	Conditional
	Future developments/opportunities	International development good	Positive
I5	Attraction of low energy design	Low energy design always good	Positive
	Importance of Passive House	Growing in stature	Positive
	Financial costs and benefits	Value can be demonstrated	Positive
	Government/regulatory issues	Changes have created problems	Negative
	Issues from practice	Challenging but good potential	Positive
	Technical issues	No real difficulties—fabric is key	Positive
	Barriers	UK/EU changes concerning	Conditional
	Future developments/opportunities	Certification/rigour important	Positive

MVHR: mechanical ventilation with heat recovery systems.

One of the intended future outcomes will be to instigate a greater number of combined discussions between larger or regionally grouped numbers of professionals in settings which would allow their skills and expertise to be analysed and optimized. Outcomes could be advertised and thus used to encourage a greater number of clients. It would also be appropriate to carry out more on-going in-depth discussion with similar professionals and to monitor changes over a period of time.

The current preoccupations often associated with transient government effects may change, as will the UK relationship with the European Union and other nations.

Although the Passive House Standard would seem to be well-understood and arguments have been put forward in this paper for its promotion by designers/builders in order to improve energy efficiency whilst at the same time seeking improved design quality, there is still scope for advancement. Research carried out in Belgium following the recasting of the EU Energy Performance of Buildings Directive (which occurred in 2010) sought ways to improve the Passive House certification process from end-user perspectives and concerns [57]. Though the report revealed good levels of satisfaction, some issues around potential flaws in building services were revealed; this is in line with some of the concerns of the interviewee evidence presented in this paper.

One need that was specified was for more "user-friendly" ventilation systems and was linked to better information provision, indicating that good interaction between designers and occupants would be welcome, but also indicating an area for more development and greater research. Case studies of a relatively small number of Passive House and Code for Sustainable Homes certified dwellings investigated with respect to air quality also found concerns about ventilation [58]. In most of the buildings studied, the researchers found evidence of pollutant concentrations breaching or approaching the recommended limits, again indicating that further research might be needed to optimize ventilation and also required for a better understanding of occupant/client needs.

8. Conclusions

The importance of Passive House and the equivalent standards of low energy building design should not be underestimated. In particular, the best low energy designs not only produce reductions in energy costs but also offer occupants the potential for higher quality environments and more stable and controlled levels of thermal comfort. These co-benefits should be more fully exploited in order to promote energy efficient design when government legislation and regulation is not leading the way.

From the specific evidence offered from the interviewees, some specific conclusions can be identified that relate to UK practices. The UK is facing a different situation to that of a number of other European countries resulting from the impacts of the forthcoming exit from the European Union, perceptions of different climatic backgrounds, and perceptions of different occupant and other stakeholder attitudes.

A further significant issue is the apparent reduction in enthusiasm by the UK government to carry through previous commitments to low energy design as noted by the interviewees. This is linked to the decision to leave the EU, bringing the potential to ignore previous European Directives, but some reduction of enthusiasm dates back to 2010 with the ending of "goldplating" [39]. This was in effect a decision to go for the minimum required standards relating to European legislation, rather than anything in advance of this, in order to minimize initial costs for UK business and to streamline processes. Whilst reductions in costs and red tape can be welcome, it can also mean that opportunities to improve energy performance in this case are not encouraged.

A key factor emerging from both the reviews carried out and from the interviews has been the potential opportunities for Passive House and low energy design professionals in the UK to try to exploit the opportunity to provide higher quality design as a means to generate business. It may be that energy efficiency and costs are the first attractants, but there is a much larger business potential in promoting the wider benefits.

There is a risk that this will lead to a focus on richer clients able to afford higher levels of design, but this may also lead to aspirational attractions in the future for a wider range of the public.

The following bullet points summarize the key areas of comment looking forward:

- The interviewees considered there was great potential now becoming apparent to improve low energy design and to encourage more widespread use of standards such as Passive House.
- They also felt that the use of Passive House and low energy standards could be enhanced if good quality information on benefits over a period of time were more easily available.

- Evidence from exemplars was needed, though television and other media did provide better publicity because of the number of new building projects and refurbishments featured in the media which now overtly advocated high environmental quality and low energy demand.
- All interviewees saw benefits from longer-term relationships with clients which did not just focus on single projects or on low energy alone; in some sense, the low energy outcome represents other beneficial impacts such as higher quality design in general and greater robustness.
- The interviewees each mentioned with different degrees of emphasis the need for policies to help develop solutions to the retrofit problem (the difficulty in finding suitable technologies and techniques for existing buildings to bring them to low energy standards).

A final concluding comment would be to raise the issue of how Passive House and low energy design of buildings can best be accommodated in the UK at a time of significant change, with a potential move away from mandatory regulations to voluntary standards acting as the back-drop. The evidence from the interviewees seems to be that there are some interesting avenues of development but also of a need to broadcast information effectively and to engage with stakeholders. Whilst there are clearly some barriers, perhaps more importantly the research has shown there to be a range of opportunities too: opportunities to improve energy efficiency in buildings and opportunities for suitably skilled and knowledgeable professions to exploit interest and develop business potential. This is a live issue in research terms for the foreseeable future.

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