Understanding current retrofit practices to prevent the unintended consequences affecting IEQ and health

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Abstract. The climate crisis demands an urgent societal shift, and the UK government has responded with a strong policy targeting energy retrofit to improve the energy performance of homes to achieve the net zero target by 2050. However, research has shown that standard retrofit measures have resulted in undesirable unintended consequences. Incorrect interventions such as using incompatible materials can affect the equilibrium of the building, increasing the risk of surface and interstitial condensation due to excessive humidity levels. Mould growth may develop under high levels of humidity, damaging the building fabric but also posing a risk to the occupants; it has been linked to asthma exacerbation and other respiratory infections. Therefore, what is needed is a well-integrated retrofit approach that not only reduces energy use but protects the building and the health and well-being of its occupants. This paper discusses the retrofit practices, the main challenges that retrofit practitioners face in the UK, and which guidance and tools they work with through the lens of the impact on occupants. A deeper understanding of the current practices is needed if those unintended consequences are to be avoided. For instance, replacing a 'fabric-first' mindset with a 'people-first' approach that considers more factors like the causes of thermal discomfort, and the gains to be made from passive and adaptive comfort approaches, could contribute to deliverer energy and carbon savings and increased building's indoor environment quality and usability justified.

1 Introduction

The climate crisis demands an urgent societal change in the way we use our buildings and adapt them to the future. In response to the imminent need to drastically reduce energy consumption and CO_2 emissions, strategies such as energy retrofitting of existing buildings are one of the most important actions that need to be taken. The UK government has a strong energy retrofit policy to improve the energy efficiency of homes and achieve the net zero target by 2050 [1].

The net zero strategy prioritises the replacement of gas boilers with heat pumps and the expansion of heat networks, as well as investment in low-carbon technologies and green materials [2]. According to UK housing associations, in the year 2021-2022 the main retrofit measures were external and cavity wall insulation, loft insulation and the installation of heat pumps. Other measures such as improved glazing, insulated floors and doors and mechanical ventilation with heat recovery are implemented in a lower degree [3].

As Wade and Visscher note, the rate of current retrofit is not high enough to meet net zero targets [4]. Retrofitting needs to be increased tenfold to achieve a meaningful overall result to meet such targets [5]. The Committee for Climate Change estimates that still 29 million homes need to be retrofitted in the UK [6].

There is a legitimate need to engage in the retrofitting scale up process, but in parallel it is crucial to set clear targets for future retrofits, as their number will increase massively the coming years. As Jagarajan et al., showed, current research lacks a systematic review of what is known about sustainable retrofits and research has shown that standard retrofit measures have led to undesirable, unintended consequences [7, 8].

Unfitting interventions such as the use of incompatible materials can affect the balance of the building and increase the risk of surface and interstitial condensation due to excessive humidity. In 2020, there were still around 23.5 million homes in England that had problems with damp and humidity [9]. According to Ortiz and Ital, retrofitted homes have a higher potential risk of developing indoor damp and overheating [10].

This risk results directly from improving the airtightness of the building envelope and thermal insulation. Most current retrofit approaches seem to focus on energy savings and improving the thermal performance of building envelopes, neglecting other important parameters like thermal comfort, indoor air quality and occupants' health.

Mould is one of the main risks. It can develop under conditions of high humidities and apart of damaging the building fabric, it has been linked to exacerbation of asthma and other respiratory infections [11]. Around 5.4 million people in the UK suffer from asthma, which has

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been linked to indoor dampness, mould contamination and other chemicals [12].

Ventilation is a key parameter for indoor environmental quality (thermal comfort and indoor air quality) and essential in addressing the unintended consequences of retrofit. However, it is not often considered in the retrofitting design. The latest guidance for retrofit PAS2035 includes an assessment of ventilation and attempts to address this issue [13]. Traditional ventilation criteria although are designed to be directly related to thermal comfort, tends to be overestimated. On the other hand, there is a need for the development of heath-based ventilation guidelines as the limits and recommendations for exposure to indoor air pollutants are based on epidemiological studies [14-15]. From the users' point of view, the perception of thermal comfort and overall comfort is an important factor determining the perceived state of indoor air quality [16- 17].

People in industrialised countries spend 90% of their time indoors and are exposed to increased levels of indoor air pollutants [18]. The amount of time people spend indoors has been increased in recent years in the context of the global pandemic, leading to an increased collective awareness of indoor air quality, which has increased the pressure to consider indoor air quality in new and retrofitted buildings [19].

The current energy crisis increased the interest in thermal comfort, overheating and cold winter conditions in the UK. Thousands of articles have been published not only on the effects of increasing overheating, inadequate ventilation, and poor indoor environmental conditions but also because of the growing public awareness of the building environment's role in human health.

Comfortable and healthier buildings are undeniably important to users, but to what extent they form part of the goals of current energy retrofit practises and what tools practitioners have in their toolbox to ensure health and wellbeing are not compromised? To this end, the focus of the work presented in this paper was to collect data from the field itself. Retrofit practises, key challenges, guidelines, and planning tools are important factors for a shift towards energy retrofits that aim for comfortable and healthier buildings.

2 Methods

A survey was developed and distributed within retrofit practises to gain a deeper understanding of the practitioners' perspectives and find solutions and identify the gaps in current practice to address the health risks associated with the unintended consequences of retrofitting.

The survey aimed to collect data on the main challenges faced by retrofit professionals in the UK and the guidance and tools they work with from the perspective of impact on residents. It also aimed to identify the barriers in perceptions and guidance to move from a building fabric-first mindset to a people-centred approach that considers other factors, such as the causes of poor indoor environment quality and thermal discomfort.

The survey consisted of 4 parts and 28 multiple-choice and open-ended questions. The first part includes questions concerning the participants: experience, role in retrofitting, special interests. The second part of the survey contains questions on participants' perceptions: important aspects and challenges of retrofitting. The third part collected information about the most important measures, building types and their geographical location. The fourth part of the survey refers the pre and post retrofit assessments and the tools and regulations used to plan the measures.

The survey was delivered using Opinio software an online platform. The survey was distributed to participants by email. As in other socio-technical studies on perceptions and attitudes towards retrofitting and energy efficiency, participants were recruited through 'snowballing'. This means that they were recommended by personal contacts and by the participants themselves. Although 'snowballing sampling" can raise concerns about the representativeness of the sample, it is recommended as a sampling method for ‘hard to reach’ participants [20]. In this case, it was difficult to reach participants who are working practitioners, as the survey took half an hour of their working time and they had to talk about perceptions and challenges related to their own work. Hence, additional criteria were selected for the sample to address these concerns; participants must be involved in retrofitting (research and practise) in the UK and have several years of experience. The sample of thirty participants included both genders as it has been noted that much socio-technical data on retrofitting focuses mainly on male participants [21-22]. The sample size is indicative of similar studies, and it includes people working in different areas of retrofit: research, design, implementation, scaling, retrofitting of heritage buildings, production of guidelines.

2.1 Data Analysis

The analysis required two different approaches to analysis. The quantitative data was analysed statistically, and the qualitative data was collected and analysed thematically using NVivo software. Some of the participants sent long emails in response to the survey, which were included in the qualitative analysis after their consent.

Thematic analysis allows for a deeper understanding of behaviour and perceptions. Participants had the opportunity to write about their approaches, expectations, and experiences. The analysis of this data would lead to insights and can be combined with the literature review to link and compare theory and practise.

3 Results

The results investigate the link between current practice of energy retrofit and indoor environment. The results are divided in four parts: the sample demographics to create the context of the responses, identification of

current practices, that can affect occupants' comfort and health, and the discussion of how these practices can be changed. The discussion focuses on the gaps in the current practice and attempts to identify the first steps towards the implementation of indoor environmental quality.

3.1 Sample demographics

The role of the participant [Fig.1] in the retrofit process is crucial to the perceptions and experiences as well, their background and the projects that have worked on [23]. Most of the participants are retrofit coordinators and retrofit designers, and this can explain the technical and practical aspect reflected on their replies.

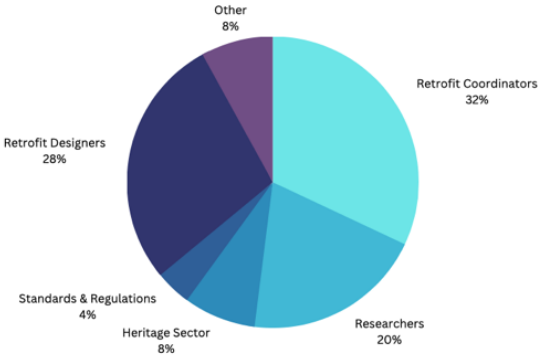

Fig. 1. Participants' role in retrofit

Most participants have worked in more than 5 retrofit projects; in their majority residential [Fig.2] projects dispersed all over the UK, [Fig.3]. Other studies usually are locally focused e.g., Ireland and West Midlands [24]. This could influence the types of challenges they have faced, for example regarding suitable contractors or skilled workers.

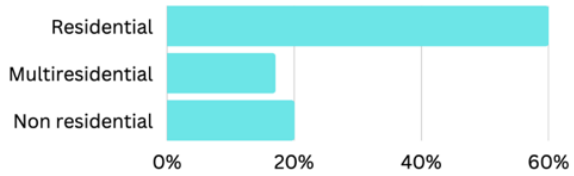

Fig. 2. Types of retrofitted buildings

Fig. 3. Density of retrofit projects across UK

3.2 Retrofit current practices

To investigate the relationship between the retrofit practices and indoor environmental quality the following thematic map was produced [Fig.4]:

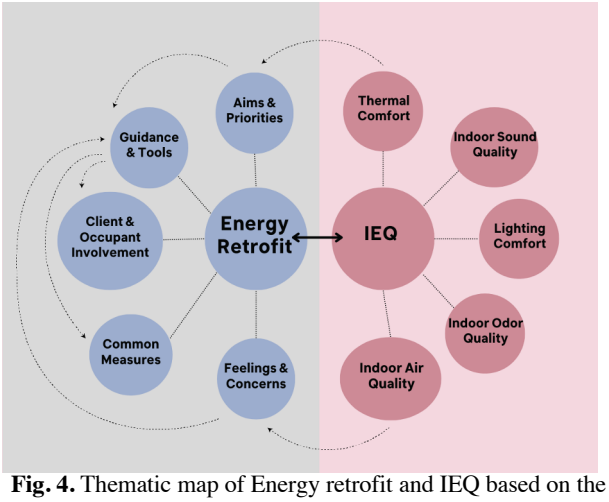

Fig. 4. Thematic map of Energy retrofit and IEQ based on the surveys

From the indoor environmental quality parameters, the focus was on thermal comfort and indoor air quality as they were the only parameters identified in the survey from the practitioners.

3.2.1 Retrofit priorities

The most important priority for 90% of professionals is energy reduction. "*For me retrofit is about energy efficiency and carbon reduction. Everything else is refurbishment or renovation.*" Reduction of energy use and carbon emissions are the most repeated priorities among the participants, especially between retrofit coordinators and designers. Retrofit in practice is dominated by an approach that focuses mainly on energy and financial aspects, as found in the survey, and confirmed in the literature [25-27].

3.2.1 Most common retrofit measures

The most common retrofit measures reported are building repairs, draughtproofing, repairs/replacement of windows and external doors, decarbonizing of heating/cooling, improving ventilation, loft and floor insulation, cavity wall insulation. As we can see, the range of retrofit measures are broader than the ones reported from housing associations [3] and could be linked with the different types of buildings retrofitted.

3.2.2 Main concerns

The main concerns and challenges mentioned by professionals were the lack of funding, the implementation process, and technical problems when designing or specifying ventilation systems, external wall insulation and window replacements. The technical aspect of retrofitting is the aspect most participants mentioned as a main concern, although they note that has evolved over the last decade. The lack of suitable

contractors is also mentioned. The tension between energy goals and heritage conservation is also a key concern.

Finally, few participants are concerned about residents' health and the unintended consequences the retrofitting may create. A participant mentioned: "*it is important to understand the energy efficiency and health aspect of retrofit, together with their buy-in to the key priority*'', while another participant highlighted the need for "*an ecological and holistic approach to design and specification*''.

3.3 Practices that pose risk to health

3.3.1 Indoor Air quality

Indoor air quality is recognised as one important purpose of a retrofit [28]. Although, there have been examples in other European countries of guidelines for indoor air quality implementation [29], most of the research to date on energy retrofits in the UK has focused on energy efficiency only without looking at the impact of retrofit measures on IAQ and health [30]. This is also reflected in the survey results. Even though, 63,3 % of the participants recognize indoor air quality as an important outcome of the energy retrofit, there is no described criteria or assessment of indoor air quality regarding pollutants, particles, dust, etc., or any relevant guidance or tools mentioned. Few participants have only assessed internal CO_2 levels. Indoor air quality is a topic for future consideration, as one participant mentioned, "*as monitors get cheaper, also looking at CO_2 monitoring*".

3.3.2 Humidity and ventilation

In 2021, 6.5 million (27%) UK households reported the presence of damp and/or mould patches on the walls or ceilings in their homes, most commonly in bedrooms or bathrooms [31]. Participants recognised the importance of reducing humidity problems and the need for appropriate ventilation: "*Managing moisture risk, damp and avoiding unintended consequences*". However, there are still technical problems in the detailed design of ventilation and its implementation phase. Damp investigation, moisture content of existing materials and external visual survey to identify leaks etc. are the measures taken to prevent unintended consequences, as practitioners mention.

3.3.3 Thermal comfort

Thermal comfort although a requirement, isn't adequately considered in the retrofit process. Thermal comfort is recognized as a key priority by 76% of the participants. Thermal comfort satisfaction is considered an indicator of a successful retrofit, even though only 16,7% of them perform any kind of thermal comfort assessment after retrofit.

Half of the participants don't use any standards in the retrofit process. They rely on experience as they commented: "*None, do what we think is most suitable*'', "*I have been undertaking sustainability 'audits' for decades and use this knowledge. Now starting to use PAS*''. The most common used standard is PAS2035, which is the latest retrofit guidance in the UK. It is risk-based on a 'whole-house' or 'whole building' retrofit strategy. Although it addresses critical points such as appropriate ventilation design, there is not yet a specific process for designing and assessing thermal comfort.

When thermal comfort is considered is reduced to air temperatures, as it was validated by the survey and neglecting others, maybe more important parameters generating discomfort, such as uneven or radiant temperatures and non-physical parameters such as expectations and controls [32].

Inadequate consideration of thermal comfort may potentially increase the negative effects to occupants' health. Thermal discomfort can reduce productivity and cause brain fog, especially when sleep quality is degraded [33]. Overheating in summer, is linked with heat stress that can lead to heat exhaustion and premature mortality, especially amongst the more vulnerable. Inadequate thermal comfort in the winter, is also connected with excess mortality in the UK, because of the colder climate and a range of problems and diseases such as high blood pressure, common colds increase, pneumonia, and asthma attacks [34-35].

3.4 Discussion

Introducing clear indoor air quality and environmental guidance based on occupants as one of the pillars of energy retrofit could positively impact the long-term outcomes of retrofit interventions. As, shown, a broader implementation and understanding of indoor air quality and thermal comfort could provide a compass for the implementation of environmental quality in the retrofit process, as they are closely linked with appropriate ventilation.

Indoor air quality, although recognised as the main aim of retrofitting, has yet to be considered in their design. When considered, it has been only reduced to monitoring CO_2 levels, neglecting other important factors such as odors, chemicals, outdoor air particles, volatile organic compounds [36].

Thermal comfort is addressed only through mandatory simulation controls in public funded retrofits, which tends to be overestimated according to post retrofit assessments. In practice, only a third of the practitioners of this study has collected data post-retrofitted, which is limited to air temperature. In the survey, two points as the first step towards a shift in the paradigm were identified: Perceived environmental quality assessment could be used as the first step, as most of the practitioners are in contact with the users. The second step is the introduction of pre- and post-retrofit assessments. The main concerns and barriers described by professionals are technical issues, unskilled workers and lack of financial resources and time.

The established relationship between the professionals and the clients [37] could help in the thermal comfort and indoor air quality perception

assessment. The participants highlighted "*Unless the Clients/ Occupants feel that the retrofitting exercise was worthwhile, then they will not help 'spread the word' to others*''. Furthermore, as the participants point out, clients and occupants are not always the same person. Occupants' involvement can be proven crucial in this process, as it can give evidence of perceived thermal and indoor air quality.

4 Conclusions

The need for good environmental quality in retrofitted buildings to protect comfort, health and well beings of users is imminent. The planned energy retrofit scaling up in the next decade only accentuates this need.

Retrofit practices is dominated by energy and financial approaches. Practitioners although recognise the importance of comfortable and healthier homes, they are not reflected on their practices. They recognise the health risk associated to excessive moisture. Even with the introduction of PAS2035, concerns about appropriate and detailed ventilation design are still a top priority. Regulations and guidance are used only by half of the practitioners.

Transitioning from a 'fabric-first' mindset with a 'people-first' approach that considers the building's indoor environment quality and usability require a change in the current practice culture. and in the tools and guidance available to minimize health risks from inadequate design.

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Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was funded by EPRSC and Historic England.