CLIMA 2022
Eye on 2030 | Towards digitalized, healthy, circular and energy efficient HVAC
REHVA 14th HVAC World Congress
22nd – 25th May, Rotterdam, The Netherlands

Going active: How do people envision the next generation of buildings?

Elli Nikolaidou [a],* *Ian* Walker [b], *David* Coley [a], *Stephen* Allen [a], *Daniel* Fosas [c]

[a] Department of Architecture and Civil Engineering, University of Bath, Bath, United Kingdom

[b] Department of Psychological Sciences, University of Surrey, Guildford, United Kingdom

[c] School of Engineering, University of Edinburgh, Edinburgh, United Kingdom

Abstract. With several countries having declared a climate emergency and set decarbonisation targets, the built environment is expected to change radically. Several building standards have been developed to reduce carbon dioxide emissions from buildings, but they do not provide a clear pathway to a net zero future. The recently launched Active Building Code (ABCode) offers guidance on minimising the environmental impact of the next generation of buildings termed Active Buildings (ABs). This is achieved through their synergetic relationship with the grid. This paper presents our two-stage investigation into the stakeholder perceptions of ABs. In stage 1, we collected thoughts on the future of the built environment through a series of online focus group discussions with 30 industry experts. In stage 2, we quantified the ideas that arose from stage 1 through an online survey of 30 academics and researchers. Participants answered four questions, namely: (i) what is missing from existing regulations and standards; (ii) what is an AB; (iii) how should the performance of ABs be assessed; and (iv) what are the challenges to the popularisation of ABs. The data that was collected from the focus groups and the survey was analysed visually and statistically using logistic regression to identify the aspects stakeholders find important when envisioning the next generation of buildings. No significant differences were, in general, observed between the two groups, with industry and academia agreeing that whole-life carbon, energy demand, and energy flexibility should be used for the performance assessment of ABs – therefore aligning with the metrics suggested by the ABCode. Both groups interpreted 'activeness' as responsiveness, with industry experts highlighting the need to better define the relationship between buildings and the grid. They also regarded people's mindset as the biggest challenge faced by ABs, due to the general tendency to make decisions based on capital cost. Academics and researchers also worried about the cost of technologies involved, which is however expected to drop over time. Results should be used to inform regulations and standards to make sure these are comprehended by all stakeholders and ultimately drive down carbon on all building projects.

Keywords. Active Buildings, decarbonisation, stakeholder engagement.
DOI: https://doi.org/10.34641/clima.2022.325

1. Introduction

With human-induced global warming having caused multiple changes in the climate system [1], several countries have now declared a climate emergency. To act on it, countries will have to shift onto a path of decarbonisation, setting targets and timelines for net zero carbon. Countries will thus have to achieve a balance between the amount of carbon they add to the atmosphere and the amount they remove from it [2]. Aiming to achieve such a balance and ultimately stop its contribution to global warming by 2050, the UK was the first major economy to pass a net zero emissions law [3]. The building sector is expected to play a critical role in reaching this net zero target, as buildings are associated with approximately 40% of total carbon dioxide (CO_2) emissions in Europe [4]. However, reports produced by experts, such as the LETI Climate Emergency Design Guide [5], state that current building regulations are seriously lagging behind the trajectory required to achieve net zero and stop global warming. In a similar way, voluntary building standards do not push the decarbonisation agenda far enough, as they do not always encourage holistic solutions, nor do they offer incentives for well-performing buildings [6].

In more detail, buildings commonly draw the energy they require to satisfy the needs of their occupants from the grid. Hence, they are commonly regarded as passive users of energy, not as active parts of the energy infrastructure. Thanks to technologies such as solar panels and batteries, buildings are however able to support a bi-directional relationship with the grid. Such a relationship can provide the grid with a greater energy flexibility, which is vital to meeting net zero – given the time-varying renewable energy generation [7]. Active Buildings (ABs) aim to exploit this missed opportunity [8]. These are buildings that produce, store, and share energy (Fig. 1) based on the needs of their occupants, as well as of the grid [9]. Thanks to their active interaction with the grid, ABs can help both the building and energy sectors reach net zero. At the same time, such a synergetic relationship can reduce peak demands and thus the need to invest in energy infrastructure. It can also transform building occupants into prosumers (that is, producers and consumers of renewable energy) and hence reduce their energy bills.

If we are to adopt such an approach, stakeholders would need some form of guidance on what an AB is and how its performance should be assessed during the design and in-use stages. The easiest way to do this would be via some form of building code. Given that building technologies and energy infrastructure are rapidly evolving and that creativity in design is necessary, any proposed Active Building Code needs itself to be active – i.e., to evolve over time. ABCode1 is our initial proposition for an Active Building Code (ABCode) [10]. Additional iterations (e.g., ABCode2, ABCode3, etc.) may emerge in the future to account for any advances in the building and energy sectors, and ensure that we are on track for decarbonisation.

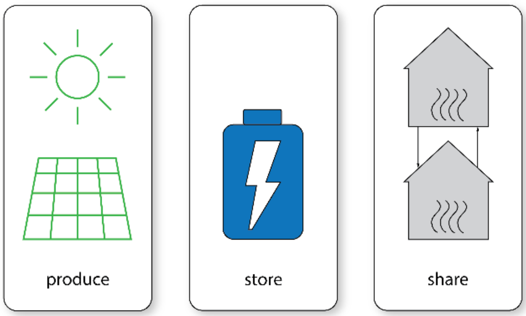

Fig. 1 – Going active: Produce, store, and share energy.

This paper presents our two-stage investigation into the stakeholder perceptions of the next generation of buildings called Active Buildings (ABs), aiming to:

1) Identify the aspects that are missing from existing regulations and standards, which should be accounted for when developing or revising relevant frameworks;

2) Justify our initial proposition for an Active Building Code (ABCode) and provide a clear definition of ABs and a suitable framework for assessing their performance; and

3) Identify the barriers to the popularisation of ABs, which should be dealt with by future iterations of the ABCode.

2. Research Methods

Section 2 describes the data collection and analysis process applied in this study.

2.1 Data collection

The first stage of our investigation aimed to help us get an insight into industry thinking. The focus group method was used, as this is recommended for cases where researchers wish to get a feel for an emerging topic, and an understanding of what is important to a given population [11] – but may not yet know what questions must be asked quantitatively [12]. Twelve focus group discussions were conducted, with each group comprising two or three industry experts and the moderator/facilitator (i.e., one of the authors of this paper). These were decided to be online – and not face-to-face – due to COVID-19. Online focus group discussions are accompanied by great savings in time, cost, and CO_2 emissions [13].

Each discussion lasted for approximately one hour. Initially, participants briefly introduced themselves. They then engaged in a general discussion about the future of the built environment in view of the net zero target – including the extent to which existing building regulations and standards support such a target. Finally, they participated in a more specific discussion about ABs, providing their definition of 'active' without having any knowledge of the term. They also shared their thoughts on the performance assessment of ABs, as well as on the barriers to their acceptance. Each of the sessions was videorecorded upon agreement of all participants, with the help of Microsoft Teams. As focus group discussions do not seek to sample representatively from a population, participants were all selected on the basis of their extensive experience within the building and energy sectors. In particular, they are experienced industry practitioners across the whole value chain, having a variety of backgrounds and work experience (i.e., architecture, engineering, sustainability consulting, energy management, and housing development).

This sampling strategy is called purposive sampling, as participants are selected purposely to yield rich information [14]. 30 industry experts were recruited in this study. The total number of participants – and therefore of focus groups – was dictated by the so-called 'saturation point'; i.e., the point at which no new information was emerging from the discussions [15]. An initial round of five focus groups were here conducted. As no saturation was reached, additional participants were recruited, and a second round of seven focus groups were conducted – until no new information was emerging. Regarding the size of the groups, a low number of participants per group was here selected due to the complexity of the topic. In more detail, triads and dyads were preferred as they offer a balance between the individual and the group context, and therefore allow participants to become familiar with the topic and reflect on what they hear from others [16].

The second stage of our investigation aimed to help us get an insight into academic thinking. An online survey was used, as this would help us quantify the ideas that emerged from the first stage (i.e., the focus group discussions). The survey included four close-ended questions to reflect the themes that emerged from the discussions with the industry experts. The options that were given to participants reflected the most popular responses among the industry experts. The survey was completed by a total number of 30 academics and researchers, who had the freedom to select up to two options per question.

2.2 Data analysis

Grounded Theory was here used to analyse the data that was collected from the focus group discussions in the first stage of our investigation. This is a well-known approach to theory generation, developed by Barney Glaser and Anselm Strauss in the 1960s [15]. After becoming familiar with the data by listening to all the recordings and keeping notes, we completed the coding step by attaching labels to text segments. Coding was essential for generating core categories (themes), which can provide an easily recognisable description of any valuable data. Four themes arose through constant comparison (i.e., the definition of codes and their comparison to previously identified codes). These were then expressed in the form of questions (as presented in Section 3) – which were subsequently posed to academics and researchers through an online survey in the second stage of our investigation. The data that was collected from the focus group discussions and the survey was analysed visually (in Python), and statistically (in R, using a logistic regression model).

Focusing on the statistical analysis of the responses, a generalised linear model was here used to predict the binary outcome (i.e., whether a specific option is selected by a person, or not). The $lme4$ package for R and, in particular, its $glm()$ function was used to fit such a model and to analyse the fitted model. The fitted model revealed the interaction or not between options and the two groups of stakeholders. That is, it showed whether industry experts, and academics and researchers, tend to respond in a different way, or not. Note that, analysis automatically used the first option (i.e., the first label of the x axis in Fig. 2–5) as the reference category. It then showed whether the rest of options are significantly different from it, or not. In other words, each pair of responses (i.e., of blue and green circles in Fig. 2–5) was compared to the reference category. Finally, the odds ratios from the binary logistic regression were calculated in R using $exp(model\$coefficients)$ to demonstrate the options that are more likely to be voted for by any stakeholder – and that should be hence prioritised when designing the next generation of buildings. It is worth pointing out that conclusions refer to the collected data. In the future, additional observations could be collected to boost statistical power.

3. Results

Section 3 presents results in the form of four major themes. These express the topics that emerged from the online focus group discussions with the industry experts. They also reflect the close-ended questions that were then posed to academics and researchers. These had the freedom to select up to two responses (among the most popular responses provided by the industry experts, as shown on the x axis in Fig. 2–5).

3.1 Theme 1: What is missing from existing regulations and standards?

The great majority of the industry experts regarded *performance verification* as the aspect that is mainly missing from regulations and standards (Fig. 2). In more detail, all focus groups brought to discussion

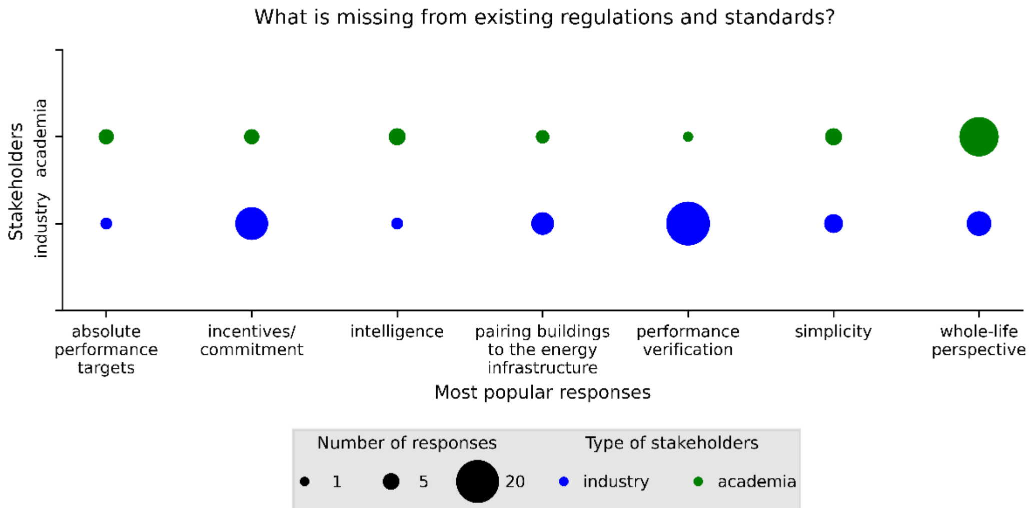

Fig. 2 – The aspects that are missing from existing regulations and standards, according to the 30 industry experts (blue) and the 30 academics and researchers (green).

the lack of a compulsory scheme for post-occupancy evaluation for all building types, expressing worry that this may prevent buildings from achieving net zero carbon in operation. The second most popular response was *incentives/commitment*. Almost half of the industry experts stated that the current lack of carbon incentives does not motivate stakeholders to invest in greener solutions. Another omission is that there is not any agreement that forces stakeholders to commit to a high level of performance in use. In the case of academics and researchers, none of these two aspects were popular responses, as they were voted by one and four persons, respectively. *Whole-life perspective* was the most popular response for these stakeholders, who appear to believe that the whole-life performance of buildings is not dealt with sufficiently by existing regulations and standards.

Focusing on the statistical analysis of responses, the logistic regression model in R indicated that options and groups interacted significantly in the case of the following options: *performance verification* (p-value = 0.002); *incentives/commitment* (p-value = 0.03); and *pairing buildings to the energy infrastructure* (p-value = 0.05). This implies that, in these occasions, academics and researchers responded significantly differently from industry experts – using *absolute performance targets* as the reference category. The analysis also showed that these three options as well as *whole-life perspective* were significantly different from the reference category. The calculation of the odds ratios confirmed the popularity of *performance verification*, *commitment*, *whole-life perspective*, and *pairing buildings to the energy infrastructure*. In more detail, it showed that the odds of someone voting for these options are greater than the odds of someone voting for *absolute performance targets* by a factor of 21, 10.71, 6, and 5.1, respectively.

3.2 Theme 2: What is an AB?

When asked to provide their own definition of active without any prior knowledge of the term, industry experts highlighted the importance of designing and delivering buildings that are *responsive to the needs of the energy infrastructure* (Fig. 3). ABs should thus be active parts of the grid, playing an important role in its decarbonisation and also minimising its need for upgrade – which can be very expensive. Around one third of the industry experts connected the term 'activeness' with the *responsiveness to internal and external conditions*. ABs are thus expected to directly respond to inputs, such as the weather, with the aim of optimizing building energy performance. Another interpretation of activeness was the *responsiveness to the needs of occupants*. ABs are hence expected to interact with their end users to satisfy their needs, such as heating and cooling, and ultimately maximise their health and wellbeing. This was chosen by half of the academics and researchers who participated in the survey, while the *responsiveness to the needs of the energy infrastructure* was selected by only one academic. The *responsiveness to conditions* was the most popular response for this type of stakeholders.

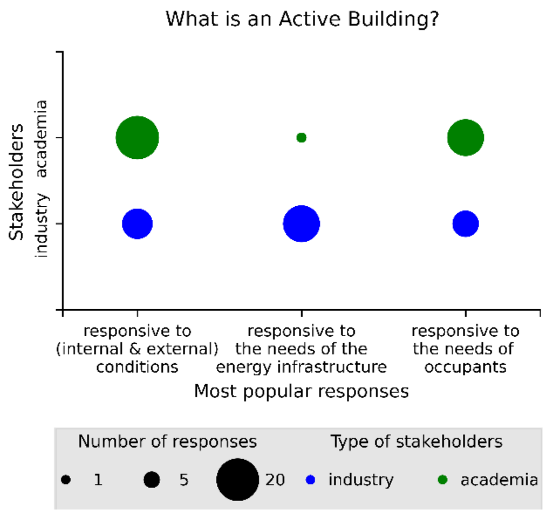

Fig. 3 – The definition of an Active Building, according to the 30 industry experts (blue) and the 30 academics and researchers (green).

The logistic regression model in R showed that the interaction between options and groups was highly significant just in the case of the *responsiveness to the needs of the energy infrastructure* (p-value = 0.0004). This is thus the only occasion where academics and researchers responded significantly differently from industry experts. No other significant difference was found as none of the options is significantly different from the reference category (as a pair of responses). The calculation of the odds ratios suggested that the odds of someone voting for the *responsiveness to the needs of the energy infrastructure* are slightly greater than the odds of someone voting for *responsiveness to internal and external conditions* by a factor of 1.5.

3.3 Theme 3: How should the performance of ABs be assessed?

Evaluating the performance of buildings during the design and in-use stages is critical in ensuring that we are always on track for decarbonisation. It is still an open question though what metrics must be used. This question yielded a consensus of opinion among stakeholders, as the most popular response for both groups (i.e., industry and academia) was *whole-life carbon* (Fig. 4). That is, the majority of stakeholders support the use of a target for the whole-life carbon performance of buildings, with the aim of increasing potential savings in their operational and embodied carbon sides – and ultimately mitigating the climate emergency. The second most popular response was *energy demand*. Several stakeholders stated that this metric will gain popularity over the next few years, as electricity is getting closer to its decarbonisation. They also claimed that this can be easily measured in real life and judged against predicted performance values. Other proposed metrics were *comfort*, *energy flexibility*, and *peak demand*. The latter was found to be important for three industry experts, but was not selected by any academic or researcher.

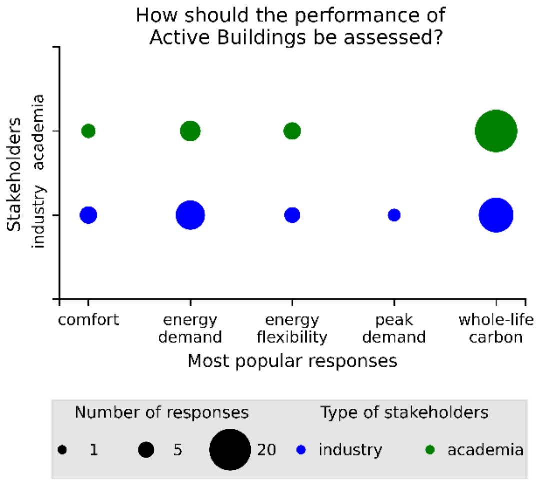

Fig. 4 – The metrics for assessing the performance of Active Buildings, according to the 30 industry experts (blue) and the 30 academics and researchers (green).

The logistic regression model verified that the two groups responded in a similar way, as there was no occasion where the interaction between options and groups was statistically significant. It also indicated that *whole-life carbon* (p-value < 0.0001) and *energy demand* (p-value = 0.02) were significantly different from *comfort*. The calculation of the odds ratios confirmed the popularity of *whole-life carbon*, and *energy demand*, followed by *energy flexibility*. That is, it showed that the odds of someone voting for them are greater than the odds of someone voting for *comfort* by a factor of 7.54, 2.7, and 1.1, respectively.

3.4 Theme 4: What are the challenges to the popularisation of ABs?

The industry experts also referred to the potential challenges to the popularisation of ABs (Fig. 5). *Our culture* was found to be the biggest challenge, as our cultural mindset determines the acceptance – or not – of a new concept and therefore drives the market. Embedding net zero carbon in people's mindset may prove to be challenging, as the carbon fluency of the general population is not there yet. This means that people do not automatically do things that improve the carbon performance of buildings, but have to be nudged into doing the right thing. It is also difficult to convince people to care about the life-cycle carbon performance of buildings at the expense of capital cost. The *lack of evidence* was also considered as a main challenge. In particular, given that this is a new concept, a database of evidence has not been built yet. This is however essential for demonstrating the real-world benefits of the concept and ultimately for convincing the various stakeholders to adopt it. The *lack of combined authorities* was also found to be a challenge to the popularisation of the AB concept. It is thought that there is a lack of local connectivity, as well as a lag between planning policies and best practice – as the former often refer to a performance that barely passes the building regulations, and thus not force stakeholders to opt for greener solutions. *Expensive technologies* was only mentioned by two industry experts, but was the most popular answer for academics and researchers. This was followed by *our culture* and *skills shortage* – as there is still a shortage in terms of labour, but also of professionals with a knowledge and experience of how to deliver well-performing buildings. None of the academics or researchers voted for the *lack of evidence*.

The logistic regression model showed that options and groups interacted significantly only in the case of *expensive technologies* (p-value = 0.005). In other words, this option led to a different response pattern as it was considered as the most significant challenge by academics and researchers, but as the smallest challenge by industry experts. *Our culture* (p-value = 0.002), the *lack of evidence* (p-value = 0.007), and the *lack of combined authorities* (p-value = 0.04) were significantly different from *data control*, as the latter was not a popular response for either group. The calculation of the odds ratios confirmed that *our culture* is the most likely response, with the odds of someone voting for it being greater than the odds of someone voting for *data control* by a factor of 9. The latter is the least likely response, followed by *skills shortage*.

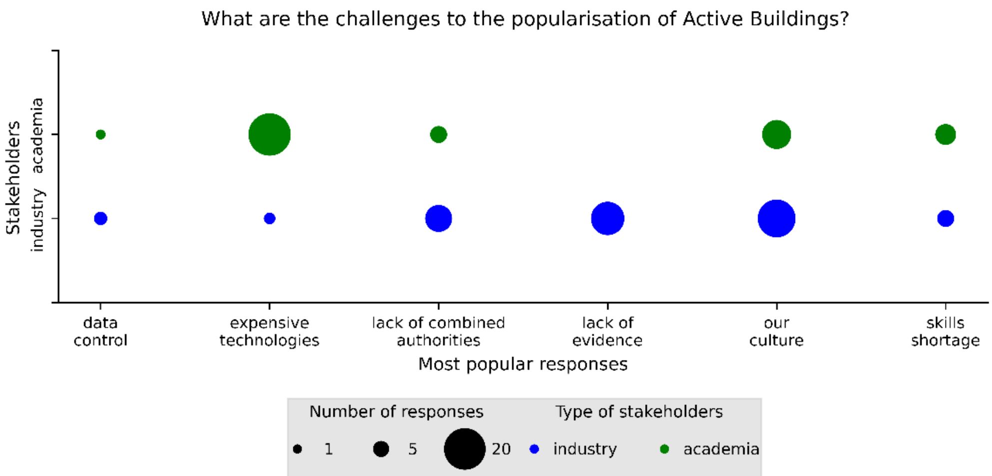

Fig. 5 – The potential challenges to the popularisation of Active Buildings, according to the 30 industry experts (blue) and the 30 academics and researchers (green).

4. Discussion

Section 4 discusses the stakeholder perceptions of the next generation of (active) buildings, as revealed from the focus group discussions with the industry experts, as well as from the survey of the academics and researchers.

4.1 Current situation

The discussions with the industry experts revealed the immediate need to re-evaluate how we design, construct, and operate buildings – if we are to reach net zero and tackle the climate emergency. Existing building regulations and standards will have to be revised accordingly as they were found to be missing aspects that are vital for achieving decarbonisation. The aspects that were mentioned by the majority of industry experts were *performance verification* and *incentives/commitment*. That is, there is a need for a compulsory scheme for post-occupancy evaluation to ensure that buildings are truly net zero carbon in their operation. There is also a need for incentives to motivate different stakeholders to invest in low carbon solutions.

The online survey of the academics and researchers highlighted another aspect that is currently missing from regulations and standards, namely, a *whole-life perspective*. That is, a more holistic way of thinking and acting is needed in terms of minimising the CO_2 emissions of (new and existing) buildings. This calls for a whole-life carbon assessment to be embedded in the decision-making process. As we are gradually moving towards a better operational performance of buildings, the consideration of and reporting on embodied carbon is becoming even more crucial.

The importance of these three aspects was verified by the statistical analysis of the responses of both groups (i.e., industry and academia). These aspects were followed (in order of importance) by *pairing buildings to the energy infrastructure* and *simplicity*. Hence, to achieve decarbonisation, it is important to encourage and legislate the synergetic relationship between buildings and the grid. To ensure the wide adoption of any standard even from the early design stages, it needs to rely on a simple, well-understood formula. Finally, the revision of existing standards or the development of new ones should account for *absolute performance targets* and *intelligence*. That is, assessing the performance of buildings in relation to notional buildings (as currently proposed by the regulations) was reported to often lead to inefficient building shapes. Absolute performance targets are hence needed to prevent designers from developing poor design solutions. Despite their important role in ensuring the optimal performance of buildings, smart building technologies were also found to be commonly neglected by regulations and standards.

4.2 Going active

Aiming to cast light on the characteristics of the next generation of (active) buildings, both groups were asked to interpret 'activeness', without having any prior knowledge of the term. All industry experts perceived activeness as 'responsiveness', with the great majority of them referring to a *responsiveness to the needs of the energy infrastructure*. That is, to minimise the detrimental effect of both the building and energy sectors on the environment, buildings will have to be reactive to the needs of the grid. This agrees with the ABCode which was built around two main principles: whole-life sustainability and energy network support. Most of academics and researchers interpreted activeness as *responsiveness to internal and external conditions*. This emphasises the need to design buildings that react to changes in real time (e.g., a temperature drop), but also in the long term (e.g., a new building use). Another interpretation of the activeness was the *responsiveness to the needs of occupants*. That is, the design of buildings should include a user-centred control system that ensures the health, wellbeing, and comfort of occupants.

Another topic that arose from the discussions with the industry experts was the use of a suitable metric for assessing the performance of (active) buildings. This topic yielded a consensus, as the majority of the participants in both groups advocated the adoption of *whole-life carbon*, followed by *energy demand*, and *energy flexibility*. This also aligns with the metrics suggested by the ABCode, namely: embodied carbon, energy consumption, renewable energy production, and energy flexibility. As with the embodied carbon, energy flexibility is becoming increasingly critical in achieving decarbonisation. In more detail, achieving a stable and decarbonised grid is calling for the use of storage technologies – and hence for a metric that incentivises their use. The inclusion of *comfort* and *peak demand* in the evaluation framework for ABs was also brought to discussion. The former echoes the importance of user experience, and the latter is a reflection of the direct impact of buildings on the energy infrastructure.

4.3 Challenges and opportunities

The discussions also revealed the challenges to the popularisation of ABs, with the majority of industry experts regarding *our culture* as the biggest barrier. That is, according to industry experts, stakeholders tend to be driven by the capital cost of buildings. It may hence be challenging to convince them to opt for a solution that is associated with a higher capital expenditure, even if the payback period is short. The *lack of evidence* was found to be the second biggest challenge. This is also related to the way of thinking and acting of stakeholders who, in the absence of sufficient evidence, may not be convinced that it is worth adopting a new concept. The *lack of combined authorities* was also found to be a barrier, showing the catalytic role of stakeholders – and in particular of local authorities – in the wide adoption of such a new concept. In more detail, industry experts stated that there is an absence of local connectivity which detrimentally affects decision-making, as it does not encourage stakeholders to commit to building to a better standard. Interestingly, the great majority of academics and researchers considered the *high cost of technologies* as the main challenge to the adoption of the AB concept. This was mentioned by only two industry experts, with both of them stating that this is expected to change over the next years, given the rising demand for such technologies. *Skills shortage* and *data control* are also potential challenges. The former refers to the lack of experience in delivering high-performance buildings and the associated skills gap. The latter indicates the existing reticence with sharing data, which may prevent data management from reaching its full potential.

In addition to drawing attention to the barriers the wide adoption of the AB concept may possibly face, the discussions with the industry experts indicated future opportunities. In other words, they revealed approaches and technologies that are expected to be gaining popularity on our way to decarbonisation – and that should thus be further expanded in future iterations of the ABCode. Focusing on social aspects, there is an increasing demand for healthy buildings, which was accelerated due to COVID-19. The ability of ABs to boost the *health, wellbeing, and comfort* of their occupants, should hence be further promoted. The applicability of the AB concept to a community of buildings should also be underlined as, in addition to any environmental and financial benefits, it offers a sense of *collectiveness* that adds value to the user experience. The growing interest in *circular economy* is another opportunity that should be henceforth harnessed by the ABCode, which already encourages users to consider the life-cycle environmental effect of buildings. Regarding any technical aspects, the ability of ABs to provide energy flexibility should be expanded by harnessing emerging technologies e.g., *smart technologies*, *storage systems*, *electric vehicles*, and *digital twin*.

5. Conclusions

As countries declare a climate emergency one after another, setting targets and timelines for net zero carbon is becoming crucial. The building sector is a major contributor to carbon dioxide emissions, and hence a vital player in addressing the climate crisis. Nevertheless, building regulations and standards are failing to promote holistic solutions, hence seriously lagging behind the trajectory needed to achieve net zero. Despite the direct link between buildings and the grid, regulations and standards lack a synergistic way of thinking and acting. This is certainly a missed opportunity for the decarbonisation of both sectors. In this context, we recently introduced the Active Building Code (ABCode) [10]. This is a new building standard that promotes the synergetic relationship between the electrical grid and the next generation of buildings termed Active Buildings (ABs), in order to help both the energy and building sectors reach net zero.

This paper presented the stakeholder perceptions of ABs, as arose from the focus group discussions with 30 industry experts and the survey of 30 academics and researchers. Existing regulations and standards were found to be missing valuable aspects, namely (in an order of importance, as defined by the two groups of stakeholders): *performance verification*, *incentives and commitment*, *whole-life perspective*, *pairing buildings to energy infrastructure*, *simplicity*, *absolute performance targets*, and *intelligence*. The need to pair buildings to the energy infrastructure was also revealed by the definition of an AB, as provided by the majority of industry experts. That is, an AB is a building that is *responsive to the needs of the energy infrastructure*, being in line with the definition included in the ABCode. Academics and researchers interpreted activeness as *responsiveness to internal and external conditions* or *responsiveness to the needs of occupants*, hence further highlighting the need for adaptive buildings. With respect to the metric(s) for assessing the performance of ABs, both groups of stakeholders stated that *whole-life carbon*, *energy demand*, and *energy flexibility* should be the way forward. This again aligns with the metrics that are proposed in the ABCode. The inclusion of *comfort* and of *peak demand* was also brought to discussion. Finally, the barriers that must be removed to drive the scale-up of ABs were also revealed: *our culture*, *lack of evidence*, *lack of combined authorities*, *high cost of technologies*, *skills shortage*, and *data control*.

To conclude, the (visual and statistical) analysis of responses revealed the aspects that are more likely to be voted for by any stakeholder – and that should be prioritised when designing the next generation of buildings. No significant statistical differences were in general observed between the responses from the two groups of stakeholders. In the future, additional responses should be collected to increase statistical power, and hence draw safer conclusions about the response patterns of different stakeholders. Future research should also build on the opportunities that arose from the focus group discussions. These may cover both social and technical aspects, in order to further improve the carbon performance of ABs and ensure these are delivering the best user experience. The stakeholder perceptions that were expressed in this study could be useful in writing regulations and standards that not only drive down carbon, but are also widely comprehended and accepted.

Acknowledgement

This study was conducted in the context of the Active Building Centre Research Programme (EP/V012053 /1). The programme brings together several leading universities, businesses, as well as service providers to develop innovative ideas and technologies which will enable the construction industry to transform into a net zero emissions sector. It is funded through the UKRI Transforming Construction Challenge.

We would like to warmly thank each industry expert who participated in the focus group discussions, and each academic or researcher who participated in the survey for their valuable input. We would also like to thank Dr Emma Cliffe for her valuable advice on the statistical analysis of the collected data.

References

1. Hoegh-Guldberg O, Jacob D, Taylor M, Bindi M, Brown S, Camilloni I, et al. Impacts of 1.5°C of global warming on natural and human systems. World Meteorological Organization. 2018.

2. National Grid. What is net zero? [Internet]. 2021 [cited 2022 Jan 13]. Available from: https://www.nationalgrid.com/stories/energy-explained/what-is-net-zero

3. UK Government. The Climate Change Act 2008 (2050 Target Amendment) Order 2019. 2019.

4. European Commission. Clean energy for all Europeans. 2019.

5. LETI. Climate Emergency Design Guide. 2020.

6. Nikolaidou E, Fosas D, Roberts M, Allen S, Walker I, Coley D. Buildings as energy infrastructure, not passive consumers. Active Building Centre Research Programme (University of Bath). 2020.

7. National Grid. Flexibility [Internet]. 2021 [cited 2022 Jan 13]. Available from: https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2021/system-flexibility

8. Active Building Centre Research Programme. The Active Building concept [Internet]. 2022. [cited 2022 Jan 10]. Available from: https://abc-rp.com/about-us/

9. Bankovskis A. One million homes constructed as"buildings as power stations". SPECIFIC Innovation and Knowledge Centre; 2017.

10. Fosas D, Nikolaidou E, Roberts M, Allen S, Walker I, Coley D. Towards active buildings: Rating grid-servicing buildings. Build Serv Eng Res Technol. 2021;42(2):129–55.

11. Kontio J, Bragge J, Lehtola L. The focus group method as an empirical tool in software engineering. In: Guide to advanced empirical software engineering. London: Springer; 2008. p. 93–116.

12. Kamberelis G, Dimitriadis G. Focus groups: Contingent articulations of pedagogy, politics, and inquiry. In: Collecting and interpreting qualitative materials. Los Angeles: SAGE Publications; 2008.

13. Stewart DW, Shamdasani P. Online focus groups. J Advert. 2017;46(1):48–60.

14. Patton MQ. Qualitative research. In: Encyclopedia of Statistics in Behavioral Science. Chippenham: John Wiley and Sons; 2005.

15. Glaser BG, Strauss AL. The discovery of grounded theory: Strategies for qualitative research. New Brunswick: Aldine Transaction; 1967.

16. Finch H, Lewis J, Turley C. Focus groups. In: Ritchie J, Lewis J, McNaughton Nicholls C, Ormston R, editors. Qualitative research practice: A guide for social science students and researchers. London: SAGE Publications; 2013.

17. Nikolaidou E, Walker I, Coley D, Allen S, Fosas D. Dataset for "Going active: How do people envision the next generation of buildings?". University of Bath Research Data Archive; 2022. Available from: https://doi.org/10.15125/BATH-01125

Data access statement

The data that was collected and analysed during this study is available at the University of Bath Research Data Archive [17].