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Developing Tools to Enable the UK Construction Industry to Adopt the Active Building Concept for Net Zero Carbon Buildings

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Abstract: The research project discussed in this paper is driven by the United Kingdom's (UK's) need to reduce operational energy and carbon by promoting the adoption of the Active Building (AB) concept for UK building projects. The AB concept offers a practical solution to reducing the operational energy use and carbon emissions of buildings by using emerging technologies applied to architectural design; thus, helping the UK meet its decarbonisation targets and, consequently, helping to combat the global problem of climate change. The aim of the project was to design and implement an AB Protocol with an AB Toolkit, to provide a knowledge base and sustainable architectural design guidance to aid the design of ABs. The AB Toolkit was tested, evaluated, and refined by engaging with architectural designers in the UK through focus groups (FGs) that combined data collection with knowledge dissemination—a method which provided a contribution to the continuous professional development (CPD) of architectural designers in the UK, while aiding the research project. The FG data proved the original hypothesis that a whole host of measures are needed to support the adoption of the AB concept (as outlined in the AB Protocol), but that some design guidance was needed initially to enable the development of other supporting measures. Therefore, the main output of this research project was the development of a structured approach to enable architectural designers and other built-environment professionals to adopt the AB concept for the delivery of net zero operational energy buildings, supporting the aims of the SPECIFIC Innovation and Knowledge Centre, Swansea University, and the Active Building Centre (ABC). The method of data collection developed, and the structured approach to enabling the adoption of a new concept outlined, could be beneficial to other researchers.

Keywords: Active Buildings; net zero operational carbon; net zero operational energy use; building design; sustainable architectural design; flexible energy systems; decarbonisation integrated renewables; energy storage

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1. Introduction

Globally, buildings are responsible for approximately 40% of energy consumption and 28% of carbon emissions [1], and hence, they are large contributors to global warming. Following the 27th Conference of Parties (COP27) held in November 2022 [2], the UK Climate Change Committee reported that the UK must implement its Net Zero Strategy and strengthen its response to climate adaptation [3]. To meet climate change mitigation goals, viable solutions to reduce energy consumption and greenhouse gas (GHG) emissions in the built-environment sector are desperately needed. The Active Building (AB) concept provides one such solution.

ABs are "buildings that support the wider grid network by intelligently integrating renewable energy technologies for heat, power and transport" [4]—their aim is to achieve this by combining renewable energy generation with energy storage and smart controls. There are six principles (Table 1) to the AB concept, aimed at reducing operational energy consumption, generating renewable energy, and controlling the import and export of energy to or from the UK National Grid, to balance overall energy supply and demand. The project detailed in this paper formed part of a Professional Doctorate in the Sustainable Built Environment (DSBE) which was focused on the Active Building concept and was completed in January 2022 by the first author [5].

Table 1. The Active Building (AB) Principles [5].

	Principle		Description
REDUCE	1.	**Building fabric and passive design**	Buildings are designed in harmony with their site location and site conditions. They have high levels of fabric efficiency, with well-insulated and airtight construction to ensure warmth is retained within the building in winter months and the risk of overheating in summer months is reduced, creating a comfortable and stable indoor environment for occupants all year round. Very little energy is needed for heating or cooling, and energy bills are low.
	2.	**Energy efficient systems and data monitoring**	Energy-efficient systems with smart control strategies are employed to further minimise energy used for heating, ventilation, cooling, and lighting. Data capture via inbuilt monitoring enables optimisation and refinement of control strategies.
OPTIMISE	3.	**On-site renewable energy generation**	Renewable energy generation is incorporated to supply buildings with low-carbon energy. This could include solar photovoltaics, solar thermal, wind, water, air source, or ground source.
	4.	**Energy storage**	Both thermal and electrical storage are included to maximise the use of renewable energy, mitigate peak demand, reduce the requirement to oversize systems, and enable greater control of energy consumption.
CONTROL	5.	**Electric vehicle integration**	Where appropriate Active Buildings integrate smart electric vehicle charge points. This enables energy to be shared with vehicles in a controlled way.
	6.	**Intelligently manage interaction with grid**	In addition to controlling energy use within a building, control strategies and energy storage enable Active Buildings to manage their interaction with wider energy networks, controlling when energy is imported from and exported to the grid—this helps stabilise and reduce pressure on the grid from otherwise uncontrolled import and export, which is critical in a decarbonised society.

While reducing the operational energy consumption and associated carbon emissions from buildings, ABs also contribute to a flexible energy system that is necessary as transport and heating are decarbonised in the UK [6,7]. As the UK progresses towards a decarbonised society, the need for energy flexibility between buildings and energy networks is critical [8].

In addition to assisting the UK's decarbonisation goals, the AB concept provides an approach to building projects that, if followed, could help building designers achieve some of the United Nations (UN) Sustainable Development Goals (SDGs) [9]. UN SDGs addressed by ABs are outlined by O'Sullivan et al. [10] as Goal Seven: Affordable and Clean Energy; Goal Nine: Industry, Innovation, and Infrastructure; Goal 11: Sustainable Cities and Communities; and Goal 12: Responsible Consumption and Production [9]. Through ABs reduced energy consumption, optimal use of renewable energy generation, and lower operational carbon emissions, the authors suggest Goal 13: Climate Action is also addressed. With the latest SDG Report stating that energy-related CO_2 emissions increased by 6% in 2021, reaching their highest level ever; and warning that progress in energy efficiency needs to be faster to achieve global climate goals [11]; the need for solutions to tackle the SDGs is ever more urgent.

This research project focused on developing methods to enable the AB concept to be adopted by UK architectural designers, through disseminating knowledge developed from SPECIFIC's AB demonstrator buildings and through providing building design guidance. Prior to commencing this project, an AB Protocol was developed (Figure 1 below) which identified a series of measures SPECIFIC could take to enable the UK construction industry to adopt the AB concept. These were informed by literature reviews and a pilot study undertaken as part of the project, and by the first author's experience as an architect in practice and whilst working at SPECIFIC.

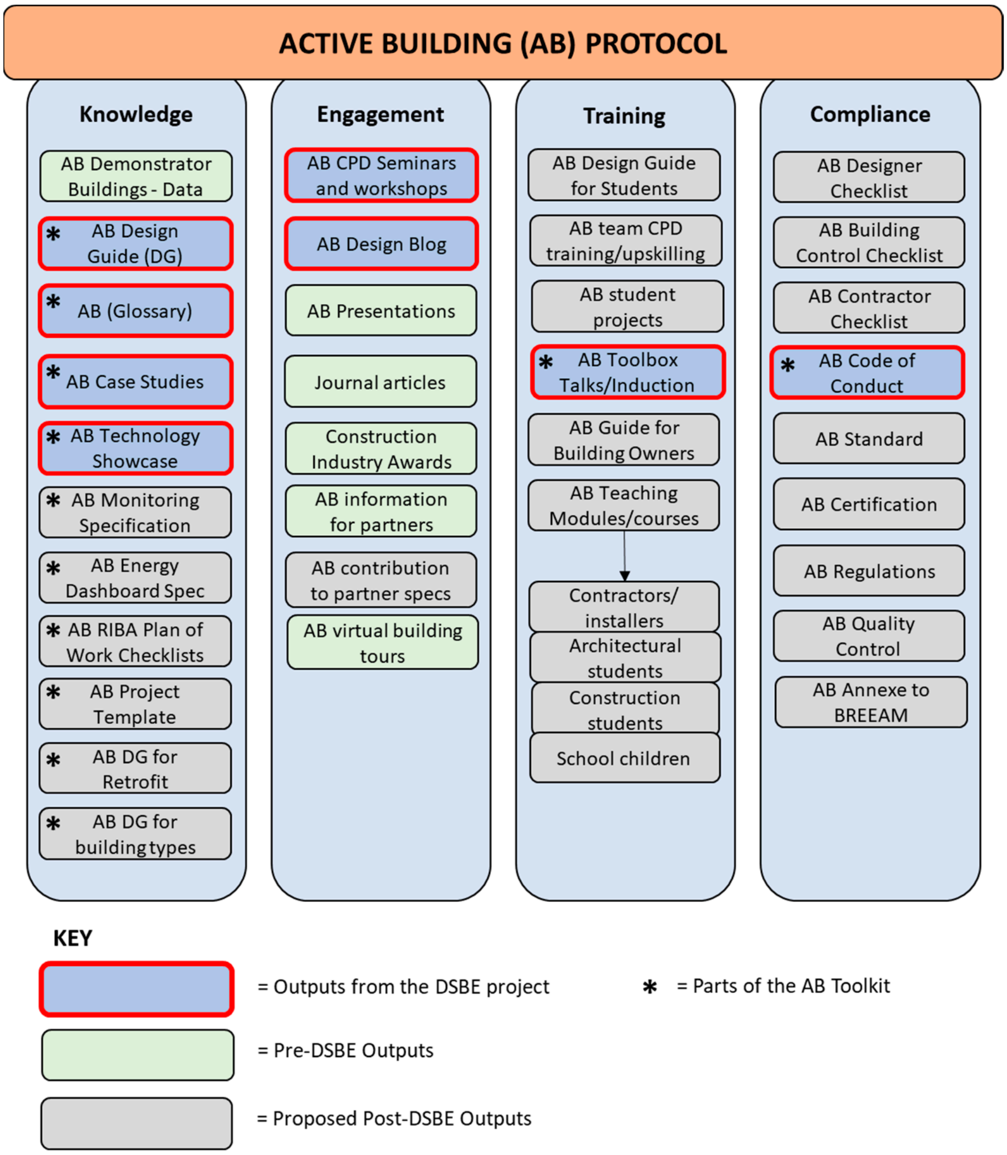

Figure 1. The AB Protocol developed by the author prior to commencing this research project [5].

The focus of this research project was to develop a knowledge base and design guidance (AB Toolkit), which will aid the design of AB projects and will contribute to the progression of other measures identified in the Protocol. For example, providing AB design guidance will enable further AB case studies to be designed and developed, thus providing further evidence and learnings to support the development of AB training courses, standards, and business models; and to inform potential legislative changes.

Between 2014 and 2018, the first author designed, and project managed the construction of several AB demonstrator buildings, with the aim to test the integration of novel low-carbon technologies into buildings, rather than in isolation, thus accelerating the research into such technologies [12,13]. The building demonstrators provide valuable data on the performance of emerging technologies, and learnings that could be shared with technology developers and with construction industry stakeholders [14].

In 2019 the Active Building Centre (ABC), Swansea University, was established through the Transforming Construction Challenge (TCC), within the UK Government's Industrial Strategy [15]. The ABC was formed to continue SPECIFIC's work by investigating tools to enable the AB concept to be rolled out across the UK [16]. Whilst SPECIFIC is focused on fundamental research and development (R&D) and one-off building demonstrators, the ABC intends to apply the AB concept to multiple commercial projects [17]. As described in the AB Protocol (Figure 1), several AB tools were identified to enable both SPECIFIC and the ABC to work with collaborative partners to use the AB concept on building projects across the UK. Thus, this research project was focused on influencing both organisations. Several research questions were considered to steer this research project, as indicated below:

(a) What is the most effective way to enable the adoption of the AB concept in UK construction projects?
(b) Who are the Key Influencers to construction projects?
(c) Is the information on the design and operation of ABs needed to develop other enablers to the adoption of the AB concept? If so, what format should this take, and what information should it include?

The first research question was answered in an earlier project [5] and resulted in the development of the AB Protocol, shown in Figure 1 above.

Key influencers to construction projects include clients, who hold the brief, budget, and set timescales; architects, who often act as lead consultants within design and delivery teams; building contractors; and government policymakers and regulatory bodies, who set performance standards for buildings.

Without knowledge and evidence that the AB concept is effective in reducing operational energy consumption and carbon emissions from buildings, it is difficult for clients to support the use of the AB concept. Government funding initiatives can enable clients to risk the use of a new concept. For example, the Welsh Government's Innovative Housing Programme (IHP) was used to enable a housing association to trial the use of the AB concept in the development of 16 Active Homes in Wales [18]. These incorporated building-integrated photovoltaics, battery storage, and transpired solar collectors, and they were fully electric in operation, as detailed in the Building for 2050 report commissioned by the UK government [19]. Without additional financial support, however, clients are often unable to risk using a new concept, or new and emerging technologies, on their building projects. Similarly, building contractors, commonly employed in the UK to deliver safe and secure buildings that meet required design criteria, performance standards, and regulations, cannot risk employing innovative concepts or technologies on buildings, unless directed by clients to do so. Policymakers and regulatory bodies within governments cannot mandate the use of a particular concept or set performance targets without significant evidence that targets are achievable within reasonable boundaries. They must also ensure there is a robust supply chain to deliver the standards they set, so any new requirements must be accompanied by training programmes and a level of surety that the requirements are viable.

Based on these factors, this research project was focused on developing a knowledge base, including design guidance, that architects could use to influence the design of buildings to gain further evidence of the effectiveness of the AB concept. Architectural designers were selected as the main participants in the study due to their position of influence in a design team. They are usually the first consultants to be appointed by a client when embarking on a building project [20], and normally take the role of lead designer [21]. This established a manageable task for this research project, whilst acknowledging that the knowledge base developed (the AB Toolkit) is just one of a series of enablers to the use of the AB concept on construction projects.

The third question is answered through this research project. From previous research and the first author's experience of the organisations' SPECIFIC and the ABC, a gap in knowledge was identified in that no design guidance or body of knowledge, such as AB case studies, existed prior to this research project. This knowledge base was needed before the other enablers identified could be developed. For example, business models, training material, and an AB standard or certification scheme, will draw on evidence provided by AB case studies. While the AB Toolkit developed within this project includes two AB case studies, further case studies are needed of different building types to generate evidence. To develop these, a clear set of design guidelines is needed, as outlined in the ABDG (part of the AB Toolkit). Architectural designers routinely refer to design guidance documents, such as Building Regulation Approved Documents [22], when designing building projects and research precedents (or case studies) to inform their designs. Thus, these designers are familiar with these document types.

2. Literature Review of UK Approaches to Net Zero Carbon Buildings

The so-called "climate emergency" [23] identified by many countries, cities, and societies, has been highlighted to the global population and (relevant to this research project) the UK Government and construction industry via many events and initiatives between 2018 and 2020. In addition, other literature of relevance includes the "Climate Emergency Guide" [24] and the "RIBA 2030 Climate Challenge" [25] that propose clear energy performance targets for buildings, which should be followed if the UK is to achieve net-zero carbon by 2050 [26].

Extensive recent literature was found on the benefits of an approach where buildings have a flexible relationship with the energy grids in a low-carbon society. For example, reporting on how the UK could achieve its 2030 targets for renewable energy, Wartsila [27] stated that a combination of renewable energy and flexible technologies, including energy storage, will drive the most value to society in terms of both cost savings and carbon emission reductions. The key factor is the need for power system flexibility [8], which aligns with the AB concept, the capability of a building to present a flexible relationship with the energy grid, balancing supply, and demand, and has a greater benefit to the UK's energy systems, than being "energy positive", which was SPECIFIC's stance prior to analysing their building demonstrators. Furthermore, Wartsila [27] found that higher levels of renewable energy can be utilised by employing flexible energy distribution systems. Through deploying intelligent control systems and energy storage, buildings can help to balance the energy system, which is critical if the UK is to meet its decarbonisation targets for transport [28] and heating of buildings [29].

Other literature of note to support the promotion of the AB concept is research associated with the UK Government's TCC [15] as developed by the ABC [10,30–32], which investigates the notion of buildings incorporating flexible energy demand strategies, to support demand-side energy policies as a contribution to climate change mitigation in the UK [33].

There is an increasing number of research publications focused on the relationship between energy-efficient buildings and energy grids in the context of achieving a net zero-carbon built environment, which align with the AB concept and the role of ABs in a zero-carbon built environment; hence, the need for enablers to the adoption of the AB concept.

The original notion when developing the AB concept was that net zero energy buildings should be "energy-positive", generating as much energy as they consume over an annual period. However, data from the AB demonstrators led to the evolution of this concept, to the notion of energy-flexible buildings; in other words, evidence from the AB demonstrators suggested that the ability of a building to help stabilise the energy grids is more valuable to a decarbonised built environment [34–38]. The use of demand-response and energy flexibility between a building and the energy grid could provide a new approach to developing net zero energy buildings [35]. Furthermore, building energy systems that can control demand could offer a solution to deal with the increased amount of renewable energy generation in an already constrained energy grid [38]. Razmara et al. [37] propose that energy storage and predictive control, used in conjunction with renewable energy sources, can provide energy demand-response and flexibility, to reduce the peak demand of energy grids.

Researchers employed by the ABC have authored a series of white papers outlining the increasingly critical role ABs have to play in enabling flexible energy systems for a net zero carbon future [8,30–32]. These papers discuss the global and UK context in relation to the policy landscape, climate change commitments, and the need to support the energy networks that were designed to distribute centralised energy sources and must now adapt to respond to distributed energy sources provided by renewables. Strbac et al. [32] describe energy system flexibility as being the ability to adjust generation or consumption according to network constraints and highlight the role of smart electric vehicle (EV) charging in increasing the ability to integrate more renewable energy sources into buildings, whilst reducing reliance on high-cost, low-carbon grid-scale generation, such as nuclear energy.

The energy flexibility of ABs is discussed by O-Sullivan et al. [10] in the context of changing consumer energy demand profiles, through "demand shifting", via smart meters. While this is challenging from a societal perspective, due to fears over data security and privacy, to fulfill their critical role in achieving a decarbonised society, buildings must become active parts of the energy infrastructure through a more dynamic relationship with the energy grid [31]. As a continuation of SPECIFIC's research work, the ABC are also considering solutions to enable the adoption of the AB concept in building projects, which are not demonstrators. As suggested in the AB Protocol (Figure 1) an energy rating system is proposed to help enable the use of the AB concept in building projects, setting clear energy performance targets that should be achieved to gain AB status. Researchers at the ABC are investigating this and have developed ABCode1 [39], the first rating system for ABs, which is yet to be trialed on a live AB project. More evidence is needed to support the development of an AB rating system or standard; hence, the need for the AB Toolkit, which includes evidence from AB case studies and design guidance to aid the design of further case studies (thus providing further evidence).

3. Methods

Prior to testing the ABDG on a live building project, it was decided to test a first draft of the guide using a qualitative mixed-mode methodology [40], consisting of focus groups (FGs) combined with questionnaires, which provided access to a relatively large sample group within the timescales (five months), by capturing feedback from several participants at once.

FGs would enable the collection of data from multiple participants at the same time, while also providing an opportunity to share knowledge on the AB concept with built-environment professionals. As FGs are well established as a method to collect feedback on new products or concepts [41,42], they are entirely applicable to this project. A pilot study was conducted prior to this research project to trial this method of testing and developing design guidance, where four FGs were held with architectural designers [5]. The FGs undertaken during the pilot study provided the authors with confidence that this method was appropriate for both collecting data on the developing design guidance and for providing knowledge to architectural designers [5].

The FGs took place primarily with architectural designers, mainly because architects are key influencers to construction projects in the UK, often acting as lead consultants on projects and the first consultant to be appointed by the client [20]. All architectural designers were considered experts for the purpose of this research, as they each have experience in consulting guidance documents when progressing with building projects—a shared phenomenon. They are aware of the information they need and their preference for how that information is presented, have shared common values, and hence, a sense of solidarity, after Merton [43].

From an epistemological viewpoint, it was anticipated that the personal and professional experiences of participants in the study would inform their opinions and, hence, the data, describing phenomenological [40,44] and interpretivism epistemologies [45], that is, an understanding of the reasons driving their decisions and how participants will perceive the challenges they face and potential solutions to address such challenges.

FGs are interactive discussions organised to explore a specific set of issues, with the "focus" being an activity (such as reviewing a DG) or debating a set of questions [41]. As such, FGs are often used within "communication research" such as evaluating educational material, and the interaction between participants and researcher is integral to their success [41]. By their nature, FGs generate data from collective views, as well as generating an understanding of participants' experiences and beliefs [42]. In this study, the FGs were designed to combine learning with data collection, informing participants about ABs and their potential role in helping the UK Government meet climate-change targets [46] and asking participants to review the developing ABDG, providing feedback via a questionnaire as well as an FG discussion. The views of architectural designers would depend on their own experience of using design guidance for building projects, their preferred format for receiving design guidance, and the type of information they require to aid the design of ABs.

The mixed-mode qualitative methods used in this project to identify challenges designers face (in terms of low-energy building design) and to develop potential solutions to reduce such challenges (the ABDG, or AB Toolkit) describe an abductive approach [40]. The incorporation of questionnaires within the FGs provided multiple ways participants could engage with the researcher through both a semi-structured and structured approach [47]. This allowed the semi-structured FG discussions to explore wider issues around the ABDG and challenges faced by designers, while the structured questionnaires enabled the collection of targeted data about the design and content of the ABDG.

The semi-structured format used for the FGs included a 30-min presentation on ABs and the research project, after which participants were asked to review the ABDG, before partaking in a discussion session, after Lucas [48]. Participants were given one hour to review the ABDG, using a questionnaire to guide their feedback. The questionnaire was structured under five sections: Structure, Aesthetics, AB Explanation, Technical Content, and General [5]. These sections were selected based on the first author's own design guide analysis which she undertook prior to commencing this research project. The sections represented the considerations that were determined as the most important factors in ensuring design guidance is easily followed. Within each section, there were two to six quantitative questions, that used the Likert scale to gain responses [49]; and one to six qualitative questions, where participants could provide additional feedback. In total there were 30 questions: 17 Likert scale questions and 13 qualitative questions.

Following the review period, a discussion was then facilitated to gain further views on the ABDG and its role in aiding the design of ABs. The unstructured discussions often reverted to challenges facing designers in using a new concept and the objectivity of their work, which provided context to the study. The need to balance providing sufficient knowledge (value) with collecting sufficient data, within a reasonable session duration, was an important consideration. The FGs included workshops with participants that were members of the Royal Society of Architects in Wales (RSAW), which typically took place over a three-hour period (morning or afternoon); whereas individual architectural practices preferred sessions of 1–1.5 h in duration.

For this study, the decision to use mainly qualitative methods relates to the nature of the information sought from participants, that is, to gain their views on the design and content of the developing ABDG. An element of quantitative data was collected with questions that used the Likert-Scale [49], and this was supported by related qualitative data collected from discussions and written responses [47].

The abductive approach taken in this study describes "open problem solving" where the desired outcome at the start of the study was to develop tools to enable the adoption of the AB concept in construction projects, and the final project outputs—the AB Toolkit and AB Roadmap—were developed during the study, after Steen [50]. While developing and testing the ABDG as a solution to enable the use of the AB concept, further challenges were identified [50]. The challenge of enabling the adoption of the AB concept could not be solved by selecting one best solution (such as the AB Toolkit), but rather identified the need for a range of solutions (the AB Roadmap).

Meanwhile, the interpretivist approach also used [45] sought to understand and explain the phenomenon under investigation, which was the architectural design of net zero energy, net zero carbon ABs, and included understanding the challenges facing designers and the most appropriate way of presenting information to address such challenges [51]. As well as selecting participants who are involved and interested in the topic, another important factor considered in the FG design was ensuring that relevant data could be collected within the timescales (1.5–3 h) of the FG, after Acocella [52]. This was challenging, as the participants needed enough time to digest the information on ABs, review the ABDG, and complete their questionnaires, before returning to the discussion session. To combat the time restrictions, the ABDG was split into sections, and participants were asked to review one or two sections, depending on available time. It was anticipated this would produce the required feedback, as each section used similar graphical styles and had similar levels of content. The time restrictions of the FGs, as desired by the organising party or practice taking part, were balanced with collecting sufficient data. Table 2 below summarises the key factors influencing FG design determined during this project.

Table 2. Summary of Key Factors influencing FG design, as determined by the first author during this study [5].

Sampling Strategy (refer Section 3.1 below)		
1. Use of Published table 2. Information Power 3. Data Saturation		
Format		
Time of Day	Morning, Lunchtime, Afternoon, Evening	
Duration	1.5 h, 3 h	
Venue	Architects Office, SPECIFIC's Active Classroom, Royal Society of Architects in Wales (RSAW) venue	
Desired Outcomes		
• Share knowledge on ABs, provide learning • Gain feedback on developing ABDG		
Participant Group		
• Architectural designers		
Knowledge/Learning (motivation to attend)	**Data Collection Method**	
	Qualitative	**Quantitative**
• Gain Continuous Professional Development (CPD) points • Learn about AB concept • Learn about innovative technologies • Review current legislative targets	Questionnaire FG discussions Observation	Questionnaire
Challenges		
• Attract sufficient participants—link to a learning event (after Fylan et al. 2016) • Balance knowledge sharing with data collection • Budgetary—travel expenses and time commitment of participants		

The FGs used in this research project could be considered as collaborative design or co-design workshops, as architectural designers were asked to contribute to the design of the developing ABDG [50]. Participants (the final design guidance users) were involved in the design of the ABDG, drawing on their collective creativity through a process of joint inquiry [50]. The participants shared their knowledge and experience of designing buildings and using DG documents to inform the design and content of the developing ABDG. This approach involved developing shared understanding and was used to improve decision-making about the design of the ABDG, information to include in the knowledge base (AB Toolkit), and the identification of future work for SPECIFIC and the ABC. This approach of using co-design principles to engage the end users (building designers) in the development of the document(s) they will be expected to use, is likely to be more successful than taking a top-down approach, where end users are presented with a finished document [50]. Engaging end users in shaping the documents they will be using enables the developer of the documents to learn from and with the end users, leading to improved understanding and insights [53].

In FGs larger than 12 participants, it is recommended to divide the group [54]. In this study, participants were asked to review the ABDG in groups of two to three, or individually. The group was then reconvened for the discussion when participants were invited to provide their feedback to the first author and other participants. At this stage, participants spoke freely about their opinions on the ABDG, often discussing challenges to the adoption of the AB concept. Most participants were observed to engage in discussions, and the level of engagement was not dependent on the first author's involvement as the facilitator, which suggested a high level of interest in the research topic. Interest was observed in three distinct areas: the design of the ABDG; the content of the ABDG; and the challenges in introducing the AB concept into construction projects.

Two main aims of FGs are to facilitate interaction among participants and to maximise the collection of high-quality data in a short time of 1–3 h [52], thus venue choice is important. In this study, FGs took place either in the offices of the architectural practice taking part or at a venue selected by the RSAW. Either setting was informal and provided a comfortable environment to maximise interactions. All FGs were accompanied by refreshments, which contributed to creating a relaxed atmosphere. Participants were selected for FGs from the same profession—architectural design—describing a homogeneous group [52]. Some inhibitions were observed by RIBA Part II architectural assistants with less than two years of experience; while senior architects and directors with more than 10 years of experience, tended to dominate discussions. Acocella [52] recommends avoiding including participants with hierarchical positions, and the tendency for dominant participants is also discussed by Smithson [54] as a limitation of FGs. However, the FGs in this study were designed as learning events, as well as for data collection, so the authors did not want to prevent interested participants from attending the sessions. Any potential imbalance was addressed through the use of questionnaires, where participants, answered questions that would be anonymised and not feel inhibited.

Having a specific topic that is interesting and familiar to participants increases the likelihood of interaction and gaining the data needed by the researcher to fully analyse their topic [52]. As the topic of this study was to determine the participant's views on the development of an ABDG related to low-energy building design, the participants had a vested interest in contributing to the document's development. All architectural designers must familiarise themselves with ways to achieve energy and carbon reduction targets set out in the RIBA 2030 Climate Challenge [25]. Therefore, contributing to the design of the ABDG, which describes methods to reduce operational energy and carbon from buildings, is highly relevant to them.

To summarise, the FGs were designed as a CPD activity, which architectural designers are familiar with attending, creating a natural environment for the participants. The first author is an architect herself, so she understood the challenges facing the research participants, providing her with an empathic view [55]. Furthermore, although the aim of this project was to gain feedback on the developing ABDG, it also included discussions on the challenges and enablers to the adoption of the AB concept. The data collected allowed the enablers identified in the AB Protocol to be expanded to create an AB Roadmap for

SPECIFIC and the ABC. The ABDG (part of the AB Protocol) was tested within this project and evolved into an AB Toolkit as a final project output.

3.1. Sampling Strategy

For this research project, the selected "experts" to review the developing ABDG were restricted to architectural designers in Wales, UK. Whilst other building design professionals might also use the guidance, it was decided to focus on architectural designers, due to the fact that architectural designers are predominantly the lead designers for the majority of building projects within the UK [20]. It would be unrealistic to target all architectural designers in the UK and, as such, a robust sampling strategy was used to select a suitable number of experts from within Wales, UK.

Adopting a sampling approach to research implies belief in the ability to generalise the consensus of a wide population from a pre-determined sample of that population [40]. The qualitative research methods used in this study, and the way they were used, had a direct correlation with the sampling strategy adopted, as detailed below.

Non-probabilistic strategies of purposive, targeted, snowball, convenience, and voluntary responses were used, which are deemed more appropriate for qualitative research studies than random sampling [55]. In purposive sampling, the researcher can choose either a homogeneous group of people, with similar backgrounds, experiences, and insight into the research study topic; or a heterogeneous group, depending on the aim of the study. As the aim of this study was to determine views on the design and content of an ABDG for use by architectural designers, selecting a homogeneous sample of architectural designers offered the best way to meet the aim.

Although it is recommended to avoid convenience sampling [47], the design of the FGs in this research study meant that some convenience sampling was used, as the decision was made not to control who attended the FGs, particularly those organised through other parties (such as the RSAW). This was not considered a significant issue for this study. The purpose of the FGs was explicit, so the summary of their content was straightforward and presented to potential participants via a promotional flyer. All FGs included voluntary-response sampling, whereas the FGs were promoted to targeted groups, attendance at the groups depended on participants registering for them and contributing to the discussions therein.

As a rule-of-thumb, FG projects typically use homogeneous groups of participants, rely on a semi-structured process, have 6–10 participants, and use 3—5 groups per project [54,56]. When using a representative sample of a particular population, rather than seeking to explore diversity (or cross-case analysis), other literature also suggests that 2–5 groups may be sufficient [41,57,58]. These rules-of-thumb are useful considerations at the research design stage. The suggested rule of 3–5 groups is based on a claim that more groups seldom provide meaningful new insights [57], which aligns with the experience and review of the data saturation point within this research project. A target number of groups was determined when planning the study but a flexible approach to increase or decrease the sample size was taken, as the data was collected and analysed [57,58].

Some researchers recommend strangers are used in groups [56,57], whereas others have observed advantages in pre-existing groups where participants relate easily to each other's comments [41]. In this study, it was found that anyone involved in designing and delivering building projects could relate to each other, all having the same end goal and experiencing similar challenges and constraints. This was true whether participants were known to each other before the sessions or if they were strangers, so there was no evidence that the use of either group characteristic affected the data collected.

Whereas sample sizes for quantitative research can be determined using the power calculation [59], there is no similar calculation for qualitative research studies, so qualitative researchers must use other robust methods [58]. Three main methods for determining sample size were used in this study, as described in the following text:

i. Initially, the use of a table of recommended sample sizes [60];

ii. Use of the "Information Power" method [58];
iii. During data analysis, examination of the Data Saturation Point [61].

i Use of published table (Israel, 2009).

Adopting a published table for determining sample size [60], an approximate target sample size was established during the research planning stage. The sample for the study was restricted to architectural designers in Wales, due to time and financial constraints of reaching the wider UK population of architectural designers. When commencing the study, in 2019, there were 762 ARB (Architects Registration Board) registered architects in Wales [62] and 365 architectural technologists registered with the Chartered Institute of Architectural Technologists (CIAT) (source: email from CIAT Membership Director, 2nd March 2020)—1127 architectural designers in total. In determining an appropriate sample size, the percentage of the total population of architectural designers in Wales that would provide a reasonable representation of the overall population was considered. According to Israel [60], the less variable (or more homogeneous) a population, the smaller the sample size needed. Furthermore, fewer participants are needed for a research study if the nature of the topic is clear, and the quality of data is good [63]. The subject of this study is clear, that is, the developing ABDG; and from the authors' combined experience, the participants (architectural designers) are skilled communicators, so able to provide good quality data for analysis. It was also anticipated that the multi-method approach to data collection, of qualitative FG data and qualitative and quantitative questionnaire data, would contribute to the collection of good quality data overall. It was therefore expected that fewer participants than needed for a less focused study with a more varied population [63], would be needed before saturation is reached.

It is good research practice to include 10% more participants than the minimum recommended, to account for non-responses [60] or, in the case of this study, potential cancellation of or non-attendance at FGs. For the population of 1127 architectural designers in Wales, using guidance from the published table [60], it was anticipated 95 participants would provide a suitable sample size to give a precision level of +/−10% and a confidence level of 95%. Thus, it was decided to target 105 participants, an extra 10% to the 95 participants identified above.

ii Information Power.

Malterud et al. [58] discuss sample size as being dependent on five factors: the aim of the study; sample specificity (homogeneity); use of established theory/methods; quality of dialogue; and analysis strategy. Indeed, Malterud et al. [58] call this "information power" (illustrated in Figure 2 below) and theorise that the more information the sample holds, the fewer the number of participants needed.

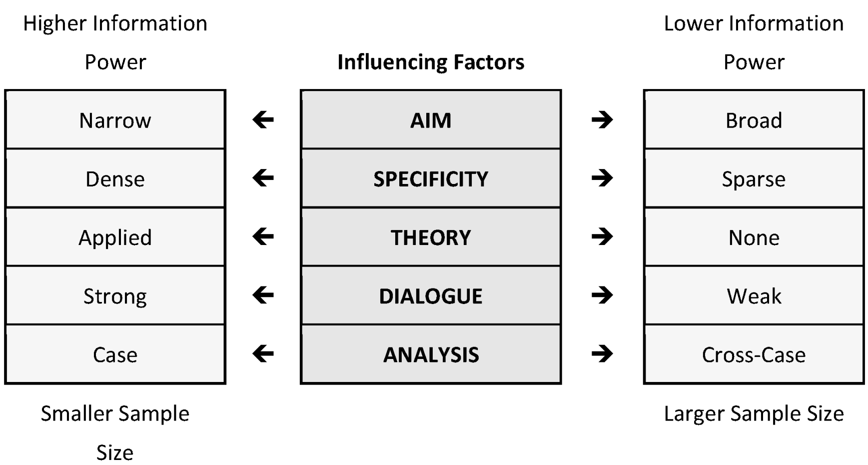

Figure 2. Information power adapted from Malterud et al. [58].

Each factor identified in the "information power" method was examined, to determine applicability to this project. In summary, this study was considered to have high "information power" for each factor, suggesting a smaller sample size would be needed, and the study aim was narrow, participants were highly specific to the study aim, the study was theoretically informed, the interview dialogue was anticipated to be strong, and the analysis included in-depth exploration of narratives, rather than cross-examination of results. Therefore, fewer participants should have been needed. This was further tested by examining data saturation as described below.

iii Data Saturation.

The goal of determining a sample size for a qualitative research study is to ensure it will yield data rich enough to understand the phenomenon under investigation. Sample size will vary depending on the nature of the study [63] and, for a purposive study, the sample size should be guided by the principle of saturation [64]. Saturation is reached when there is no or little new learning or insights from additional participants' feedback or from observation, issues begin to be repeated, and further data collection becomes redundant [47,61,65]. Theoretical saturation is applied to data collection in an iterative process of sampling, collecting, and analysing data, until all aspects of the phenomenon under study are explored and exhausted to support an emerging theory [ibid]. According to Freitas et al. [54], data saturation usually occurs after the third or fourth FG. Hence, while a sampling strategy can be partially determined prior to undertaking a study, this must be reviewed and adjusted during the data collection phase. Although it is difficult to determine the necessary sample size in advance of a study as the saturation point is unknown, in this study, a low saturation point had been anticipated, as the research topic was particularly focused, and the original sample group was homogeneous. Therefore, methods one and two were considered to guide the number of participants, with the understanding that this could be increased or reduced depending on the saturation point.

3.2. Limitations

The most effective way to test and evaluate the ABDG is to trial use of it on a live project. However, as this was not possible within the timescales of this project, the ABDG was tested through FGs (supplemented with questionnaires) with architectural designers.

Ideally, more experts in the field of net zero carbon building design would have contributed to the creation of the ABDG and AB Toolkit, possibly through creating a stakeholder committee group to inform content and format. This would have inevitably taken more time and relied on time commitments from others, which it was felt would add complications to the study, but it is intended to involve a wider group in future iterations of the Toolkit. For example, a Young Persons' Guide to Active Buildings is currently under development and will be tested with an expert panel of school teachers in 2023.

4. Results

Thematic analysis methods were used to analyse data collected [66–68], which involved identifying themes emerging from the data. The FG discussions were non-structured, to enable conversations to flow freely, thereby gaining context for the study, while a questionnaire, used to aid discussions and design guide analysis, was designed according to five main themes: structure, aesthetics, AB explanation, technical content, and general. Thus, the FG data were analysed according to themes emerging from the data, whereas questionnaire data was initially analysed according to the five themes it was structured under. The data was then merged to determine final themes, which were then used to refine the ABDG into the AB Toolkit and identify other measures needed to enable the adoption of the AB concept for UK construction projects.

To capture data from the FGs, each session was recorded and transcribed with permission from the participants. The data was then analysed to determine themes into which the data could be categorised, using an inductive approach [68]. Tables 3 and 4 below summarise the themes emerging from the four FGs regarding the design and content of the ABDG.

Table 3. Summary of combined FG data regarding the "Design" of the ABDG [5].

DESIGN			
Upper Level Theme	**Lower Level Theme**	**Sub-Level Theme 1**	**Sub-Level Theme 2**
Structure	Clarity	Easy to read	
		Easy to reference	
	Navigation	Find information	
		Skip to information	
	Format	Online website	
		App	
Presentation	Page content	Too cluttered	
		Too much	
		No hierarchy	
	Diagrams	Graphics	Better quality
			Consistent
			Simple
		Quantity	More
			Balance with text
	Text	Typeface	Size
			Colour/contrast
		Quantity	Bullet points
			Short paragraphs
			Too much
		Writing style	Simple
			Clear
	Other formats	Flow Charts	
		Tables	
		Proformas	

Table 4. Summary of combined FG data regarding the "Content" of the ABDG [5].

CONTENT		
Upper Level Theme	**Lower Level Theme**	**Sub-Level Theme 1**
Benchmarking	Targets	Energy Use Intensity
		Something measurable
		Minimum requirements
	Checklists	Against RIBA Plan of Work—goals
		For clients
	Other design standards	Adopted by Local Authority guidelines
		Link to Welsh Government DQR standard
General	Quantity	
	Importance of ABs	Benefits at start of document
		Urgency to tackle climate change
	Passive design	Traditional concepts
Retrofit	Heritage Section	
	Application to existing buildings	

Table 4. *Cont.*

CONTENT		
Upper Level Theme	**Lower Level Theme**	**Sub-Level Theme 1**
Data	Data protection	How to share anonymously
	Data monitoring	Who collects data
		How is data used
	Data ownership	Who controls data
	Network capacity	
	Carbon footprint	
Plant	Location	
	Spatial requirements	Duct lengths
		Space for equipment
Technologies	Limitations	
	Example applications	
	Technical	More guidance
		Comparisons between systems
Cost	Commercial	Capex v opex
		Upfront costs
	Value for money	Value of one product against another
		Cost v efficiency
Different building types	Mixed use	
	Density	Affect on use of AB concept
Case studies	Worked example	Performance of buildings in use
		Understand how technologies work together
		Understand the AB process
	Evidence	Prove the AB concept works, persuade clients
		Reduce risks of uncertainty

In addition to the design and content of the ABDG, data was also collected regarding challenges in adopting the AB concept and consequently additional support needed to enable the use of the AB concept. The themes related to challenges and support (or enablers) identified from each FG are summarised in Table 5 below.

Assessing Saturation Point in Data Collection

To assess the saturation point [61], that is, the point at which no new themes are identified, an appropriate method was sought from other research projects in academic literature. For instance, in a study of 40 FGs, by Guest et al. [69], referred to by Hennink et al. [61], most themes identified were found to emerge from the first FG, and just three out of 40 FGs were sufficient to identify the most prevalent themes across the data, leading them to conclude that two to three FGs were sufficient to capture 80% of the themes. Hennink et al. found that even in a study involving a diverse sample group of participants, saturation was reached within five FGs [61]. All the studies examined demonstrated that saturation was achieved after just four FGs whether groups of participants were homogeneous or heterogeneous.

Table 5. Summary of themes developed from all FGs, in addition to data collected on ABDG [5].

CHALLENGES & ENABLERS			
Upper-Level Theme	**Lower-Level Theme**	**Sub-Theme Level 1**	**Sub-Theme Level 2**
Procurement	Form of Contract	Un-connected	
		Un-collaborative	
		D&B predominantly used	Cost-driven not value-based
	Different agendas	Contractors v designers	
		Misalignment of views	
	Value engineering		
	Early engagement	Contractors	
		M&E consultants	
Innovation	Benefits of R&D	Not recognised	
	Risk aspect	"but we don't do it like that"	
	No true innovation		
Business Case	Capital cost	Not enough capital	
		Construction is too cheap	
	Operational cost	Less than standard building	Persuade clients
	Life Cycle Cost		
Installation & Commissioning	Commissioning	Better understanding of systems	
		Contractual obligation	
	Installation	Proper installation of equipment	
	Use of BIM	Clash detection	
		Record what was built	
Post-construction	Building Performance	Monitoring	
	Occupants	Support system	Simple version of O&M Manual
			Simple control interfaces
Legislation	Carbon tax		
	Needs to be legislated		
Culture	Culture change needed	Change in outlook	
		Change mindsets	Public and designers
Skills, education and knowledge	Contractor workforce	Gain understanding	
		Quality of construction	
		Skillsets to deliver	
		Local labour	
	Occupants		
	Designers	Manage clients	
		Deliver new concept	
Different Guides	Occupants	Home user guide	
	Clients	Sell AB concept	
AB Standard	Standard	Measure AB success	Goals
		Standard to aspire to	
	Certification		

In this study, the FGs were analysed in chronological order of the date on which they occurred. Table 6 below shows the number of participants at each session, alongside the number of themes identified within the session, the number of new themes emerging from each, and the saturation point.

Table 6. Number (No.) of themes emerging from the sample groups of participants.

	FG1	FG2	FG3	FG4
No. Participants	4	7	11	9
Total No. of themes	16	10	15	11
New Themes	16	4	4	0
% Saturation	62%	15%	15%	0%

The early saturation of themes is likely to be due to the specific focus on assessing an ABDG, combined with the knowledge and experience of the homogeneous population of architectural designers. As described above, theoretical saturation is reached when no new data to contribute to the research emerges, or when new information produces little or no change to the Theme Dictionary [61]. In this study, theoretical saturation was reached after the first four FGs. Data collected after this point could be used to support the data collected from the FGs but offered few additional insights, hence was not essential.

While the results presented in this paper provided sufficient data to inform the next stage of the ABDG, which was to develop it into a Toolkit of information for designers of AB projects, further testing will be undertaken, by using the Toolkit on live AB projects, which is the best way to test its effectiveness (to be documented in another paper).

The main findings are that, in terms of design, the way information is presented has a direct correlation with the absorption of information and hence use of the information; and that a knowledge base and design guidance (the AB Toolkit), while useful to aid design, will not enable adoption of the AB concept alone. Other measures are needed to facilitate the use of the AB concept, some of which were identified in the AB Protocol developed prior to undertaking this study. The further enablers identified during this study, combined with those presented in the AB Protocol will form a roadmap of future work for SPECIFIC and the ABC.

5. Discussion

A gap in organisational practice was identified by the first author when SPECIFIC started to engage with developers to encourage them to deploy the AB concept on their own low-carbon building projects, targeting low to net operational energy use. This was even more apparent when the ABC was established in 2018 [15] with the aim of rolling out the AB concept in building projects across the UK. The lack of clarity on how to utilise the AB concept in designing low-carbon buildings made the design of AB projects by design professionals challenging. Hence, the first author sought to devise methods appropriate for building designers to share her experience of designing AB projects by disseminating knowledge and data from the AB demonstrators she had previously designed [12,13], through the first author's "Active Buildings in Practice" CPD Seminar; and through the AB Toolkit [70]—a final project output.

This study addresses the gap in organisational practice, that neither SPECIFIC nor the ABC had a body of knowledge or design guidance to aid the design of AB projects, commencing with an understanding that there are a host of challenges to enable the UK construction industry to adopt the AB concept developed by SPECIFIC [5]. This understanding was based on the first author's own experience as an architect working in both UK architectural practice and at SPECIFIC, together with challenges identified from the literature reviews and a pilot study [5].

The measures identified are considerable and it would have been too onerous a task to address every measure within this study. It was therefore decided to focus on the development of knowledge and design guidance, which was suited to the first author's background as a designer and manageable within the project timeframe. Thus, an ABDG was developed and tested with the intended users of the guidance, architectural designers. Data collected provided feedback on the design and content of the ABDG, and highlighted further enablers needed to support utilisation of the AB concept, which correlated with the previously prepared AB Protocol (Figure 1). The data was then used to refine the ABDG into an AB Toolkit and a roadmap of measures for SPECIFIC and the ABC to prioritise in their future work.

Without the body of knowledge developed as the AB Toolkit, it would be difficult for either SPECIFIC or the ABC to progress their work in enabling the AB concept to be adopted within UK construction projects. Information developed through this research project and presented in the form of the AB Toolkit of information and design guidance will be used as a base from which other tools to enable the adoption of the AB concept can be developed. The enablers identified in Table 7 below were determined from the data collected within this project. These will provide a focus for both SPECIFIC and the ABC in their endeavours to help the UK meet its net zero carbon targets by 2050 [26].

Table 7. Roadmap of Enablers to the Adoption of the AB concept in UK construction projects [5].

<table>
<tr><th>2021</th><th>2022</th><th>2030</th><th>2050 (UK Net Zero Carbon Target [26])</th></tr>
<tr><td>Research Project complete</td><td colspan="3">Further enablers to the adoption of the AB concept to be developed</td></tr>
<tr><td rowspan="3">AB Toolkit = Knowledge base and design guidance (output from this research project)</td><td>AB performance specifications</td><td>AB business models</td><td rowspan="3">AB concept for net zero carbon, net zero energy buildings fully adopted by UK construction industry</td></tr>
<tr><td>AB guides for different end users, e.g., building users, facility managers, building contractors, other built environment professionals</td><td>AB compliance tools: AB standard, AB certification schemes</td></tr>
<tr><td>AB training resources</td><td></td></tr>
<tr><td></td><td colspan="3">AB Case Studies developed as further AB projects are completed</td></tr>
<tr><td></td><td colspan="3">Continued knowledge dissemination via CPDs, conferences, publications</td></tr>
</table>

This research project contributes to the existing literature in two areas. Firstly, the development of the AB Toolkit and the identification of further tools needed to enable the adoption of the AB concept by the construction industry. Prior to the completion of this project, SPECIFIC and the ABC had no body of knowledge or design guidance to use when developing or aiding the development of AB projects. This was not only a barrier to progressing AB projects but also to enable the development of further tools that are needed for the widespread adoption of the AB concept, such as training resources and certification schemes. The AB concept provides a viable solution to developing net zero-carbon buildings, as demonstrated by the AB case studies referenced in this paper [12,13]. For the UK to reach its net zero carbon targets by 2050, viable solutions such as the AB concept are urgently needed, and designers need to be armed with the information to allow them to design net zero carbon buildings.

Secondly, the research methods used within this project add to the existing literature. Designing FGs suitable for both data collection and learning provides more opportunities to engage with built environment professionals, such as architectural designers, when undertaking research projects. In addition to assisting research progress, FG participants are also able to gain CPD learning, hence enhancing their existing knowledge and experience, and allowing them to offer their clients net zero carbon solutions. This could also be applicable to other professions or industry sectors.

Finally, the use of a questionnaire within FGs is a novel method not found in the existing literature. This enabled the collection of both qualitative and quantitative data; and verbal and written data, in a relatively short time period (1–3 h). This was beneficial as it gave participants the opportunity to provide feedback either openly, via a discussion forum, or anonymously, through the questionnaire, to suit their preferences.

6. Conclusions

This research project commenced with an understanding that there are many challenges to enabling the UK construction industry to adopt the AB concept developed by SPECIFIC for low-carbon buildings. These were presented in the first author's original hypothesis, as an AB Protocol. The challenges and measures were based on the first author's own experience as an architect in practice and whilst working at SPECIFIC, the literature review, and the results of a pilot study. The results of this project, where discussions on developing design guidance included the type of information and support that would enable architectural designers to adopt the AB concept, proved this hypothesis correct while identifying further enablers. Hence, the data collected was combined with the AB Protocol to develop a roadmap of priorities for SPECIFIC and the ABC.

The measures identified in the AB Protocol are considerable and will form the basis of work for both SPECIFIC and the ABC in their future work, as part of the journey to net zero by 2050. The research questions asked how SPECIFIC could enable the UK construction industry to adopt the AB concept for UK construction projects; who the key influencers are to construction projects; whether developing design guidance and knowledge would aid the development of other enablers; what format such support should take; and what information is needed.

As the UK construction sector seeks solutions to meet zero-carbon targets set by the UK government [5], this research project has presented ABs as a solution to help achieve the decarbonisation of buildings. Through undertaking a literature review, reflecting on her experience, and the fieldwork undertaken with architectural designers, the first author determined that clear guidance on AB design and knowledge gained from her AB projects could enable the development of additional tools to enable the use of the AB concept, with a view to decarbonising UK buildings. Evidence and learnings from the AB demonstrators (presented as AB case studies within the AB Toolkit) will inform other enablers to the adoption of the AB concept, such as business models, standards, qualifications, and changes to regulations.

The knowledge gained from this study was assembled into two main project outputs: the AB Toolkit, which was tested during the study; and the AB Roadmap, describing future priorities for SPECIFIC and the ABC, thereby influencing their organisational practice. Interest in this work both before and after undertaking the FGs suggests a need for the AB Toolkit and other project assistance as outlined in Section 5 above.

This study developed information to address a gap in organisational practice for both SPECIFIC and the ABC in that no clear design guidance or way to share learnings from AB projects existed. This was a significant barrier to the widespread adoption of the AB concept in building projects across the UK. The collective knowledge compiled in the AB Toolkit can now be used by both SPECIFIC and the ABC to develop future work programmes to create ways to enable the AB concept to be applied to building projects to help both the Welsh and UK Governments achieve their zero carbon objectives [26,71].

In undertaking the research, the authors have trialed a new way of collecting data—combining questionnaires with FGs designed as learning events—which may be useful for other researchers.

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