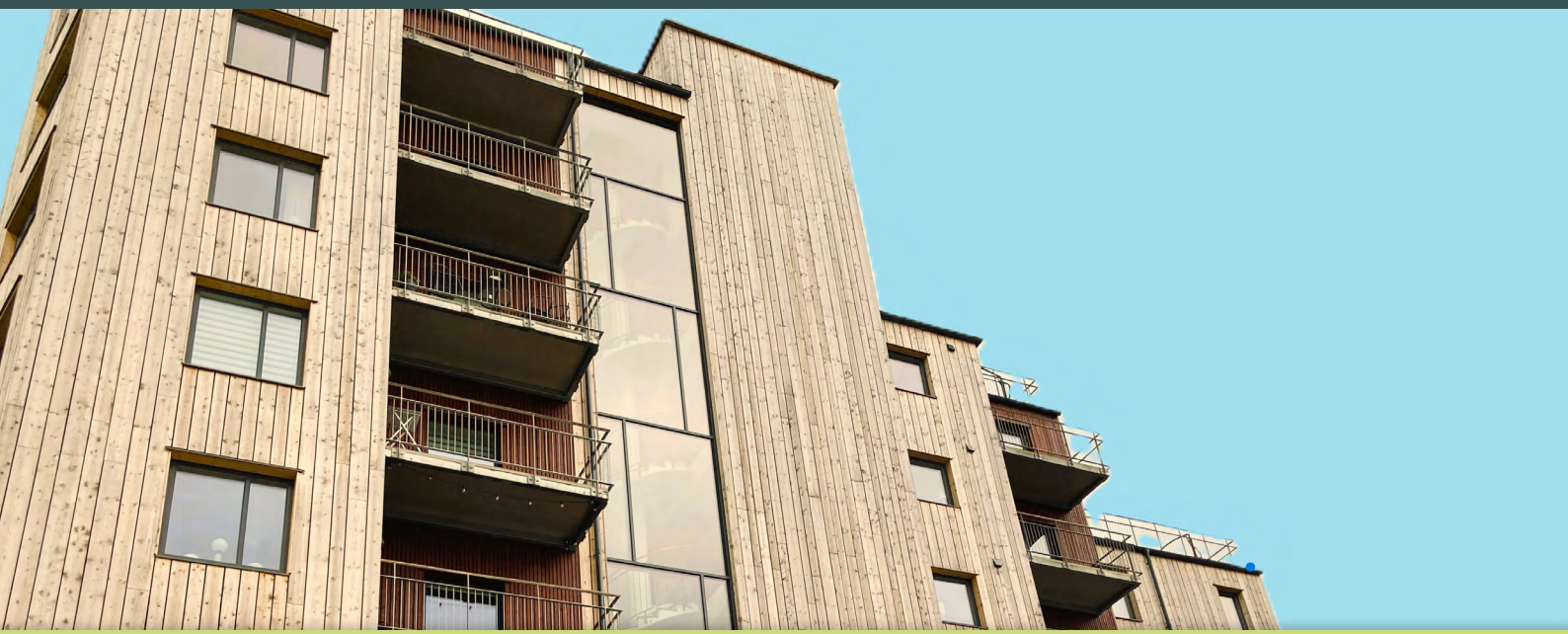
Barriers to the wider use of offsite construction and biobased building materials in UK housebuilding

FINDINGS FROM THE SHELTER PROJECT



Timber apartment building in Växjö, Sweden. Växjö promotes biobased building materials. It has set wooden construction targets for new development and features many residential and non-residential timber buildings, some delivered through offsite construction.

INTRODUCTION

Offsite construction and biobased building materials, particularly when employed together, provide opportunities to deliver low carbon, high quality homes at pace, helping to address the climate crisis and the many housing crises occurring across local communities. This construction method and these building materials are, however, underutilised in UK housebuilding. The Sustainable Housing for Eco-friendly Living and Thriving Environments (SHELTER) Project explored why this is the case. The project featured interviews and a focus group with senior professionals from the UK's construction, housebuilding and biobased building materials industries, and a review of recent evidence published in the academic and grey literatures. This summary presents the headline findings from the project and their possible implications for policy and practice.

OFFSITE CONSTRUCTION AND BIOBASED BUILDING MATERIALS

Offsite construction is "the process of planning, designing, fabricating, transporting and assembling building elements for rapid site assembly to a greater degree of finish than in traditional piecemeal on-site construction." (Smith, 2016, p.1). The products of offsite construction vary in their degree of prefabrication ranging from componentised, to panelised, to modularised elements (Smith, 2016). Biobased building materials are "materials derived from once-living organisms such as agricultural straws, hemp, flax, cotton stalks, and cork" (Dams et al, 2023, p.764). Various benefits have been associated with the use of offsite construction and biobased building materials. Offsite construction has been reported to reduce the time and cost of development, minimise construction waste, improve quality control, and reduce whole-life embodied carbon (Kosbar et al., 2023; Smith et al., 2023; Deakin et al., 2020). Biobased building materials can help control internal environmental fluctuations in humidity and temperature supporting occupant health and wellbeing while reducing energy use, they sequester carbon dioxide during their growth phase, and they are reusable, recyclable, and renewable when responsibly sourced and managed (Dams et al, 2023; Arup, 2024; Carcassi et al., 2024). The benefits of offsite construction and biobased materials can be amplified when the two are used in tandem (Romero Quidel et al., 2023; Sutkowska et al., 2024). Despite their benefits, offsite construction and biobased building materials have yet to transition into the UK's mainstream housebuilding industry.

BARRIERS TO USING OFFSITE CONSTRUCTION AND BIOBASED BUILDING MATERIALS

Several recent systematic reviews and studies have investigated barriers to the wider use of offsite construction and biobased building materials in the housebuilding and construction industries, although recent research on barriers to the wider use of offsite construction with biobased materials is lacking. A wide range of social, cultural, regulatory, economic, and technical factors emerge as potential barriers. Tables 1 and 2 present the more commonly reported barriers organised by broad themes. The barriers identified within the construction industry frequently correspond to those identified in the housebuilding industry. The broad factors found to deter the wider use of offsite construction often reflect those found to deter the wider use of biobased building materials. Barriers common to both include: higher upfront costs relative to 'conventional' construction methods and materials; misconceptions, limited knowledge and limited experience in the construction industry of biobased materials and offsite construction; costly, complex and lengthy processes for obtaining accreditation, warranties and demonstrating compliance with regulation; building regulations and contracts that favour conventional construction methods and materials; risk-averse orientations in the construction and finance industries coupled with a preference for familiar methods and materials; insufficient production/manufacturing capacity to support larger projects, and insufficient data on the benefits and performance of offsite construction and biobased building materials. In the few recent studies that have considered the issue, a couple of challenges specific to using biobased materials in offsite construction are identified (Table 2). These relate to the properties of biobased materials and the cost and ease of obtaining prefabricated biobased components.

Table 1: Barriers to the wider use of offsite construction

Economic	Offsite construction is associated with high upfront costs. The cost of developing manufacturing facilities to produce the prefabricated components that are then assembled onsite can be particularly high. High upfront costs routinely emerge across the literature as the key challenge in offsite construction. The cost of individual homes constructed through offsite construction can be more expensive than homes constructed via traditional building techniques unless economies of scale are achieved. This may deter some homebuyers and affordable housing providers from selecting offsite properties. A consistent pipeline of demand is required to produce the economies of scale needed to realise the potential cost savings of offsite construction. Consistent demand is particularly important for offsite developers due to the high upfront and ongoing operating costs associated with the factory-based business model. In the UK, respondents to a House of Lords inquiry into the modular housing industry reported that the pipeline of demand within the UK was insufficient (Moylan, 2024). Lenders and insurance providers can view innovative construction methods as riskier than conventional methods. Insurance providers can also impose a higher premium on offsite projects. In the UK, however, Make UK Modular, a membership body representing companies operating within the modular housing industry and adjacent sectors, reports that its members have not identified any problems with the mortgageability of modular homes. It notes that all its members use the UK's Build Offsite Property Assurance Scheme (BOPAS) that was developed to provide assurance to lenders of the durability of offsite manufactured systems. The typical business models of many mainstream housebuilders are not suited to offsite construction.
Policy, Performance, Warranties	Obtaining warranties for offsite projects can be a complex and lengthy process. Insurers can be reluctant to accept compliance with building standards / regulation as sufficient to demonstrate the safety, compliance, and performance of a building developed using offsite construction. Building regulations / standards, accompanying guidance, and building inspection regimes are devised with the particularities of onsite construction rather than offsite construction in mind. This can lead to delays and additional cost when they are applied to offsite projects. Policy does not adequately support offsite housing.

Table 1: Barriers to the wider use of offsite construction	
Socio-cultural	There can be limited knowledge of offsite construction, plus misconceptions and scepticism about its quality and durability, amongst the public. The construction industry has limited knowledge and experience of offsite construction. A lack of relevant skills and knowledge produces labour shortages while the cost of training staff contributes to the high upfront costs of offsite construction. Limited knowledge and experience of offsite construction creates risk for clients, architects, developers, and other stakeholders. This can lead to a preference for conventional construction methods. Limited understanding of the value and benefits of offsite construction can restrict market demand. A lack of data on the benefits of offsite construction can deter actors in the construction industry and clients from investing in this method. For Smith et al. (2023, p.59), commenting on offsite housing in the US, "the first step in transforming offsite construction into a fully functional manufacturing industry requires developing a data culture".
Production and Procurement	Difficulties transporting larger precast components to site due to unsuitable transport infrastructure and/or regulatory factors. Transporting materials to a factory and prefabricated components to site can reduce the potential carbon savings of offsite construction and introduce additional cost. Transporting prefabricated components to site can damage components. Modifying the design of an offsite project is difficult but there is a preference amongst homebuyers and regulatory bodies for flexibility in building design. Introducing flexibility impacts the productivity gains of factory methods which rely on the manufacture of standardised components. Integrating and connecting the offsite components of a project with onsite components can present challenges particularly when onsite workers have limited knowledge of offsite construction. Insufficient offsite manufacturing capacity to meet the demand of larger construction projects. Traditional design-bid-build procurement models that are common in the construction and housebuilding industries do not suit offsite construction. There needs to be greater collaboration at the outset between the various parties involved in designing and delivering a project than is usual in these models. There can be reluctance amongst the different parties involved in a project to accept alternative procurement models.

BARRIERS TO USING OFFSITE CONSTRUCTION AND BIOBASED BUILDING MATERIALS IN UK HOUSEBUILDING

Many of the recent systematic reviews and studies that have examined barriers to the wider use of offsite construction and biobased building materials have focused on alternative or larger geographies and sectors than the UK housebuilding industry. Consequently, the relevance of these barriers to UK housebuilding is unclear. Further, there is very little information available on possible barriers to the wider use of offsite construction with biobased materials. To shed light on these issues, we completed interviews and a focus group with senior professionals from the UK's housebuilding, construction and biobased building materials industries. Participants included directors, founders, managers and senior officers at SME housebuilders, modular building providers, architectural practices, plus suppliers, consultants, and construction companies that specialise in biobased building materials. Participants were identified and recruited through existing contacts and networks, industry membership bodies, snowball sampling, and desktop research. A loose set of talking points steered the interviews and focus group

Our participants identified a range of challenges that impacted the wider use of offsite construction and biobased building materials in UK housebuilding. Often these reflected past findings on barriers to the wider adoption of these materials and method. We found clearer differences in the specific factors that deter the wider use of biobased building materials, and those that deter greater use of offsite construction, than some past studies suggest. Barriers to using biobased building materials in offsite housing were not generally reported by participants. Participants in fact pointed to examples of the successful use of biobased materials in prefabricated components, such as timber frames that are manufactured offsite.

Table 2: Barriers to the wider use of biobased building materials

Economic	Biobased building materials can be more expensive than conventional building materials, although this is not always the case. Biobased materials can also produce cost savings over a building's lifetime due to reduced operating costs linked to the performance of the materials. Clients may not be willing or able, though, to accept longer term savings for higher initial costs. Sustainable elements in a building can be value engineered out. Altering conventional construction methods developed for conventional building materials to suit biobased materials can introduce additional cost.
Policy, Performance and Accreditation	More performance data for biobased building materials is needed to build confidence within the wider construction industry to use these materials and to facilitate the accreditation of more materials. Building regulations / standards and associated testing and inspection regimes are designed for conventional building materials and are less suited to biobased materials. Concerns about the performance and durability of biobased materials are found amongst some in the construction industry. This can, however, be associated with insufficient knowledge of these materials and how to use them within a building. The performance of biobased materials can be improved through additional processing and/or treatment. Lime, for example, can be used as a binder in biobased materials to improve fire performance. Within the construction industry there can be an expectation that biobased building materials should perform in the same way as conventional materials. Policy does not adequately support the wider use of biobased building materials. Biobased materials are more variable than conventional building materials and this may pose challenges in achieving a consistent standard of quality across large-scale production. Prefabrication with biobased materials is more difficult to obtain and expensive relative to conventional building materials.
Socio-cultural	The construction industry can be resistant to innovation and tends to rely on familiar materials and methods. Misconceptions and prejudice towards biobased building materials, and a lack of confidence in their performance and durability, is found amongst some in the construction industry. Limited knowledge and experience of biobased materials can result in contractors pricing risk into every component of a project that employs these materials. Contractors with limited knowledge and experience of biobased materials may employ conventional construction methods with these materials which could result in issues and defects. Limited knowledge of biobased building materials amongst the wider public.
Production	Supply of biobased materials can be insufficient to meet the needs of larger construction projects. Transporting materials to a processing facility and then to site impacts a building's Whole Life-Cycle Carbon (WLC) Assessment. Sourcing materials locally could address this issue but it may be more expensive. Also, the ability to grow the crops used in biobased building materials locally will vary between areas due to regulatory, geographic and climate factors. Biobased materials rely on agricultural and forestry practices that are vulnerable to the effects of weather, climate, and other external factors. This may have implications for the stability of the supply chain. Prefabrication with biobased materials, compared to prefabrication with conventional construction materials, introduces intricacies and time-intensive fabrication processes with more variables.

For our participants, the absence of a sufficiently supportive policy environment was the critical barrier to the wider adoption of biobased building materials. Fire safety regulations and the fire safety testing regime were said to restrict where and when biobased materials can be used in buildings. The insulation standards outlined in Building Regulations were said to respond to the properties and performance of conventional insulation materials rather than those of biobased materials. To meet the standard, potentially large volumes of biobased insulation materials can be required increasing project costs and potentially impacting property and scheme design. A couple of participants identified differing orientations to biobased building materials between local planning authorities, with some resistant to their use. However, an architect participant reported no issues with local planning authorities when biobased building materials were specified for a building. A couple of participants reported difficulties in assuring building control officers with less knowledge of biobased building materials of the performance and compliance of these materials. However, an SME housebuilder participant reported no issues with building control when biobased materials were included in a building. At the national level, there was seen to be a lack of strong policy support for biobased building materials. Several participants thought that a strong policy prompt would be needed for mainstream housebuilders to transition to these materials. Certain European countries, including France and Austria, were identified as leaders in the use and manufacture of biobased building materials and this was attributed to the presence of a more supportive policy environment.

Timber apartment building, Växjö, Sweden

Two factors formed, for our participants, the key barriers to the wider use of offsite construction in UK housebuilding. First, the need to sustain a continuous pipeline of demand to support the continuous operation of an offsite manufacturing facility was considered particularly challenging. Delays in securing planning permission for projects, and the business models used by many mainstream housebuilders that rely on building properties only as they are sold, were not thought conducive to sustaining continuous demand. Second, the procurement model commonly used in the construction and housebuilding industries was thought incompatible with the close collaboration between all parties in the development process that offsite construction requires. For example, participants commented that a building should be designed with the offsite manufacturer not commissioned separately. The housebuilders we spoke to who used offsite construction had brought all design, manufacture, and onsite assembly functions in-house to ensure their effective integration.

In addition to the aforementioned critical issues, several other factors were seen to potentially deter the wider use of offsite construction and biobased building materials in UK housebuilding. These related to economic, regulatory, and socio-cultural issues. In terms of economic issues, the high initial set-up costs for offsite manufacturing, and the high cost of developing processing facilities for biobased materials, which impacts the price of these materials, were highlighted as challenges. Further, biobased building materials were identified as potentially more expensive than conventional building materials, partly because of the differing scales of production associated with these two types of material. Although acknowledged as potentially more expensive, participants highlighted that biobased materials can serve more than one function in a building, reduce heating and cooling requirements, and reduce a building's operating costs. Moreover, the clients that typically chose these materials were said to be motivated by the properties and performance of a material, such as its suitability for heritage buildings, rather than by cost. A last economic issue reported by a couple of participants concerned the tendency for contractors with limited experience of biobased materials to price in higher levels of risk increasing overall project costs.

Securing mortgage finance and insurance for offsite housing, or for housing constructed with biobased building materials, was not identified by our participants as a challenge. Past research suggests, though, that both can be difficult for both types of housing. Our participants reported that complying with Building Regulations, using accredited biobased building materials and, for some offsite developers, accreditation by the Buildoffsite Property Assurance Scheme (BOPAS), gave confidence to mortgage providers and insurers. A further divergence from past research

concerned perspectives on the adequacy of performance data for biobased building materials, and the adequacy of the supply of these materials. Our participants reported no issues in being able to source materials in sufficient quantities and they were satisfied with the amount of performance data available, noting that the data allowed them to demonstrate performance to regulators. Participants also reported using accredited materials in order to ensure and demonstrate performance.

In terms of regulatory issues, the need to respond to differing planning requirements in different areas was said to restrict opportunities for offsite developers to manufacture and use standardised components. Opportunities for standardisation were also thought to be affected by the preference amongst homebuyers and clients for personalised building designs. Participants reported that this requirement for design flexibility affected the potential efficiency gains of offsite construction and formed a further potential barrier to the wider use of this construction method in UK housebuilding.

In terms of socio-cultural issues, participants identified the construction and housebuilding industries as risk averse with a preference for familiar construction materials and methods. This was seen to form a barrier to the wider use of both offsite construction and biobased building materials. There was also seen to be limited knowledge and experience of biobased building materials in these industries and this was identified as a further barrier to their wider use. Participants supported providing more education and training on these materials. Differing from past research, no specific knowledge gaps in respect of offsite construction were noted by the participants who used this method.

IMPLICATIONS AND RECOMMENDATIONS

To support the wider use of biobased building materials and offsite construction in UK housebuilding, the findings from our research suggest that efforts could be directed towards: building a regulatory environment that better supports biobased building materials and offsite construction, investigating and encouraging alternatives to the procurement structures and business models commonly used by mainstream housebuilders, developing housebuilders' knowledge of biobased building materials, and supporting companies with the high cost of establishing manufacturing facilities to process biobased materials and to produce prefabricated components for offsite housing.

In terms of prioritising activities, our findings suggest that attention could initially focus on producing a more supportive policy environment for biobased building materials, promoting procurement models that address the needs of offsite construction, and tackling factors that disrupt, while promoting those that support, a continuous pipeline of demand for offsite manufacturing facilities. To these ends, policymakers could work with industry and other stakeholders to identify current policy that may deter the use of biobased building materials and the feasibility of amending this policy. The introduction of new policy that proactively encourages the use of biobased materials could also be explored, possibly by examining the content and impact of relevant measures introduced in other countries. In all these activities, the focus should be on promoting the traceability and transparency of biobased building materials and encouraging those materials with the least potential to cause harm. Some treatments, binders, processes and so forth applied to some biobased materials can have harmful effects, the carbon-based nature of these materials increases the potential for the emission of Volatile Organic Compounds (VOCs), and materials that include fossil-fuel derived substances will affect a building's Whole Life-Cycle Carbon (WLC) Assessment.

Timber apartment building, Växjö, Sweden

Policymakers, along with the housebuilding industry and relevant professional and membership bodies, could also develop additional support, training, and guidance for housebuilders on alternative procurement models that better address the needs of offsite construction. Current procurement frameworks that support organisations to procure offsite housing could be evaluated to determine their impact, use, and possible limitations. The findings from this exercise could inform the modification of existing frameworks and/or the creation of new frameworks. To support the continuous demand pipeline needed for offsite construction, policymakers could consider opportunities to further promote this construction method in the development of publicly-funded housing. For example, while Homes England (2016), England's social housing funding body, currently promotes offsite construction through its Affordable Housing Programme (2021-2026), some argue that this support should go further. A recent House of Lords inquiry into the UK's modular housing industry recommended that affordable housing providers should be required to use a minimum proportion of modular or panelised methods in their overall use of Modern Methods of Construction (MMC) in projects supported by the programme (Moylan, 2024). Policymakers could examine the possible impacts and implications of implementing this recommendation. Policymakers might also explore innovative ways to address the time taken to secure planning permission for housing development. Successive governments have introduced various planning reforms with the aim of reducing the time taken to determine planning applications. A comprehensive evaluation of the impacts of these reforms could inform the development of new recommendations that build on past successes and avoid past mistakes.

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