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Innovative Housing Programme, year two: lessons learnt

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Innovative Housing Programme, year two: lessons learnt

Industryline Research

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Views expressed in this report are those of the researcher and not necessarily those of the Welsh Government.

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Glossary

Air Quality Index:
A measure that evaluates indoor air quality across different building types by considering CO_2 levels, temperature, and humidity.

CO_2 (carbon dioxide):
A colourless, odourless gas produced by burning carbon-based materials and by respiration. In this report, CO_2 levels refer to the internal concentration of CO_2 in the air, measured in parts per million (ppm).

Damp and mould element:
Refers to issues related to moisture and fungal growth in buildings, impacting health and structural integrity.

DQR:
Design Quality Requirements.

EPC:
Energy Performance Certificate.

IHP:
Innovative Housing Programme.

kW:
Kilowatt, a unit of power equivalent to 1,000 watts.

kWh:
Kilowatt-hour, a unit of energy equivalent to one kilowatt of power used for one hour. It is commonly used as a standard measurement for energy usage.

MMC:
Modern Methods of Construction.

Modular construction:
A construction method in which buildings are made from pre-fabricated sections.

MVHR:

Mechanical Ventilation with Heat Recovery.

Passivhaus:

A standard for energy efficiency in buildings, reducing their ecological footprint.

PV:

Photovoltaic panels (relating to the conversion of light into electricity).

SIPS:

Structural Insulated Panels.

Solar thermal collectors:

Devices that collect and use solar energy to heat water or air for domestic or industrial use.

Solcer House:

An ‘energy positive’ house designed by Cardiff University and SPECIFIC Innovation.

Traditional design or traditional construction:

Refers to developments that use conventional construction techniques and materials, such as bricks and mortar, concrete frames, etc. These methods employ construction designs and practices that have been widely accepted in the mainstream housing market for many decades.

U-values:

A measure of heat loss in a building element, such as a wall, floor, or roof. The lower the U-value, the better the insulation provided.

WFGA:

The Well-being of Future Generations (Wales) Act 2015.

WRAP:

Waste and Resources Action Programme.

1. Introduction

About the Innovative Housing Programme

1.1 Established in 2017, the Welsh Government's Innovative Housing Programme (IHP)[1] was commissioned to support innovation within housing development across Wales. The programme targets critical elements of the housing supply chain, including construction techniques, delivery pathways, and housing models. Its goals for the second year (2018-2019) were to:

- Increase the supply of affordable housing in Wales
- Support the seven goals enshrined in the Well-being of Future Generations (Wales) Act 2015 (WFGA)[2]
- Address the cost and value of new homes and develop housing that meets current and future housing needs
- Support innovators through the use of alternative approaches and demonstrate the benefits of such approaches to encourage uptake
- Harness opportunities to deliver jobs and skills training and to develop local industry
- Publicly disseminate key findings and maximise learning

1.2 To inform future innovative housing programmes and enable knowledge sharing from the schemes funded during the Innovative Housing Programme, the Welsh Government has commissioned research to understand the lessons learned during the second year of the Innovative Housing Programme. Within this, there was a specific focus on:

- The identification of planning barriers
- Construction challenges
- Workforce issues
- The benefits experienced in the programme by development schemes initiated during the year two funding period of the IHP (2018-2019)

The research spanned from August 2023 to April 2024 and was guided by a series of overarching research questions, which were:

1. What experiences, lessons, and challenges can be identified from the IHP Year Two funded schemes, including in relation to:

[1] Innovative housing programme | GOV.WALES
[2] Well-being of Future Generations (Wales) Act 2015 | GOV.WALES

- Planning experiences and barriers
- Construction (challenges and benefits)
- Workforce availability and skills (challenges and benefits)

2. How do the IHP Year Two schemes compare to traditional construction-type developments in relation to:

   - Build costs
   - Waste materials during construction
   - Pace of build
   - Energy performance

3. How do the IHP Year Two lessons learned compare with the early lessons from Year One of the IHP, including:

   - The enhancements and challenges in planning and construction that can be recognised compared to the first year of the IHP
   - The changes brought by the inclusion of market housebuilders and other developers in the programme

4. Are the projects funded during IHP Year Two delivering the outcomes proposed in funding applications, including:

   - The assessment of outcome areas that have proved challenging to achieve
   - The factors that affect the success of outcomes, such as build type, technology, social factors, etc.
   - How outcomes and objectives have or have not been delivered at different development stages (i.e. during the planning phase, construction phase, or post-completion)

5. What strategic opportunities and learning for future developments can be identified from this research in relation to:

   - Process improvements and best practices
   - Policy adjustments
   - Other strategies to enhance the effectiveness of the IHP and its overarching goals

Purpose and structure of the report

1.3 This report provides a summary of the learning that emerged during the developments funded during the second year of the IHP (2018-2019). It can also be used to enable the sharing of key lessons between participating organisations and

as a resource to those considering seeking funding through the scheme in the future.

1.4 This report provides a detailed analysis of both qualitative and quantitative findings to address the overarching research questions. Insights related to the integration of findings across different themes are presented. The report concludes with a comprehensive summary of main outcomes and recommendations.

2. The Innovative Housing Programme

2.1 Established in 2017, the Welsh Government's Innovative Housing Programme (IHP) was commissioned to support innovation in housing delivery across Wales. The programme targets innovations in three key areas of the housing supply process: construction techniques, delivery pathways, and housing models. Throughout its duration, the IHP has allocated £155 million in capital. The budget breakdown for the first three years of the programme was as follows: Year One (2017 to 2018) £10 million; Year Two (2018 to 2019) £35 million; Year Three (2019 to 2020) £45 million. These funds are largely directed towards projects utilising modern methods of construction. These broad aims are set within a complex and changing policy landscape, which has shaped and informed the schemes developed during IHP Year Two.

Need and demand for housing in Wales

2.2 Figures outlined in the 'Estimates of housing need: 2019-based' indicate that an estimated average of 7,400 additional housing units are required annually in Wales between 2019/20 and 2023/24. Of these, approximately 3,500 units (48% of the total) are needed in the affordable housing sector (intermediate and social rents). This includes an annual average of 1,100 units to address the current backlog of unmet housing needs over the first five years[3].

2.3 This backlog has strained the social rented sector, with waiting lists reaching record lengths. Further economic challenges, exacerbated by the COVID-19 pandemic and other factors, have intensified affordability issues in the housing sector. Figures show that in 2022, an average full-time employee in Wales had to spend 6.2 times their earnings to purchase a home[4]. This compares with just three times the average earnings in 1997. Within the rental sector, the Office for National Statistics reports that private rental prices in Wales increased by 7.1% in the 12 months to December 2023, making Wales the country with the highest increase in rental prices in the United Kingdom[5].

2.4 Annual Monitoring Reports for Local Planning Authorities' Local Development Plans (LDPs) indicate that the construction of new properties has lagged behind

[3] Estimates of housing need: 2019-based | GOV.WALES
[4] Housing affordability in England and Wales: 2022 | ONS
[5] Index of Private Housing Rental Prices, UK : December 2023 | ONS

projections[6], often due to pandemic-related disruptions and changing policies. These changes prompted some local authorities to redevelop their LDPs and strategic direction to align with new policy goals.

2.5 Together, these factors have placed considerable pressure on housing services and necessitated a heightened reliance on temporary accommodation. For the 2022 to 2023 year, 12,537 households were assessed as homeless; these included 2,739 dependent children under the age of 16 residing in temporary housing. The number marked a 7% increase from the 2021 to 2022 year and an 11% increase from the 2017 to 2018 year[7][8]. In response to these growing pressures, the UK government introduced new regulations in 2023, requiring more frequent local housing market assessments. These regulations underscore the government's commitment to 'securing a path towards adequate housing,' including addressing fair rents and affordability, further supporting long-term housing needs[9].

IHP 2 within the wider Welsh policy context

2.6 In response to these complex factors and challenges, the Welsh Government has published regulatory frameworks and legislation that aim to address immediate economic pressures and ensure sustainable housing solutions that contribute to the wellbeing of future generations.

Well-being of Future Generations

2.7 The Well-being of Future Generations (Wales) Act 2015[10] is the overarching legislation that, through its seven goals, aims to improve Wales's social, economic, environmental, and cultural well-being. These goals are designed to ensure that public bodies consider the long-term impact of their decisions, aiming to prevent persistent problems such as poverty, health inequalities, and climate change. The IHP subsequently centred its application process around the requirements of the Act by ensuring developers demonstrate that their projects align with the seven goals. Applicants had to demonstrate how their project would innovate in at least one (but not more than three) areas aligned with the seven goals of the Well-being of Future Generations (Wales) Act 2015[11].

6 Development Plans | GOV.WALES
7 Homelessness April 2022 to March 2023 | GOV.WALES
8 Homelessness April 2017 to March 2018 | GOV.WALES
9 Securing Path Towards Adequate Housing including Fair Rents and Affordability | GOV.WALES
10 National Well-Being Act | GOV.WALES
11 Innovative Housing Programme Guidance | GOV.WALES

2.8 Amendments to the Well-being of Future Generations (Wales) Act were also proposed in 2022 to strengthen climate action and social equity, impacting housing by increasing environmental and social sustainability requirements[12].

Carbon reduction and fuel poverty

2.9 Within this framework, broader government objectives have existed, aimed at promoting a resource-efficient construction sector and substantial carbon emission reductions. These objectives, such as targeting an 80% reduction in greenhouse gases by 2050 as stipulated by the Environment (Wales) Act 2016[13], have been important drivers in the Welsh Government's continued commitment to promoting more sustainable forms of construction and living. In further efforts to achieve Net Zero commitments, the Welsh Government has maintained its commitment to investing in housing, with a strategic emphasis on sustainable development and the utilisation of Modern Methods of Construction (MMC). This includes a strategy unveiled in 2020, which encourages the widespread adoption of MMC to enhance the scale and pace of housing construction while reducing carbon footprints and fostering innovation[14].

2.10 Furthering this, in 2021, the Welsh Government published an updated national housing strategy[15] emphasising sustainable housing and the accelerated use of MMC, thereby demonstrating a cohesive and consistent approach to increasing innovation through policy. This is supported by recent advancements in digital and construction technologies, including AI and 3D printing, which offer new opportunities for innovation in construction techniques

2.11 These technological advancements are supported by policies and investments, such as the £10 million allocated to modular factories under the Wales Infrastructure Investment Plan[16]. This highlights the Welsh Government-led push towards innovative, sustainable housing solutions.

2.12 Further supporting this, the Welsh Government's Warm Homes programme was established to improve energy efficiency in homes[17]. Environmental legislation has also seen updates, with new carbon emission targets introduced in 2023 to mitigate the impacts of climate change. This legislative context underpins the IHP's goals of

[12] FG Section 20 Review | Future Generations Wales
[13] Environment Wales Act 2016 | GOV.WALES
[14] Social house building strategy | GOV.WALES
[15] Action Plan | GOV.WALES
[16] Wales Infrastructure Investment Plan Project Pipeline 2019 | GOV.WALES
[17] Cold Weather Resilience Plan | GOV.WALES

reducing the environmental impact of new housing developments and addressing issues of fuel poverty—a persisting challenge, as indicated by the Welsh Housing Conditions Survey[18]. In response, the Welsh Government released an updated strategy[19] in 2024 to combat fuel poverty by placing greater emphasis on energy efficiency and affordability in housing projects. These emergent policy and regulatory changes underscore the importance of the IHP as an agent of change within the sector and a 'testing ground' for mainstream innovative housing solutions.

2.13 Moreover, while existing within regulatory frameworks primarily aimed at traditional construction methods, the IHP has sought to challenge traditional construction outlooks.

Welsh Development Quality Requirement (WDQR)

2.14 The Welsh Development Quality Requirement (WDQR)[20] is an integral part of the policy context, which primarily outlines standards for new-build social housing. The WDQR 2021 sets requirements for all new builds, including achieving an EPC A rating with non-fossil fuel heating and hot water systems. Replacing the earlier Design Quality Requirements, it covers an extensive range of housing specifications, such as the size of the house, the living environment, and the suitability of the building for its intended use, among other factors[21].

2.15 Most recently, in October 2023, the Welsh Government introduced a new Welsh Housing Quality Standard (WHQS) featuring 'the biggest changes to social housing in more than 20 years'[22].The WHQS 2023 is the standard for existing social housing in Wales. By addressing decarbonisation in the social housing stock, it aims to elevate existing social housing to a standard close to that of WDQR 2021. This includes requiring social landlords to retrofit existing homes to achieve an EPC A rating in the future, with an interim step of achieving EPC C (SAP 75) by 31 March 2030. The WHQS outlines ambitious targets to improve the overall quality of people's lives, raise the bar for social housing, and reflect the voice of tenants in Wales. This new standard also prioritises improvements to damp and mould elements, broadband access, and building safety.

18 Welsh Housing Conditions Survey Background | GOV.WALES
19 They Work for You | Senedd
20 Development Quality Requirements for Housing Associations | GOV.WALES
21 WDQR replaces the Development Quality Requirement (DQR)
22 Welsh Housing Quality Standard 2023 | GOV.WALES

2.16 The WHQS further underlines the crucial role that the IHP plays in the housing sector as a unique, multifaceted approach towards developing housing solutions that address the sector's current policy application challenges and housing solutions that are affordable, sustainable, and of high quality. The IHP aims to challenge traditional technologies, thereby enabling an increase in the scale and pace of social housing construction and tackling fuel poverty.

3. Methodology

To conduct this research project, Industryline Research developed a comprehensive evaluation aligned with the HM Treasury Magenta Book: Central Government Guidance on Evaluation (2020)[23].

Initial research phase

3.1 Upon project commencement, data was securely shared on all 23 schemes funded during the second year of the IHP. Access included scheme contact details, the year-one report documentation, and the original applications that developers submitted for the 2018-2019 IHP funding period[24]. Schemes were categorised by build type, with the classifications of these developments established in collaboration with the Welsh Government. In instances in which schemes overlapped in categorisation, the schemes' original proposed outcomes and objectives were utilised to determine the most appropriate category.

Table 3.1: Scheme classification types

Build type categorisation	Construction type	Schemes Year Two
Modular, Sub-Assemblies, and Component	Developments using modules, prefabricated components, or sub-assemblies	5
Energy Efficiency and Green Model	Building models prioritising energy efficiency, green energy utilisation, and a reduced carbon footprint	6
Timber Construction	Building methods that primarily use timber as the main construction material	7
Traditional Construction	Builds constructed using traditional methods of construction	1
Passivhaus or Passivhaus Principles	Ultra-low-energy buildings that require little energy for space heating or cooling	4

3.2 The initial research phase involved a review of the first-year report. This review aimed to categorise key points and data, identify patterns, themes, and biases, and interpret qualitative material for comparative analysis. The original year-two applications were also reviewed to summarise objectives and proposed outcomes. This process, along with the acquisition of secondary data sets, facilitated the collection of data to inform the analysis and comparisons with traditional

[23] The Magenta Book | GOV.UK
[24] Innovative Housing Programme funded schemes 2018-2019 | GOV.WALES

construction types. Additionally, the team developed a detailed semi-structured topic guide for the qualitative research phase, informed by the year-one discussion guide, to facilitate comparisons over time[25]. This discussion guide is included in Appendix A.

Qualitative data collection

3.3 For each scheme, a minimum of two individuals were contacted. In some instances, it was feasible to engage only with a representative from either the developer or the construction partner. On other occasions, respondents nominated by the initial contacts served as additional or alternative interviewees, with at least one participant being engaged with for each of the 23 schemes. Industryline Research also contacted other organisations and individuals, including representatives from the recognised supply chains of specific schemes, contractors, and other pertinent bodies.

3.4 In total, 33 interviews were conducted, ranging from individual sessions to group interviews involving up to five participants. Six of these interviews were conducted with multiple participants, and 27 were held as one-to-one discussions. Interviews were available in either Welsh or English.

3.5 Interviews were recorded and transcribed using the artificial intelligence software Speak AI. This was then reviewed by a member of the research team for accuracy and anonymity. The anonymised data was then subjected to thematic analysis, differentiating by build type.

Quantitative data analysis

3.6 Monitoring data for 13 schemes in the second year of the IHP was provided by Trustmark, which manages the monitoring data reported by systems installed in some of the schemes on behalf of the Welsh Government. These monitoring systems were part of the funding conditions of IHP Year Two. This data included metrics on building energy, internal humidity, temperature readings, carbon dioxide levels, and resident heating usage. These metrics were integrated with secondary weather data and cost models developed during the first phase of the research. This integration enhanced the understanding of how objectives and outcomes were achieved. This phase of analysis provided insights into performance by build type and enabled the triangulation of qualitative data. Weather data was obtained

[25] Research to Identify Early Lessons Emerging from Innovative Housing Programme | GOV.WALES

through MET office data sets and Visual Crossing data. The schemes included within the monitoring data analysis can be found in the Appendix.

Approach to analysis

3.7 The quantitative data collected from the scheme application forms and the data provided by Trustmark Ltd have been analysed and triangulated with the qualitative data from the 33 interviews. Trustmark data was available for 13 schemes, representing 56% of the total projects. These schemes included a diverse mix of building types and geographic locations, thus providing a balanced cross-section of the programme. Data from the remaining 10 schemes was limited due to delays in receiving or installing the monitoring equipment or delays in construction.

3.8 Scheme performance data and scheme monitoring data went through a data cleansing process to enhance the quality and usability of the collected data. This process included identifying and removing outliers that could have skewed the analysis and distorted the findings. Such outliers might arise from anomalies in data collection or unique circumstances that do not reflect typical scheme performance.

3.9 Furthermore, in recognition of the variability introduced by different housing sizes and occupancy levels, the analysis was adjusted to account for variations among one-bedroom, two-bedroom, and three-bedroom houses.

3.10 Recognising that occupancy can influence energy usage, internal humidity, and temperature readings, we developed a methodological approach in order to normalise this data. This was approached through a multipronged strategy. In some cases, this normalisation was based on ‘total occupancy’, which, based on policy-advocated rightsizing measures, considered each property size (three-bedroom, two-bedroom, etc.) as being correctly occupied. Other methods include normalising data based on floor area or using variable weighting to ensure that variable factors have a proportionate weighting in analysis. This normalisation process ensured a fairer comparison across schemes by averaging the data to adjust for these variables and thereby accurately reflect the performance characteristics of each building type, devoid of bias introduced by size or occupancy variations. Additionally, the availability of scheme application data and interview findings enabled the effective utilisation of the monitoring dataset. These outputs strengthened the reliability and generalisability of the monitoring data across the IHP.

Qualitative analysis

3.11 Thematic analysis was conducted on the anonymised transcripts. The themes identified in this analysis were then integrated with the analysis from phase one of the scheme applications and cross-referenced with the monitoring data analysis to ensure that the themes, perspectives, and lessons learnt were validated through quantitative and qualitative research.

3.12 The following sections explore the experiences of developers and their construction partners in undertaking the development of IHP Year Two schemes. The insights that participants shared during these interviews have been integrated with quantitative data to provide robust evidence and key learnings regarding the planning process, strategic development of schemes, construction activities, and formation and management of a suitably skilled workforce.

4. Lessons learnt: factors around planning

4.1 The lessons learnt in relation to this area of innovative housing development are:

- The acceptance of innovative approaches by planners and the challenges faced
- Resident objections and the importance of early dialogue with residents, key local authority officers, and local councillors
- Visual design and perceptions

The acceptance of innovative approaches by planners and the challenges faced

4.2 In the second year of the IHP, participants noted that local authority planners were generally receptive to the innovative approaches proposed. During the research engagement, six developers reported that gaining support from planners for these innovative schemes had, in their opinion, become comparable to gaining planner support for traditional-type developments. According to developers and constructors, planners were perceived by them as appearing to view innovative approaches—ranging from modular constructions to energy-efficient technologies—as essential for modernising housing. Further probing of these perspectives during interviews indicated that this greater acceptance often stems from the fact that the IHP aligns with broader policy goals to enhance housing quality and sustainability.

4.3 Participants also suggested that the Welsh Government's efforts to support MMC and innovation might have influenced planners' increased acceptance of these construction approaches. This support is evident in publications such as the Welsh Government's Re-imagining Social House Building in Wales and Net Zero strategic plan, which provide planners with robust frameworks that emphasise the importance of innovative construction methods and energy-efficient technologies. These strategies align with the promotion of MMC. In alignment with these strategies in favour of MMC, the then Housing Minister, Julie James underscored the importance of MMC[26].

> 'Developing the MMC industry in Wales presents us with a great opportunity to not only build beautiful new social housing, but also kick-start a new industry that will become increasingly important for our economy.' – Housing Minister Julie James

[26] Wales targets 'factory-made' modular housing | Government Business

4.4 Planners were motivated to support developments that promised to advance these goals, thereby leading to a more streamlined review process. Additionally, the growing awareness of these types of developments was highlighted as a perceived driving factor in their acceptance.

> ‘The planners have become more accustomed to that style of property. There were some standard issues, such as objections by the community council, though.’ – Developer

4.5 Despite the overall acceptance, specific regulatory challenges remained. These challenges were more pronounced in certain contexts, such as rural areas with stringent planning restrictions and where innovative designs did not align well with existing guidelines[27].

> ‘Planning restrictions meant that we couldn't increase the number of properties in that sort of settlement, which limited our scope significantly.’ – Developer

4.6 This underscored a recurrent theme in certain areas of development, where although planners were seen as supporting the design, concerns arose around existing regulatory frameworks and guidelines which had, in the opinion of many respondents, not fully adapted to accommodate these innovations, thus leading to practical difficulties in the approval process. This was rooted in a mismatch between innovative designs and planning guidelines, which primarily focused on traditional development.

> ‘Regulations can sometimes come across as anti-innovation due to the fact that they are centred around traditional brick and block, gas boiler type developments’ – Construction Partner

4.7 In this regard, some respondents felt that planners were tasked with evaluating projects that sometimes fell outside the standard regulatory frameworks. This was further exemplified by respondents who were involved in projects such as those employing innovative housing models. These respondents felt that there was a lack of clear precedent in local planning guidelines, which created uncertainties in approval processes.

4.8 For example, one developer highlighted this in relation to the classification of short-term housing developments.

[27] Technical Advice Note (TAN) 6: Planning for Sustainable Rural Communities | GOV.WALES

‘It was treated as a traditional development for planning consent as opposed to temporary. I think there’s probably a bit of learning to do with the local authority planning team.’ – Developer

4.9 Another participant indicated that they were forced to change their development design to accommodate energy efficiency regulations that did not account for their specific methods.

‘Because regulations say that we have to achieve energy performance certificate (EPC) requirements, our specification had to be changed to meet those standards because the Modern Methods of Construction (MMC) we were using didn’t fit within the existing criteria.’ – Developer

4.10 This illustrates the desire by many respondents for further adjustments in planning standards needed to accommodate MMC and energy performance criteria, which are often more advanced than traditional building techniques.

4.11 However, regarding the planning process and its acceptance among local authorities, developers and construction partners believed that the innovative proposals featured in year two had received acceptance and support from planners. This sentiment was echoed across the general planning experience, which was considered overall as being positive throughout. This fact is exemplified below.

‘Compared to our past experiences, this really demonstrates how local authority planners are beginning to support innovations and the Welsh Government's overall goal of achieving Net Zero and changing how people's homes affect the environment.’ – Developer and constructor

4.12 Another developer echoed the sentiment that government support had impacted the planning process.

‘The Welsh Government's support through the IHP and working with planning authorities has been commendable.’ – Developer

4.13 Within this overarching sentiment, a few participants said that certain regulations and policies were restrictive towards innovations and discouraged certain innovative approaches, such as temporary housing initiatives or those that measured metrics in a non-conventional manner. However, upon reflection, participants indicated that they felt that progress had been made, as exemplified by the following quote, which highlighted that changes for the better had begun to be made since the start of IHP.

‘It did feel like regulations hindered our design, but we’ve continued with the type of development we tried here, and we have noticed that it is getting easier with recent changes and updates to things [standards and regulations].’- Developer

Resident objections and the importance of early dialogue with residents, key local authority officers, and local councillors

4.14 Alongside perspectives on the regulatory challenges surrounding innovative approaches, nearly half of respondents felt that community objections were the biggest challenges to development.

‘The planning process is affected by local residents and the local councillors, but with planners and councillors, normally they'll have their own view, but they normally reiterate the voice of the residents.’ – Developer

4.15 Community objections to schemes proved to be a source of delays and complications in obtaining planning permission for several schemes. However, the nature of the objections appeared to relate less to the innovative nature of the schemes or to their IHP status. Respondents from seven schemes outlined that they believed that the objections given by the local community were typical of those surrounding social housing developments, as underscored by a variety of quotes.

‘There were some typical issues, such as objections from the community council. However, they often object to social housing projects.’ – Developer

‘There were some objections regarding parking, which were not related to the innovative aspects of the project. This occurred in an established social housing area where residents with multiple cars were concerned about losing their usual parking spaces away from their homes due to the increase in residents.’ – Social Landlord

4.16 Within this context, several social landlords highlighted the negative preconceptions about and prejudices against social developments, with residents raising concerns that the developments would house those prone to anti-social behaviour, which would be potentially damaging to the area. Participants from three separate schemes commissioned during IHP Year Two outlined this.

‘Local residents believed that schemes would be full of drug takers, offenders, or other troublemakers, and they were initially very against developments.’ – Social Landlord

‘People in the area were concerned that the scheme would be rife with anti-social behaviour due to the groups/demographics they imagined would become residents.’ – Developer

‘Residents so often have prejudices around council housing that we almost expect those types of discussions to take place around risks to the community, and it takes a lot of patience and changing of perceptions to ease people’s minds.’ – Social Landlord

4.17 These objections and resident concerns are typical of most social developments. However, community acceptance became particularly challenging when socially innovative approaches were combined with innovative building designs[28] [29].

4.18 One scheme had opted to integrate offenders into the workforce as part of a social rehabilitation initiative. This approach was chosen to provide offenders with valuable work experience and skills training, facilitating their reintegration into society and reducing recidivism. The programme aimed to not only assist in workforce development but also to contribute positively to the community by supporting social rehabilitation. However, this initiative faced resistance from residents, particularly because the construction site was located near a school. The involvement of offenders in the workforce raised safety concerns among parents and other community members. These concerns were compounded by general misconceptions about offenders and heightened security sensitivities given the proximity to young children. Anecdotal evidence from the project indicated that the initial misinterpretation by local residents contributed to the resistance.

‘Particularly due to the innovative social programme on this project of training offenders on-site, there were major concerns from parents so there was a need to reassure the parents of the children in school.’ – Project Manager

4.19 The developer acknowledged that more proactive communication with the community could have alleviated these concerns much earlier in the project. Efforts to inform and engage the community commenced after opposition, which the developer felt initially exacerbated mistrust and resistance.

4.20 Once communication improved, detailing the levels of offender involvement, the nature of their crimes (non-violent offenders were chosen), and the strict protocols and supervision in place, community concerns began to ease. The development

[28] The drivers of perceptions of anti-social behaviour report | GOV.UK
[29] Tenure social mix and perceptions of antisocial behaviour | Urban Studies Journal

team implemented several measures, including regular community meetings, transparent updates on project progress, and open days at the site where residents could meet the workforce and understand the security measures in place. These efforts highlighted the importance of early and transparent engagement with local communities, especially when projects involve sensitive or potentially controversial elements.

> ‘A lot of time had to go into reassuring the parents of the children in school. However, afterwards you find them more accepting, which highlights the importance of early engagement with local residents and including them in the details of projects.’ – Project Manager

4.21 In this regard, a key learning across the second year of the IHP was the importance of early engagement with residents, key local authority officers, and local councillors to mitigate local concerns and enable a smooth planning process through the support of local residents.

Visual design and perceptions

4.22 Mirroring findings from the IHP Year One Lessons Learned report[30], developers thought that the appearance of innovative designs led to resistance in some cases, particularly within traditional settings. Concerns about the development designs, which originated from both planning authorities and communities, were primarily concerned with aesthetics rather than the utility or environmental benefits of the projects. In rural areas, for instance, planning restrictions were tightly coupled with the character and density of the existing settlements, such that increasing the number of properties or introducing starkly modern designs was met with resistance.

> ‘Particularly in smaller villages, locals have a vision of what the area should look like, and modern designs can contrast too much with their solar panels, charging ports, and they don’t fit in, hindering boots on the ground.’ – Construction

4.23 One housing association Project Manager articulated this sentiment, stating:

> ‘The big issue with innovative designs is people can’t get past the look. This goes for both residents being concerned about living there and the community objecting. In some respects, innovative builds get the communities back up

[30] Research to identify early lessons emerging from the Innovative Housing Programme | GOV.WALES

because there's this association that they won't fit in with the local aesthetic or that they can't look traditional.' – Housing Association Project Manager

4.24 Qualitative data demonstrated across several schemes showed a belief by developers that projects introducing visual changes to neighbourhoods frequently faced initial resistance. People often have deep-rooted preferences for traditional designs that resonate with local history and cultural identity[31] [32]. Innovative designs that deviate from these norms can be seen as out of place, thus leading to a lack of acceptance. Exceptions did exist to these circumstances, with one scheme stating:

'The actual planning application was quick, even though the houses were of a different style and introduced a new type of build to the local area.' – Developer

4.25 However, when schemes deviated from the typical aesthetics design of an area, dialogue between developers and residents led to constructive outcomes such that modifications were made to harmonise the new developments with the existing built environment. A response from community consultations is highlighted in the following quotes from two developments.

'While the initial designs were innovative, they did not complement the existing architectural styles, leading us to modify several elements to better fit the community's landscape.' – Developer

'Early engagement with the community helped modify perceptions that were initially negative due to the unusual appearance of the buildings. We managed to turn around the sentiment by incorporating some of their feedback into the final designs.' – Developer

4.26 Alternatively, one developer outlined how they had identified this risk early on and had chosen to maintain a more traditional design that focused on integrating innovative technology rather than changes to building fabric. They felt that this approach led to improved acceptance of the scheme.

'Appearance is often a key point in whether local residents will object, and in consideration of this, we decided to focus on innovation elsewhere, like technological innovations.' – Developer

[31] Understanding Traditional Buildings | The Tywi Centre
[32] The Development of the Welsh Country House | ORCA Cardiff

4.27 In this regard, resistance to innovative housing designs based on their appearance is a common challenge in the field of architecture and urban planning[33]. In some cases, demonstrating that innovative, efficient homes can maintain a traditional aesthetic can increase public acceptance of these approaches, as can the consideration of local aesthetics in building design.

[33] From Boring Boxes to Beautiful Cost-Effective Houses: A study about housing development and exterior architectural preferences | KTH

5. Lessons learnt: development strategies

5.1 While still pertaining to planning, lessons associated with development strategies extend beyond the immediate regulatory and permission-based aspects of developments to include broader reflections such as strategic, financial, and operational considerations that impact the broader scope and sustainability of housing projects. The lessons learnt in relation to this area of innovative housing development are:

- Economic challenges and financial considerations
- Community feedback and design adaptations
- Human factors in housing design

Economic challenges and financial impacts of IHP funding

5.2 Developers have identified the economic challenges associated with the development of innovative housing projects. Schemes encountered substantial financial challenges, primarily due to the increased costs of employing innovative construction methods compared to traditional builds, with innovative projects often necessitating a higher upfront investment. This sentiment finds support in research publications, which suggest that MMC often entail higher initial capital and production costs[34] [35] [36]. These costs are higher due to the increased investments needed for prefabricated components, logistics, and specialised machinery, which typically exceed those for traditional construction methods. Some participants felt that these challenges were exacerbated by the limitations of typical social development funding opportunities in terms of both the rules imposed and the funding amounts.

> 'The premium was such that we would not have been able to deliver it under the social housing grant so IHP funding was instrumental.' – Developer

5.3 This theme persisted across many developers and constructor partners who recognised that the financial burden of innovative developments was substantial and that external funding was a crucial element of their feasibility.

5.4 Respondents across developments believed that the IHP2 played a pivotal role in this aspect, as it provided the financial backing that developers needed to venture

[34] Roadmap for Increased Adoption of MMC in Public Housing Delivery | GOV.IE
[35] Modern Methods of Construction (MMC): A long and ongoing journey | IStructE
[36] Review of the Business Contingencies Influencing Broader Adoption: Modern Methods of Construction (MMC) | Buildings Journal

into these cost-intensive projects. This support was about not just covering the higher costs but also incentivising local authorities and housing associations to shifting towards more sustainable and technologically advanced housing solutions.

> ‘IHP funding was an incentive at that time to make such a step forward.’ – Developer

> ‘For these schemes, funding was critical because everyone knows that the cost of delivering these is so high compared to traditional methods; there's not enough sort of work in the sector to warrant any economies of scale.’ – Developer

5.5 In this regard, one developer highlighted that, from a business aspect, their organisation typically avoided trialling new methods of construction due to the associated financial risks. However, they now use the design they trialled under IHP Year Two on a more regular basis because the experimental nature of the IHP funding allowed them to reduce risk in the long run and factor their learnings into their financial strategies for those new developments.

5.6 In managing project risks, developers also reported that they had learned to account for unexpected costs. These unexpected expenses often necessitated careful financial planning and contingency measures. It was noted:

> ‘Financial planning for these projects needs to be robust enough to handle unexpected costs and delays.’ – Developer

5.7 It was believed that the innovative nature of builds heightened the risk of unexpected costs, as the supply chain and appropriately skilled workforce were seen to be more difficult to source or less available. This means that delays and associated costs would be higher in the event of construction issues. In some circumstances, these additional costs were not associated with the innovation of developments but were typical of standard developments. One scheme had been built on the outskirts of a local authority boundary and had to make unexpected on-site access improvements during the development's non-regulatory planning phase.

> ‘We had some additional works and designs to do in order to get the roads to that standard.’ – Developer

5.8 To mitigate financial challenges and distribute the fiscal risks (the potential financial responsibilities associated with government-funded projects), some developers adopted mixed development strategies or established constructor-developer partnerships. One of these strategies involved integrating both social and private

housing within the same projects, allowing them to balance the projects' financial costs by offering some of the housing stock to the constructor, thereby reducing the higher costs associated with the construction. This was highlighted by a specialist contractor who had approached the housing association themselves rather than the more typical scenario in which the developer approaches the contractor. This shared approach not only helped manage the high costs but also ensured the projects' overall sustainability.

5.9 In addition to high construction costs, developers noted the need to consider the ongoing costs associated with the maintenance and replacement of innovative technology. Often, the installation of these systems translated into higher operational costs, including the need for specialised maintenance skills, which required internal teams to undergo upskilling. Developers expressed concerns about the sustainability of these costs, emphasising the need for robust financial planning beyond the construction phase.

> 'The bigger issue for us is the future maintenance because these units are expensive to replace.' – Developer

5.10 These perspectives highlight how respondents felt that, during IHP Year Two developments, they had to manage a complex financial landscape, including high initial costs, potential unexpected expenditures, and increased operational costs, which required long-term planning. This mirrors the challenges identified in IHP Year One, when participants noted the difficulty of accurately costing a scheme they had never attempted before[37]. In both years, the need for careful economic planning and strategic financial management remained central themes as developers explored approaches that addressed the high costs of innovation while ensuring long-term value and comfort for residents. This led to reflections across multiple schemes around rent-setting considerations. Some housing associations and local authority respondents reflected on potential adjustments to rent rates for residents in these schemes, considering the possibility of higher rents for more energy-efficient housing.

> 'These houses are really energy efficient, and they cost much less to run than most of our typical housing stock, so there is a need for consideration...Should they be needs allocated or should rates be slightly higher to reflect the lower bills

[37] Research to Identify Early Lessons Emerging from Innovative Housing Programme | GOV.WALES

and maintain fairness amongst all our tenants. This is something that needs to be addressed over the long term.' – Social Landlord

5.11 However, the practical application of these measures was described as difficult to enact on a large and consistent scale. There was also a concern that this would affect the overall IHP targets of affordable energy and reducing fuel poverty among tenants. As one developer stated:

'Economic sustainability isn't just about funding; it's about creating developments that can sustain themselves and their communities.' – Developer

5.12 The few private sector schemes involved in the IHP Year Two also reflected on the financial concerns in developing innovative housing solutions. For them, the financial aspect of development strategies was even more emphasised due to the need to achieve profit targets.

'Social housing is outperforming the private market (regarding living space size requirements and other housing quality regulations), with no change in sight… It is very difficult to maintain the commercial viability of a development if you also need to conform to social housing's standards.' – Constructor

5.13 This was associated with the perceived inability of the private sector to reflect the value of innovative approaches in terms of financial increases house prices. Developers stated:

'We expected more buy-in for these innovative homes.' – Developer.

'Typically, about 10% are interested in the innovations but for most, their concern is the location.' – Developer

5.14 This indicated a gap between the anticipated market appeal of innovative features and the actual buyer priorities, which remain traditionally inclined towards factors like location over technological or ecological advancements. Consequently, while innovative developments might offer substantial long-term benefits, the immediate financial returns do not always align with the expectations of private sector investors, who must balance innovation with market-driven demands to ensure profitability.

Community feedback and design adaptations

5.15 The integration of community and resident feedback into the design of innovative housing projects was a key takeaway with regard to ensuring long-term development success. This engagement was fundamental in bridging the gap

between modern construction techniques and local expectations. Ensuring that developments resonated well with the communities for which they were designed was a priority for developers, as outlined by one participant:

> ‘Real community engagement starts long before any construction begins; it's about building relationships.’ – Social Landlord

5.16 The process of integrating community feedback into housing designs proved to be dynamic and iterative, with developers recognising that this engagement was essential for not only gaining planning approval but also ensuring that the communities embraced the completed projects. For instance, adaptations made to designs were not merely cosmetic but were also functional, addressing direct feedback from potential residents, especially those with specific needs such as mobility issues. One poignant example shared was:

> ‘One man being placed in the development was over the moon. He was crying with happiness because where he was currently living wasn't suitable for his electric wheelchair, so a property that considered his needs was life-changing.’ – Developer

5.17 Developers noted that the process of engaging with the community could often mitigate initial resistance and lead to better outcomes in terms of resident satisfaction and project success. This was further supported by regular interactions with the community to keep them informed and involved.

> ‘Gaining support from the local community was essential. We held regular meetings to keep them informed and involved.’ – Developer

5.18 However, the path to integrating innovative housing into communities was not without its challenges. Developers had to carefully balance the drive for innovation with the social needs and preferences of the tenants. This delicate interplay was highlighted by the need to address both progressive technological features and the practical realities of the prospective occupants.

> ‘There's a conflict between being too progressive and addressing social needs versus mechanical aspects.’ – Constructor

5.19 Often, the design adaptations following community feedback led to changes in project plans. Adjustments were made to better fit community preferences and needs, thus demonstrating the flexibility and responsiveness that innovative housing development requires.

‘Originally, we were meant to have an apartment block at one end of the site and then some houses further along, but it became (*due to community engagement prior to our planning application*) just one terrace of houses.’ – Developer

5.20 In summary, the lessons from the second year of the IHP emphasised the importance of community involvement in the planning and design stages of innovative housing projects. By actively engaging with the community and being responsive to their feedback, developers could make necessary design adaptations that not only addressed regulatory and aesthetic concerns but also enhanced functionality and promoted community acceptance of the projects. This approach facilitated a smoother integration of innovative housing into diverse urban settings, thus paving the way for more sustainable and community-focused developments in future phases of the programme. This was exemplified by one developer's reflections:

‘Early engagement with the community helped modify perceptions that were initially negative due to the unusual appearance of the buildings. We managed to turn around the sentiment by incorporating some of their feedback into the final designs.’ – Developer

Human factors in housing design

5.21 During IHP Year Two, the role of human factors in the design and operation of innovative housing projects was highlighted as a key finding/lesson. These factors encompass a variety of lessons about how the behaviours and lifestyles of occupants can influence the success of innovative designs and strategies. It became clear that development strategies must carefully consider these human elements to ensure that schemes perform against their proposed outcomes.

5.22 The impact of occupancy on internal temperature was a particularly illustrative example. Preliminary data analysis of monitoring data across the available IHP Year Two schemes revealed that houses with more occupants tend to have warmer internal climates. A comparison of average internal temperatures by presumed occupancy (bedroom numbers) across all construction types showed that buildings with more than two bedrooms had an average internal temperature of 21.6°C, while buildings with only one bedroom had an average internal temperature of 19.9°C. While occupant lifestyles and behaviour likely affect these temperatures, alongside

building fabric and design, other research has also found that higher occupancy levels lead to higher internal temperatures[38] [39].

5.23 Additional evidence for the impact of occupancy on internal temperature—and its implications for building design and housing allocation—comes from a technical report that the Department for Energy Security & Net Zero published in 2023 in collaboration with the Building Research Establishment (BRE). This report explained that 'occupants' activities provide heat gains into the space to decrease space heating demand'[40]. This finding aligns with other research showing that occupancy, including that of neighbouring units, can affect indoor thermal comfort and energy use, thus emphasising the importance of considering a human presence in energy models and building performance assessments[41].

5.24 The influence of individual tenant behaviours on the performance of buildings emerged as an important factor. There were many individual examples of these findings, with one discussion highlighting a case in which a resident had complained of low temperatures and a broken heating system. Inspection later proved that the tenant didn't understand the importance of maintaining an ambient temperature in the installed system, which used sub-floor heating methods; the resident had experienced only properties with radiators that provided radiant heat, in comparison to this property, which focused on climate control.

5.25 Another example of human factors affecting building performance was identified through discrepancies in energy usage. One notable instance involved a tenant whose preference for a warmer environment led to much higher energy usage compared to other units. This was initially mistaken for a system malfunction.

> 'We had one outlier on the scheme with significantly more energy usage than any other house. We originally thought there must be a problem with the energy systems. But when we investigated, we found out that the tenant had immigrated from a hot country and preferred to keep the heating on extensively, because she preferred a very hot environment.' – Social Landlord

5.26 In many cases, outliers and 'poor performances of systems' were traced back to either personal preferences and lifestyles or a lack of tenant understanding of how

38 Study on the Impacts of occupancy on energy demand | ScienceDirect
39 Passivhaus Technical Papers | Passivhaus Trust
40 FHS Occupancy Assumptions | GOV.UK
41 Impact of unoccupied flats on the thermal discomfort and energy demand: Case of a multi-residential building | ScienceDirect

systems are designed to work rather than construction flaws or system failures. This example underscores the importance of considering these human factors and lifestyles when allocating tenants. Consideration of who goes into buildings can affect the progress against outcomes for schemes and compromise scheme design approaches. This learning is particularly important in light of the fact that lifestyle decisions can affect the performance of neighbouring houses.

5.27 Furthermore, the success of innovative housing developments often hinges on the tenants' understanding and acceptance of non-traditional technologies and systems. Instances of poor tenant buy-in highlight the need for education strategies that instruct residents on the functions and benefits of novel technologies. Developers have noted the critical nature of this educational need.

> 'People feel like guinea pigs which you know is always going to happen with innovative homes, but yeah, a lot of schemes have struggled with buy-in. Tenant adaptation is critical; they need to feel at home in these innovative environments, not like they're in a science experiment.' – Developer

5.28 Additionally, developers have emphasised the importance of aligning innovative aspirations with the practical and social realities of prospective occupants. This perspective underscores the intricate interplay between the ambition to implement housing innovation and the need to cater to the lived experiences and preferences of the tenants.

> 'The challenge with new technologies is not just technical—it's also about user acceptance and integration into daily life.' – Developer

5.29 In conclusion, addressing human factors in housing design is about not only achieving technical efficiency but also ensuring that technological advancements align with tenant behaviours and preferences. This approach enhances tenant satisfaction while ensuring the effective utilisation of innovative features, thereby optimising performance and achieving the intended environmental and economic benefits.

6. Lessons learnt: workforce

6.1 Research findings are organised into the following key thematic areas:

- Workforce skills and development
- Contractor partnerships in innovative housing development
- The importance of responsibility in project management

Workforce skills and development

6.2 Concerning the dynamics of the workforce within innovative construction projects, developers frequently highlight the scarcity of skilled labour capable of installing and maintaining the technologies integral to MMC and innovative approaches. This concern is primarily noted in developer-led schemes, as constructor-led projects often have an established workforce prior to development. Developers and non-specialist constructors (those not specialising in a particular build type) frequently cite these shortages as barriers to project execution.

> ‘There's a noticeable lack of expertise in innovative technology within the workforce.’ – Developer

> ‘The contractors typically have very traditional skill sets, and there is a significant gap in understanding how new systems work.’ – Developer

6.3 These observations are supported by the Federation of Master Builders' State of Trade Survey, which highlights critical shortages in skilled trades such as carpenters, electricians, and site managers[42]. While these shortages are a general issue within the construction sector, qualitative findings have highlighted that constructors and developers consider these issues to be particularly pronounced in innovative developments. This shortage is exacerbated by factors such as an ageing workforce, a decline in young entrants to the sector, and competition from other industries that offer more stable employment and competitive salaries.

6.4 This shortage is further evident in maintenance, as developers feel that installers are too thinly stretched to offer reliable upkeep on systems. This, coupled with the traditional skill sets typically held by housing association and local authority maintenance teams, has prompted efforts to upskill the current workforce, particularly internal maintenance teams, deemed crucial to the long-term sustainability of innovative projects. For example, the shortage of skills in handling

[42] Reports and Publications | Federation of Master Builders

advanced building technologies has led to increased training initiatives within companies.

> ‘Training our workforce in new construction methods was vital for project execution.’ – Developer

> ‘...our own maintenance team requires training to manage the systems.’ – Social Landlord

6.5 These training efforts aim to meet immediate project needs and provide broader social benefits by enhancing local employment prospects and elevating skill levels through apprenticeships. Engagement in training and development is seen as essential for the success of innovative housing projects, reflecting a serious investment in human capital[43]. A site manager commented on the ongoing necessity of these initiatives:

> ‘Continuous training and development of our workforce are not just beneficial; they're necessary for project success.’ – Site Manager

6.6 This was illustrated when a local factory was established, enhancing local job creation and facilitating on-site training.

> ‘Exploring this type of build allowed a local factory to be established and resulted in local jobs and training.’ – Developer

6.7 Overall, the challenges associated with workforce skills and development in the context of innovative construction projects underline the need for a strategic approach to managing and growing the workforce from developers and thus ensure that projects remain on track and receive adequate resources.

Contractor partnerships in innovative housing development

6.8 During the second year of the Innovative Housing Programme, the integration of private sector developers marked an evolution in the approach to constructing innovative housing. This period saw the establishment of a variety of constructor-developer partnerships. The types of partnerships formed to deliver IHP2 varied widely: flexible arrangements in which social landlords and contractors shared schemes, mixed developments that allocated a set number of houses to constructors, and more traditional paid partnership agreements. One notable initiative involved a local authority setting up a separate organisation/corporate

[43] Human capital refers to the economic value of a worker's abilities and skills.

entity specialising in innovative builds, which was regularly partnered with for future projects.

6.9 The inclusion of construction firms specialising in innovative builds in IHP Year Two was crucial to addressing and reducing workforce-related challenges. These firms often brought with them a ready-made team skilled in contemporary construction techniques. Thus, they smoothed the transition to innovative practices for some developers. For instance, contractors with experience in Beattie passive systems[44] already had teams trained for such technologies.

> ‘With the contractors they often work on the Beattie passive systems so they had already trained staff. This expertise was instrumental in mitigating the steep learning curve often associated with innovative construction methods.’ – Project Leader

6.10 The benefits of these partnerships extended beyond filling skill gaps. They fostered a learning environment where all parties could adapt to new procurement processes and roles, thereby improving overall project delivery and encouraging adaptive learning across these collaborations.

> ‘One of the benefits of this whole experience has been that this was new for us in terms of the procurement process and the roles of the different players.’ – Social Landlord

6.11 Having specialised roles within partnerships proved essential for the success of these projects.

> ‘Having a nominated subcontractor who managed and oversaw how each party fit in with the design process was a new approach for our organisation that aided in the project's success’ – Developer

6.12 The financial stability of contractors emerged as a consideration for some respondents. It was outlined by developers that the financial health of any potential partner was a key factor in moving forward with their partner organisation, as it was seen as paramount to ensuring project continuity and risk mitigation.

> ‘The contractor's financial stability was a big concern, especially after our past experiences.’ – Developer

[44] Beattie Passive is a Passivhaus-certified build system designed and manufactured by Beattie Passive Ltd. Beattie entered administration in March 2024, which might impact the applicability of some of the lessons learned with regard to their inclusion in this research project.

6.13 The flexibility and adaptability that these partnerships required were further tested during the global pandemic, which disrupted project timelines.

> ‘The pandemic really threw our timelines off. We had to adjust and replan several times’ – Contractor

> ‘COVID-19 restrictions meant we couldn't access sites when we planned, which led to some delays...working together with our constructor to develop contingency plans for various scenarios really helped minimise them.’ – Developer

6.14 Research and case studies further support the efficacy of these partnerships in improving project performance and fostering a cooperative environment that enhances skills exchange and problem-solving capabilities among the workforce[45] [46].

6.15 Effective partnering in construction not only addresses immediate technical and operational needs but also builds a foundation for long-term workforce management.

> ‘By partnering with a local developer, the project allowed for local apprentices, trainees, and full-time jobs in the areas.’ – Developer/Social Landlord

6.16 This was explained by one developer, illustrating the broader benefits of such collaborations both for the local community and towards developing and maintaining a skilled local workforce. Moreover, the trust and open communication that these partnerships established help mitigate workforce-related issues and create a more positive work environment.

The importance of responsibility in project management

6.17 Echoing the previous emphasis on the benefits of specialist skill sets during the construction of innovative builds, developers conveyed the need to appoint a dedicated individual to oversee the installation and integration of systems related to innovative technology. Challenges in the continuity of installing technology led to many participants expressing their belief in the value of having a responsible party, such as a mechanical and electrical (M&E) engineer, ensure the efficient integration of various technology systems during the installation phase. This was in reflection of gaps in expertise, which frequently led to project challenges.

[45] Partnering Mechanism in Construction | ASCE Library
[46] Behavioural Aspects in Construction Partnering | ScienceDirect

‘We are finding installation and maintenance challenging on the innovative technology. The biggest issue we've had is with our own internal experience.’ – Developer

6.18 In response to these challenges, many respondents recognised the potential benefits of having a designated individual to coordinate and train teams. They believed that appointing a responsible individual would enhance the overall integration of innovative technologies.

‘In hindsight, we may be better off appointing a mechanical and electrical engineer to train and coordinate things better.’ – Project Leader

6.19 The complexity of integrating innovative systems into construction projects often necessitates a specialised oversight role. As one developer pointed out:

‘The contractors typically have very traditional skill sets...there is a significant gap in the overarching understanding of how the systems work.’ – Developer

‘We had to go and remediate because things weren't necessarily installed quite as we expect, which highlights the need for accountability in installation. Ideally, there would be a designated expert with overarching knowledge of the systems who could coordinate the technology and manage the different contractors and stages of installation.’ – Social Landlord

6.20 The process of establishing effective collaboration in projects involving complex, innovative technologies was also highlighted.

‘Effective collaboration requires clear communication channels and well-defined roles, which are often hard to establish in complex projects’ – Constructor

6.21 This was made more difficult during the pandemic because restrictions often meant that only one person could be present for the installation at a time. This led to continuity issues.

‘The only issues we've had with the innovative tech was everything was completed during the pandemic, so only one person could be present for the install at a time. This created the issue that there was poor continuity between installing the technology and it would have benefited from a project overseer.’ – Project Manager

6.22 Learning from these experiences, some developers said that, for subsequent projects, they had employed a designated individual (such as an M&E engineer) who managed and oversaw the delivery of technology.

‘They were all learning on the job. The first phase would have been quite problematic if we hadn’t had designated experts managing and overseeing the delivery of the interactive technology.’ – Developer

7. Lessons learnt: construction

7.1 The lessons learnt and overarching themes in relation to this area of innovative housing development are:

- Supply chain challenges in innovative housing construction
- Innovative technology challenges
- Identifying and assessing the preferred construction approach

Supply chain challenges in innovative housing construction

7.2 During the second year of the Innovative Housing Programme, developers and contractors faced concerns related to the supply chain. It posed risks to the completion timelines of innovative housing projects and complicated the overall construction process.

> 'Supply chain reliability can make or break the project timeline.' – Developer

> 'We wanted to explore new construction methods, but ensuring the availability of materials was a concern.' – Developer

7.3 These challenges were particularly pronounced during the adoption of new construction methodologies like the Passivhaus approach, which requires specific materials often not readily available within the UK. The limited development of supply chains for Passivhaus standard materials in the UK meant that developers often had to source these materials internationally—increasing both costs and complexity. This issue echoed sentiments from the lessons learnt from IHP year one[47].

7.4 Similarly, concerns were raised regarding the supply of materials for timber frame buildings. Some respondents felt that the timber supply chain, particularly in Wales, remains underdeveloped. This is supported by the fact that, currently, the small quantity of Welsh timber (4% of the harvest) flowing into UK construction remains the preserve of large-scale processors[48]. However, focused efforts to improve the local supply chain throughout the region are ongoing.

7.5 Exceptions to this view were expressed by developers who specialised in timber frame or modular builds or who partnered with contractors with specialisms. In these cases, supply chain issues were not experienced. The benefits of constructor

[47] Research to Identify Early Lessons Emerging from Innovative Housing Programme | GOV.WALES
[48] Home-Grown Homes Report | Wood Knowledge Wales

partnerships became particularly evident in these contexts, as these firms often brought pre-established supply chains that could support the quick and efficient deployment of necessary materials. One Social Landlord highlighted the efficiency of such arrangements, stating:

> 'As the constructor specialised in prefabricated timber frames, they already had an established supply chain and contracts in place for timber grown in forests in mid-Wales.' – Social Landlord

7.6 Innovative technology supply chains presented another layer of complexity. Developers consistently highlighted these as a critical concern during the construction process.

> 'The supply chain was a challenge. We felt that the technology supply chain was very limited in the area.' – Developer

7.7 The need to source components from overseas, typically from countries like Germany, France, or Austria, introduced additional delays and complications. This reliance on international suppliers reflects broader trends and European Union policies, such as the Net-Zero Industry Act, which set a target for European Union member states to produce 40% of their annual deployment needs in net-zero technologies by 2030 based on National Energy and Climate Plans (NECPs) and to capture 25% of the global market value for these technologies[49]. Despite these challenges, some developers made deliberate efforts to support local supply chains by engaging Welsh firms, even if they were considered intermediaries.

> 'While components of the technology are sourced by supplies from overseas...we still consider the social value of using Welsh business.' – Developer

Implementing innovative technologies

7.8 In Year Two of the IHP, the use of advanced technologies in housing projects enabled the gathering of insights related to these technologies' challenges and benefits. This illustrated the complexities of managing innovative systems within the construction process from procurement to installation and performance. Implementing technologies such as Mechanical Ventilation with Heat Recovery (MVHR) systems with commercial specifications, ground source heat pumps, and photovoltaic (PV) films presented challenges. Contractors and developers often find these technologies complex and labour-intensive to install and maintain. During the

[49] Net Zero Industry Act | European Commission

interviews, four schemes were reported to have experienced difficulty with regard to the practical delivery of integrating MVHR systems into buildings. One developer highlighted that installers had trouble due to the system's complexity.

> ‘Installing MVHR commercial spec with 110mm ducts for heat pumps is complex.’ – Constructor

7.9 While certain technological challenges were site or workforce-specific, some were indicative of more generalised trends.

> ‘The underdeveloped power grid hindered energy export from the scheme.’ – Constructor

7.10 This highlighted a consistent theme across scheme respondents: The coordination of different systems within projects, which often required precise synchronisation and integration, was difficult.

> ‘Coordinating the different innovative systems was a big challenge throughout.’ – Social Landlord/Developer

7.11 This underscores the importance of earlier responses on workforce skills, which emphasised the requirements for employing individuals with extensive system knowledge to oversee integration processes within innovative approaches. In a generalised sense, this was further supported by the high design consultancy and administration costs outlined in the IHP Year Two applications.

7.12 In terms of the successes and outcomes of implementing innovative technology into schemes, most respondents were confident of the homes' ability to meet or exceed quality standards. There was an overarching sentiment that homes were effective in reducing fuel bills.

7.13 However, within this belief that the technology had been successfully implemented, there was also a consideration that during the construction process, energy generation technology accounted for the greatest proportion of the overall cost per house built for IHP Year Two. These technologies were integrated to combat increasing fuel poverty. However, one developer reflected on the consequences of the higher costs of implementing innovative technology.

> ‘It's not enough to just say, yes, they have low energy bills, that's a success. The target is to provide housing at scale, and it is important to remember that we must keep looking at the cost-to-benefit ratio of technology – it's about balancing

innovation and technological advances while still maximising housing provisions.' – Developer

7.14 This underscores findings from qualitative research that construction approaches must align with broader strategies for long-term change. The case study below uses data from four timber-framed houses developed under IHP Year Two to illustrate the relationship between the costs of implementing innovative technology and the benefits gained. The fact that these four houses were selected based on data availability rather than random sampling might present a limitation regarding representativeness and generalisability. This selection reflects the constraints of the data available at the time of analysis.

Case study: timber-framed house technology

7.15 Data was taken from four timber-framed houses with different energy-generating technologies and associated costs across four schemes built under IHP Year Two. The costs of their innovative technology and energy import were assessed over the same six-month period and then tabulated to provide a clear example of the costs and benefits of using these technologies within timber-framed buildings. It is important to note that limitations are associated with this data. These limitations are discussed below. The schemes were as follows:

Table 7.1: Scheme cost technology

Scheme	Features
A	• PV inset roof panels • Tesla battery (installed in the loft space) • Energy monitoring systems • Transpired solar collector (TSC)
B	• Renewable energy and ventilation system
C	• 5.4kW PV array and immersion • 5kW battery storage
D	• PV panels

Table 7.2: Scheme denominator and energy usage by scheme cost technology

Scheme	Per-Building Six-Month Average Energy Import (kWh)	Per-Building Monthly Average Energy Import (kWh)	Technology Cost per Building (£)
A	18,067.75	3,011.25	12,916.29
B	0.038	0.007	22,000.00
C	0.502	0.083	10,930.83
D	2,225	370.8	480.77

Source: *Trustmark Ltd: IHP scheme monitoring data*

7.16 This analysis highlights the numerous trade-offs that developers must navigate between cost, efficiency, and sustainability. Developers adopt different strategies to balance initial investments with the benefits of reduced energy dependence and enhanced sustainability.

7.17 While this study primarily focuses on energy import data, it is important to acknowledge that some schemes might also export energy—a factor that the current analysis doesn't capture. This limitation prevents a comprehensive assessment of each scheme's overall energy balance. Moreover, variations in energy import might be influenced by specific tariff structures or operational strategies that the available data does not reflect. For instance, Scheme A's high energy import could result from an intentional design choice, such as utilising a free overnight tariff to charge batteries, thereby affecting the overall import figures. Future studies would benefit from a more comprehensive data collection approach that includes energy export figures and detailed operational insights. This would provide a fuller picture of each scheme's performance, thus enabling a more accurate evaluation of their respective sustainability and efficiency outcomes. However, this short case study serves to demonstrate how the implementation of innovative technology and design faces challenges throughout the various implementation phases, from design through to installation and usage.

7.18 It is also important to note that the cost data was acquired at the application stage. Scheme costs likely changed beyond this point due to changes in the scheme following the application stage and external factors such as inflation and issues related to supply chains.

Choosing the preferred construction approach

7.19 Developers and constructors provided detailed perspectives regarding the lessons and outcomes of their selected development designs and models. In the following section, we consider these perspectives in combination with building performance data and costs from a range of IHP Year Two schemes. Thus, we provide data to help the reader understand the outcomes and impacts of innovative construction approaches. It is important to restate the limitations associated with the data. Outcome data is limited to internal air quality and does not consider the wide range of outcomes and impacts resulting from the schemes. Cost data was acquired at the application stage, and costs likely changed as schemes changed following the application stage and also as a result of external factors such as inflation or supply

chain issues. Developers approached the IHP with a wide and varied range of experiences and motivations for selecting scheme types. These varied among developers, with cost, familiarity, availability of information, and other factors all influencing decisions.

Modular, sub-assemblies, and components

7.20 Modular construction refers to the use of prefabricated modules or components, which are built off-site and then assembled on-site. In projects utilising modular construction, developers appreciated the efficiency-related benefits, with one noting the ease of assembly:

> 'It was built in cassettes...quick to get up.' – Developer

7.21 Wastage was also found to be reduced. According to WRAP[50], off-site construction generates up to 90% less waste than site-based building.

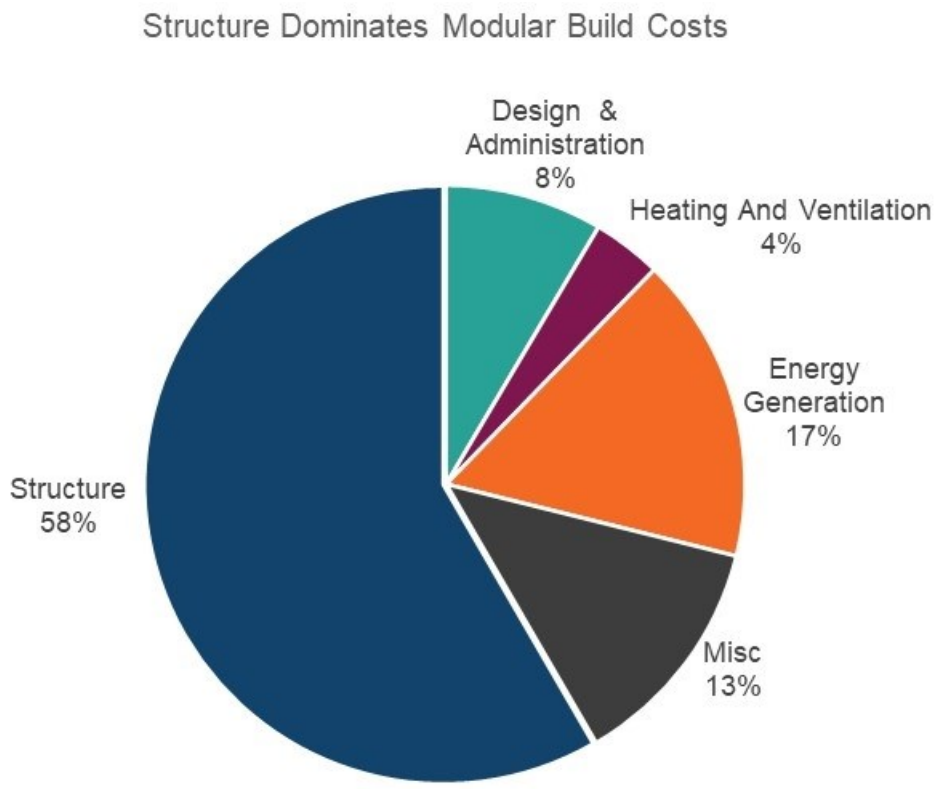
7.22 These projects were not without challenges. Internal expertise and logistical issues were barriers.

> 'The biggest issue we've had is with our own internal experience (discussing how modular build steps are carried out).' – Developer

7.23 However, costs associated with the structure of modular builds were comprised the greatest proportion of build costs as compared to other build types. Cost data from original applications was validated during qualitative engagements to generate an understanding of costs associated with each build. This is demonstrated by Figure 7.1, where structure dominates the costs.

[50] Case study: Waste minimisation through offsite construction | Waste & Resources Action Programme UK

Figure 7.1: Structure costs as a percentage of total modular build costs



Source: Trustmark Ltd: IHP scheme monitoring data.

Passivhaus or Passivhaus principles

7.24 Passivhaus is an ultra-low-energy building standard that emphasises high levels of insulation, airtightness, and mechanical ventilation to optimise energy efficiency. Developers working with Passivhaus principles reported substantial benefits, particularly in energy savings. Key advantages cited by respondents included:

> ‘Significant reductions in energy bills’ – Developer

> ‘Exceptional airtightness leading to minimal energy costs.’ – Developer

7.25 However, to fully realise these benefits, participants across these projects—including developers, constructors, and representatives from organisations involved in the management and testing of Passivhaus schemes—stressed the importance of educating tenants effectively. Proper tenant education ensures that the systems are used correctly, thereby maximising energy efficiency and maintaining the long-term performance of these highly efficient homes.

> ‘Educating the tenants is one of the biggest things because the systems aren’t being used as they should be in a lot of cases.’ – Social Landlord

7.26 These reflections highlight the fact that from the perspectives of local authorities, the real-world applications of these standards sometimes fell short of expectations. Several interviews highlighted this fact.

> ‘Passivhaus obviously performs on paper way better for air tightness and for heat loss, but in the real world I'm not sure how much difference it makes in pounds and pence.’ – Social Landlord

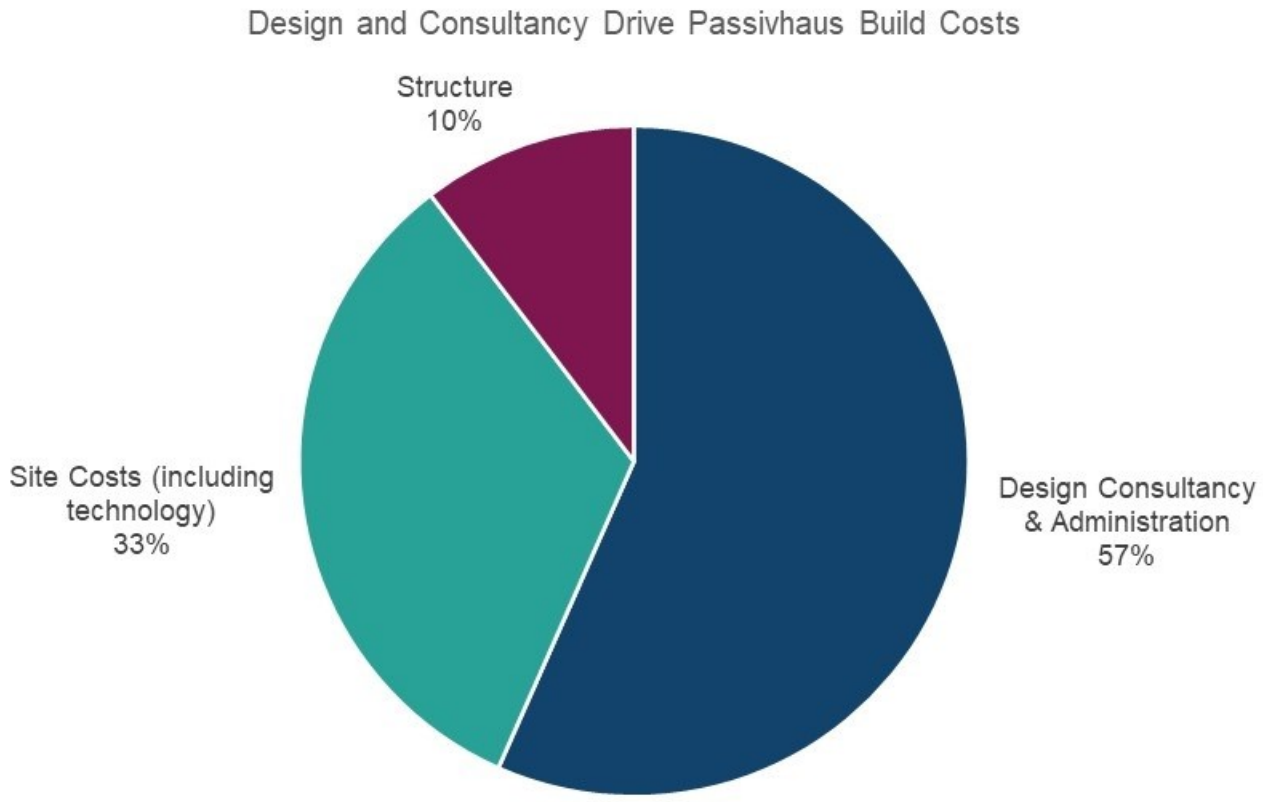
7.27 The initial cost, long-term maintenance, and system replacement were also noted as being challenging and costly.

> ‘It's maintaining it which is challenging and costly. It's also replacing it in 10 to 15 years’ time – Social Landlord

> ‘The Passivhaus standard presents a challenge due to an overly extensive supply chain. Implementing Passivhaus standards is a nightmare and too repetitive.’ – Developer

7.28 This is substantiated in project costings across Passivhaus schemes. They show the extensive cost surrounding accreditation, consultancy, and other design parameters.

Figure 7.2: Innovation costs across Passivhaus or Passivhaus principles builds



Source: Trustmark Ltd: IHP scheme monitoring data.

Energy efficiency and green model

7.29 Energy-efficient and green model schemes are developments that prioritise technologies and designs that minimise energy consumption and environmental impact. In some cases, these design models overlapped with other build types, occasionally using timber frames, Passivhaus principles, or modular construction techniques. However, these schemes were typified by an 'environmental-centric' approach that aimed to ensure high energy efficiency, the utilisation of green energy, and the production of a low/reduced carbon footprint.

7.30 During this research, when we engaged with developers focusing on energy efficiency and green models, all respondents conveyed the viewpoint that these projects often outperformed traditional schemes regarding tenant outcomes. Most respondents attributed this fact to increased efficiency and reduced bills. Two respondents also highlighted that they felt that these types of schemes, by focusing on objectives over a specific approach, increased the likelihood of long-term success. In this regard, these developers thought that a selective approach to development, centred on energy efficiency and reducing the carbon footprint, allowed different design features to be 'cherry-picked' to suit the specific make-up of the area and community.

> 'Not having to stick to one specific approach and the ability to integrate different aspects and ideas from different designs really allowed us to shape the development towards the local context of the build site and local community.' – Developer

7.31 One social landlord suggested that tenant outcomes were improved, as green models prevented tenants from feeling like 'guinea pigs'. Housing was more akin to traditional builds.

> 'Compared to more 'high-tech' developments, these houses are closer to what people (the residents) expect from a house, so there [are] less fuel bills and less emissions produced, but tenants still feel like they live in a 'normal home'.' – Developer

7.32 Developers believed that green models aided in the Welsh Government's Net Zero commitments, as low-carbon footprint developments can be built without relying on specific supply chains or design constraints that could hinder progress.

7.33 However, technical and economic challenges, such as infrastructural limitations and complex pricing strategies, were prevalent. Developers suggested that technical challenges were highly contextual, with strategies occasionally proving difficult to implement during the construction phases. One example highlighted issues surrounding plans to provide low or no-cost energy generation by exporting energy to the grid when the scheme had a surplus and taking energy from the grid during times when energy-generating technology was insufficient to meet residents' power demands (such as during winter months when solar energy production is reduced).

> ‘The underdeveloped power grid hindered energy export from the scheme.’ – Developer

7.34 During these discussions, one respondent discussed the difficulties involved in assigning fuel costs within schemes that utilise shared energy management systems. Reflections centred on how best to account for different amounts of energy usage amongst residents when also considering occupation levels, generating technology per house, and other factors.

> ‘Pricing 5 KW PV systems in terms of value addition to homes and pricing strategies is challenging.’ – Developer[51]

7.35 This example highlights the viewpoint that as green models are aimed towards reduced carbon footprints and high energy efficiency, the supply chains, approaches, and technology, as well as other factors, must be specific to each scheme. Furthering this point, some respondents said that they felt this meant that the scalability of these approaches was somewhat impacted.

> ‘This is a solid approach on [the] small scale, but there is a direct correlation between the scale and difficulty in achieving success with these schemes. The more you build, the more difficult the supply chain is to source locally, the further you have to reach to source materials, and the carbon footprint goes up and up.’ – Developer

7.36 Alongside scalability concerns among some developers, respondents from three out of the six energy-efficient and green model schemes cited project cost management as a concern that they felt was specifically linked to this build method. This was

[51] Some developers find it difficult to assess the correct pricing strategy for rent and house prices when considering the value of energy generation technology. This challenge is further complicated by external factors that can reduce the efficiency of these technologies.

exemplified by one respondent who outlined how they perceived costing to be difficult.

> ‘If each house is targeted to have a specific carbon footprint and be energy positive, then each house, depending on its orientation, intended occupation, positioning and such, needs to be designed independently…that can be a nightmare for costing.’ - Developer

Timber construction

7.37 Timber construction focuses on using wood as the primary structural material. It is typically viewed as a more sustainable, lower embodied carbon approach than traditionally constructed developments. A lower embodied carbon approach refers to the reduction in greenhouse gas emissions associated with the production, transport, and assembly of building materials. Within IHP Year Two, respondents involved in timber-constructed developments reflected on the environmental successes of this approach. They indicated that utilising locally established timber supply chains within Welsh regions enhanced the delivery pace of the projects, particularly when the projects partnered with constructors who specialised in this area and had already established resources.

> ‘Using Welsh larch, the constructor already had supply chains…set up which was beneficial for the speed of construction.’ – Developer

7.38 At the same time, developers and constructors both emphasised that with regard to the carbon footprint and environmental impact of these schemes, they believed their projects benefited the environment.

> ‘The timber construction allowed us to use sustainable resources and reduce the overall environmental impact of our projects.’ – Developer

7.39 This belief is supported by research studies, with one notable example highlighting that a three-bedroom semi-detached house constructed using offsite panelised timber frame stores approximately 34 tonnes of carbon dioxide (CO_2) within its fabric[52].

7.40 In terms of energy efficiency, timber frame open panel systems, although not as energy efficient as closed panels, still provide better thermal performance than brick and block-built houses. While more expensive than timber frame, structural insulated panels (SIPS) represent one of the most energy-efficient and airtight

[52] Review of Carbon Footprint Reduction in Construction Industry | MDPI

building systems available, with U-values typically between 0.19 and 0.27 W/m²K[53]. This demonstrates the range of timber construction options available, allowing developers to select systems based on their priorities, such as cost or energy efficiency.

7.41 Developers also praised the speed of delivery with regard to timber-framed construction. This is supported by research suggesting that, on average, timber frame houses can be built around eight weeks faster than builds using traditional construction methods[54].

7.42 However, supply chain disruptions had an impact when they arose.

> 'Finding the right materials at the right time was a hurdle, especially with the supply chain disruptions' – Developer

7.43 Another developer indicated that supply chain disruptions and quality issues were setbacks during their project.

> 'We had to switch suppliers midway due to delays and quality issues.' – Developer

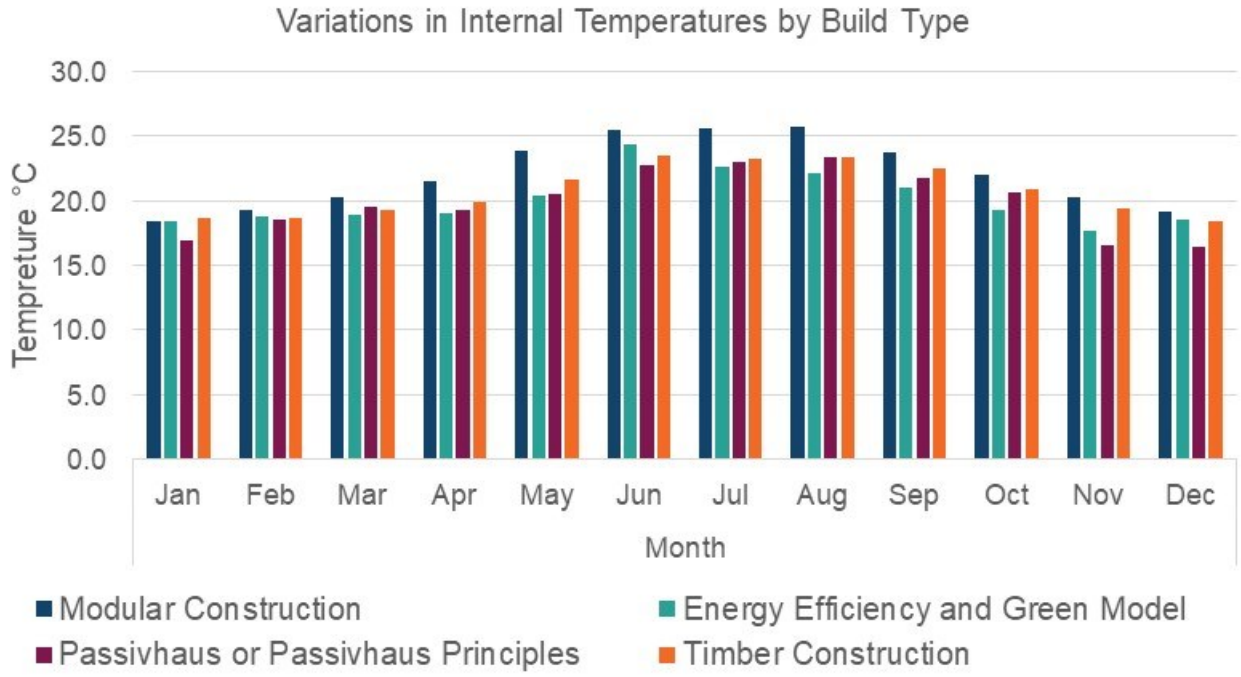
Seasonal performance of build types

7.44 To build on developers' and constructors' perspectives on their chosen construction designs and methods and assess the performance of different builds, we combined monitoring data with external data so that we could understand the average performance of the IHP Year Two build types. To account for construction and occupancy timelines, data from between January 2022 and December 2022 was used .

7.45 To begin, this section presents an analysis of internal temperature, humidity, and CO_2 levels to determine how each build type performs across different seasons. By examining these factors and incorporating energy usage and other data, we can assess the outcomes for occupants, as well as the sustainability of each construction approach. Designed to lead on from each of the above build overview sections, this analysis begins with an overview and description of key data sets. Then, it builds upon them to enable a firm interpretation of findings, ensuring that each piece contributes to our understanding of the preferred construction approach.

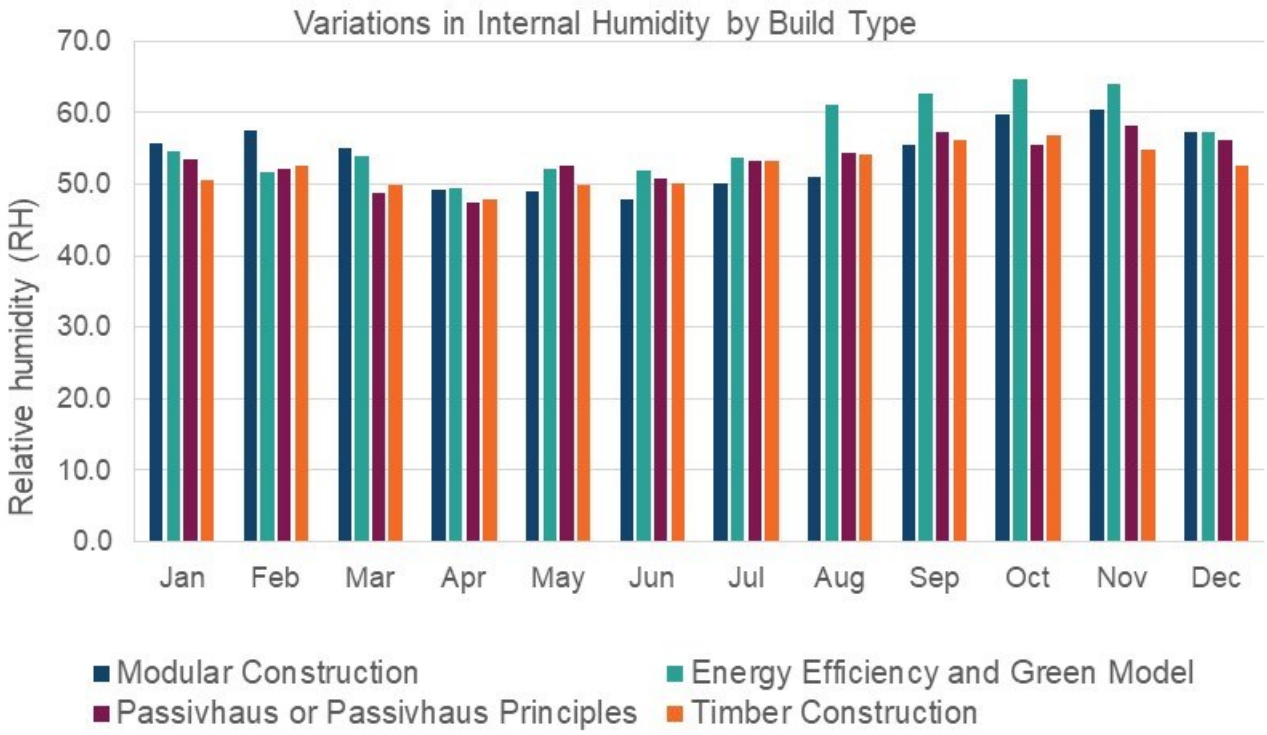
53 Which Wall Material Has the Best U Value? | Home Building UK
54 Home-Grown Homes Report | Wood Knowledge Wales

Figure 7.3: Monthly average internal temperatures by build type



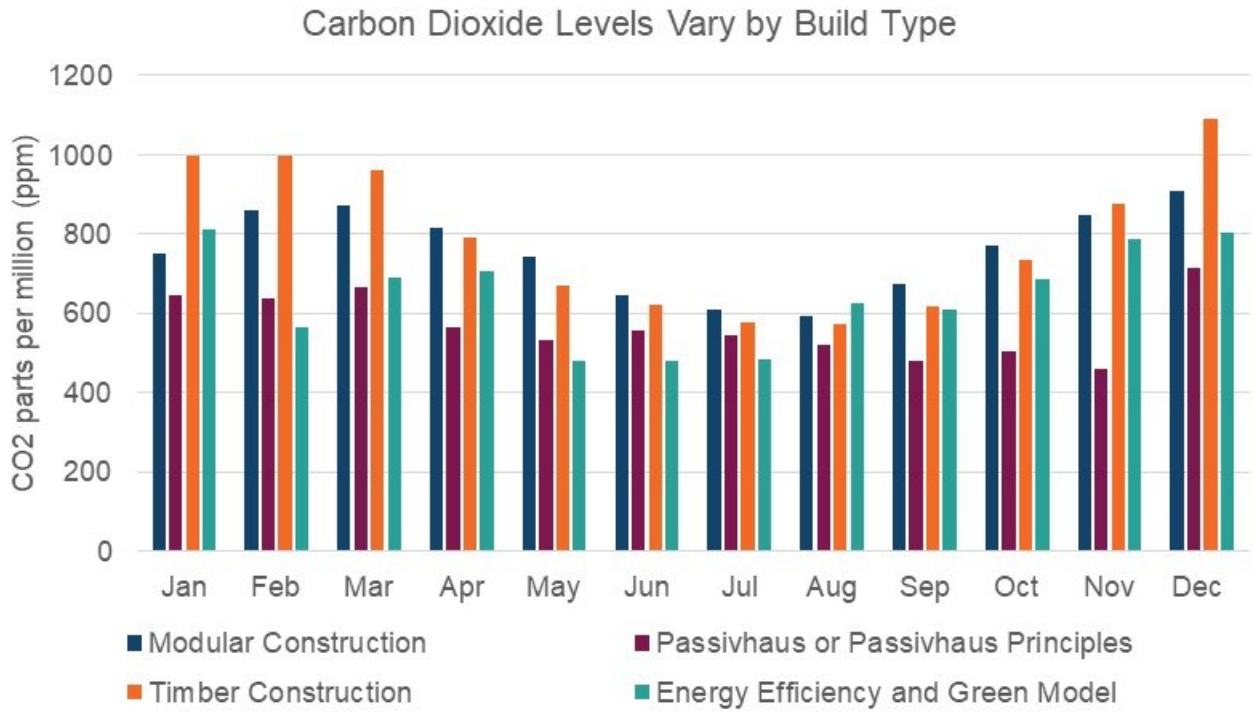
Source: Trustmark Ltd: IHP scheme monitoring data.

Figure 7.4: Monthly average internal humidity by build type



Source: Trustmark Ltd: IHP scheme monitoring data.

Figure 7.5: Monthly average internal carbon dioxide averaged across build types, 2022



Source: Trustmark Ltd: IHP scheme monitoring data.

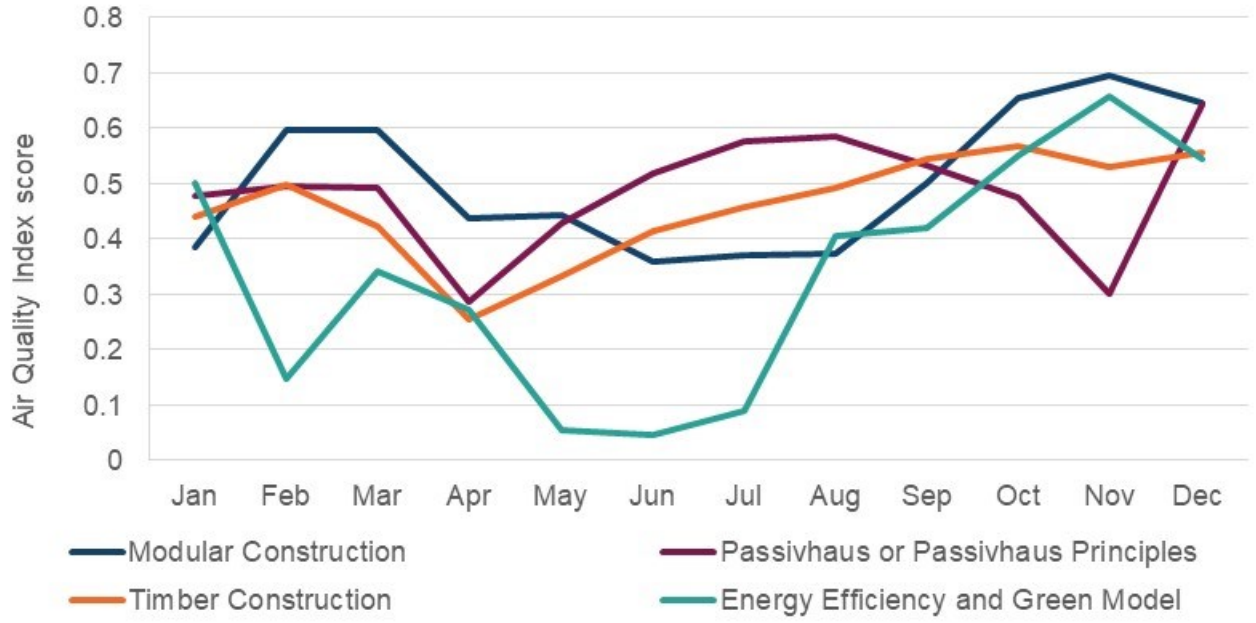
Air quality index

7.46 Utilising the averaged metrics of internal temperature, humidity, and CO_2 levels presented above, we assessed the air quality across different build types by generating an air quality index (AQI). By creating these AQI scores, we could evaluate the range of these metrics holistically, thus ensuring that we assessed how each build performed across all three areas of indoor environmental quality. This comprehensive approach provides a more complete picture of each building type's ability to maintain healthy indoor environments.

7.47 We calculated the index by normalising and weighting CO_2 concentrations, temperatures, and humidity levels, assigning greater importance to CO_2 due to its impact on air quality. This method ensures that each factor contributes appropriately based on its relevance to overall air quality. A higher score indicates better air quality. Figure 7.6 illustrates the monthly AQI averaged across build types; it shows noticeable peaks and troughs over time. One possible explanation for the peaks and troughs observed in the AQI data is seasonal variation. For example, during colder months, occupants tend to keep their windows closed to retain heat, which reduces ventilation and increases indoor CO_2 levels and humidity. Additionally, limitations in the data—such as equipment performance and the limited number of

schemes monitored—might introduce inconsistencies. Despite these limitations, the AQI provides valuable insights into overall trends in indoor environmental quality across different build types.

Figure 7.6: Monthly air quality averaged across builds per month build types



Source: Trustmark Ltd: IHP scheme monitoring data.

7.48 Passivhaus buildings consistently achieved higher AQI scores throughout the year, particularly during the summer months, indicating superior indoor air quality. Modular construction and Timber Construction timber construction showed higher AQI scores during the colder months, suggesting effective maintenance of indoor conditions during these periods. Energy efficiency and green models displayed variability in AQI scores, peaking during transitional months like September and October. This variability suggests that while these models can achieve excellent air quality under certain conditions, they might require more active management or design enhancements to maintain consistent performance.

7.49 The findings indicate that no single construction approach is universally optimal. Each build type presents a set of trade-offs between performance outcomes, costs, and practical implementation challenges. Selecting the preferred construction approach requires a nuanced, context-driven evaluation considering project-specific objectives, local conditions, and long-term sustainability goals. Developers and policymakers must balance performance metrics with financial feasibility, supply chain reliability, and occupant needs.

8. Main learnings

Year Two of the IHP featured a range of schemes that offered broad insights into various lessons and findings related to the unique, innovative nature of the developed schemes. This section provides an overview of the main learnings from the evaluation. The findings are intended to inform future innovative housing programmes, the development of innovative housing, and innovation in housing development.

Planning

Acceptance of Innovative Approaches: Local authority planners were generally receptive to innovative approaches proposed by developers, viewing them as integral to modernising the housing landscape. This acceptance was attributed to the alignment of the IHP with broader policy goals aimed at enhancing housing quality and sustainability, supported by government initiatives promoting MMC.

Regulatory Challenges: Specific regulatory challenges were more pronounced in rural areas with stringent planning restrictions. For example, some developments faced limitations in increasing property numbers due to existing settlement regulations. This highlighted the need for updates in planning guidelines to accommodate innovative designs.

Community Engagement: Early and transparent dialogue with local residents, key local authority officers, and local councillors was critical in mitigating community objections and enabling a smooth planning process. Addressing community concerns early helped reduce resistance related to the innovative aspects of the developments.

Strategic development

Economic Challenges and Financial Considerations: The costs associated with MMC were reported as being higher than those for traditional builds. These financial pressures often required external funding, and many developers emphasised that without IHP funding, they would not have been able to trial these innovative approaches. This financial backing not only made the developments possible but also incentivised local authorities and housing associations to consider more sustainable and technologically advanced housing solutions.

Community Feedback and Design Adaptations: Incorporating community feedback into the design of developments proved essential for ensuring the success of

innovative housing schemes. Developers recognised that early engagement with residents and local stakeholders was vital for gaining planning approvals and fostering community support. Adaptations based on community input helped developers better align the innovative designs with local preferences and needs, thereby improving overall acceptance and satisfaction once the schemes were completed.

Human Factors in Housing Design: Developers highlighted how tenant behaviours and lifestyles could affect the performance and success of innovative designs. Proper tenant education on using new technologies was essential for achieving the intended benefits of energy efficiency and comfort. Additionally, developers acknowledged that while technological advancements are important, aligning these innovations with residents' practical needs and preferences is equally critical for long-term success.

Workforce challenges

Skilled Labour Shortage: There was a noticeable scarcity of skilled labour capable of installing and maintaining innovative technologies. This shortage necessitated training programmes to upskill the local workforce and internal maintenance teams. Developers had to invest in training to ensure that their teams could manage the new technologies effectively.

Contractor Partnerships: Partnerships with construction firms specialising in innovative builds were crucial to reducing workforce-related issues. These firms brought pre-established teams skilled in contemporary construction techniques, which facilitated the integration of innovative practices.

Project Management: Appointing a dedicated individual, such as a mechanical and electrical (M&E) engineer, was recommended for overseeing the installation and integration of different systems and thereby ensuring efficient project execution. This role was critical to managing the complexities of innovative projects and ensuring that all systems functioned cohesively.

Construction

Supply Chain Issues: Developers frequently encountered difficulties with supply chains for specialist materials. These difficulties posed risks to construction timelines and costs. The challenges were particularly pronounced in projects that

adopted new construction methodologies like Passivhaus, for which materials often had to be sourced internationally, thereby increasing costs and complexity.

Financial Considerations: The financial challenges of innovative developments were substantial, with higher initial costs and potential unexpected expenditures. IHP funding was crucial to providing the necessary financial backing to bridge these gaps. Developers noted that IHP funding enabled them to trial new methods and technologies that they would otherwise have avoided due to financial risks.

Technological Integration: Implementing advanced technologies such as MVHR systems and ground source heat pumps presented challenges in terms of installation and maintenance. Coordinating different systems within projects often required precise synchronisation, highlighting the need for skilled oversight.

9. Appendix

Appendix A: discussion guide

Introducing the session

Overview/purpose: The beginning of all interviews should give each respondent the same information. This information includes the purpose of the research, the interviewer's identity, and any other regulatory information (GDPR, confidentiality, timings, etc.).

Structure

Introduce yourself: 'My name is [Name] from the Industryline Research team.'

State the purpose: Discuss the IHP project related to courses and training.

Confirm availability: Ask if now is a good time; reschedule if necessary.

Provide a brief overview: The session will last 30-45 minutes.

Explain the recording process:

- Calls are recorded for accuracy
- Recordings are deleted after 14 days
- Only Industryline Research staff have access

Assure confidentiality:

- Responses are confidential
- Demographic information may be used in reports without personal identifiers

Ensure consent:

- Seek affirmation: Confirm that the participant understands and is okay with the process, including recording their voice
- Ensure comfort: Participants can voice discomfort or stop the session at any point
- Confirm consent: Acknowledge receipt of the signed consent form and reaffirm their willingness to continue

Section 1: IHP Involvement

Overview/Purpose: This section is designed to profile the respondent's involvement with the IHP and address the motivators, comparisons, and key takeaways from their experiences under the programme from an organisational perspective.

Begin with a recap/overview of their scheme to ensure that the scheme notes are correct and it is the right participant.

What motivated your organisation to apply for funding under the IHP?

- Why did you choose to participate in the second year of the IHP rather than the first year?
- When and how did you become aware of the Innovative Housing Programme?
- Were you actively looking for funding for your project?
- Did you consider any other schemes or streams of funding?
- If so, what other schemes did you apply for?

How did your IHP proposal differ from the standard housing development strategies you usually propose/plan?

- If applicable, why did you adopt this deviation from your typical developments, and what did you see as the advantages of these changes?
- Were the above advantages the main driving factors for adopting this type of development strategy for this project, or were there other factors that influenced your decision?
- What have been the impacts of participating in the IHP for your organisation? Specifically concerning the impacts (positive or negative) of engaging in a project that differs from standard housing developments, under IHP funding?

Have there been any benefits of participating in the IHP for your organisation and for your customers?

    - If none, attempt to draw out pain-free areas during the programme.

- Have there been any disadvantages or drawbacks to participating in the IHP?
    - If none, attempt to draw out friction points.
- Have there been any differences in providing housing through this scheme over your standard provision?
    - If so, in what ways?
- Was your project or organisation experiencing any barriers prior to receipt of IHP funding?

Section 2: lessons learned

Overview/purpose: This section is designed to understand specific barriers, challenges, and advantages of the planning, construction, and staffing of each scheme.

Planning Section – Developers only

Could you share your experience in navigating the scheme(s) through the planning stages?

- Were there unforeseen or surprising planning hurdles?
- Did approval times meet your expectations?
    - Ensure that expected/actual timelines are discussed.
- How extensive was the assessment of the scheme by planning authorities, and in your opinion, how did it compare to the assessment of more traditional schemes?
- Regarding (state how the scheme is unique/innovative), did any complications occur during the planning process due to the scheme's unique nature?
- Was there ample support from planning officers?
- Did planning conditions align with your expectations?
- Did you encounter any issues with public procurement?

How does the planning process for this scheme compare to the planning process for housing developments built using traditional construction techniques, such as linear construction with bricks/concrete blocks, that you have been involved with?

- Concerning timeframes, attitudes of planning officers, extent of support, complexity, decisions, and the nature of planning conditions.

What are the main takeaways from the planning phase that you believe others should know when considering a similar route?

Upon reflection, would there be alterations to your planning method if you undertook this project again?

Construction Section – Developers and Contractors

Could you provide a brief overview of the construction method related to this scheme?

- Were there any unique facets to the approach?
- What led to this specific method's adoption?

Could you delve into your experiences during the scheme's construction phase?

- What were the inherent challenges of the chosen method?
- Strategies for overcoming these?
- Notable benefits or drawbacks?
- Topics encompassing supply chain management, infrastructure, and technology nuances?

What main insights about the construction technique would you suggest to those considering similar endeavours?

Looking back, would you adapt your construction strategies if you had to redo this project? If so, how?

Workforce and Skills Section – Developers and Contractors

Can you pinpoint the primary workforce hurdles encountered during this scheme?

- How did you go about assembling your workforce?
- Short-term vs. permanent hires?
- Was a crew present before you received funding?
- Was the scheme's innovative nature a challenge?
- Did the workforce issues relate solely to construction positions, or was it more widespread?

[If yet to be addressed] Were there specific challenges in sourcing a skilled team to ensure that the scheme met high standards?

- Implications of these challenges?
- Effects on the schedule, scheme quality, and budget?
- Resolution strategies?
- Was training a part of the solution?

Were there instances in which workforce challenges affected the planning and construction phases?

What are the key lessons that you've identified in relation to the workforce and skills that you would like to highlight for others?

Upon reflection, would you make adjustments in relation to workforce and skills if you took on this project again?

Section 3: IHP vs. Conventional Building

Overview/Purpose: This section is designed to provide clarity on how traditional builds and those undertaken under the Innovative Housing Programme are either alike or different.

How do your experiences differ between housing projects under the IHP compared to traditional building programmes?

- To clarify, are these variances solely related to the IHP, or do they pertain to novel approaches as a whole?

[If yet to be addressed] Have you noticed cost disparities in construction between IHP and standard schemes?

- What do these cost variations pertain to? For instance, workforce, materials, etc.

[If yet to be addressed] Were there any material availability distinctions between the IHP and conventional schemes?

- Which materials were notably harder to procure?
- How did you address these challenges? Did you resort to alternative materials? What were the ramifications?

How did construction waste material levels between IHP and typical schemes compare?

- Were certain materials more wasteful?
- What caused this excessive waste?
- Were there strategies implemented to curb this waste? Were there cost implications due to this waste?
- Repeat comparison of site wastage with added insights: Now probe the costs, sustainability, and overall differences between the two build types in terms of wastage. Ask them to reaffirm their answer in consideration of an understanding of materials vs. prices vs. volume.

Did you observe differences in construction speed between IHP and regular schemes?

- What were the primary reasons for either accelerated or delayed construction periods? What were the consequences of such time variations?

Section 4: specific challenges

Overview/Purpose: This section is designed to understand the challenges associated with specific build types, as categorised and as individual projects.

Are there any unique challenges or advantages you'd like to pinpoint concerning the construction methods used in your IHP projects that haven't been discussed?

- Specific issues regarding MMC, OSM, and their comparison to standard techniques?

Are there any unique challenges or advantages you'd like to highlight about the different site types used for your IHP projects that haven't been discussed?

*Challenges might vary based on factors such as brownfield/greenfield, urban/rural locales, site size, land ownership, geographical features, site conditions (like remediation necessities), conservation concerns, etc.

Section 5: outcomes and outputs

Overview/purpose: This section is intended to provide clarity on the final results, outputs, and community impact resulting from the IHP funding.

Developers only

Note: Adjust questions based on individual project details from the application forms filled out by successful developers.

How would you rate your performance in delivering the proposed outputs and outcomes from your initial proposals?

- Planning?
- Construction phase?
- Final completion?

Scheme-specific questions

Use this section to inquire about any questions stemming from your review of the application forms and learning presentations if they have not been discussed yet.

Scheme-specific questions will be reviewed during update meetings to discuss any potential changes and tailoring required.

Appendix B: comparative spider graph methodology

The Air Quality Index (AQI) scores were developed to evaluate indoor air quality across different building types by considering three key environmental parameters: CO2 concentration, internal temperature, and humidity. The following steps outline the methodology used:

1. Data Collection: Monthly average data for CO2 concentration, temperature, and humidity were gathered for each building type. This data was compiled to ensure consistent temporal and categorical coverage.
2. Normalization: Each parameter was normalised to a 0-1 scale using Min-Max scaling. This step allowed the different metrics, which have varying units and ranges, to be comparable by rescaling them to a uniform scale.
3. Weight Assignment: Weights were assigned to each parameter to reflect their relative importance in determining overall air quality:
    - CO2 Concentration: 0.4 (higher weight due to its significant impact on air quality and health)
    - Temperature: 0.3 (moderate weight as it affects comfort and perception of air quality)
    - Humidity: 0.3 (moderate weight as it impacts comfort and potential for allergen growth)
4. Index Calculation: The normalised values for each parameter were multiplied by their respective weights and summed to create the weighted AQI score:

    AQI Score = 0.4 × Normalized CO2 + 0.3 × Normalised Temperature + 0.3 × Normalised Humidity

    This calculation was performed for each month and building type to assess their relative air quality performance throughout the year.

5. Interpretation of Scores: Higher AQI scores indicate better air quality, reflecting optimal combinations of CO2 levels, temperature, and humidity. The resulting table provides insights into seasonal air quality trends and highlights the comparative performance of different building constructions.

Appendix C: data dictionary

Due to the unavailability of a complete data dictionary from the data provider, researchers have made the following assumptions regarding data descriptions and measurement units:

Category	Description	Unit of Measurement
Internal Temperature	The average internal temperature recorded in building with monitoring systems.	Degrees Celsius (°C)
External Temperature	The average external temperature recorded in the scheme's coordinates/postcode.	Degrees Celsius (°C)
Internal Humidity	The internal relative humidity of the air inside the building.	Percentage (%) (Relative Humidity, RH)
External Humidity	The relative humidity of the air outside in the scheme's coordinates/postcode.	Percentage (%) (Relative Humidity, RH)
CO_2 Levels	The internal concentration of CO_2 in the air.	Parts per million (ppm)
Energy Usage	The amount of energy. This was separated as energy used, energy imported from the grid, and energy generated.	Kilowatt-hour (kWh)
Averaged Temperature Across Each Month	The average temperature recorded for each month.	Degrees Celsius (°C)
Temperature Difference	The difference between internal and external temperatures.	Degrees Celsius (°C)
Cost	The monetary cost associated with energy usage or other relevant factors. All figures use GBP.	Pounds (£)
Internal vs. External Temperature Percentage Change	The percentage change between internal and external temperatures.	Percentage (%)
Humidity Percentage Change (External vs. Internal)	The percentage change in humidity levels from external to internal environments.	Percentage (%)