Increasing offsite housing construction in Scotland:
An evidence base to support new policy and systems

Final Report

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Context

The reader may find it helpful to understand the context in which this research took place. This research commenced in November 2018 and since then there has been a number of significant events relating to construction that will create change in the sector.

For example, the Independent Review of Building Regulations and Fire Safety, published in May 2018, challenges the construction sector to improve its health and safety culture to deliver high-quality, safe buildings. The Grenfell Tower Fire inquiry began in September 2017 to investigate the causes of the fire and other related issues. Findings from the first report of the inquiry were not released until October 2019 - after this research had concluded. In Scotland, the ramifications of some key reports were still to be fully impact assessed prior to the research. These include the 'Review of Building Standards Compliance and Enforcement in Scotland' by Prof. John Cole issued in June 2018.

Above all, the Scottish Government's target for the Affordable Housing Supply Programme remains a key objective for the affordable housing sector in Scotland during the life of this Parliament and it is hoped that this study will contribute to that target to some extent and, moreso, to future programmes.

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Executive summary

Introduction

The purpose of this project is to provide evidence of the potential contribution offsite construction offers to address the challenges faced by the affordable housing sector in Scotland. Funding for the project is drawn from the Construction Scotland Innovation Centre, Scottish Government and Scottish Enterprise.

The project is made up of three components:

- a research project mapping the benefits of offsite construction and the barriers confronting the sector's potential contribution to affordable housing in Scotland;
- a study to understand the current and future capacity of offsite construction to overcome these barriers and for the sector to increase the contribution it makes to the provision of affordable housing in Scotland;
- a series of co-design workshops with key stakeholders to consider how offsite construction can overcome the barriers the sector currently faces and realize the potential contribution it can make to the future of affordable housing in Scotland.

The evidence the project offers is sourced from:

- an analysis of 3,500 scientific documents on affordable housing;
- a systematic review of more than 500 academic publications on offsite construction;
- interviews with experts involved in offsite construction and the provision of affordable housing in Scotland;
- a multiple-case study analysis of offsite affordable housing construction projects in Scotland;
- a desktop survey of the offsite construction sector in Scotland and the financial status of the business they conduct, in terms of productivity and growth;
- a series of co-design workshops with key stakeholders from the offsite construction sector and involved in the delivery of affordable housing in Scotland.

For the purposes of this project, following definition of offsite construction is adopted:

> The manufacture and pre-assembly of construction components, elements, or modules, in a factory before being fully assembled onsite. There are four main categories: panelised systems, modular or volumetric systems, sub-assemblies and components, and hybrid systems (which combine different categories).

Within the term offsite construction there is a broad spectrum of both 'advancement' (the application of smart manufacturing methods and digital technologies to increase productivity, efficiency and sustainability) and 'enhancement' (growth in the amount of construction undertaken in the factory compared to onsite e.g. rather than just constructing the frame, also adding insulation, windows and cladding).

Findings

The main findings of the three work streams are as follows:

1. Benefits and Barriers:

When correctly applied, the use of offsite construction can benefit the provision of affordable housing in Scotland by:

- reducing the time taken in the design and build stages of construction;
- improving the cost and quality of construction;
- lowering the levels of waste, energy consumption and carbon emissions from the manufacturing and assembly of affordable housing;
- developing a more diverse workforce in the construction sector;
- improving the health and safety standards of the workforce employed in the provision of affordable housing.

However, a number of barriers also exist:

- a longstanding preference for agencies in the housing supply chain to use traditional construction methods;
- the costs of modern methods and the tendency for offsite manufacture and assembly systems to be dependent on economies of scale;
- the logistics of transporting components to site can be expensive and run the risk of increasing energy consumption and carbon emission (depending on the location of manufacturing plants and sites where the housing is assembled);
- a different, more technically enhanced and digitally-enabled set of skills is needed in order for all the stakeholders involved in the supply chain to be competent in managing the manufacturing and assembly of affordable housing;
- the vulnerability of housing provision to fluctuating market conditions in the construction sector.

2. Present and Future Capacity:

The review of capacity within the offsite manufacturing sector across Scotland finds:

- there are now 33 identified companies manufacturing offsite products in Scotland and 19 sub-assembly suppliers, 75% of them using timber, 15% steel and 10% concrete components;
- the 33 offsite manufacturers are projecting an increase in the sector's annual turnover from £291 million to £343 million (18%) over the next 5 years. This equates to a growth rate of approximately 3.5% p.a.;
- by 2023 employment in the sector is also expected to increase from 1,854 to 1,896 (2%);
- this increase in turnover relative to employment reflects the productivity gains secured by the sector over the past 5 years and the companies' expectation this growth shall continue up to 2023.

In conducting interviews with 15 of the manufacturing companies (who account for 55% of the annual turnover and 78% of the employees), the review also finds:

- 85% of the manufacturers' annual turnover relates to housing, with the private sector accounting for 54%, the public (social and affordable) sector 31%;
- the capacity of the companies to supply the housing sector is the equivalent of approximately 12,400 units per annum, with an internal floor area of 61 m^2 per unit;
- in line with productivity gains achieved by the manufacturers over the past 5 years, the companies estimate that by 2023 this capacity will grow to 18,000 units (an increase of approximately 45%). Of the 18,000 units, the manufacturers speculate that approximately 5,200 would be for the social or affordable housing sector (although the companies suggest actual number will vary depending on the size of the units);
- this growth would also be resource-efficient, with 86% of waste materials being recycled compared to the 75% currently achieved from traditional methods of construction;

- in the longer term, 11 of the companies also propose to set up additional manufacturing plants and should these plans come to fruition it is estimated:
    - this extra capacity would provide the opportunity to produce 14,152 additional housing units per annum;
    - this could increase the production of housing units to 32,152 per annum (approximately 79% on the 2023 figure).
- the supply chains for these companies are currently located within the UK, with 85% of the products sourced from suppliers based in Scotland. This indicates any increase in the productivity of the offsite sector would result in growth of the Scottish supply chain;
- the existence of a secure pipe-line is stated to be the most critical factor in realising this extra capacity and economic uncertainty is seen as the greatest barrier to the growth of the offsite sector.

This growth in the capacity of the offsite sector does provide evidence to suggest the expansion of manufacturing and assembly systems is challenging the preference for traditional methods of construction, as a large proportion of the offsite sector's turnover does concentrate on the provision of either private, social or affordable housing. The evidence also indicates the increases in productivity arising from the growth of the offsite sector over the next 5 years will lead to an increase in the construction of affordable housing. The review also suggests any such expansion shall reduce the waste produced by the sector when compared to traditional methods of construction and consolidate the supply chain. This also suggests that an uncertain economic outlook is the greatest barrier to the growth of the offsite sector and potential contribution which it can make to the construction of affordable housing in Scotland.

3. Realizing the potential benefits:

In order to realise the potential benefits such an increase in productivity and growth in capacity offers, the co-design workshops found any future development of affordable housing by the offsite sector in Scotland would need to be modified by:

- adopting a collaborative approach to procurement, whereby the full range of stakeholders involved in the commissioning, design and construction of affordable housing, come together at the outset, instead of at the stages where they traditionally interact with one another;
- shifting to a 'design for manufacture' approach to affordable housing provision, rather than 'manufacture for design'. This will involve a move towards greater standardisation of components, specification of materials and product design;
- ensuring better dissemination of offsite construction experiences so that risks and benefits are better understood;
- adopting a whole life-cycle approach to the assessment of value for money in order that the potential benefits offsite construction offers can be fully understood;
- creating a pipeline of demand across commissioning bodies in order to allow the efficiencies of offsite construction to be maximised and encourage investment in affordable housing;
- deploying innovative business models that use the aforementioned approaches and which allow manufacturing and assembly systems to increase productivity and contribute to the growth of the offsite sector;
- enhancing government assistance by:
    - assisting with the capital investment needed to fund any expansion of the manufacturing systems and further improvements in waste management, energy consumption and carbon emissions related to assembly;
    - supporting the adoption of digital technologies to increase productivity and the rate of growth;

- offering grants to assist with the training of a skilled offsite workforce, especially as "multi-skilled operatives" capable of increasing levels of productivity and contributing to the growth of the sector.

Recommendations

In light of these findings, the following recommendations are offered to key stakeholders in the affordable housing sector:

1. Given that Scotland already successfully adopts offsite approaches to most of its housing construction, a more clearly articulated national strategy is needed in order to recognise this and to set out the future direction of travel The findings of this study suggest the current manufacturing sector has an appetite for expansion and progressive adoption of more advanced manufacturing systems and these opportunities should be captured in this strategy. This strategy should also be seen as a vehicle which contributes to the targets that Scottish Government has set for net zero carbon, zero waste and the circular economy.

2. The current approach to affordable housing development is traditional – even when an offsite provider is appointed to build the homes. This traditional approach (characterised by 'manufacture for design' rather than 'design for manufacture') is recognised as inefficient by key stakeholders and the sector should therefore develop a strategy to transform these traditional approaches in order to ensure that the potential benefits of offsite manufacturing are realised.

3. This transformation strategy should be based on;
   - a collaborative approach to procurement, rather than the traditional sequential approach;
   - a whole life cost approach to evaluation rather than the traditional initial capital cost business models;
   - greater standardisation of house types and components;
   - development of a pipeline of demand that will allow the manufacturing sector to maximise productivity and encourage investment in more productive plant and equipment.

4. Whilst many stakeholders are keen to understand the benefits and barriers of offsite construction, they feel the evidence base currently available to justify the adoption of such an approach is insufficient to warrant this. Whilst this study should provide some reassurance, there is a need for a more systematic analysis of the available evidence, so the lessons learnt can be based on an open system of evaluation and information sharing.

5. As part of any new strategy, it may be appropriate to introduce incentives to stimulate the market and promote the widespread adoption of modern methods of construction – for example the Scottish Government may wish to consider:
   a. allocating a % of all affordable housing funding for projects which demonstrate greater use of offsite construction;
   b. providing targeted support to SMEs in the offsite sector able to adopt modern methods of construction, by way of the Enterprise Agencies and through the Construction Scotland Innovation Centre;
   c. supporting capital investment in manufacturing facilities through the Building Scotland Fund and the Scottish National Investment Bank;
   d. reviewing how the planning process could be streamlined based on approval of certain standard systems and/or designs. Stakeholders felt this could dramatically speed up the construction process;

e. examining how the current grant and payment arrangements could be modified to better support the different staged risks and outlay associated with certain modern methods of construction.

Introduction

The Scottish Government seeks to maximise value for money achieved through the Affordable Housing Supply Programme and is keen to understand how greater use of offsite manufacturing, or adoption of more advanced systems, might assist in that aim.

Scotland already delivers more than 80% of its new homes using offsite systems. However, the majority of these are quite simple, open frame timber panel systems rather than more advanced closed panel, modular or volumetric systems. To date Scottish evidence from these more advanced systems has been limited and the experience of these projects has sometimes been challenging.

In order to inform future policy in this area, the Scottish Government, Scottish Enterprise and Construction Scotland Innovation Centre have commissioned this research so that future policy consideration can be based on good quality evidence. Although much has been reported about offsite manufacturing, there is currently no easily accessible evidence relating to affordable housing. It is hoped that if effective policy can be developed and implemented in the field of affordable housing, then the wider housing market will also benefit from that experience. This work is therefore a potentially significant contribution to the modernisation of the Scottish construction industry.

The main aims of this report are therefore;

- To provide a good evidence base of the relevant experience of offsite manufacturing across the world;
- To assess the current nature and scale of the Scottish offsite housing manufacturing sector and its likely future shape, and;
- To consider whether the core housing development and construction processes – developed to support traditional approaches – need to be changed in order to better support offsite approaches.

Once published, the Scottish Government looks forward to discussing the findings with partners across the affordable housing sector and working with them to shape future policy in this area.

1. Project 1

1.1. Introduction

Project 1 was undertaken in 3 stages (see Table 1). The first stage involved mapping the issues that currently impact upon the affordable housing sector at the international level and investigating the relevance of these international issues within Scotland. Stage 2 involved a systematic review of the literature concerning offsite construction at the international level, and as before, investigating the relevance of these issues within Scotland. In Stage 3, four case studies, all located in Scotland, have been documented to further explore the benefits and barriers of offsite construction.

STAGE 1. Affordable housing: Mapping the issues	• 99 Issues identified from 3,000+ publications • Grouped into 7 stages of the value chain • Design and Construction stage selected for analysis (15 issues) • 15 issues tested on 23 experts through surveys/interviews • Key findings
STAGE 2. Offsite construction: Mapping the barriers and benefits	• Analysis of 615 publications • 5 benefits identified • 7 barriers identified • 26 issues tested on 23 experts through surveys/interviews • Key findings
STAGE 3. 4 case studies	• Key learning issues identified and mapped against barriers/benefits identified in Stage 2. • Key findings

Table 1. An overview of Project 1.

1.2. Affordable housing: Mapping the issues

In order to map the main issues which currently impact on affordable housing provision at the international level, a bibliometric analysis has been conducted of 3,566 scientific publications dealing with affordable housing produced between 2013 and 2017. These publications represent the most recent scientific literature on affordable housing and from the analysis conducted it is possible to capture 99 issues. These have subsequently been grouped by their position in the affordable housing value chain.

This value chain is composed of 7 stages: (1) Policy development; (2) Local regulation and urban planning; (3) Land assembly; (4) Essential services and infrastructure; (5) Design and construction; (6) Distribution; (7) Occupancy and community development (see Table 2). The 15 issues relating to ‘Design and construction’ were then subject to further analysis.

Value-adding activities	Actors
Policy development	National Governments
Local regulation and urban planning	Local Governments
Land assembly	Developers
Essential services and infrastructure	Utility Companies and public-service providers
Design and construction	Architects, Engineers and Surveyors
Distribution	Brokers (Property Managers; Social Landlords; Banks)
Occupancy and community development	Tenants, Social Landlords, Community Councils

Table 2. Affordable Housing value chain.

1.3. The design and construction of affordable housing in Scotland: Mapping the issues

The relevance of the 15 issues relating to the "Design and construction" stage of affordable housing has been analysed in the Scottish context, with 23 experts in affordable housing provision representing Scottish Government, housing associations, city councils and industry. The data has been collected by combining semi-structured telephone interviews and an online survey. Appendix 4.1 provides an overview of the statements which have been used to structure the interview process.

1.3.1 Data analysis: Key findings[1]

Finding 1	The majority of respondents agree that statutory standards for the quality of new build affordable homes in Scotland will continue to rise.
Finding 2	The respondents are not clear as to whether those experts involved in the design and construction of affordable housing, have the skills required to meet the needs of the sector.
Finding 3	Most respondents disagree with the premise that the construction of affordable housing in Scotland is underperforming due to poor project management.
Finding 4	Cost overruns are an issue with 48% of respondents disagreeing with the premise that affordable housing projects rarely experience cost overruns and 35% neutral on this issue.
Finding 5	The majority of respondents agree that the development of brownfield sites for affordable housing in Scotland is inhibited by technical issues.
Finding 6	A minority of respondents agree that the design and construction of affordable housing in Scotland typically results in low operational and maintenance costs.
Finding 7	43% of respondents agree that the design and construction of affordable housing in Scotland typically results in low operational and maintenance costs.
Finding 8	About half of respondents agree that the way in which affordable homes are currently designed and built in Scotland prevent neighbours experiencing noise-related issues.
Finding 9	The majority of respondents agree that the environmental impact of the construction and materials used in affordable housing is a matter that should be give more attention in Scotland.
Finding 10	The respondents are divided as to whether the affordable housing sector in Scotland takes proper account of waste management and 39% were either neutral or didn't know.
Finding 11	The majority of respondents agree that the affordable housing sector in Scotland is well prepared to meet the higher standards of energy efficiency expected from the sector.
Finding 12	The majority of respondents agree that there is scope to improve health and safety standards in the construction of affordable housing in Scotland.
Finding 13	The majority of respondents disagree with the premise that the design and construction of affordable housing in Scotland maximises productivity.
Finding 14	The majority of respondents agree that the way in which affordable housing is designed and constructed in Scotland maximises social and environmental benefits.
Finding 15	The majority of respondents agree that the performance of the affordable housing sector in Scotland could be improved if the overall development period for new homes was reduced.

[1] Further analysis of the interviews can be found in Appendix 4.2.

1.4. Offsite construction for housing construction: Mapping the main benefits and barriers

A systemic review has been conducted of the findings from the last 20 years of empirical studies reporting on the benefits of and barriers to offsite construction adoption. In the analysis, 615 scientific documents have been included, which were published between 1999 and 2018, identifying 26 main components. This evidence-mapping exercise has made it possible to identify 5 main benefits (see Table 3) and 7 main barriers (see Table 4), which are discussed below. Appendix 4.3. summarises the discussion by highlighting some of the key quantitative findings extracted from the discussion of barriers and benefits.

Benefits
1. Accelerated construction cycle and productivity with increased quality
2. Safer and healthier onsite working conditions with fewer onsite workers
3. Reduced costs
4. Reduced onsite storage requirements
5. Improved environmental sustainability

Table 3. Main benefits of offsite construction adoption.

Barriers
1. High initial costs for capacity building
2. Ineffective transportation logistics
3. Insufficient manufacturing capacity
4. Insufficient market demand due to unawareness and adversary culture
5. Inappropriate business model and supply chain configuration
6. Lack of building standards, design codes, and policy support
7. Lack of skilled professionals

Table 4. Main barriers to offsite construction adoption.

1.4.1. The Main benefits of offsite construction[2]

Benefit 1: Accelerated construction cycle and productivity with increased quality

Compared to conventional building construction techniques, offsite construction has the potential to increase production rates and overall product quality, while shortening completion times due to fast onsite building assembly. One of the main factors enabling this accelerated assembly process is the transfer of construction activities from the site to the factory. This deployment of controlled environments allows the constructability of the delivery phase to be better envisioned and executed, while the number of onsite trade contractors is reduced.

Evidence of offsite construction's capacity to accelerate the construction process and increase production rates is provided by the Task Group 57 of the International Council for Research and Innovation in Building and Construction (CIB). Founded in 2004 by the Board of CIB, the group of researchers composing the Task Group were tasked with conducting market-driven research on the impact generated by industrialization in the construction sector. The investigation, which was conducted under the leadership of the Swiss Federal Institute of Technology (ETH Zurich) and Eindhoven University of Technology, was completed in 2010 and found that the introduction of industrialised processes and production techniques in the residential building sector of North American and European countries had already shortened the construction duration by 37%. This

[2] The literature to support this section can be found in Appendix 4.4.

figure suggests the industrialization processes that offsite construction introduces can help address major and historical construction problems, such as the instability of the workflow, low productivity, timeliness, and delays.

Evidence of fast construction, accelerated productivity, and delay reduction capacity can also be sourced in research which focuses attention on the use of offsite technologies in China. For example, researchers report on a construction project which proceeded with record-breaking speed in Changsha. By deploying offsite construction techniques, this project made it possible to build a 30-storey hotel in 15 days (T30 Tower Hotel). In another example, researchers report on a similar experience by introducing Mini Sky City, a 57-floor skyscraper which has been completed in 19 working days. The authors have estimated that the use of traditional building techniques would have required more than one-year of onsite construction in order to develop the same building.

Both projects demonstrate that by introducing manufacturing principles in the construction process, offsite construction can help tackle the productivity challenge that the housing sector is currently facing. This point is further highlighted in a research project carried out in Australia, which analyses seven construction projects deploying offsite construction methods. These projects include the Mercure Apartments, a residential building in Newcastle, New South Wales. Here, offsite construction methods helped reduce the total construction time because the structure of the building was completed while the modules for the apartments were being manufactured.

Both developed in Australia, Little Hero and Concorde South, are two additional examples of residential buildings in which the use of offsite construction technology has accelerated the overall construction cycle. Little Hero is a nine-story building with 63 apartments designed and built by deploying Hickory's UB System, which includes a precast core and prefabricated apartment modules. With a synchronized onsite/offsite construction program, the building was completed in nine months. Similar to Little Hero in terms of units, Concorde South is a six-story building with 77 apartments. The building, whose modules were designed and fabricated in an Australian factory and delivered to the site via a mix of road and sea transportation, was built onsite in eight and a half days.

In addition, research has provided evidence to suggest that offsite construction can deliver more products of better quality in less time than conventional building construction techniques. Using the UK construction industry as a case study, this analyses demonstrates that the major benefits of offsite construction are: time reduction, decreased accidents onsite, cost and time certainty, and improved quality of the final product.

Benefit 2: Safer and healthier onsite working conditions with fewer job site workers

Offsite construction brings the advantages of less physical workload and fewer jobs for onsite workers, helping the construction sector to cope with health and safety issues. After conducting a survey with experienced professionals and a case study analysis of seven residential and non-residential buildings in Hong Kong, researchers have observed that offsite construction techniques delivered (1) labour savings of 16%, on average, compared with traditional building techniques, and (2) up to 30% in some projects. The highly organized operations made it possible to achieve a higher productivity by deploying a smaller labour force. In addition, the analysis demonstrates that security incidents were reduced by approximately 6%. This suggests offsite construction techniques can lower the risk of injuries, illnesses, and fatalities, in particular by reducing the onsite congestion of personnel and diversity of materials.

A positive correlation between offsite construction techniques and onsite labour force requirement is also captured in India, which sought to compare two affordable housing developments with similar characteristics, i.e. geographical locations and number of units, but built using different construction techniques: industrialized and traditional, respectively. The findings demonstrate that the use of

industrialised processes and production techniques have produced several advantages, which include a 40% onsite labour force reduction.

Despite being an industrial facility, additional evidence is also provided by the redevelopment of the Woolston Wastewater Treatment Works (WWTW) in Southampton, United Kingdom. In describing the WWTW project, the authors point out that the adoption of an offsite approach has accelerated construction delivery, provided programme and cost savings, and "reduced the numbers of onsite personnel, total man-hours, and high-risk construction activities." More specifically, the use of a precast concrete elements (65% of the walls) made it possible to reduce the number of operatives by two-thirds when compared with traditional onsite concrete construction techniques, improving health and safety conditions.

Additional lessons derived from current practice demonstrate that the benefits which a more stable working environment offer include the reduction of noise and dust, and work conducted in unconfined and congested spaces, which helps to lower the risk of injuries and fatalities. Taking into account the evidence sourced from the Chinese construction industry, researchers estimate that offsite construction methods can reduce onsite dust and noise by about 9.5%, helping the sector to meet higher health and safety standards compared to traditional construction techniques.

Benefit 3: Reduced costs

Offsite construction can offer significant cost advantages over traditional onsite construction. The available empirical evidence demonstrates that offsite construction adoption can improve the workflow continuity, increase efficiencies in the use of resources, minimize construction waste, and reduce the number of onsite contractors and time spent in construction. All these aspects contribute to a lowering of the overall construction costs.

For example, in reporting on a multiple case study analysis, researchers have shown that the use of offsite construction techniques made it possible to obtain an average of between 15% and 16% reduction in construction time and labour requirement, respectively. Also, timber formwork and concrete works were reduced by 74%-87% and 51%-60%.

Research conducted by Central South University and National University of Singapore reports on a potential 5-10% saving on construction costs through the adoption of offsite construction techniques. This potential mainly results from the higher efficiencies that industrialized production processes of building components can offer, combined with a quick onsite assembly, reduced onsite manpower and an increased labour efficiency. The industrialized production process also offers a higher level of predictability, which makes it possible to have an improved degree of cost certainty and an increased labour efficiency.

Additional evidence of the economic benefits that offsite construction can deliver is provided with a cost-performance analysis of 20 medium- and high-rise residential buildings developed by UK housebuilders and in which offsite construction solutions (wall panel systems) were adopted. The findings show that construction cost savings compared to traditional building techniques ranged from 11% to 32%.

A case study analysis also demonstrates that the use of offsite construction technology can help lower construction costs due to the decreased amount of time which is necessary to spend on quality assurance. The factory environment enables the components to be strictly controlled though automated technological systems. In addition, research has demonstrated that better supervision and shortened construction time are some of the key advantages of adopting offsite construction techniques and contribute to reduce the overall construction costs.

Case study research conducted by KPMG confirms that offsite construction methods can deliver economic benefits. In the analysed cases, financial net savings of 7% were identified as a consequence of the shortened construction period.

Benefit 4: Reduced onsite storage requirements

An additional benefit of using offsite construction methods is the reduced need for onsite storage requirements for material and equipment. Despite being less discussed in the available literature on offsite construction, current studies that focus attention on this benefit reveal that reduced onsite storage requirement helps decrease onsite congestion and address safety concerns, making on site working environments healthier and safer. In addition, it can also contribute to additional costs savings.

However, it is important to note that this benefit can be affected by potential issues which offsite construction methods can generate. This relates to the need to move and stock large precast elements. When the site area is limited, offsite storage facilities can be necessary, and this would generate extra costs. However, lessons from practice show that just-in-time delivery principles and feasibility studies are effective tools for mitigating this issue and keeping the onsite storage area to a minimum.

Benefit 5: Improved environmental sustainability

The waste reduction factor is considered as one of the greatest benefits of using offsite construction methods and significant research efforts have been made in order to demonstrate it. Most of the evidence currently available can be sourced from case study analyses which focus their attention on offsite construction projects in Asia. For example, researchers conducting one of the early studies in Hong Kong found that construction waste could be reduced by up to 84.7% if offsite construction technology is applied. This data results from a multi-case study analysis comparing 14 traditional construction projects with 16 offsite construction projects. While conducting a comprehensive review of the evolution of prefabricated residential building systems in Hong Kong, in both the public and private sectors, researchers found a 52% waste reduction level when traditional construction techniques are replaced by an approach based on offsite construction technology. An investigation of the T30 Tower Hotel shows several benefits that include magnitude 9-earthquake resistance, low construction cost, high thermal efficiency (leading to low maintenance cost), and only 1% construction waste generation compared with conventional buildings.

Additional environmental benefits that offsite construction technology can deliver include a reduction of greenhouse gas emissions. Researchers investigated the differences in greenhouse gas emission between offsite prefabrication and conventional construction methods by comparing two residential projects in China. The results show that the use of offsite methods reduces greenhouse gas emissions per square meter compared with the conventional construction. The former has produced 336 kg/m2, while the latter 368 kg/m2. According to the study, the largest proportion of greenhouse gas has been generated by the embodied emissions of building materials, which accounted for approximately 85%. Four elements that positively contributed to reduce emissions are the embodied GHG emissions of building materials, transportation of building materials, resource consumption of equipment and techniques, and transportation of waste and soil, which accounted for approximately 86%, 18%, 10%, and 0.2%, of reduced emissions, respectively.

Investigations conducted by various researchers have generated consistent results. One study investigated the life-cycle energy use of offsite components and the corresponding effect on the total embodied energy use by comparing eight construction projects developed in Sichuan, Shanghai, and Shenzhen. The results of the analysis show that “14% of the total energy consumption could be saved by using prefabricated components over using an equivalent amount of cast-in-place ones”. Evidence proving that offsite construction methods can reduce building life-cycle carbon emissions

is also provided by other researchers, whose empirical analysis of 27 prefabricated buildings capture that “on average, 15.6% of embodied and 3.2% of operational carbon reductions were achieved through prefabrication, as compared with their traditional base cases.”

Finally, by comparing the level of embodied carbon between two traditional residential buildings and a low energy, affordable house built using an offsite panellised modular timber frame system, researchers find that the latter house resulted in a 34% reduction in embodied carbon. The buildings subject to analysis are located in Norfolk, UK.

In addition to reduced life cycle energy use, reduced production of construction waste, and reduced material requirements, using offsite construction methods has also proven effective in reducing water consumption. Researchers report on potential water consumption savings of approximately 40%.

1.4.2. The main barriers to offsite construction[3]

Barrier 1: High initial costs for capacity development and training

There are mixed results regarding the costs associated with offsite construction adoption. As previously discussed, there is evidence suggesting that offsite construction is not a prohibitively expensive solution and the deployment of offsite construction techniques can help reduce the overall construction costs. However, available research also demonstrates that some high initial costs can surface and become a major barrier hindering the adoption of offsite construction techniques.

The high initial costs involved in offsite construction are mainly associated with the investment required for setting up specialized factories for the manufacture of offsite construction components, and these costs impact on their price. For example, this initial investment, which is an added cost compared to conventional construction, is reducing the implementation of offsite construction in various regions of China. Researchers have estimated that due to this initial investment, adopting offsite construction techniques in China is 20% more expensive than traditional construction methods. In addition, in a survey conducted by researchers on the top 100 housebuilders operating in the United Kingdom, suggests these capital costs are one of the main barriers to the adoption of offsite manufacture in the country.

Along with the high initial investment and capital costs for the development of the necessary manufacturing capacity, initial costs related to the education and training of unqualified labour are also reported as factors inhibiting the development of the offsite construction sector. Research provides evidence that suggests “reorganization in the training and use of the local labour force” was a critical barrier to offsite construction development in Hong Kong, which requires “machine-oriented skills both onsite and in the factory” to increase.

Barrier 2: Ineffective transportation logistics

In comparing the environmental performance of two residential buildings located in Beijing, China, researchers have demonstrated that offsite construction techniques can offer a reduced environmental impact. In comparing the two buildings, the one developed by deploying offsite construction techniques has shown the following benefits: a 36% reduction in resource depletion; 6.6% reduction in health damage; and 3.5% reduction in ecosystem damage. Additional environmental benefits are reported by researchers, whose empirical analysis of a group of residential developments shows that offsite construction techniques have been instrumental in: decreasing material use and energy consumption by 20%, reducing emissions of carbon dioxide, sulphur dioxide and nitrogen oxides by 20%; and reducing emissions of carbon monoxide by 16%.

[3] The literature to support this section can be found in Appendix 4.5.

However, as other researchers observe, “the long-distance transportation of prefabricated items by road might offset their greenhouse gas mitigation benefits.”

In addition to the environmental benefits that offsite construction techniques can generate, current literature demonstrates that the transportation of prefabricated components can also threaten traffic safety, due to the frequent movement of heavy and bulky construction elements in densely populated areas, and the intensive use of roadways can impact on their maintenance, generating additional costs.

Research focusing on the practice also shows that additional logistics-related issues which can inhibit the adoption of offsite construction techniques in the affordable housing sector and these include: the limited load capacity, height, and width of tunnels, bridges, and roads; the risk of damaging prefabricated components during transportation; difficulties in gaining access to building sites due to the size of prefabricated items; and limited storage capacity, “which makes warehouses essential for temporary storage”, thereby increasing construction costs.

Research also reveals that when manufactures tend to set their fabrication yards in a remote area for cheaper labour and land cost, longer transportation routes becomes necessary and this might generate higher transportation costs, severe delays in delivering prefabricated components to construction sites, and additional environmental degradation. An extensive analysis conducted by researchers in the United States demonstrates that the high cost of transporting prefabricated components is one of the main factors limiting the use of offsite construction techniques.

Potential solutions to these issues include: (1) assembling the prefabricated modules in close proximity to the construction site, so that additional transportation efforts may be reduced; (2) making transportation more sustainable by replacing petroleum-based fuels with environmentally-friendly alternatives; (3) using just-in-time delivery in order to minimize the need for onsite storage space and improve site management: and (4) investing in extensive coordination and communication among project stakeholders in order to examine the limitations of module transportation

Barrier 3: Insufficient manufacturing capacity

Increasing the adoption of offsite construction techniques in the housing sector is closely associated with the capacity of manufacturers and suppliers operating in the offsite construction sector. However, this capacity, which is required to satisfy market needs, is not always sufficient. For example, researchers have focused attention on China and explored the barriers to offsite construction adoption in residential buildings. Their analysis demonstrates that the use of offsite construction techniques is inhibited by the lack of offsite manufacturers able to satisfy the demand for offsite components. “Housing developers have to produce the building blocks as well as to buy it, which stretches the production chain and increases the overall cost.” Research in China confirms the presence of this issue, which tends to inhibit the modernization of China’s construction industry. This in turn tending to undermine the commitment of the national government to extend the deployment of offsite construction techniques, especially as a means to in order to “boost productivity.”

Current research provides evidence suggesting that insufficient manufacturing capacity is mainly caused by two factors, which lead to an imbalance between component supply and demand: (1) the cost barriers previously discussed (see Barrier 1); and (2) a fluctuating market demand, which does not lead to any economies of scale benefits.

The survey conducted by researchers in China revealed that the lack of offsite manufacturers is an effect produced by the high initial set-up costs, which manufacturers cannot cope with, due to both the presence of an immature market, which does not justify the upfront investment. This last point is particularly important when manufacturers are small or medium-sized companies with limited

investment capacity for R&D activities. The research also confirms that the lack of adequate financial resources for developing the necessary manufacturing capacity can lead to poor product quality. This phenomenon is also reported in the United States.

In addition, even if the investment is made, with irregular demand, manufacturers can experience difficulties in achieving a fast return on investment, with longer capital payback periods. This can cause difficulties in obtaining financial support from credit institutions, which are more familiar with the traditional construction approach.

Barrier 4: Insufficient market demand due to unawareness and adversary culture

Evidence can be found of the role that poor awareness and adversary culture play in reducing market demand for offsite construction and limiting the development of the sector. For example, poor awareness of the cost savings that offsite construction methods can deliver was found to be one of the main factors which prevented their extensive use in the US building construction sector. As research has shown, the incapacity to perceive the value and benefits of offsite construction techniques has also proved to be a factor limiting the development of the offsite construction sector in the Australian construction industry.

Similarly, while observing the construction market in China, research shows that "many stakeholders lack a comprehensive or systematic understanding of prefabricated construction [and] numerous enterprises involved in exploitation, design, component and module production, assembly and construction, supervision and testing, do not recognize this new construction mode and simply lack the capacity to upgrade their technologies accordingly." The presence of this issue, which limits the diffusion of offsite construction techniques in China, is also confirmed by interviews with industry experts, suggesting "the level of public awareness and acceptance of prefabricated buildings is still relatively low."

In addition, as a technological innovation, the adoption of offsite construction techniques can also be affected by resistance, which is generated by the protectionism and conservatism of the sector and the scepticism of the public. For example, the reluctance to innovation of the construction industry and issues of purchasers' perceptions have been reported by researchers as two of the main barriers to offsite construction in the UK.

Researchers in New Zealand provide further evidence of this with the findings of an investigation which classifies the main barriers to the adoption of offsite construction. Here, "the reluctance to adopt unfamiliar processes" is put down to a conservative market approach and limited client mind-set, together with the limited expertise of designers, the lack of experienced manufacturers, and the lack of research and development capacity of the construction sector.

Barrier 5: Inappropriate business model and supply chain configuration

The supply chain and business model which currently regulate traditional construction approaches do not fit the technical requirements of offsite construction projects. However, evidence from practical examples of offsite construction projects suggest the current design and construction process of offsite construction buildings is still largely based on such traditional configurations. The significance of this challenge is captured by researchers, in which unfavourable organizational factors are described as one of the main barriers to offsite construction adoption in the United Kingdom. These findings are also confirmed in the Australian and Chinese context.

Offsite construction adoption requires a radical change in the conventional approach to project delivery and calls for an increased level of integration between design, building component supply, logistics, and building construction. In addition, the adoption of offsite construction techniques requires an increased investment in the project planning stage, early commitment, and early

engagement of all the stakeholders involved in the design and construction process. However, these key factors tend to conflict with the fragmented nature of the construction industry and its supply chain.

Offsite construction projects involve a high degree of collaboration and successful implementation depends upon the early involvement of all key stakeholders (architects, consultants, manufacturers, suppliers, clients, contractors, local governments, etc.), who are required to work closely in order to manage heterogeneous tasks related to design, construction, operation, and maintenance. This requirement, for example, clearly clashes with design-bid-build procurement methods, which result in an inadequate stakeholder collaboration when applied in the framework of offsite construction projects. “Designer and constructor are most likely hired separately rather than being the same entity or on the same team of a project. Under this structure, the main problem that has been detected is the absence of any interaction among design and construction teams, resulting in suboptimal solutions, lack of constructability, and change orders”. As researchers note, one of the main issues with offsite construction projects is that actors “usually have individual rather than common goals. This creates a tendency to work separately without cooperation or information sharing among the stakeholders. […] There is a need for more detailed and effective cooperation in all stages […] including design, procurement, prefabrication, transportation, onsite assembly, construction, installation, declaration, and operation.”

Barrier 6: Lack of building standards, design codes, and policy support

The development of national building standards and design codes aligned with international regulations is crucial to increase the adoption of offsite construction. Without codes and standards, for example, severe compatibility problems can surface during the onsite assembly process, in particular when multiple manufacturers collaborate in delivering the same project.

As researchers point out in their analysis of offsite construction adoption in China, the codes and standards of the past are not suitable for supporting offsite construction practice, in which a high level of standardization is necessary. In order to cope with this issue, national governments are required to intervene by means of new policies and regulations that the offsite construction industry is required to adhere. However, “although numerous offsite-construction-related policies and regulations have been introduced, the majority of them are seen as general implementation frameworks and incentive mechanisms, rather than specific decision-making guidance, effective working procedures, detailed goals, steps and measures. These documents do not include sufficient workable standards with which the accreditation, quality check/assurance and sign-off of the component design, manufacturing and assembly could follow”.

In the United States, Hong Kong, the United Kingdom, and Sweden, the lack of regulations and policies has not been reported as a critical barrier to offsite construction adoption. As researchers note, this suggests the regulations and policies that these countries have framed are effectively facilitating the adoption of offsite construction techniques.

“For example, the Swedish Standards Institute published specifications and standards for industrialized architectural design in the early 1960s. In Japan, a series of financial and technical policies were implemented to promote housing industrialization. The Hong Kong Buildings Department (HKBD) implemented a series of incentive schemes through Joint Practice Notes 1 and 2, which promoted the application of green building technologies and prefabrication. HKBD also required the prefabrication rate of concrete elements being used in public housing to reach 65% and granted Gross Floor Area (GFA) exemption to those buildings that use prefabricated components. These schemes also significantly increased the enthusiasm of local developers to adopt offsite construction components. Singapore required buildings to have prefabricated elements to achieve ‘buildability’ and then coupled this requirement with its issuance of a series of policies, regulations,

and standards. All these initiatives show that the government policies and regulations in various countries serve an essential function in promoting offsite construction development".

Barrier 7: Lack of skilled professionals

Several studies provide the evidence necessary to include the lack of skilled professionals in the list of barriers to advancing offsite construction. Current research suggests the lack of qualified construction workers is one of the main factors inhibiting the adoption of offsite construction techniques in China, Australia, New Zealand and the United Kingdom, where an absence of the necessary training programmes has been highlighted.

Researchers suggest this condition reflects the current engineering and architecture curricula, which tend to focus little attention on offsite construction techniques, whose deployment implies radical changes in the approach to design, fabrication, and construction. In fact, as many commenters point out, most of the knowledge on offsite construction is currently learned on the job." Therefore, to "secure long-term workforce provisions", investments should be made not only to upskill existing workers with formal educational processes but also to introduce offsite construction practice in the current academic qualifications.

In addition to undermining the possibility to expand offsite construction, this limitation can lead to the preparation of insufficiently qualified workers, who lack the appropriate technical and management experience, and whose employment can lead to severe problems, such as inferior structural performance, delays, construction safety accidents, and "unexpected costs are likely to arise".

1.5. Semi-structured interviews: Stakeholders with experience in offsite housing construction in Scotland

The relevance of the barriers and benefits of offsite construction, as captured in the systematic review, has been analysed in the Scottish context, by interviewing 23 experts in offsite construction. The experts represent Scottish Government, housing associations, city councils and industry. The data has been collected by semi-structured telephone interviews.

1.5.1 Data analysis: Key findings[4]

Finding 1	The majority of respondents agree that high costs inhibit the adoption of offsite construction methods for the development of affordable housing.
Finding 2	Most respondents agree that modern methods of offsite construction can help reduce the cost of affordable housing developments.
Finding 3	43% of respondents agree that the adoption of offsite construction methods for affordable housing is hampered by transportation logistics, whereas 26% disagree with this premise.
Finding 4	The majority of respondents agree that offsite construction methods contribute to safer and healthier onsite working conditions.
Finding 5	The majority of respondents agree that insufficient manufacturing capacity restricts the adoption of offsite construction methods in the development of affordable housing.

[4] Further analysis of the interviews can be found in Appendix 4.6.

Finding 6	The majority of respondents agree that the adoption of offsite construction methods increases the productivity of affordable housing provision compared to traditional methods.
Finding 7	The majority of respondents disagree that the adoption of offsite construction methods in the development of affordable housing is restricted by concerns about build quality.
Finding 8	The majority of respondents agree that offsite construction methods speed up the construction process for affordable homes.
Finding 9	The majority of respondents agree that the adoption of offsite construction methods in the affordable housing sector is restricted by an industry preference for traditional construction methods.
Finding 10	The majority of respondents agree that in standardising the assembly of components offsite, offsite construction methods reduce delays in the construction of affordable housing.
Finding 11	The majority of respondents disagree that building standards and design codes do not support the adoption of offsite construction method in the development of affordable housing.
Finding 12	The majority of respondents agree that offsite construction methods help reduce waste in affordable housing provision when compared to traditional construction methods.
Finding 13	The majority of respondents agree that the use of offsite construction techniques for affordable housing is restricted by the lack of professionals with the necessary skill sets.
Finding 14	The majority of respondents agree that offsite construction methods improve recycling processes in the development of affordable homes when compared to traditional methods.
Finding 15	The majority of respondents disagree with the assertion that the standard business model that underpins affordable housing developments is inappropriate to support offsite construction.
Finding 16	The majority of respondents agree that offsite construction methods improve energy efficiency in the affordable housing sector compared to traditional construction methods.
Finding 17	The respondents were divided as to whether it is insufficient market demand that restricts the use of offsite construction methods in the development of affordable housing.
Finding 18	The majority of respondents agree that offsite construction methods contribute to lower carbon emissions when compared to traditional construction methods for affordable housing.
Finding 19	Most respondents disagree with the premise that residents living in affordable housing prefer homes built using traditional construction methods.
Finding 20	Whilst 35% of respondents agreed that offsite construction methods result in reduced water consumption compared to traditional methods for affordable housing, the majority (65%) were either neutral or didn't know.
Finding 21	There was no agreement amongst the respondents as to whether the adoption of offsite construction is currently well supported by Scottish policy initiatives for the affordable housing sector.
Finding 22	The majority of respondents agree that offsite construction methods help the affordable housing sector meet lean construction objectives (i.e. maximising value and minimising waste).

Finding 23	Only 35% of respondents agree that housing development staff (in councils and housing associations) have sufficient skills and experience to manage projects involving offsite construction.
Finding 24	The majority of respondents agree that offsite construction methods reduce storage requirements during the construction of affordable homes.
Finding 25	The majority of respondents agree that offsite construction methods reduce noise problems during the construction of affordable homes.
Finding 26	43% of respondents agree that offsite construction methods reduce dust problems during the construction of affordable homes.

1.6. Multi case study analysis

Four case studies, all located in Scotland, have been documented to further explore the benefits and barriers of offsite construction (see Figure 1). The case studies were supplemented by expert interviews. The barriers and benefits emerging from the case studies have been mapped against those which emerged from the systematic review of the literature (see Table 5).

Figure 1. Location of the 4 case studies.

		Alva	Anderston	Yoker	Portobello
BNEFITS	**BE01.** The adoption of offsite construction methods increases the productivity and quality of affordable housing provision compared to traditional methods.				
	BE02. Offsite construction methods speed up the construction process for affordable homes.				
	BE03. In standardising the assembly of components onsite, offsite construction methods reduce delays in the construction of affordable housing.				
	BE04. Offsite construction methods contribute to safer and healthier onsite working conditions.				
	BE05. Offsite construction methods reduce noise problems during the construction of affordable homes.				
	BE06. Offsite construction methods reduce dust problems during the construction of affordable homes.				
	BE07. Modern methods of offsite construction help reduce the cost of affordable housing developments.				
	BE08. Offsite construction methods reduce onsite storage requirements during the construction of affordable homes.				
	BE09. Offsite construction methods help reduce construction waste in affordable housing provision compared to traditional construction methods.				
	BE10. Offsite construction methods improve recycling processes in the development of affordable homes when compared to traditional construction methods.				
	BE11. Offsite construction methods improve energy efficiency in the affordable housing sector compared to traditional construction methods.				
	BE12. Offsite construction methods contribute to lower carbon emissions when compared to traditional methods for affordable housing.				
	BE13. Offsite construction methods result in reduced water consumption compared to traditional construction methods for affordable housing.				
	BE14. Offsite construction methods help the affordable housing sector meet lean construction requirements (i.e. maximising value and minimising waste).				
BARRIERS	**BA01.** The adoption of offsite construction methods for the development of affordable housing is inhibited by high initial costs.				
	BA02. The adoption of offsite construction methods for affordable housing is hampered by ineffective transportation logistics.				
	BA03. Insufficient manufacturing capacity restricts the adoption of offsite construction methods.				
	BA04. The adoption of offsite construction methods in the development of affordable housing is restricted by concerns about build quality and aesthetic.				
	BA05. Insufficient market demand limits the use of offsite construction methods in the development of affordable housing.				
	BA06. Residents living in affordable housing prefer homes built using traditional construction methods.				
	BA07. The adoption of offsite construction methods in the affordable housing sector is restricted by an industry preference for traditional construction methods.				
	BA08. The standard business model that underpins affordable housing developments is inappropriate to support offsite construction.				
	BA09. Building standards and design codes do not support the adoption of offsite construction methods in the development of affordable housing.				
	BA10. The adoption of offsite construction is not well supported through policy initiatives for the affordable housing sector.				
	BA11. The use of offsite construction techniques for affordable housing is restricted by the lack of professionals with the necessary skill sets.				
	BA12. Housing development staff (in councils and housing associations) have sufficient skills and experience to manage projects involving offsite construction.				

Table. 5. Case study analysis: Mapping the benefits and barriers.

1.6.1. Case study 1: The Alva Volumetric Housing Development[5]

Name of project	Alva Volumetric Housing Development
Project location	Alva, Clackmannanshire, Scotland
Project sector	Affordable housing
Date of completion	September 2017
Principle form of construction	Timber volumetric
Client	Link Group / Paragon Housing Association
Main contractor	Marshall Construction Ltd
Project value	£5.3 million

Figure 2. New housing in Alva.

The Alva Volumetric Housing Development is a 48 unit social housing development in Clackmannanshire, Scotland.

The small town of Alva, an idyllic semi-rural location at the foot of the Ochil Hills, is home to approximately 5000 residents and is situated in close proximity to the larger populations of Alloa and Stirling, which provide additional amenities.

Tigh Grian on behalf of the Link Group and Paragon Housing Association managed the development. The development was also supported by the Scottish Government's Greener Home Initiative scheme.

[5] Key quotes from expert interviews can be found in Appendix 4.7

The 48 housing units were built using an innovative timber volumetric system developed offsite. This method of construction provides increased build quality whilst providing the opportunity to reduce costs, time and waste.

The development includes 16 one-bedroom flats in a four-in-a-block configuration, 24 two-bedroom semi-detached and detached dwellings, and 8 three bedroom semi-detached dwellings. This diverse range of housing is intended to provide modern and sustainable accommodation for a range of tenants including individuals, couples and families.

The site layout was developed through a pre-application consultation with Clackmannanshire Council, which sought to integrate the new development into the existing surroundings.

Swift Ltd fabricated the housing pods in Wales before transporting them to site and being assembled on pre-prepared foundations. An efficient 16-stage production line ensured each pod was fully assembled and included wall and floor finishes, glazing, staircases, doors, toilets and fully fitted with electrical and plumbing services. Each pod was built using structurally insulated panels, providing excellent thermal and sound insulation, helping to reduce energy costs and reduce the transmission of external noise.

Transportation of the pods from Wales to Scotland proved to be logistically challenging, with some jurisdictions requiring a police escort. Once delivered to site by lorry, the pods were externally finished. This work was conducted by Marshall Construction Ltd. Different facades ensured that each house type had a unique identity, utilising a varied palette of materials including smooth white render, timber cladding, facing brick and stone cladding.

The homes were designed to achieve Gold standard for Scottish Building Standards Section 7 (sustainability), the first offsite project in Scotland built to such demanding standards. To achieve such a rating the development included various energy efficient features, including:

Mechanical ventilation with heat recovery (MVHR)
MVHR provides ventilation and heat recovery to each home. The system works by capturing warm, stale air from the kitchen and bathrooms. Fresh air from outside is filtered into the heat recovery system which mixes with the warm air, providing warm, clean air which prevents the build-up of condensation, damp and mould in the home.

ESP Ecocent heat pump
The ESP Ecocent Heat Pump heats the domestic hot water supply in the home up to 60°C, using wasted heat from indoors and warm air from outside. The unit switches on and off as required and re-heats the hot water cylinder after hot water is used.

Solar photovoltaic panels
The solar photovoltaic panels fixed to the roofs, provide the homes with free electricity during daylight, even without direct sunlight. Solar panels harness renewable energy from the sun and do not emit harmful carbon dioxide emissions.

Key Findings

- The Alva project demonstrates that timber volumetric construction methods can successfully deliver affordable housing projects at a reduced cost.

- Whilst the factory assembly of components can ensure a consistent level of quality and help deliver housing developments in a timely manner, attention to quality control is essential.

- Consideration should be given to transportation logistics as a key challenge.

- Adopting offsite construction can bring a range of benefits including: reduced construction waste, improved energy efficiency, lower carbon emissions, a healthier and safer working onsite environment, and reduced onsite storage requirements.

- The uptake of offsite construction remains frustrated by an industry preference for traditional construction methods, not helped by a lack of manufacturing capacity in Scotland.

- The business model allocated a disproportionate amount of risk to the developer as it failed to reflect the specific requirements of offsite construction projects.

1.6.2. Case study 2: Anderston Regeneration (Phases 4 and 5)[6]

Name of project	Anderston Regeneration (Phases 4 and 5)
Project location	Anderston, Glasgow, Scotland
Project sector	Affordable housing
Date of completion	July 2018
Principle form of construction	iQ panelised timber frame
Client	Sanctuary Group
Main contractor	CCG (Scotland) Ltd
Project value	£25 million

Figure 3. Newly completed housing in Anderston.

Anderston, a densely populated residential area located between St Vincent Street and Houldsworth Street to the west of Glasgow city centre, has been the focus of significant regeneration in the last decade. The development, delivered over 5 phases, has provided Anderston with 542 new, mixed-tenure homes.

Designed by Collective Architecture on behalf of Sanctuary Scotland, the completion of Phases 4 & 5 in 2018 marked the culmination of these extensive regeneration activities that aimed to revitalise this key urban quarter. The project was built by CCG (Scotland) and received additional funding from the Scottish Government and Glasgow City Council.

Traditionally a working-class community, the area had been subject to various transformations during the last century, in an attempt to provide housing that was both decent and affordable. In the late 1960's, the Victorian tenements were demolished and replaced with concrete tower blocks, which themselves became notorious for their cramped conditions, extensive damp and general disrepair.

The current Anderston Regeneration Masterplan sought to demolish these substandard tower blocks and replace them with modern, energy efficient housing that met the needs and aspirations of local people.

A key aim of the masterplan was to improve connectivity between Anderston and the adjoining communities, achieved by the inclusion of large open spaces and new pedestrian routes as well as

[6] Key quotes from expert interviews can be found in Appendix 4.8

provision for cyclists. With very few car parking spaces available, the developments in Phases 4 & 5 actively discourage car use amongst tenants, instead promoting more active and environmentally conscious forms of transport.

In 2009, work commenced on Phases 1 & 2, a diverse mix of 2-storey townhouses and low-rise apartment blocks that were completed in 2011. The 178 new homes, all intended for social rent, were designed with a mix of traditional brickwork and multi-coloured aluminium panels.

Following this, Phases 3A and 3B provided an additional 49 mixed-tenure homes and 109 flats respectively over a two-year period. Featuring zinc panelling and a buff brick finish, the new homes provide a modern aesthetic that pays subtle homage to the traditional local vernacular.

Phases 4 & 5, which began in 2017 and completed by mid-2018, would deliver the final instalment of 206 new properties. These concluding phases were seen as critical in reintegrating Anderston back into the fabric of the city by reinstating a section of Argyll Street that was razed in the 1960's as part of an earlier redevelopment plan for the area. Such development has served to strengthen the links between Anderston and its surrounding areas, including the increasingly popular Finnieston.

The 206 new properties, a mix of two and three-bedroom flats in five apartment blocks, provide residents with a spacious modern layout, featuring full height windows and balconies to maximise light and take advantage of magnificent vistas across the city. Finished in a combination of sandstone and brick, the new apartments are available for social rent whilst the remainder made available for shared-equity and mid-market rent.

The five apartment blocks, ranging from four to seven stories, were constructed by CCG (Scotland) Ltd using an innovative 'iQ' panelised timber frame system alongside sections of traditional blockwork. Manufactured under factory-controlled conditions, the 'iQ' system was completed to Stage 3 of the offsite manufacturing process (OSM), ensuring high standards of air tightness.

As well as being from a renewable source, the timber 'iQ' system provided other advantages, including improved energy efficiency. In addressing the issue of fuel poverty amongst its tenants, Sanctuary had specified a construction system that would deliver high standards of energy performance, resulting in lower operational costs for residents when aligned with energy efficient appliances and solar PV. Another important consideration was the speed of assembly. Sanctuary were keen to minimise disruption for local residents during the construction phase, ensuring the new homes would be built as quickly as possible. With the 'iQ' system, windows, doors and insulation were pre-installed offsite, the new apartments were wind and watertight in only 36 weeks.

Adopting a fabric first approach, Phase 4 was designed to achieve Bronze level for sustainability under Section 7 of the Scottish Building Regulations. Phase 5 also achieved Bronze level, attained by the use of solar photovoltaic panels (PV), whilst also accomplishing Silver Level Aspect 1 & 2 under Section 7 of the Scottish Building Regulations.

The regeneration of Anderston has also been notable in terms of the community benefits that have been delivered, including six full-time jobs, 20 trade apprenticeships, 5 work placements as well as financial contributions to community projects, including art installations.

Key findings

- The Anderston project has successfully showcased the innovative timber 'iQ' system developed by CCG.

- The 'iQ' offsite construction system, manufactured in factory-controlled conditions, helps homes achieve high energy efficiency standards and reduced household costs.

- Located in a busy city centre location, the project has demonstrated that offsite construction is ideal for large-scale urban regeneration projects.

- The speed of construction ensured minimal disruption to residents.

- Less storage was required on site and wastage was kept to a minimum.

- Unless building standards and design codes keep pace with the evolution of offsite construction, traditional construction practices will continue to be selected in order to avoid delays and additional costs associated with compliance.

1.6.3. Case study 4: Ellerslie Road, Yoker[7]

Name of project	Ellerslie Road, Yoker
Project location	Yoker, Glasgow, Scotland
Project sector	Affordable housing
Date of completion	December 2017
Principle form of construction	Cross laminated timber (CLT)
Client	Sanctuary Scotland
Main contractor	CCG (Scotland) Ltd
Project value	£5.5 million

Figure 4. Construction work at Yoker.

Located to the west of Glasgow city centre on the banks of the River Clyde, Ellerslie Road in Yoker is a new seven storey flatted development. Available for mid-market rent, the 42 new apartments, which feature a mix of one, two and three bedrooms, were commissioned by Sanctuary Scotland, one of Scotland's leading housing associations.

Designed by MAST architects and built by CCG (Scotland) Ltd, the project is unique in having delivered Scotland's tallest timber building, constructed entirely from cross laminated timber (CLT). The Yoker project features a superstructure built entirely from CLT, including the communal areas and lift shaft. Due to the innovative nature of the build, a Building Warrant was only granted following the submission of evidence to Scottish Building Standards Division, Glasgow City Council and Scottish Fire and Rescue Services.

This innovative construction project is the culmination of several years of dedicated research undertaken by CCG (Scotland) Ltd into the use of CLT products, assisted by experts from Edinburgh Napier University. Another key feature of the project was the use of Building Information Modelling (BIM) to optimise design, structural performance and sustainability.

[7] Key quotes from expert interviews can be found in Appendix 4.9

Manufactured in a factory-controlled environment, CLT are engineered panels consisting of various layers of timber that are glued and pressed together at 90° angles, forming a product that is as strong and stiff as steel. Due to the two-way spanning system, CLT is well suited for load bearing structural components such as walls and floors. In addition, CLT is a fire resistant product.

Working alongside CLT specialists Eurban, the entire seven-storey superstructure was erected (wind and watertight) in just 16 weeks. Three blocks of accommodation are centred around one central stair, with the entire superstructure built from CLT, including the common areas and lift shaft, equating to 1,170 cubic meters of timber and 936,000 kg of embodied CO_2. Due to the lightweight form of the material and the exposure to winds, engineers were hired to construct a bespoke platform to support the CLT superstructure as it evolved.

The building is clad using a combination of rainscreen cladding and the Alumasc Acrylic Brick Slip System that replicates a traditional brick aesthetic, eliminating the requirement for a masonry skin as well as the need for wet trades.

The use of CLT has enabled high standards of air tightness to be achieved. Residents will also benefit from PV panels installed on the building's roof, which as well as providing a source of renewable energy is envisaged to reduce household energy costs.

In adopting CLT as the principal means of construction, the project benefited from reduced construction time and reduced material wastage.

Key findings

- The Yoker project has demonstrated the suitability of CLT in constructing multi storey residential homes.
- Offsite construction methods can speed up the construction process, reduce overall costs and help reduce waste whilst maximising value (lean construction).
- Offsite products can improve energy efficiency and reduce carbon emissions.
- Traditional business models are unsuited to offsite construction.
- Building codes and design codes should be updated to reflect offsite construction methods.
- In Scotland, manufacturing capacity for offsite products is insufficient, and awareness of companies providing such services is low.
- There is a sectoral predisposition towards using traditional construction methods, which should be challenged.

1.6.4. Case study 4: Bath Street, Portobello[8]

Name of project	Bath Street, Portobello
Project location	Portobello, Edinburgh, Scotland
Project sector	Housing (private)
Date of completion	2017
Principle form of construction	Cross-laminated timber
Client	Bath Street Collective Custom Build
Main contractor	HM Raitt & Sons
Project value	£1.2 million

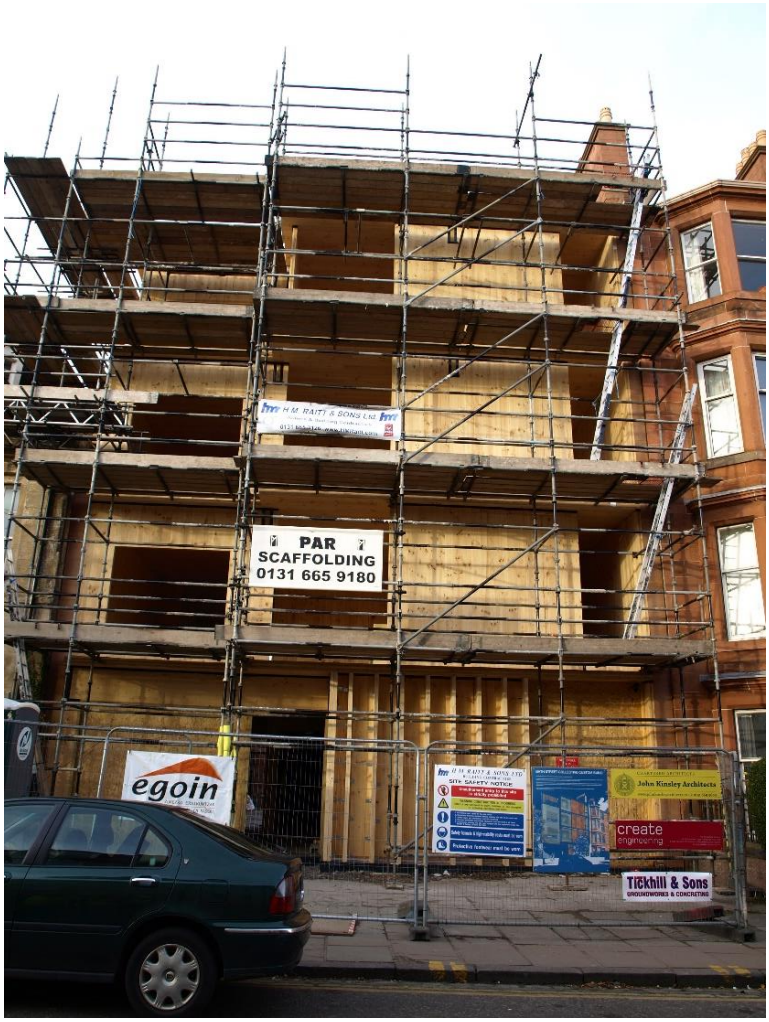


Figure 5. The Portobello project during the construction phase.

Inspired by the German communal-build 'Baugruppen' concept, architect John Kinsley has been at the forefront of an innovative 'collective custom build' project in Portobello, Edinburgh. Along with three other local families, John and Jenny Kinsley collectively purchased a plot of land and built four eco-friendly apartments.

A major incentive in adopting a collective custom build approach was to remove the need for a private developer – resulting in a significant financial saving. This approach, gaining popularity in Germany, is now responsible for delivering 10% of new homes in Berlin.

[8] Key quotes from expert interviews can be found in Appendix 4.10

Living in an adjacent street in Portobello, the Kinsley's were aware of a 400m² plot on Bath Street that had previously been the site of a cinema and demolished 15 years previously. With the site in mind, the next step for the Kinsley's was to find other interested parties, willing to join the collective build project.

After promoting their project online and hosting a public event in a local café, three local families were persuaded to join the collective. A financial expert was called in to help advise the group on how to pool their funds and constitute a single legal entity.

A limited company, Bath Street Collective Custom Build (BCCB) was created with four shares being issued and four directors appointed (with equal representation for each flat).

With BCCB acting as the client, the Ecology Building Society provided the capital needed to progress with project and employ John Kinsley as the principle architect. BCCB agreed to purchase the site for £250,000 from the current owners, subject to planning permission. With planning consent subsequently granted, the site was purchased and a local contractor appointed, HM Raitt & Sons, to deliver the development on a budget of £833,000. The design of the new building offers a modern take on the traditional Scottish tenement with a central stairwell providing access to each flat.

A key feature of the development is the use of cross-laminated timber (CLT) for the building's superstructure. Egoin, a company based in the Basque region of Spain, manufactured these prefabricated panels.

The roof and wall sections, each up to 13.5 by 3m, were manufactured in Egoin's factory to ensure precision and quality control. The prefabricated panels were then transported to site before being craned into position and fixed into place with heavy-duty metal brackets. The main-frame and roof were erected in nine days.

With the external load bearing walls, floor levels and internal stairwell in place, each family was then able to specify the interior layout. Using non load-bearing stud partition walls, the families could create a bespoke interior that could be reconfigured in the future, providing flexibility for changing household dynamics.

Internally, each flat features high ceilings and spacious rooms to maximise amount of sunlight. In John and Jenny's flat, the internal face of the CLT panels has been left exposed adding to the modern ambience.

All the families were in agreement that the development should be low-energy and make use of low-maintenance, sustainable materials. To meet this aim, the build was designed to meet Passivhaus standards of insulation and airtightness. Each flat is fitted with a mechanical heat recovery ventilation system and power is generated from solar photovoltaic panels. The homes are so well insulated, including triple glazed windows, there is no requirement for a central heating system.

Key findings

- The Portobello project has demonstrated that offsite construction methods are suitable for compact, gap-site developments.
- The use of offsite construction methods accelerated the speed of development.
- Onsite construction waste was reduced significantly.

- Offsite construction solutions have proved effective in improving energy efficiency leading to lower household energy consumption, and as a consequence, lower carbon emissions.

- A shortage of local manufacturers meant the CLT product had to be supplied from abroad.

- Whilst offsite construction may initially appear an expensive alternative, closer examination reveals the cost to be comparable to traditional methods.

- Offsite construction can provide an ideal solution to small consortiums looking to maximise value for money on building projects.

2. Project 2

2.1. Introduction

In 2013 the offsite sector in Scotland had ambitions to grow from approximately £125 million in 2013 to £230 million in 2018 (Smith et al. 2013). This report builds upon these findings and investigates the capacity and productivity of the offsite construction sector in Scotland in 2018 and in 5 years' time utilising four research stages:

1. Desktop study mapping the offsite construction sector in Scotland;
2. Telephone survey with a duration of approximately 1 hour carried out among 15 key offsite manufacturers based in Scotland. This included a comparison with data for 8 recurring companies between the 2013 and 2018 offsite capacity studies;
3. Business models analysis of companies with publically available financial records;
4. Asset Reviews undertaken by the Scottish Manufacturing Advisory Service (SMAS), which provided insights into companies' productivity and strategies for growth. This component will be reported separately at a later date on completion of the asset reviews.

This part of the report describes:

- the mapping of the offsite sector in Scotland and the sampled companied for telephone interviews;
- interview results regarding manufacturing capability;
- interview results regarding capacity and productivity;
- business models review including the size of the offsite sector.

The main findings from the project are shown in Figure 6. References to literature can be found in Appendix 4.11.

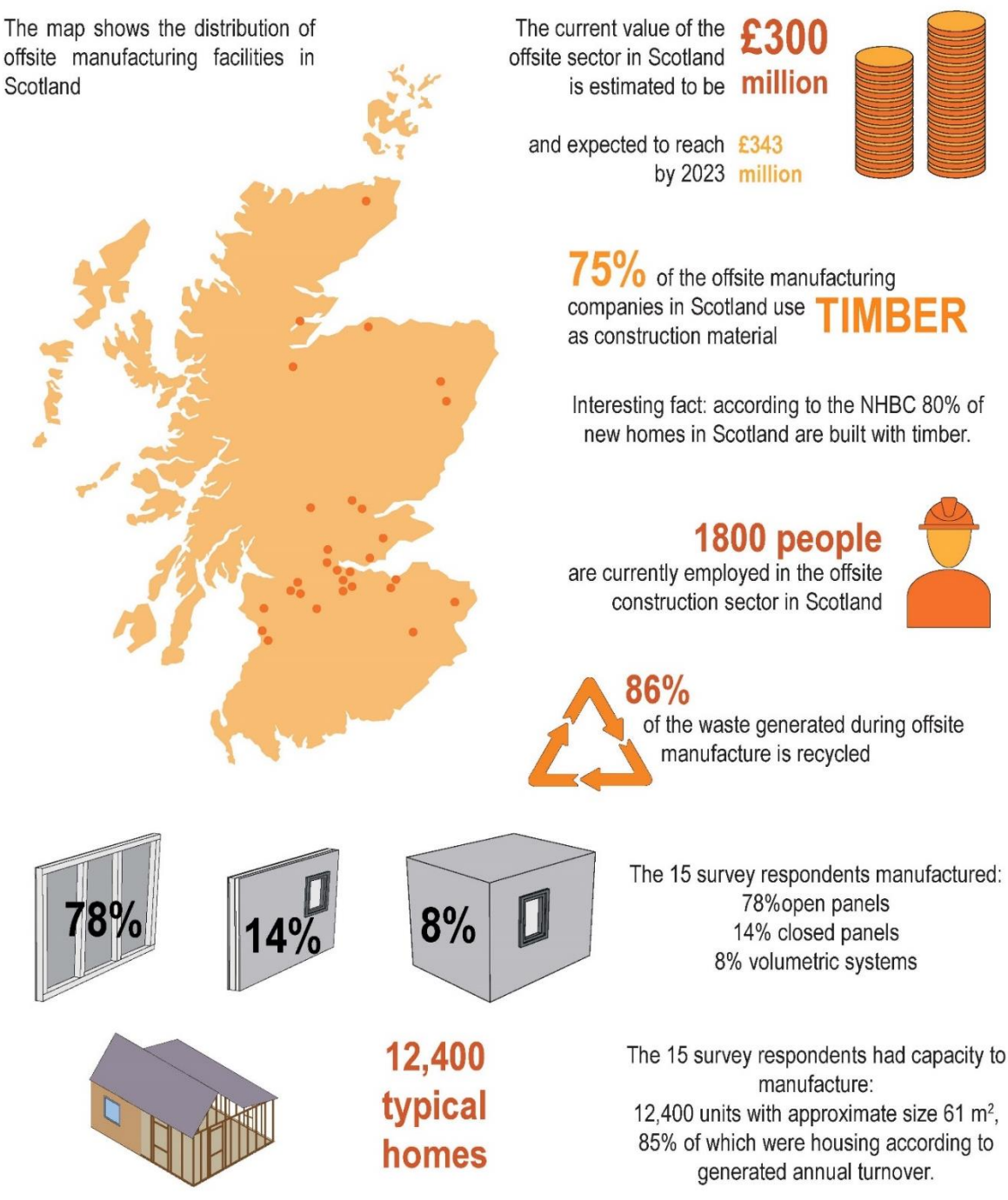


Figure 6 – Scottish offsite construction sector infographic.

2.2. Mapping of the offsite sector in Scotland

The mapping desktop study identified 33 offsite products manufacturers and 19 supply chain sub-assembly manufacturing companies that can potentially supply to the offsite sector, all based in Scotland. The difference between these two types of companies is shown in Fig. 6 and more details on their definitions are available in Appendices 4.12. and 4.13. The results totalled 52 companies as the research 'target sample', whose categorisation and geographic distribution can be seen in Table 6 and Fig. 7. The companies captured in this study were those with an online presence and accounts available in publicly available records of businesses in the UK as a means of validation (Companies House 2018). In general the identified companies who reported financial data had above £2 million annual turnover and employed more than 40 people, and those with abridged accounts reported at least 2 people employed. This mapping study is therefore as accurate a representation of the offsite sector as is practically possible, and does not take into consideration small sole trader or undocumented activities which are challenging to quantify and are typically outside the scope of market analysis research due to their marginal impact on overall results.

52 offsite companies	Timber companies	39	Offsite products manufacturers	31
			Sub-assemblies manufacturers	8
	Steel companies	8	Offsite products manufacturers	2
			Sub-assemblies manufacturers	6
	Concrete companies	5	Offsite products manufacturers	0
			Sub-assemblies manufacturers	5

Table 6 – Offsite manufacturing companies identified in Scotland.

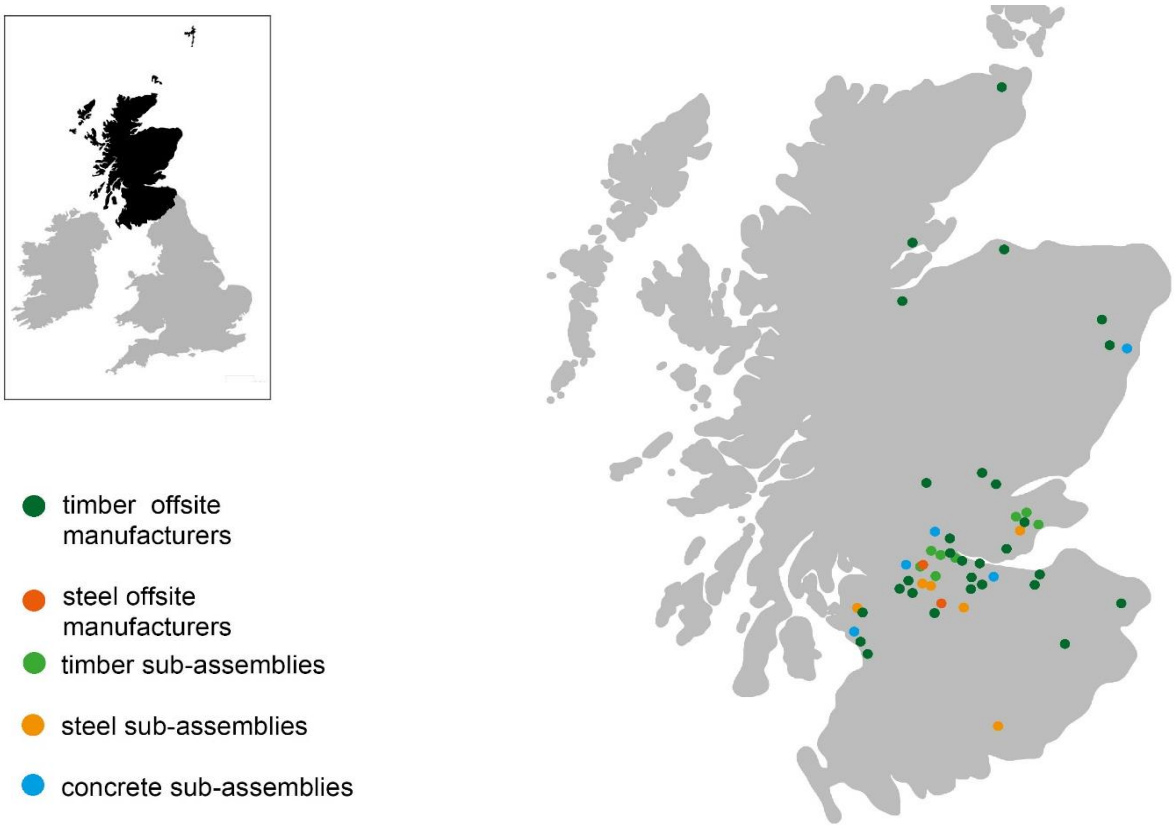


Figure 7 – Map of the Offsite manufacturers and sub-assemblies potential suppliers in Scotland identified for the study. Access to interactive online map: http://bit.ly/companiesmap

2.2.1 Number of and size of the surveyed sample of manufacturers

Among the above mapped companies, **13** manufacturers and **2** sub-assembly supply chain companies participated in the telephone survey, all of whom were timber companies.

Table 7 reports the total annual turnover generated by the 15 companies, who had in total £283 million in revenue from offsite plants within and outside Scotland in 2018. The offsite manufacturer's annual turnover constituted approximately 26% of the annual turnover of the larger groups to which some of the manufacturers belonged. The companies projected that in the next 5 years their annual turnover from offsite plants in Scotland would increase by almost 80%.

Total annual turnover			
Including all divisions 2017/2018	From offsite plants outside Scotland 2017/2018	From offsite plants in Scotland 2017/2018	From offsite plants in Scotland 2022/2023
1088.6 M	119.6 M	163.7 M	290.5 M

Note: 'All divisions' = the entire group for businesses whose offsite division is part of a larger group

Table 7 – Total annual turnovers for the participants. (N=15)

2.2.2. Annual turnover 2013 vs. 2018

The results from 7 offsite companies that participated in both surveys in 2013 and 2018 are compared in Fig. 8. Their actual annual turnover in 2018 was approximately 3% higher than the predicted turnover for the same year, indicating stable growth in the sector. It is anticipated that the speed of growth will decrease in the next 5 years, as the projected growth for 2023 is 58% higher than the annual turnover of 2018, compared to 77% in the previous 5-year period.

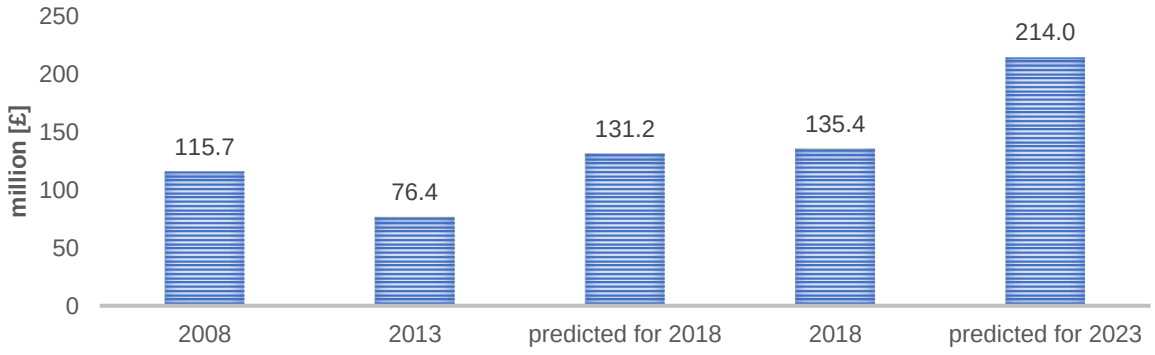


Figure 8. Comparison of the annual turnovers of the recurring companies. (N=7)

2.2.3. Number of manufacturing plants and plans for expansion

Among the 15 interviewed companies, the total number of manufacturing plants in Scotland was 19, specifically 16 plants were operated by offsite manufacturers and 3 by sub-assembly companies. Among these 60% had manufacturing plants only in Scotland, and the remaining 40% had plants both in Scotland and in other parts of the UK. In addition, 73% of the surveyed companies had plans to set up new manufacturing plants. If these plans came to fruition, in total 21,000 m^2 of new offsite product manufacturing space would be created resulting in approximately 460 new jobs, and increased capacity by an additional 14,152 units per annum.

2.2.4. Number of full-time employees and their distribution

Among the 15 interviewed companies, Fig. 9 presents how the total of 1,443 employees were distributed among different types of labour, with the majority working in the offsite manufacturing operations. Table 8 shows the projections for full-time employees, calculated cumulatively for all the participants with an expected increase of **560 people (+39%)**, creating new jobs in the sector.

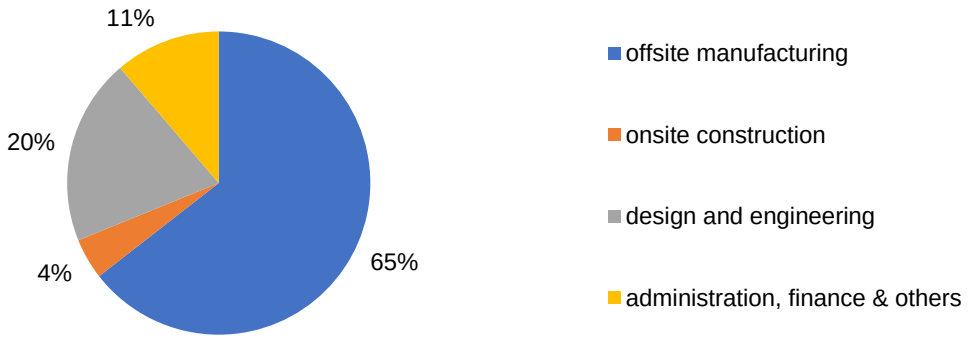


Figure 9. Percentage of the employee for each category in 2018. (N=15)

	Currently	In the next 5 years if working at full capacity (excl. expansion plans)
Offsite manufacturers	1243	1738
Sub-assemblies manufacturers	200	220
TOTAL	1443	2003

Table 8. Current and projected number of full-time employees of the participants (N=15)

2.2.5. Total number of employees 2013 vs. 2018

Fig. 10 reports how the total number of the full-time employees had changed over the past 10 years for the companies that participated in both surveys. From 2013 the number of employees had increased by 28% in 2018 and it was projected that it would increase by 38% by 2023. The latter increase was consistent with the full sample of 15 companies.

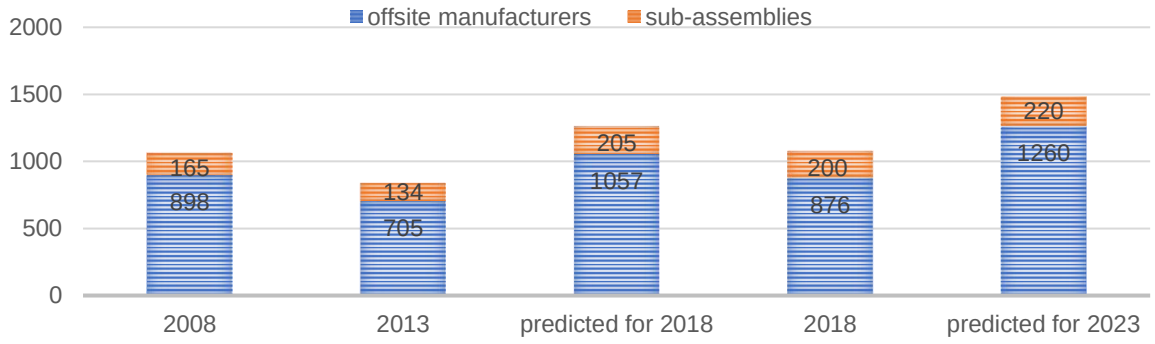


Figure 10. Development of the total number of employees of the recurring companies. (N=8)

2.3. Manufacturing capability of the surveyed offsite manufacturers

2.3.1. Turnover generated by each offsite product

The distribution of annual turnover generated by offsite products with different levels of enhancement is shown in Fig. 11:

- Almost half of the annual turnover in 2017/2018 was generated by 2D elements sub-category 0, which included internal and external wall panels, floor panels and cassettes, roof cassettes and trusses, and structural framing;
- 2D elements sub-category 1 generated around 35% of the annual turnover in 2017/2018; the products manufactured were similar to the ones produced for sub-category 0, with a higher level of enhancement;
- 3D elements sub-category 3 represented the highest level of enhancement and a comparatively low level of annual turnover (8%);
- The remaining current annual turnover in 2017/2018 was generated by 2D elements sub-categories 2 and 3;
- According to the companies' projection in the following 5 years, the distribution of offsite products would increase slightly for the systems with higher levels of enhancement, and a decrease in 2-D products subcategory 0.

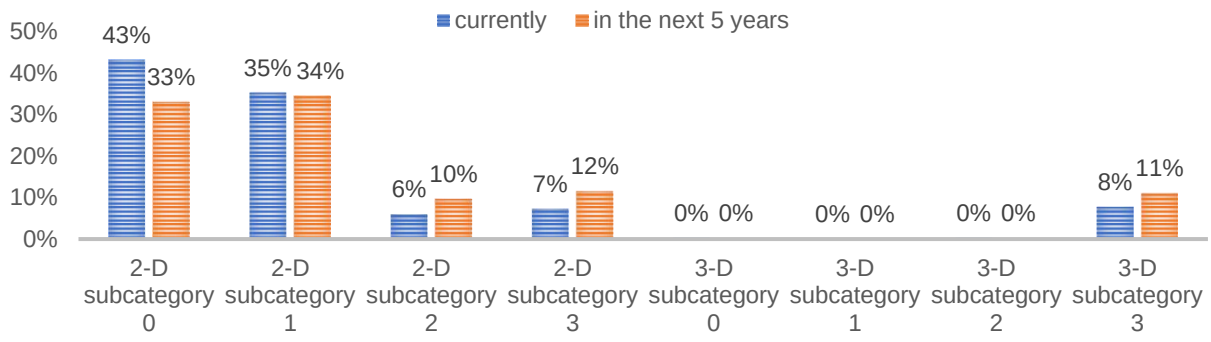


Figure 11. Current and projected percentages of the annual turnover for each offsite product sub-category. (N=14)

The differences in level of enhancement compared with the available data from 2013 are shown in Fig. 12. From this it can be seen that:

- approximately 95% of the annual turnover was generated by 2D elements and approximately 5% by 3D elements;
- the production of 2D elements subcategories 1, 2, and 3 increased over time at the expense of 2D elements subcategory 0.

These results were broadly consistent with previous research, which found that in the UK volumetric systems represented approximately 5% of the UK house-building market within this time-frame (NHBC 2016).

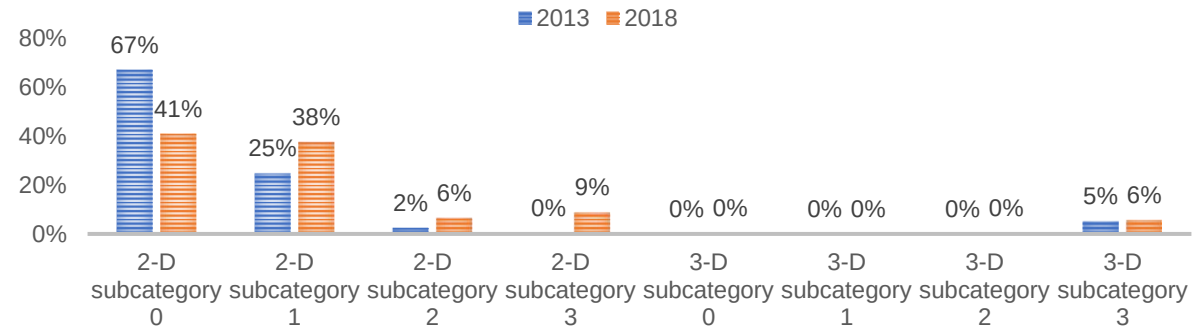


Figure 12. Comparison between the annual turnover generated by each offsite product subcategory for the recurring companies. (N=7)

2.3.2. Bespoke versus standard products

Overall 64% of the surveyed companies offered bespoke services, and each company included on average 5 customisation services (see Fig. 13). Internal finishes, dimensions of the units and thermal insulators were the three most offered customisation options, indicating possibilities for adaptation of offsite products to client's requirements.

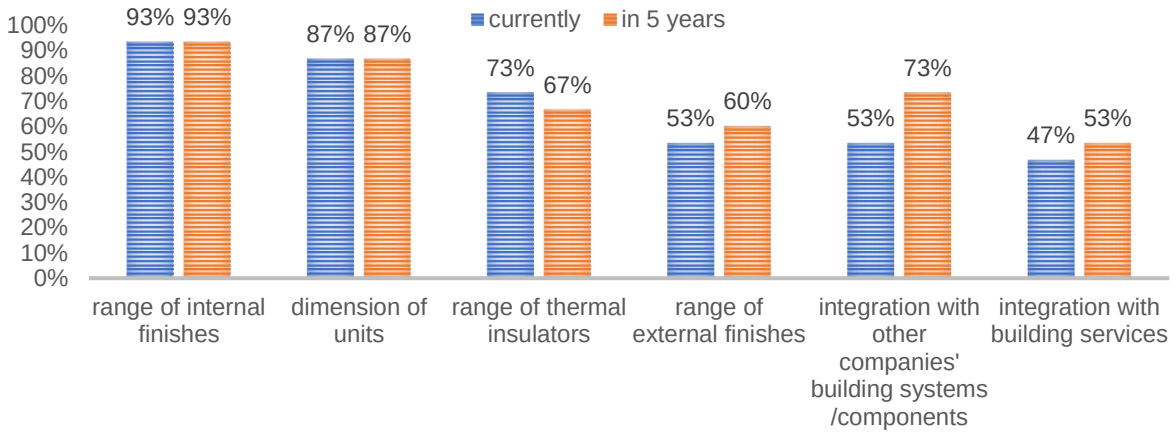


Figure 13. Percentage of the companies that offer a certain customisation service. (N=15)

2.3.3. Manufacturing processes

The data grouped in this sub-section provides an overview on the manufacturing processes applied by offsite companies in Scotland (Appendix 4.13. defines the levels of automation). Fig. 14 shows to what extent each level of automation was applied in the production processes of the surveyed sample, on average. The results demonstrated that most of the manufacturing processes were manual, with some use of mechanisation, together making up 80% of the production process. This was broadly in line with previous research, which identified that workers in Scotland were high-skilled and worked plentiful hours, but had lower access to plant and equipment than in other Organisation for Economic Cooperation and Development (OECD) countries (Kelly et al. 2018).

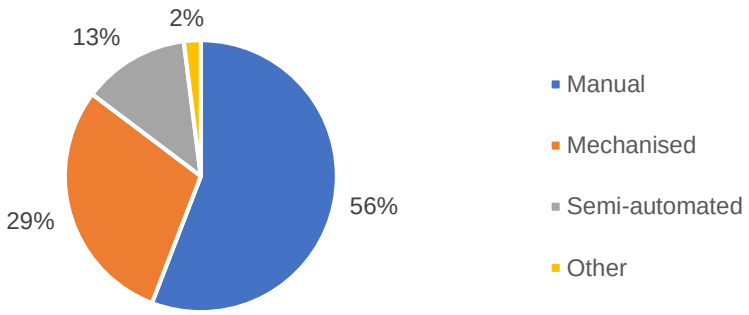


Figure 14. Percentage of application of each level of automation. (N=15)

In addition, the most applied level of BIM in the design process was Level 1, while in manufacturing and construction it was level 0. In comparison, BIM Levels 2 and 3 were used only by a small percentage of surveyed companies. These results corresponded to the high percentage of manual processes.

The participants were also asked to give a level of importance of a series of measures for improvement of the production process, shown in Fig. 15. The top measures were reduction in transport of material and minimisation of defective parts and waste, both of which may be associate with Lean 'muda' wastes reduction (Dave et al. 2013). Very few companies rated the use of multi-use equipment and machines as important. The surveyed companies also reported that they invested approximately 7% of their annual turnover on Research & Development (R&D), and if maintained this could contribute to furthering their process efficiencies with increased use of semi-automation and digitisation.

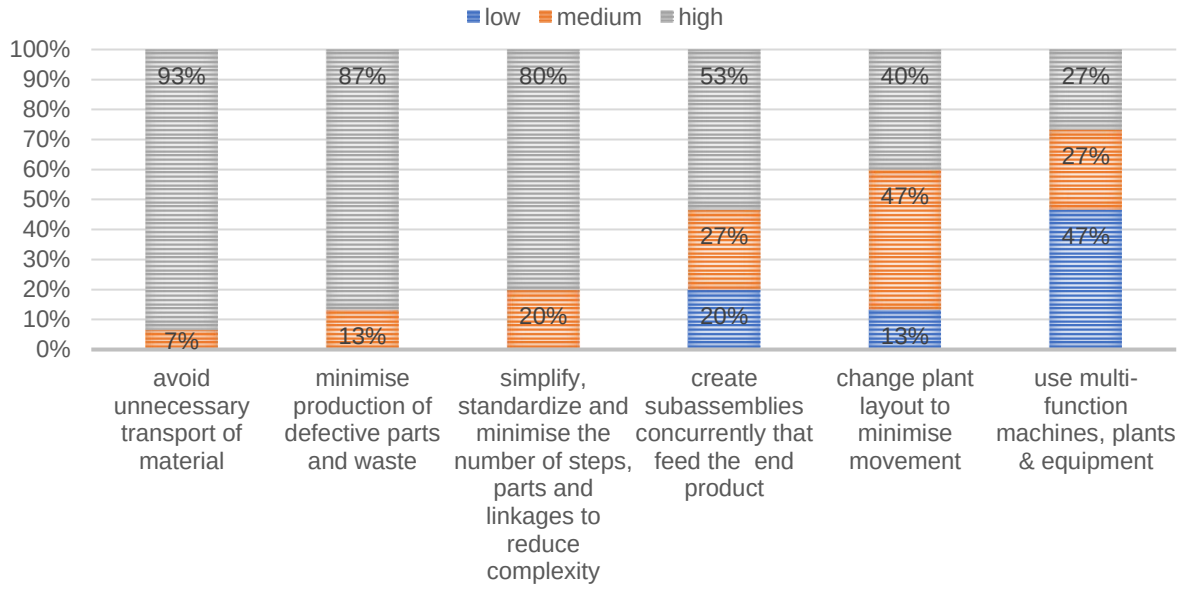


Figure 15. Level of importance of each production improvement method. (N=15)

The amount of waste materials produced by the manufacturers can be telling of their materials efficiency. The surveyed manufacturers recycled 86% of their waste by weight, which was higher than typical rate in the construction industry of approximately 75% (WRAP 2015). The combined amount of waste produced by the surveyed offsite products manufacturers (excluding the suppliers) was approximately 3,000 tonnes per annum in total. This can be estimated at only **0.24 tonnes of**

waste per produced unit-equivalent, of which only 0.03 tonnes would be sent to landfill. In comparison the traditional construction of a typical dwelling can generate between 5 and 13 tonnes of waste materials (Zero Waste Scotland 2012). Because construction & demolition activities generated approximately 61% of all of UK's waste materials by weight, the material efficiencies demonstrated by the surveyed offsite companies can have a significant impact on increasing the sustainability of construction (DEFRA 2019; WRAP 2007).

2.4. Offsite manufacturing capacity and productivity

2.4.1. Capacity for production of homes

The production capacity of a manufacturing facility typically refers to the ratio between the actual output achievable with machines and labour, and the theoretical maximum capacity if all the resources were utilised 100% of the time (Elmaghraby 1991; Garbie 2014). This reports focuses on the actual capacity of the surveyed offsite manufacturing companies, and two variables were used to correlate this figure: a) production output per week measured in linear meters of panels, area of panels, or internal floor area of modules; and b) the number of average 'units' (homes) produced by manufacturer per annum.[9]

Overall it can be estimated that the surveyed 13 offsite products manufacturers had a combined capacity to produce approximately **12,400 units**, each with estimated internal floor area of 61 m^2, or a compact 2-bedroom dwelling. Please note that this was a theoretical unit of measurement derived from the reported metre squared and linear meters of products data. Over the next 5 years the manufacturers anticipated that their capacity would grow to approximately **18,000 units** per annum, a projected capacity increase of 45% by 2023. This was in line with the planned labour and annual turnover increases.

2.4.2. Labour productivity

Productivity typically refers to the ratio of the product's output to the product's input (Fried et al. 1993). There are four levels to productivity measurement with increasing level of detail – industry, company, project and person (Kenley 2014). Two ratios were selected for measurement of output-based productivity using labour-hours input measures for greater accuracy at an industry level (OECD 2001; Solow 1957). Data from the telephone survey was available regarding people employed on the shop floor (production area), their estimated working hours per week, and their shift patterns to calculate the labour input. The output was calculated as explained in the capacity section. The results in Table 9 showed that per labour-hour approximately 0.6 m^2 of internal floor area of offsite manufactured systems were produced, and that each unit-equivalent required an input of approximately 470 labour-hours on average across the surveyed manufacturers.

	Ratio 1	**Ratio 2**
Equation	$productivity\ 1 = \frac{output\ floor\ area}{labour - hours}$	$productivity\ 2 = \frac{labour - hours}{unit - equivalent}$
Value	0.63	468.49
Units	m^2 per labour-hour	labour-hours per unit-equivalent

[9] This was done to minimise the chance of skewing data due to the selection of 'unit' typology in the capacity calculations (Duncheva and Bradley 2019). The differences in level of enhancement between the different manufacturers were disregarded in this calculation.

Table 9. Labour productivity calculations with equations adapted from (Duncheva and Bradley 2019; OECD 2001). (N=13, offsite products manufacturers)

2.4.3. Labour productivity 2013 vs. 2018

Comparable labour productivity data between the 2013 and 2018 study was available using data for total number of employees in the companies, and the companies' output in number of average homes per annum. The labour-productivity shown in Fig. 16 was therefore calculated using the following equation from, with adjustments for differences in specified typical home unit in the two surveys (3-bedroom semidetached house in 2013, and 2-bedroom apartment in 2018) (Duncheva and Bradley 2019):

$$productivity\ 3 = \frac{adjusted\ output\ in\ unit - equivalent}{total\ number\ of\ full - time\ employees}$$

The influence of the economic downturn of 2008 was attested by a decrease in productivity in the following years. From 2013 the trend was upward with labour-productivity nearly doubling by 2018, close to the predicted estimate for the same year. It was anticipated that productivity would continue to rise until 2023, albeit at a slower pace. These results suggested that among the recurring sample productivity has surpassed pre-recession levels and was gradually being improved through investment in skills and R&D. This was an important result in the political context of a need to better understand the productivity impact of offsite construction on the Scottish economy, and HM Government's emphasis on productivity in their construction strategy (Economy Energy and Fair Work Committee 2019; HM Government 2017).

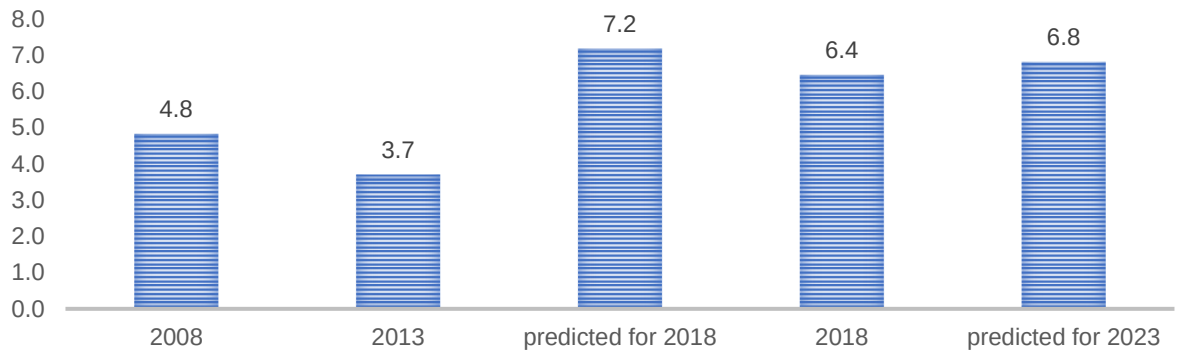


Figure 16. Number of average homes produced per full-time employee per annum by the recurring offsite manufacturers adjusted for differences in unit-equivalents in 2013 (3-bed semi-detached house ca 115 m^2) and 2018 (2-bedroom apartment ca 61m^2) studies. (N=6)

2.4.4. Production skills demand

A fundamental element to support the capacity growth of the offsite sector is the availability of people with the necessary skills to manufacture offsite products. The most demanded production (or 'shop floor') skills according to the number of mentions were related to production assembly and basic joinery, followed by erectors and finishing joiners as shown in Fig. 17. Electricians, plumbers and plasterers were less needed. This can be associated with the lower output of products with higher levels of enhancement in the factory. The required levels of qualification are shown in Fig. 18, confirming the anticipated importance of apprenticeships in mitigating the skills challenges in construction (Smith 2019). In addition, the companies reported that they invested approximately 2.7% of their annual turnover on skills development across the production and office in 2017/2018.

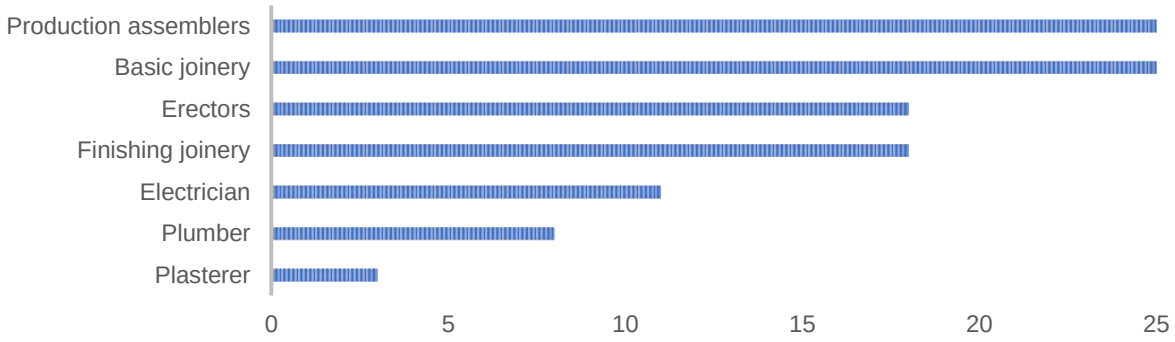


Figure 17. List of shop-floor trades and their demand (according to the number of mentions across all levels of qualification). (N=15)

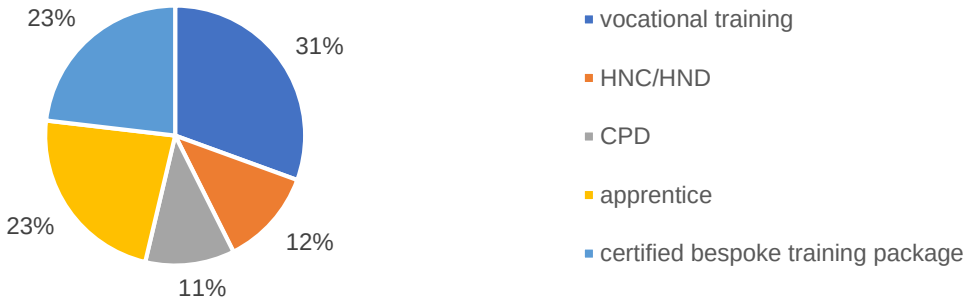


Figure 18. Levels of training required at the shop-floor. (N=15)

2.4.5. Development of production skills and professions employed by the recurring companies

Fig. 19 reports the percentage of the recurring companies who required people with a certain production skill both in 2013 and 2018. It was evident that two roles experienced a steep increase in demand in 2018: joiners and production assemblers. The dominance of offsite products with low levels of enhancement combined with the prevalent manual production methods can explain the increase in demand for basic joiners and production assemblers

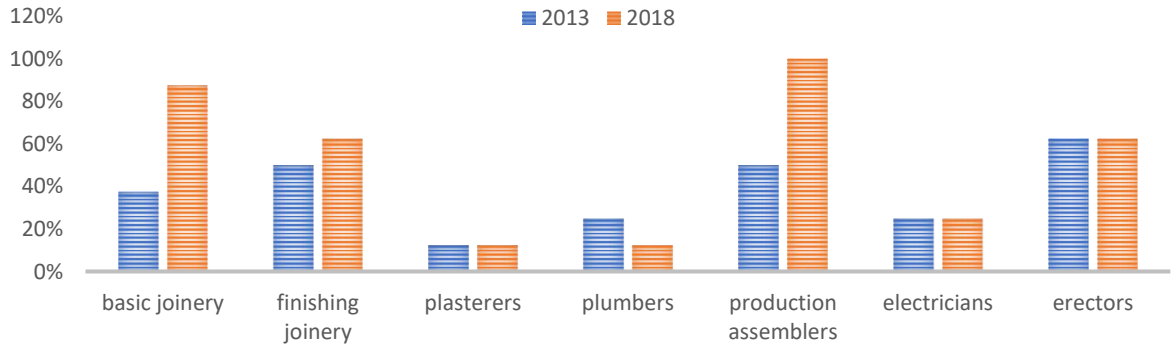


Figure 19. Comparison of shop-floor trades demand. (N=8)

2.4.6. Multi-trade operative

The future of manufacturing is anticipated to require multi-trade operatives according to (Duncheva et al. 2018), and the survey participants were asked to identify the top four trades they would require from a multi-skilled person. The results may be grouped in four multi-trade operative typologies shown in Table 10.

Multi-trade category	Number of companies
Production only	5
Production + onsite	3
Production + design/management	4
Soft skills (literacy, numeracy)	2

Table 10. Number of multi-trade typologies frequency of mention. (N=14)

Among the specific skills, the following were mostly envisioned with either apprenticeship, bespoke training and HNC/HND levels:

- Joinery
- Production Assembly
- Mechanical, Electrical, Plumbing (MEP) trades
- Soft skills

2.5. Market, supply chain and growth factors of the surveyed offsite manufacturers

2.5.1. Turnover generated by each market sector

Fig. 20 show the market sector distribution of the 2017/2018 annual turnover among the surveyed manufacturers, where it can be seen that approximately 85% of the total was generated by the housing sector. Other markets in increasing order according to revenue were: office and commercial buildings (4%), hotels and tourist accommodation (3%), educational buildings (3%), care homes (2%), halls of residence (2%) and others (2%). However the manufacturers anticipated that in the next 5 years, the revenue generated from retirement homes, offices, commercial and educational sector would increase marginally, with an associated expected decrease in private housing output.

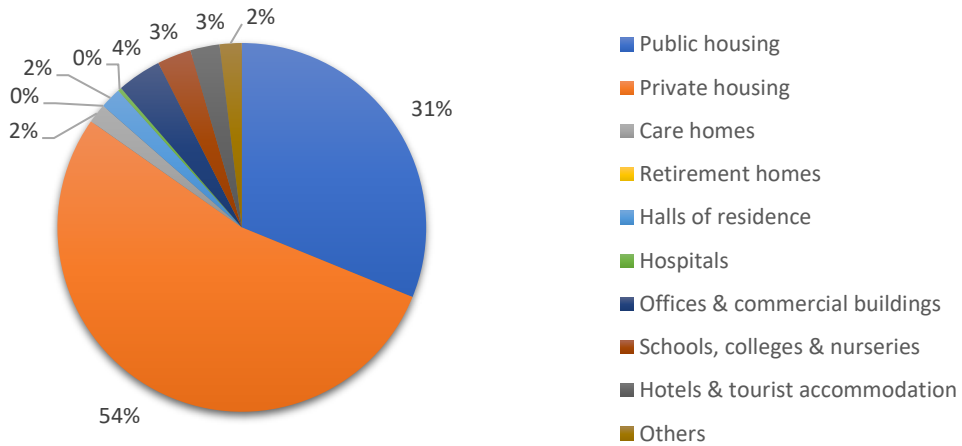


Figure 20. Current percentage of annual turnover generated by each sector market. (N=14)

2.5.2. Supply chain incoming products

The top 10 products on average procured on by the surveyed companies through their supply chains, regardless of relationship type, are listed in Table 11. The results demonstrated that the supply chains of offsite manufacturers in Scotland were closely inter-connected with the rest of the UK, mainland Europe countries such as Germany and Finland, as well as internationally with Canada. Among the business-to-business relationships (46% of the products above), the majority of suppy chain partners were located within Scotland, followed by England and the European Union (EU), as shown in Fig. 21.

Product type	**Supply chain business location**
Timber	Sweden, Finland, Canada, France, Russia, UK
Oriented Strand Board (OSB)	UK, Germany
Insulation	Germany, France, Czech Republic, Poland, UK
Windows and doors	Scandinavia, Austria, UK
Metalwork, fasteners, plates, nails, saws	Germany, UK
Plasterboard	Europe, UK
Timber joists	Scotland, Poland
Mechanical, electrical and plumbing systems	Austria, Germany, Scandinavia, France, UK
Trusses	Scotland
Chipboard	England, Scotland

Table 11. Key supply chain links of the surveyed offsite companies. (N=15)

Figure 21. Percentage of participants who reported a business-to-business supply chain relationship according to supplier location. The locations with the top 3 frequency are highlighted in bold, the remaining were less than 1%. (N=15)

2.5.3. Relationships with other countries

The participants were asked which relationship they had with businesses outside of Scotland, including supply, export, licence, joint venture, and manufacturing facilities. Fig. 22 shows a heat map of these business relationships according to frequency of mentions by the surveyed companies. Both in 2018 and 2023, relationships were reported with all four parts of the UK (England, Scotland, Wales and Northern Ireland), **eight** European countries, and five international countries. The offsite manufacturers supplied to the UK, **France,** the Falkland Islands, **Germany,** Portugal and Belgium in 2018, and had intentions to extend this with more European countries in 2023. The companies exported to the same list of countries as the supply list, with the addition of Greece for 2018, with projections to increase the scope with South America, the USA and more areas of mainland Europe. The 2018 licence, joint venture, and manufacturing facilities were mostly limited to England and Scotland, with intentions to extend into **New Zealand** and Australia. This demonstrates the truly

international business reach of the Scottish offsite sector at a time when business relationships with mainland Europe face uncertainty.

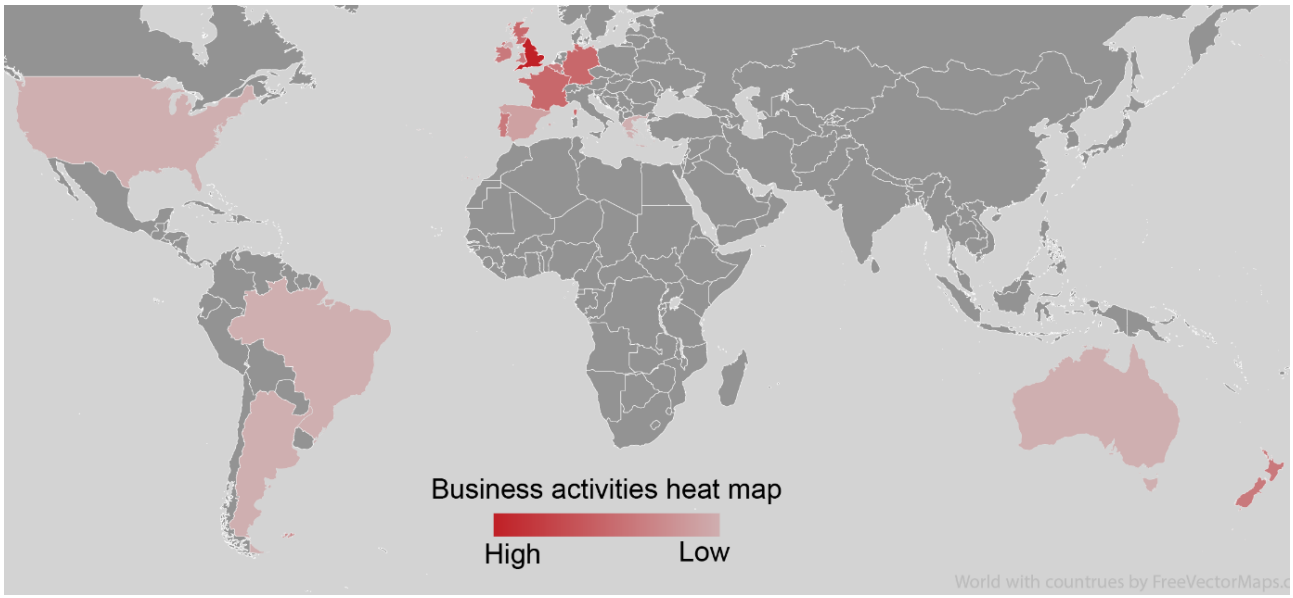


Figure 22. Supply, export, licence, joint venture and manufacturing facilities business relationships heat map of the surveyed offsite manufacturers. (N=15)

In addition, the surveyed companies reported they had delivered offsite products as far away as between **5,000 miles** and **330 miles** away from their manufacturing facilities. In addition, the surveyed companies reported they spent approximately 5% of their annual turnover on transportation of the offsite products, cost of transportation can therefore be considered to have a relatively low impact on final cost. The survey did not cover standard distance of sites to the factories, which would be associated with the expenditure on transportation. With an average maximum transportation distance of 2,200 miles potential customers across the UK should have a wide variety of **systems and manufacturers to choose from regardless of their location**, be it remote or dense urban environments.

2.5.4. Barriers and drivers to increased capacity among the surveyed offsite manufacturers

The factors influencing the capacity and growth of the offsite sector in Scotland were ranked according to importance by the surveyed companies, and the top three factors in each category from 2013 and 2018 are summarised in Table 12. The aspects common to both questionnaires are highlighted in red if the factor had the same ranking in both years, or in blue if the same factor had different rankings in both years. From these results the following key observations can be made:

- The **greatest barrier** to the growth of the offsite sector in Scotland were the **fluctuations of the economy** and the construction market. This was followed in 2018 by standards and permits, indicating that external influences over which the offsite sector had limited control were the leading barriers to growth;
- Demand for housing and sustainability remained consistent **drivers** in 2013 and 2018, however with the passage of time **clients' requirements** gradually increased in importance. These may be inter-connected with reduced time onsite, improved health and safety and increased environmental credentials in response to demand for housing;

- **Government assistance** continued to be needed predominantly in **capital investment funding** geared towards manufacturing facilities capacity growth, with a consistent emphasis also on the need for grants for skills, training and apprenticeships;
- Increased product & process efficiency was a common theme in all areas for **technical development**, with importance in 2018 given mostly to **low-carbon technologies**.

Order of importance	BARRIERS	
	2013	**2018**
1	Fluctuations in the economy and, correspondingly, the construction market	
2	Excessive competition in the sector	Local planning or building control
3	Limited predictability due to non-standardisation and late design changes	Building regulations & standards
	DRIVERS	
	2013	**2018**
1	Improved on-site activities including construction time and health and safety	Client requirements, relationships and partnering
2	Government policy and building regulation requirements	Improved on-site activities including construction time and health and safety
3	Housing shortage and the need for efficient systems	
	Environmental credentials and the need for more sustainable envelopes and reduced waste	
	GOVERNMENT ASSISTANCE/INCENTIVES	
	2013	**2018**
1	Government procurement requiring offsite systems	Capital investment funding
2	Capital investment funding	Research & innovation grant
3	Skills training & apprenticeship grants	
	TECHNICAL INVESTMENT	
	2013	**2018**
1	Building envelope advancements (structural, thermal and acoustic)	Development of low carbon technologies compatible with offsite
2	Process improvement and information and communication technology implementation	Building envelope advancements (structural, thermal and acoustic)
3	Supply chain integration and Building Information Management (BIM)	Process improvement and information and communication technology implementation

Table 12. The most highly ranked barriers, drivers, to increasing the capacity of offsite construction in the next 5 years. (2013 N=14 and 2018 N=15, full sample ranges)

Overall, **resource-efficiency** was an over-arching factor for the growth of the offsite sector in Scotland, the development of which needed to be underpinned by stable market conditions, capital investment, skills development and implementation of new technologies. In addition, a **secure pipe-line of projects** and a **strong leadership with a clear strategy** for the offsite sector were critical factors enabling the scaling of the capacity sector, as the participants revealed via an open-ended question. Some responses also emphasised on the need to improve the image of the offsite sector in the eyes of consumers, and to raise awareness on practical topics such as availability of mortgages. Due to the political context, participants also had an opportunity to express their views on how Brexit might affect the sector. The comments were split between those who anticipated major disruptions in projects going ahead and orders, as well as labour, timber and specialist materials sourcing from Europe; and those who stated that the full impact is uncertain and it would be detrimental to the construction economy but to what extend they could not foresee. Regarding the need for investment in skills, in 2019 the CITB made a £1.2 million investment in the creation and dissemination of publicly available offsite construction knowledge. The content will cover topics

ranging across introduction to offsite principles, design, manufacturing, and construction management.

2.6. Business models review

Production capacity and annual turnover are indicators of the growth of the sector, however whether this growth can be sustained would depend on the financial health of the offsite sector in Scotland. The publicly available records of the identified 33 offsite manufacturers in Scotland were analysed using the Financial Analysis Made Easy (FAME) database, which contains detailed financial information on 1.6 million companies in the UK and the Republic of Ireland (linked to Companies House submissions) (Bureau Van Dijk 2019). The financial analysis included a two-stage process:

1. Estimation of the size of the offsite sector as a whole using available data for 19 companies with detailed financial information, out of the 33 identified the mapping desktop study. The remaining 14 companies did not deposit full financial accounts due to the company size[10] and estimations were made for their contribution to the size of the offsite sector in Scotland;
2. Financial health analysis using established financial ratios for offsite products manufacturers with available detailed records, grouped according to business model type.

2.6.1. Size of the offsite sector in Scotland as a whole

Section 4 presented the size of the surveyed companies, and this section extends the analysis with an estimation of the size of the offsite sector in Scotland as a whole. The 19 companies with available detailed information had a **combined annual turnover of £259.28 million and 1,574 people employed** in the financial year ending in 2018 as reported to Companies House (HM Government 2019). Please note that this analysis did not capture sole trader operations, which are typically outside the scope of market capacity research reports (Egan Consulting 2019).

The number of people employed in the 14 smaller business with abridged accounts was estimated using reported numbers on people employed within their balance sheets[11] – 280 employees in total. The revenue of each of the small companies may be estimated using the average annual turnover generated per employee among the 19 companies with available financial data (£164,727), totalling approximately **£46.12 million**. This may be compared to the estimated annual turnover per employee from the telephone survey (£113,444), which would total approximately **£36.76 million** for 280 people employed. This estimate can be combined with the value of the 19 companies with known financials to arrive at an approximate size of the offsite sector in Scotland.

Therefore the size of the offsite sector in Scotland as a whole measured in annual turnover can be estimated at between £291 million and £305 million (on average £298 million, +/- 2%) with approximately 1,854 people employed among the identified 33 offsite products manufacturers in the financial year ending in 2018.

Projections for growth are typically based on historic trends in terms of percent change, and detailed historic annual turnover data available from FAME was used for nine offsite products

[10] HM Government only require abridged accounts from small entities (complying with two out three conditions: annual turnover no more than £10.2 million, balance sheet no more than £5.1 million and no more than 50 employees), and micro entities (annual turnover no more than £632,000, balance sheet no more than £316,000, and no more than 10 employees) (Companies House 2018).

[11] 12 were 'small' as stated in balance sheets and had average number of people employed, 1 was classified as micro due to missing accounts as a new company and estimated at 5 people employed based (the company was contacted via telephone to check this assumption), and 1 was estimated at 5% of number of people employed for offsite production within a larger housebuilding business, based upon information provided by a similar company over the telephone.

manufacturers[12], the results of which may be seen in Fig. 23. It is interesting to observe that the trends of change in annual turnover and people employed followed a similar pattern of peaks and troughs over the past 10 years. This showed both the cyclical nature of the construction industry, and the tendency of offsite manufacturers to grow and compress their workforce as the market conditions changed. The size of the offsite sector in Scotland in 5 years' time (by 2023), may be estimated using a linear projection with an estimated error of margin of +/- 15%[13] to account for the cyclical nature of the sector.

Knowing the approximate size of the sector in 2018, the percent change from 2008 to 2018, and the projected percent increase to 2023, the size of the sector in 5 years' time can be projected to be approximately **£343 million** (190% of 2008) with potential fluctuation between £370 million and £316 million. Similarly, it is projected that the number of people employed in offsite product companies in 2023 will be approximately **1,896** (136% of 2008), with potential variation between 2,105 and 1,687 depending on the cyclical nature of the sector.

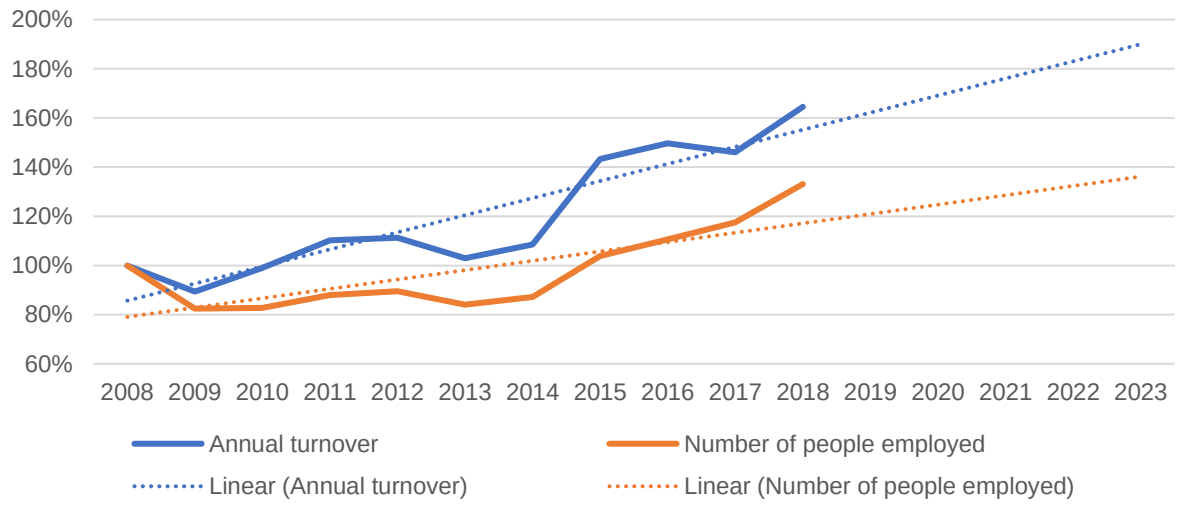


Figure 23. Annual Turnover and Number of People Employed change per annum, sourced from historic financial records data from FAME. The linear projections to 2023 have +/- 15% error bars to account for possible fluctuations due to the cyclical trends of the sector. (N=9)

During the financial ratios analysis, two main business models were identified: those of companies performing only design and manufacturing functions, and manufacturers part of a larger homebuilding group with several businesses. Regarding profitability margins, the studied offsite companies tended to outperform available benchmark data for the construction and manufacturing industries. However some profit margins as low as 0.2% were a sign of caution and the financial notes revealed these were inter-connected with investment in geographic diversification and the rising price of timber, both consequential of Brexit. The design and manufacturing companies took longer to collect debt, and paid credit sooner than those part of a larger homebuilding group. This was likely associated with a difference between short-term business strategies for the single entities, and the ability to look at more long-term business strategies for those companies belonging to a bigger group. Supporting this argument was the liquidity of the design and manufacturing companies, which was higher than for those part of a larger group.

[12] The following assumptions were made to fill missing data points from financial records: annual turnover - 4 points for 2018 inserted as reported in the telephone survey by the respective companies, 3 points averaged between values for previous and following years; number of people employed – 3 points for 2018 based on telephone survey, 3 points averaged between values for previous and following years, 3 points filled based on estimations of the manufacturer's data as a proportion of the group's data.

[13] Assumption made based on peaks and troughs of the data between 2008 and 2018.

Overall, compared to the often observed financial issues in construction with 'boom-and-bust' cycles, the business models review suggested that the offsite manufacturing companies were financially healthy with some signs of caution regarding short-term profitability.

2.7. Conclusions

This report presented results from a telephone survey of 15 offsite sector manufacturers in Scotland and a review of 18 Scottish offsite manufacturers' business models. From the data five main conclusion strands can be identified as characteristics of the offsite construction sector in Scotland:

1. **Sector growth:** The sector as a whole was estimated to grow in terms of annual turnover and number of people employed in the next 5 years, from approximately £298 million and 1,854 people employed in 2018, to approximately £343 million and 1,896 people employed. In addition, the telephone surveyed sample of offsite manufacturers' annual turnover, number of full-time employees and capacity to deliver homes have all increased steadily from 2008 to 2018. Annual turnover from manufacturing plants in Scotland was projected to increase by 77% between 2018 and 2023, up to approximately £290 million with corresponding growth in capacity up to approximately 18,000 units per annum. The business-to-business supply chain relationships of the surveyed companies were centred in Scotland, therefore such growth would have a positive effect on the Scottish supply chain such as roof truss and board materials manufacturers and suppliers.

2. **Resource-efficiency:** Labour-productivity measured in typical homes output per full-time employee has increased over the past 10 years, with projections to reach nearly 7 unit-equivalents per employee per annum in 2023. Combined with the low quantities of waste materials generated from manufacturing (0.24 tonnes per unit-equivalent, of which 0.03 tonnes sent to landfill), these results indicate an increasing resource-efficiency (labour and materials) among the surveyed representatives of the offsite sector in Scotland. However, the participants expected that the economic consequence of Brexit could slow down this growth due to challenges in project pipeline, labour and materials sourcing.

3. **Housing-centred markets and products with emphasis on sustainability:** The offsite sector in Scotland continued to be centred on homebuilding, with 85% of annual turnover originating from private (54%) and public housing (31%) in 2017/2018, driven by housing demand in the market. This corresponded to approximately 90% of the surveyed companies' revenues dedicated to 2D timber systems (panels) mainly with low levels of enhancement, which are typically suitable for flexibility in design with varying house-types and late client changes. By 2023 it was anticipated that the levels of enhancement of the systems would increase marginally, meaning more work would be completed in the factory. This could be in response to reported drivers for offsite construction as client's requirements and priorities to reduce time onsite with improved health & safety, as well the emphasis on increasingly low-carbon solutions. These three drivers indicate emphasis on all three areas of sustainability: economic (time), social (worker's health and safety) and environmental (low-carbon).

4. **Production focussed on people**: Underpinning the points above were high requirements for skilled production assemblers and joiners, indicating a higher degree of specialisation for offsite production. Simultaneously, 56% of the surveyed manufacturers' processes were based on manual production and use of multi-purpose equipment was ranked the lowest in importance of method for production efficiency increase. The survey participants ranked skills and training as the 3rd most important area for support by the government in both surveys of 2013 and 2018. Such an investment would supplement the 2.7% of annual turnover invested by in skills by the surveyed manufacturers on average. Yet capital investment support was ranked as the top area for government support in 2018 by the survey participants, and this

could be utilised to increase the semi-automation capability of the surveyed manufacturers, with relevant requirements for upskilling of staff.

5. **Healthy financial situation dependent on market fluctuations:** Two main business models were identified, those of single entities and of manufacturers belonging to a larger group. Where benchmark data for the construction industry in Scotland was available, the companies studied in this sample tended to have upward trends where the industry's trend was downward suggesting financial health better than that of the industry. Yet significant fluctuations were observed in profitability from year to year, signifying the sector's vulnerability to the variations in the market demand, labour and materials sourcing conditions. A secure pipe-line of work was identified as critical area for governmental support by the survey participants, and this could help to alleviate the financial fluctuation challenges faced by the offsite manufacturers.

3. Project 3

3.1. Introduction

Project 3, “Co-designing Solutions” through engagement with a diverse group of stakeholders in the housing sector, ultimately aimed to co-design recommendations that could improve the overall off-site construction (OSC) process and enable wider adoption.

The Innovation School at the Glasgow School of Art were commissioned to design and deliver a series of iterative co-design workshops, to identify, develop and test possible solutions and improvements to increase the level of OSC housing in Scotland. The project brought together perspectives from across the construction sector to explore the innovation challenges and opportunities around OSC through the practice of co-design, in collaborative events in the East, West and North of Scotland. This approach involved cross sector stakeholders following an iterative process of progressive problem solving to develop and refine options. In total the project engaged 63 participants and 42 UK organisations at participatory workshops across Scotland.

Utilising the knowledge, experience and perspectives of the critical stakeholders from the OSC industry, the affordable housing sector, the private housing sector and the broader supply chain, key insights were uncovered, analysed and developed. This resulted in a detailed series of Innovation Actions which have the potential to be taken forward as suggestions to stimulate innovation in OSC. The outputs from across the three workshop generated the recommendations from this co-design project. The list of Workshop attendees can be found in Appendix 4.15.

3.2. Co-designing Solutions Process

A series of three, interlinked co-design workshops explored the innovation challenges and opportunities around OSC, and co-designed, iterated and refined potential solutions and improvements, leading to a series of recommendations and actions on how all the stakeholders can take forward this agenda. The overall process is shown in Fig 22.

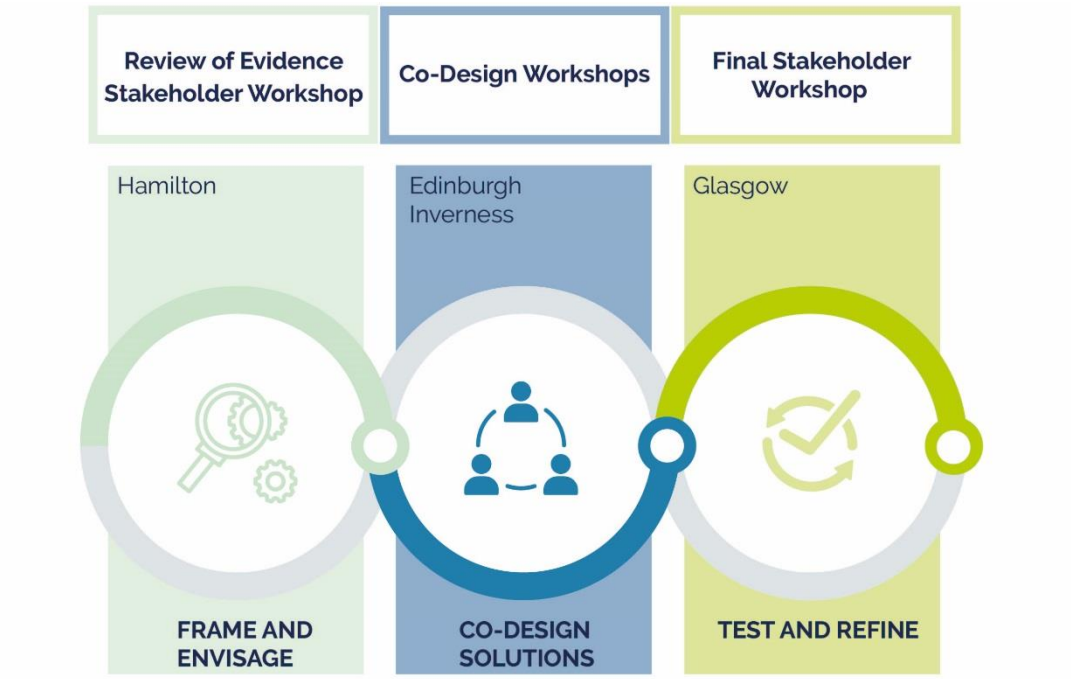


Fig 22. Workshop process overview

3.2.1. Review of outputs from Projects 1 & 2

The initial phases of this project explored the data and evidence of the challenges, issues and barriers faced by the affordable housing sector (Project 1) and examined the current and future OSC industry capacity (Project 2) including the capabilities and capacity of the current company base, and forecast capacity in 5 years-time. These phases included literature review, desk research, questionnaires, and interviews with industry and key stakeholders. The outputs from project 1 and 2 were reviewed and informed the five initial key themes that acted as provocation areas for exploration in the first stage of the co-design process. These were:

- design and performance;
- culture and perceptions;
- cost, funding and procurement;
- capacity and resources;
- skills.

These five themes acted as a key input into the first stakeholder workshop, forming the basis of our discussion, and helping to shape the key areas to focus on for the next phase.

3.2.2. Stage 1: Stakeholder Workshop - Frame and Envisage

The first one-day workshop brought together experts from policy, the construction industry, architecture and design, academia, and government, to help inform the understanding of the current state of OSC and delve deeper into the challenges and questions to be resolved. This launch event, held at the Construction Scotland Innovation Centre in Hamilton was introduced by Kevin Stewart MSP, Minister for Local Government, Housing & Planning. As an initial discussion participants shared their ambitions for offsite construction in Scotland. This is summarised in a collective document in the form of an offsite “Manifesto” – see Appendix 4.16. This was also revisited in the final workshop to ensure that participants felt the co-design process had focused on the key elements and important factors.

The expert group then spent time fully describing the overall process and all its elements by mapping the “House Journey”, from the commissioning, design, construction, hand over, use and eventual post-use, to better understand the steps and interrelationship between the different elements. The maps from different groups are built on by subsequent workshops and have been combined to create the first collective view of the total end to end OSC construction journey from a multi stakeholder perspective. Onto the House Journey stakeholders flagged current issues and opportunities for OSC and shared some initial visions for how this process could be improved. Figure 24 and Figure 25 provide a combined illustration of the complete House Journey, the issues, and opportunities raised by our experts.

This final stage of the workshop explored in depth the challenges and opportunities identified through the five key themes, staying longer in the question and identifying the importance for offsite. The outputs from this final stage were analysed and collated initially into ten process challenges and opportunities for OSC that should be taken forward as a potential innovation or solution. A subsequent challenge was added during one of the co-design workshops resulting in a total of eleven challenges. Fig 23 shows the summary of those challenges, with a more detailed description in Appendix 4.17.

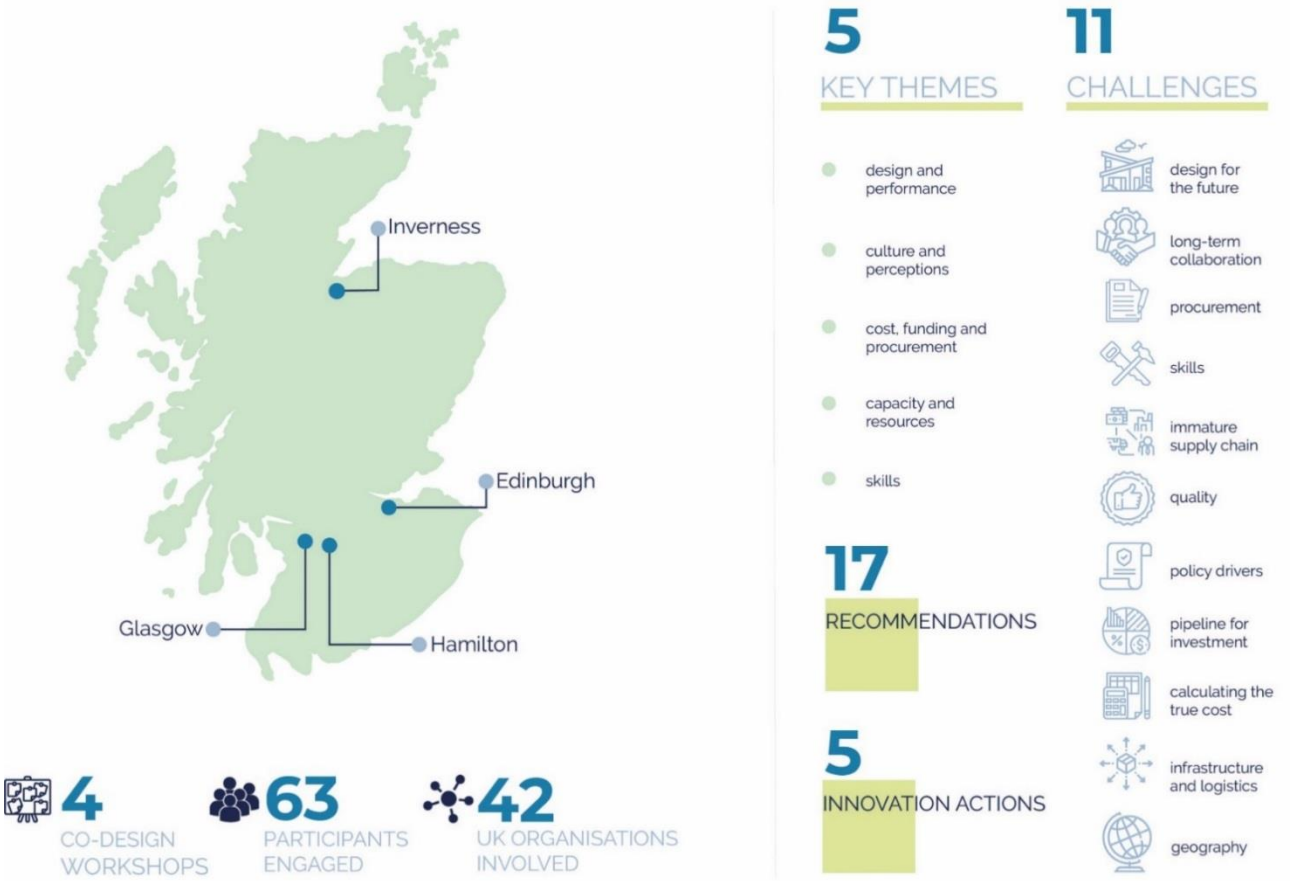


Figure 23. Overall Project 3, Key themes and challenges

3.2.3 Stage 2: Co-Designing Solutions Workshops

The discussions from the first workshop were reviewed, analysed and collated to form a list of eleven more detailed challenges for OSC that could be taken forward into the next co-design phase of the project, to further develop these innovation challenges and opportunities. Two co-design workshops were held in Edinburgh and Inverness, to ensure wide representation across Scotland and that any specific geographical issues (e.g. rural environment issues) were fully explored and addressed. Consequently, it was in this part in the process the eleventh challenge of Geography was added. Stakeholders were asked to prioritise their key challenges and to collectively work up initial ideas and actions to address them. There was also an opportunity to review and supplement the House Journey.

The workshops produced seventeen co-designed recommendations for change and innovation in OSC based on the prioritised challenges. These outline recommendations were then taken forward into the final workshop. A full list of recommendations can be seen in the P.I.E.R. Review section, Appendix 4.18. and are summarised below. The outline recommendations were:

- Encourage collaboration for continuous improvement;
- Ensure early involvement of all actors;
- Involve users and the community to understand needs and desires;
- Introduce incentives to stimulate the market and promote early adoption;
- Adapt financial payment models to reflect shared risk;
- Ensure there is a long-term strategy and visibility of pipeline of investment;
- Develop and adapt current workforce for the new skills and roles that will be required;
- Plan for new and incoming skills and capability development for future workforce;

- Introduce a Scotland wide “Gold Standard” quality of build;
- Explore routes to standardisation of components for OSC without compromising flexibility;
- Evidence the true cost for whole projects and whole life using offsite approaches;
- Capture and share good practice case studies to communicate OSC benefits;
- Ensure procurement approaches include quality and whole life criteria;
- Explore the potential for optimising home-grown materials and supply;
- Implement an open source build system;
- Adapt the current planning process to the OSC approach;
- Collate and publicly share life-time performance data.

3.2.4 Stage 3: Final Stakeholder Workshop: Test and Refine

The final one-day stakeholder workshop brought together existing project partners and additional experts from the construction industry and academia. In the workshop, the findings from projects 1 and 2 were presented and discussed, together with the initial findings and outline recommendations collated from the co-design workshops at stage 2. Stakeholders were asked to review and prioritise the seventeen recommendations, and to select their top five to take forward into more detailed Innovation Action plans. This was achieved through a P.I.E.R. review process, collectively assessing each recommendation against Potential; Importance; Ease; and Resources. Each idea is given a combined score based on the four categories, with the highest ranking taken forward further.

Two stakeholder groups each conducted a P.I.E.R. review of the seventeen ideas and actions, the resulting combined list prioritised five to be taken forward and developed into more detailed Innovation Action plans.

It was interesting to note some of the conflict and agreement between the two groups in terms of their ranking. Also, it was noteworthy to see that some of the ideas, while ranking as highly important with a high potential, where overall ranked low because they were perceived to be problematic and would be resource heavy. Although five were taken forward into further action planning and development, all seventeen recommendations are important to consider as opportunities for OSC innovation. The full P.I.E.R. reviews can be seen in Appendix 4.17.

The five prioritised recommendations were:

- Ensure procurement approaches include quality and whole life criteria;
- Ensure early involvement of all actors;
- Capture and share good practice case studies to communicate offsite benefits;
- Introduce incentives to stimulate the market and promote early adoption;
- Collate and publicly share life-time performance data;

These five key recommendations were developed by self-selected working groups into five Innovations Actions. The action plans summarise what needs to be done in order to achieve the objectives for each innovation, including individual key actions, stakeholders who should be involved and the potential challenges. Details of each of the five can be seen in the Innovation Actions section, Appendix 4.19.

3.3 Conclusions

The co-design workshops allowed discussion around the challenges and opportunities within construction, and for OSC approaches more specifically. Our research found that currently:

- **Life time building performance data for OSC is not collated nor publicly shared**. This hampers the industry’s ability to understand the true cost of OSC as well as impeding continuous

improvement and innovation in design. Such data could play a role in creating customer demand by, for example, providing data that buyers could use when making purchasing decisions.

- **In the main, building quality and whole life criteria are not well understood and fail to influence established practices such as current procurement.** Lack of robust whole life data positions OSC as a less cost-effective approach to traditional construction. This does not consider the true cost benefits of OSC and does not support informed appropriate decision making.

- **There are many examples of successful OSC projects, yet these best practice cases are not well publicised and the lessons learned are not readily shared.** This restricts the wider communication of the benefits of OSC and restricts the capture of valuable technical and social feedback that could help drive further innovation.

- **The current OSC process is fragmented and lacking in early collaboration between relevant stakeholders.** Continually maintaining a collaborative working environment at the beginning of the OSC process could ensure cross-departmental synergy and could therefore aid the process of moving towards a more integrated approach to working. In doing so it could benefit project budgets and sustain a high degree of quality in capital cost. This commitment and method of engagement within the primary stages of the process can enable a stronger, greater visibility of pipeline for investment as well as a positive outlook on the criteria required to design affordable and adaptable, high quality homes for the future.

- **A considerable barrier to accelerating OSC projects and generating sharable data is the current lack of long term and appropriate funding available**. There are two key funding factors influencing OSC. Lack of long-term collaborative funding strategies, and mechanisms to stimulate early adoption.

- **Long-term strategies with collaboration from actors as well as political involvement is necessary in order to gather and update resources, secure commitment to projects and acquire funding through innovation partnerships.**

- **Using incentives as a grant mechanism to encourage early adoption will in turn create value for OSC at large.** This added value is gained from testing via pilots to produce critical feedback.

To conclude, offsite itself is not the panacea to all of the construction industry's ailments. For offsite manufacturing to stimulate a transformation across industry, there is an onus on clients and suppliers to quantify its longer-term asset value, and start to develop more suitable business cases that include whole-life whole-cost analysis. The industry, and clients in particular, must also look to re-develop compatible procurement and contractual strategies to enable more collaborative investments in offsite.

In order to enhance the current OSC process, to enable wider adoption and take advantage of the benefits OSC offers there are a number of areas that have therefore been identified as a priority to take forward. From this research we recommend:

- Collation and public sharing of life-time performance data. This will involve:
    - A clear definition of building performance data;
    - Customer engagement to understand buyer values;
    - Continuous measuring and monitoring.

- Early involvement of all actors in OSC projects. This will include:

    - Creating a transparent process to show target cost, value and risk.

- Procurement approaches which include quality and whole life criteria. Key to this will be:
    - A defined and established standard of quality and whole life criteria;
    - A structured and measured incentivized process;
    - A new business model development.

- Capturing and sharing good practice case studies. This will implicate:
    - Adopting new building performance quality measurement tools;
    - Introducing incentives to stimulate the market and promote early adoption.

- Introduce Incentives to stimulate the market and promote early adoption. It will be essential to:
    - Agree a collective strategic approach to encourage partnership and bring confidence;
    - Generate additional programme resources to support;
    - Maintain collaborative commitment and build confidence;

3.4 Recommendations

While the construction industry is buoyed by predicted growth and expansion, it continues to underperform in a number of strategic areas: productivity and quality, challenges in continuity of planning and delivery pipelines, skills shortages and data transparency. OSC - the prefabrication, modularisation and standardisation of construction processes and assets within controlled factory environments – is frequently quoted across government and industry as a potential catalyst in stimulating improvement in the sector and meeting these challenges. It also has a role to play in addressing the UK's housing shortage.

This programme of work was commissioned to provide recommendations to the Government and the wider sector to help influence the policy for OSC for the future.

This co-design element of the project sought to develop a dialogue between key stakeholders in the OSC and the affordable housing sector, by way of interlinked workshops held in Inverness, Edinburgh and Glasgow. These workshops aimed to explore the potential there is to co-design solutions that are fully able to overcome the barriers to any expansion of the OSC sector, and which inhibit the development of advanced manufacturing systems that are able to serve the affordable housing sector. In this regard, Project 3 found:

- While there are many examples of successful OSC, these case studies are not well publicised and the lessons learned are not readily shared. This restricts a wider communication of the benefits which OSC offers and fails to capture the lessons learnt that could help drive further innovation in the affordable housing sector.

- The absence of reliable data on OSC, also serves to hamper the industry's ability to understand the true cost of provision, as well as inhibiting the innovations needed for advanced manufacturing systems to out-perform tradition methods of provision not just in cost and time (see Project 2) but also in terms of quality.

- OSC should adopt whole life-cycle costing as a basis to present the true cost of provision (as a measure of cost, time and quality) and as a set of metrics providing the evidence needed to show how advanced manufacturing systems can out-perform traditional methods.

- In making the case for whole life-cycle costing, OSC should develop a collaborative working environment better able to represent the full range of stakeholders involved in the advanced

manufacturing systems and the benefits they offer. The lessons learnt from such collaboration should also be shared and used to showcase how modern methods of construction can be drawn upon as a business model able to overcome the barriers that otherwise inhibit them from meeting the challenges which the affordable housing sector face.

- Such a commitment to collaborative working should also be used as the basis of a business case setting out how to service the development of a pipeline approach to OSC, covering not only investment in the production and assembly stages of the manufacturing systems, such as plant and machinery, but the use and occupation of the affordable houses built from the application of such methods.

- Any attempts made by business to accelerate the development of OSC by way of investment in advanced manufacturing systems and through any adoption of a pipeline approach, should also take account of what might be best referred to as the public value of offsite housing, especially in relation to those construction methods which capture the full cost of provision and also realise all the environmental and social benefits advanced manufacturing systems offer the affordable housing sector.

- The procurement of such value should be fully accountable to all stakeholders involved in OSC and allow advanced manufacturing systems to secure a pipeline of affordable housing that is stable not only in terms of cost, time and quality, but also in relation to the volume, mass and scale of provision.

These findings of Project 3 suggest the evidence available to account for the performance of OSC in comparison to other, more traditional methods, needs to be fully transparent, so it can be open to proper scrutiny from members of the public. To help with this, it proposed a number of innovations: for example; shared information, whole life-cycle costing, collaborative working and a pipeline approach which should be championed in order to accelerate the development of advanced manufacturing systems for OSC.

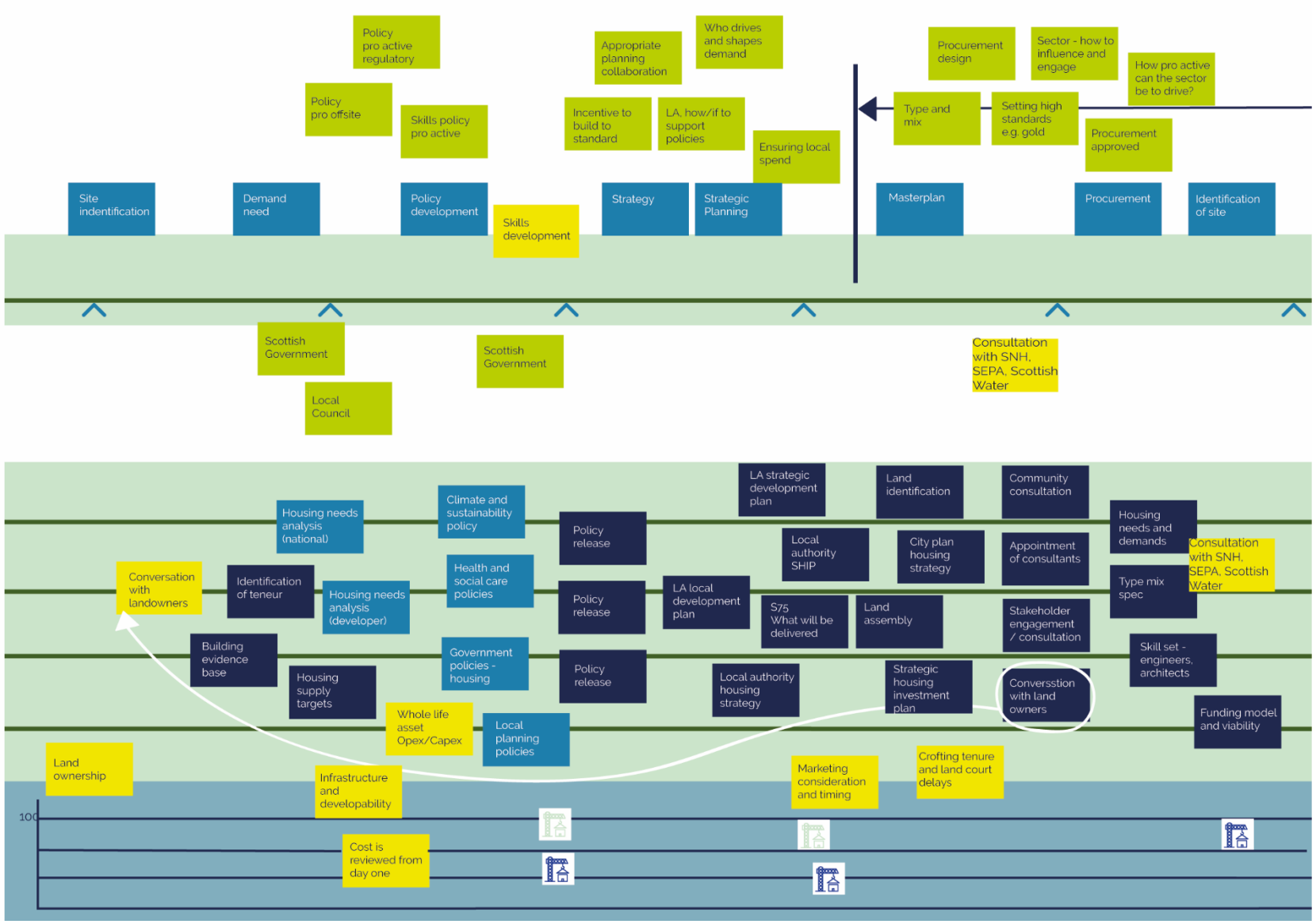


Figure 24: The House Journey (Part A)

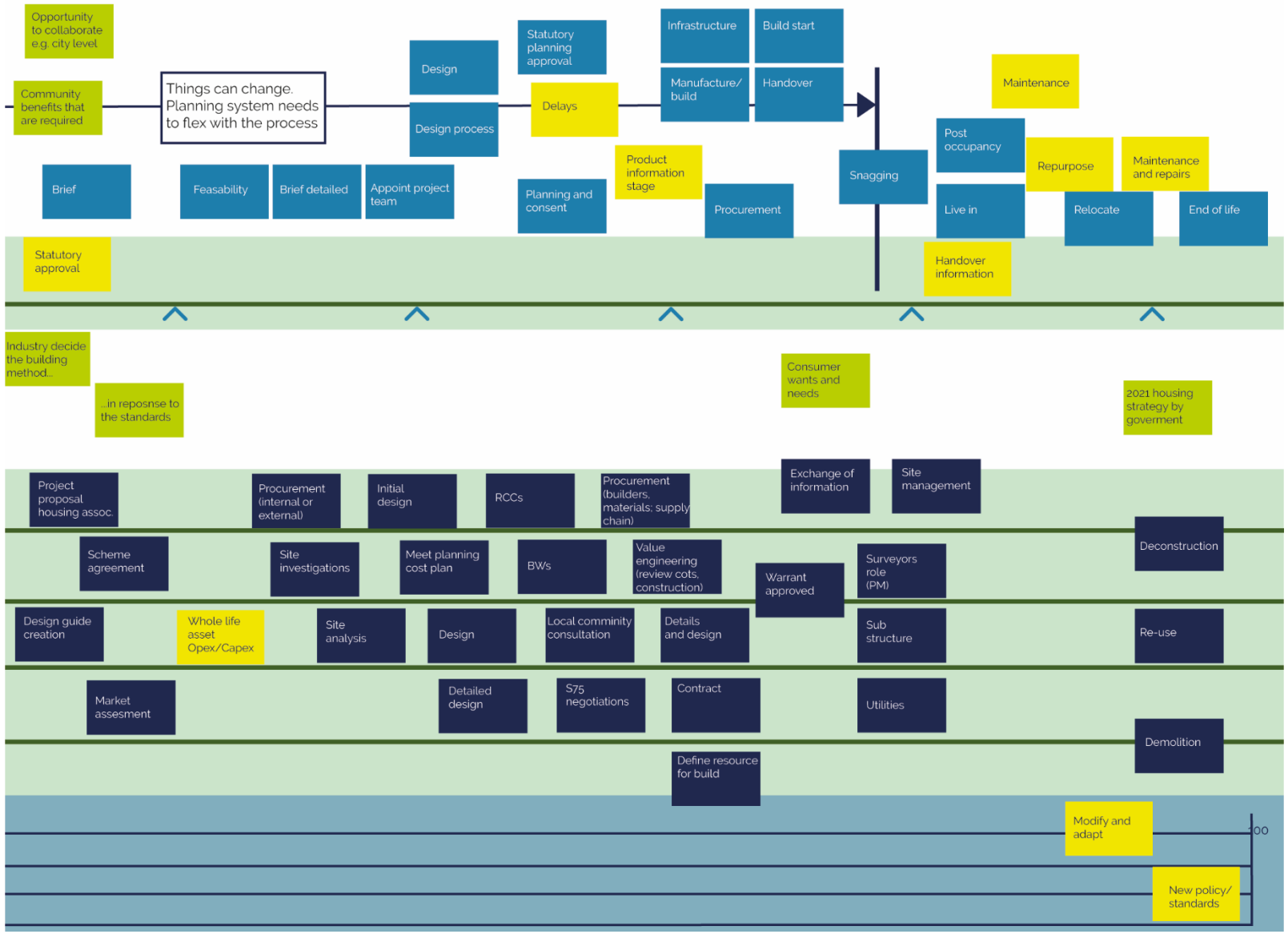


Figure 25: The House Journey (Part B)

4. Appendices

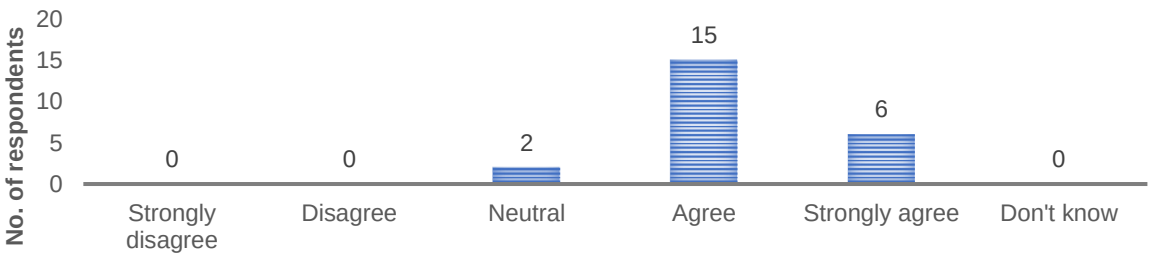
4.1. Statements for questionnaires

Statement
1. Statutory standards for the quality of new build affordable homes in Scotland will continue to increase.
2. The skills of those involved in designing and constructing affordable housing do not currently meet the needs of the sector.
3. The construction of affordable housing in Scotland is underperforming due to poor project management.
4. In Scotland, the budgets set for affordable housing construction projects rarely experience cost overruns.
5. In Scotland, the development of brownfield sites for affordable housing is inhibited by technical issues.
6. In Scotland, the current approach to the design of affordable homes is flexible in meeting the needs of residents.
7. In Scotland, the design and construction of affordable housing typically results in low operational and maintenance costs.
8. The way in which affordable homes in Scotland are currently designed and built prevents neighbours experiencing noise-related problems.
9. In Scotland, the environmental impact of the construction and materials used in affordable housing needs to be given more attention.
10. In Scotland, the affordable housing sector takes proper account of waste management.
11. In Scotland, the affordable housing sector is well prepared to meet the higher standards expected for energy efficiency.
12. In Scotland, there is scope to improve health and safety standards in the construction of affordable housing.
13. In Scotland, the way in which affordable housing is designed and constructed maximises productivity.
14. In Scotland, the way in which affordable housing is designed and constructed maximises wider social and environmental benefits.
15. The performance of the affordable housing sector could be improved if the overall development period for new homes was reduced.

4.2: Data analysis - Main findings

Finding 1: The majority of respondents agree that statutory standards for the quality of new build affordable homes in Scotland will continue to rise.

Results



'Statutory standards for the quality of new build affordable homes in Scotland will continue to increase'

Key quotes

“Agree. I think that the standard that we have been building to through affordable housing supply program the Scottish Government over the last 20 years has always been high. It's been much higher than the private sector offering. And I think that the quality will continue to sort of increase because that's just what's always happened.”

“I would agree with that. You've got the energy efficiency targets and the carbon emissions targets. So, that will push in terms of energy efficiency and material waste and then you've got a refined process in terms of design. You've got BIM being introduced. BIM will push health and safety further which will change design approaches and I think all of that will feed into the building standards and planning standards of how we deliver housing.”

“I think it's clear that Scottish Government policy is very much looking to continually improve the standards for energy efficiency and sustainability, so I think those are the areas that are likely to see continued.”

“If you look at things like energy efficiency and building standards, I just think that standards in general and expectation will continue to drive those standards up.”

“I agree. Obviously it's got to increase in line with building regulations which are going to be increasing as we get towards 2021 where we are changing to the next stage, so they will have to increase the quality.”

“Strongly agree. There are new energy efficiency standards coming through and it's called EESSH and EESSH 2. Energy efficiency standards for social housing one and two. So, the standards are going to go up for energy efficiency and the quality standards will go up anyway, I think, because of the need for value for money and lower maintenance costs.”

“I think with the increased focus from the Scottish government on energy efficiency standards and changes to building regulations, I definitely think that standards are going to increase.”

“Yes, strongly agree. We have EESSH standards and I'm aware that as we speak there is a revised standard coming out. There are the issues following Grenfell and the fire safety issues seem to be more stringent for affordable housing than just mainstream building control, I can see that happening. Then we have our own standards, we tend to be very safety conscience, so where there is an issue we tend to raise the bar for ourselves.”

“I think with the increasing emphasis on things like fire safety, energy efficiency and carbon reduction targets that's just going to add to the quality benchmark for affordable housing.”

“I would agree with that. Presumably there would be an element of legislation required there. I know that currently were looking at things like requirement for sprinklers and stuff like that. I suppose you kind of hope that standards will always increase.”

“I think so yes, I strongly agree with that. I think with the increased focus from the Scottish government on energy efficiency standards and changes to building regulations, I definitely think that standards are going to increase.”

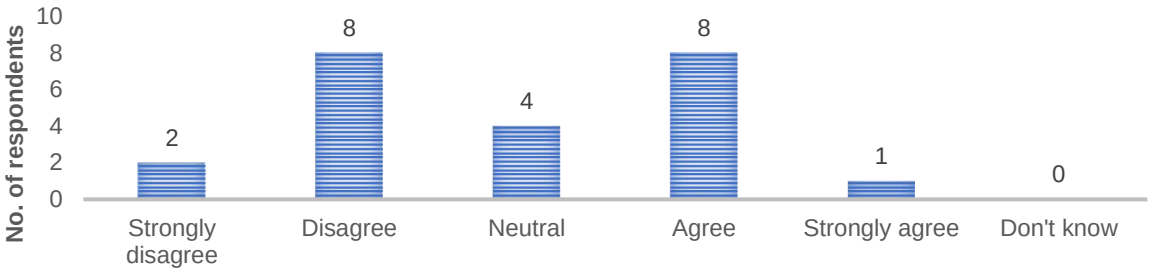
“Strongly agree. I think with the increasing emphasis on things like fire safety, energy efficiency and carbon reduction targets that's just going to add to the quality benchmark for affordable housing.”

“I would agree with that. I think building standards are continuing to increase. What I would say though is that it’s very much aimed at the social rented sector. And I think that needs to extend to all affordable housing tenures for the intermediate tenures, as well as social

rent also. I think that it should align across all tenures. You've got standards coming out for the private sector as well and I think ideally they should all align."

Finding 2: The respondents are not clear as to whether those experts involved in the design and construction of affordable housing, have the skills required to meet the needs of the sector.

Results



'The skills of those involved in designing and constructing affordable housing do not currently meet the needs of the sector

Key quotes

"I think in terms of design and construction of affordable housing the skills are definitely there and I think we are delivering a good standard of product. However, in terms of some of the workforce actually on-site, I think we are struggling. We're struggling for bricklayers so we're having to look at alternative approaches to materials such as render and cladding and every local authority has their own preferences on material finishes. I think the construction and design skills are definitely there but I think the day-to-day workforce isn't."

"The houses that we're building now are not performing in the way that they should, so there must be issues there in terms of the design team's understanding and not constructing them as they suit should be. And that's particularly around things like indoor air quality, standards of installation and cold bridging"

"They meet my needs at the moment and I'm the sector. I don't see that the design and construction side of the industry are, generally speaking, lacking in skills."

"I think we have a high level of skill in the construction sector in Scotland. We may not have the numbers, but I think we've got the quality."

"I probably disagree with that. I think there are people out there who can do all that. I think sometimes the issue is a question of capacity."

"I think the skills are there. I think there's a lot of really good skills, knowledge, expertise and good projects. I think what lacks is sharing that."

"I would note a shortage of skilled construction workers and that's partly due to the demographic, so aging workforce and potentially due to Brexit. Those are things that will make it worse."

"To some extent. It depends on the developer, it depends on the association that's doing the work, in terms of the design, when it actually comes to construction, I think there is a shortage of skills for the moment across most of the trades."

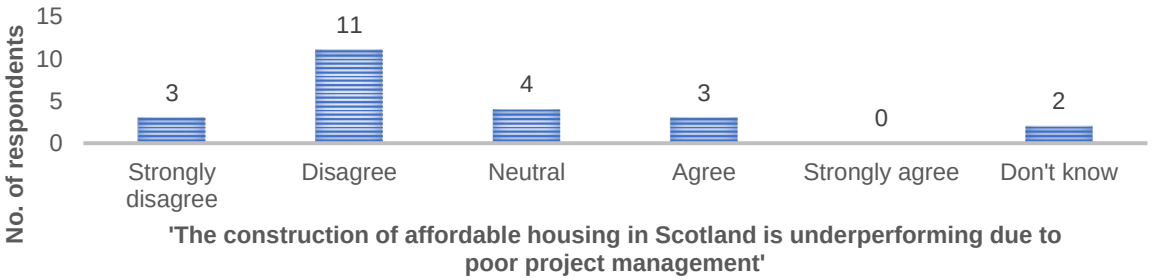
"I would probably agree. I think particularly when you're bringing in new technologies, for example communal and district heating. There were certainly issues of finding people who were skilled enough in doing that sort of thing in residential units."

"I would say neutral for that one. I think it depends. There's obviously opportunities through modern methods of construction for new skills to be involved and retraining opportunities for people. I think that's in the area where there's probably still quite a lot of work to do."

"I would probably agree with that. I think it's really about saying that the skills that are there, are spread too thinly. And it's not an attractive industry for people to enter into at an entry level position."

Finding 3: Most respondents disagree with the premise that the construction of affordable housing in Scotland is underperforming due to poor project management.

Results



Key quotes

"Disagree. I mean we're having in delays and we're having issues that all sites probably have, some things particularly prior to when sites start, but I wouldn't say the construction phase is underperforming due to poor project management."

"I would strongly disagree. Within the context of local authority housing and social landlords, we are quite often trying to develop brownfield sites which are more problematic and require a higher level of problem solving and ingenuity to achieve construction on those sites. So, I think we do actually go over and above. I think we're performing well actually."

"I see no evidence of that. I disagree, I mean I've seen examples of poor project management and a reluctance to innovate. There may be a number stuck in their ways but I don't necessarily regard that as negligent or deficient in any way. You know they are still pretty good at what they do."

"I strongly disagree with that. I think they are doing a fantastic job delivering on affordable housing in Scotland."

"I would disagree with that. There are other factors affecting the performance of the industry that are more important than project management."

"I think it could improve but then things could always improve. We should be getting better at project management, to say that it is poor is overstated."

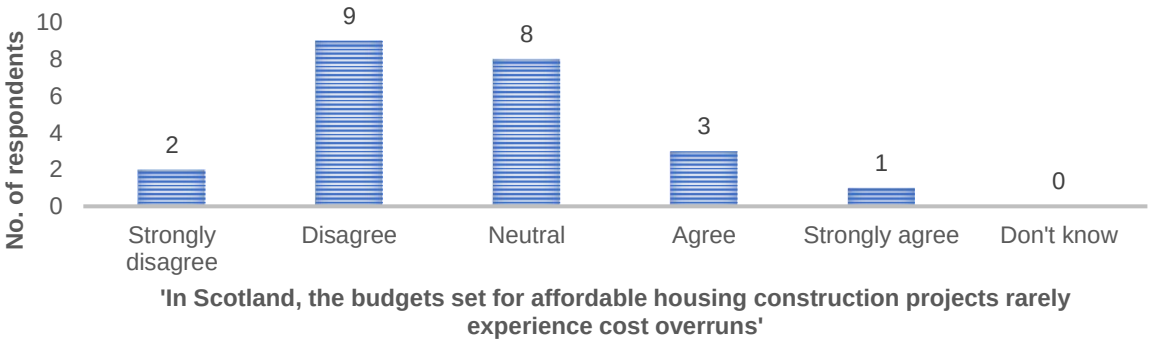
"Well first of its not underperforming. Secondly neither is it is suffering from poor project management."

"I would disagree with that as well, generally disagree. We have recently seen an increase in number of projects approved and we're starting to see more completions coming through, so no I don't think there's an underperformance there."

"There are other factors affecting the performance of the industry that are more important than project management. I think it's about how the markets are currently behaving. I think we're stuck with high construction prices, I think were suffering from Brexit, I think developers are pushing up land prices."

Finding 4: Cost overruns are an issue with 48% of respondents disagreeing with the premise that affordable housing projects rarely experience cost overruns and 35% neutral on this issue.

Results



'In Scotland, the budgets set for affordable housing construction projects rarely experience cost overruns'

Key quotes

"Probably disagree. With the development of brownfield sites, you're dealing with a lot of unknowns. For instance you have regeneration sites where there is old foundations, you have services that when you go to dig on site they're not in the locations that you expected. You're trying to tap into an existing Scottish Water network which might not have the capacity. So you do have cost over runs because you're having to juggle a lot of unknown problems."

"I would disagree. They quite frequently have cost overruns."

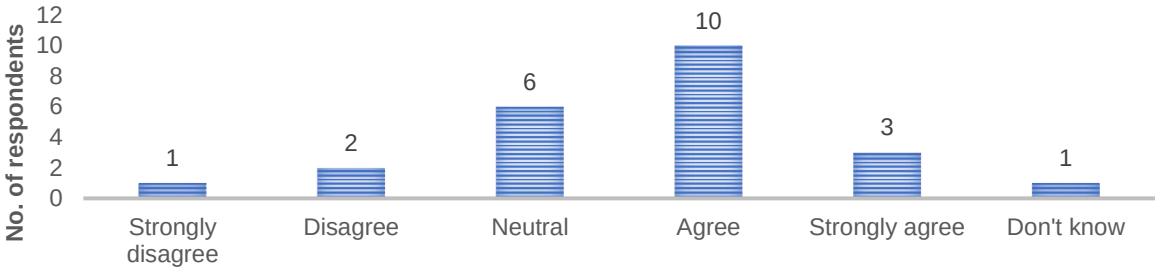
"Yes, I strongly disagree. The only way they don't occur an overrun is where the contingency is set much higher."

"Mildly disagree with that. I think the customer themselves should manage contingency levels within manageable proportions especially for more complex construction projects."

"Disagree. What we are finding at the moment is that all of our projects are coming in above benchmark. That's partly due to build inflation and we do have some projects that have to come back at completion stage to look for more money. We are also losing trades, for example brick layers are going on one site up until lunchtime and then they are moving to another site in the afternoon, and that's just delaying projects."

Finding 5: The majority of respondents agree that the development of brownfield sites for affordable housing in Scotland is inhibited by technical issues.

Results



'In Scotland, the development of brownfield sites for affordable housing is inhibited by technical issues'

Key quotes

"I think that's true. I think its cost related. Its things like demolition costs and permissions and utilities. It's the time and effort and everything that goes with that makes it much more difficult."

"I would agree because it impacts on cost. The issues are basically what's under the ground, so its ground conditions, it's having to spend more abnormals on foundations or decontamination, and in an inner city location you may be looking at a more constrained site."

"I would agree but I would say that it's the same for the private sector. It's a sector wide problem. I suppose one issue is that the private sector houses being built for sale are probably are going to make more money so can maybe afford more remediation. So, that might mean that it appears to be less of an obstacle to them."

"Well they are more challenging and there's more risk. In the starting process you don't know exactly how problematic it's going to be, you have to invest in the investigation to find that out. A greenfield site is definitely easier."

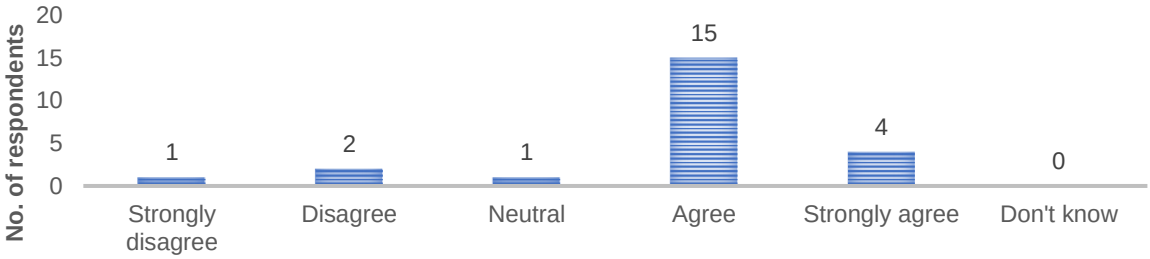
"By their nature, brownfield sites they tend to be more difficult to develop. They are often contaminated and they can have other issues. If it's a former industrial area they might have noisy neighbouring businesses. That can be difficult to get past noise control."

"Strongly agree with that one. You've got very difficult Brownfield sites where ground remediation works are required, restricted access, some of them are quite landlocked as well, and we've looked at maybe craning in materials and it just doesn't stack up financially for us."

"There is usually a technical solution to any issue but it is the cost that prevents projects proceeding."

Finding 6: Most respondents agree that the current approach to the design of affordable homes in Scotland is flexible in meeting the needs of residents.

Results



'In Scotland, the current approach to the design of affordable homes is flexible in meeting the needs of residents'

Key quotes

"You're not wanting to build houses that are not adaptable, if the circumstances change or the family size perhaps increases or dare I say it, but people get older or less are able to get around. So, I think that we've always looked to build in flexibility."

"Yeah I would agree with that. I think certainly for us, we have an idea of our local residents requirements and needs and from the outset we try and incorporate them into our overall development, from even the housing Mix and the housing type. We will have consultation events where people can see the layouts and see how the houses are working and input into the process and they're constantly refining that going forward. So, what did we learn from this project and what can we develop and add into the next project."

"I think design has become much more flexible. We've certainly had different property type; wheelchair accessible, variable needs. We've done a couple of properties where they've got attic trusses so that if a family grows you can do a loft conversion, so I think there's more flexibility built in but there's probably more that could be done."

"Yes, I agree strongly, the key is meeting the needs of the residents. And yes, we have we have strong varying needs."

"I think if you're organised from the outset and if your development team is working with the housing management team and doing pre allocations then you can deal with people with particular needs then and develop properties for those very specific needs."

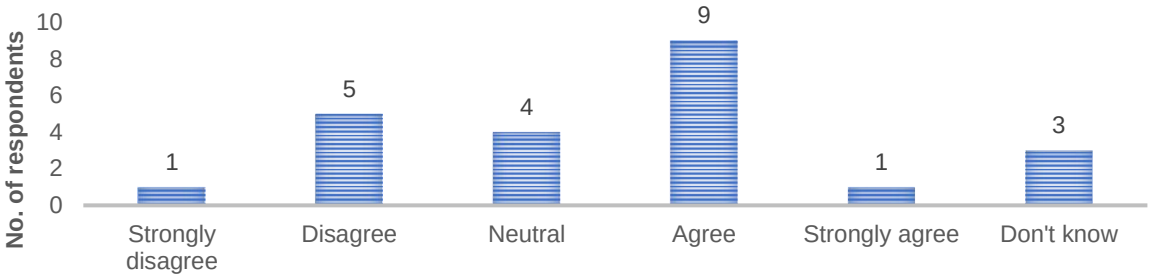
"We're doing a lot of specific housing, tailor made housing. We are doing lots of houses for wheelchair users, for special families, for all sorts, so I think the ability is there."

"We feel that our homes are flexible enough to meet the needs of residents because it will meet Housing for Variable Needs.

"I think what we're starting to see is more of a push towards things like the place standard and engaging Communities earlier on in the process In terms of delivery of homes"

Finding 7: A minority of respondents agree that the design and construction of affordable housing in Scotland typically results in low operational and maintenance costs.

Results



'In Scotland, the design and construction of affordable housing typically results in low operational and maintenance costs'

Key quotes

"Agree with that. We were noting that firstly we are increasingly building to a Silver standard. As an example, in 2017/18 the financial year 2017/18, 63 percent of all the homes that we approved were built to the higher energy efficiency silver standard. And that figures increasing. So, that's leading to low running costs for tenants."

"I would agree with that. Certainly we're working in with our asset teams to create energy efficient homes that are meeting the silver standards. So it basically minimises any complex detailing and make sure appliances and devices that are in use in the property are all kind of long life and low maintenance."

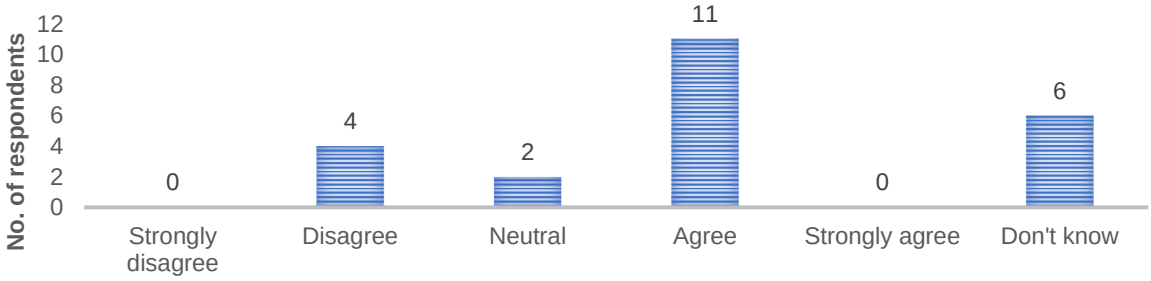
"I would agree with that and it's certainly something we've put a lot of thought into with our houses. In talking to the technical people in housing associations that I've dealt with, you know that's a big consideration in terms of looking at operational and maintenance costs. I think they do it much better than the private sector."

"Agree. The operational costs, that's the end user, the tenant. I mean the heating systems and hot water systems are extremely efficient. New build maintenance costs have remained, other than inflation, fairly low with very little maintenance costs in the first 10 years of a new built development. So, we must be doing something right in how we actually put them together in the first place."

"Yes, I would agree with that. Again, because in Glasgow we're built to the gold standard for carbon reduction and that requires a certain amount of air tightness and I think we are creating low operation costs for those buildings. There are low running costs."

Finding 8: About half of respondents agree that the way in which affordable homes are currently designed and built in Scotland prevent neighbours experiencing noise-related issues.

Results



'The way in which affordable homes in Scotland are currently designed and built prevents neighbours experiencing noise related problems'

Key quotes

"Agree. Recently we have seen planners keeping noise pollution or noise reduction very seriously."

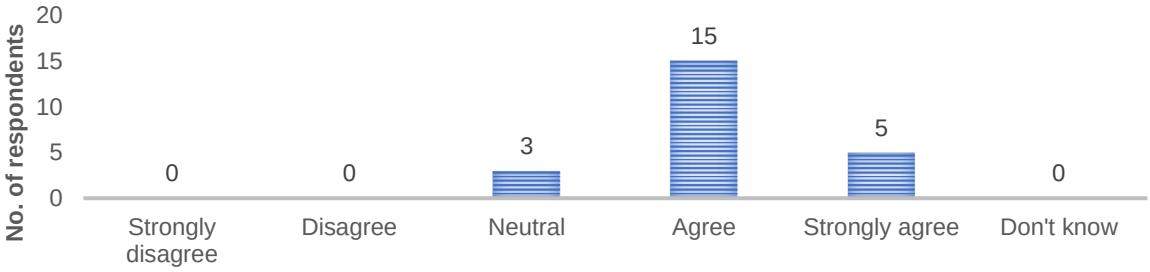
"We've certainly designed our houses to think about noise, both in terms of the construction of the separating walls but also how the houses have been laid out. So, I have to agree, based on what we've done here."

"The current building regs around noise transfer are particularly challenging. And it's obviously easier to achieve in a new build"

"I would agree with that statement. We don't see a lot of feedback from tenants suggesting that new housing has got poor noise reducing qualities, either between houses or between the house and the external environment. I think the changes to the building regulations in the last two or three years have increased the performance of both party walls and internal partitions."

Finding 9: The majority of respondents agree that the environmental impact of the construction and materials used in affordable housing is a matter that should be give more attention in Scotland.

Results



'In Scotland, the environmental impact of the construction and materials used in affordable housing needs to be given more attention'

Key quotes

"Yes, I would agree. I think it's just about careful choices and just a more holistic view of material usage."

"The impact of construction materials is rarely considered."

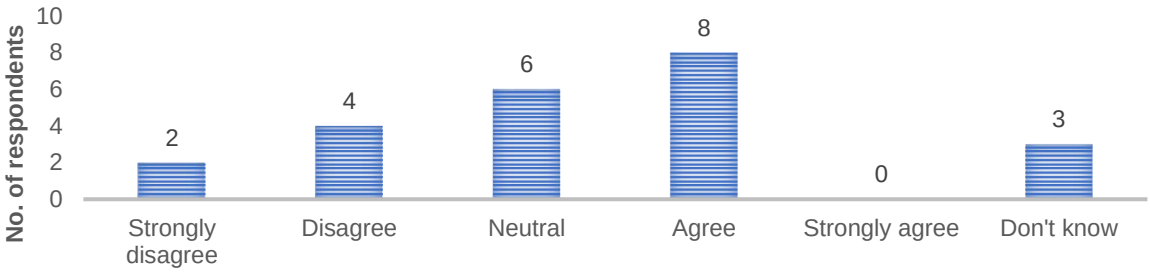
"There's too much emphasis on performance and use rather than things like embodied energy, provenance, all that kind of stuff. I mean we address that to a certain extent but not as much as we should. There are measures that could be taken around the design specification of houses to help that."

"I still believe that most of the organisations that I deal with have got pretty strong environmental credentials and do try to stick to sustainable design"

"I don't think you could argue with environmental impact needing a lot of attention."

Finding 10: The respondents are divided as to whether the affordable housing sector in Scotland takes proper account of waste management and 39% were either neutral or didn't know.

Results



'In Scotland, the affordable housing sector takes proper account of waste management'

Key quotes

"I think it probably does take account of waste management, so I probably say agree, but I think that improvements could be made."

"I would say we try and design out waste, but it's how you actually manage it on site. Somebody can say they're doing it and they can tick all the boxes but unless you're there, day in day out, you've no way of actually checking or actually benchmarking if it is happening."

"I disagree with that. I think the construction industry is still not great at thinking about waste management. It's something that the industry does to tick a box but I think they do it kicking and screaming, rather than actually proactively doing it."

"It's not a consideration, no. I think it's viewed as a nice to have or we should be doing something, but I don't think anybody is particularly doing it. So much of what we do is done by cost and basically the people who fund us and the people we regulate us are interested in the upfront capital cost. That is their primary concern; units and cost, and that's what drives our activity. Waste Management just doesn't get looked at."

"I think we take some account of waste management proper. Whether it's as much as

possible, I don't know. I think some of that responsibility lies with contractors rather than with us."

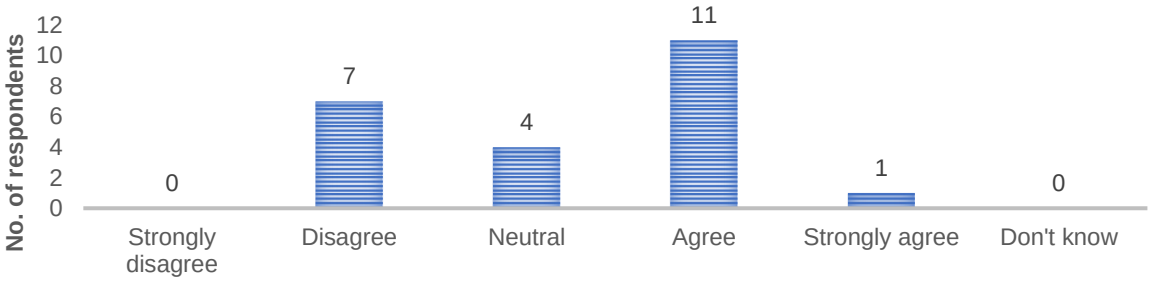
"I think it probably pays lip service in terms of KPI's. We have KPI'S with contractors but to the extent to which we follow them through is another matter. The good contractors will, for financial reasons, minimise waste but given the nature of construction industry it's not necessarily guaranteed. It needs more leadership."

"You can always do better. You have KPI's on the amount of waste that goes offsite. The extent to which we design our properties to minimize the waste could probably improve."

"I think over the years it's definitely improving, but I don't think it's good enough. I don't think legally, we the construction industry are required to have a sort of site waste management plan. I think that's something they should consider to help reduce further waste and save on disposal costs. So yes, I would strongly disagree with that."

Finding 11. The majority of respondents agree that the affordable housing sector in Scotland is well prepared to meet the higher standards of energy efficiency expected from the sector.

Results



'In Scotland, the affordable housing sector is well prepared to meet the higher standards expected for energy efficiency'

Key quotes

"I think it's got a track record in looking to build products that are highly energy efficient. I think that's because of the nature of affordable housing, with the landlord's wanting to keep the cost down for their tenants.

"I would say so, I think we're aware of the silver standards and the gold standards of building regulations and the carbon emission targets so I think we're all kind of slowly moving towards these targets, and looking at new ways of delivering them."

"We've got EESSH 2 coming, and in terms of the social renting sector I think those standards are improving."

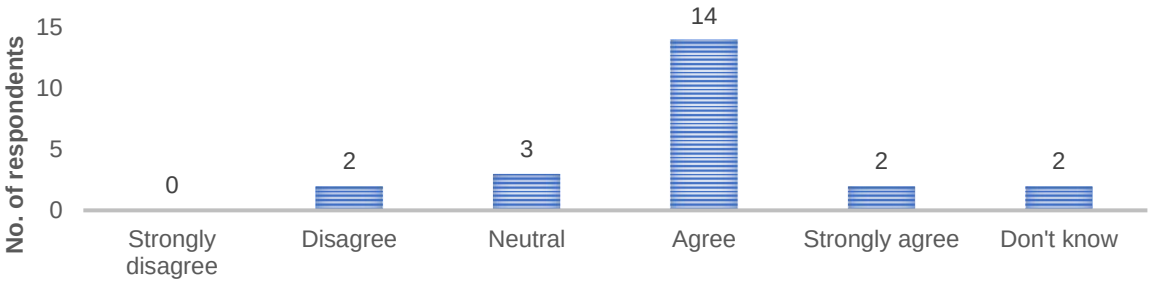
"Yeah, I'd agree but there has to be a discussion about levels of government grant input (with regards to) tenants rent, because this will be affected by increased standards I think."

"Yes, I agree. I don't know if we have the funds necessary to support it as well, but we have the enthusiasm and the skills."

"I agree with that. I would still say that we can do more going ahead. We could be better at using more renewable energy and may be looking at the Passivhaus type buildings or something similar."

Finding 12: The majority of respondents agree that there is scope to improve health and safety standards in the construction of affordable housing in Scotland.

Results



'In Scotland, there is scope to improve health and safety standards in the construction of affordable housing'

Key quotes

"Agree. There is always scope to improve. One of the big movements is BIM and CDM working together to try and design out risk and get safer ways of delivering construction on site, and how you put the house together whilst minimising the risk to operatives."

"I would agree. I think it's something that again has come a long way but something that nobody could ever be complacent about."

"I would agree. I think things have come a long way in the last sort of 20 years but I think there's still room for improvement."

"Yes, I would agree with that. We do comply with the CPM regulations but beyond that in terms of making sure that the practices are maintained on site by contractors and particularly with the sub-contractors."

"I would probably agree with that. I think everybody does try but there will be occasional lapses but the legislation is pretty tight."

"I'd say I agree. There's always room for improvement. That said, it's pretty good. I think generally health and safety is taken quite seriously across both public and private delivery. So, I think we're in a good place, but there's always more that can be done."

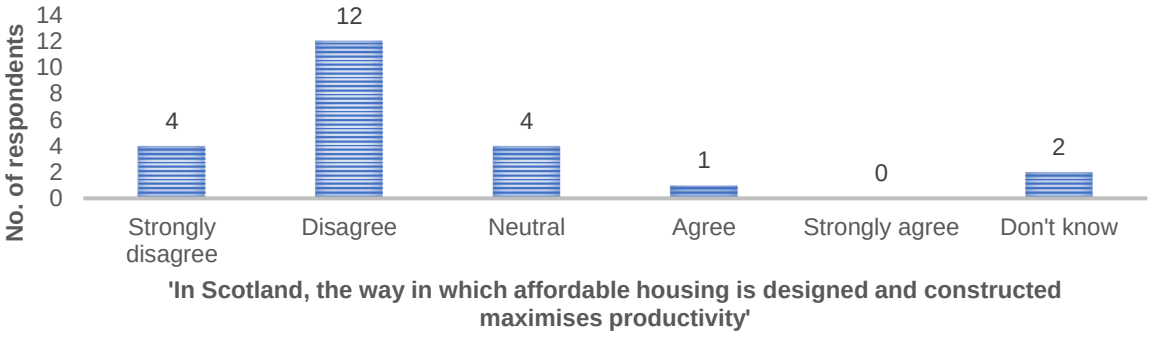
"I would say yes. We're still seeing examples of people being run over by diggers and things like that. Health and safety needs to be a core element"

"I would say agree because I think there's always scope to improve and reducing the amount of materials on site, reducing those hazards, would help that."

"I don't think Scotland is particularly bad in terms of Health & Safety but there is always room for improvement."

Finding 13. The majority of respondents disagree with the premise that the design and construction of affordable housing in Scotland maximises productivity.

Results



'In Scotland, the way in which affordable housing is designed and constructed maximises productivity'

Key quotes

"Strongly disagree. I think sites are notoriously bad for being inefficient. There's definitely in my mind scope to drive efficiency and improve productivity."

"I would disagree with that one. I'm not sure it's an easy one to resolve. I think the way that the whole construction industry has gone over recent years in terms of going down design and build routes. I don't think that's necessarily the best way to maximize our delivery of any construction projects. I just don't think it's the best way of doing it."

"Probably disagree with that. Some of that's down to more structural issues in terms of not being able to organise volume procurement arrangements which would allow some rationalization of design and construction."

"I disagree with that. I think because the program is so fragmented. It's fragmented into every geographical area, with lots and lots of different players. But the other side of that is, if it was to be more efficient you would basically be taking out a whole sector of SME businesses, small developers who are required for future maintenance and the economy. So, there's two sides to that."

"I suppose it's to do with the materials that are used and the time it takes to construct using a kind of traditional build programme. There is obviously a lot of people on site, a lot of different skills used to construct so there's may be potential there to improve on that."

"We disagree with that one. If you were to have more standardization there would be much more productivity and perhaps even lower cost because you'd designing more standard products."

I think probably from the way that traditional construction is done there is lots of opportunity to improve productivity. I think it's certainly an area where there's room for improvement and I would expect with all these things what you'll see is a tipping point where the private sector will eventually land on some key productivity increases which will then make it much more profitable for them to be involved and that will then start to roll out a bit of a step change."

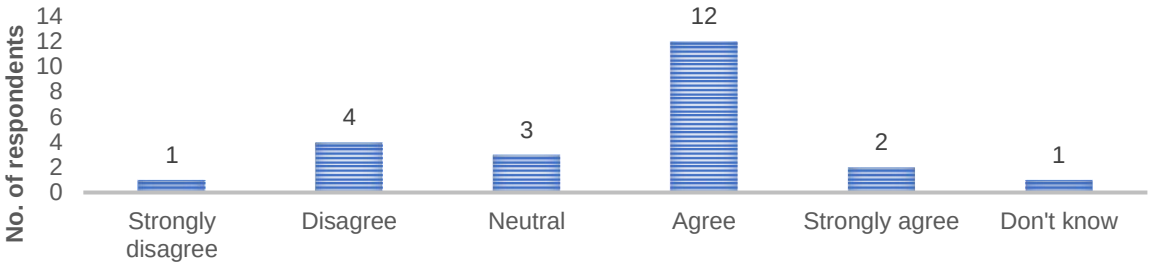
"I strongly disagree. I just think we could be more far more productive than we are."

"Strongly disagree. There is no real efficiency across the supply chain. It's still reasonably bespoke and I think there is definite scope for increasing standardisation."

"I strongly disagree with that one. I think the affordable housing sector we should be collaborating to look at standardizing some sort of footprint for affordable housing for a variety of house types. I think that would be extremely beneficial in terms of maximizing efficiency and productivity."

Finding 14: The majority of respondents agree that the way in which affordable housing is designed and constructed in Scotland maximises wider social and environmental benefits.

Results



'In Scotland, the way in which affordable housing is designed and constructed maximises wider social and environmental benefits'

Key quotes

"I would agree, yes. I think you're trying to deliver energy efficient homes that meet the needs of our tenants and residents. I think we're giving them safe warm, dry homes. It's going to have a health benefit to them. Obviously, if they're energy-efficient you've got the environmental benefits as well. Also, given that it's brownfield sites, you're developing areas that have maybe lain empty for generations. So, yes, I would agree."

"I think I agree on that. I think particularly around design and moving to more inclusive and tenure blind estates. In environmental terms, looking at the use of cars moving towards electric vehicles and charging points. So, I think in terms of design and thinking about creation of new estates, there is a lot more thought given to the kind of social and environmental aspects."

"I agree to a certain extent. There's been quite a lot of work on social environmental benefits arising from housing programs. But there's always scope for improvement."

"I agree with that. That's because of my experience with the registered landlords I work with here. They do try to ensure that there is really good apprenticeship schemes and give back to communities."

"I would hope so, in terms of things like placemaking and how communities are designed. How the projects fits into the wider community. How people circulate around it. I suppose there is room for improvement in terms of some of the projects that are completed. I think some of that's down to planning."

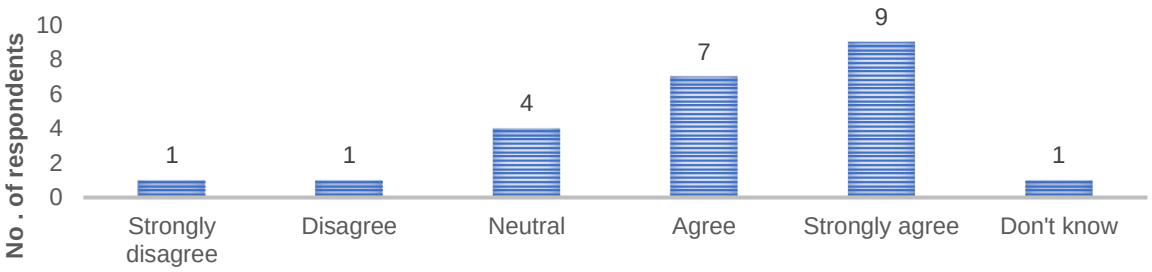
"I would agree with that. What we see through the grant funding of affordable housing is a kind of willingness, by the organisations delivering it, to look at the environmental impact and look at ways of reducing their carbon footprint."

"Speaking for a rural island community the use of local contractors and suppliers provides local employment which feeds back into the local economy."

"I think it's really up to the planners, local authority planning authorities, that control that side of things, and make sure that happens. We can only encourage it. It's difficult I think when we're giving grant money to say this has to be done, but we do encourage it in our applications."

Finding 15: The majority of respondents agree that the performance of the affordable housing sector in Scotland could be improved if the overall development period for new homes was reduced.

Results



'The performance of the affordable housing sector could be improved if the overall development period for new homes was reduced'

Key quotes

"Yes, strongly agree. The time it takes to actually achieve a build from your first concept and having the land to handing it over keys is probably in the region of two years, two and a half years. If you could shorten that delivery time but still have a quality product then that is in everybody's interest."

"I think if we could spend less time on site as a specific part of the development period, we would potentially get better cost efficiency and other benefits as well. The longer we spend on site the more that we are exposed to the vagaries of the weather and other such things."

"Strongly Agree. Things always take far too long in the sector. And this is a problem with the 50,000 unit target. I don't believe we've got a lack of finance, we've got generous grant regimes, and we've got very eager private lenders lots of reason of easing finance. We've got plenty of land and we've got huge political will. What we don't have is a slick way of doing it. It's time that'll prevent us from reaching the target and not anything else."
"Strongly agree with that. We see jobs time and time again that should be delivered in six months and take a year and you just take even the site preliminaries and overheads, that's a massive, massive amount of money."

"I strongly agree. I think if the quality is guaranteed. The one thing that always worries me is I don't want to be repeating any mistakes made in the 1960's with those attempts to accelerate things. I've spent a lot of my career demolishing 1960s buildings. I don't want to be looking in 30 years' time or whatever seeing the things I've built get demolished. So, I think as long as we have the quality guarantee put in there, we should be ok."

4.3. Key findings extracted from the discussion of barriers and benefits

KEY QUANTITATIVE FINDING
The introduction of industrialised processes and production techniques in the residential building sector of North American and European countries shortened the construction duration by 37%.
In China, deploying offsite construction techniques made it possible to complete a 30-storey hotel in 15 days (T30 Tower Hotel) and a 57-floor skyscraper in 19 working days. Research on Australian offsite constructions reports on similar data, with a six-story building with 77 apartments built onsite in eight and a half days.
A case study analysis of seven residential and non-residential buildings in Hong Kong demonstrates that offsite construction techniques delivered (1) labour saving of 16%, on average, compared with traditional building techniques, and (2) up to 30% in some projects. Security incidents were also reduced, by approximately 6%.
Additional research estimates a 40% onsite labour force reduction and about 9.5% reduction of onsite dust and noise.
Research conducted by Central South University and National University of Singapore reports on a potential 5-10% saving on construction costs through the adoption of offsite construction techniques.
A cost-performance analysis of 20 medium- and high-rise residential buildings developed by UK housebuilders shows that construction cost savings compared to traditional building techniques ranged from 11% to 32%.
KPMG confirms that offsite construction methods can deliver economic benefits, estimating financial net savings of 7%, which are a consequence of the shortened construction period.
Research suggests construction waste could be reduced by up to 84.7% if offsite construction technology is applied and reports of potential water consumption savings of approximately 40%.
An analysis of the T30 Tower Hotel shows several benefits that only 1% construction waste generation compared with conventional buildings.
An empirical analysis of 27 prefabricated buildings capture that “on average, 15.6% of embodied and 3.2% of operational carbon reductions were achieved through prefabrication, as compared with their traditional base cases.”
A comparative analysis of the level of embodied carbon between two traditional residential buildings and a low energy, affordable house built using an offsite panellised modular timber frame system shows that the latter house resulted in a 34% reduction in embodied carbon. The buildings subject to analysis are located in Norfolk, UK.
Research conducted in China suggests “14% of the total energy consumption could be saved by using prefabricated components over using an equivalent amount of cast-in-place ones.”
Due to this initial investment, adopting offsite construction techniques in China is 20% more expensive than traditional construction methods.

4.4. List of references: Benefits of offsite construction adoption

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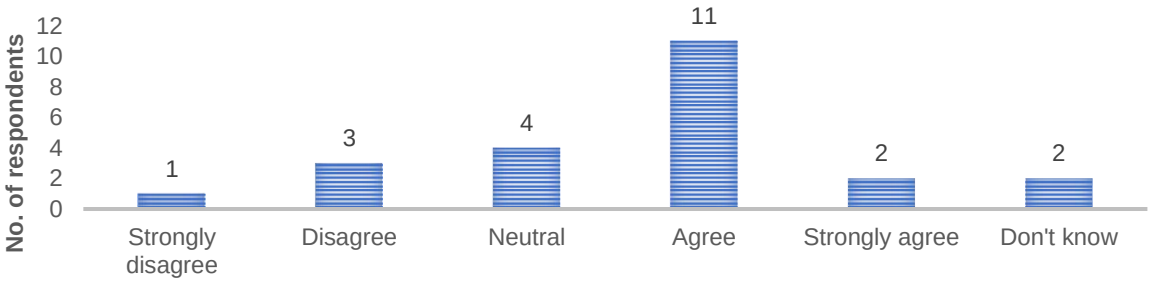
4.6. Data analysis - main findings

Finding 1. The majority of respondents agree that high costs inhibit the adoption of offsite construction methods for the development of affordable housing.

Results



'The adoption of offsite construction methods for the development of affordable housing is inhibited by high costs'

Key quotes

"I think upfront costs. So the actual build costs can be high but if a developer is just looking, whether it be a housing association or a local authority or whoever, if they're just looking at the build costs or the development costs and not the whole life cost I think it can be an expensive... it can appear often as an expensive alternative to more conventional forms of building."

"I do tend to agree with that statement. We currently use offsite construction methods extensively but there are some methods that we would like to use which are inhibited by cost. Namely CLT specifically at the moment, which is an area we would like to get into but it is proving difficult."

"In my personal experience the benefits haven't been demonstrated to justify the higher costs. When you've got a project where you can't actually see the benefits of the higher cost, it was very difficult for me to justify that in terms of funding."

"Probably agree. I think because it's relatively new technology so it's less available and there's potentially less contractors with the experience of building."

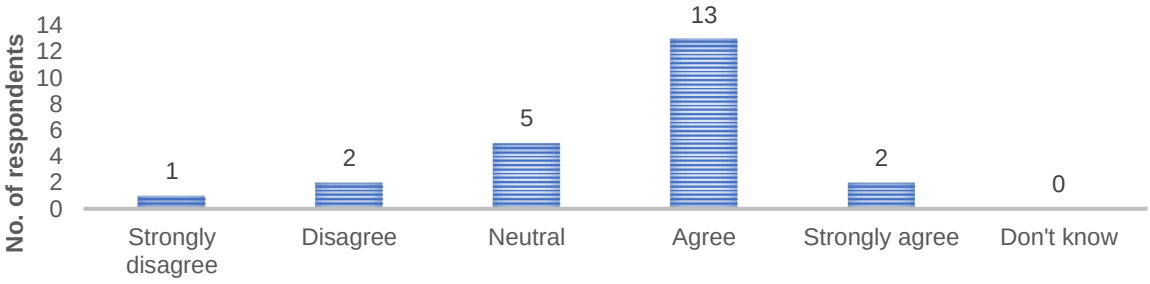
"Yes, strongly agree. The area I work in there have been a number of projects which have been tendered and the costs included looking at offsite construction. The cost for offsite construction tenders have been far higher than traditional methods."

"It depends on which category of offsite construction you're looking at. Once you get into open and closed panels and into modular you start paying slightly different premiums."

"I would agree. We are always having to find ways to achieve value for money and make savings. If there is a more expensive option and a less expensive option, we invariably have to look seriously at the less expensive option."

Finding 2. Most respondents agree that modern methods of offsite construction can help reduce the cost of affordable housing developments.

Results



'Modern methods of offsite construction can help reduce the cost of affordable housing developments'

Key quotes

"I think if you look at the whole life cost using offsite methods, you should require less reworks, snagging and less maintenance issues once it's actually complete."

"Strongly agree with that one. The reduction in cost comes from being more efficient in the build. So less time on site, less disruption due to weather, less reliance on contractors. So you know you can build when you want to build and at a time that suits you. There is less waste in terms of days lost, so just on that side of it it's more affordable. Some of the materials that we have been looking at are bringing down the cost of building as well."

"I agree with that. I think the potential is most definitely there. We are at the minute in a kind of early adoption phase. Looking ahead, I think we can probably see that there is a tipping point somewhere fairly soon down the line, where there will be a greater number of offsite construction providers active in the affordable housing sector. There will be more choice, more competition and the costs will come down I think."

"I think where you've got repetition of type or standard house types then that would promote lower costs, so I would agree."

"I think that the very nature of it being constructed offsite it can cut down delays in terms of the weather etc, so you tend to get the product delivered more quickly. I think for this climate it is the best form of construction."

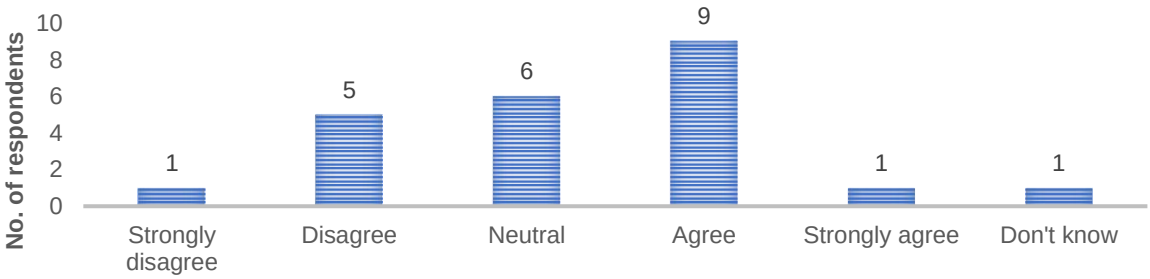
"Yes, I would agree with that. However, what you've got is basically factory production lines but they are not working at their optimum. So, yes, I would say the possibility of reducing the unit cost is there but often, or what we're seeing just now, is the market isn't mature enough to have different levels of competition between providers. So, while I would say yes it could help reduce costs, but we're not at that stage yet."

"I think it's generally accepted that while there can be an increase in the capital cost of the project because of the offsite manufacturing process the benefit is the programme delivery and that it for shortens the time on site and therefore reduces the cost at that end."

"I would agree with that. The potential for labour saving, in a period of rising labour cost and in the context of a lack of skilled labour. That is where I would see a particular advantage."

Finding 3. 43% of respondents agree that the adoption of offsite construction methods for affordable housing is hampered by transportation logistics, whereas 26% disagree with this premise.

Results



'The adoption of offsite construction methods for affordable housing is hampered by transportation logistics'

Key quotes

"Possibly, neutral I guess. Again for us because we're focusing on rural and islands. It depends how rural and remote you are. There's quite a lot of single track roads which can be unsuitable for certainly larger vehicles. So you'll have to get a bit more creative as to what size of panels and what size of modules you can actually scale down to. The more remote you get the more difficult it is just to use the current road networks because they're just not designed for heavy traffic really or for large traffic."

"I would probably disagree with that. I don't think there is a lot of evidence for that statement. It might be the case in very rural locations, with single track roads. In places where you see signs like 'unsuitable for caravans or large vehicles'."

"Neutral, it depends on where the site is based, if it was in a rural location there would be some difficulty, more urban setting not so much but it's a huge amount of kit to transport from the factory to the site and there could be some issues within more rural locations."

"I'm not aware of it, I think it may be to a certain extent constrained by transportation but I think if we are talking about the size and scale of bits of buildings that can be brought to site, and I think the existing transport methods seem to be able to deal with it. So, I would disagree with that."

"I will agree with that. Because you can't always use offsite construction, particularly in remote locations if you're dealing with single track roads etc. The only other alternative to that is helicoptering it in and that would just be cost prohibitive so, it's it doesn't always suit rural locations."

"Strongly agree. So, if they are pre-made panels or whatever we've got to get them onto an island so obviously there is the transportation cost of that. Because we have a government subsidy road equivalent tariffs on our ferries which reduces fares but that doesn't extend to commercial vehicles. Also in rural locations getting large lorries delivering on single track roads is difficult."

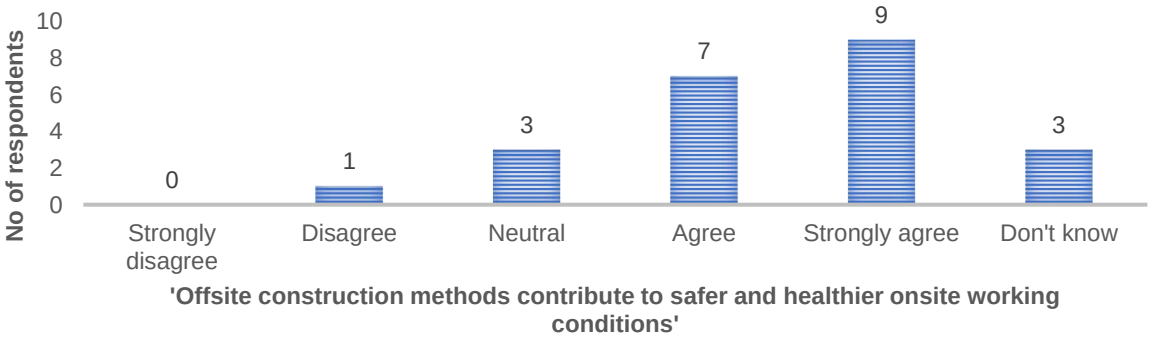
"I would probably disagree with that. I don't think there's any evidence of that as really a factor."

"Yes, that can happen, especially if we're dealing with the Highlands and Islands rural areas and it all depends on where the supplier is."

"I agree. Clearly there are roads in Scotland which cannot take wide loads. One has to accept that and we have been working on modular systems that will be used that can be used in remote communities."

Finding 4. The majority of respondents agree that offsite construction methods contribute to safer and healthier onsite working conditions.

Results



Key quotes

"I think working in a factory environment, it is easier to control health and safety and workers are less exposed. So, I generally think it's just a safer place. It's not without risk but I think that the risks can be more easily controlled and are more easily mitigated within a factory."

"It's a no brainer. In the construction phase there are fewer people onsite."

"Yes, I would agree with that. You are doing most of it indoors, so activities that would otherwise have taken place outdoors, exposed to the elements. If things are happening

indoors in the factory then they are not happening outdoors on the site. You have got more control over the environment and what's happening."

"I would agree with that. I think the production of the kits and the factory setting means that you potentially got fewer trades and machines on the site. I think it's probably a more controlled environment when you're in the factory setting rather than outside in all weathers on a site."

"Yes, I strongly agree with that. A big reduction from working at height, a big reduction in use of scaffolding. Obviously, a lot more undercover working, not having to work in the bad weather and bad conditions."

"I would agree with that. As it's in a factory setting, most of the construction is getting done there and they're just piecing it together once they get the kit on site."

"Strongly agree. I think the examples we've seen where offsite has been taken to the maximum, the onsite conditions are a lot more agreeable for everybody involved. If we can work around a shorter period of exposure to the elements as possible, it benefits on site workers as well as us basically."

"Yes, I would agree, but it all depends on the quality and standards of workforce and supervision. So, winching big panels into place can be safer but if you haven't got the operatives trained on site, you suddenly introduce a higher risk environment."

"I put strongly agree. I think that the offsite element means that there is less construction in terms of the superstructure coming out on site so therefore the less construction there is on site is inherently more of a safe environment. In terms of healthier for the same reason if much of the build is controlled under factory conditions like health and safety also addresses any health-related issues with construction."

"Without question. First of all, you are reducing the amount of site activities by almost 50% by working offsite and preparing your housing units in a factory."

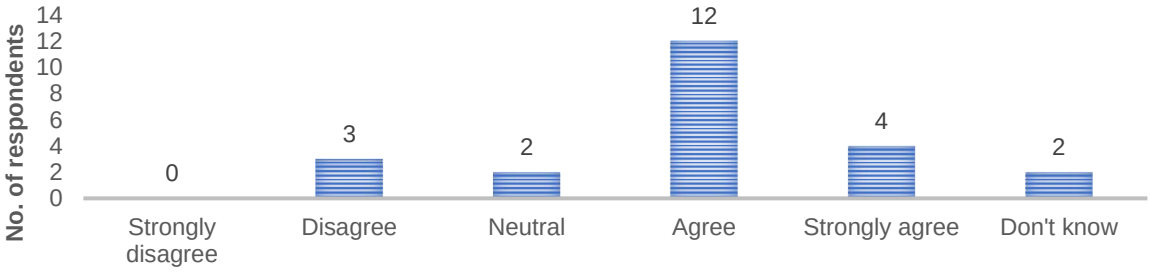
"Strongly agree with that one. There's not the same requirements to work at height and less chance of things falling. We think it's generally a safer environment for people to work in."

"I think it does contribute to safer and healthier on safe working environments. I think it is reducing the level of construction traffic that is going in and out and therefore it can only be safer and healthier."

"I would strongly agree with that. The inherent time savings allow better management practises on site, especially management time is freed up for the purposes intended. In terms of transportation logistics there are fewer vehicle movements around the site, so you have got an inherently safer site environment. You have also got less labour, so safety issues are lessened."

Finding 5. The majority of respondents agree that insufficient manufacturing capacity restricts the adoption of offsite construction methods in the development of affordable housing.

Results



'Insufficient manufacturing capacity restricts the adoption of offsite construction methods in the development of affordable housing'

Key quotes

"Yes, strongly agree. At the moment, in a rural context, there is nobody doing it at such a scale that it becomes appealing to affordable housing, because generally affordable housing is looking at economies of scale. So, they need to do quite large scale developments to make it work out anyway but because of that, there's not really anybody that is able to produce at that sort of scale at the moment. So yes, there is an issue about the capacity of manufacturing."

"I'd agree with that. I think it's a matter of time before the capacity starts to move in favour of increased manufacturing capacity and possibly new people coming into the market."

"I would agree with that. Well there isn't a lot of choice is there. There are one or two manufacturers and that's about it. It's still not a mainstream."

"I would say that's true and it just reflects the fact that there's limits capacity in the entire construction market."

"I only know of Stewart Milne and CCG that do off site construction, there doesn't seem to be very many other companies that seem to be doing this type of offsite manufacturing."

"I would strongly agree with that because apart from the one contractor, there isn't a great deal of uptake in the contracting field at the moment in Scotland."

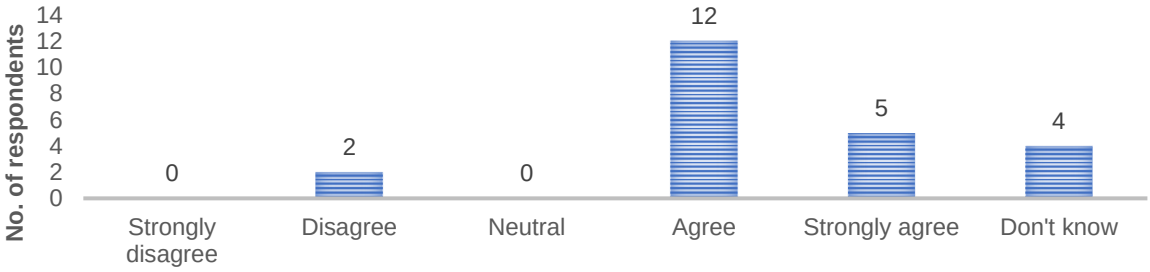
"We're back to the market not being mature enough and not having enough levels of competition between the providers. So, at this stage, yes, it could be said to restrict the adoption of offsite construction but there are so many other factors that will restrict the adoption of offsite construction."

"I've put agree. The reason I put that is not that I don't think there's enough people with the capability to produce the offsite construction. Our experience is that those who have that capacity, are at or are nearing their own capacity."

"The capacity is down to the volume really that they can produce because it's not cheap setting up the factories in the first place. So, capacity is really quite important in being able to construct these factories and keep them running and keep people employed."

Finding 6. The majority of respondents agree that the adoption of offsite construction methods increases the productivity of affordable housing provision compared to traditional methods.

Results



'The adoption of offsite construction methods increases the productivity of affordable housing provision compared to traditional methods'

Key quotes

"Evidence suggests that productivity within offsite construction manufacturing is much higher than it is on the building site. It's also less wasteful, more efficient, you can organise labour more easily within a facility. You can also try and sweat the assets higher in a manufacturing facility in terms of equipment and technology, you can run it for example 24-hours a day potentially. It would be difficult to build houses 24-hours a day out on site."

"Absolutely, yes. The big issue is the affordable housing suppliers are still not all that keen on using offsite. But yes, if it is adopted then it absolutely increases the productivity. There is less waste, less reliance on weather. It's much quicker everything is made to a more accurate level so there's less snagging on site."

"I would agree with that. Certainly, in terms of looking at some of the construction phase elements of the programs that we have for pipeline projects, there certainly potential to increase the productivity. On the other hand, I don't think we have enough of a frame of reference to assess that just yet."

"I would agree with that. You can get significantly reduced contract periods. You are less at the mercy of weather delays. I think you definitely can improve productivity compared to traditional methods."

"I would say yes it does increase the productivity of affordable housing. I think I mentioned that earlier on, certainly it's just amazing how quickly once they get the kits on site, how quickly they can build out houses and get them off site. For a 20-unit development, if it was a kind of a traditional approach which I've done in the past, you're probably talking about maybe 14-15 months on site, whereas the offsite construction is cutting it down by about 4 or 5 months."

"I would probably agree with that. Economies of scale and cost relating to that."

"It can but it needs an understanding of what they're doing and how they do it before it actually becomes a really slick method of working. I've seen some prefabricated units go up in super slick time and I've seen other ones where they've had to winch it on, find it doesn't sit, take it off, winch it on again, take it off again and all this forward and backwards sort of stuff and then the big hammer appears that batters the hell out of the panels to try and get them to fit."

"Strongly agree. I think it can increase productivity provided that you've got enough providers and that they have capacity."

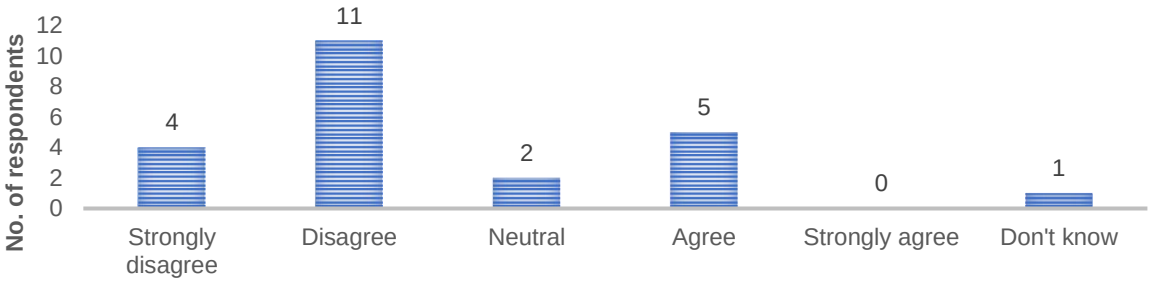
"I strongly agree. There is no question that when you are in a weatherproof envelope and you can arrange the work along a production line, you make very good use of skills. A much smaller workforce is necessary to produce the equivalent of a traditional build because the workforce is working with all their materials to hand for that particular shift or particular workstation. You are not being instructed by weather or the distance between your workstations and on a muddy building site although that might be only a few yards, it's still a loss of productivity."

"I think the answer is agree, but the caveat of that is the only bit of the project that improves efficiency around is the building of stuff above the ground, and that's half or two thirds of the activity."

"Strongly agree. By reason that the speed and efficiency of build, essentially allows you to build more home faster and better."

Finding 7. The majority of respondents disagree that the adoption of offsite construction methods in the development of affordable housing is restricted by concerns about build quality.

Results



'The adoption of offsite construction methods in the development of affordable housing is restricted by concerns about build quality'

Key quotes

"I think the quality of offsite construction is better. I think there have been some examples where perhaps it hasn't lived up to its potential. In the affordable housing sector I think a number of key clients have had their fingers burnt and there's a lot of talk in the sector about the bad examples. But I think in the main, quality is higher."

"I would disagree. I don't see any evidence of that. It's much more compatible with the move towards greater thermal performance of buildings, towards even gold standard Passivhaus standards. I think offsite construction can better deliver on those issues."

"I would disagree with that. The design and build tolerances that you get working in factory conditions are going to be much better than stuff built on site, in my opinion. That's not to say there aren't some examples of poor quality."

"Personally, I've never had any concerns about the build quality. They're fantastic houses we are getting."

"I would strongly disagree with that. I think it's quite the reverse, we get better build quality out of offsite than we do traditional. The more offsite we can do, basically the better quality we'll be able to achieve."

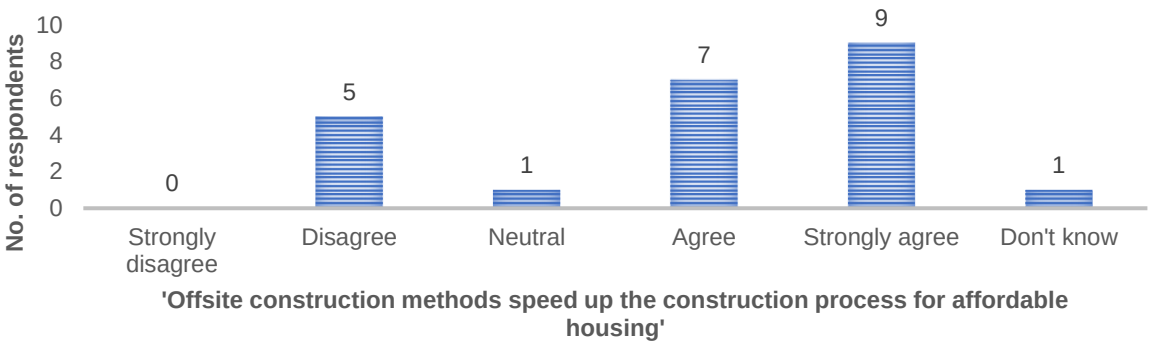
"I would disagree with that. I don't think we had ever had any issues about the build quality and that might have been that both the offsite contractor and the architects explained the construction method very clearly to us and what the benefits would be. So, I don't think we ever had any concern about the quality."

"I strongly disagree with that statement. You can achieve a build quality that is going to be hard to achieve on site."

"I would strongly disagree. I think the build quality is probably better because you're doing quality control in a factory setting. I'm not aware of anybody that has concerns about the quality."

Finding 8. The majority of respondents agree that offsite construction methods speed up the construction process for affordable homes.

Results



Key quotes

"If you're doing offsite in factory conditions it makes everything easier, more manageable and you can schedule things a lot better. When it gets to the site itself, depending on the type of model that you using exactly, almost sort of click and go, you're ready to go. So yes, it's a much more efficient method of construction."
"I would agree with that. That what's got most of us into offsite construction in the first place, because we can deliver units quicker during the construction phase."

"I'd strongly agree with that. Projects where we've tried to max the offsite elements, they tend to be very fast. The site we finished a few years ago was 48 units, which would normally take about 12 months in, and we did it in 8."

"I'd agree with that. For us, it meant there was a shorter time on site because the panels were coming just when they were needed. It meant it cut down the build time which was good for us because of our weather issues, it's a very exposed site."

"I would agree with that but if the design and construction isn't pulled together by people who know what they are doing, you can start introducing delays where issues have been found and things have to be put right."

"Yes strongly agree, just because of the benefits in terms of reducing time on site and therefore reducing the build programme."

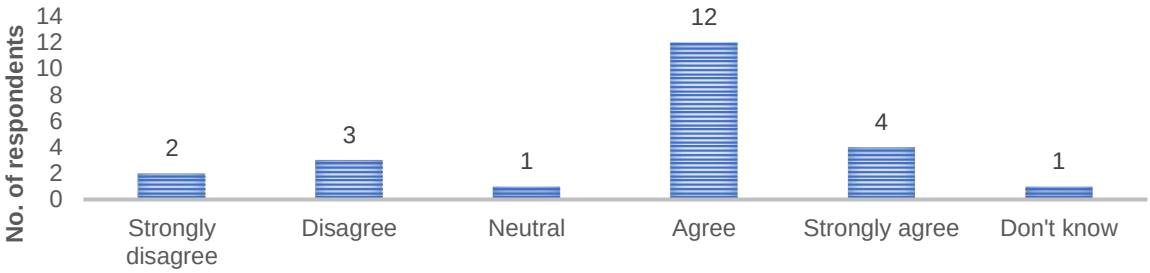
"I think there is evidence to support that conjecture, so that's an agree, but as with everything it presupposes that other elements of the process are managed properly and effectively. This is an activity that focuses on putting things above the ground and under the roof line, it can improve that, but it can't improve the process of landscaping, the process of getting the water connection or the process of getting the roads guys to give you a consent."

"I would agree. I think there are lots of good projects going on across the country where you will see offsite construction is ensuring that houses are going up quicker and that's great when we're looking at region-specific housing targets of the Scottish government."

"I would strongly agree. Offsite manufacturing inherently allows speed of erection and construction at site level."

Finding 9. The majority of respondents agree that the adoption of offsite construction methods in the affordable housing sector is restricted by an industry preference for traditional construction methods.

Results



'The adoption of offsite construction methods in the affordable housing sector is restricted by an industry preference for traditional construction methods'

Key quotes

"I agree that it does restrict. At a UK level it would definitely be a 5 (strongly agree). I think in Scotland that will be tempered so it will probably be a 4 (agree), in that I think we're more accepting of offsite methods but not entirely yet."
"Strongly agree with that. The big developers are still keen on just doing things exactly how they always have done and until that changes it's going to be quite difficult for offsite, I think to break into the market in a more mainstream fashion."

"Yes, I would agree. Change is always a challenge for people and people go with what they know. I think it's as much a lack of awareness as anything."

"I would agree with that. It's changing. I think the issue with the construction industry is it is very traditional, there are a lot of rivalries and people who don't want to be first adopters of new technologies in case their competitors aren't doing this. So, I think there are some issues there."

"I would agree with that. I think it's because it's what they know. They have their supply chains in place. They understand the product; they understand what they're doing, and

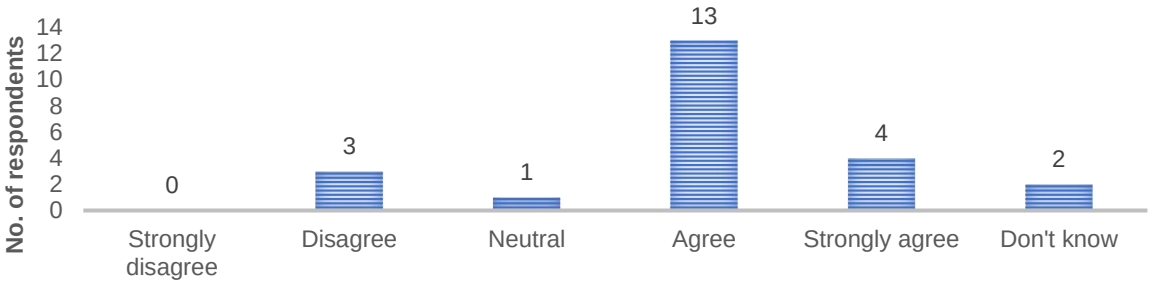
it would be a big change for them to have the confidence to go down a different route. At the end of the day it really needs to be driven as much by the private sector as the affordable sector."

"I would strongly agree with that statement. Construction is pretty hidebound by conservativism. Inevitably when you are dealing with projects in the millions you are going to find yourself being confronted by caution."

"I would agree with that. It goes back to the cautious nature of some of us in the sector on the basis that we go for the traditional design and build – which has always delivered. So, if you're trying something new then is it still going to deliver something of the same quality? I still think people are still quite sceptical about that, so I would agree that people still have a preference for traditional construction methods."

Finding 10. The majority of respondents agree that in standardising the assembly of components offsite, offsite construction methods reduce delays in the construction of affordable housing.

Results



'In standardising the assembly of components onsite, offsite construction methods reduce delays in the construction of affordable housing'

Key quotes

"I would strongly agree with that. I think that again is the attraction. To use that awful cliché, if it can be made to do what it says on the tin then the potential is definitely there to do that. It's got much more certainty in the outcome."

"I agree with that. The main concern we had about delays was that related to weather. Ensuring that materials were delivered as they were needed, and they weren't waiting around. That happened because there was good communication between all the different people involved in the team. So yes, definitely agree with that."

"Yes, however we very rarely standardise across the board in new housing developments. So, yes if we were able to standardise it, it would reduce delays."

"Yes, strongly agree because more of what can be controlled in the factory has less of an impact in terms of the sequencing of works."

"I agree. The only reason I didn't mark it down from strongly agree is that I don't believe in total standardisation. I believe that there ought to be some individuality and tailoring to particular needs and that can be done within modular."

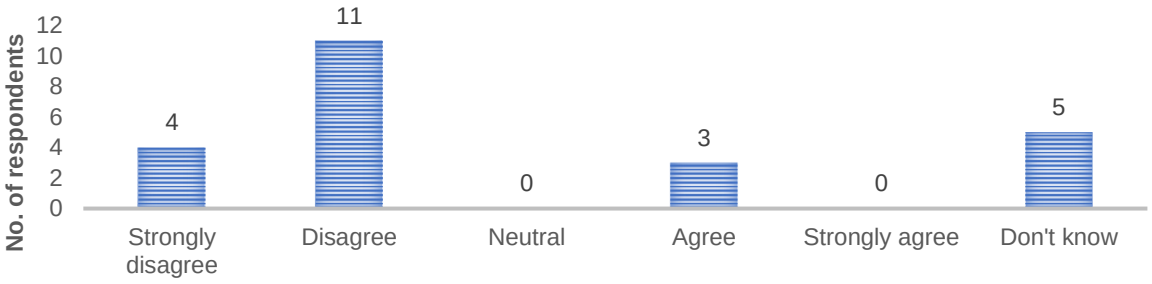
“I think it's a qualified agree. It can reduce delays in the particular phase where it's managed well but there is no evidence that the offsite or modern methods section of the industry is any better at delivering on time and on cost - largely because it doesn't have much of a track record as yet, not the social sector anyway, but I think it could.”

“I would agree with that. Offsite construction does reduce delays if you are standardizing.”

“I would agree with that. It simplifies process.”

Finding 11. The majority of respondents disagree that building standards and design codes do not support the adoption of offsite construction method in the development of affordable housing.

Results



'Building standards and design codes do not support the adoption of offsite construction methods in the development of affordable housing'

Key quotes

“I would disagree with that. I am based on the planning service and we share an office with the building standards and planners. I don't pick up from them that any of the projects for offsite construction having posted them any particular issues in their planning and standards, and in fact design codes as well.”

“It's not really been my experience with the projects I'm on site with, no I wouldn’t say that, I wouldn’t agree with that.”

“I would say strongly disagree. I'm not close enough to the building standards to say if there are real constraints or obstacles but my perception is that there aren't. Design codes shouldn't really constrain us either because we can do standardisation and offsite manufacturing and still do high quality design and high quality environments and help to create successful places.”

“I would strongly disagree with that; I think the building standards completely allows for it.”

“I disagree with that. They do support it absolutely because we're trying to get more energy efficient homes and moving towards higher standards as we go forward. So, it does and obviously the standards that are claimed to be achieved by offsite construction are much higher.”

“Strongly disagree. We're more than capable of complying with the building regulations and design codes.”

"I disagree. The gold standard is perfectly achievable and very straightforward."

"Strongly disagree with that. Providing the offsite manufacturing product is compliant with building standards, that building standards will have any problem with it."

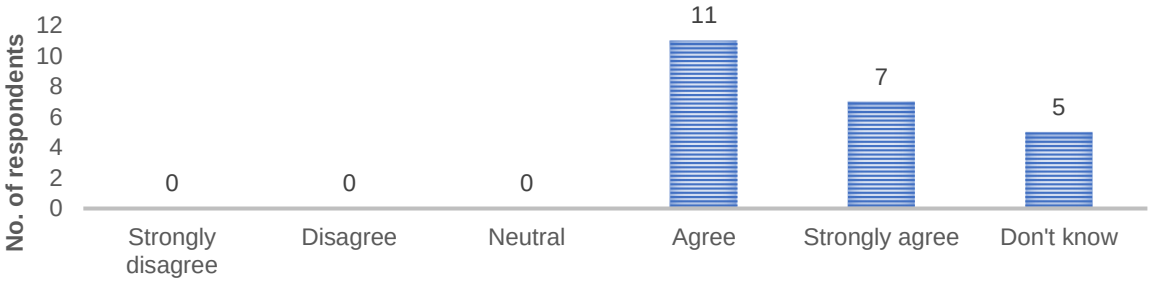
"I disagree. I'm not aware of any evidence that that's the case but I'm also not aware of any particular rigidity in the offsite design and build process that suggests it's not capable of being properly flexible or responding to bespoke type needs."

"I would disagree. I think building standards support the adoption of offsite construction methods."

"In relation to panelised construction I would strongly disagree, I see no evidence of that."

Finding 12. The majority of respondents agree that offsite construction methods help reduce waste in affordable housing provision when compared to traditional construction methods.

Results



'Offsite construction methods help reduce construction waste in affordable housing provison when compared to traditional construction methods'

Key quotes

"I think conventional house building is incredibly wasteful. It's not uncommon for a house builders, big plc type house builders, if they are building housing estate of say 20 houses they would buy an extra one of everything. So, an extra kitchen, an extra bathroom and an extra door set or a whole set of doors and that's because they can't guarantee the quality of fitting. So, they think that they will need extra because things will go wrong, but invariably it's not actually quite that bad and they're left with spares and it all just goes in the skip brand new."

"I strongly agree. It can make a significant contribution to reducing construction waste. You see it a lot when you look at most building sites these days, compared to 15, 20 years ago. It looks completely different in terms of how much debris is lying about."

"I would agree. If systems are mechanised, then these computerised cutting machines should be able to cut more accurately than a man on a site."

"I agree. I think given the factory setting, where you have got a controlled environment, there are fewer mistakes that would be made because you are running the product through a machine rather than literally man handled. So, there should be fewer opportunities for error. I'm aware that we still have got to do the sub structure works on site and that requires man power and machinery but if we are able to look to the

superstructure and design out as much as we can, in terms of waste and repeat works then I would anticipate that would reduce waste."

"I would strongly agree. Just by doing a panelised system or a modular system in a factory, it's going to have a huge impact. Your ability to use materials more efficiently and then effectively recycle what's left."

"I would strongly agree. Waste can be captured and recycled in a much more efficient way if it's done in a factory rather than on a wet windy building site."

"I would agree. Because you're using a factory-controlled process, there isn't as much waste as you see onsite."

"I would agree. The less that is built onsite, the more is built in a controlled environment then you are going to get reduced initial wastage and the proper recycling of any waste materials."
"I would agree. I've been on so many sites and looked at traditional construction, and yes, the waste there is phenomenal."

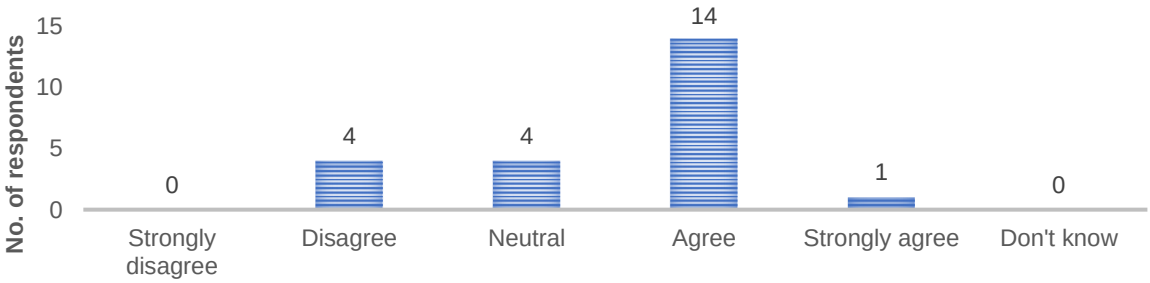
"Strongly agree. Basically, if the construction can be controlled in a factory environment then there is very much a focus on reduced waste."

"Strongly agree. You are bulk buying. The materials are coming into the factory. Packaging is either recycled or in some instances the factories are using the timber waste to actually burn on site to produce the heating for the factory. It is a very efficient recycling process. Plasterboard which is always a horrible thing to recycle, is easy in a factory and could be returned to the manufacturers for reprocessing."

"I would agree with that. The manufacturing process that we employ is virtually zero waste. We use optimising technology to ensure that materials are cut to accurate and required lengths and those offcuts that we have are reused elsewhere in the process. Plasterboard offcuts and waste is taken back to source, to the manufacturer for recycle."

Finding 13. The majority of respondents agree that the use of offsite construction techniques for affordable housing is restricted by the lack of professionals with the necessary skill sets.

Results



'The use of offsite construction techniques for affordable housing is restricted by the lack of professionals with the necessary skill sets'

Key quotes

"Yes, I would agree. I think there are labour shortages and there are skill shortages as well."

“I think in order for offsite to be done well, a professional skill set or a level of professionalism needs to be achieved. If there is a lack of people with the skills then it's not going to be done well, it's going to be done to a substandard level.”

“I don't think that's exclusive to offsite construction techniques, but I would agree with it. There is a recruitment crisis that is not only present but is deepening.”

“Yes probably. Are you going to develop new skill sets that are going to be used? If you are going to acquire these skills you are going to have to use them. But if the demand isn’t there, then why would you do that? There’s no point in doing it if it’s not going to be used. The main driver is cost. Until it is clear that these approaches reduce cost, I don’t see it will ever take off.”

“I suppose I would tend to agree. There are definitely people out there who have these techniques but is it widely enough demonstrated across the profession, I’m not entirely sure.”

“I've got a tendency to agree with that. I think that the industry in general, and that's contractors, consultants, architects, the whole lot, are maybe needing to develop their skills in these areas.”

“They need to have a much bigger understanding of the engineering of a site. I think there is a difference between the production of the kit and the production of an offsite manufactured element and the delivery and build on site. I think that's where the skills gap is.”

“Probably agree with that. From a rural experience there's not many contractors that have experience of both methods.”

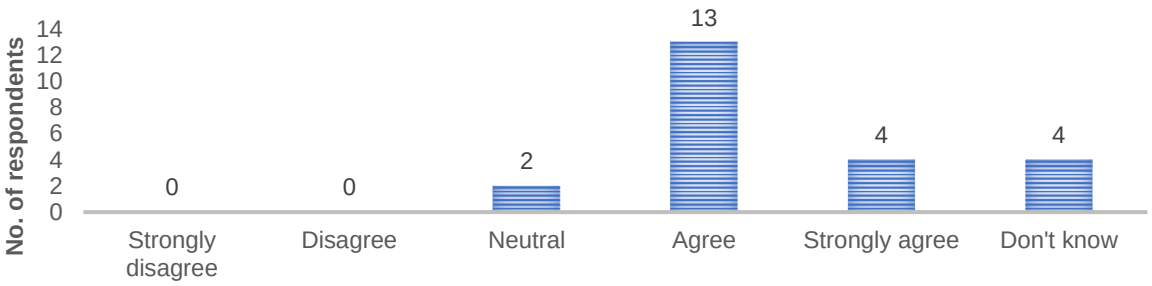
“Yes, I would agree with that. The amount of times where we have sat with different professionals who argue that black is white.”

“I would agree with that. The manufacturing companies have the skills because they are doing it, but the professional side with the development officers, maybe they don't have the knowledge or skills.”

“Agree. I think there is a general shortage of skills and awareness but I don't think it's restricted particularly to the affordable housing sector. The necessary skill set is an issue but it's not restricted to just the affordable housing sector itself. I think the construction sector; the design sector also struggles with it. It's moving out of people's comfort zones.”

Finding 14. The majority of respondents agree that offsite construction methods improve recycling processes in the development of affordable homes when compared to traditional methods.

Results



'Offsite construction methods improve recycling processes in the development of affordable homes when compared to traditional construction methods'

Key quotes

"Agree. I think waste materials in a factory environment can be much more easily aggregated and reused for other things and managed through the use of proper bins and skips for different materials, waste sorting, and all that type of thing. That encourages people to reuse items and recycle items."

"Agree. Well it should, again because of the factory control element."

"I would agree with that. You are working to different, better factory standards and also in the design of the product."

"I would tend to agree. The more work that is done in controlled conditions, the more likely I think that you are going to have successful recycling of materials."

"I would say that when you go through these factories there does appear to be less waste because everything seems to be neat and tidy and they just use what they need."

"Strongly agree. Obviously, any waste that is controlled in a factory environment can be recycled and reused."

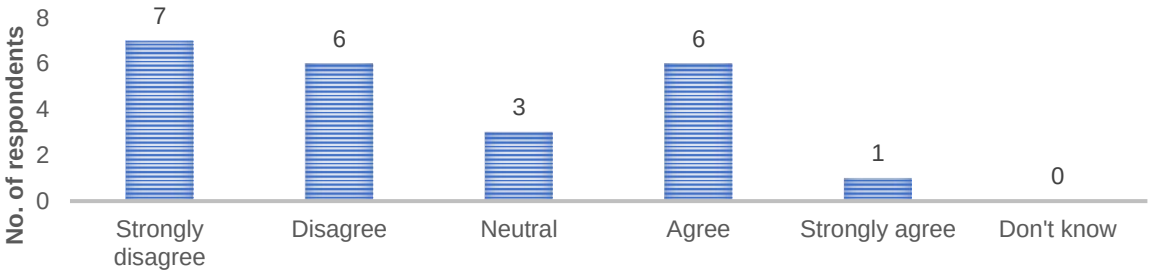
"I would strongly agree with that. There is very little waste."

"I would probably agree with that because I have seen some of the garbage that builders put underneath the ground when they are doing traditional construction. So, I'm assuming that will improve in relation to recycling processes because if it's been done offsite, then I assume that it will be recycled in the correct manner and not just dumped under the ground."

"I would agree with that. I think traditional construction enjoys a higher level of waste than companies using offsite technology."

Finding 15. The majority of respondents disagree with the assertion that the standard business model that underpins affordable housing developments is inappropriate to support offsite construction.

Results



'The standard business model that underpins affordable housing developments is inappropriate to support offsite construction'

Key quotes

"I would disagree with that, possibly even strongly disagree with that. I don't know that there is a standard business model. There are quite variations in the business model nothing that would suggest it is too standardized and too rigid to compliment affordable housing development."

"I strongly disagree with that. I don't see anything in the standard business model for affordable that has much impact on forms of construction anyway. We would tend to see a benefit as the contractors would gain faster and more predictable onsite periods, so that would help us than hinder us."

"I would disagree with that. The model is fine as long as it recognizes that if there are higher costs associated to it that the difference will need to be made up in additional grant. Because the way housing associations work, we work on a residual basis, so we know what private loans we can support through our rents and the difference has to be made up in grant."

"I would strongly disagree with that. It doesn't discriminate against one or the other. It's a very straightforward process of government support to various organisations. So, I suppose it's the only thing that it may discriminate against is on cost basis because it's currently more expensive to do offsite construction."

"I would disagree. I would say the standard business model is flexible enough to cope with any sort of housing development."

"Strongly disagree. Again we are seeing throughout Scotland that there is different degrees of offsite manufacturing already happening. So, there is precedence, there's a clear track record that the business model is not impacting on this the stability of offsite construction."

"Strongly disagree. The issue might be around procurement but that's the only issue in terms of what housing associations like to do in terms of grant funding and things like that there's no restriction there about using off site manufacturing."

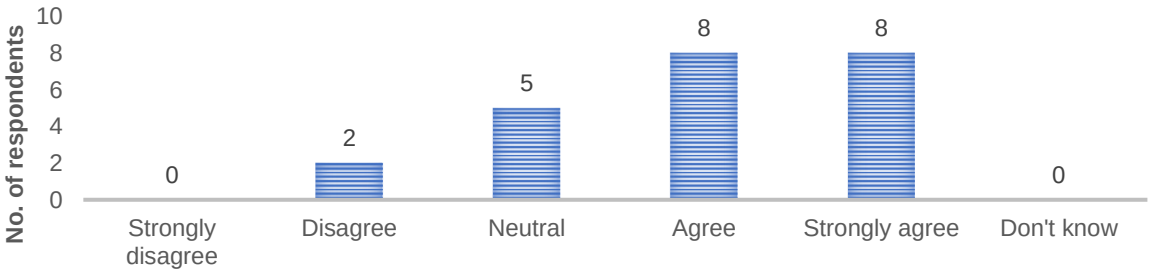
"I strongly disagree. I don't think there's anything in the business model that bears on this. There are things in the procurement process that bear on it and there might even

be things in the approval process that bear on it, but I don't think there's anything in the business model of affordable housing that has any real impact."

"I disagree. I think if you've got a business model for your affordable housing developments then it is a business model that can be used for any type of construction. I think it's just about how you tie that into financial payments and mechanisms and how you bringing your own private finance. At what stage. So, I think the business model is the same, so I would disagree with that."
"I strongly disagree. I see absolutely no evidence, and in fact affordable housing development could only advantage the business model, because if you can build houses faster and better, you get income in quicker, you get tenants enjoying the benefits of better product."

Finding 16. The majority of respondents agree that offsite construction methods improve energy efficiency in the affordable housing sector compared to traditional construction methods.

Results



'Offsite construction methods improve energy efficiency in the affordable housing sector compared to traditional construction methods'

Key quotes

"Yes, I probably agree. I think the buildings tend to be of higher thermal performance where they are constructed offsite so that then means the residents of the building don't have to turn the heating on so much for example. So, that improves energy efficiency. However, a lot of that is down to behavioural education and change with the residents themselves. They need to be educated and informed how to operate these buildings and what not to do and to do. If the companies that build them or the social housing providers aren't giving the residents the right information or are advising the wrong way or not giving them a learning and teaching around how to operate their new building then it just doesn't work at all."

"Agree. I suppose it goes back again to the factory conditions and that and you should be able to control the environment better."

"I agreed with that. I would say because there is a controlled factory environment where the kits are erected, there are better tolerances so I would anticipate fewer mistakes and fewer defects and better air tightness and obviously in terms of energy efficiency."

"I strongly agree with that. The biggest enemy of energy efficiency is uncontrolled ventilation and you can achieve much better standards of, for example, air tightness compared to traditional construction methods, in my option."

I strongly agree. I think we are moving towards renewable energy and that kind of thing, much more controlled over quality on site and reducing air leakage in houses. Offsite is far more a predictable performer than traditional as far as I'm concerned."

"I would agree with that as it should be about quality control and air tightness."

"Yes, I would agree with that. You tend to find that the whole thing has been designed and sorted through and the insulation, the Vapour barriers that sort of thing is all incorporated in the panel as it's being made on the production line, so yes there is an improved jointing. There's improved fixing between the materials and components. There's less chance of gaps that don't get filled or are just left opened. So yes, I would say that energy efficiency is improved because it tends to be a higher quality of finish in the product itself. What you're having in traditional construction is that one trade tends to cover up the trade that made a mess before or left gaps."

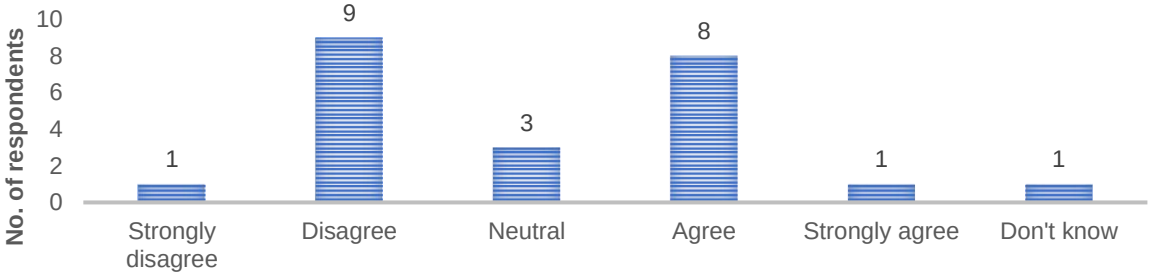
"Yes, strongly agree. I think there is less chance for issues like air leakage which can typically happen on a site level and therefore improves energy efficiency."

"Strongly agree. At the heart of any endeavour to improve energy efficiency you have to cut down air leakage. You've got to try and achieve air tightness and that is best done at the factory level with precision between components and their jointing."

"I would say strongly agree, because the nature of the offsite process allows better precision than the full construction of your structural walls, from the inner leaf plasterboard to the insulation, the installation of windows and doors, there is inherently less leakage and permeability and really there is no excuse for poor thermal performance."

Finding 17. The respondents were divided as to whether it is insufficient market demand that restricts the use of offsite construction methods in the development of affordable housing.

Results



'Insufficient market demand limits the use of offsite construction methods in the development of affordable housing'

Key quotes

"I would say agree. So, in order for an offsite manufacturer to invest in a facility they need to have certainty of demand and at the moment there's a massive disconnect. Companies are not making the Investment to increase capacity and to really develop that capability because they don't have certainty of demand. Conversely, the housing associations and local authorities are not committed to offsite construction. They've got reservations about the capabilities and capacity of the companies."

"I would agree with that. I think it's a bit of a movable piece, somewhere between early adoption and the tipping point, so that's in the next five years."

“I disagree. I am not aware of a lack of market demand. I think there might be a lack of awareness or a potential fear of the unknown but more and more councils and RSL's opt to take on that option.”

“I would tend to agree that the demand in the market does still limit the offsite construction methods, but maybe I’ll tend to be neutral on that one actually. People who buy a new car want the most up to date, the most fuel efficient than the most stylish and the easier to maintain. In housing they are quite happy have houses that were designed in the 1970's which I quite honestly don’t understand.”

“I'm somewhere between neutral and agree. In some respects, we are always treated as the people who should be industry leaders or bringing forward the industry in a way that the private sector isn't expected to. The private sector just gets on with it, builds whatever it wants to build, sells it and then runs away as quickly as possible. Whereas we have a longer-term relationship with the housing stock. So, it's in our interest to make sure they are of a high standard. There are particular external drivers to that, from the point of view from the funder, who we have to satisfy, that's the grant funder. I think doing as much as we reasonably could, but I think we could always do more to push demand. People are a little bit wary about pushing against an industry which doesn't have the capacity.”

“I would agree. I think the private sector really need to see that this is a benefit and offer some value in the marketplace because until they perceive it to be a market for offsite construction in the private sector or the building regulations force their hands, then I think that the demand won't be there.”

“I disagree with that. I think that people really want to do offsite construction, everybody wants to love it, everybody wants to do it but I think that any particular issues around it in terms of performance tend to make people very cautious. I think the companies that are doing it need to basically get the costs being equal to traditional methods and issues around quality need to be resolved.”

“People won't move until they been convinced that the new way is better. So, I wouldn't say it was insufficient market demand. I think the market is there and demand has been as good as it has been certainly in affordable housing sector with the way that the government policy is. It's just that you have development directors and CEO’s that are reluctant to go down that route because they've seen other people get their fingers burnt.”

“Disagree. There are huge amounts of market demand for all construction. So yes, demand isn't an issue at the moment. The government has set a target for 50000 new homes by 2021 and most of these are going have to be on site in the next few years to meet that 2021 target. The construction industry is very busy at the moment.”

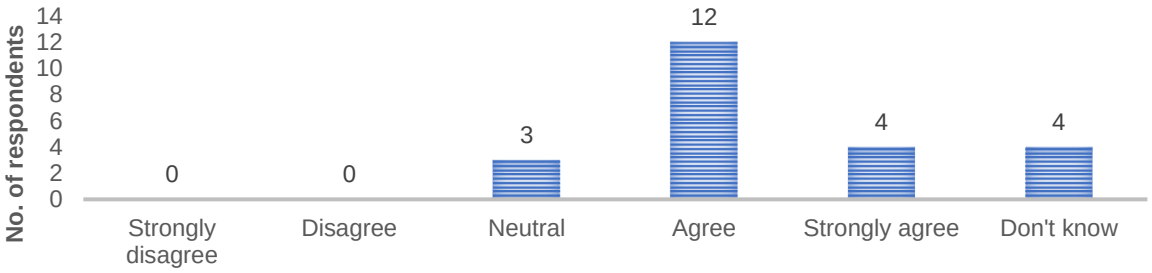
“I would probably disagree with that because people are looking for a house and if it's affordable and its energy efficient. I don't think that limits the use of offsite construction and I think people are just grateful for a house. So, if it's offsite construction or traditional it doesn't really matter.”

“I disagree with that. Because offsite is a term that is creeping into the language, there are perhaps more enquires as to what it is and why we should use. Awareness is being raised, but that awareness is a little bit of creep from the south, perhaps more so than in Scotland. We have been using offsite technology in Scotland timber systems since

the 1950's, so it's not new, it's not rocket science, it's just a different method of assembly arising from key factors in the market, pushing it in that direction."

Finding 18. The majority of respondents agree that offsite construction methods contribute to lower carbon emissions when compared to traditional construction methods for affordable housing.

Results



'Offsite construction methods contribute to lower carbon emissions when compared to traditional construction methods for affordable housing'

Key quotes

"I will probably say that is true. I think it's probably just more efficient to build it in one place because if you're building it in a particularly remotely location all the workers are having to travel there and back and all of the supplies need to be taken there as well and there's lots of back-and-forth, lots of unnecessary journeys perhaps."

"I think they do, due to just simple things like less time on site and less heavy machinery involved and the materials used themselves can be a bit more effective. Less use of, or for some houses, there's no concrete used in the walls and things like that. So, yes I would strongly agree."

"I agree. We have got fewer trips to site by lorries and associated construction workers and machines and so on. Yes, I would agree that there is lower carbon emissions."

"I would agree. I honestly think there would be no point in doing it unless that was the case, so we are looking at very low energy housing solutions."

"I would tend to agree but I think it's how easy it is to make them contribute. I think offsite construction has a lot of benefits in terms of predictability and control of quality in relation to energy performance. It's not to say that traditional construction methods can't get you these results, but it's harder to do in my opinion."

"Yes, if you've got a high-quality product and it goes together well and you've got people who know how to work the systems to get the best out of them. Sometimes you've got to re-educate your tenant and sometimes it's a different approach to actually get the best out of it, but yes generally, I agree."

"I've said strongly agree on the basis there that if you've got a more efficient product, there is less heat loss, improved SAP ratings and therefore less carbon impact."

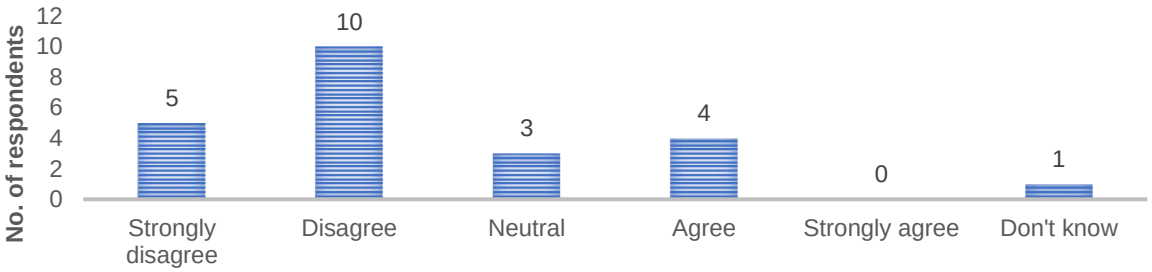
"At the very simplest level, you reduce vehicle movements significantly. Very simply you can cut down your carbon miles very easily. Now I know carbon emissions go

beyond that, but concentrating your manufacturing and being allowed to buy in bulk does exactly the same."

"I would agree with that. The use of timber is inherently efficient in driving lower carbon emissions, in terms of the construction delivery, you have got fewer vehicle movements and arguably fewer logistics issues in taking materials to site. Again, the efficiency is improved."

Finding 19. Most respondents disagree with the premise that residents living in affordable housing prefer homes built using traditional construction methods.

Results



'Residents living in affordable housing prefer homes built using traditional construction methods'

Key quotes

"I disagree. I don't think many residents would necessarily be aware of the construction methods and I don't see it as a determining factor in a let. They will be more interested in location, size of property to meet housing need and the amenities within the house and the surrounding environment."

"I don't think there is much evidence in saying that people prefer to live in traditional construction methods, I think they want to live in places that they can afford, and that is best produced by this approach. Also, they want to live in a very high-quality environment, so not just the interior but the external environment. So, I would say I disagree with that statement."

"I don't think residents are interested in the method of construction, they are interested in how the house looks, how energy efficient it is to cut down their bills etc. So, I don't really think it's an issue for residents."

"Our tenants are very happy knowing that their heating bills are going to be lower than in previous houses that they've lived in. That was a huge driver for us because a lot of people in our community are living in extreme fuel poverty and so everyone was really on board with the benefits of the construction method. The architect has worked with the tenants about how the mechanical heat recovery system works so they know that it doesn't work the same way as traditional heating system. So, I think I'd strongly disagree with that."

"I would disagree with that. As long as people have a nice house, keeps in the heat and is pleasant to live in, I don't think the construction method would matter."

"I've found that a lot of our residents don't know the difference between the two different types of construction methods. They see the house and they can touch the house

they're delighted with the new house, but the vast majority of them I would say wouldn't know the difference in the first place."

"Strongly disagree. I think that's more of a historic perception that people like the old fashioned bricks and mortar. These days, I think if you were to ask many of the residents who live in houses I'm not sure they would actually know the difference, or be concerned about it. The focus for them is obviously the heating and running costs."

"I disagree with that statement. My own experience is most people don't care a damn. The reason being that plasterboard applied in a factory is the same as plasterboard applied on site."

"Strongly disagree. I would think that very few residents will actually know how their house is constructed, or care."

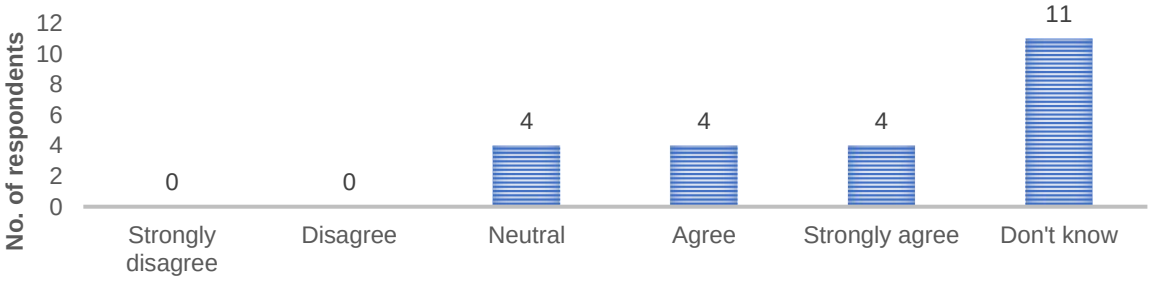
"I don't think I can ever recall anybody refusing a house on the grounds that it was a non-traditional. So, strongly disagree."

"Strongly disagree. The people we are dealing with within the sector are just grateful for a house and affordable house."

"I would strongly disagree. I don't even think they are aware. One of our clients recently announced that she didn't care how it was built, as long as she got a product with a given level of specification, she was perfectly happy."

Finding 20. Whilst 35% of respondents agreed that offsite construction methods result in reduced water consumption compared to traditional methods for affordable housing, the majority (65%) were either neutral or didn't know.

Results



'Offsite construction methods result in reduced water consumption compared to traditional construction methods for affordable housing'

Key quotes

"I think that's probably a neutral. I think the link is a little bit tenuous."

"Neutral on that. I don't know enough about water consumption. I guess in theory it should, but I don't know enough to answer."

"I don't know. It's not something I am aware of."

"Strongly agree. Traditional construction methods are wet and they use a lot of water for manufacturing materials like concrete blocks."

"I would agree, purely because of the way that they're finished, and the wall finishes etc don't require the amount of water for the delivery."

"It should do if it cuts down on particular wet trades, I think really but it still depends on the way we have offsite construction. If we use cladding effectively and obviously the choice of finishes as well really."

"I've said strongly agree. If we're using an envelope which adopts a cladding solution, a brick slip solution then there's less wet trades involved and therefore there's less reliance on water consumption on site."

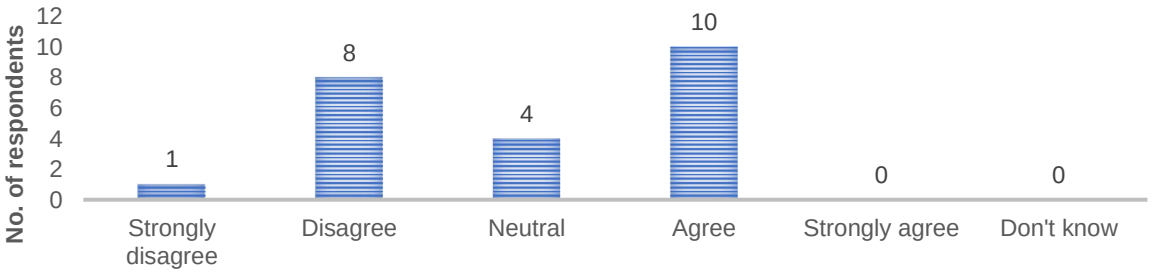
"Once again back to the environment. You have much tighter control of your resources and you are looking to build dry as much as possible."

"Yes, I agree with that. If you have it in a factory environment you can control how much water is used whereas on site you may be just a bit more haphazard about how much you actually use. So yes, we think there will be a reduction in water usage."

"It may do, I genuinely don't know. I don't think it's anything we have seriously measured."

Finding 21. There was no agreement amongst the respondents as to whether the adoption of offsite construction is currently well supported by Scottish policy initiatives for the affordable housing sector.

Results



'The adoption of offsite construction is currently well supported by Scottish policy initiatives for the affordable housing sector'

Key quotes

"I disagree with that. I don't think there is any policy in place to encourage offsite in the social housing side. To be fair, I don't think it's all to be left in the hands of the Scottish government because I think they are limited as to what they can do with housing associations and local authorities."

"I would slightly disagree with that. There could be more support in terms of policy initiatives and if there was an equivalent challenge fund similar to say the self-build pilot fund or the rural housing fund."

"Strongly disagree. I've seen no indication that that's a priority, or very little indication. I think they have to be clear why they want to promote it."

"I've agreed with this one. I think there is a definite promotion of offsite manufacture. I do think that it is supported, I think there could be more done, but I would agree."

“I agree, but we could always do more and the more we could do is about focusing on how you incentivise affordable housing developers to go down this route. There needs to be an incentive programme, there needs to sufficient investment in it, there needs to be collaboration in the sector, if you get all these things and that is supported by Scottish policy then yes, I would agree.”

“I would disagree with that one. Nobody is giving me more grant funding for example to develop housing in a particular way. That would be the biggest incentive to me as far as supporting initiatives are concerned. If the government was really concerned about supporting offsite construction, they would be giving me more money to explore how to do it properly.”

“I think it is supported, so I'll say I'll agree there. I think a lot of it is more talk than really understanding the implications of it, and the cost of it, and the importance of the private sector being engaged in the process. So, I think yes, I think the policy is there, the Scottish government policies very much looking at how we can use offsite construction as a method of delivery and as I say, that is why we have been trialling it.”

“Yes, it is. So, it is actually up to the contractors and developers about how far they go with it. So, I think a lot of people doing partial offsite construction.”

“It's supported and it's encouraged by a number of initiatives. It's maybe not as well embraced by everyone in the affordable housing sector, but we've got to get people up the learning curve and embracing the new or better ways of doing it.”

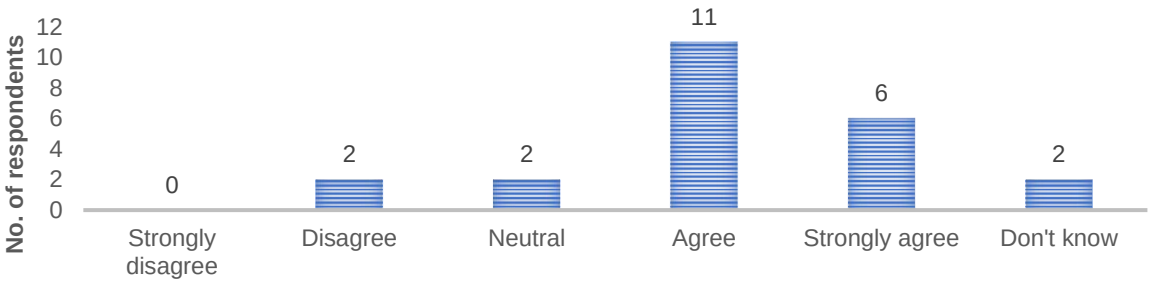
“If you're going to move beyond a panelised construction and start looking at modularised and more effective offsite construction, there is nothing. There is just nothing there to support that within the housing policy other than fine words. Unless you have something legislative or something that pushes forward a change why would anybody want to move from something, they are comfortable with? I think frankly the Scottish government has to start looking at the way it creates a marketplace for this otherwise we're going to be stuck at the level of timber frame stroke panelised.”

“A couple of the manufacturers in Scotland are putting huge investment into panelised construction but frankly it is just one micro step away from normal timber frame. To go beyond that you need to tool up. You need a different approach and that just cannot be done without a reasonable market place.”

“I'm going to agree. The local housing strategy supports offsite manufacturing. Scottish government guidance for the affordable housing supply programme supports offsite manufacturing and other things coming out from Scottish government in terms of policy are all quite supportive of it. So, I think yes, it is well supported.”

Finding 22. The majority of respondents agree that offsite construction methods help the affordable housing sector meet lean construction objectives (i.e. maximising value and minimising waste).

Results



'Offsite construction methods help the affordable housing sector meet lean construction objectives (i.e. maximising value and minimising waste)

Key quotes

"I think although offsite by definition is LEAN, thereby the more offsite houses that are built the more LEAN processes will be adopted and the more LEAN these companies will become in their processes because they will be more experienced and understand it more."

"I would assume so if it was used for maximizing value. I think that's a key driver in offsite construction. Also, what we have seen in the reduction in build site wastage, yes, I would strongly agree."

"Yes, I would strongly agree with that. I think that's central plank of the offsite manufacturing process."

"Yes, lean construction isn't necessarily an explicit objective of what we do, but it's kind of implicit in that standards that we have to operate to. I would agree but maybe not strongly agree. There's a benefit there yes."

"I would agree with that but again if you've got situations where your site isn't managed properly or you've got issues with just-in-time type deliveries or you're having issues with labour on site and people aren't finishing off the job in time, to a required standard before the next trade comes in or whatever is coming along next. You can lose that advantage and it can end up costing you more."

"Strongly agree. It's evident that it minimises waste and obviously the efficiency in terms of quality and build programme then you're maximizing value."

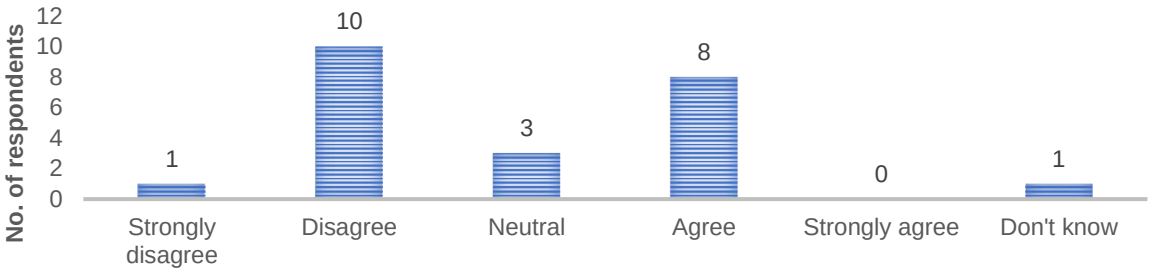
"It's an axiom. That is a statement that stands on its own right."

"I agree with that. I think that is the case, but I don't think enough of that is actually publicized. I think that's where, from a government perspective, they need to be showing us that actually it is that better value for money and it does minimise waste. So, think it would be good to see more examples of that."

"Strongly agree. The streamlining of process within the factory environment, allowing speed, efficiency and economy and performance."

Finding 23. Only 35% of respondents agree that housing development staff (in councils and housing associations) have sufficient skills and experience to manage projects involving offsite construction.

Results



'Housing development staff (in councils and housing associations) have sufficient skills and experience to manage projects involving offsite construction'

Key quotes

"Disagree. I would just point to some examples that have been done really badly because some housing associations people and local authorities haven't procured solutions well or haven't understood that the cheapest isn't always the best or the most appropriate. Further work and research could have been done before going for a particular supplier or procuring in that way."

"I would disagree. I think, just in general, they're not quite as experienced. It's not actually a criticism of them at all, it's just they don't do offsite as much. So, I just think they've not really had the experience of offsite."

"Disagree. People like to do what they have always done. There is generally a resistance to innovation unless someone else has shown that it's effective."

"I agree. I think that it's a transferrable skill and I think it's more about building in familiarity or doing the awareness raising, for example, through the work you are doing or anecdotally talking to other councils or through other networks, whether its technical staff or development staff can learn more about how that actually works."

"I would disagree because it is early days and people don't want to be first adopters of new technology."

"Yes, I think we do and I would say that primarily because managing offsite construction is almost entirely a contractor's responsibility, rather than our own developers. So, we manage the projects but the nuts and bolts of it are contractors and our consultants to deal with. The part it impeaches on us is relevantly small. It doesn't make a great deal of difference to me as far as I can see as far as the development process is concerned, provided we have the right contractors and consultants with the right skills in place."

"I'm fairly neutral on that really. It's a mixed picture because, not so much managing projects on site but in commissioning projects. So, having the confidence to commission projects in a particular way I suppose."

"I agree with that because they do have the skills to deal with either, but obviously it's the same skill that's required for any build."

"Again, it's a mixed bag. Some of them are well up to speed. They've got everything fixed and they know what they're wanting and they go out to get it. Other ones are new at it. You get people who just don't know what they're doing."

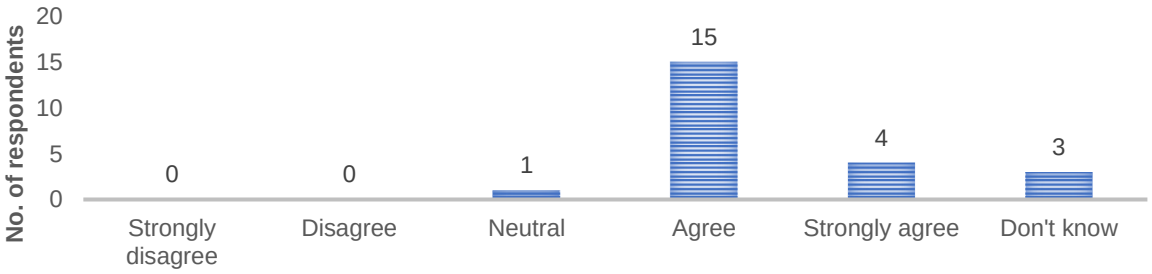
"I'm going to agree because what housing development staff do is they put together a team of people with the relevant expertise. So, if a contractor is looking to deliver offsite construction, they will have the expertise within that team. So, we have a full range of consultants and contractors that we can appoint."

"I would probably disagree. I think at the moment some organisations have been fortunate in that they still have people who have got skills but I don't think there's enough for them that really understands offsite construction and what can be the positive and the negatives of that. So, I think it's a journey that again we need to invest more into."

"I think I disagree with that statement. I think there is an element of again, training, awareness, that needs to be evolved on the other side of the table. For organisations to adopt offsite you need to have people who understand it and get it."

Finding 24. The majority of respondents agree that offsite construction methods reduce storage requirements during the construction of affordable homes.

Results



'Offsite construction methods reduce storage requirements onsite during the construction of affordable homes'

Key quotes

"I would agree. If you've got a supply chain and logistical setup well in place you don't actually need much storage on site at all. You can pretty much deliver it just-in-time."

"If you can plan it right and you plan ahead then yes there should be minimal storage requirements for offsite."

"Yes, I strongly agree with that. I think that's part of the attractiveness of it - to reduce onsite storage."

"I agree. Because obviously we are bringing the kits to site so the contractor is not ordering up all the component parts that would make up the house and then storing them on site which involves a number of trips to the site. They are bringing the kits shrink wrapped on lorries, so they are able to deliver to site with the crane in situ and it's very quick. I would agree that there is less requirement for storage which can be important for us, particularly because we work in town centre locations. The opportunities for storage on site can be limited."

"I think that has to be true if you are bringing stock on site and erecting it immediately and you have got reduced wet trades, reduced scaffolding."

"I would agree with it. If we get a just-in-time supply chain established between an offsite manufacturing facility and the site, then there shouldn't be a requirement for storage in the same extent as where you have pallets of bricks and blocks and timber lying about waiting to be assembled. If that assembly can be done offsite then storage requirements should reduce substantially."

"I'd agree with that. I think it's not about the having the space for storage, but I think the risk of storage in the Scottish climate can be sometimes an issue."

"Yes, if you're working to a just-in-time and everything is working and you've got your man power there, you've got your materials there and things are coming on. The problem comes whatever weak link you come across. If you start getting all these kits arriving on site and you've got nowhere to put them or nowhere to put them yet, it can actually increase your storage requirements and it's a nightmare when you see things arriving and you can't actually take delivery because you've got no space."

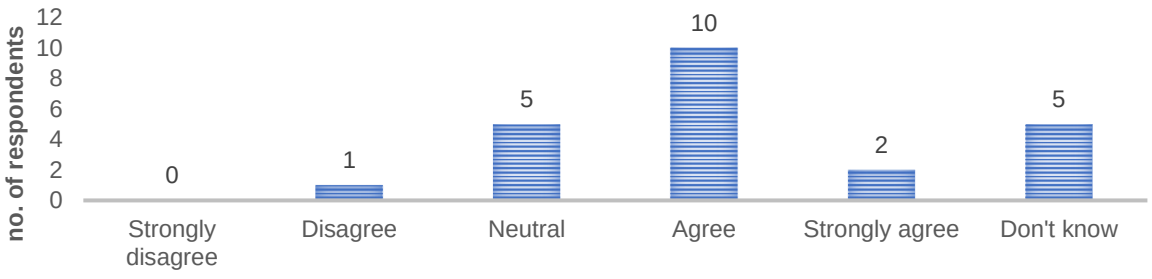
"Ultimately if you're getting say a closed panel that's coming to site with the external skin already applied then yes inherently there will be much less demanding site storage requirements."

"I agree. The components that are being brought onto the site and fabricated very quickly on site so that there is no need for storing big pallets of bricks or whatever."
"I think I would agree with that. I think if it's as it should be, then you are reducing storage requirements."

"I would strongly agree. A large proportion of product is being built offsite and there is inherently less requirement for storage of materials on site."

Finding 25. The majority of respondents agree that offsite construction methods reduce noise problems during the construction of affordable homes.

Results



'Offsite construction methods reduce noise problems during the construction of affordable homes'

Key quotes

"I would agree with that because there is less work actually being done on site."

"I think so. That's what we have been led to believe because there is less noise over time because there's less people needed; less machinery needed."

"I've agreed but it's a tentative agree because I am anticipating with there being relatively fewer trades on site, so you have fewer machines and vehicles going on and off the site. But at the same time I appreciate that there are lorries arriving with kits and a crane in situ. You could have sub structure works that necessitate piling or grouting or any other kind of remediation. So, I would agree for super structure but substructure I think it would be more site specific."

"If you have got a shorter contract period, you are going to have less noise, maybe not less noise on a daily basis but certainly less noise over say 6 months of a contract compared to 12 months."

"I would agree with that. The majority of the work is done in a factory environment, it makes sense, it seems to be that noise pollution would be reduced on site."

"I would agree with that, although the vast majority of noise on the site is associated to the ground works and particularly if you've got rock removal or a you've got piling to do and that's nothing to do with the kits."

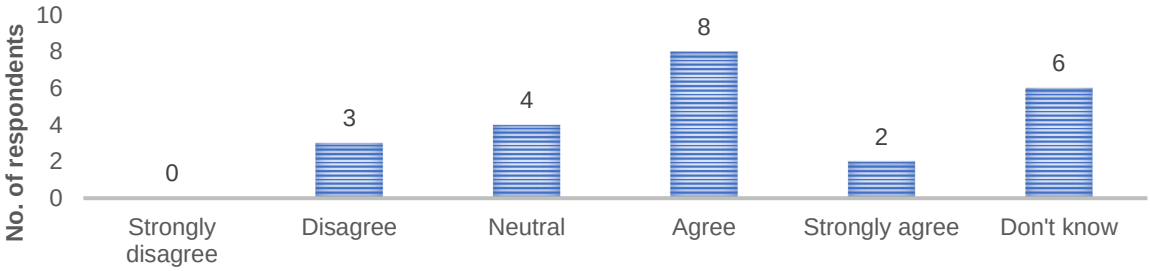
"If you've got a shorter build period the noise on site is bound to be, if not reduced in volume, it will be reduced in the overall length of time."

"I agree because obviously the more of the build that can be undertaken in the factory then means inherently there's less construction taking place on site and therefore less potential noise and nuisance issues."

"If you consider the sort of aggregate reduction in duration, then the elimination of nuisance over an extended period is much reduced."

Finding 26. 43% of respondents agree that offsite construction methods reduce dust problems during the construction of affordable homes.

Results



'Offsite construction methods reduce dust problems during the construction of affordable homes'

Key quotes

"Yes, I would agree with that. I was listening somebody speak this week about silica dust and apparently that's a major health and safety issue and it's likely to become a bigger issue like asbestos in the future particularly for certain trades such as roofing and things like that where tiles and slates are being cut on site. So I think doing that in a factory with equipment, machinery would reduce the risk of that."

"Yes, it should do. You have less loose material flying about the place."

“Again, I think that has to be true. If you are bringing in a panelised system or a modular system and then you bring in roof sections, all being craned onto site, all pre manufactured in the offsite facility, you are bound to be doing less sawing and less work with the sand and cement, so yes, I think that goes with the territory.”

“I think the that more you can cut down construction by traditional methods you should probably be able to reduce dust and other nuisances on site, but again I don't really think that's a major question if you like, certainly in this part of the country. I would tend to agree but it's not, it's not a big issue really.”

“I'm neutral on that because I don't know what dust is generated in the factory. I have not been there actually during the production process. So, on site you're going to reduce the dust, but I couldn't comment on whether or not whether it’s more injurious to health because you're in the closed environment or not.”

“Neutral, because it really depends a lot of the dust is probably attached with the excavations and foundation makeup really and if you still using very traditional trades to do that really. There will be some construction methods you might be able to make lighter foundation designs but I don't know if it would necessarily make a big difference.”

“Yes, agree and again because it's largely undertaken in a factory controlled environment then the issue of dust is lessened.”

“Yes and no. There is little or no dust of course produced if you deliver modularised but you're still going to get dust from the site works operations.”
“Disagree with that one. Dust is dust and it comes in from the mud on site and sanding things down in the house, doing the plastering.”

“I'm not so convinced about that because most of that is to do with the muck shifting and substructure and those kinds of issues. So, to a very limited extent yes but I would broadly be neutral on that one.”

“I'm sure that's possible a lot of it depends on the site doesn't it so I'm kind of neutral on that one.”

“In terms of dust generally across the site I would say that I don’t know if there is any significant difference. You have still got the sub structure, you have the over clad, the roof, then you have got the electrics, plumbing, these are all trades and activities that happen after the kit is erected on site. So, there is still a large amount of site process that can lead to dust.”

4.7. Alva case study: Key Quotes

In drawing upon your experience of the Alva project, what are the main barriers to offsite construction?

Expert 1: Alva raised transportation challenges that might not happen elsewhere. The pods were manufactured in Wales, and of course, we were building in Scotland. That meant the pods had to be transported through three jurisdictions - Wales, England, and Scotland – each with different police regulations.

The factory was only 30 miles from the English border, but the roads were very narrow. The police wouldn’t let us transport the pods during the school run and at various other

times during the day. Therefore, we were very restricted as to when we could undertake that short journey.

Once we crossed the Welsh border, the journey north through England was plain sailing, following the M6. However, once we arrived at the Scottish border, new regulations applied in relation to police escorts. Initially, Police Scotland wanted each wagon to be escorted by two police cars, one at the front and one at the rear. Our convoys could be 4 wagons, each carrying one pod. This meant we needed eight police cars for the escort, with at least 8 police officers. Because the police viewed the escort as a low-risk activity, they used old fleet vehicles, that otherwise would might not be used on normal duties. So, some of these vehicles had 250,000 miles on the clock, and because of their condition, we had breakdowns involving police vehicles. We asked, and Police Scotland agreed, to reduce the escort to one car at the front of the convoy and one car at the back, so that cut our costs dramatically.

The next problem we faced was at the M74 Raith interchange, just outside Hamilton, where there were roadworks. We were not allowed to use the interchange during busy periods, so we had a situation with the convoy stuck at a service station until we could proceed - it was a nightmare. On occasion, the tractor had to be decoupled from the pod and returned south to be re-united the next day. A good logistics manager would have been handy!

Ideally, we would have selected a manufacturer much closer to site, but at the time, the Welsh supplier were the only company manufacturing th~~is~~ product we had commissioned. However, we would never do that again. We have since sourced potential suppliers across the central belt, the geographical criteria being a good road network and potentially even close to water.

Another barrier to offsite is resistance from within construction sector in Scotland. I was speaking to a colleague from a housing association, a first-class, blue-chip type organization, that build a lot of homes. His view was "*the houses are fantastic, the standard of finishing is great, they are gold standard, they're safer and quicker to build – it's just a pity they are not yet cheaper."*

Because offsite is new and innovative, the product is not yet cheaper, and as a result, people will select the default, traditional methods of construction. I will often hear about frameworks that don't do this type of thing. So, we have encountered a reluctance within the sector to change and try something new. We have spoken at length about this issue at various forums and have volunteered the view that we have a different attitude to innovation in Scotland. South of the border the 'early bird catches the worm', but north of the border, it's the 'second mouse that gets the cheese'.

That's changing – trade bodies like SFHA and of course the Construction Scotland Innovation Centre and the BRE have worked hard to encourage fresh thinking and we have been fortunate to work with them and encouraged to have their continued support. We were very keen to ensure what we delivered with Link Group and Paragon HA as a Scottish first – Gold Standard Affordable Housing – is used as a launchpad for more, particularly maximizing "lessons learned", some of which were very expensive lessons.

In addition, there is certainly plenty encouragement from the Scottish Government, whose support, not just financial, at Alva was first class.

Housing development staff need to buy-in to offsite construction. Again, I think this goes back to the innovation issue, and traditional construction being the default

position. In addition, the role of the developer and the developer/client relationship was an issue at Alva. RSLs are used to Design and Build Contracts or being part of the Design team. That was not the case at Alva and I have always felt it was not reflected by sufficient alteration to standard contracts nor understood at ground level.

This did lead to a confusion that would not normally exist. We spent a lot of money on research and development before we brought this product to market and I remain firmly of the view the innovators role of designer, land owner, grant recipient and risk taker had never been properly understood on this site and another that was planned at the same time but was abandoned for this reason. It was a challenge separating this project from the modus operandi.

Also, because the project was so innovative, and did not involve mainstream Social Housing Grant we had to deliver the development on a turnkey basis – so, we had to accept all the risk. In a normal house build project, the builder would receive staged payments from the client. We didn't have that at Alva, and I don't think there was sufficient appreciation that we were taking all of the risk, including the overruns. In the event, the pod manufacturer went into Administration during the latter stages of the project, meaning that risk taking had a substantial financial impact on Tigh Grian who also took full responsibility - technical and financial - to complete. That effort was not supported the way I would have liked. Thankfully, the Scottish Government responded differently and were very supportive. Between us, we ensured safe delivery of the development, albeit very late and well over budget – but still using below the benchmark level of mainstream SHG.

Using what was little more than an off the shelf the Sale and Purchase Agreement was just not suitable for what we were doing. So, we have learnt these lessons from Alva. I find the role of Tigh Grian as developer was eventually reflected, but still not understood. However, that's not to say that modular construction has to be delivered using the developer route – that was only necessary here because of the challenge fund that was used to part finance it and the innovative nature of our design. Once it is mainstream, normal rules can apply.

Expert 2: Transportation logistics became quite problematic on the Alva project. A company from north Wales was selected to manufacture and supply the volumetric panels. In hindsight, this was very problematic. The lorries, carrying abnormal loads, had to pass through three jurisdictions – Wales, England and Scotland. Even within England, there were 3 or 4 jurisdictions in which the lorries had to pass through. Each jurisdiction has different road traffic regulations, relating to permissible loads, and specifically the dimensions of the load. So, we had to conform to all these regulations at different points of the journey, meaning at certain sections a police escort was required – which were paid services. In addition, it was necessary to carefully coordinate the timing of the police escort, as the loads needed to be moved overnight to avoid disruption to the road network. Because of this requirement, the officers providing the escort had to have volunteered for overtime. The extent of this problem was not fully envisaged at the planning stage, which was an oversight. I believe the presumption was that the supplier would be responsible for getting the product to site. So, in the end, there was a delay to the start of the project whilst the transportation logistics were addressed.

I believe build quality is another concern. We hear many plaudits in relation to offsite construction – it performs well, it's clean, it's fast, it's safe, it's cost effective – and the research shows it's possible to achieve such benefits if you are working with an experienced manufacturer. However, at Alva, our supplier was not experienced in manufacturing the product, and because of this, quality was compromised in certain

instances. Critically, I do not believe sufficient checks were undertaken in the factory and I understand the company did not have the workforce to cope with the volume of work. I believe anyone that was involved in the Alva project, would be much more cautious in choosing a supplier for future offsite projects because of this experience.

Another barrier is manufacturing capacity. Very simply, when it comes to volumetric construction, there aren't many suppliers that specialize in manufacturing this particular product. We have seen suppliers that ordinarily produce panelised systems, try to enter the volumetric market, but have then subsequently retreated. Perhaps this is because volumetric systems have a lower profit margin, or the product is simply not in demand. So, given these prevailing market conditions, I believe it's difficult for any company to sustain themselves purely by supplying a volumetric product – and as a result, there are very few suppliers out there. Market evidence would suggest that demand at this point in time is focused on panelised systems, not volumetric.

In drawing upon your experience of the Alva project, what are the main benefits of offsite construction?

Expert 1: Reduced cost can be a benefit of offsite construction. Where you are working in a factory environment, where everything is to hand, you don't have to work in a linear fashion. Everything required is already in the factory, you're not waiting for things to arrive at different stages. Workers can be based at one central place, throughout the construction period. There should be no delays and damage should be kept to a minimum. It also means scaffolding onsite is up for less time. If you can synchronize the trades properly – electricians and plumbers – these people can be on site when the pods arrive and start work immediately.

All these factors can contribute to a lower cost. If you shorten the construction time, you shorten the borrowing time as well, meaning less interest charges on borrowed finance.

Improved health and safety is another benefit of offsite construction. Operatives are working under a roof, protected from the elements. There are proper, comfortable facilities for workers, such as WCs and canteen spaces. People are not working at height. So, everyone is working in a much safer environment.

We have also seen more of what we call 'toolbox mentoring', within the factory environment. All the workers are much better supervised, compared to normal building sites. The supervisors are overseeing the process, they have regular meetings with the operatives and the inspection of work is so much easier being indoors. So, working conditions are much better. Also, there is less transport involved in offsite construction, which contributes to improved safety.

Another benefit of offsite is maximizing value and minimizing waste. Again, it's back to synchronization. When the pods arrive on site, everyone can start work simultaneously. We had painters, electricians and plumbers all starting at the same time – and there was very little waste generated on site, the same with the factory.

When constructing a house on a traditional building site, it is difficult to schedule work, because progress is dependent upon various factors. Whereas at Alva, I could tell Marshall Construction (the main contractor) that there are four pods arriving on Tuesday. So, they knew that the roof would need to be tiled, and they could schedule the work, they could order the materials needed. Due to these efficiencies, offsite maximizes value.

Expert 2: Offsite construction definitely improves health and safety on building sites. The site at Alva was compact, with not a lot of space to do anything. Despite this, the site was almost immaculate. There was just 42 little concrete floor plates on top of which everything was stored. It really was noticeable how clean the site was – there was very little noise, very little dust. It was a safe, healthy environment for operatives.

At the Alva project we were aiming to not only demonstrate that volumetric is a feasible and viable method of construction, we were also trying to achieve very high levels of sustainability, in terms of reducing carbon emissions. To meet this aim, we were trialling new heating and ventilation systems. Whilst we did have some problems later on, the first batch of pods that arrived on site performed extremely well when tested. The service penetrations for the ventilation and heating system were extremely precise, ensuring that air tightness was not compromised. I believe it would be difficult to get that level of precision out-with a factory environment. It must be stated that low carbon, low energy and low cost are not the same thing. The quest for the first had a profoundly negative effect on the latter.

Another benefit that was noticeable from the Alva project, was how little storage space was needed on site. When the volumetric pods arrived on site, they were craned into their final position straight off the lorry. This level of convenience is ideal for compact sites, gap sites and inner city regeneration projects where space is limited. Strong winds can of course be a problem when operating a crane, but can be overcome with careful planning.

4.8. Anderston case study: Key quotes

In drawing upon your experience of the Anderston project, what are the main barriers to offsite construction?

I think building regulations can be a barrier. At Anderston, there was an issue with the communal areas between the apartments, areas like the stairwells. Building regulations required these common areas to be constructed using materials that are non-combustible, so CLT panels could not be used in these areas, despite the fact that CLT chars and actually performs better than steel when exposed to fire, which tends to buckle and collapse. So, because of these regulations, these common areas had to be built using conventional blockwork construction as opposed to the CLT panels used to build the apartments. Whilst the apartments themselves were constructed very quickly, leaving big gaps for the blockwork sections. If building standards allowed CLT or closed timber panels to be used in these common areas, which in my opinion are perfectly suitable materials, the whole construction process would be a lot quicker and more efficient.

As a consequence of the current building regulations, I think we will continue to see a preference for traditional, established construction methods that the industry is familiar in delivering. I think if the regulations were to be refreshed, and for example, CLT panels could be used in communal areas, we would see greater uptake in offsite construction across the sector.

In drawing upon your experience of the Anderston project, what are the main benefits of offsite construction?

The main benefit of using offsite manufacturing is the speed of construction. Again, this was very apparent during the Anderston project. One of the blocks I observed, Block 5B, made use of floor cassettes instead of loose ‘I’ joists. The floor slabs also

arrived on site pre-insulated. Both of these features contributed to a much faster construction period onsite, with a greater level of enhancement is undertaken in the factory.

Because the construction process is quicker and more efficient, the likelihood of delays occurring is reduced substantially. During the Anderson project, CCG had a very good understanding of the construction programme, so their schedule was very accurate and efficient – minimising the potential for any delays.

Another benefit of offsite construction is reducing waste. If you go to most building sites, skips are overflowing with all sorts of wasted materials – offcuts, things that had been damaged or installed incorrectly – which are then discarded and sent to landfill. When manufacturing in factory conditions, less waste is created, which ultimately means money is being saved.

An additional feature of offsite construction is reduced storage requirements during the construction period. At Anderston, by the time work had begun on the last apartment block, there was very little space on site. Having the panels delivered to site, just in time for use, the panels were installed directly from the back of a lorry and finished in 2 or 3 hours. So, offsite construction methods are ideal for compact sites or city centre locations.

4.9. Yoker case study: Key quotes

In drawing upon your experience of the Yoker project, what are the main barriers to offsite construction?

Expert 1: I think one of the main barriers to offsite construction is resistance from within the sector itself, which tends to be focused on traditional methods of construction – without realising the benefits of offsite construction, in terms of not only building performance, but how it compares financially as well.

Another barrier is the standard business model for construction projects which is often unsuitable for offsite construction projects, where many of the costs are front-loaded. With the traditional construction model, these costs occur further down the line – and so the coordination of an offsite project is completely different to a traditional construction project. New tools like RIBA DfMA guidance, if used more frequently by the Clients, Main Contractors and Architects, could help in changing the old established traditional process.

Another issue is the management of offsite construction projects. As I mentioned, with offsite construction you have to manage a front-loaded programme (at design stage) and ensure that is well coordinated and efficient. It is necessary to employ relevant specialists very early on in the project, such as offsite technology specialist consultants (here Solid Timber Superstructure Consultants like Eurban), M&E consultants, fire & acoustic consultants. The management of the project at the early stages is critical and is a different dynamic compared to traditional construction projects (key coordination happens at RIBA Stage 2&3 rather that Stage 4 as it is with a traditional procurement route).

Expert 2: One of the main problems encountered at Yoker related to building standards. The project involved the use of cross laminated timber, which is an innovative new product. There was a feeling that some of the officers from building control were unfamiliar with the system, and how the product could be incorporated

into building standards. This caused delays to the schedule, in terms of receiving permissions to proceed. Fire safety was one of the main issues that concerned building control. Fortunately, CCG and others on the project were able to demonstrate the suitability of cross laminated timber, and the permissions were eventually granted – but not without delaying the programme.

I don't think this problem of unfamiliarity is restricted to those working in building control. Generally speaking, I would suggest that many people working in the construction sector have a poor understanding of offsite construction methods and innovative, new products such as cross laminated timber. Because these people don't have the necessary skill sets or understanding of offsite construction methods, the default position is always to return to what they are familiar with – standard, traditional construction methods. So, there is a real need to get the sector up to speed when it comes to offsite construction. It might be a steep learning curve for some in the industry, but it's absolutely necessary and very achievable with the right approach.

Another barrier, more of a generic statement rather than directly related to the Yoker project, is the awareness of companies in Scotland that provide offsite construction services. At present, there are only a small number of companies that can provide offsite systems, CCG being one such example. I would be doubtful if many architects or developers are familiar with these companies and the services they offer. I think there should be a concerted effort to grow this segment of the market and really promote these companies, and encourage others to form.

In drawing upon your experience of the Yoker project, what are the main benefits of offsite construction?

Expert 1: If the right technology is used, you save money. With proper coordination, the offsite construction process is much more efficient than traditional methods. The pre-fabricated panels, produced in controlled environments, arrive on site just-in-time and installation is very quick. Installation of the superstructure can be approximately 40% faster than traditional construction methods. The technology is clean, dry and fast – and this increases the speed of construction and reduces significantly risk, which brings costs down.

Also, CLT is a high quality product, and when installed properly you have an airtight structure that performs well when in-use. This has an impact on future maintenance costs.

With offsite construction, you also have less waste, less pollution, less site traffic and less noise. Building sites are also safer as there are less operatives on site.

Expert 2: I think one of the key benefits of offsite construction relates to productivity. We are not building as many homes in Scotland as we need to be doing. We all recognize this problem exists. The difficulty is that, using traditional methods, building a house or a block of flats is a prolonged exercise, requiring multiple trades to be correctly coordinated over the space of many months – much of which happens on wet, muddy building sites in the middle of winter, with limited daylight. Transferring much of the process into a factory environment means construction can be much more efficient and streamlined – meaning we can build at much higher volumes.

Another benefit of offsite construction is that it can help improve energy efficiency. At Yoker, the cross laminated timber panels provided the necessary thermal mass to ensure the product was effective. Whilst the insulation was added onsite at Yoker, rather than in the factory setting, it was still possible to get the panels wind and

watertight in a very short space of time. The only problem we encountered was in certain areas where the panels had been penetrated to allow for services, and not properly resealed. However, done properly, you can penetrate the panels without compromising their performance – you just need to ensure any gaps are sealed properly.

Related to the previous point, the improved energy performance of homes can contribute significantly to lower carbon emissions, in terms of not only operational use but also embodied carbon. So, I would suggest that offsite construction can be a major contributor to Scotland meeting its carbon emission targets.

4.10. Portobello case study: Key quotes

In drawing upon your experience of the Portobello project, what are the main barriers to offsite construction?

Initially, cost was an issue. When we compared the cost of CLT to steel frame with Bison floor slabs, the CLT was more expensive in terms of capital costs. However, once we realised that the product does not require block wall infills, or plasterboard linings, or additional fireproofing, then that gap in cost narrowed quite significantly.

We would have preferred to use a CLT product that was sourced locally from a Scottish supplier, but that option was not available to us. The only companies we could source the CLT from at the time were located in Spain, Austria and Germany. The reason we chose Egoin, a company from Spain, was because their UK rep at the time lived in Edinburgh and had been very helpful during the initial design stages. We also did a price comparison with the other manufacturers, and Egoin were competitive in that regard, so we selected them on that basis.

In choosing an offsite construction method, we were also faced with logistical challenges in terms of site delivery, offloading and road closures. We had to apply for a road closure permit to enable us to construct the CLT frame, which took about 6-8 weeks to be approved, so we had to be well organised in terms of co-ordinating transportation to site. The street itself is fairly narrow, but the process was well managed by Egoin.

In drawing upon your experience of the Portobello project, what are the main benefits of offsite construction?

Speed of construction was a big advantage. We took about 2 months out of the programme using CLT compared to conventional construction methods. Effectively you have one product, CLT, doing multiple jobs. It's replacing the steel frame, concrete slabs, blockwork walls, fireproofing of steelworks and plasterboard linings. In using CLT, we eliminated the need for all these different trades, speeding up the construction process. In our project, we went for ground floor slab to working on the roof in two weeks.

The homes are also extremely energy efficient, to the extent that there is no requirement for central heating. The building is extremely well insulated and meets Passivhaus standards, so energy costs for residents are low.
Another benefit of using offsite construction was the reduction in construction waste. Compared to conventional forms of construction, there was very little waste as essentially the building arrives to site in kit form.

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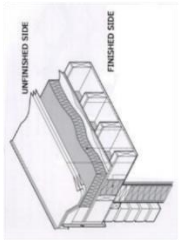
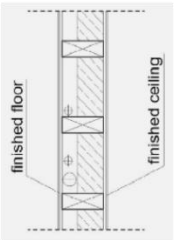
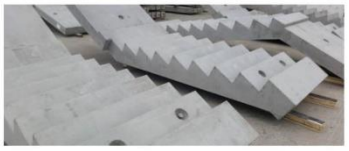
4.12. Definitions: Offsite projects

SUBCATEGORIES	CATEGORIES: 2-D Elements – Walls	2-D Elements – Floors	2-D Elements – Roofs	3-D Modules
0	Uninsulated open panels: with first skin on only one side (e.g. OSB on one side of timber panels). 	Uninsulated floor panels with decking only on one side and exposed joists/beams. 	Uninsulated open panels: with first skin on only one side (e.g. OSB on one side of timber panels). 	Uninsulated modules whose surfaces have first skin on only one side. 
1	Insulated open or closed panels without finished linings (e.g. SIPs). 	Insulated floor panels without finishes. 	Insulated open or closed panels without finished linings. 	Insulated modules without finished linings. 
2	Insulated closed panels finished on one side (either internally or externally). 	Insulated floor panels finished on one side (either upper or lower side). 	Insulated closed panels finished on one side (either internally or externally). 	Insulated modules with finished lining on one side (either internally or externally). 
3	Insulated closed panels fully finished internally and externally, with integration of services (i.e. with electrical and mechanical services, windows and doors). 	Insulated floor panels fully finished on the upper and lower sides, with integration of services (i.e. with electrical and mechanical services). 	Insulated closed panels fully finished internally and externally, with integration of services (i.e. with electrical and mechanical services, windows). 	Modules fully finished on all sides, with integrated services (i.e. with electrical and mechanical services, windows and doors). 

4.13. Definitions - Sub-assembly products

	TRUSSES	LINEAR ELEMENTS	STAIRS
TIMBER			
STEEL			
CONCRETE			

4.14. Definitions - Levels of automation

Definition of the levels of automation (Adapted from (Kotha, S, and Orne 1989) within (Frohm, J., Lindström, V., Stahre, J. and Winroth 2008)).

Production type	**Definition**	**Example in offsite manufacturing**
Manual	A human operator performs an operation manually with a minimum of tools. Component assembly using simple fixtures and hand tools would be an example.	Benches
Mechanisation	The operator employs mechanical assistance in performing an operation, as in the fabrication of parts using milling machines, lathes or presses.	Butterfly table
Semi-automation	A fixed program machine may employ pneumatic logic, mechanical sequencing or numerical control to execute a sequence of operations. No provision is made for exceptions to the normal process, and a human operator will typically be necessary to complete the task.	Framing station
Automation	Under programmable control, a machine may execute a sequence of operations and compensate for exceptions that may occur. A machine may be programmed to perform different tasks as well, without needing input from a human operator.	Robotic Arm

4.15 Workshop attendees

GOVERNMENT	**Scottish Government** Mark Turley Thomas Lennon Stephen Garvin Mairi Ross Grey Steven Paterson
LOCAL GOVERNMENT AND NDPB	**Scottish Enterprise** Margaret Watson **Highlands and Islands Enterprise** Dave Macleod **Scottish Futures Trust** Karen Campbell Paul Dodd Colin Proctor **Scotland Excel** Jennifer Bowles Graeme Sutherland
LOCAL COUNCILS	**Glasgow City Council** Michelle Mundie **West Dunbartonshire Council** John Kerr **Perth & Kinross Council** Campbell Hall **City of Edinburgh Council** Michelle Fraser **Angus Council** Andrea Wilson Jacky Adamson **Highland Council** Allan Maguire **Fife Council** David Weir
ACADEMICS	**Glasgow School of Art** Madeline Smith Paul Smith Vanessa Lang **Edinburgh Napier University** Robert Hairstans Mark Deakin
INNOVATION AND RESEARCH	**Construction Scotland Innovation Centre** Andrew Nurse Rohan Bush Lynsey Brydson Stephen Good Sam Hart Kaye Keenan **MTC/CIH** Ross Chipperfield **Aseptium** Pawel de Sternberd Stojalowski **Cast Consultancy** Mark Farmer
MANUFACTURING	**Donaldson Timber Engineering** Jonathan Fellingham **Scotframe** Philip Edwards **Carbon Dynamic Scotland** Matt Stevenson **Norscot Joinery Ltd** Ian Nicolson **BSW Timber Ltd** Oliver Stephen

CONSTRUCTION	**Stewart Milne Group** Alex Goodfellow **Robertson Group** Clare Reid Nicola Jackson **CCG** Calum Murray
ARCHITECURE AND DESIGN	**MAST architects** Michael Jarvis **HTA Design Consultancy** Mark Ackerley **Smith Scott Mullan** Eugene Mullan **4c Engineering Company** Peter Macdonald **MAKAR** Neil Sutherland
HOUSING ASSOCIATIONS	**Berwickshire Housing Association** Angela Taylor **Albyn Housing Association** Helen Cameron **SFHA** Sarah Boyack Lorna Wilson **Highland Housing Alliance** Gail Matheson **Port of Leith Housing Association** Gordon Cameron **Eildon Housing Association** John Duncun **Wheatley Group** Gordon Barbour **Places for People** Neil Ross Ben Dyer
REPRESENTATIVE BODIES	**ALACHO** Tony Cain **SFHA** Sarah Boyack Lorna Wilson
NGO	**Zero Waste Scotland** Clive Bowman Fiona Craig Nick Ribbons
CAMPAIGNING	**Build Offsite** Joe Dyde

4.16. Manifesto

In the first stakeholder workshop participants shared their ambitions for OSC in Scotland, which was summarised as an offsite “Manifesto”.

Why increase OSC in housing?

- For new business opportunities;
- To grow existing businesses and create new ones;
- To meet the future market demand;
- To create safe, compliant buildings that work;
- Because it’s efficient;
- For improved quality of homes and buildings;
- To make it part of the norm;
- For the improvement of predictability;

- For the consistent standard;
- To capture the benefit for the clients and the users;
- For the whole life cost improvement;
- To build houses that are built for a longer life and allow longer lending;
- To create a good place to live and to create a community;
- To build houses that are better than now;
- To hit the house building targets;
- To build customised houses;
- To future proof the industry in terms of technology and performance;
- For the ambition to continue to innovate and grow offsite potential;
- To help balance cost, quality, and demand for affordable housing;
- To mitigate the challenges of rural.

What will it take?

- A change in the culture and understanding of the industry;
- A better understanding of other drivers and opportunities for collaboration;
- More support for businesses to engage and take forward opportunity;
- Financial and funding models that are supportive of the process;
- Shaping demand;
- Addressing skills shortages, demographic and diversification;
- Seamless information flow;
- Implementation of digital tools;
- Evidence of benefit of offsite to help inform decision makers;
- An understanding of whole life costs;
- Ensuring the regulatory environment works seamlessly with the process.

4.17. The Eleven Challenges

Pipeline for Investment
To implement a long term strategic and collaborative initiative with a sector-wide approach to maintaining value and quality.

Skills
To create a sense of skills identity for current and future workforce to allow greater social awareness of OSC methods.

Immature Supply Chain
To adopt flexible construction methods whilst incentivising the value of procurement by maintaining an integrated supply chain.

Calculating the True Cost
To provide evidence of the true costs in the initial stages of the process along with a standardised method of costing to ensure a fairer distribution of costs with no compromise to quality.

Design for Future
To instil an evidence-based approach, as well as a user-focused design approach, to allow for collaborative and adaptable future outlooks.

Long Term Collaboration
To continually evaluate and maintain a consistent steam of information throughout the process to provide room for collaborative working and engagement.

Policy Drivers
To establish political involvement through collaborative working with government to create targets suitable to policy criteria in effect to strive towards financial incentives.

Quality
To develop a skills capacity which enables OSC methods with a combination of involving the user and engaging with a multitude of stakeholders to gain flexibility with consistent quality.

Procurement
To initiate procurement within the first stage of the process to create cross-departmental synergy and produce an integrated approach to maintaining budgets and the quality of capital cost.

Infrastructure and Logistics
To allow for easy access requirements and transport needs which provides systematic and sustainable sequencing through efficient collaboration, communication and project management

Geography
To maintain fair, and equal, geographic distribution of expertise and value of offsite which ensures an increasing proportion of productivity across the nation.

4.18. P.I.E.R. Review

Summary of group scoring

Group 1	Group 2
ensure procurement approaches include quality and whole life criteria (1) (2)	ensure early involvement of all actors (1) (3)
capture and share good practice case studies to communicate off-site benefits (2)	capture and share good practice case studies to communicate off-site benefits (2)
introduce incentives to stimulate the market and promote early adoption (4)	introduce incentives to stimulate the market and promote early adoption (2)
collate and publicly share life-time performance data (5)	collate and publicly share life-time performance data (2)
	ensure there is a long-term strategy and visibility of pipeline of investment (2)
	plan for new and incoming skills and capability development or future workforce (2)
	ensure procurement approaches include quality and whole life criteria (2)

The numbers are in relation to the actions Potential, Importance, Ease and Resources, then accumulated at the side as a result.

GROUP 1

Encourage collaboration for continuous improvement	
4 5 3 3	15
Ensure early involvement of all actors	
4 5 4 5	18
Involve users and the community to understand needs and desires	
2 1 5 4	12
Introduce incentives to stimulate the market and promote early adoption	
5 5 4 3	17
Adapt financial payment models to reflect shared risk	
5 5 2 4	16
Ensure there is a long-term strategy and visibility of pipeline of investment	
5 5 2 5	17
Develop and adapt current workforce for the new skills and roles that will be required	
3 4 3 4	14
Plan for new and incoming skills and capability development for future workforce	
5 5 4 3	17
Introduce a Scotland wide "Gold Standard" quality of build	
5 5 4 2	16
Explore routes to standardisation of components for off-site build without compromising flexibility	
5 5 2 3	15
Evidence the true cost for whole projects and whole life using off-site approaches	
4 5 3 4	16
Capture and share good practice case studies to communicate off-site benefits	
3 4 5 5	17
Ensure procurement approaches include quality and whole life criteria	
5 5 3 4	17
Explore the potential for optimising homegrown materials and supply	
5 5 3 2	15
Implement an open source build system	
5 2 1 3	11
Adapt the current planning process to the off-site approach	
5 5 3 3	16
Collate and publicly share life-time performance data	
5 5 3 4	17

Top performers group 1
Joint second total for 6 actions
[1] Ensure early involvement of all actors
[2] Introduce incentives to stimulate the market and promote early adoption
Ensure there is a long-term strategy and visibility of pipeline of investment
Plan for new and incoming skills and capability development for future workforce
Capture and share good practice case studies to communicate offsite benefits
Ensure procurement approaches include quality and whole life criteria
Collate and publicly share life-time performance data

GROUP 2

Encourage collaboration for continuous improvement	
4 4 3 4	15
Ensure early involvement of all actors	
4 4 4 4	16
Involve users and the community to understand needs and desires	
5 3 4 4	16
Introduce incentives to stimulate the market and promote early adoption	
5 4 4 2.5	15.5
Adapt financial payment models to reflect shared risk	
3 3 5 4	15
Ensure there is a long-term strategy and visibility of pipeline of investment	
5 5 1 3	14
Develop and adapt current workforce for the new skills and roles that will be required	
3 4 4 2	13
Plan for new and incoming skills and capability development for future workforce	
3 3.5 3 2	11.5
Introduce a Scotland wide "Gold Standard" quality of build	
5 4 4 2	15
Explore routes to standardisation of components for off-site build without compromising flexibility	
4 5 2 4	15
Evidence the true cost for whole projects and whole life using off-site approaches	
4 4 2 2	12
Capture and share good practice case studies to communicate off-site benefits	
4 5 4 4	17
Ensure procurement approaches include quality and whole life criteria	
5 5 4 4	18
Explore the potential for optimising homegrown materials and supply	
5 5 1 1	12

Implement an open source build system	
4 2 1 3	10
Adapt the current planning process to the off-site approach	
4 5 1 4	14
Collate and publicly share life-time performance data	
3 4 4 4	14

Top performers group 2
Joint positions were re-voted so won't correlate to highlighted score from 2nd onwards.

[1] Ensure procurement approaches include quality and whole life criteria
[2] Capture and share good practice case studies to communicate offsite benefits
[3] Ensure early involvement of all actors
[4] Introduce incentives to stimulate the market and promote early adoption
[5] Collate and publicly share life-time performance data

4.19. Innovation Actions

What follows are the detailed Innovation action plans for each of the five prioritised ideas selected through the P.I.E.R. review process. The action plans summarise what needs to be done in order to achieve the objectives for each innovation, including individual key actions, stakeholders who should, be involved and the potential challenges.

Innovation aim 1: Ensure procurement approaches include quality and whole life criteria

Collaborating efficiently across departments in hope to ensure consistent assessment of information will enable procurement approaches to develop a whole project and whole life cost model. In order to pursue this approach evidence of the true cost is required in the initial stages of the briefing process along with a standardised method of costing to produce a fairer distribution of costs with no compromise on quality.

Objectives:
[1] Collaboration across departments to ensure consistent assessment
[2] Use whole project and whole life costs

Actions:
[1] Define and establish a standard of quality and whole life criteria

Summary: the need to define and establish a high standard of quality and whole life criteria for building development teams and maintenance teams is an important stage in certifying collaborative working. With procurement teams involved and the influence of other sector involvement, an accumulation of information could be collected as an evidence base to support appropriate decision-making within offsite. With a definitive idea and greater clarity and agreement on what quality and whole life criteria means, these decisions could be the platform to instilling a higher degree of quality and efficiency in cost for offsite construction.
Who needs to be involved: procurement, building and maintenance teams, local authorities, housing associations.

[2] Structure and measure an incentivised process

Summary: create and use a specifically defined construction handbook which is methodical and structured in its approach to act as a guidance to measure the offsite process and value. Mandating this handbook across the industry could bring upon incentives to ensure consistent, high quality actions take place, as well as further educate actors of the standard and quality that should be maintained for offsite. Using the connections within the Scottish Government projects teams will allow for accurate data to be collected and collated as content for the handbook. Doing so will warrant trust.
Who needs to be involved: Scottish Government, procurement teams, suppliers, SME's.

[3] Develop a new business model

Summary: the education and awareness of procurement, building and finance teams could be developed if an appropriate weighting model was in place. This model would need to work to both extremes of the scale, very small and very large geographies and contexts, in order for it to be used effectively as a standard of quality and whole life criteria.
Who needs to be involved: Scottish Government, procurement, building and finance teams.

Challenges:
Key challenges will be: avoiding perverse outcomes which include 'box ticking' exercises for offsite.

Low support and use of various tools and technologies involving the generation and management of digital representations of physical and functional characteristics of places.

Finance models currently used are based on low up-front high life-time costs, which could create financial tension if they were switched without educating the process and benefits.

Innovation aim 2: Ensure early involvement of all actors

Continually maintaining a collaborative working environment at the beginning of the offsite process will ensure cross-departmental synergy and will therefore aid the process of moving towards a more integrated approach to procurement, design and delivery. In doing so it should benefit project budgets and sustain a high degree of quality in capital cost, whilst minimising the need for redesign and rework. This commitment and method of engagement within the primary stages of the process enables a stronger, greater visibility of pipeline for investment as well as a positive outlook on the criteria required to design affordable and adaptable, high quality homes for the future.

Objectives:
[1] Maintain a collaborative working environment for contractors, manufacturers and architects
[2] Include procurement at initial start of the process
[3] Foster a growing, skilled workforce
[4] Efficiently manage constraints in areas such as land ownership by effective communication and planning

Actions:
[1] Outline the vision for the client

Summary: working to a defined project scope and brief is essential to engage all actors effectively. Maintaining an up-to-date knowledge of the skill set required for offsite, and a sense of land ownership policies, at the beginning of the process is indispensable. By involving and engaging with all actors in the initial stages of the project ensures greater efficiency in both time and cost.
Who needs to be involved: clients, contractors, manufacturers, local authorities, design-led team.

[2] Create a transparent process to show target cost, value and risks

Summary: providing a transparent outline from the off-set which details the costs, the value each topic area brings and the potentials risks involved allows for a greater understanding and acceptance to each of the partners involved. Sharing this information to all actors at the beginning of the process creates a support network whilst increasing the knowledge and acceptability of the supply chain. Making these details comprehensive and easily accessible will provide a useful tool to make informed decisions and be efficient with time management.
Who needs to be involved: clients, contractors, manufacturers.

Challenges:
Key challenges will be: unwillingness of actors to collaborate effectively, notwithstanding factors such as lack of confidence and trust in the capability and performance of associated partners, as well as other work responsibilities and commitments.

This approach to working could elude to the idea of increased costs being occurred and bring forward the issues and time constraints of statutory approvals and barriers in procurement.

Innovation aim 3: Capture and share good practice case studies to communicate offsite benefits

Pulling together information from case studies has the potential to significantly improve the understanding of offsite for all actors involved. Communicating effectively could change, as well as improve, the attitudes and behaviours in favour of offsite. Case studies detailing the benefits and requirements for investing collaboratively long term, will identify a wider measure of quality and performance through the methods of offsite. Capacity for investment. Investment is required to maintain open source data that produces predictive and real-time information.

Objectives:
[1] Create a value of performance
[2] Support the value of collaborative approaches
[3] Disseminate to advocate for offsite

Actions:
[1] Adopt new build performance and quality measurements tools

Summary: a more in-depth scope of both technical data and customer research is necessary to be collated and collected in order to implement a better value of performance and quality for offsite. Currently, there are assets already available that

were created by the Scottish Government, however feedback suggests these resources are not easily accessible. Enforcing a real-time data mechanism which highlights topics such as offsite energy saving, will stimulate interest from users and better communication of the benefits offsite brings to the housing process.
Who needs to be involved: Scottish Government, Scotland's housing network and associations, local authorities.

[2] Extend the SFHA online presence

Summary: updating the SFHA website to include valuable and informative resources such as: offsite case studies, blogs, contacts and useful links; will help broaden the knowledge of offsite and encourage engagement. To make these resources known, promotion through social media channels and bulletins could be the starting link to marketing the material. The content curated would need to be agreed on as standard then effectively managed within existing resources.
Who needs to be involved: Scottish Government, CSIC, housing associations – Future Thinking Leads, local authorities, developers.

Challenges:
Key challenges will be: resolving any IT issues that occur through reporting and analysis.

Changing the perceptions of stakeholders associated with local authorities and housing associations to persevere within an adaptive environment.

Making the resources which deem useful to the public accessible not only to SFHA members.

Innovation aim 4: Introduce incentives to stimulate the market and promote early adoption

Long term strategies with collaboration from actors as well as political involvement is necessary in order to gather and update resources, secure commitment to projects and acquire funding through innovation partnerships. Using incentives as a grant mechanism to encourage early adoption will in turn create value. This value is gained from testing as pilot to produce critical feedback.

Objectives:
[1] Include incentives for pilots
[2] Introduce a wider value of building performance certificates
[3] Enhance grants support

Actions:
[1] Agree a collective strategic approach

Summary: if all key partners are addressing their investments in a long term, strategic way which encourages partnership, this will help build consistency across the country. The strategy could be supported from UK collaboration funding through innovation partnerships which run multi-year. This long-term collaborative approach would bring the confidence needed to the market.
Who needs to be involved: local authorities, councillors, manufacturers, political bodies, RSLs, UK funders and Building Scotland Fund.

[2] Generate additional programme resources

Summary: funding from the Scottish Government could play a crucial role in generating important material for the Affordable Housing Supply Programme. Doing so will develop meaningful and measurable data, influencing pilots for offsite.
Who needs to be involved: Scottish Government.

[3] Maintain collaborative commitment

Summary: increasing the percentage of programme to offsite on a multi-year basis will stimulate the market and provide a better indication of what is required to make offsite successful. Spending the time and resources demonstrates a commitment to the project and in turn will build confidence in actors involved.
Who needs to be involved: Scottish Government, TMDF authorities, councillors, RSLs and local authorities.

Challenges:
Key challenges will be: the dearth of consistency across local authority boundaries could undermine the purpose of carrying out a strategy to entice early adoption.

The complications involved in bids for funding and procurement.

The potential risk to the profile of RSLs, councils and manufacturers. The risk including unsupported or endorsed actions.

There is a lack of visibility in the industry which can cause difficulties in the required changes in behaviour. It's also political supports, long term, of this approach is also needed. This can lead to low support and guidance from bodies such as the Scottish Government, it is not prioritised sufficiently.

Budget uncertainty can straddle the commitment and agreement to long-term policy resources and actions.

Innovation aim 5: Collate and publicly share life-time performance data

Collating and making available life time building performance data will help the industry to understand the true cost of offsite construction, help to shape the attitudes and perceptions of offsite construction, and support continuous improvement and innovation in the design, production process, and maintenance of housing. It could also play a role in creating customer demand by providing open information that buyers can use to base their purchasing decisions on. Public information could also impact on type and availability of mortgage lenders' products.

Objectives:
[1] Include information about building performance
[2] Enable flexibility in mortgage options
[3] Develop future running costs models
[4] Raise awareness of the benefits for the home owner
[5] Maintain building information management

Actions:
[1] Define what building performance should include

Summary: include a ‘circular’ performance report for homes that accounts for carbon rating, material waste, adaptability of building, re-use potential, health of materials; illustrate the whole life value and whole life cost benefits of the asset; and development meaningful and measurable metrics using evidence-based research.

Who needs to be involved: Zero Waste Scotland, Scottish Government, public sector housing associations.

[2] Engage users

Summary: engaging with customers to understand their values and their motivations when choosing a place to live; speaking with people already living in offsite constructed housing to understand their experiences.
Who needs to be involved: home owners, housing residents, research institutions, mortgage companies.

[3] Measure and monitor
Summary: the ongoing measuring and monitoring of new building performance metrics is a critical action for the success of this innovation. The key will be developing new user-friendly systems for collecting and presenting data, for example material health ratings, also developing and selecting appropriate technology led or human led solutions performance monitoring.
Who needs to be involved: researchers, private technology companies.

Challenges:
Key challenges will be: understanding the main driver for publicly available data, and finding who will be motivated to own the action and take it forward.