Research Note on Offsite Construction

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Executive Summary

Offsite construction is a specialised segment of industrialised construction where components are manufactured in a factory and then assembled on-site. Known for streamlining the construction process, offsite methods – including modular and prefabricated approaches – are gaining traction in the EU construction sector due to their potential to reduce costs, increase productivity, and deliver environmental and social benefits. However, realising these benefits requires significant economies of scale. These can be supported through measures such as stimulating demand, enhancing standardisation, and investing in training to address skills shortages.

In terms of its economic benefits, offsite construction may lower costs through increased productivity due to manufacturing processes and reduced on-site labour requirements. The controlled environment of factories enhances quality control and minimises errors, significantly reducing rework and – according to existing estimates – cutting construction time by up to 20-60% relative to traditional construction methods.[1] Standardised processes may further drive cost savings by enabling economies of scale, although achieving this benefit relies on widespread adoption. According to a study by McKinsey, modular construction can also cut costs by 20% in the right environment [2], demonstrating its potential economic benefits.

Offsite construction can also offer significant environmental advantages, including lower life cycle emissions, reduced waste, more efficient use of materials, and a higher rate of material reuse. Research suggest that increasing the use of offsite construction methods can lead to a 10-15% reduction in construction waste during the production and manufacturing phases. [44] Additionally, prefabricated units can be disassembled and reconfigured for repurposing at the end of their life cycle, further enhancing sustainability benefits.

The potential for accelerated construction timelines that is achievable through the use of offsite methods make it a viable approach to meet construction demands across the EU, particularly in Member States facing housing shortages. Examples from Ireland and Sweden demonstrate how offsite construction can efficiently address affordable housing needs. Offsite construction is generally less labour-intensive and safer than traditional on-site methods, [3] making it an attractive alternative from both a labour efficiency and a safety perspective. Beyond housing, offsite methods have also been successfully applied to other sectors, such as healthcare, where modular hospital units were rapidly deployed during the COVID-19 pandemic in countries like the UK [4] and Italy [5].

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1 According to research conducted by EY in 2021 under Project Ireland 2040 and the work of the Construction Sector Group's (CSG) Innovation and Digital Adoption Sub-Group. See: NESC Boosting Ireland's Housing Supply: Modern Methods of Construction Council Report (2024), available at the following link.

2 McKinsey & Company (2019). Modular construction: From projects to products. Available at the following link: https://www.mckinsey.com/~/media/mckinsey/business%20functions/operations/our%20insights/modular%20construction%20from%20projects%20to%20products%20new/modular-construction-from-projects-to-products-full-report-new.pdf

3 Ahn, S., Crouch, L., Kim, T. W., & Rameezdeen, R. (2020). Comparison of worker safety risks between onsite and offsite construction methods: A site management perspective. *Journal of construction engineering and management*, *146*(9), 05020010.

4 Autodesk. (2021, October 20). 3 examples of modular and prefab hospitals constructed to fight COVID-19. Retrieved from https://www.autodesk.com/design-make/articles/modular-hospitals?utm_source=chatgpt.com

5 ArchDaily. (2020, April 22). *Carlo Ratti's first intensive care pod installed at a temporary hospital in Turin*. Retrieved from https://www.archdaily.com/938074/carlo-rattis-first-intensive-care-pod-installed-at-a-temporary-hospital-in-turin-italy?utm_source=chatgpt.com

Similarly, prefabrication has been widely used in infrastructure projects, such as highways, bridges and rail systems, offering precision and speed in construction. [6, 7, 8, 9]

Despite its benefits, offsite construction faces multiple challenges that hinder its widespread adoption in the EU, with one of the most pressing being the **skills gap**, compounded by existing labour shortages. Bridging this gap requires a skills shift from traditional on-site methods to industrialised processes, such as modular assembly and digital design – using tools like Building Information Modelling (BIM), and addressing the need for specialised roles like integrated designers and offsite construction project managers. In the short term, skills certification programmes and simplified assembly methods can make offsite work more accessible, while long-term efforts should focus on targeted education and apprenticeships to attract new talent, including women and young workers. Collaboration between governments, industry practitioners, and educational institutions is essential. Vocational training and partnerships with universities can equip workers with critical technical and digital skills. Promoting safer, predictable factory-based environments and aligning construction careers with sustainability goals can further attract younger generations. Sweden's success in integrating factory-based roles into mainstream construction demonstrates how strategic workforce development can support offsite construction's growth while enhancing efficiency and quality.

Secondly, the **lack of a harmonised regulatory environment** creates distinct challenges to the uptake of offsite construction. At the EU level, Member States each maintain different building codes and standards, which restricts the scalability of offsite methods across borders. Enhanced harmonisation is essential to maximise the benefits of offsite construction by simplifying cross-border collaboration, reducing delays caused by local regulatory discrepancies, and allowing suppliers to operate within a predictable framework. A cohesive EU market for offsite construction would streamline trade in prefabricated components and help reduce costs. This, however, requires greater regulatory alignment.

To address these issues, the updated European Construction Products Regulation (CPR) is poised to strengthen the single market for construction products by addressing some key standardisation needs. At the national level, some countries like Sweden have adopted cohesive national regulations that facilitate offsite adoption. However, in many other Member States regulatory fragmentation persists, with building codes primarily designed for conventional construction, without considering offsite construction. This lack of alignment complicates compliance for offsite methods and increases costs, further limiting their scalability.

Offsite construction also necessitates an **integrated approach** among architects, manufacturers, and contractors from the design phase through to assembly. Misalignments in the value chain – scheduling conflicts, design-production mismatches, or logistical inefficiencies – can lead to costly delays and inefficiencies. Greater collaboration and early stakeholder involvement are key to addressing these challenges, while improved coordination tools and standardisation can help streamline processes, enhance compatibility, and reduce complexity across the supply chain.

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6 Grimshaw. (n.d.). *London Bridge Station redevelopment case study*. Retrieved from https://grimshaw.global/sustainability/london-bridge-case-study/

7 McDonald, N., Carter, C., & Abu-Hawash, A. (2016). *Modular steel superstructures for accelerated bridge construction: Iowa DOT case studies*. Retrieved from https://www.aisc.org/globalassets/nsba/conference-proceedings/2016/mcdonald---2016-wsbs-final.pdf

8 Pradhananga, P., ElZomor, M., & Gada, G. M. (2023). Investigating the impact of alternative technical concepts for project delivery of accelerated bridge construction. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *15*(2), 04522059.

9 Tezel, A., & Koskela, L. (2023). Off-site construction in highways projects: management, technical, and technology perspectives from the United Kingdom. *Construction Management and Economics*, *41*(6), 475-499.

Another significant challenge to offsite construction is its **financing model**, which requires substantial upfront investment in manufacturing facilities, which can be a barrier, particularly for smaller firms. Conventional financing models for construction projects do not always align with the needs of offsite construction, which often requires larger initial capital for factories, specialised equipment, and stable and predictable demand. For example, in Spain, the limited adoption of offsite methods is partially attributed to restricted access to bank financing under existing regulations. Increased government support through tax incentives – as seen in Ireland – or targeted public procurement, can help lower these financial barriers, making offsite construction more accessible. Addressing this challenge will require enhanced financial support mechanisms tailored to the needs of offsite construction. Government interventions, such as tax incentives – like those implemented in Ireland – can help reduce financial barriers and foster growth in the sector. Public procurement, particularly in the affordable housing sector, can support other measures in creating a more sustained demand – as seen in Germany and Australia – where government-backed prefabricated housing initiatives have encouraged offsite adoption, while Ireland has been investigating the potential for 'pre-manufactured value' to be evaluated in public tenders for housing. [10] Additionally, by integrating design quality, durability, and environmental impact into procurement criteria, governments can stimulate investment in higher-quality offsite construction. This, combined with fiscal measures like tax reliefs to offset the cost of building offsite facilities, could play a role in making offsite construction more viable and accessible across the EU.

Finally, offsite construction continues to face **cultural resistance**, with many stakeholders – including consumers and industry professionals – remaining sceptical about prefabrication's reliability, quality, and design flexibility. These perceptions persist despite significant advancements in materials and techniques that ensure durability, sustainability, and adaptability to diverse design needs. Highlighting successful projects can effectively challenge these misconceptions. Additionally, targeted training programmes for design professionals and real-world demonstrations can play a pivotal role in shifting attitudes, fostering acceptance of offsite methods, and motivating a much-needed new generation of workers to enter the offsite construction market.

Overall, offsite construction holds significant potential to modernise the EU construction sector, offering effective solutions to pressing challenges in housing and infrastructure. Realising this potential will require achieving economies of scale across the EU. Drawing inspiration from successful national approaches – such as those highlighted in the case studies below – can guide the development of targeted interventions to address key challenges and foster an enabling environment for offsite construction to thrive.

[10] Government of Ireland (2024): Roadmap for increased adoption of Modern Methods of Construction (MMC) in Public Housing Delivery. Available at https://www.gov.ie/en/publication/f0cd6-housing-for-all-innovation-and-productivity/#roadmap-for-increased-adoption-of-modern-methods-of-construction-mmc-in-public-housing-delivery

1 Introduction

1.1 Research objectives and scope

This short research paper provides an assessment of industrialised construction methods and techniques used in off-site construction, and their potential impact in the EU construction sector. In what follows, we provide an overview of the current state of play in industrialised construction methods in the EU, including its potential benefits and challenges. We draw evidence from policies and developments in a selection of EU Member States who are at the forefront in off-site construction. We will also look at policies and developments in third countries, where relevant, to draw lessons and comparisons.

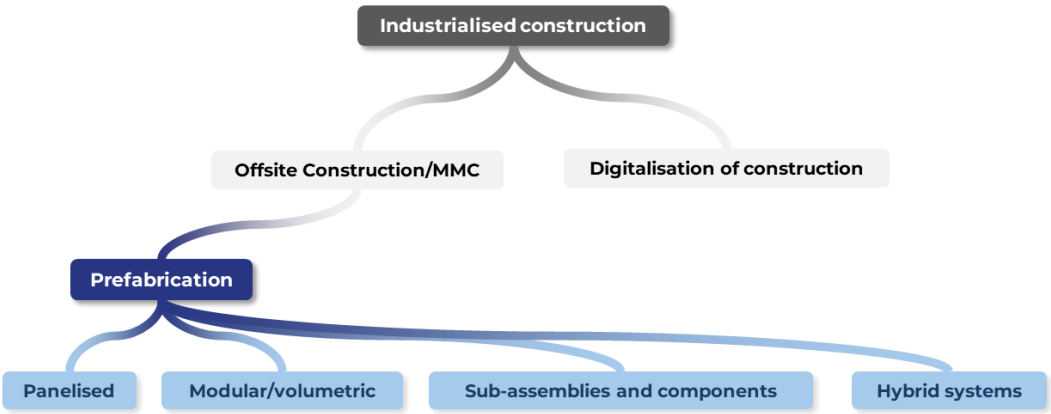
Our findings are based on a combination of desk research and targeted interviews with stakeholders in the construction industry, including members of industry associations; public bodies; and construction firms.

1.2 Defining and contextualising offsite construction

The term industrialised construction refers to an overarching construction approach which aims to integrate increased elements of automation and mechanisation into construction processes. The term describes an industry wide shift in focus from traditional, labour-intensive, methods to a more standardised production process, focusing on product based, rather than project based construction.

This includes not only the shift from on site to factory settings, but also the increased use of technologies, digitalisation, standardisation, automation, and the integration of processes into construction operations such as health and safety processes, and quality control procedures. Over the years, the term “industrialisation of construction” has become broader to encompass further aspects of digitalisation and changes in industrial approaches. Today, the industrialisation of construction goes deeper than mere automation and standardisation, as it also touches upon different aspects of its digitalisation.

Figure 1. Placing offsite construction in context



Source: Own elaboration.

In this context, the term **Modern Methods of Construction (MMC)** refers to a subset of industrialised construction. MMC is also used as an umbrella term covering all methods that depart from conventional construction processes. In general, MMC is used to describe construction that takes place offsite, typically in a factory, as opposed to traditional on-site construction. **The term offsite construction is used by many as interchangeable with MMC**.[11]

Offsite construction encompasses all production processes that are not "on site". It typically refers to the process of manufacturing and pre-assembling construction components in a factory setting, which are assembled on-site. The idea of offsite construction is to deliver construction elements or units to the construction site at an advanced state, ranging from completed individual units or building elements to full modular construction units produced in a factory setting. This process is called prefabrication and is a specific method within offsite construction. Prefabrication is thus a method within offsite construction, and whilst the concept of has been around since the industrial revolution, the large-scale implementation of prefabrication has only developed recently and is growing.

Prefabrication includes the construction of panellised and volumetric (3D) units or models produced in the factory to then transported to the construction site and integrated with the rest of the building. Such building units can include 3D components such as complete bedrooms, bathrooms and kitchens, as well as flat units or panels used to make walls, floors and roofs. Building models may then be assembled on-site, sometimes even stacked on site to form multi-story buildings.[12] The process of off-site construction removes a much of the activity from the construction site, increasing safety and making the construction site activity, organisation and efficiency.

Prefabricated components are not only used for new buildings but also in renovation projects, where components or even complete modular units can be used to retrofit existing buildings. Further, the use of prefabricated methods has the potential to accelerate the speed of renovations, decrease the risk and increase the efficiency and effectiveness of the renovation project.

There are four main categories of prefabricated construction: panelised systems, modular or volumetric systems, sub-assemblies and components, and hybrid systems (which combine different categories).[13] 3D modular construction therefore goes a step further than panelised components and creates complete sections of or even entire building modules off site.

Finally, the **digitalisation** of construction is related to the industrialisation of construction and focuses on the application of advanced technologies for increased automation and mechanisation processes. Digitalised construction and industrialised construction are not the same, but are highly connected as digitalisation further enables industrialisation, and industrialisation also further drives digitalisation. Both the digitalisation of construction and the industrialisation of construction enable further offsite construction and pre-fabrication methods.

Certain advanced technologies such as 3D printing, robotics and automation systems have gained traction in construction and are able to create complex and customised building components offsite. Whilst these individual technologies are outside the scope of this paper, they are important to mention as they contribute to efficiency and productivity gains within offsite construction.

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11 CIOB. 2024. Modern methods of construction: barriers and benefits for Irish housing, available at the following https://www.ciob.org/industry/policy-research/MMC-Ireland

12 Property Industry Ireland. 2021. Innovation increasing supply - How offsite construction can help address the housing crisis. Available at https://www.ibec.ie/-/media/documents/media-press-release/property-industry-ireland---off-site-construction-report.pdf.

13 Deakin. M, et al. 2020. Increasing Offsite Housing Construction in Scotland: An evidence base to support new policy and systems. Available at https://radar.gsa.ac.uk/7283/1/OFFSITE%20PROJECT%20-%20FINAL%20REPORT%2014-01-2020.pdf.

2 Offsite construction: context and history

2.1 General overview

Over the past decade, the construction sector faced increasing political, economic, social, and environmental challenges, including the rising cost of materials, escalating housing prices, labour shortages, and increased sustainability demands. Offsite construction methods – such as prefabrication and modularisation – are often highlighted for their potential to increase efficiency, quality and sustainability, whilst managing costs. However, despite these potential benefits, industrialised construction methods remain a small segment of the broader construction industry. Their adoption has struggled to scale up in the European market due to a range of barriers, and understanding these obstacles is crucial to unlocking their potential.

Europe's construction industry, particularly within the housing sector, is grappling with substantial challenges. The demand for high quality buildings, including renovations, and affordable housing has increased significantly. However, this demand has struggled to be met with an increased supply, leading to housing shortages or inadequate housing across the Union. [14] Additionally, the current rate of renovation needs to increase to meet EU climate and energy targets. For instance, under the Renovation Wave Strategy, the EU aims to renovate 35 million buildings by 2030, and at least double the annual rate of energy renovations in the EU. [15]

While offsite construction remains a niche part of the industry, it is gradually gaining traction in some European countries – particularly in countries such as Sweden, Finland, Ireland, and, to a lesser extent, the UK. **Nordic countries are at the forefront, with Sweden constructing over 90% of its one- to two family housing units using prefabrication methods**. Further, in Ireland, offsite construction and the process of prefabrication has gained popularity and is being implemented as a response to housing shortages.

Member States such as Austria, Germany and Switzerland are focusing on increasing use of **modular wooden elements for houses due to its perceived environmental benefits** and contribution to achieving climate protection goals. [16] However, off site construction remains less widespread compared to conventional construction methods in many other Member States. For instance, **in Spain, only 1% of single-family homes are built using industrialised systems.** [17]

Housing and construction are primarily a competence of the Member States, with national laws governing housing construction and housing regulations. However, EU legislation, such as the **Construction Products Regulation (CPR)**, and the **Energy Performance of Buildings Directive (EPBD)**, have set a European framework that harmonises and standardises certain requirements across the EU, including product standards, performance criteria, environmental performance, and energy efficiency standards. Despite this overarching EU framework, offsite constructions and prefabricated modular homes must comply with national or regional building regulations, building

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[14] See, for instance, Frayne, C. et al. 2022. Housing Market Developments in the Euro Area: Focus on Housing Affordability. Available at the following link.: https://economy-finance.ec.europa.eu/system/files/2022-09/dp171_en.pdf

[15] See European Commission '' Renovation Wave''. (2024). Available at the following link: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en

[16] See SDG21 (2020). Status report 2020 on timber construction in Germany published. Available at the following link: https://sdg21.eu/en/blog/situation-report-2020-on-timber-construction-in-germany-rails

[17] European Building Summit Barcelona (2023). Available at the following link: https://europeanbuildingsummit.com/en/26971/

codes, and spatial planning rules. As a result, manufacturers face differing rules and compliance standards across European Member States.
The affordability and availability of housing have become increasingly challenging across the EU, with housing prices rising an average 48% between 2015 and 2023. [18] This surge is mainly due to higher building costs and a decrease in construction that has limited supply. In response, European Commission president Ursula von der Leyen announced housing as one of the EU's main priorities for the current 2024-2029 mandate, pledging to develop a European Affordable Housing Plan to help tackle the crisis. Furthermore, as of autumn 2024, the EU has its first EU commissioner with direct responsibility for housing.

The 2024-2029 mandate includes several initiatives aimed at improving the EU's housing stock. These include the new **European Bauhaus initiative**, which aims to foster solutions for the built environment through stakeholder engagement and provides tools and guidance. Further, the Commission will allocate funding from the Cohesion Fund to affordable housing, aiming to set up an EU-wide investment platform in coordination with the European Investment Bank to further stimulate investment. [19] Overall, offsite construction and prefabrication methods are expected to be an integral part of Europe's future housing strategy; potentially, they may play an increasingly important role in meeting future housing demands efficiently and sustainably.

2.2 Historical overview and lessons learned

The industrialisation of construction is not a new concept. It first emerged during the industrial revolution, when production processes first began to become more mechanised. This period saw the initial use of prefabrication in construction, particularly in the UK, where many buildings from this time were built using prefabricated components. The idea of prefabrication steadily grew and by the early 20th century, it became more popular, especially in the United States, where wooden kit houses – packages containing all the necessary components for on-site assembly – began to gain traction. [20]

In the aftermath of World War II, industrialised construction gained significant momentum due to the urgent need for rapid reconstruction of housing and infrastructure. Many countries turned to prefabrication as a practical solution to address housing shortages. The rise of the welfare state in the Western world further fuelled the demand for public housing, leading to a boom in the construction of prefabricated units. Their standardised nature made them ideal for mass production, enabling quick and cost-effective housing solutions. Additionally, these prefabricated units aligned with the period's ethos of fostering a "collective nature" among people by promoting uniformity and community-oriented living spaces. [21] One prominent example are the **Plattenbau** housing blocks built in Eastern Europe, which used three-dimensional modules and prefabricated concrete panels. Mass residential complexes were built in a very short timespan and developed into entire neighbourhoods of identical repeated housing blocks.

However, the challenges of centralised decision-making in Eastern European (post-)communist countries, including the Soviet Union, compounded the limitations of this approach. Bottlenecks in

[18] European Parliament (2024). Rising housing costs in the EU: the facts (infographics). Available at the following link: https://www.europarl.europa.eu/topics/en/article/20241014STO24542/rising-housing-costs-in-the-eu-the-facts-infographics

[19] European Commission (2024) Mission Letter from Ursula von der Leyen to Dan Jorgensen, Commissioner-designate for Energy and Housing. Pg. 7. Available at https://commission.europa.eu/document/download/1c203799-0137-482e-bd18-4f6813535986_en?filename=Mission%20letter%20-%20JORGENSEN.pdf.

[20] Buildoffsite: Historical milestones in industrialised construction. Available at https://buildoffsite.fundacionlaboral.org/what-is-industrialised-construction/

[21] Alazzaz, F., & Whyte, A. 2014. Uptake of off-site construction: benefit and future application. *International Journal of Civil and Environmental Engineering*, *8*(12), 1219-1223.

material supply and design approvals restricted the ability of local authorities to innovate or adapt central plans to the needs of specific communities. [22] While the method excelled at addressing the urgent need for housing by focusing on speed and quantity, it often came at the expense of quality.

The resulting urban structures were highly monotonous, lacking design variety, and were frequently criticised as "ugly" due to their uniform and utilitarian aesthetic. In Bratislava, for instance, residential buildings constructed from prefabricated panels housed over 100,000 people. [23] Similarly, in Czechoslovakia, mass-scale housing production relied on only around 20 different types of buildings. This limited variety contributed to the perception that these structures were uninspired and dehumanising, earning the nickname 'houses for rabbits', a term reflecting the public's view of their cramped and repetitive nature.

A similar approach was adopted in other parts of the world during the post-war period. In London, more than 156,000 prefabricated homes were built between 1945 and 1948.[24] While many of the prefabricated homes were intended as temporary solutions, they became long-term dwellings, with some still inhabited today. In the United States, the development of **Lustron houses** were a notable experiment in prefabrication. These steel homes, consisting of over 3,300 prefabricated parts, were designed to be assembled on-site in an average of 350 hours, or about two weeks. Despite the construction of thousands of Lustron homes in just two years, the company eventually went bankrupt, which highlighted the financial challenges associated with scaling such innovations. [25] Nevertheless, prefabrication still gained traction in the US during the 1950s, and by 1958, approximately 10% of new houses were prefabricated, reflecting the growing acceptance of this industrialised construction method. [26]

Overall, the post-war surge in industrialised construction demonstrated its potential to address society's needs for buildings in a cost-effective and efficient manner. However, it also revealed inherent limitations at that time, such as the **poor design and construction quality**, lack of **flexibility**, and the monotony of housing structures.

Today, the advancements in digital technologies within the construction sector offer potential to overcome some of these earlier limitations, including the lack of individuality often associated with standardisation. Modern digital tools can facilitate customisation and enhance design flexibility, allowing the use of diverse materials without compromising on design precision, efficiency, and sustainability considerations. However, despite these advancements, the large-scale adoption and implementation of these technologies remain limited.

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22 Malaia, K. 2020. A unit of homemaking: The prefabricated panel and domestic architecture in the late Soviet Union. Architectural Histories, Vol 8(1). Available at https://journal.eahn.org/article/id/7603/.

23 Magazine 2023. Bratislava's Panelaks Monoliths. Available at the following link : https://www.mmzoneblog.com/bratislava-s-panelaks-monoliths

24 "The century makers: 1945". The Telegraph. Telegraph Media Group. 2003-10-11. Archived from the original on 2012-03-08. Retrieved 2011-06-27.

25 See more details at https://savingplaces.org/stories/lustrons-building-an-american-dream-house.

26 Springer, John. 1958. "Ordering a house from the factory". Popular Science. Archived from the original on 16 June 2021. Retrieved 28 December 2019.

3 Potential benefits of offsite construction and prefabrication methods

The construction sector has an important role to play in meeting future societal and economic needs whilst also paving the way for a more sustainable future. With increased construction prices, property prices and higher demand, the construction sector must develop new innovative solutions and undergo systematic changes to meet supply at an affordable price. Industrialised, off-site construction methods have the potential to significantly improve construction processes in terms of cost, productivity, and sustainability. The potential benefits of offsite construction and prefabrication methods can be divided into economic, environmental and social benefits with the main benefits including enhanced productivity, lower cost, improved quality, decreased construction time, enhanced sustainability and safety. [27]

3.1 Economic benefits

Productivity and costs

The construction sector suffers from stagnated labour productivity, labour shortages and increasing costs. [28, 29] In the EU, productivity in construction is 30% lower than for manufacturing, and it showed the largest cumulative fall between Q4 2019 and Q1 2024 compared to other sectors.[30] Building costs for new residential buildings increased by 34% between 2018 and 2023, as higher material and labour costs were not offset by efficiency gains. Offsite construction methods have the potential to increase the productivity of construction.

Firstly, prefabrication methods make many processes standardised and reduce the complexity of the buildings, thereby making it easier and faster to build.[31] Second, factory conditions are more predictable than external conditions, meaning errors should be less likely to be made and the overall construction process is less prone to external influences such as the weather. This also means that, in theory, there should be less need for rework, thereby decreasing the chances of construction delays, although this may need to be evaluated in practice. Third, prefabrication allows on-site and offsite work to run simultaneously, thereby making it less dependent on the overall construction schedule or material deliveries. [32] **Offsite construction has the potential to achieve at 20-60% reduction in the average construction programme time**. [33]

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27 Y. Chen, et al. 2010. Sustainable performance criteria for construction method selection in concrete buildings. Automation in Construction. vol. 19, p.235-244.

28 McKinsey Global Institute. 2017. Re-inventing construction: a route to higher productivity. Available at https://www.mckinsey.com/~/media/mckinsey/business%20functions/operations/our%20insights/reinventing%20construction%20through%20a%20productivity%20revolution/mgi-reinventing-construction-a-route-to-higher-productivity-full-report.pdf.

29 See Eurostat (2024). Construction producer prices or costs, new residential buildings - quarterly data. Available at the following link: https://ec.europa.eu/eurostat/databrowser/view/STS_COPI_Q/default/line?lang=en

30 European Central Bank (2024) Recent country-specific and sectoral developments in labour productivity in the euro area. Available at https://www.ecb.europa.eu/press/economic-bulletin/focus/2024/html/ecb.ebbox202405_02~d69d7cac99.en.html.

31 See, for example, Cruz-Rios and Grau, 2020; and Gallego-Schmid et al., 2020.

32 Li, C.Z.; et al. 2016. Schedule risks in prefabrication housing production in Hong Kong: A social network analysis. *Journal of Cleaner Production*, Vol 136, 482–494

33 According to research conducted by EY in 2021 under Project Ireland 2040 and the work of the Construction Sector Group's (CSG) Innovation and Digital Adoption Sub-Group. See: NESC Boosting Ireland's Housing Supply: Modern Methods of Construction Council Report (2024), available at the following https://www.nesc.ie/publications/boosting-irelands-housing-supply-modern-methods-of-construction/#:~:text=It%20finds%20that%20greater%20adoption,both%20new%20and%20existing%20stock.

Not only do offsite construction methods benefit from increased productivity, but in theory, they also lead to cost savings across various domains. Firstly, cost savings can be achieved through time-related costs due to faster construction. Second, due to the automation and mechanisation of processes, units can be built with decreased on site labour, thereby saving on site labour costs as well as maintenance costs. [34] Cost savings could also be achieved through improved cost certainty and the reduction of material use. According to a study by McKinsey, modular construction can cut costs by 20% in the right environment. [35] Further, the same report states that modular construction has the potential to scale to an industry that represents more than 100 billion in US and European real estate, which would lead to $20 billion in annual savings. It is important to note however, that such savings are achieved under specific conditions and that cost savings in reality are far more nuanced. Therefore, while offsite construction is not necessarily current cheaper, it has the potential to be in the future.

3.2 Quality improvement

A further potential benefit of offsite construction is quality improvement. Due to standardisation and mechanisation, there are not only decreased chances for errors, but also tighter quality controls quality of the construction products. Tighter quality controls can ensure that products meet higher standards and precise fabrication techniques in a factory controlled environment also contribute to generally fewer defects and longer lasting products. As a result offsite construction requires less frequent maintenance, thereby also leading to long terms savings.

Additionally, due to the standardised construction approach, offsite construction also has the potential to continuously improve its products and quality output, something which cannot be done with unique onsite projects.[36] This is also because prefabricated products allow for specific modules or products to be traced back to the manufacturing source, leading to increased accountability within production and therefore increased quality assurance.

Ease of upgrades and renovations

Prefabrication methods, especially for modular elements, also significantly simplifies the process or upgrading or renovation buildings. Modules can be replaced, removed or reconfigured without replacing the entire building structure, and such an adaptability makes it easier to modernise building, repurpose spaces and integrate or add new elements or technologies. Further, standardised prefabricated components can also be designed in a way that allows for changes or compatibility with new systems or components in the future. These can be designed with a forward thinking approach to ensure that future upgrade are possible and would align with the existing structure of the building. This overall extends the lifespan of buildings, reduces the need for renovations and have overall productivity, cost and sustainability benefits.

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34 Sutrisna, M.; Cooper-Cooke, B.; Goulding, J.; Ezcan, V. Investigating the Cost of Offsite Construction Housing in Western Australia. Int. J. Hous. Mark. Anal. 2019, 12, 5–24.

35 McKinsey & Company (2019). Modular construction: From projects to products. Available at the following link: https://www.mckinsey.com/~/media/mckinsey/business%20functions/operations/our%20insights/modular%20construction%20from%20projects%20to%20products%20new/modular-construction-from-projects-to-products-full-report-new.pdf

36 Alazzaz, F., & Whyte, A. (2014). Uptake of off-site construction: benefit and future application. *International Journal of Civil and Environmental Engineering*, *8*(12), 1219-1223.

3.3 Environmental benefits

Lower carbon emissions

The construction sector currently accounts for around 38% of all energy related CO_2 emissions globally. [37] Offsite construction has the potential to lower life cycle emissions due to the overall reduction of energy used during the production and construction process. A study has found that, compared to conventional systems, prefabricated buildings reduce GHG emissions, energy use, resource scarcity, and damage to both health and the ecosystem. [38] However, the extent of the environmental impact varies depending on conditions and is difficult to quantity. GHG reduction is said to be achieved due to decreased transport and the use of less energy intensive machinery. . Further, prefabricated components can also be designed to include high-performance insulation and incorporate energy-efficient technologies such as solar panels, heat pumps, and advanced ventilation systems.

Finally, modern prefabricated homes may use products with low embodied carbon.[39]. Prefabricated elements made from timber can potentially contribute to carbon removals. The actual impact of timber buildings varies among studies and stakeholders, however one study found that a total CO_2-reduction of 18% could be achieved by 2030 if 50% of new residential construction is bio-based. [40] The question also remains if enough biobased material would be available for this. Hence, timber buildings can potentially largely contribute to achieving a lower carbon footprint, but opinions vary in this regard.

Reduction in construction waste, material savings, and waste recycling

The construction sector is also responsible for over 35% of the EU's total waste generation and generates roughly half of the demand for material extraction. Industrialised construction methods offer significant potential to reduce waste and shift to a circular economy. Research differs in the quantifying waste reduction with one paper stating that increasing material methods can lead to a 10-15% construction waste reduction in the production and manufacturing phases [41], whilst another report suggests that volumetric offsite construction systems could reduce waste on-site between 70 - 90% when compared to traditional construction. [42] This is because offsite construction methods have increased material efficiency, a higher rate of re-use of materials, and material requirements are calculated more accurately in a factory setting.

Further, by employing traceable standardised modular components, prefabricated units can be disassembled and reconfigured to be repurposed at the end of their life cycle, thereby increasing recycling rates in comparison to traditional methods of construction. [43] This also make offsite recycling cheaper than on-site recycling as it requires fewer bins, fewer trucks, lower transportation costs and less space. [44]

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37 UNEP. 2020. Building sector emissions hit record high, but low-carbon pandemic recovery can help transform sector – UN report. UN Environment Programme.

38 Rocha, P. F., Ferreira, N. O., Pimenta, F., & Pereira, N. B. (2022). Impacts of prefabrication in the building construction industry. *Encyclopedia*, *3*(1), 28-45.pp 34. Accessed here: https://www.mdpi.com/2673-8392/3/1/3

39 Kouhirostami, M., & Chini, A. R. (2022). Comparison of carbon emissions of modular and site-built residential construction. *Proc., of the 2022 Modular and Off-Site Construction Summit. Edmonton, AB: University of Alberta Libraries*.

40 See https://circulareconomy.europa.eu/platform/sites/default/files/2023-10/Impact%20scan%20for%20timber%20construction%20in%20Europe.pdf.

41 Lawson, R. M., Ogden, R. G., & Bergin, R. (2012). Application of modular construction in high-rise buildings. *Journal of architectural engineering*, *18*(2), 148-154. Accessed : https://ascelibrary.org/doi/abs/10.1061/(ASCE)AE.1943-5568.0000057

42 See https://www.howickltd.com/asset/327.pdf%20p.1.

43 EY (2021). Detailed description of needs for Irish construction/built environment sector, report, Ernst and Young

44 Waste Solutions USA. On-site vs. Off-site Sorting: Which Construction Waste Method Is Best? Available at https://www.wastesolutionsusa.com/on-site-vs-off-site-sorting-which-construction-waste-method-is-best/.

3.4 Social benefits

Improved safety **and societal impacts**

Construction work can be very labour intensive and working conditions are sometimes unpredictable and even dangerous. Whilst health and safety standards have increased significantly in the construction sector, a certain risk remains for workers on construction sites. Offsite construction and the increased use of digitalisation, standardisation and controlled environment in construction can make accidents and injuries less likely, hence offering a potentially safer working environment. This is especially due to the significantly fewer work-at-height tasks included in the offsite construction. [45] Offsite methodologies can be significantly safer and present fewer risks on the construction site. [46] Offsite construction also offers a general reduction in onsite working time, thereby reducing on-site safety hazards, as well as reducing noise and air pollution, for all surrounding citizens, as well as traffic delays. [47] Offsite construction therefore also has the potential to decrease negative societal impacts of construction.

Addressing skills and labour shortages

Construction is consistently ranked among the sectors facing the highest labour shortages in the EU, and the sector is expected to see further labour shortages in the future.[48] Less labour is required to construct a building through offsite methods, making it an attractive alternative to conventional methods from a labour perspective.[49] Further, the overall training that is required can be simpler for workers in offsite construction methods.[50] This is justified by the fact that the construction process is transferred from on-site to a factory setting, meaning workers mainly need to learn their role in the production line without necessarily understanding the diverse elements of onsite construction. In reality, any sector shift to offsite construction would be more complex than that, and some but not all on-site construction jobs would be transferred to a factory setting. Hence there will always be a need for work on site, although the nature of the work and the training required will change. Therefore, re-skilling and upskilling may be required in the form of a holistic skill shift across the industry.

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45 Ahn, S., Crouch, L., Kim, T. W., & Rameezdeen, R. (2020). Comparison of worker safety risks between onsite and offsite construction methods: A site management perspective. *Journal of construction engineering and management*, *146*(9), 05020010. Accessed by: https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29CO.1943-7862.0001890

46 Odo, N., & Rankin, J. (2022, November). Quantifying Safety in Off-site Construction. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1101, No. 4, p. 042018). Pp.10. IOP Publishing.

47 Modular Building Institute (2024). The Environmental Impact of Traditional vs. Modular Construction. Accessed by: https://www.modular.org/2021/07/14/the-environmental-impact-of-traditonal-vs-modular-construction/

48 European Employment Services (2024). There's no better time to pursue a career in the construction sector. Accessed here: https://eures.europa.eu/theres-no-better-time-pursue-career-construction-sector-2024-06-21_en

49 Jaillon, L. & Poon, C. S., 2008. Sustainable construction aspects of using prefabrication in dense urban environment: a Hong Kong case study. Construction Management and Economics, 26(9), pp. 953-966.

50 See https://constructiondigital.com/construction-projects/top-six-benefits-of-offsite-construction.

4 Current challenges to offsite construction

4.1 The skills gap

The transition to industrialised and offsite construction methods is likely to give rise to a significant skills challenge within the construction industry. Conventional construction workers are primarily trained in labour-intensive, on-site methods, which do not align with the expertise required for prefabrication, modular construction, and the use of advanced digital tools. Offsite construction relies on a combination of skilled factory workers, specialised installers, and digital designers, which represents a shift in the workforce and an evolving division of labour.[51] Addressing this challenge will require a mix of reskilling and upskilling initiatives, with recent research pointing more strongly towards upskilling – enhancing the technical and digital capabilities of the existing workforce, and ensuring they can adapt to the precision and efficiency demands of offsite construction methods.[52]

The construction industry already faces a shortage of workers for conventional methods of construction with labour demand projected to continue growing until 2035. An estimated 4.1 million people will be needed to replace the retiring workforce, [53] alongside an additional projected growth of an additional 90 thousand roles. However, the potential growth in labour demand for offsite construction remains unclear, particularly as the sector expands and requires specialised technical skills. This challenge is further compounded by declining interest in construction careers among younger generations, underscoring the urgent need for targeted workforce development and upskilling initiatives.

To overcome this, immediate and long-term solutions are needed. In the short term, **certification programmes** can be introduced to **standardise skills across the workforce**, focusing on areas such as modular assembly, prefabrication, and BIM. Certification ensures that workers are proficient in specific tasks, improving the reliability and quality of modular projects. Another short-term solution is the **simplification of processes, or "IKEA-isation"**. By breaking complex tasks into simple, intuitive steps, such as using color-coded components or visual assembly guides, workers with limited technical expertise can more easily complete tasks, thereby reducing the need for extensive training.

Long-term strategies should focus on **building deeper technical knowledge** across the workforce. This includes training in digital construction tools like BIM and robotics for automated assembly, as well as advanced manufacturing techniques for offsite production. Apprenticeships, specialised educational programmes, and targeted industry training (such as the examples in the Spain and Australia case studies below, or Ireland's CitA training programme [54]) are crucial to developing workers who can handle the complexities of modern construction. Furthermore, a **cross-disciplinary understanding**, where workers see how their roles fit into the broader industrialised process, will enhance efficiency and collaboration.

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51 CIOB. 2024. Modern methods of construction: barriers and benefits for Irish housing, available at https://www.ciob.org/industry/policy-research/MMC-Ireland.

52 Assaad, R. H., El-Adaway, I. H., Hastak, M., & LaScola Needy, K. (2022). The impact of offsite construction on the workforce: Required skillset and prioritization of training needs. Journal of construction engineering and management, 148(7), 04022056. Link available at https://scholarsmine.mst.edu/civarc_enveng_facwork/2304/.

53 CEDEFOP. Construction workers: skills opportunities and challenges (2023 update). Available at https://www.cedefop.europa.eu/en/data-insights/construction-workers-skills-opportunities-and-challenges-2023-update?utm_source=chatgpt.com.

54 CitA Skillnet Training. Link available at https://www.cita.ie/cita-skillnet/.

Addressing the skills gap is an opportunity to modernise the construction workforce. [55] Short-term solutions, can temporarily help accelerate the adoption of offsite methods, while long-term investments in technical training can help ensure a resilient and capable workforce for the future. Additionally, by introducing cutting-edge technologies into the industry, these strategies can make construction careers more attractive to younger generations, aligning with trends in digitalisation and sustainability.

4.2 Regulatory hurdles

While the EU's construction regulatory landscape broadly aims to harmonise standards to promote innovation and efficiency across the single market, variations across national and local regulations still create substantial challenges. Regulatory hurdles range from **permitting and building codes** and **standardisation, insurance** – which affect the feasibility, cost, and scalability of offsite construction – to limitations in **public procurement** and **fragmented demand across Member States**.

National regulations vary widely across EU Member States, with countries – and in some cases, regions – maintaining their own standards in diverse areas such as safety, structural integrity, energy efficiency, and fire protection. Industry stakeholders highlight that **building codes** are sometimes in need of updating to incorporate modular or prefabricated components, causing them to not fit neatly into existing regulatory frameworks. Offsite construction projects must thus often navigate complex and **fragmented permitting systems** that may not accommodate the unique aspects of modular construction. For example, while one country's building code may allow the use of timber prefabricated panels, another may impose stricter fire regulations that require additional safety measures, creating inconsistencies. These discrepancies lead to delays, higher costs, and increased uncertainty, discouraging investment in offsite methods across the **single market**.

The EU's focus on harmonisation, particularly through the new **Construction Products Regulation (CPR)**, [56] aims to address some of these challenges by **standardizing product performance requirements**. The CPR sets out requirements for the safety, durability and environmental performance of construction products, supporting **cross-border market fluidity** [57] within the European Economic Area (EEA). Products covered by harmonised technical specifications under the CPR must carry a CE mark and be accompanied by a Declaration of Performance, which helps ensure consistency in quality and reliability across Member States. Development of new harmonised European standards for integrated kits of construction products that are prefabricated would make it much easier for such elements to be traded across the single market.

For offsite construction, the **CPR serves both as an enabler and as a framework** for further harmonisation. It **facilitates the cross-border movement** of standardised construction products by ensuring that prefabricated components meet a uniform safety benchmark. However, its coverage is limited to products defined under harmonised technical specifications, and when a product or element is not harmonised, it becomes subject to national – or sometimes regional – regulations, which can create additional compliance challenges. European designers, and manufacturers had

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55 Perera, S., Ginigaddara, B., Feng, Y., & Rahnamayiezekavat, P. (2022). The new generation of construction skills: Transition from onsite to offsite. In *Innovation in construction: A practical guide to transforming the construction industry* (pp. 429-446). Cham: Springer International Publishing.

56 Construction Products Regulation (EU) 2024/3110.

57 Free trade in construction products within Europe (Government of the Netherlands). Available at https://www.government.nl/topics/construction-products/free-trade-in-construction-products-within-europe.

voiced their concerns that the 2011 CPR[58] focused primarily on conventional construction materials and techniques, creating **ambiguity in the certification** of innovative modular or prefabricated systems. This lack of clarity has often resulted in **additional compliance pathways** to meet local interpretations of safety and performance standards. Manufacturers also faced the challenge of making ad-hoc modifications to prefabricated structures, which diminished their efficiency gains. As the new CPR introduces clearer guidance and broader harmonisation for offsite and prefabricated systems, it aims to reduce reliance on national regulations.

Safety, energy efficiency and environmental benchmarks also vary significantly across EU Member States due to differences in climate, geography, and national policies. Such regional differences often require prefabricated components to be customised to meet local specifications. Use of offsite methods could support implementation of the Energy Performance of Buildings Directive (EPBD), which sets minimum energy performance standards for new and renovated buildings. Prefabricated components, typically designed with advanced insulation and energy-efficient materials, align with these goals.

The **insurance sector is hesitant** to cover modular and prefabricated methods due to uncertainties about clear safety and performance benchmarks in local building codes for non-traditional construction techniques. [59, 60] Offsite construction complicates the **risk profile of projects**, as insurance must cover both the factory manufacturing phase and the on-site assembly. The absence of consistent and standardised regulations at the national and EU level can lead to lack of, or higher insurance premiums for offsite projects compared to traditional methods, adding to costs and creating further barriers to widespread adoption.

Overall, regulatory compliance requirements frequently favour traditional construction methods, restricting the flexibility needed to incorporate modern prefabrication techniques.

4.3 Integration of the value chain

Offsite construction requires a shift from conventional, siloed workflows to a more **integrated approach** where stakeholders collaborate from the early stages of design to ensure the smooth execution of the entire project. [61] In conventional construction, different decisions can be made at various stages without as much need for synchronisation. [62] In offsite construction, **supply chain coordination is critical**. Prefabricated components must fit together precisely, requiring collaborative planning from the outset to avoid delays or shortages in supply that can have a domino effect stalling the entire project. Additionally, offsite construction reportedly leaves construction firms less able to control the pace of build at the individual unit level and to commit to production schedules well ahead of sales, increasing the risk of accumulating stock that has already been contracted but remains unsold. [63]

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58 Regulation (EU) No 305/2011 on harmonised conditions for the marketing of construction products. Available https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32011R0305.

59 Construction Executive. Common Risks and Insurance Complications of Modular Construction. Link available at https://www.constructionexec.com/article/common-risks-and-insurance-complications-of-modular-construction?utm_source=chatgpt.com.

60 NFP. Top Five Modular Construction Risks - And How to Address Them. Link available at https://www.nfp.com/media/izje50fi/top-five-modular-construction-risks-and-how-to-address-them.pdf?utm_source=chatgpt.com.

61 Masood R, Lim JBP, González VA, Roy K, Khan KIA. A Systematic Review on Supply Chain Management in Prefabricated House-Building Research. *Buildings*. 2022; 12(1):40.

62 Martin, D.S. (2021). Piece by piece: how Ireland's modular housing sector is struggling to recover from the pandemic, *The Currency*, 21st June 2021.

63 Project Production Institute. Match Supply with Demand: A Case Study Implementing Production System Optimization (PSO) for Offsite Construction. Link available at https://projectproduction.org/journal/match-supply-with-demand-a-case-study-implementing-production-system-optimization-pso-for-offsite-construction/?utm_source=chatgpt.com.

Because architects, manufacturers and contractors must work more closely to optimise designs for prefabrication, there are emerging opportunities to integrate this fragmented sector. For instance, medium and large consulting engineering firms are increasingly engaging in **early contractor involvement,** as early as the tender stage, to facilitate this integrated approach.

Standardisation in areas such as safety, environmental performance, and technical specifications, plays a central role in coordinating processes across the value chain by ensuring diverse actors operate under know and predictable standards. Designers, manufactures and contractors frequently emphasise the importance of standardisation for **compatibility and efficiency across the value chain.** Uniform specifications can reduce complexity and help align the various components produced by different suppliers, which is crucial for building a cohesive and competitive EU market for construction products. Increased harmonisation of EU-standards allows stakeholders to operate within predictable regulatory frameworks across member states. This can help enhance EU market fluidity and reduce the barriers posed by national requirements.

The shift to offsite methods requires **new forms of coordination** and project management approaches. Early Contractor Involvement (ECI), now being adopted by many medium and large consulting engineering firms, is one example of fostering closer alignment across the project lifecycle. Engaging contractors and other stakeholders at the tender stage enables input on design optimisations for prefabrication, allowing issues to be addressed proactively rather than reactively.

Construction Information Management Systems (CIMS), including tools like Building Information Modelling (BIM), Enterprise Resource Planning (ERP) systems, and Supply Chain Management (SCM) platforms, play a key role in cross-value chain coordination. They support integration of scheduling, resource allocation, and real-time communication across actors. For example, BIM offers a unified digital platform that **enables all parties to work from a shared 3D model**, ensuring alignment across the value chain by facilitating operations and collaborative work. [64] For instance, with the project's specifications and timelines, allowing for better **logistical planning, just-in-time delivery**, and preventing misalignment when components arrive on-site. Despite its clear advantages, the adoption of CIMS, and BIM specifically is not yet widespread. Industry actors note how in some countries, like the UK, the Netherlands, and Sweden, BIM adoption is encouraged or even mandated for public projects, which is driving higher usage rates. However, in other Member States and smaller projects, uptake is slower due to the **costs of implementation**, **training requirements**, and the **perception that BIM may be more suited to large-scale or complex projects**.

Ultimately, this integrated approach necessitates a new **working culture within the industry**, where **stronger networks** address fragmentation by allowing for better cross-disciplinary collaboration and more **integrated workflows**. While there are challenges to widespread adoption, particularly for smaller projects, the benefits of offsite methods underscore their potential to motivate the reshaping of construction processes.

4.4 The financial landscape

The financing of offsite construction presents challenges compared to conventional construction, primarily due to the different cost structures and the **need for significant upfront investments**. While the overall project cost and financing mechanisms are similar, the industrialisation of construction processes requires larger initial capital investments in plant, machinery, and specialised facilities. These investments often surpass the upfront costs of traditional construction methods, making it difficult for smaller players to enter the market.

[64] European Building Summit (2023). Statement from Ramón Ribó. Barcelona, Spain.

Uncertainty of demand often discourages upfront investments in the necessary infrastructure, such as manufacturing facilities or specialised machinery. Currently the supply chain related to offsite construction is still limited, meaning that the **facilities and markets needed for its implementation are not widely available**. [65, 66, 67, 68] Additionally, the limited number of suppliers drives prices up, further straining financing models. However, with increased competition and supply chain development, **costs are expected to decrease**, [69] making offsite construction more accessible.

Offsite construction methods are **not inherently cheaper**, and can even be more expensive than conventional methods when applied on a smaller scale. Unlocking the cost savings discussed in the preceding section largely depends on achieving **economies of scale**. The greater the integration of offsite methods across large-scale projects, the more cost-effective the process becomes. Profitability is realised when a significant portion of the building is constructed offsite, requiring substantial demand to justify the heavy investment in standardised production processes. For it to become financially viable, significant market demand and large-scale implementation are essential. Standardisation plays a key role in improving cost efficiency, as the more standardised the components and processes, the greater the potential for cost reductions. Therefore, **offsite construction's financial success depends on expanding market size and ensuring a stable, predictable demand**, particularly in sectors such as public or social housing, where bulk demand can support the investment needed for industrialised methods.

Public procurement (PP) is frequently viewed by stakeholders as an enabler for greater offsite prefabrication to ensuring the required steady stream of work that to drive down costs and improve efficiency. However, several limitations hinder the effectiveness of PP. Firstly, it is important not to overestimate the potential of PP in ensuring steady demand. Additionally, one of PP's primary issues is the prevalent **short-term focus on immediate cost savings**, which often overshadows the long-term value that prefabricated housing can provide. This approach can lead to decisions that neglect the substantial lifecycle benefits associated with prefabrication, ultimately resulting in higher costs and compromised quality over time. **Public entities also face resource and scope constraints** that limit their capacity to develop effective procurement strategies that fully integrate prefabrication strategically, thereby preventing the realisation of its potential benefits. Moreover, the implementation of the Energy Performance of Buildings Directive (EPBD) will directly influence PP by prioritising energy efficiency and sustainability. Offsite construction methods may be leveraged to align more closely with these goals, as they offer the potential to reduce energy use, and provide lifecycle benefits.

4.5 Cultural resistance

Resistance to change among stakeholders also poses a challenge, as many stakeholders are unfamiliar or sceptical about the benefits and processes of prefabrication, particularly about its reliability and quality. Consumers often view prefabricated homes as less durable and with a shorter lifecycle. This perception persists is despite advancements in materials and techniques that ensure

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65 Tennakoon, et al. 2023. Uncertainties affecting the offsite construction supply chain resilience: a systematic literature review, *Construction Innovation*.

66 Osborne Clarke. The future of the construction industry: offsite construction, next-generation connectivity and artificial intelligence. Available at https://www.osborneclarke.com/insights/future-construction-industry-offsite-construction-next-generation-connectivity-artificial-intelligence.

67 BCG. 2019. The Offsite Revolution in Construction. Available following https://web-assets.bcg.com/img-src/BCG-The-Offsite-Revolution-in-Construction-May-2019-R_tcm9-219473.pdf.

68 See in https://medium.com/@Desapex/understanding-offsite-construction-cf8de0f3a55d.

69 CIOB. 2024. Modern methods of construction: barriers and benefits for Irish housing, available at https://www.ciob.org/industry/policy-research/MMC-Ireland.

these structures meet or exceed traditional standards. For example, modular homes in countries like Sweden demonstrate high energy efficiency and durability, challenging these misconceptions. Nevertheless, these views are not trivial, as they are often founded on sound criticism raised by manufacturers, architects and engineers. While prefabrication in the housing sector presents significant advantages, these benefits depend on the adherence to best practices. Concerns raised by various stakeholders – including design professionals, construction firms, and regulatory bodies – often focus on lifecycle sustainability, durability, renovation potential, structural and climate resilience, and safety.

Offsite construction additionally raises apprehension over **design flexibility**, believing it **limits creativity**. Modern prefabrication methods are not necessarily as limited as the public imagination portrays them, as they allow for a wide range of customisable designs with the productisation of construction. For instance, in projects like the Dalston Lane timber development in London, modular construction was used to create a visually striking, sustainable building, proving that industrialised methods can offer both flexibility and innovation.

To change deep-seated attitudes, **demonstration** of successful projects can be important. Training programmes for design professionals, showcasing real-world examples of high-quality modular buildings, can help shift the mindset pave the way to the adoption of those offsite construction methods that yield significant benefits.

5 The state of play in the uptake of offsite construction methods in the housing sector in the EU and third countries

5.1 Ireland

Ireland has been experiencing a severe housing shortage in the last decade and housing is now consistently the number one issue of concern for the Irish public due to both its scarcity and unaffordability. The core issue driving the crisis is the inadequate supply of housing to meet the growing demand. To address this, the Irish Government launched a new housing plan for Ireland in 2021 titled ''Housing for all'' which aims to increase affordable housing across the country by delivering an average of 33,000 new homes annually until 2030. The plan also has several other objectives such as increasing the number of state-built social housing, combating homelessness, decreasing the cost of building housing and making the housing stock more environmentally friendly. [70]

MMC, the term used for offsite construction in Ireland, is expected to play a significant role under the Housing for All Initiative, which is reflected in the adoption of the *Roadmap for increased adoption of MMC for public housing delivery*. The roadmap promises to significantly accelerate the delivery of affordable and social housing through offsite construction, with the government aiming to apply MMC to the majority of 10,000 new social housing units annually. [71] Further, the government aims to reduce the delivery time for social housing projects from the current 18 months to just 12 months. To support the strategy and the targets set under it, the government has established a 100 million EUR fund to alleviate local authority loans on sites suitable for social housing projects using MMC and has designated 35 sites across 12 local authorities for housing development through prefabrication. [72]

To implement MMC successfully across Ireland, the roadmap outlines 6 thematic areas which are crucial for the widespread adoption of MMC in Ireland's residential sector: Development and further procurement approaches, regulations and standards, capital, finance and insurance, skills development, industry competitiveness and capacity and effective policy execution and communication.

Firstly, to ensure that MMC projects are viable and to attract investment in modular or volumetric construction by construction manufacturers in Ireland, the government is focusing on developing adequate contracts and setting up more attractive public procurement procedures. Long term contracts along with secure procurement opportunities will incentivise long term investments in the 3D modular construction market. Further, public sector procurement for 3D modular construction projects can also serve as a testing ground for experimenting with MMC and standardisation options, something that is not possible with private sector clients. Due to these factors, the Irish government aims to expand the use of the design and build procurement approach and is developing public procurement frameworks tailored to support MMC adoption. This includes

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70 Housing for All – A new housing plan for Ireland. Available at https://www.gov.ie/en/publication/ef5ec-housing-for-all-a-new-housing-plan-for-ireland/#view-the-plan.

71 See MMC Ireland. Roadmap for Increased Adoption of Modern Methods of Construction in Public Housing Delivery. Available at https://mmcireland.ie/roadmap-for-increased-adoption-of-modern-methods-of-construction-in-public-housing-delivery/.

72 Ibid.

developing criteria that can be used to evaluate tenders for public contracts for housing using MMC (including consideration of the pre-manufactured value, PMV). [73]

Second, the Irish government has been developing several financial incentives in the form of tax relief schemes and capital grants to boost investment in MMC. Tax relief schemes can help reduce the financial burden of the high upfront investments needed to transition to prefabricated construction methods, especially for SMEs. The most relevant scheme is the Growth and Sustainability Loan Scheme (CSLS), which will make competitively priced loans between (25,000 EUR – 3 million EUR) available to SMEs for up to 10 years. Capital grants will also support specific types of investments, for example building new offsite factories or expanding current facilities. Such government backed loans, or financial agreements make it more financially viable for companies to transition to MMC long term.

Third, the government has focussed on addressing the issue of design standardisation and has contracted Hawkins Brown, a MMC architectural practice in Ireland to develop a number of standard residential designs that can be built across the country. Further, plans are in place to develop a standard for state funded purpose-built student accommodation. In addition, Irish and UK firms are currently working together to create standardised modular housing units that can be used in both markets with minimal modifications. Standardisation of designs and alignment across major elements is crucial for the large-scale deployment of offsite methods and has the potential to massively boost the scale of MMC in Ireland.

Finally, as seen across many EU Member States, the skills gap has been a key issue that the Irish government is attempting to address. The transition to MMC requires a transition in design skills, planning skills and technologies. A report commissioned by Ireland's Further Education and Trading Authority on the '*'Analysis of Skills for Residential Construction and Retrofitting 2023-2030' has* quantified the additional construction skills needed to meet the governments housing targets and further plans are in place to develop and implement an action plan and recommendations based on the findings. The initiatives involve, among others, expanding training and upskilling opportunities for workers and setting up strategies to attract new talent in the construction sector.

Another crucial benefit of MMC in Ireland is its environmental impact potential. Ireland is among the highest emitters per capita in the OECD and the EU, with an estimated 37% of Irelands carbon emissions coming from the built environment.[74] Offsite construction ensures increased compliance with environmental and building standards, constructing more energy efficient buildings which can substantially lower heating costs as well as general emissions. Timber, which is a naturally occurring carbon capture resource, can be built through MMC and will be used in 46% of the new MMC constructed residential homes. [75]

To conclude, the maturity of MMC in Ireland and the strategies developed to address current MMC challenges show Ireland's potential to become a leader in MMC. In contrast to other Member States, Ireland is ahead in developing concrete actions for implementation and its collaboration between the government and market actors. MMC provides a significant opportunity for Ireland to decarbonise their new housing supply whilst being able to deliver on their goals of developing affordable housing at a national scale.

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[73] Government of Ireland, Roadmap for increased adoption of Modern Methods of Construction in Public Housing delivery. See https://assets.gov.ie/263098/6a696fcc-eb81-484d-8028-4b1929ebca53.pdf

[75] CIF (2021), Modern Methods of Construction, Dublin: Construction Industry Federation.

5.2 Spain

Spain's industrialised construction sector is currently underdeveloped, with only about 1% of buildings constructed using industrialised systems.[76] However, it has significant growth potential driven by rising demand for affordable housing and an evolving regulatory landscape. Spain faces a housing shortage of approximately 600,000 homes, pushing property prices higher and making housing less affordable for many[77] To address this, the government's 20,000 Housing Plan aims to increase public housing stock from 2.5% to 8% by 2030, backed by €340 million in investments. Industrialised methods, particularly prefabrication, are seen as essential to meeting this demand efficiently and sustainably. [78, 79]

The Hoja de Ruta Construye 2025 emphasises the urgent need for **standardisation in prefabrication processes** and components, as the current fragmented supply chains lead to inefficiencies and higher costs. [80] Industry representatives from the Spanish National Confederation of Construction (CNC) also note that Spain's prefabricated market remains **largely localised**, with very limited cross-border trade; primarily, the prefabrication industry imports materials, and very rarely construction products. Standardisation would not only streamline production but also improve supply chain resilience, particularly in Spain's domestic market for precast concrete, which is dominant for infrastructure and housing projects.

Spain's Technical Building Code (CTE) is recognised as a strong bottleneck.[81] With the **absence of specific regulatory recognition** for off-site construction, access to traditional bank financing is hampered, as Spanish banks typically require physical assets as collateral. Industrialised projects, which generate much of their value in factories before being transported to site, do not meet this criterion, forcing developers to turn to alternative financing mechanisms at higher costs [82]. The need for legislative reform is pressing, as recognised by REBUILD 2024, where industry stakeholders are pushing for an updated CTE to legitimise factory-built structures within Spain's financial and regulatory frameworks. [83]

Digital transformation remains underutilised in the sector, although adoption of BIM and data analytics have shown promise in improving project predictability and reducing construction timelines. The integration of lean construction techniques, which prioritise efficiency and cost control, is seen as a vital strategy for maximizing the potential of industrialised methods, especially in urban housing.

Despite these challenges, leading players such as Europa Prefabri, ABC Modular, and Pacadar Group are capitalizing on government investments in infrastructure projects –particularly in transportation – to drive the adoption of industrialised methods of construction. Precast concrete continues to dominate, thanks to its widespread applicability across residential, commercial, and

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76 Market Wide Research (2023). Spain Construction Market Analysis – Industry Size, Share, Research Report, Insights, Covid-19 Impacts, Trends, Growth and Forecast 2024-2032. Available at https://markwideresearch.com/spain-construction-market/.

77 See in https://inspain.news/from-boom-to-deficit-spains-housing-crisis-deepens-as-construction-slumps/.

78 As reported in GlobalNewswire at https://www.globenewswire.com/news-release/2024/06/18/2900622/0/en/Spain-Prefabricated-Construction-Industry-Databook-2024-100-KPIs-Market-Size-Forecast-by-End-Markets-Precast-Products-and-Precast-Materials-Forecasts-to-2028.html.

79 Construye2025 - Hoja de Ruta 2022 – 2025, available at https://construye2025.cl/wp-content/uploads/2022/07/Hoja-de-Ruta-Construye2025-2022-2025.pdf

80 Ibid

81 Código Técnico de la Edificación de España (CTE), available at https://www.codigotecnico.org/.

82 Spain Prefabricated Buildings Market Size & Share Analysis - Growth Trends & Forecasts (2024 – 2029). Available at https://www.mordorintelligence.com/industry-reports/spain-prefabricated-buildings-market.

83 Construye2025 - Hoja de Ruta 2022 – 2025, available at https://construye2025.cl/wp-content/uploads/2022/07/Hoja-de-Ruta-Construye2025-2022-2025.pdf

infrastructure sectors. [84] Lightweight prefabrication methods, especially those involving wood, are gaining traction, influenced by Nordic models, with wood-based prefabrication becoming increasingly prominent in Spain in modular prefabricated methods for housing.

However, the weakness in supplier networks and the shortage of skilled labour remain critical obstacles. Construye2025 calls for targeted investment in worker training and certification programmes – largely absent in Spain according to industry representatives – to bridge this skills gap and ensure that the workforce can support the sector's expansion.

In conclusion, while Spain's industrialised construction sector is well-positioned for growth, critically, **its expansion depends on regulatory reforms, financial innovation, technological integration, and workforce re-skilling**. The market's trajectory will be defined by its ability to overcome these barriers and fully leverage government policy and EU sustainability frameworks.

Box 1. Case study: *iCONS – Asociación Navarra Clúster para la Industrialización de la Construcción*

A noteworthy example of this potential for growth potential can be seen in Navarre, Spain, **iCONS**[85] – officially known as the **Navarre Cluster Association for the Industrialisation of Construction** – was established in 2022 as a public-private partnership aimed at enhancing the regional construction sector. Initially formed by 11 entities with a combined turnover of €456 million, iCONS has grown to bring 61 entities together, which collectively generate €4.574 billion in annual revenue and represent 21,400 workers. This rapid expansion reflects the cluster's strategic intent to position Navarre as a leader in industrialised construction.

The region's economic profile is particularly conducive to this initiative, as **Navarre has a robust building tradition** having pioneered high energy rating standards two decades ago and established the **first Passivhaus building in Spain.** [86] These precedents provide a strong foundation for advancing industrialisation in the region. The presence of advanced manufacturing companies, such as Viguetas Navarras[87], which specialises in robotic construction, alongside innovative firms like NSM [88] and Madergia, [89] underscores the region's capacity for industrialised construction.

iCONS is primarily focused on industrialisation, digitalisation, sustainability, rehabilitation, and talent development, and has initiated several key activities. Working groups are compiling specifications for industrialised construction to **provide clear guidelines for public administrations and private developers**. They are also conducting comparative studies that examine the efficiency and effectiveness of traditional versus industrialised methods. Engagement with professional bodies, including the Official College of Architects, [90] is also a key priority to promote best practices and facilitate knowledge sharing. Moreover, the cluster is also investing in talent development by launching a **micro-credential programme in construction industrialisation** in collaboration with the Public University of Navarra aiming to bridge the skills gap in the construction industry.

iCONS aims to further modernise the construction sector in Navarre, but also to set a precedent for industrialisation practices across Spain. It is an excellent possibilist case study demonstrating the

84 Spain Prefabricated Buildings Market Size & Share Analysis - Growth Trends & Forecasts (2024 - 2029). Available at the following https://www.mordorintelligence.com/industry-reports/spain-prefabricated-buildings-market.

85 iCONS - Navarre Cluster Association for the Industrialisation of Construction. Link: https://www.iconscluster.com/

86 BUILD UP - 128 Passive House apartments in residential development in Navarra. Link: https://build-up.ec.europa.eu/en/resources-and-tools/case-studies/128-passive-house-apartments-residential-development-navarra

87 Viguetas Navarras. Link: https://www.viguetasnavarras.com/

88 NSM (Nueva Construccion Modular). Link: https://www.nuevosistemamodular.com/

89 Madergia. Link: https://www.madergia.com/

90 Colegio Oficial de Arquitectos Vasco-Navarro. Link: https://www.coavna.com/.

effectiveness of coordinated efforts between public and private stakeholders in driving sectoral transformation.

5.3 Sweden

Sweden is widely regarding as the global exemplar of offsite manufacturing of prefabricated housing. In Sweden, 90% of one- and two-family houses are constructed using prefabrication methods, predominantly utilizing 2D panelised systems. The country has a long history in this space, having been building houses in factories since the 1940s and since then it has become a well-established practice, particularly for smaller homes. [91] The real boom in offsite construction took place with the Million Homes programme, a large public housing programme implemented between 1965 and 1974 which built over 1 million new homes. This also ingrained a strong cultural acceptance of modular homes in Sweden, a sentiment that persists today.

The evolvement and success of offsite manufacturing in Sweden also stems from the challenging construction weather in Sweden. With long, dark winters and heavy rainfall, offsite construction minimises time spent on the building site and provides a safe and predictable way to build in a factory environment.

Due to the historical use of prefabrication and the institutional use of offsite construction, the right ecosystem is in place to make prefabrication advantageous. For example, due to its widespread use, prefabrication is more financially attractive as it has reached economies of scale. In terms of funding, banks do not discriminate between offsite and onsite construction for obtaining a loan or funding and Swedish banks also facilitate funding for prefabrication projects. Another significant advantage in Sweden is consistent nationwide building codes and contract laws. [92] Unlike other EU member states where building codes can differ per state or county, Sweden has standardised regulations which eliminates the need for contract negotiations or specification changes. Finally, Sweden has strongly established processes, an abundance of manufacturers for panelised systems and integrated production and supply chain operations.

Sweden is currently undergoing a major construction boom and skills shortages are apparent in the traditional construction sector. Given the institutionalisation of offsite construction and prefabrication, training for factory-based construction roles is also generally considered more straightforward compared to on-site construction. The younger generation also prefers factory settings where conditions are less harsh than traditional sites and provide a more stable, safe and predictable working environment. Hence, offsite construction is only deemed to increase further.

Sweden's focus on sustainability is deeply embedded in the country's construction ethos, which pushes for further offsite construction. Sweden is also known for its widespread use of timber modular systems, partly due to its strong wood industry and a longstanding tradition of prefabrication. In fact, around half of Sweden comprises of forests that can be made into quality timber. This percentage still makes it the world's highest percentage of factory built wooden houses in the world and due to the high timber usage in Sweden, carbon emissions from construction

[91] https://builtoffsite.com.au/emag/issue-05/sweden-became-home-prefab/

[92] Trullii. July 2024. Lessons from Sweden: How Canada Can Transform its Construction Industry with Offsite Solutions. Available at https://www.trullii.com/post/lessons-from-sweden-how-canada-can-transform-its-construction-industry-with-offsite-solutions.

consists of only 20% in Sweden, compared to the global average of 40%. [93,94] This is because timber has carbon capturing properties and traps carbon within its structure. Further, while the material costs for timber are higher, wooden houses are typically built faster and with less net energy use. Given these benefits, and the abundance of timber in Sweden, the Swedish government is also heavily focused on further increasing the use of timber modular systems across the country.

However, the increased use of wood in buildings currently poses significant challenges. Firstly, the use of wood materials creates increased health and safety concerns for residents as wood buildings are perceived to be more prone to fire hazards and potential for water damage. This is because wood construction can create small air gaps in modular buildings which increase the potential for fires to spread. Consequently, fire safety regulations are stricter for wooden structures, making them more expensive to build due to the additional precautions required. Second, due to the increased perceived risk, housing insurance for wood houses is also more expensive and more difficult to obtain. Therefore, while regulations in Sweden do not inherently hinder the increased use of timber construction, it also does not necessarily promote it.

Box 2. Case study: the BoKlok Project in Stockholm

One notable government initiative in Sweden is the BoKlok Project, a joint venture between IKEA and the Swedish construction company Skanska. BoKlok is a residential housing concept which emerged in 1997 aiming to provide affordable and sustainable homes ''ordinary'' Swedish people. To date, BoKlok has developed about 15,000 homes across Sweden, Finland and Norway with plans to expand to other markets.[95]

The homes primarily made of wood, ensuring carbon capturing properties are built completely offsite in a safe, dry and efficient manner. Through their offsite construction, they have reduced the number of deliveries to the site by over 75% and removed the number of overall transport movements by 50%. Further, occupants typically cut their carbon emissions by 55%, because of the fabric efficiencies and the air source heat pump technology installed when they move into a BoKlok home. [96]

One of BoKlok's most iconic projects was the SilviaBo housing project, a collaboration which took place between IKEA, Skanska and the Queen of Sweden. Queen Silvia came up with the idea to build and built modular BoKlok housing for the elderly and people with dementia. The project started in 2015 and was developed in response to the country's ageing population and resultant demand for accessible dwellings.

Similarly to other BoKlok buildings, the houses are made of prefabricated timber units, but with incorporated social facilities and modifications to make it more ''dementia friendly''. For example, wide entrances and flat walkways are incorporated to make it more wheelchair accessible, with automatic door-openers, low shower walls, heat sensors and extra floor lighting. Features also include clearer signalling for people with dementia and enlarged wayfinding.[97]

Further, a social community element is added, which includes a community garden with flowers and home-grown vegetables as well as a clubhouse. The overarching aim of the project is to enable to elderly to live longer independently and in their own home, ultimately decreasing the need for care homes and saving the government money spent on care.

93 The New York Times. June 2024. How an American dream of housing became a reality in Sweden. Available at https://www.nytimes.com/2024/06/08/headway/how-an-american-dream-of-housing-became-a-reality-in-sweden.html.

94 See at https://builtoffsite.com.au/emag/issue-05/sweden-became-home-prefab/.

95 See https://www.boklok.com/global/.

96 Ibid.

97 More details are reported at https://www.dezeen.com/2019/08/20/ikea-boklok-prefabricated-silviabo-elderly-housing/.

5.4 Germany

Much like in other Member States, Germany's construction industry faces challenges, with over 70% of construction projects exceeding budget and, reportedly, about 10% of homes costing at least 30% more than initially planned.[98] The German federal government has set an ambitious goal of creating 400,000 new apartments annually; however, only 295,000 were completed last year.[99] This shortfall can be attributed to complicated requirements, lengthy approval processes, rising personnel and material costs, and increasing interest rates, all contributing to a struggling construction sector.

Amidst these challenges, Germany has invested in offsite construction. Currently, over 20% of the country's housing stock is reportedly built using offsite construction—with a prevalence of modular building techniques (also known as **Modulbau**).[100] Modulbau facilitates high levels of prefabrication in controlled factory settings, significantly reducing both construction time and the environmental impact associated with traditional on-site building methods. Prefabricated modules are typically fully equipped—complete with fittings, plumbing, and furnishings—before being transported for on-site assembly. According to a recent review, German modular builders are able to cut construction time by approximately 50% while also exercising a strict process of quality control. [101]

To further address the housing crisis, the German government has initiated a €2 billion investment aimed at increasing the availability of affordable, climate-friendly housing. This initiative is particularly notable as it mandates a comprehensive evaluation of a building's entire carbon life cycle—from construction through operation to eventual deconstruction. The funding under this initiative is allocated to a new programme titled "Climate-Friendly New Construction in the Low-Price Segment" (KNN). By guaranteeing a steady pipeline of work for modular builders, this program can support the growth of modular and prefabricated construction methods, especially in the affordable housing sector. The *Kreditanstalt für Wiederaufbau* (KfW), Germany's development bank, complements this initiative by offering favourable loans with interest rates as low as 1-2% for terms ranging from 10 to 35 years, significantly below market rates. [102]

While the initiative is not designed explicitly for offsite construction firms, according to a recent intervention by Germany's Federal Minister of Construction and Housing, modular construction is expected to play a pivotal role in achieving these ambitious goals. [103]

An important aspect of Germany's offsite industry concerns the perception of modular housing in the country. This has reportedly shifted positively in recent years, and it is now associated with high-quality construction. This transformation can be linked to the introduction of quality standards and certification schemes, such as the Golden Cube and the Hausbau Design Award. These certifications recognise successful modular projects, demonstrate their quality, and encourage more clients to opt for innovative building techniques. In addition, Germany's educational institutions offer

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98 As reported in Medium, available at https://medium.com/blue-future-partners/is-offsite-construction-the-solution-to-a-broken-process-f776ffda59b6.

99 DW. April 2024.German housing crisis: Like winning the lottery! Available at the following link.

100 While Germany is often indicated as a country with a good track record in offsite construction, figures on the uptake of offsite construction in Germany are difficult to find. But see https://buildingbetter.org.uk/learning-lessons-from-abroad-to-drive-up-use-of-mmc/.

101 See Deutsche BauZeitschrift. 2019. DBZ Sonderheft: Modulbau. Available at https://www.dbz.de/download/1511205/DBZ-Sonderheft-Modulbau-2019.pdf.

102 Details on the initiative are provided in a press release by KfW. Available at https://www.kfw.de/%C3%9Cber-die-KfW/Newsroom/Aktuelles/Pressemitteilungen-Details_823616.html.

103 As reported in https://builtoffsite.com.au/news/modular-construction-primed-for-massive-government-support-in-germany/ .

training programmes that focus on modular construction techniques at different levels, together with broader engineering processes suitable for offsite methods.[104]

5.5 The UK

In the United Kingdom, offsite construction – often subsumed under the wider umbrella term of MMC – has long being recognised as a solution to the country's housing shortage. Having long struggled to achieve their ow construction goals, successive UK government have increasingly expressed their support for offsite construction. The 2017 Housing White Paper (Fixing our broken housing market) made several commitments to support offsite construction. This commitment is reaffirmed in the Affordable Homes Programme (AHP), which received 11.5B in funding for the 2021-26 period. [105] The UK government has also moved to ease residential planning permissions in high-density areas.

Currently, the government's own goal is to deliver 300,000 new homes annually.[106] Yet the UK's construction industry is building approximately 200,000 homes per year—one third short of target.[107]

Despite increasing government support in recent years, the uptake of offsite construction remains limited in the UK. The only exception is Scotland, where over 80% of new homes are reportedly built starting from timber frames prefabricated and delivered to the site.[108] This stands in contrast with England, where only between 10% and 15% of new housing is built off-site. [109] This is corroborated by data collected by Glenigan and the NBS, which indicates that among all new-build projects utilising MMC in 2023, only 5% were dedicated to private housing; and 10% to social housing. [110]

That off-site has become more prevalent in social housing is confirmed in a recent survey carried out by the National Housing Federation and Building Better among UK housing associations, which points to over one-third of new social housing projects being completed using MMC—for a total of over 5,000 homes for social housing for the year 2022-23. [111] Despite the relatively low concentration of off-site in the housing sector, Glenigan data does suggest that the uptake of MMC

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104 See Arup. 2019. How MMC can deliver "more" through the planning system. Available at https://thinkhouse.org.uk/site/assets/files/1446/arup.pdf.

105 Discussions on the potential benefits of offsite construction in the UK go back to the 1998 report on *Rethinking Construction*. Available at https://constructingexcellence.org.uk/wp-content/uploads/2014/10/rethinking_construction_report.pdf. Another influential report on the issue, *Modernise or Die*, came out in 2016. Available at https://www.constructionleadershipcouncil.co.uk/wp-content/uploads/2016/10/Farmer-Review.pdf.

106 It is worth noting that this objective may change under the new government, which came into power in the summer of 2024.

107 According to data from the Office for National Statistics (ONS), in 2022, new homes were distributed as follows 171,190 in England, 5,270 in Wales, 20,770 in Scotland, and 7,300 in Northern Ireland. The ONS notes that while each country uses its own data sources, these figures primarily refer to new builds, excluding some conversions or changes of use. Data is available https://www.ons.gov.uk/peoplepopulationandcommunity/housing/articles/ukhousebuildingdata/financialyearendingmarch2022.

108 Architecture and Design Scotland. 2020. Using Offsite Construction for Housing Delivery in Scotland. Available at the following https://www.ads.org.uk/sites/default/files/2022-05/case-study-using-offsite-construction-housing-delivery-2020.pdf.

109 European Federation for Living (EFL). 2020. Offsite Construction: A New Pathway Towards More Affordable, Sustainable Homes. Available at https://www.ons.gov.uk/peoplepopulationandcommunity/housing/articles/ukhousebuildingdata/financialyearendingmarch2022.

110 See the NBS. 2023. Digital Construction Report, available at https://www.thenbs.com/digital-construction-report-2023/.

111 Building Better and National Housing Federation. 2024. State of MMC Delivery in Social Housing. Available at https://www.housing.org.uk/globalassets/files/building-better/mmc-report-2024/mmc-survey-report.pdf.

approaches has grown in the UK. In 2017, fewer than 10% of new-build projects employed MMC approaches. This share grew to 16% in 2023. The same dataset points to MMC having made larger inroads in other sector. The proportion of new-build projects that included at least some off-site elements are reportedly higher for industrial builds (almost 30% of new projects); education (15%); and hotels and leisure (11%). [112]

The reasons for the limited uptake of offsite construction—particularly in the private housing market—include the lack of skilled workers; [113] difficulties in getting off-site homes insured; [114] and, more importantly, a combination of large upfront capital costs and uncertainty in market conditions. In some markets, such as the UK, the limited uptake of offsite construction is related to a housebuilding business model which hinges on responding rapidly to changing market conditions. [115]

Offsite construction reportedly leaves construction firms less able to control the pace of build at the individual unit level, and to commit to production schedule well ahead of sales – with the risk of accumulating stock that has already been contracted but remains unsold. Offsite construction would require access to a predictable stream of demand for new housing, allowing builders to commit to larger production schedules; and to be less dependent on the careful management of their cashflow. These findings suggest that in the UK, more widespread use of public procurement for both social and private housing might be able to support a greater uptake of offsite construction by the industry.

5.6 Australia

Over the past decade, Australia's interest in prefabricated construction has expanded beyond remote housing projects into schools, hospitals, healthcare facilities, commercial properties, and public infrastructure. [116] Yet, despite its progress, prefabrication still accounts for just 8% of the AUD 150 billion construction industry – up from 3% a decade ago.[117] The sector's goal is to reach 30% of the market by 2033, [118] driven by a compound annual growth rate of 15%. [119] PrefabAUS, the industry's main representative body, sees the mainstreaming of prefabrication as crucial for meeting the government's National Housing Accord (NHA) target of building 1.2 million new homes by 2030.

Faster, more efficient construction methods will be required to meet the NHA. Prefabrication is seen as a solution by shifting labour-intensive tasks to factory settings which. In the Australian context, reduction of on-site labour construction times can raise up to 50%. [120] Despite these efficiency gains, cost parity with traditional construction persists, primarily due to the lack of a consumer

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112 See NBS. 2023. Digital Construction Report, available at https://www.thenbs.com/digital-construction-report-2023/.

113 See, for instance, REHAU. 2023. Offsite Construction Report. Available at https://www.rehau.com/uk-en/offsite-construction-report.

114 As discussed during the recent inquiry into offsite construction at the UK's House of Lords. The proceedings are available https://committees.parliament.uk/work/5809/offsite-manufacture-for-construction/.

115 See Lang R. et al 2016. Are housebuilders' production strategies a barrier to offsite construction uptake in the UK? Available at https://www.researchgate.net/publication/359711102_Are_housebuilders'_production_strategies_a_barrier_to_offsite_construction_uptake_in_the_UK; and Pan, W. et al. 2008. Leading UK housebuilders' utilisation of offsite modern methods of construction. Available following https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=e470f350ff7b065b01a8fb6abbd445c1c1f91824.

116 Zhang, Z. et al. 2022. Current State of Using Prefabricated Construction in Australia. Buildings , *12*, 1355.

117 Ibid

118 PrefabAUS. A Prefabrication Industry Roadmap 2023 – 2033. Building the future we want.

119 Mordor Intelligence. *Australia Prefabricated Buildings Industry—Growth, Trends, COVID-19 Impact, And Forecasts (2021–2026)*.

120 PrefabAUS. A Prefabrication Industry Roadmap 2023 – 2033. Building the future we want.

demand enabling an economy of scale. Today, the high upfront investments in technology and logistics negate the potential savings of prefabrication, diminishing its competitive edge on price.

Capital investment thus remains challenge in Australia. Prefabrication requires significant upfront spending on factory setups, but without financing models adapted to modular construction, scaling remains difficult. Banks and the industry are starting to collaborate on developing prefab-specific contracts and banking products to mitigate risks and attract more investment. Yet, today financing still remains a major bottleneck: traditional construction loans, are based on incremental progress and do not align with prefabrication's off-site production model. Developers struggle to secure funding, and banks have been slow to develop products tailored to modular construction.

When it comes to the regulatory enabling environment, state-level programmes are leading the way. For instance, Queensland's QBuild [121] is investing in delivering modular housing for key workers in remote regions, while running a successful apprenticeship program upskilling tradespeople in MMC techniques (*see case study below*). New South Wales' modular housing task force [122] is driving efforts to incorporate prefabrication into public projects: the state recently launched a trial to build 8,000 modular social housing units, using design competitions to encourage collaboration between architects and modular builders. Meanwhile, the State of Victoria has developed an Offsite Construction Guide [123] and is working on a Modular Construction Handbook in collaboration with the Australian Building Codes Board to standardise modular construction compliance and quality across public and private projects.

Despite state-level initiatives, national support for prefabrication in Australia remains patchy and insufficient to scale the industry. The key barriers are the absence of unified standards, a lack of tailored financing models, and fragmented supply chains. To address them, the industry is pushing for federal regulatory reforms, including the implementation of national standards, improved access to capital, and the integration of DfMA and Design for Disassembly in public procurement.

Australia's prefabrication sector is gradually building scale, largely through strategic partnerships between developers, manufacturers, and suppliers. These alliances are helping to share the risks of the capital-intensive investments required for high-volume, automated production. With the right policy shifts, capital support, and technological innovation, prefabrication could move from a niche solution to a mainstream force in the construction industry, addressing the country's pressing housing and infrastructure challenges. The challenge lies in scaling these efforts across both public and private sectors to unlock the full potential of industrialised construction.

Box 3. Case study: QBuild – Queensland's Modular Construction Initiative

QBuild is Queensland's state-run construction body, responsible for maintaining and building government-owned assets, from schools to health facilities. Recently, its MMC programme has become a core component of its strategy to rapidly deliver housing, particularly for key workers such as teachers, nurses, and police officers in regional and remote areas. Its network of Rapid Accommodation and Apprenticeship Centres (RAACs), are located in Eagle Farm, Zillmere, and Cairns, which specialise in the off-site manufacturing of modular homes, which are then transported and assembled on-site. The programme aims to deliver 439 homes by 2027 under the Government Employee Housing Capital Works Programme.

Queensland is leveraging the programme to invest in its future workforce. The programme is currently upskilling 1,000 tradespeople, including 200 apprentices, in modular construction techniques, helping to

121 See in https://www.housing.qld.gov.au/about/department/business-areas/public-works/qbuild.

122 See https://www.dpie.nsw.gov.au/land-and-housing-corporation/plans-and-policies/modern-methods-of-construction/modern-methods-of-construction-taskforce.

123 See https://www.vic.gov.au/resources-and-publications.

mitigate the state's skilled labour shortages. Apprentices are trained in a variety of trades, including carpentry, plumbing, and electrical work, specifically tailored to prefabrication methods, which are having positive spillover effects into the broader labour market.

QBuild's prefabrication efforts are additionally proving valuable in disaster response situations. Prefabricated homes are manufactured ahead of time and stored off-site, allowing for rapid deployment in regions hit by natural disasters such as floods or cyclones. This flexibility has enhanced the government's ability to respond quickly to emergencies, providing temporary housing and supporting community recovery efforts.

However, QBuild's output, while impactful, is still limited relative to statewide demand. Its reliance on government contracts raises questions about broader adoption without continued public investment. Nevertheless, QBuild provides a scalable model for using prefabrication to meet housing needs and long-term infrastructure goals.

6 Conclusions and recommendations

Defined by factory-based construction processes that allow significant portions of a building to be completed off-site, then transported and assembled on location, offsite construction provides several potential benefits, including improved cost efficiency, productivity, reductions in environmental impacts, and workforce safety.

However, our research highlights a number of structural, financial, and cultural challenges that need to be addressed for greater uptake of offsite construction across the EU. In view of these challenges and the experiences of EU Member States and third countries, we propose that the following high-level recommendations can be considered.

- **Addressing the skills gap through training**: Transitioning to offsite construction requires a workforce skilled in modular assembly, digital tools like Building Information Modelling (BIM), and other advanced manufacturing techniques. Many conventional construction workers lack the specialised skills necessary for these roles, making it crucial to invest in targeted training programmes. Certification programmes, apprenticeships, and educational partnerships would be vital to generate a pool of skilled labour that is ready for offsite construction. Sweden's example demonstrates that offering safer, stable factory-based roles can attract younger generations and diversify the workforce, particularly when coupled with upskilling programmes that align with the sector's increasing focus on digitalisation and sustainability.

- **Standardisation**: A standardised regulatory framework is important for the scalability of offsite construction. Currently, Member States have different building codes, which can lead to inefficiencies and increased costs for companies operating across borders. Establishing and using consistent standards in line with Eurocodes for prefabrication and modular construction components would simplify regulatory compliance, reduce production delays, and encourage cross-border trade. Moreover, aligning national building codes with the new Construction Products Regulation (CPR), would help strengthen the single market, enabling companies to scale operations and achieve economies of scale. Standardisation would allow for greater interoperability, with prefabricated components being designed, manufactured, and used across various EU jurisdictions without requiring major modifications, ultimately enhancing the competitiveness of offsite construction within the single market.

- **Financial incentives**: One of the main financial challenges for offsite construction is the significant upfront capital investment required for factory setups and specialised equipment. Member States can address this by implementing tax relief programmes and capital grants to support companies investing in offsite construction. Ireland provides an effective model for this approach, offering tax incentives that lower financial barriers and encourage companies to invest in modular production facilities. Germany is also leveraging the KfW bank to access to capital. Establishing fiscal policies that reduce the tax burden on modular facilities can also make offsite construction more attractive and viable for a wider range of industry players.

- **Wider use of public procurement to drive demand**: Public procurement is a relevant mechanism to foster demand for offsite construction. By prioritising modular and prefabricated methods in public projects, public authorities can help create a stable demand pipeline that justifies the upfront investments needed for offsite construction facilities. Since Eurocodes should also be used as a reference for technical specifications in public contracts, procurement

may provide support to standardisation efforts. For example, in Ireland, public procurement under the *Housing for All strategy* includes design-and-build contracts tailored to modular methods, which shows how governments can use procurement to test and expand offsite approaches. To ensure long-term value, public procurement should go beyond prioritising cost efficiency to emphasise quality, durability, and environmental performance. Including criteria for innovative design in public tenders can also enhance standards and ensure that offsite projects meet both functional and aesthetic requirements. A focus on aligning procurement strategies with evolving EU standards, such as those under the revised Energy Performance of Buildings Directive (EPBD), can further incentivise sustainable offsite practices.

- **Facilitating exchange of best practices and experiences** can improve coordination and knowledge-sharing across Member States, essential for fostering innovation and collaboration. Platforms that promote the exchange of best practices can facilitate learning from successful examples. For instance, Spain's Construye 2025 initiative provides a notable example of how regional clusters can mobilise stakeholders to address local challenges. However, there is a space to enhance the leveraging of lessons from international approaches. EU-level dialogue between Member States, industry actors, and educational institutions can help to create synergies, align strategies, and improve consistency in building a supportive environment for scaling offsite construction.

- **Promoting research and innovation** can help advance towards solving the technical and logistical challenges of offsite construction. Member States and EU institutions should consider prioritising funding for initiatives that advance standardisation of components, streamline production techniques, and improve the efficiency of digital tools such as BIM and CIMS. Focused research can also explore sustainable material development, energy-efficient modular systems, and solutions to enable circular construction practices. Collaborative efforts, such as Ireland's initiative to develop standardised modular designs, demonstrate how innovation can address scalability challenges while maintaining flexibility. EU-level initiatives could further support cross-border collaboration to address shared barriers, including regulatory alignment, integration of new technologies, and enhancing supply chain resilience.