NSAI

National Standards Authority of Ireland

Údarás Um Chaighdeáin Náisiúnta na hÉireann

A Study of International Construction Quality Assurance & Certification Schemes for Modern Methods of Construction (MMC)

January 2024

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Disclaimer

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1. Overview

This study addresses milestone No. 12 of the Housing for All *Roadmap for increased adoption of Modern Methods of Construction in public housing delivery* document, published on 11 July 2023 (gov.ie, 2023). International construction quality certification schemes have been reviewed and summarised to assist benchmarking of the current NSAI Agrément process in Ireland.

The desktop research commenced with a review of European Union reports related to construction to assess the level of available data on schemes that provide technical assessment or construction quality certification. The study proceeded to investigate European best practice, with secondary detail on international locations where schemes comparable to NSAI Agrément certification are implemented.

In total, 30 initiatives focused on delivering quality in construction have been sampled across standards, technical approval and certification schemes that have relevance to the Irish Agrément process or are applied in the absence of harmonised standards.

The countries that were included in the scope have been mapped in Figure 1. The list of schemes is non-exhaustive as there may be other schemes in operation that were not identified in the NSAI search. Most countries use the term 'technical appraisal' to designate schemes which align to the NSAI Agrément process. A small number of providers offer schemes that explicitly reference Modern Methods of Construction (MMC), while most detail how existing schemes can be applied to innovative materials and systems.

Schemes entirely focused on sustainability or energy performance are considered to have a different scope to Agrément. Such schemes have been identified but not counted in the 30 schemes summarised in Appendix 1.

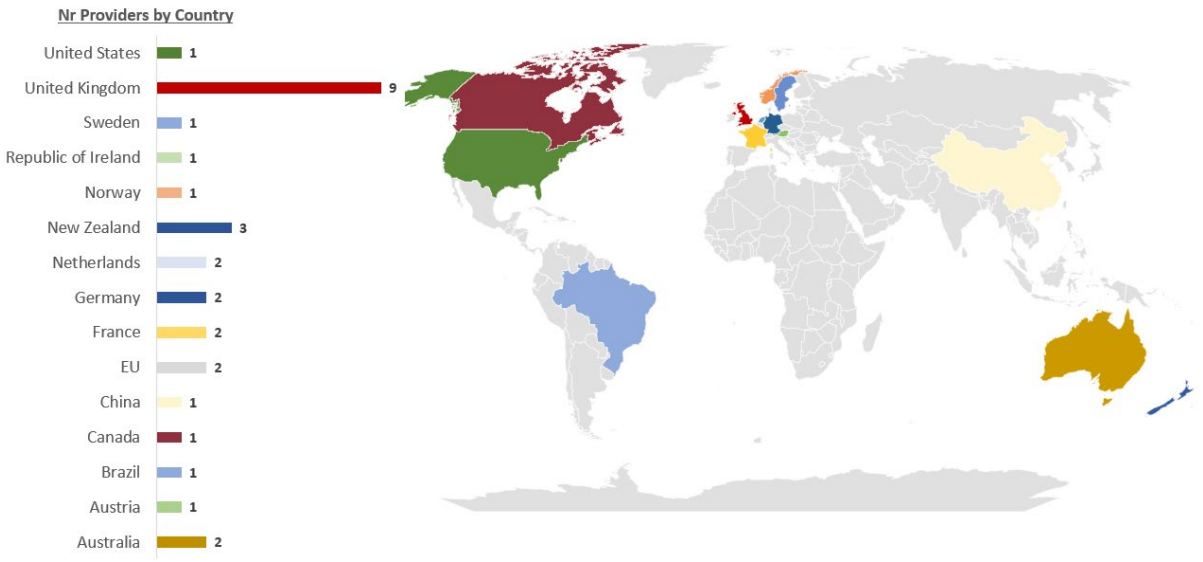

Figure 1. Locations of the 30 technical approval and building quality schemes.

MMC is an umbrella term that encompasses terms such as 'offsite manufacturing' (OSM), 'offsite fabrication or assembly' (OSA), modular construction, prefabrication, precision manufactured homes (PMH) and design for manufacture and assembly (DfMA) and/or design for reuse (DfR).

MMC can offer significant benefits for the European residential sector, such as improving the quality, productivity, sustainability and affordability of housing. MMC can also address some of the challenges faced by the sector, such as skills shortages, construction material inflation, an aging workforce, regulatory barriers and market fragmentation. However, the uptake of MMC in Europe is still relatively low compared to other regions, such as North America and Asia.

Countries like Japan, Germany and Sweden have been more successful than others in driving greater use of OSM to build new housing (Oti-Sarpong, Shojaei, Dakhli, Burgess, & Zaki, 2022). Singapore, China, Canada and the United States are also driving a shift from the use of traditional onsite construction to greater use of OSM. These countries have been identified as having achieved greater use of OSM to build new housing (Savills., 2020).

For example, in Sweden, approximately 84% of all new housing is built using OSM and, historically, between 40% (1976) and 90% (1983) of single-family homes have been constructed with offsite methods (Steinhardt & Manley, 2016).

Use of offsite methods scaled up with the Swedish 'Million Programme' (Miljonprogrammet), which saw one million homes built between 1965 and 1974 (BBC, 2021). In Japan, the proportion of all new housing built using OSM has remained between 12-16% over the past two decades (Seike, 2018). Recent figures estimate that, as of 2019, the proportion had risen to almost 20% of all new built housing in Japan (GCR, Accessed on 03.11.2019.)

2. Scarcity of MMC-specific data

The EU Construction Observatory (EU Construction Observatory, Accessed 22.11.2023) aggregates construction data, but there are limited EU reports addressing the MMC built environment or associated building certification schemes. Many EU member states adopt a federal approach to building regulations, implying that regulations and processes are not harmonised within each country, particularly within the EU-27 jurisdiction. For example, there are nine different building codes in Austria.

The Buildings Performance Institute of Europe (BPIE) published *A Guidebook to European Building Policy* in 2020 (BPIE, Guide on Building Policy, 2020). The BPIE guide highlights a 2023 journal article entitled *Assessment of Building Materials in the European Residential Building Stock: An Analysis at EU-27 Level* (Zandonella Callegher, 2023). The article includes data on construction materials used across the EU but does not specifically address MMC.

Figures 2 and 3 below are extracted from the report and illustrate the evolution of construction materials, post-World War II. The dataset contains disaggregated values for materials, by construction type, at the national level for each EU-27 member state. The data is hosted on the Zenodo platform, which is managed by CERN and is accessible here: https://doi.org/10.5281/zenodo.7984727.

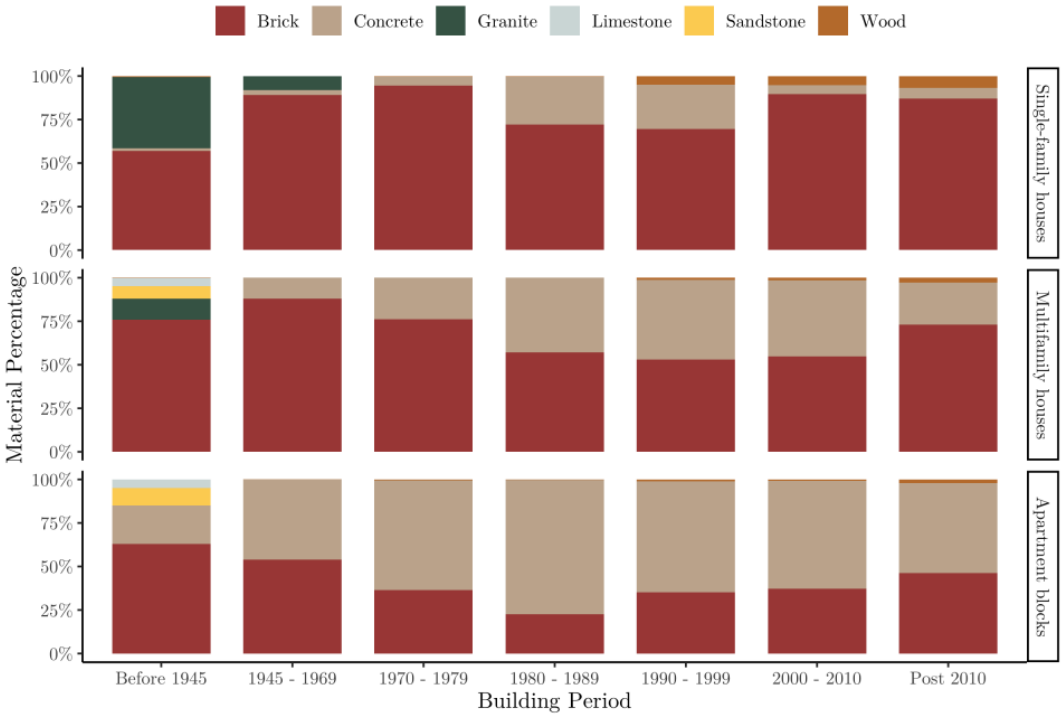

Figure 2. Percentages of wall materials, EU-27 level, with building types. Source: (Zandonella Callegher, 2023).

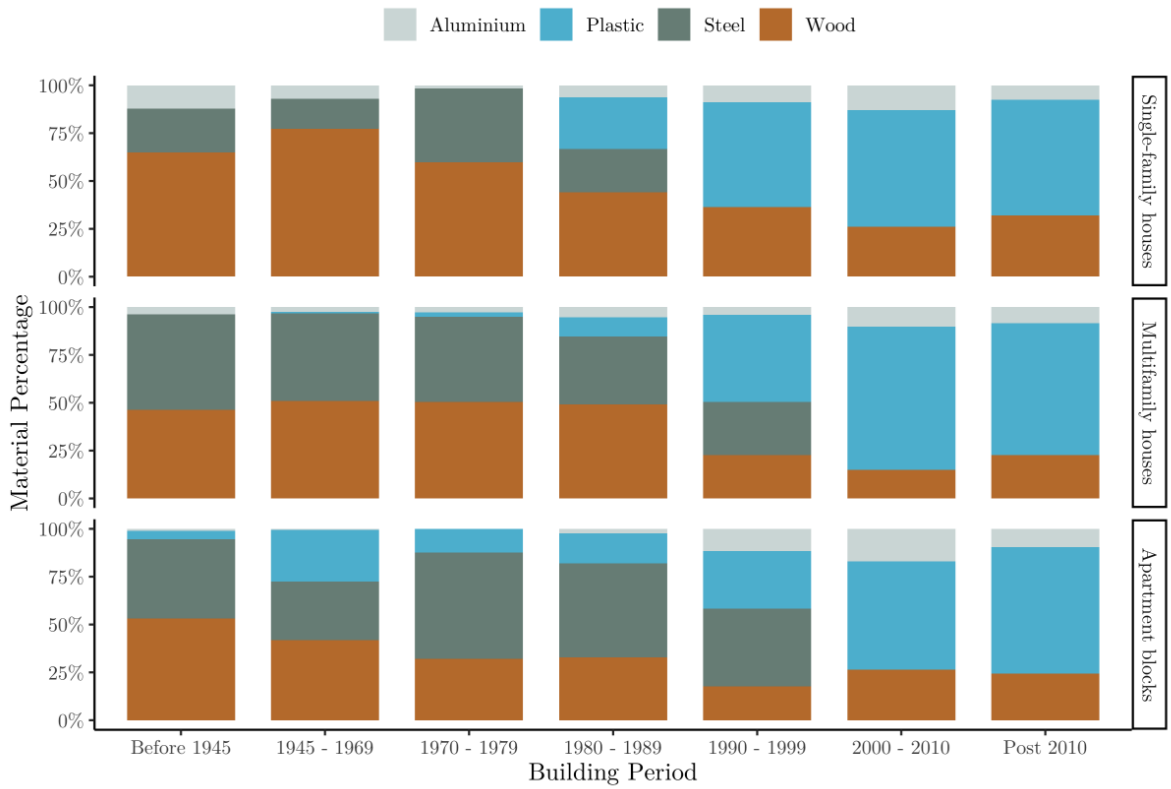

Figure 3. Percentages of window frame materials, EU-27 level, with building types. Source: (Zandonella Callegher, 2023).

The scarcity of summary level data has been acknowledged in the EU report entitled *Implementing the Paris agreement and reducing greenhouse gas emissions throughout the life cycle of buildings*. (BPIE, 2022). Other reports address EU sustainable building frameworks, but MMC is not explicitly addressed, such as *EU Sustainable Buildings Framework* – Irish Green Building Council (igbc.ie).

Similarly, a Eurostat report *Living conditions in Europe – housing* (europa.eu) includes data on housing affordability and occupancy, but does not provide a breakdown of construction types across Europe. Figure 4 illustrates an analysis of overcrowding rates.

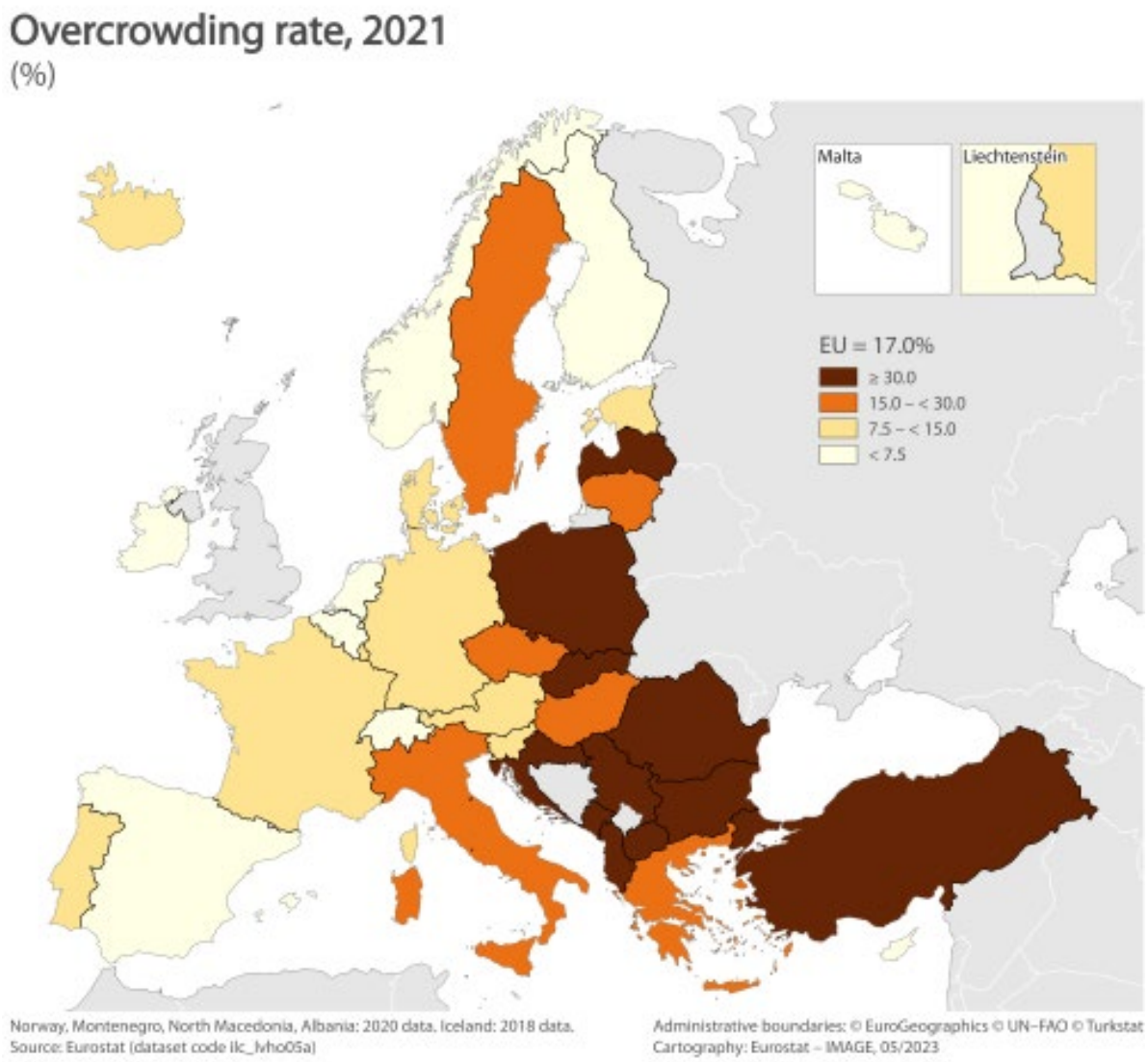

Figure 4. An example of summary data from the EU. Overcrowding data, 2021. Source: Eurostat.

In May 2020, the Construction Industry Federation (CIF) of Ireland formed a working group to analyse and report on the current state of the adoption of Modern Methods of Construction (MMC) in Ireland. The committee consisted of central figures from the housing sector as well as experts from civil engineering, modular manufacturers and general contracting companies.

Tasked with finding solutions to both the housing crisis and the pressures of climate change, the construction industry is increasingly turning to both MMC and offsite construction to meet targets and fulfil demand.

Conducted over the course of four months from February to May 2021, the second report consisted of the insights and experiences from 40 key stakeholders regarding MMC's use and adoption.

After analysis of both the qualitative and quantitative responses given by the stakeholders, the working group established 15 key themes as most important to the future adoption and use of MMC in Irish construction.

The recent CIF MMC reports published within the past three years for Ireland, contain some metrics and macroeconomic indicators related to MMC adoption and implementation in Ireland (CIF, MMC Report, Dec 2021) (Skillnet Ireland, Apr 2022). The 2020 *Building Innovation* report by the Department of Public Expenditure and Reform (DPER) identified actions for co-ordination by the Construction Sector Group (CSG) to support innovation in the Irish construction sector (DPER, Accessed 2023).

A 2020 report on behalf of DPER entitled *Economic analysis of productivity in the Irish construction sector* (KMPG FAC and TU Dublin, 2020) included a detailed roadmap for measures to increase productivity in the Irish construction sector. Both reports identified the importance of digitalisation to increase efficiency and reduce costs.

Subsequently, the European Construction Sector Observatory report on digitalisation (Digitalisation, 2021) includes 2020 status data for the digitalisation activity in each country. Ireland provided summary points on the digitalisation initiatives supporting the evolution of the construction industry and productivity of MMC based housing solutions. These points have been expanded and updated as follows:

- The Construction IT Alliance (CitA) was established in 2001. This research project between TU Dublin (formerly Dublin Institute of Technology) and SETU (formerly Waterford Institute of Technology), progressed the vision of harnessing the potential of ICT in the Irish construction industry. CitA transmits the latest information via monthly events and annual conferences while providing networking opportunities with peers.

- CitA BIM Education Forum Description: The CitA platform aims to develop the conversation around BIM in education in a consistent and joined-up way, and the forum aims to provide an opportunity for CitA members to express their views/opinions, and find out what other organisations are doing with regards to education in BIM pilot projects.

- CIF Construction 4.0 Committee (CIF, Accessed 2023) supported the establishment of the Build Digital Project, to work with the Construction Sector Group (CSG) and CSG Subgroup on Innovation & Digital Adoption. EY participated with a Detailed Description of Needs (DDN) analysis for Enterprise Ireland to develop a Research, Development & Innovation Technology Centre for the construction industry. The Action Group on MMC was established to address one of the seven actions on innovation and digital adoption stated in the KPMG/TU Dublin 2020 report (KMPG FAC and TU Dublin, 2020). This Action Group was initially overseen by the CIF Committee 4.0 to guide the development of the offsite production sector with respect to modular, MMC and offsite fabrication.

- The Build Digital Project – Remit to transform the Irish construction and built environment sectors by enabling all stakeholders, particularly SMEs, clients and suppliers, to develop, maintain and continuously improve their capabilities as digitally enabled, standards-based, agile, collaborative and sustainable participants in the delivery of Project Ireland 2040. Ref: Build Digital Project; Ref: 5 Pillars — Build Digital Project.

• The Office of Government Procurement (OGP) — BIM (Building Information Modelling) mandate requirements for public sector projects Ref: https://constructionprocurement.gov.ie/bim-requirements-in-the-cwmf-from-january-2024/.

• The LGMA (Local Government Management Agency) ePlanning updates under CSG subgroup pillar 6 — Digitise the planning application process (LGMA, Accessed 2023).

In addition to the digitalisation initiatives above, as updated from the 2021 EU report, the following professional and industry groups are developing the MMC ecosystem in Ireland:

- Construction Sector Group CSG
- CSG Subgroup on Innovation and Digital Adoption
- Modern Methods of Construction Leadership and Integration Group – DETE (enterprise.gov.ie)
- MMC Demonstration Park – Mount Lucas Construction Training
- CIF Committee 4.0 – MMC Working Group
- Ireland's National Centre for Construction Technology and Innovation – Construct Innovate™ Construct Innovate – Ireland's National Centre for Construction Innovation
- CIF have established the Smart Offsite Association (SOSA) as a forum for CIF members specialising in MMC/Offsite manufacturing.
- Construction Professionals Skillnet
- MMC Ireland https://mmcireland.ie/

3. Quality schemes by country

3.1 United Kingdom

The UK Building Regulations are the statutory instruments or statutory regulations that seek to ensure that the policies set out in the relevant legislation are carried out. The building regulations are scheduled within 18 separate headings, each designated by a letter (Part A to Part R).

The regulations address workmanship, adequate materials, structure, waterproofing and weatherisation, fire safety and means of escape, sound isolation, ventilation, safe (potable) water, protection from falling, drainage, sanitary facilities, accessibility and facilities for the disabled, electrical safety, security of a building and high-speed broadband infrastructure. The use of appropriate British standards and/or European standards is accepted as one method of complying with the building regulations requirements.

Where harmonised standards do not exist, BBA Agrément certification is accepted as a method of complying with the building regulations in the UK. The NSAI Agrément certification is the applicable scheme for the Republic of Ireland.

Note: BBA (British Board Agrément) certification is no longer valid in the EU-27, post-Brexit, and also the United Kingdom is no longer a member of the EEA (European Economic Area), as referenced in Technical Guidance Document (TGD) – Part D: Materials and Workmanship (2013) accompanying Irish Building Regulations. The National Building Control Office have communicated this in FAQ 4 located on the website (NBCO, 2023).

Definition for this Part	D3	In this Part, "proper materials" means materials which are fit for the use for which they are intended and for the conditions in which they are to be used, and includes materials which: (a) bear a CE Marking in accordance with the provisions of the Construction Products Regulation; (b) comply with an appropriate harmonised standard or European Technical Assessment in accordance with the provisions of the Construction Products Regulation; or (c) comply with an appropriate Irish Standard or Irish Agrément Certificate or with an alternative national technical specification of any State which is a contracting party to the Agreement on the European Economic Area, which provides in use an equivalent level of safety and suitability. "Agreement on the European Economic Area" means the Agreement on the European Economic Area between the European Union, its Member States and the Republic of Iceland, the Principality of Liechtenstein and the Kingdom of Norway as published in the Official Journal of the European Communities (O.J. No. L1, 03.01.1994, page 3).

Figure 5. Extracted from TGD Part D: Materials and Workmanship (2013) document.

CE marking continues to be recognised indefinitely in the UK, post-Brexit (UK Gov, Accessed 2023). The CE mark indicates that a product has been assessed to meet the European Union's safety, health and environmental protection requirements.

CE marking is mandatory for certain products sold within the European Economic Area (EEA), but it does not necessarily mean that the product is fit for all intended purposes. The EEA, as referenced in Part D of the Irish building regulations, includes Iceland, Liechtenstein and Norway (EEA, Accessed 2023).

CE marking is different from UK national approvals, such as UKCA mark, BBA Agrément, etc, which give UK-specific information about the performance and suitability of a product for a particular application in the case where no harmonised standard exists.

The relevant construction quality schemes, standards or applicable guidance documents in the UK region are:

(i) BOPAS
(ii) BRE Product Standard (BPS) 7014 – no longer being applied by BRE
(iii) BBA (British Board of Agrément)
(iv) NHBC (National House Building Council) assessment
(v) Steel Construction Institute (SCI) technical guidance and assessments
(vi) Kiwa (UK office)
(vii) CARES technical approvals
(viii) LPS 1501 Fire test requirements (innovative methods of building construction)
(ix) BSi Publicly Available Specification (PAS in development).

(i) The Build Offsite Property Assurance Scheme (BOPAS) is an accreditation system that gives assurance to lenders, developers, contractors, housing associations and homeowners. The scheme confirms that construction systems that have been designed, manufactured and installed by accredited MMC (Modern Methods of Construction) providers, will conform to industry best practice in terms of durability and system integrity.

The Risk-Based Competency Assessment Process for MMC Providers, as applied in BOPAS, was developed in conjunction with the Council of Mortgage Lenders to address the perceived risks associated with innovative construction. BOPAS also provides a warranty provision that guarantees that the property will be readily mortgageable for at least 60 years. However, some MMC providers are gaining durability assessments up to 100 years.

BOPAS is recognised by the principal mortgage lenders as a reliable and robust scheme that supports the growth and development of the MMC sector. The BOPAS guide can be downloaded (Guide, 2023), subject to registration with the service provider. Appendix 5 to the BOPAS guide details the BLP technical assessment process while Appendix 6 is the process flowchart. A summary of the process is accessible here: The BOPAS Process – BOPAS (BOPAS, 2023) and Frequently asked questions – BOPAS (FAQ, 2023).

Applicants have a 12-month window to achieve their certification, after which a review of the client engagement is initiated.

The BOPAS system is operated by LRQA together with a partner, BLP Technical Services, who is responsible for assessing MMC providers through evaluation of the construction system and resilience testing of systems, processes, and competencies from concept through to the handover. The application form is located here (BOPAS, Application form (LRQA), 2022) and the BOPAS+ Principles are listed as:

- organisational structure
- competency management
- training and development plan
- configuration management
- supply chain
- risk
- contract and document control
- project record methodology

- design and process control
- offsite manufacturing process and competence
- construction/onsite assembly process and competence
- process control, performance, monitoring and improvement
- project completion and handover.

All processes are tested against the arrangements for sustaining integrity and quality of product/service delivery, dealing with environment and project changes, and risk identification and mitigation. The service includes:

- a durability and maintenance assessment
- a process accreditation
- an online database of assessed building systems, registered sites and registered/warranted properties.

(ii) A draft version of BRE Product Standard (BPS) – BPS 7014 was published in July 2019 to underpin the process for MMC. It remains in draft at time of issue of this international study.

It was noted in 2018 by the Building Science Centre that the BRE Group drafted the standard BPS 7014 as the basis for a certification scheme for offsite construction systems and components. BPS 7014 (BRE, 2018) was intended to complement existing sector standards and initiatives, such as the Build Offsite Property Assurance Scheme (BOPAS).

(iii) British Board of Agrément (BBA): A UK certification body for construction products and systems that also provides inspection services in support of product designers and installers. The BBA issues Agrément certificates to evidence fitness for purpose of a construction product and its compliance or contribution to compliance with the various building regulations applying in the United Kingdom.

The BBA also runs the Highways Authorities Product Approval Scheme (HAPAS) for highways products. A scheme handbook (BBA, Scheme Handbook, Handbook), FAQ page (BBA, FAQ) and summary process (BBA, Process summary) are available online. The process map in Figure 6 is available online: https://www.bbacerts.co.uk/news-and-media/news/how-it-works-getting-your-product-certified.

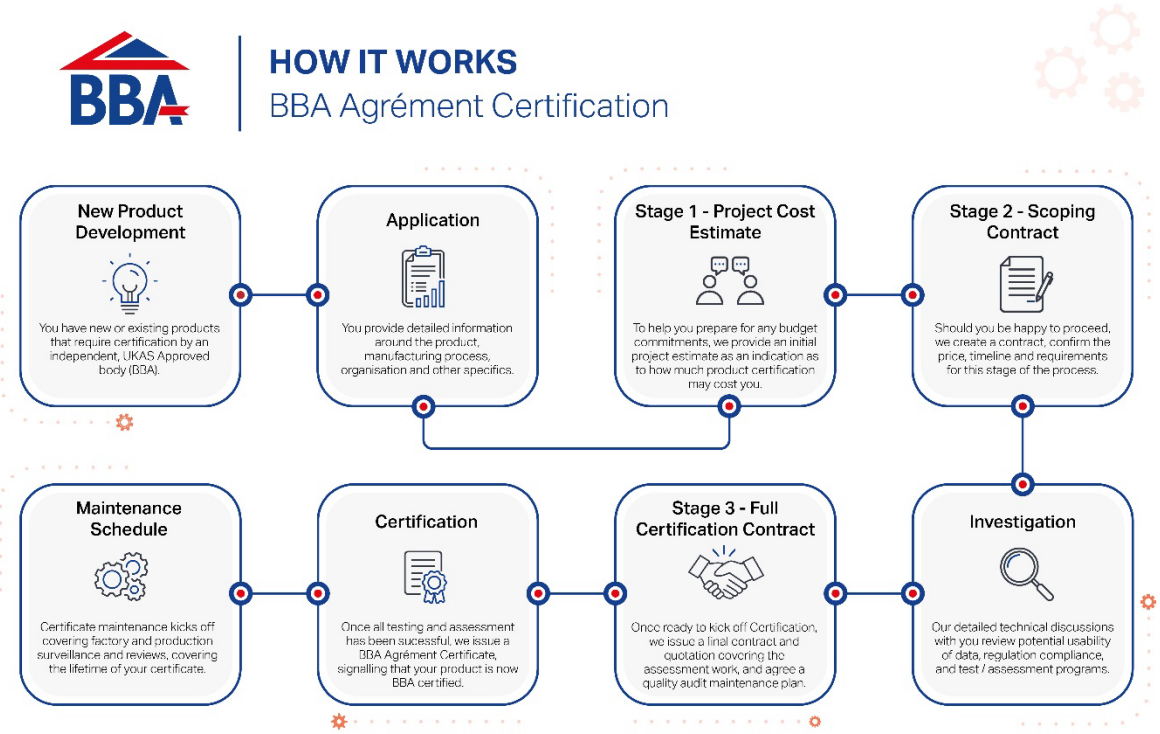

Figure 6. BBA process schematic. Please refer to the online version for ease of access; link included in section 3.1(iii) above.

Due to the varying complexity of projects and the levels of client engagement, the BBA has indicated assessment durations for MMC are difficult to quantify.

(iv) The NHBC (National House Building Council) offer the ACCEPTS assessment scheme for Quality Control of Residential Units, which provides independent and impartial verification of the quality of construction work on residential projects. The scheme aims to help builders and developers achieve high standards of workmanship, reduce defects and improve customer satisfaction. The scheme consists of three main elements:

- **Construction Quality Reviews (CQRs):** These are site-based reviews of the quality of construction work, carried out by NHBC subject experts. The CQRs can cover up to 38 build stages or focus on specific areas of interest, such as fire safety, acoustics, ventilation or cladding.
- **Construction Quality Awards (CQAs):** These are annual awards that recognise and reward the best site managers and their teams for delivering exceptional quality homes. The CQAs are based on the results of the CQRs and other NHBC inspections.
- **Construction Quality Forum (CQF):** This is a platform for sharing best practice, learning from industry experts and networking with peers. The CQF hosts regular events, webinars and workshops on various topics related to construction quality.

The service extends to:

- **Design review:** A comprehensive review of the design drawings and specifications to identify any potential issues or risks that could affect the buildability, durability or performance of the new homes.
- **Site inspection:** A regular inspection of the site during construction to monitor the quality of workmanship and compliance with the NHBC standards and building regulations.
- **Technical support:** A dedicated technical advisor who can provide guidance and advice on any technical queries or challenges that may arise during the design and construction process.
- **Training and CPD:** A variety of training courses and CPD events to help builders and developers to keep up to date with the latest technical developments and best practices in house building.

NHBC Accepts is available for all types of new homes, including conversions and renovations, low-rise and high-rise buildings, timber frame and masonry construction, and traditional and Modern Methods of Construction. NHBC can also provide bespoke services to suit the specific needs and requirements of each project.

Figure 7 outlines the NHBC process map. Figure 8 provides additional details about the NHBC inspection process (NHBC, Inspection Service, 2023). The NHBC Accepts scheme explicitly extends to Modern Methods of Construction (NHBC, NHBC Accepted Systems, Accessed 2024).

Figure 7. NHBC process map. Source: (NHBC, Inspection Service, 2023)

Figure 8. NHBC inspection stage. Source: (NHBC, Inspection Service, 2023)

NHBC also publishes technical standards that define the technical requirements and performance standards for the design and construction of new homes registered with NHBC. *NHBC Standards 2023* includes a chapter on conversions and renovations, which provides guidance on the type of project that will be acceptable to NHBC, the scope of the survey(s) and the work that will be required.

An online version of *NHBC Standards 2023* is available, which has a section on doors, windows and glazing that gives guidance on meeting the associated technical requirements.

It is noted that NHBC is also the UK's leading provider of warranty and insurance for new homes with different products for new build, conversion and renovation projects. The products include Buildmark, Buildmark Choice and Buildmark Connect. Each of these products has its own pricing structure and cover limits, which are based on factors such as the market value, contract price, rebuild cost and floor area of the units.

The NHBC Foundation produced an MMC report in 2018 entitled *Modern Methods of Construction; Who's doing what?* (NHBC, 'Modern Methods of Construction; who's doing what?', 2018).

(v) The Steel Construction Institute (SCI) offers engineering expertise and consultancy services that encompass all areas of development, assessment and specification of products. Information specific to modular building solutions is available (SCI, 2023).
SCI are accredited by UKAS to ISO IEC 17065:2012 to provide product conformity certification. SCI's current accreditation covers self-supporting modular building units (modules) comprising walls, floors and ceilings.

An example of the technical guidance provided by SCI is the SCI P424, which provides complete design guidance for light gauge steel (LGS) framing. The guide includes numerical design examples and construction details for walls, roofs, ceilings and junctions between elements. P424 also addresses the fire resistance of light gauge steel (LGS) framing and this content is summarised here: (NSC, 2021).

The evidence required for an SCI technical assessment includes:

- a product description, and scope
- a system manual
- a quality plan
- design methodology
- test reports
- material specifications and certificates
- factory production control documentation
- comprehensive typical details.

With regard to SCI technical assessment services, the indicative cycle times are six to nine months, depending on the quality of the initial information supplied by the customer and the complexity of the system under assessment.

(vi) Kiwa is an international leader in Testing, Inspection and Certification (TIC). The UK arm of the company has provided BDA Agrément services since 2010. A BDA Agrément® is a document of approximately four to eight pages that covers all relevant aspects about the fitness of the product/kit in its use. The characteristic properties of the product/kit must be determined by an accredited or notified laboratory, and the test reports shall not be older than three years.

The BDA Agrément® (kiwa, BDA Agrément, 2023) forms the assessment part of the Kiwa BDA Certification scheme and typically covers:

- conditions of use
- frame of reference, including standards, relevant codes of practice and test reports
- independently verified product characteristics
- factory production control
- annual verification procedure

- points of attention for the specifier and specific details
- installation procedure
- compliance with building regulations and any other required standards
- boundaries of use (restriction to geographical scope)
- validity aspects.

The BDA Agrément® is issued by ECBE (Expert Centre Building Envelope) and signed by the chairman and/or the responsible assessor. The BDA Agrément® is authorised by the technical director of BDA Advies, a division of Kiwa. A BDA Agrément® can be linked to a Kiwa certificate, but only if the BDA Agrément® relates to a product and its geographical scope does not cover the Netherlands (kiwa, Agrément v's kiwa conformity certificate, n.d.).

The BDA Agrément® assessment process takes into account:

- European product standards, relevant codes of practice and test reports
- independently verified product characteristics
- factory production control
- annual verification procedures
- points of attention for the specifier and specific details
- installation procedure
- compliance with Building Regulations and any other required standards
- boundaries of use (restriction to geographical scope)
- validity.

Note: BDA Agrément® information does not supersede any product Declaration of Performance (DoP) essential characteristics under harmonised European standards. Ref: BDA Agrément® Services | Kiwa UK Group

(vii) CARES offers a number of certification schemes.

- CARES offers a technical approval service to manufacturers of reinforced concrete products to gain official recognition and acceptance for their non-standard or new and innovative products. (CARES Technical Approvals, Accessed 2023).
  CARES is an approved body under the Construction Products Regulation (as amended by the Construction Products (EU Exit) Regulations 2019 and 2020). This allows for the issuing of UKCA/UKNI marks for those construction products which have a designated standard or an ETA/UKTA.
- With regard to sustainability, the CARES Sustainable Constructional Steels (SCS) scheme is noted as an accredited, independent and impartial certification scheme with the objective of improving the environmental, social and economic management of steel manufacturers and processors as well as improving the performance of products. Launched in 2009, the ninth version was released in 2020 to help deliver more sustainable construction and infrastructure across the entire global supply chain.

(viii) LPS 1501. Fire test and performance requirements for innovative methods of building construction, was developed by BRE Global and Issue 1.1 is dated 2014. It aims to help provide insurers, fire services and regulatory authorities with the assurance that building systems, such as panelised systems, maintain acceptable levels of fire protection in terms of property protection (IFSEC, Accessed 2023).

The LPS1501 standard is intended to provide a fire test, performance and classification system for innovative building systems used in building construction.

The primary objective of this LPS standard is to provide insurers, fire service and regulatory authorities with evidence that such products maintain acceptable levels of fire safety in respect to property protection and thus create confidence in the development and use of innovative building systems for applications of any number of storeys in height. In this context the scope of the standard covers the fire performance and LPCB approval of innovative building systems (pre-assembly or modular buildings) (Fire Academic, Accessed 2023).

(ix) In January 2023, the UK government announced the British Standards Institution (BSI) will develop a universally recognised standard for homes built using MMC. This will reduce costs and allow more to benefit from the technology – delivering more homes across the country and helping thousands of young people and families onto the housing ladder (BSI, 2023).

The new requirements will be introduced by the BSI via a Publicly Available Specification, PAS 8700. BSI engaged with professionals via a webinar on 6 June, 2023, which outlined the proposed content of the PAS and invited contributions to its development.

The role of trade associations in disseminating information and supporting a quality ecosystem is also acknowledged. For example, the British Constructional Steelwork Association (BCSA) has been representing the UK and the Republic of Ireland structural steel sector since 2006 (BCSA, Accessed 2023). The Light Steel Frame Association is a leading body for Modular Construction. The Building Engineering Services Association (BESA) published *TR39 – An Offsite Guide for the Building and Engineering Services Sector* in October 2015, which is 146 pages long.

Ref: https://www.thebesa.com/besa-publication-details-non-member?id=7684514480294

Ref: https://pubhtml5.com/vbpm/ttvb/ – link to online ebook version of *TR39 – An Offsite Guide for the Building and Engineering Services Sector*.

3.2 Germany

German Building Regulations govern the design and execution of construction works in Germany, as well as the use of construction products and techniques. The building regulations are based on a common model, the Model Building Code (Musterbauordnung, MBO), which has been adopted by the 16 federal states with some variations.

The building regulations specify the basic requirements for construction works, such as safety, health, environmental protection, energy efficiency and accessibility.

Deutsches Institut für Bautechnik (DIBt) (DIBt, accessed 2023): This German institute issues national technical approvals and general construction technique permits for construction products and techniques that are not covered by harmonised European standards or European Technical Assessments.

The DIBt also provides services such as testing, inspection, certification, building research and market surveillance. Structural design type approval | DIBt – Deutsches Institut für Bautechnik

The 'structural design type' approval, in bullet points below, includes similar characteristics to the Irish Agrément process. However, the DIBt offering extends to variations on the core product or system. These changes to configuration are termed 'execution' variants.

- Once verified, the structural design type can be used across multiple projects.
- The verified design may be used at various sites in Germany.
- The structural design type approval can include several execution variants or subtypes. This is intended to support clients in flexibly respond to local conditions (for example, different snow or wind load zones) while achieving the most cost-efficient design.
- The structural design type approval can be amended at any time to include additional sizes or changes in geometry, application etc.
- The evaluation report is valid for up to five years (renewable).
- The essential features of the structural design can be summarised in a 'type sheet'. Approved type sheets facilitate communication among building professionals.
- The DIBt approval stamp attests to the safety of the structural design type and helps secure the trust of customers.

The Structural Design Control Authority at DIBt is part of the DIBt network. Where an application includes innovative components requiring assessment, DIBt will assign the competent product approval expert.

Germany also operates a construction quality certification scheme called the DGNB system, which stands for Deutsche Gesellschaft für Nachhaltiges Bauen (German Society for Sustainable Building) (DGNB, Accessed 2023).

The DGNB system is a globally recognised and advanced certification system for sustainable buildings and districts. The DGNB system pursues a holistic approach to sustainability that encompasses a wide range of criteria, such as ecology, economy, socio-cultural quality, technical quality, process quality and location quality. The various certification options are shown in Figure 9.

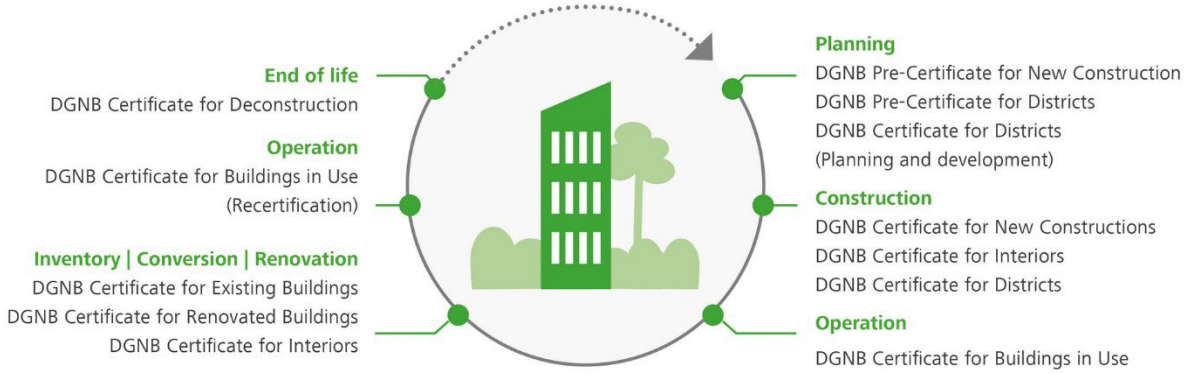

Figure 9. DGNB certification. Source: (DGNB, Accessed 2023).

The DGNB system is available in different variants for buildings, districts and interiors, depending on the type of use and the life cycle phase of the project. The DGNB system also considers the entire life cycle of a project and evaluates the overall performance of a project instead of individual measures.

The DGNB system is based on a transparent and independent certification process that serves as a quality control. As proof of this quality in building, a DGNB certificate in platinum, gold or silver can be obtained. For projects outside Germany, there is a special procedure for DGNB certification that involves local partners and adaptation to local conditions.

3.3 Sweden

Sweden has been a pioneer in MMC (Builtoffsite, 2017) with the Million Programme in the 1960s resulting in one million homes built between 1965 and 1974 (BBC, 2021) (Hall&Vidén, 2006). Since then, White Arkitekter has honed this method, designing entire neighbourhoods that are prefabricated.

MMC is ideal for building at scale because you can repeat (the design), produce in a controlled environment, maintain the quality, create less waste and work to a predictable time frame.

It is possible to produce buildings using unskilled labour and machines to replace skilled labour (BBC, 2021). Most of the buildings and areas of this era have survived quite well with routine maintenance, but in several multi-family housing areas more thoroughgoing measures have been needed.

The development patterns can be divided into six categories: everything from maintenance and conventional daily care to large-scale turnaround and demolition (Smart, 2020). Historically, between 40% (1976) and 90% (1983) of Swedish single-family homes have been constructed with offsite methods (Steinhardt & Manley, 2016).

Boverket (Boverket, 2023) is the Swedish National Board of Housing, Building and Planning. This government agency is responsible for developing and implementing the building legislation, supervising the building sector and providing guidance and information to the public and the industry.

Boverket also issues national technical approvals and European Technical Assessments for construction products and systems that are not covered by harmonised standards.

Boverket has published information on accepted assessment methods to verify the performance of construction products in addition to a database of accredited bodies who are authorised to certify products (Boverket, 2023).

Accreditation is carried out by the national accreditation body, SWEDAC. A manufacturer of construction products may choose a certification body from other countries as long as the body is competent to carry out assessments of the construction product or of production control. Search tool for accredited bodies: Search for accredited bodies – Swedac

RISE is Sweden's research institute (RISE, 2023) and innovation partner and is designated by the Swedish government as a Technical Assessment Body (TAB). TABs – Find a partner for your ETA | EOTA. The role of EOTA in appointing a TAB is detailed in section 3.14 below.

The Swedish Green Building Council (SGBC) is a non-profit organisation that promotes sustainable building practices in Sweden. The SGBC is a member of the World Green Building Council and operates the Miljöbyggnad certification scheme for buildings in Sweden. Miljöbyggnad is a comprehensive and holistic environmental assessment method that evaluates the performance of buildings across a range of criteria, such as indoor environment, energy use and materials.

Figure 10. A prefab wall panel at the EKSJÓHUS factory in Sweden.

3.4 Norway

The Norwegian Building Authority, Direktoratet for byggkvalitet, (DiBK) is the government agency responsible for developing and implementing the building legislation, supervising the building sector, and providing guidance and information to the public and the industry. The DiBK also issues national technical approvals and European Technical Assessments for construction products and systems that are not covered by harmonised standards (DiBK, n.d.).

The DiBK specifies the minimum technical requirements that buildings must meet in terms of safety, health, environment, energy and accessibility (DiBK, Regulations on technical requirements for construction works TEK17, 2017). The regulations cover a broad range of topics, such as fire safety, indoor climate, noise protection, structural safety, water supply, waste management, universal design and energy performance.

The 'central approval' process in Norway is a voluntary quality scheme for companies in the construction industry that want to document their professionalism and expertise. The process involves the following steps:

- The company must have a Norwegian organisation number and be registered in the Register of Business Enterprises or the Register of Legal Entities.
- The company must have a professional management with relevant qualifications, which match the approval area for which the company is applying. The qualifications must be documented with original certificates and transcripts, translated into Norwegian, Swedish or Danish.
- The company must have quality assurance procedures for the fulfilment of planning and building legislation. The procedures must be adapted to the company's activities and scope.
- The company must apply for central approval of the right to accept responsibility in a Scandinavian language (Norwegian, Swedish or Danish) using an online application form. The application fee is 3,000 NOK for each approval area.
- The Norwegian Building Authority will assess the application and grant or reject the central approval within 30 days. If the application is incomplete or unclear, the authority may ask for additional information or documentation.
- If the central approval is granted, the company will receive a certificate of central approval and a seal of quality that can be used in marketing and communication. The certificate is valid for three years and can be renewed by submitting a new application.
- The company must comply with the planning and building legislation and the terms of the central approval. The Norwegian Building Authority may revoke or suspend the central approval if the company fails to do so or if there are serious complaints or breaches of trust.

More information about the central approval process and its benefits are detailed on the website of the Norwegian Building Authority (DiBK, Central Approval, n.d.).

Norwegian Green Building Council (NGBC): This is a non-profit organisation that promotes sustainable building practices in Norway. The NGBC is a member of the World Green Building Council and operates the BREEAM-NOR certification scheme for buildings and districts in Norway.

BREEAM-NOR is a comprehensive and holistic environmental assessment method that evaluates the performance of buildings and districts across a range of criteria, such as management, health and wellbeing, energy, transport, water, materials, waste, land use and ecology, pollution and innovation.

Norway has been applying MMC in various projects and sectors, such as housing, education, health and transport. Some examples of Norway's application of MMC are:

- **The Plus House:** This is a project that involves building a series of modular houses that produce more energy than they consume. The houses are designed by the architecture firm Snøhetta and manufactured by the company Rindalshytter. The houses are made of prefabricated timber modules that are assembled on site. The houses feature solar panels, heat pumps, smart ventilation and insulation systems that make them energy-positive.
- **The Oslo Airport Expansion:** This is a project that involves expanding Oslo Airport by adding a new terminal building, a pier, a baggage handling system and a railway station. The project uses volumetric construction to create large-scale modules that are transported to the site and lifted into place. The modules include structural elements, façades, roofs, interiors and technical installations. The project aims to reduce construction time, costs and environmental impacts.
- **The FutureBuilt Programme:** This is a programme that supports the development of climate-friendly and high-quality urban areas in the Oslo region. The programme involves 50 pilot projects that demonstrate innovative solutions for reducing greenhouse gas emissions by 50% and enhancing urban quality. The programme uses panelised systems and hybrid systems to create buildings that are energy-efficient, adaptable and attractive.
- **18-storey timber-framed building** https://www.architecturaldigest.com/story/worlds-tallest-timber-framed-building-finally-opens-doors
- Sweco provided structural design, fire, acoustic and concrete services for the ground-breaking project, and worked closely with its project partners AB Invest A/S, Voll Arkitekter, Moelven Limtre and HENT, to successfully navigate some of the unique challenges posed by using timber in tall tower buildings. https://www.sweco.co.uk/insights/news/sweco-takes-sustainability-to-new-heights-with-worlds-tallest-timber-building/
- Sweco has a specialist building standards division: https://www.sweco.co.uk/services/building-standards/
- Mjøstårnet (moelven.com)
- **14-storey timber-framed 'Treet'**; Eur. J. Wood Prod. (2016) 74:407–424 DOI 10.1007/s00107-016-1022-5.

©Optimera

Figure 11. MMC assembly stage by Norwegian company Optimera (SAINT-GOBAIN, 2022)

A market study on the sustainable building sector in Norway has compared its strategy with the Netherlands. The contribution of the construction sector to waste minimisation is summarised but MMC is not specifically identified. (Norway, 2021)

3.5 The Netherlands

The Dutch building regulations are defined in the Building Decree 2012. This royal decree contains the technical regulations that represent the minimum requirements for all structures in the Netherlands. The requirements relate to safety, health, usability, energy efficiency and the environment. The Building Decree 2012 also sets out the Almost Energy Neutral Building requirements (BENG) for new buildings, which are intended to reduce energy consumption.

Municipal building rules: These are the rules that relate to urban planning, building on contaminated land and requirements regarding the external appearance of buildings. Building rules can differ from one municipality to another.

In the Netherlands, NEN, the Royal Netherlands Standardisation Institute, connects stakeholders to assist agreement in respect of standards and guidelines.

NEN was founded in 1916 and has been enshrined under royal decree since 2016. It has grown into a standards organisation with more than 300 employees, consisting of more than 550 standards committees and some 5,500 active committee members in their network. NEN supports the standardisation process in the Netherlands. It does this within national and/or international standards committees.

NEN manages over 31,000 standards. Those are the international (ISO, IEC), European (EN) and national (NEN) standards accepted in the Netherlands. In total, over 800 standards committees are

active, with in total over 5,000 standard committee members. NEN manages the extensive standards collection and co-ordinates the national, European and international standards committees, thus requiring a high-quality infrastructure of organisation participation.

Ref: Home – NEN

KIWA was originally an acronym in capitals for Keuringsinstituut voor WaterleidingArtikelen (Institution for the Examination of Waterworks Articles). The organisation has expanded and the rebranded Kiwa has offices in multiple countries, as evidenced earlier regarding the UK. The Kiwa BDA Agrément scheme is offered across Europe.

In the Netherlands, Kiwa BDA is delivered through their engineering firms BDA Dakadvies, BDA Geveladvies and the Kiwa BDA Testing laboratory (kiwa, BDA Roof and Facade Advice, accessed 2023). Within the engineering entities, roof and façade experts, consultants and inspectors are working on sustainable building envelopes. In collaboration with Kiwa BDA Testing, they support manufacturers throughout Europe in product development and the preparation of quality declarations, including the BDA Agrément, EADs and ETAs (kiwa, BDA Agrément (Netherlands), NL).

The BDA Agrément® is issued by ECBE (Expert Centre Building Envelope) and signed by the chairman and/or the responsible assessor. The BDA Agrément® is authorised by the technical director of the BDA Advies unit. A BDA Agrément® can be linked to a Kiwa certificate, but only if the BDA Agrément® relates to a product and its geographical scope does not cover the Netherlands (kiwa, BDA Agrément PDF, n.d.)

VCA

A construction quality certification scheme called VCA operates in the Netherlands. This stands for (in Dutch) Safety, Health and Environment Checklist for Contractors, which implies a management system-focused scheme and is therefore similar to the ISO 9000 quality system.

It is also supportive of the management systems such as ISO 14001 and OHSAS 18001 and companies supplying construction services may be tested and certified for their VGM administration system. VGM (Dutch) stands for Safety (Veiligheid), Health (Gezondheid), Environment (Milieu). VCA certification is recognised by many customers in the Netherlands and abroad as a condition for those who wish to carry out work in the Dutch jurisdiction.

Ref: About VCA – VCA Direct : VCA Direct

3.6 France

The Avis Technique (or ATec) is a certification issued in France attesting to the performance and innovation of a product in accordance with French construction standards. This opinion is formulated by a group of experts representing the various professions, known as the Groupe Spécialisé (GS). With the help of the Centre Scientifique et Technique du Bâtiment (CSTB), this group assesses the suitability for use of innovative products introduced onto the French market.

The assessment of a product to obtain the ATec is based on a rigorous audit of the manufacturing processes and checks on the quality and performance of the product. These checks are carried out by certified, independent laboratories.

ATecs are approved and issued by the Commission Responsible for Issuing Technical Appraisals (CCFAT) attached to the ministry in charge of construction and housing. Technical Appraisal – Assessments – CSTB Evaluation

The Commission for Technical Advice (CCFAT) (CCFAT, accessed 2023) grants the technical approvals but relies on the content of the ATec, as compiled by the relevant Specialised Groups (GS), as the basis for the technical assessments, https://evaluation.cstb.fr/en/technical-appraisal-atec.

The process was updated in 2019 and has been in effect since January 2021. The revisions created a new pathway for the applicant to promote exchanges between the applicant and the Specialised Group responsible for the technical appraisal. Figure 12 below is taken from the report on the revised assessment process (ccfat-bilan-modernisation-avis-technique.pdf).

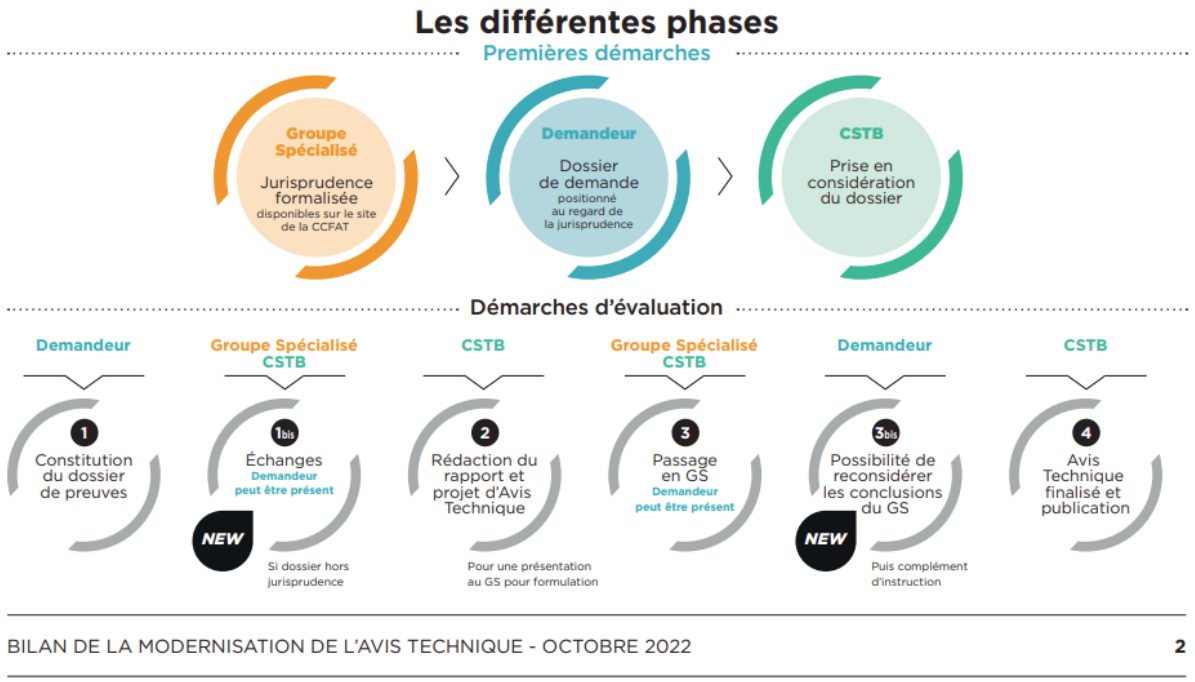

Figure 12. Source: https://www.ccfat.fr/doc/ccfat-bilan-modernisation-avis-technique.pdf

The request for a technical approval is voluntary, but the existence of a valid technical approval is often relied upon to establish the level of confidence in innovative systems. The technical notices are reference documents for insurers and technical inspectors.

Thus, products and processes under technical approval included in the "green" list by the Product Prevention Commission (C2P) of the Construction Quality Agency (AQC), generally benefit from the

same insurance conditions from insurers as those applied to traditional construction techniques, such as those covered by standards and unified technical documents (NF DTU).

The Construction Quality Agency (AQC) maintains a document depository with categories shown in Figure 13.

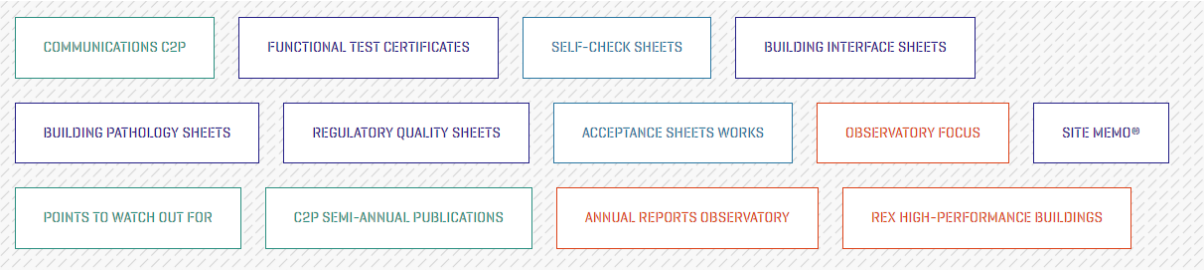

Figure 13. Source: https://qualiteconstruction.com/nos-ressources/

The CCFAT relies on one of its members, the CSTB, to manage the following aspects of the process:

- CSTB examines Technical Appraisal applications and reports them to the Specialised Groups
- CSTB manages the Secretariat of the CCFAT, records the Technical Appraisals issued and publishes them on the CSTB website
- public contracts are statutorily governed by the Documents Techniques Unifiés (DTUs), which set out rules for design, building and structural calculations and are the basis for the Technical Appraisals.

Apave is an example of a certification body that can provide an ATec to support an application for Technical Approval, as detailed above. It is noted that Apave defines an ATEx (Technical Experimentation Assessment) as a rapid technical evaluation procedure formulated by a group of experts on any innovative product or process.

The French law of 4 January 1978 established the legal basis for the technical inspection of construction (contrôle technique de la construction) (Apave, Controle-technique-de-construction, 2023). Numerous product certification bodies exist that assess innovative products for compliance with the regulations. Apave has product repositories available on its website; apave-certification.com (Apave, Product Search , 2023).

3.7 Austria

The Austrian Institute of Construction Engineering (OIB) (OIB, Accessed 2023) is a non-profit organisation that develops and publishes technical guidelines for the construction sector. The OIB issues European Technical Assessments (ETA) and Austrian Construction Engineering Approvals (BTZ) for construction products.

Thus, innovative products can obtain a CE or ÜA label. The OIB also provides technical guidance on fire protection, structural design, energy efficiency and accessibility. The OIB guidelines are harmonised with the EU directives and regulations, and are recognised by all federal states in Austria.

The Austrian Standards Institute (ASI) is the national standards body that develops and publishes national standards (ÖNORM) for various fields, including construction. The ÖNORMs are voluntary technical rules that reflect the state of the art and best practices in the industry. Some of the ÖNORMs are based on or equivalent to European or international standards, such as EN or ISO.

A detailed description or reproduction of the Austrian building laws and building regulations is not possible as there are nine different building codes in Austria. This reflects the federal approach to building regulations observed in many countries in Europe.

3.8 New Zealand (NZBC)

New Zealand has multiple routes for demonstrating products or systems comply with the building code and the government of New Zealand has published advice for stakeholders regarding how to show their products comply with the building code (Govt.nz, Building Performance, 2023).

Two appraisal schemes 'BuiltReady' and 'MultiProof' are detailed here (Gov.nz, Product Assurance, Certification Schemes 2023). BuiltReady is MMC specific and this appraisal route mirrors the Irish Agrément process. BuiltReady is a voluntary offsite manufacturer certification scheme that has been designed to support innovative and efficient building methods. BuiltReady (Govt.nz, BuiltReady, 2023) gives consumers more building choices and reduced building and consenting times and costs.

The alternative 'MultiProof' scheme is designed for builders and companies who build standardised designs. It provides evidence of compliance for Building Consent Authorities and to be eligible you must have the intention and the ability to build an approved design at least 10 times over two years.

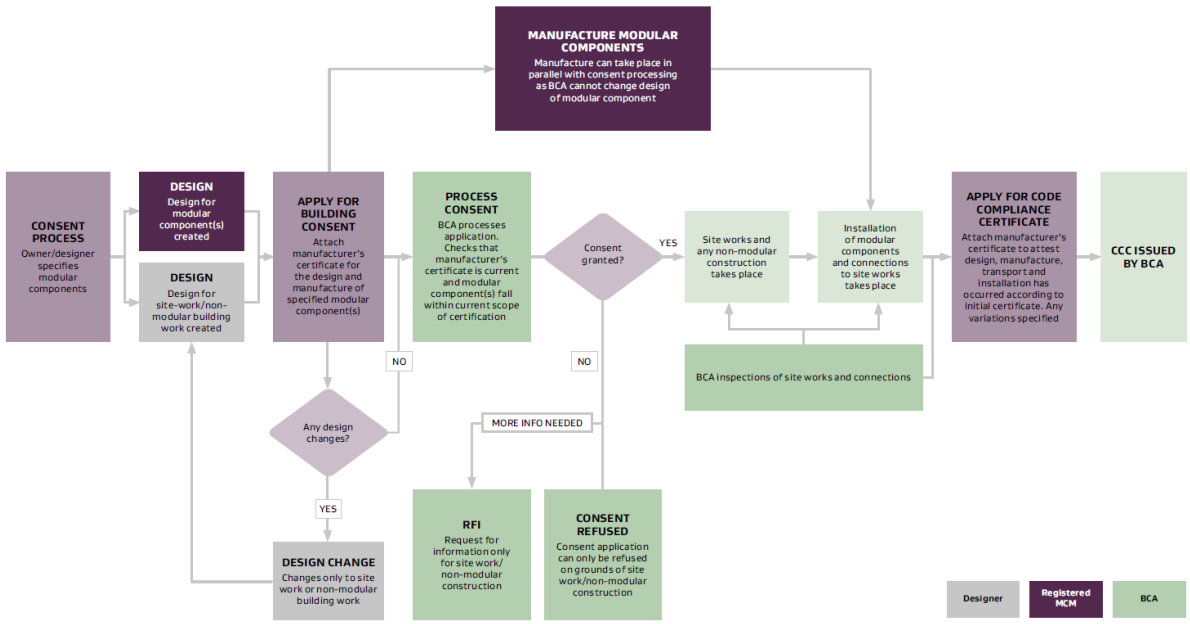

Figure 14. Certification pathway for modular manufacturers. Source: (Gov.nz, MINISTRY OF BUSINESS, INNOVATION AND EMPLOYMENT, 2022).

The BuiltReady scheme launched in late 2022 is an appraisal scheme specifically addressing MMC and is designed to expedite the building consent process (that is, the NZ Building Control Authority process.) To achieve the certification, manufacturers must use an accredited and registered modular component manufacturer certification body (MCMCB). Figure 15 demonstrates the process.

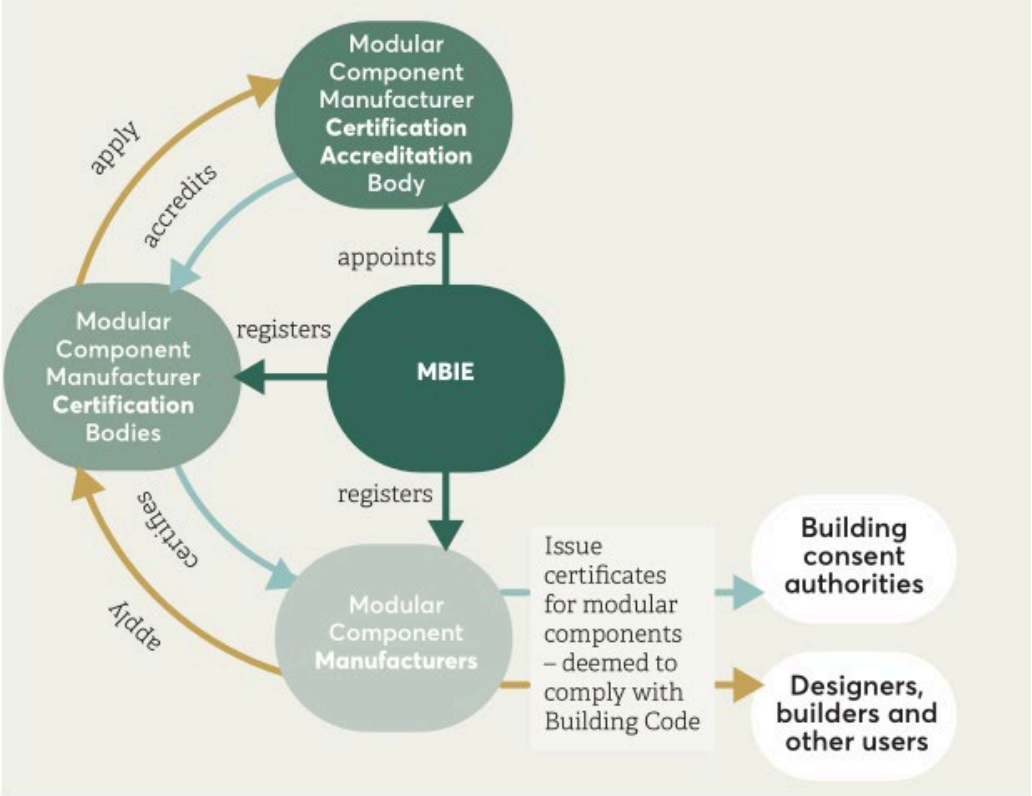

Figure 15. BuiltReady MMC scheme process. Source: https://www.buildmagazine.org.nz/index.php/articles/show/builtready-scheme

In addition to the government-led schemes identified above, industry-based schemes are also in operation in New Zealand:

- Industry-based schemes are based on product families or sectors. The product is assessed against specified and audited industry requirements.
- Industry-based schemes are voluntary. Manufacturers who belong to these schemes are responsible for making sure their products comply with the scheme requirements, as assessed by the industry organisation.

An effective industry-based scheme has:

- publicly available rules that outline the scheme framework
- a regular, publicly available programme of independent compliance audits
- a means by which complaints can be raised and dealt with
- clearly-stated penalties which can be applied if there is a breach of scheme rules, governance or expected quality of a product or system
- a governance structure consisting of industry, user and independent representatives whose role is to ensure the scheme's ongoing integrity.

Examples of industry-based schemes are:

- ready-mixed concrete, which is assessed by the New Zealand Ready Mixed Concrete Association
- glass certified by the Insulating Glass Unit Manufacturers Association.

Independent assessments

Independent assessments involve the verification of product information by competent assessors. These might include chartered professional engineers, technical experts and recognised testing laboratories.

Manufacturer or suppliers usually carry out their own product testing and analysis first. An independent assessment reviews and verifies their results. This is then recorded as an endorsement to their technical information.

Appraisals (mirrors the current Irish Agrément certificate scheme)

An appraisal is a technical opinion of a building product or system's fitness for purpose. An appraisal organisation should be independent of the product's manufacturer or distributor.

It involves extensive testing, assessment and verification of Building Code compliance, and is done by an independent appraisal organisation. An appraisal looks at any specific installation systems or processes. It recognises limitation on a product's intended scope of use.

Appraisals have no legal standing in New Zealand. However, they can be used as evidence of compliance. The product will be assessed against a wide range of performance factors including:

- the requirements of the Building Code
- performance under test conditions
- in-service performance
- accuracy of the product's technical information
- manufacturing procedures and quality control systems.

The appraisal may follow a standard assessment process if the product has few or no innovative features (for example, window frames). However, the appraisal may be specifically designed if it is testing a new or innovative building product, construction, system or feature. Appraisal organisations should have:

- thorough and validated testing procedures (for example, its processes are reviewed by a third party)
- suitably qualified staff (such as engineers and research scientists)
- regular inspections to ensure the product conforms during manufacture
- regular inspections to ensure the product conforms when in use
- knowledge of the Building Code and building science.

Appraisal organisations from outside New Zealand may provide technical assessments but the product must be assessed against the New Zealand Building Code. Examples of New Zealand-based research organisations that may be relied upon for independent appraisals include Branz and Scion, which are detailed below.

Building Research Association of New Zealand (BRANZ) is an independent and impartial research, testing, consulting and information company providing services and resources for the building system. BRANZ is funded in part by the building research levy generated from New Zealand's building and construction industry. Building systems that delivers better outcomes for all | BRANZ

According to BRANZ, the time needed to complete an appraisal varies. If all the required supporting information is provided at the start, the process usually takes three to four months. The process will take longer (a duration of six to 12 months is typical) where:

- the product or system is still under development
- supporting information is not available
- supporting information is unsatisfactory
- additional testing is required.

In respect of building control, Building Consent Authorities ("BCAs") assess consent applications for Building Code compliance. A report by Building Confidence Ltd. outlines one perspective on practical issues in the New Zealand building regulatory system (Gardiner, 2022).

Product certification (CodeMark)

The New Zealand CodeMark scheme is voluntary and provides an easily-understood and robust way to show a building product or system meets certain performance requirements of the Building Code. The product certification scheme was established by the Building Act and is administered by MBIE. The current scheme is known as CodeMark.

If a building product or system is certified under CodeMark, BCAs must accept it as complying with the Building Code (when used as specified).

Those who use a product will still need to apply for a building consent for their building work. Only accredited product certification bodies can assess building products or systems for this scheme.

There are some third-party certification bodies that are not CodeMark accredited but that do assess products against the requirements of certain standards or the Building Code and issue product certificates. Certification under these schemes is different from CodeMark in that the certificate does not have to be accepted by BCAs as evidence of compliance with the Building Code. However, it may still help as part of product assurance options to demonstrate compliance with the Building Code; particularly if the certification body is well known and reputable.

With regard to timber products and systems, Scion is a Crown Research Institute that specialises in research, science and technology development for the forestry, wood product, wood-derived materials and other biomaterial sectors.

3.9 Australia (BCA)

The Australian government has a clear guide to building product conformity: A Guide to Australian Building Product Conformity (abcb.gov.au) (Gov A. , 2023). Section 4 of the guide details the evidence required to assure conformity. Figure 16 illustrates the elements of the Australian process. As part of the planning and building system, each state/territory has a scheme of building certification (also called building surveying or auditing). These schemes authorise and regulate the activity of local council and/or private practitioners in certifying the design and construction of buildings.

JAS-ANZ is the Joint Accreditation System of Australia and New Zealand. JAS-ANZ has accredited over 130 conformity assessment bodies (as of 2021) that have certified over 140,000 organisations in over 100 countries. A certificate from a product certification body accredited by JAS-ANZ is the conformity route for proving compliance with the relevant standards.

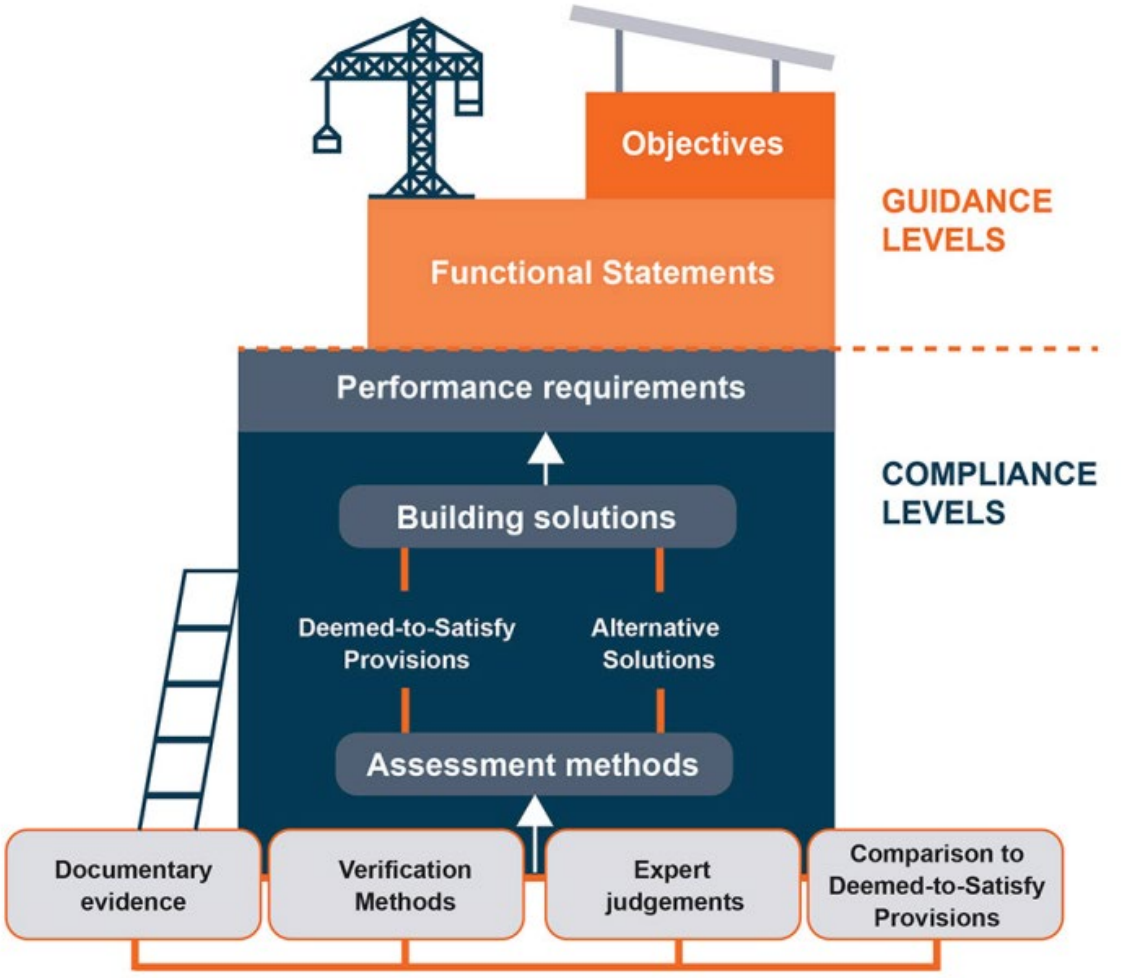

Figure 16. Australian conformity pathway. Source: Australian Building Codes Board. abcb.gov.au.

NATA and JAS-ANZ will generally accredit a testing lab or certification body to issue certificates or reports against a scope of accreditation to specific Australian standards, where such standards exist.

Furthermore, the NCC and Australian standards have been designed generally requiring testing or approval against specific and separate tests, for example, fire or acoustics. Hence that product requires multiple tests to show the full suite of NCC compliance rather than holistic performance of the completed element test.

Similarly, given the NCC and Australian standards are written generically, many of the modular and prefab construction products and systems differ greatly from manufacturer to manufacturer, so a single standard or specification may need to be developed specifically for that product.

Building product conformity in Australia, with respect to modular construction, has been addressed by this report (HIA, 2022).

It is noted that a paper was published in 2022 on the challenges confronting the growth of sustainable prefabricated building construction in Australia. This included a survey of 310 construction professionals (Navaratnam, et al., 2022, Vol. 48).

In conjunction with the detailed design and construction requirements of the NCC and Australian standards, a core component is requirements for building product testing, certification and approval (building product conformity).

The National Construction Code (NCC) contains building product conformity requirements under the 'evidence of suitability provisions,' which lists ways that a material, design or product can demonstrate compliance with the NCC requirements.

Many of the Australian standards referenced in the NCC contain testing requirements for products to show compliance with that standard. Under these provisions the NCC provides the following methods to demonstrate compliance:

- CodeMark certificate of conformance
- certificate of accreditation under a state government certification scheme (where one
- exists)
- test report by a National Association of Testing Authorities (NATA) lab
- certificate or report by a professional engineer or other appropriately qualified body
- another form of documentary evidence such a Product Technical Statement or Technical Appraisal
- certificate issued by a certification body accredited by the Joint Accreditation System of Australia and New Zealand (JAS-ANZ) – this includes industry schemes such as ACRS and EWPAA schemes (ACRS is the Australasian Certification Authority for Reinforcing and Structural Steels; EWPAA is the Engineered Wood Products Association of Australasia).

Milestone is an example of the certification companies operating in Australia (Milestone, accessed 2023). Following the withdrawal of CSIRO Appraisals in Australia, BRANZ Appraisals (as identified above in New Zealand) offer an independent third-party verification programme for building products and systems to clients in Australia.

The New Zealand-based BRANZ is also recognised by the National Association of Testing Authorities (NATA) Australia and is a registered testing authority under provisions of the National Construction Code (NCC) Building Code of Australia (BCA). This means BRANZ fire test and fire assessment reports are evidence of suitability under the BCA.

The BCA are a set of technical provisions contained within the first two chapters of the NCC and dictate the minimum mandatory requirements for the health, safety, amenity and sustainability in the design, development and construction of new buildings within Australia. The BCA is generated and updated by the Australian Building Codes Board on behalf of the commonwealth government and all state and territory governments.

The BCA comes under two volumes, Volume One is for commercial buildings (it has information regarding Class 2 to Class 9 buildings) and Volume Two is for residential buildings (it has information regarding Class 1 and Class 10 buildings which includes houses, sheds, garages and carports). The BCA states a set of measurable construction and building standards and all building work must comply against the appropriate standards as per their Volume (One or Two).

A private company has developed a software tool which presents a graphical representation of the Australian National Construction Codes (NCC) Home – Tools™ (buildingtools.co) (Tools, Accessed 2023) (Architecture&Design, Accessed 2023). Tools™ is based on a drill down menu system as shown in Figures 17 and 18.

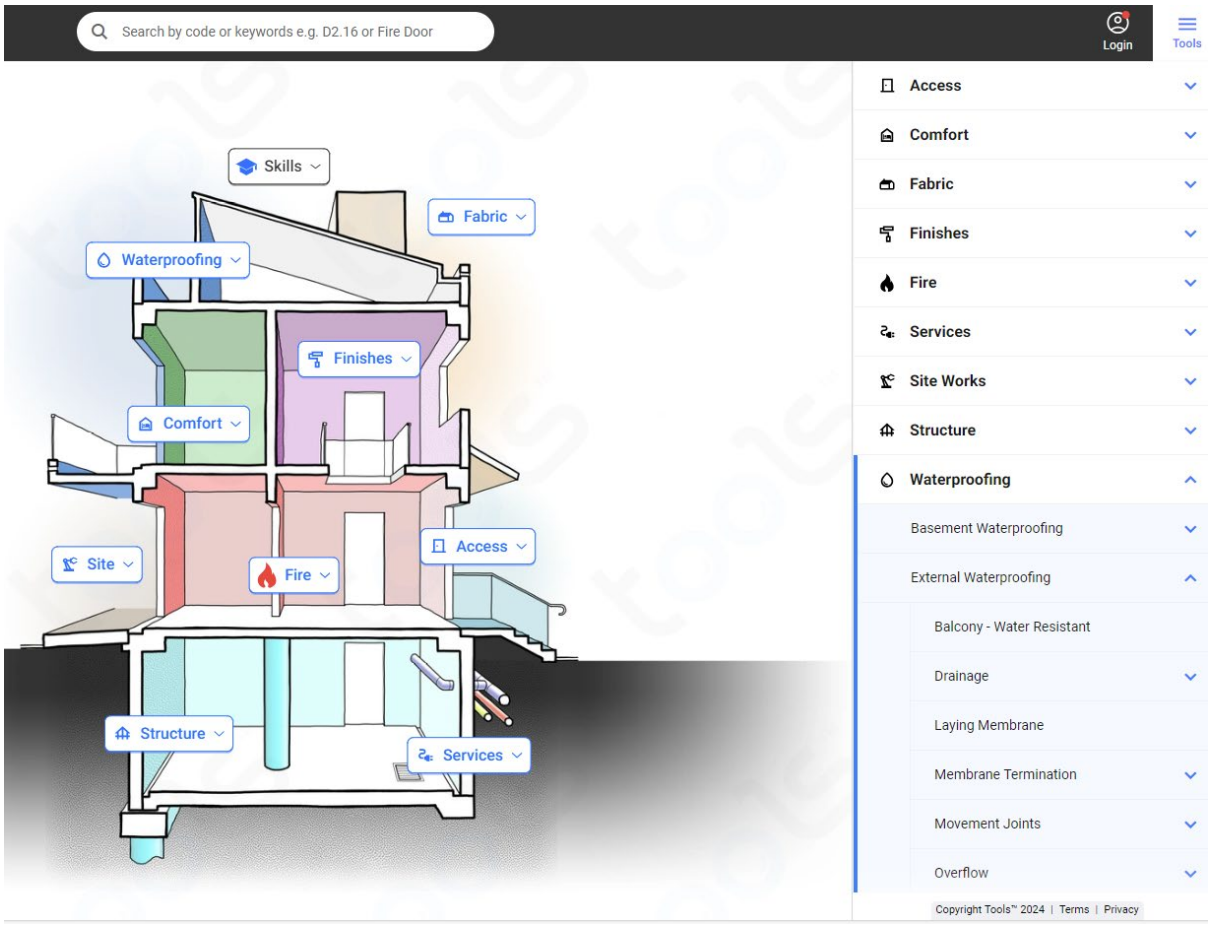

Figure 17. Home – Tools™ (buildingtools.co). Drill down menu structure. Source: (Tools, Accessed 2023)

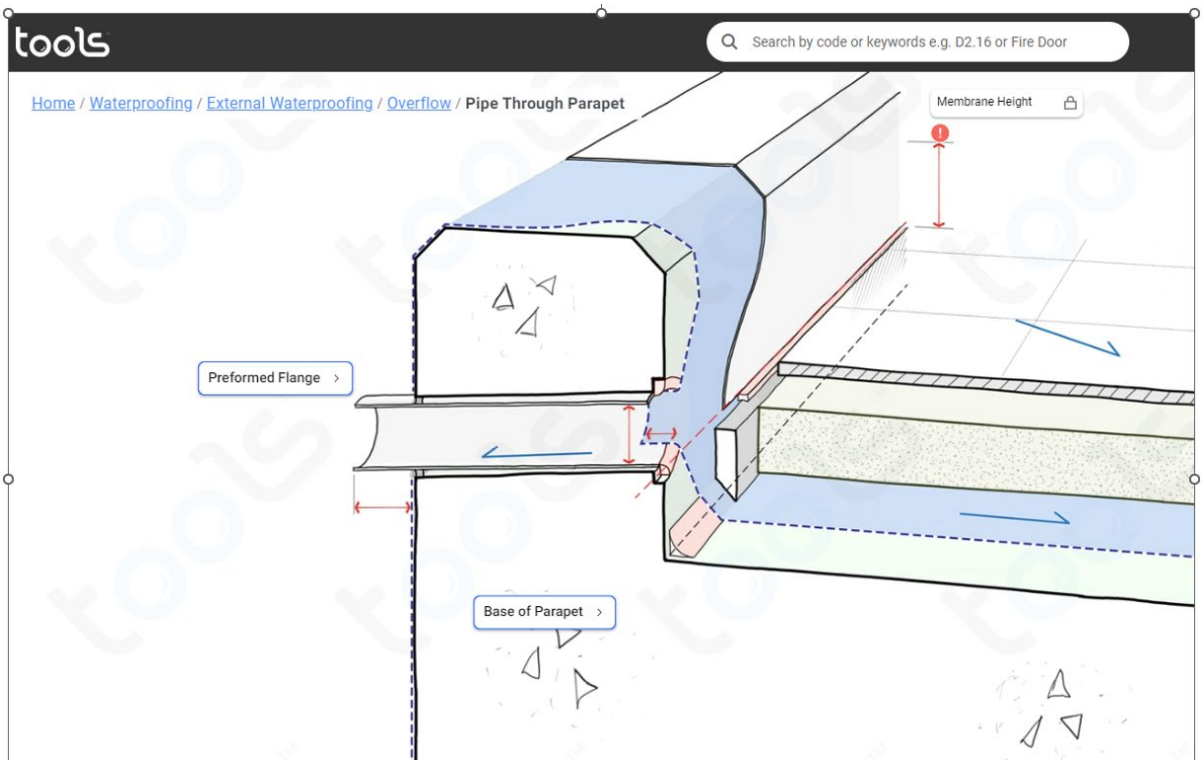

Figure 18. Home – Tools™ (buildingtools.co). Roof parapet detail. Source: (Tools, Accessed 2023)

3.10 United States

The United States operates several quality schemes including:

- **ICC Evaluation Service:** https://icc-es.org/ offers construction product assessments. ICC-ES operates internationally and can therefore evaluate products for compliance to BCA (Australia) and NZBC (New Zealand) schemes, as well as other jurisdictions. Sample reports can be viewed here: Florida Reports Directory – ICC Evaluation Service, LLC (ICC-ES)
- **Intertek**, a worldwide leader in product testing, inspection and certification, signed an agreement in July 2009 with ICC-ES, the United States' leading organisation devoted to evaluating building products for code compliance.
  Under the agreement, manufacturers of building products work with ICC-ES through Intertek, which prepares evaluation-report applications, puts together packages of technical information for study by ICC-ES engineers and handles all the steps that would otherwise be the responsibility of the product manufacturer.
  The reports, once issued, are posted on the ICC-ES website (www.icc-es.org), where they are accessible to the entire building industry and provide evidence for US code officials that the products covered in the report meet all the requirements of the applicable building codes.

In addition to the construction quality schemes above, the following standards and schemes focus on sustainability:

- **ICC 700-2012: ICC 700-2012 is the 2012 National Green Building Standard (ICC 700)** developed by the International Code Council (ICC) and the National Association of Home Builders (NAHB). It is a rating and certification system that aims to encourage increased environmental and health performance in residences and residential portions of buildings.

- **LEED** (Leadership in Energy and Environmental Design): LEED originated in the United States and is a widely-used certification scheme for green buildings (IGBC, Accessed 2023). It provides a framework for healthy, highly efficient and cost-saving green buildings, which offer environmental, social and governance benefits.

  LEED certification is a globally-recognized symbol of sustainability achievement, and it is backed by an entire industry of committed organisations and individuals paving the way for market transformation. LEED is available for virtually all building types and all building phases including new construction, interior fit outs, operations and

maintenance and core and shell. LEED 5.0 was launched in Autumn 2023 (USGBC, Accessed 2023).

- **Green Globes:** Green Globes is an online assessment protocol, rating system and guidance for green building design, operation and management. It is interactive, flexible and affordable, and provides market recognition of a building's environmental attributes through third-party verification.

3.11 Canada

Modular construction has gained popularity in Canada since the end of World War II with the booming of Canada's population and economy. It is estimated that in the last decade, factory-built residential houses make up 8-16% of the total single family housing market (Norman & Bray, 2020). The Canadian Standards Association (CSA) has developed three standards that are directly related to prefabricated and modular buildings:

- **CSA A277-16 (R2021):** Procedure for certification of prefabricated buildings, modules and panels. This standard provides the procedure for certifying buildings and partially or fully enclosed modules and panels for buildings of any occupancy. It provides requirements for certification of the factory quality programme and the prefabricated product, auditing of the factory quality program and in-factory inspection of the prefabricated product.
- **CSA Z240 MH Series-16 (R2021):** Manufactured homes. This standard provides general requirements for manufactured homes, including technical requirements and requirements on quality control, markings and provision of printed instructions.
- **CSA Z240.10.1:19:** Site preparation, foundation and installation of buildings. This standard provides requirements related to building installation, including: site preparation, permanent foundations, anchorages to resist overturning and pier toppling due to wind, connection of modules and skirting.

In addition, prefab and modular buildings must comply with local province and territory building code requirements and additional certifications are used to quantify other aspects of the modular buildings, including energy efficiency and sustainability (BC Housing, 2014). The manufacturer is responsible for implementing quality control procedures to ensure compliance with necessary performance requirements.

Furthermore, factory surveillance inspections are conducted by a third party to assess manufacturer quality control procedures and to ensure the building complies with all necessary performance requirements (Chang-Richards et al., 2019).

The following text is taken from a notice issued by the Modular Housing Association of the Prairie Provinces (MHAPP, n.d.)

> *A frequently asked question about the modular housing industry is what the difference is between the National Building Code (NBC) and the Canadian Standards Association (CSA) A277*

certification program. The short answer is that there is no difference in the resulting product. The difference is in the certification process. Homes built on site can be inspected by local authorities while under construction to assure the municipality and the customer that it complies with the NBC requirements. Factory built homes may be built great distances from their final destination and therefore it would be time consuming and expensive for those responsible to assure compliance by travelling to the factory to do these inspections. This led to the development of the CSA A277 certification program for factory built buildings.

The CSA A277 certification standard is the program used in the modular housing industry in Canada. It is effectively a quality control program run by the Standards Council of Canada through certified third-party inspection agencies such as CSA, Intertek and Quality Auditing Institute.

This program assures development officers and building inspectors that a building bearing this label is designed and constructed to the National Building Code in effect at time of construction in the location that the home will be sited.

Each factory manufacturing buildings to this standard must employ a certified third-party agency to do regular inspections of the factory and their quality assurance program to ensure compliance to the NBC and that all materials have been inspected to conform to the proper specifications.

All modular homes and most manufactured homes are currently labelled under this programme. Local authorities then only need to inspect the work done on site for compliance to the relevant codes. A summary of the quality assurance and compliance procedure in accordance with CSA A277 is shown in Figure 19. CSA A277 can be purchased here.

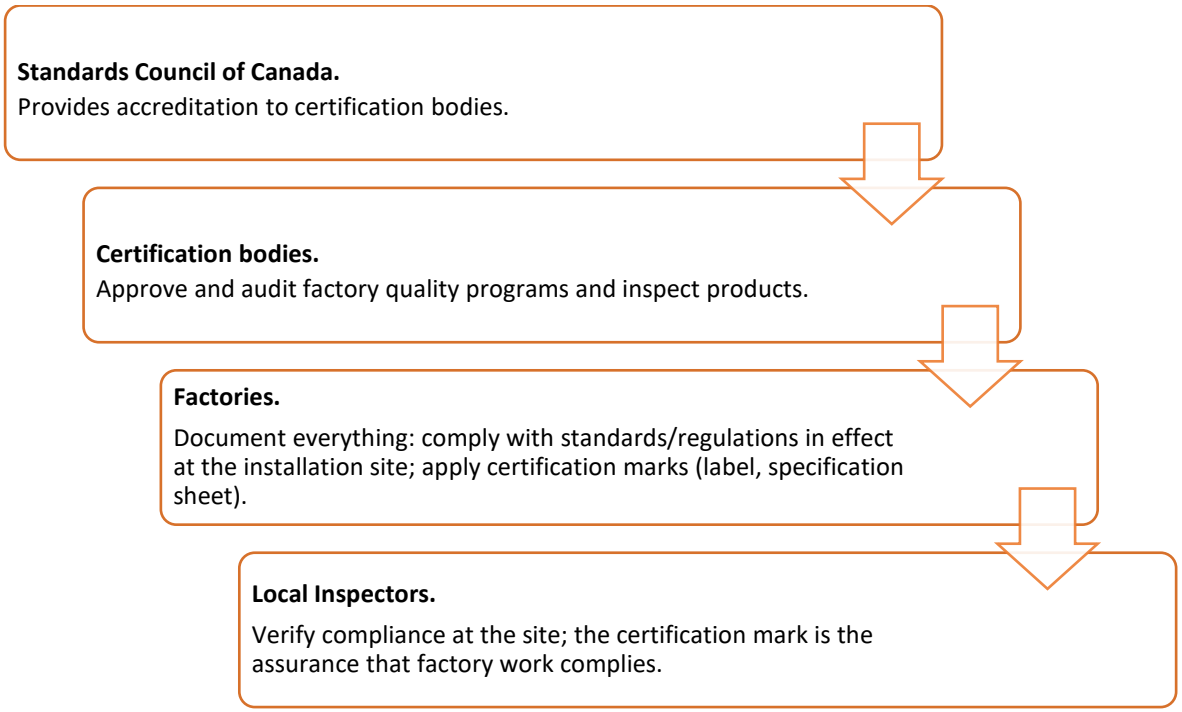

Figure 19. CSA A277 quality assurance procedure.

3.12 Brazil

The Brazilian Programme for Quality and Productivity in Housing Construction (PBQP-H) was originally established in 1990. This programme follows ISO 9001 certification methodology and is an instrument of the federal government to fulfil the commitments made by Brazil when the Istanbul Charter (Habitat II/1996) was signed. A mini-review entitled *Quality in civil construction in Brazil* details the PBQP-H approach (Massara, 2018).

The PBQP-H programme relies on 12 pillars:

1. Structuring and management of PBQP-H
2. National system of technical approvals (see below)
3. Support to the use of materials, components and constructive systems
4. System of qualification of civil construction companies
5. Quality of materials and components
6. National system of communication and information exchange
7. Training and requalification of civil construction professionals
8. Quality of laboratories
9. Improvement of technical standardisation for housing (see below)
10. Technical assistance to self-construction
11. Bilateral technical cooperation Brazil/France/IDB for PBQP-H
12. Regional programme: Social and economic challenges for housing linked to the improvement of the quality of housing in Mercosur.

The national system of technical approvals (Pillar 2 above), is comparable to the Irish Agrément system. For companies to achieve PBQP-H certification under the Qualification System of Materials, Components and Constructive Systems (SiMAC), it is necessary to undergo an audit by an 'OAC' (Conformity Assessment Body), which are accredited by the Ministry of Cities (MCidades). (Brazilian Gov, 2023)

A second pillar (Pillar 9 above) addresses the improvement of technical standardisation. In early 2017, the PBQP-H base was updated so that its guidelines complied with the requirements and performance criteria of the Brazilian Association for Technical Standards (ABNT). The national standards published by the association are named *Norma Brasileira Regulamentadora* (NBR). The first standard associated with PBQP-H is NBR 15575:2013 – Housing Buildings; Performance.

NBR 15575 came into force in 2013 to prioritise the wellbeing of users of housing units and highlighted concerns such as:

- structural systems: safety (structural, anti-fire and in use and operation)
- waterproofing systems: habitability (water tightness, thermal performance, acoustic, light, health, hygiene, air quality, functionality and accessibility, tactile and anthropodynamic comfort).

A specific case study for concrete prefabrication/offsite construction in Brazil is located here.

A 2013 document pre-dates the PBQP-H programme but still contains useful information on the interaction between Brazilian government departments and agencies in respect of scaling up affordable housing supply in Brazil: Scaling-up Affordable Housing Supply in Brazil | UN-Habitat (unhabitat.org)

3.13 China

China is one of the leading countries in the world in terms of prefabricated construction, with a large market size and government support for technological innovation.

The Chinese government, through the Ministry of Housing and Urban-Rural Development of the People's Republic of China, has released several policies to promote prefabricated construction, such as the Guidance on the Development of Prefabricated Buildings, the 13th Five-Year Prefabricated Building Action Plan and the Standard for Assessment of Prefabricated Building. These policies have been identified in a journal article entitled *A systematic overview of prefabricated construction policies* (Luo, 2021).

The Chinese government has required that the proportion of prefabricated buildings in new construction be increased to 30% by 2026 (Li, Zhang, Meng, & Hu, 2020). However, the proportion in existing building is still comparatively low, only about 5% in 2019 (Wang, Shen, & Zuo, 2019) but increasing to approximately 20% in 2022 (Shang & Wang, 2022 Vol.14).

It is noted that the term 'industrialised building' has been used in journals to describe buildings assembled with factory-produced components. In 2015, the State Council of China passed the National Standards for the Assessment of Industrialised Building (Gao & Tian, 2020)

The China State Construction Hailong Technology Company Limited (HAILONG) has pioneered new methods for modular integrated construction (MiC). Its website includes the projections set in 2020 for an annual growth of 2.3% for MMC in China, see Figure 20 below.

Figure 20. Sources: Ministry of Housing and Urban-Rural Development, National Bureau of Statistics, Ping a securities research institute.

According to Jiang et al. [1,2], there are obstacles to the adoption of prefabricated buildings in China, for example, the lack of codes and standards, as well as incomplete policies and regulations (Jiang, Li, Li, & Gao, 2018) , (Jiang, Mao, Hou, Wu, & Tan, 2018, Vol. 173).

According to a report by Kenneth Research, *China Prefabricated Construction Market to Grow on the Back* (globenewswire.com) (News, 2023), the Chinese prefabricated construction market generated a revenue of USD 33.7 billion in 2020 and is expected to touch USD 44 billion by the end of 2025, by growing with a CAGR of 6.05% during the forecast period. The report cites the increasing urbanisation in the nation and the government's growing focus on developing green buildings as the major factors driving the market growth.

Some of the key players in the China prefabricated construction market are Zhejiang Putian Integrated Housing, Shanghai Star House, Foshan Wellcamp Steel Structure & Modular Housing, Suzhou

Zhongnan Steel Structure, Shanghai Sunnyda House, Ningbo Deep Blue Smarthouse, Guangzhou Jinzhao Steel Structure Engineering and Shanghai Allstar Industrial.

These companies offer a wide range of prefab products, such as light steel villas, expandable container houses, flatpack container houses, container offices, container camps, container schools, warehouses and others. They also provide customised solutions for different customers and projects.

China has issued many policy incentives to promote the development of the prefabricated construction industry. For example, Beijing introduced the Plan of Competitive Bidding for High-Standard Commercial Housing Construction, which is linked to land prices.

According to this plan, when the premium rate of land exceeds 15%, the ownership of land development will be determined by evaluating building construction schemes, liveable technology applications and management models provided by bidders. This plan enhances motivation to develop prefabricated building technologies (Shang & Wang, 2022 Vol.14);

Furthermore, Beijing's supportive prefabrication policies specify that construction firms that use prefabricated methods of construction are allowed a maximum floor-area ratio 3% higher than the ratio for the firms using conventional construction methods. The profit margin of the extra 3% floor-area ratio offers an incentive for Beijing's construction firms to adopt prefabricated construction (Beijing Housing and Urban-Rural Construction Commission, 2010).

In 2016, new prefabricated buildings accounted for about 5% of the total area of new buildings in China. However, in the period 2017-2020, this proportion surged from 6.5% to 20.5%, and the market size expanded rapidly from CNY 283.9 billion to 1227.7 billion.

However, when compared to the penetration of prefabricated buildings in developed countries (90% in the US and Japan, 85% in France), the penetration rate of prefabricated buildings in China has the potential to increase significantly. As of 2022, the cumulative area of new prefabricated buildings in China had reached 630 million square metres with an annual growth of 50% and prefabricated buildings accounting for about 20.5% of the total area of new buildings (Shang & Wang, 2022 Vol.14).

The number of enterprises related to prefabricated buildings (hereafter referred to as 'related enterprises') has also rapidly increased.

By 2020, the number of related enterprises in China had exceeded 14,000. However, the costs of prefabricated buildings were still higher than those of traditional cast-in-place buildings, mainly because of the low-capacity utilisation rate of prefabricated component factories, single business patterns and the scattered industrial distribution of related enterprises. This ran counter to the original intention of the prefabricated building industry, namely to achieve higher cost effectiveness and production efficiency by rationally transforming the industry chain.

Statistical data suggest that when the prefabrication rate reached 60%, the costs of prefabricated buildings (in comparison to traditional buildings) increased by 33.8%. This large gap in costs greatly undermined the subjective motivation to develop prefabricated buildings and seriously impacted industrial efficiency (Shang & Wang, 2022 Vol.14).

To curb the spread of COVID-19, the first case of which was observed in the Chinese city of Wuhan, the government built the Huoshenshan hospital in Wuhan in a period of 10 days by using these prefabricated construction structures to deal with the coronavirus patients.

The ISO (International Standards Organisation) committee developing standards for prefabricated buildings is ISO/TC 59/SC 19 – Prefabricated building. The prefix ISO/TC 59 designation is for buildings and civil engineering works. The current chair of SC19, Mr Boyue Yin, has extensive experience of prefabricated construction in China. Some major projects under his supervision include the 1 million square metre Baotou demonstration housing project, completed by Hangxiao Steel Structure, China's largest modular steel structure listed company.
The chair of SC19 has developed 60 domestic prefabricated building technical standards, which cover steel structure, concrete, timber structure, bamboo structure and other buildings. The NSAI technical committee TC 150 was established in 2021 to mirror the international activity of ISO/TC 59 /SC 19 and BSI PAS 8700 in respect of the standards for prefabricated buildings.

3.14 Europe

The following European schemes ensure product conformity in the construction sector:

(i) European Technical Assessments (ETA)
(ii) harmonised European standards (hEN) and CE marking
(iii) EN 1090 certification via an accredited certification body
(iv) Eurocode structural design standards
(v) register of notified bodies
(vi) 25 EU directives related to CE marking
(vii) European Union for technical approval in construction (direct).

(i) **European Technical Assessments (ETAs)** are issued by Technical Assessment Bodies (TABs) designated for the relevant product area by the EU member and partner states in accordance with the Construction Products Regulation (EU) No 305/2011, TABs – Find a partner for your ETA | EOTA. TABs are notified bodies that have been specifically authorised to issue European Technical assessments (ETA) (EOTA Members, Accessed 2023).

The ETA route to CE marking applies to products, kits and systems for which no harmonised European standard (hEN) is available, or cannot be used, and the ETA can be used to demonstrate performance required to put a CE mark on the goods. An ETA is a technical specification that describes the product characteristics, applications, details the manufacturing site and factory production controls.

For example, RISE, as identified in section 3.3 above, is also the Swedish representative in EOTA, the European Organisation for Technical Assessment. ETA – Issuing of European Technical Assessment (ETA) and if relevant, development of European Assessment Document (EAD) | RISE

The EOTA website confirms the ETA timeline for new products is approximately nine months. A new product implies a new European Assessment Document (EAD) needs to be developed or an existing one amended. It is noted the Construction Products Regulation dictates the time allowance and nine months is therefore a minimum in the case of complex systems. EOTA states:

"Beyond averages and from practical experience, the actual processing time for an ETA depends mainly on the complexity and scope of the assessment, the time required for testing, the speed of communication between the manufacturer and the Technical Assessment Body as well as prior experience with the procedure."

The ETA process consists of the following steps:

- inquiry
- quotation
- development of an EAD
- development of an ETA
- visiting manufacturing sites, control plan, FPC
- issuing of an ETA.

When all relevant characteristics and documentation have been determined and presented, including manufacturing site, control plan, FPC etc. an ETA can be issued. In case an EAD for the product is unavailable or non-existent an EAD would have to be developed before an ETA can be issued.

Depending on the level of attestation and verification of constancy of performance (1+, 1, 2, 3 or 4), that is valid for the product, a task involving a notified body might be necessary before the CE mark can be applied to the product. RISE is a notified body for many harmonised specifications.

ETAs issued after the 1 July 2013 are valid for an indefinite period. Information on drawing up a declaration of conformity and managing documentation is available here (EU, 2023).

It is noted that schedule D3 of the Irish Technical Guidance Document Part D (TGD D), as reproduced in Figure 5 above, confirms that an ETA or CE marking may be considered as evidence of "proper materials" and are therefore alternatives to Irish Agrément certificates. The advantage of Irish Agrément certification, relative to an ETA, is that the certified MMC system will have been assessed to satisfy all relevant parts of the Irish building regulations with specific consideration of Irish environmental conditions.

(ii) Harmonised European (hEN) standards and CE marking

The Construction Product Regulation (CPR) No. 305/2011 lays down harmonised conditions for the marketing of construction products (European Commission, Construction products regulation (CPR), Accessed 2023) (EU, Full text of Regulation CPR 305/2011, Accessed 2023). From July 2013, CE marking is required for products falling under CPR.

(iii) **EN 1090** is a harmonised European standard that specifies requirements for conformity assessment of structural steel and aluminium components as well as for kits placed on the market as construction products. The assessment covers the manufacturing characteristics and, where appropriate, the structural design characteristics.
EN 1090 requires a Factory Production Control (FPC) system and extends to components and systems used in construction of farm buildings, houses, shops, stadia, bridges and other commercial buildings. Organisations in possession of a valid and in date ISO 9001 certificate can also demonstrate compliance for their operational processes, for FPC acceptance, subject to auditing. Achieving accredited certification against EN 1090 is a requirement to allow CE marking of product.

Harmonised Standards – European Commission (europa.eu)

Under The Construction Products Regulation 305/2011, it is a legal requirement for all construction products to be CE marked, hence this is a legal requirement for structural steel and aluminium. There are four execution classes of the FPC dependent on the activity of a company. EXC 1 is the simplest and applicable to farm buildings, EXC 2 is for small residential structures, EXC 3 larger residential structures/bridges, and EXC 4 for stadia, power stations and airport buildings.

The FPC system should cover:

- contacting the client
- review of requirements (with capability to deliver)
- raw materials acquisition/quality
- roles and qualifications of employees, particularly designers, welders and welding co-ordinators
- production methodologies (welding, drilling, punching etc),
- equipment to be used
- testing (as specified in the standard and by the client)
- finishing of the product.

EN 1090 certification applies to fabrication and welding companies but is also relevant to stockholders who cut or alter steel/aluminium, as this changes the characteristics.
Certification against EN 1090 is only acceptable via an accredited certification body. Certification bodies are accredited by their national accreditation body, INAB in Ireland. The certification body is then appointed by the European Commission as a notified body (OACI, Accessed 2023).

Responsibilities for steelwork contractors:

The basis for CE marking is that the manufacturer declares that its products meet specified performance characteristics defined as essential to the application of the products in the field of construction. For a manufacturer to CE mark their products they will need to be certified by an EU-27 notified body (https://single-market-economy.ec.europa.eu/single-market/goods/building-blocks/notified-bodies_en).

- EN 1090 certification requires manufacturers to operate a factory production control (FPC) system conforming to ISO 9001 QMS requirements. However, the manufacturer does not need to seek or be awarded an ISO 9001 certification, that is, the FPC can be based on an ISO 3834 system or ISO 9001 system. An FPC system will include elements that reflect the requirements of EN 1090-1.
- As welding is recognised as a specialised process, it requires its own suite of standards covered by EN ISO 3834. These outline the quality requirements that manufacturers must conform to, including qualification of welding procedures and welding personnel, material control and traceability, inspection and testing.
- Appoint a registered welding coordinator (RWC) for their fabrication facility and works.

Ref: https://www.dnv.com/services/en-1090-certification-of-steel-structures-28473
Ref: https://www.irishsteel.ie/whats-an-fpc-system/

Responsibilities for clients and main contractors:

Clients and main contractors who engage a steelwork contractor should carry out due diligence and should only appoint a steelwork contractor certified with an Execution Class equal to that for the project as determined by the designer through EN 1090-2.

- It is a legal requirement for fabricated structural steel work delivered to site to be CE marked.
- For a steelwork contractor to demonstrate the right to CE mark their products, they must provide the following three documents:
  - factory production control (FPC) certificates
  - welding certificate
  - declaration of performance (DoP).

(iv) The **Eurocodes** suite is made up by 10 European standards for structural design and each Eurocode covers particular technical aspects (European Commission, Accessed 2023).

(v) The EU maintains a register of **notified bodies**, that is, organisations accredited to award certification. The register lists the specific range of products under which an organisation is approved to certify. (European Commission, Notified Bodies (NANDO), Accessed 2023).

Notification is an act whereby a member state informs the European Commission and the other member states that a body, which fulfils the relevant requirements, has been designated to carry out conformity assessment according to a directive. Notification of notified bodies and their withdrawal are the responsibility of the notifying member state.

The EU notified body webpage includes a warning about unregulated certificates. Unregulated certificates, often called 'voluntary certificates' as well as other names, are often issued for products covered by EU harmonisation legislation by certification bodies not acting in their capacity as notified bodies under EU law.

These practices are misleading, since only notified bodies may issue certificates of compliance for harmonised products and only in the area for which they are notified. For example, if a body is notified for issuing certificates for machinery, it should not issue certificates (voluntary or other) for non-machinery products (such as personal protective equipment – masks).

(vi) 25 EU directives related to CE marking

The primary EU regulations and directives that apply to the construction sector can be found at the following links (EU Commission, Accessed 2024):

- Recommendation related to the EN Eurocodes
- Construction Products Regulation
- Public Procurement Directive
- Services Directive
- Directive on the provision of information in the field of technical standards and regulations
- Energy Performance of Buildings Directive.

Table 1 lists the EU directives related to CE marking. Red text denotes those relevant to the construction sector. Further information on each directive can be found at CE Marking Directives and Regulations (CEmarking, Accessed 2024).

#	Product Group	EU Directive No.
1	Active Implantable Medical Devices Directive (AIMDD)	90/385/EEC
2	Appliances burning gaseous fuels	EU/2016/426
3	**Applies to equipment and protective systems intended for use in potentially explosive atmospheres (ATEX)**	**2014/34/EU**
4	Cableway Installations Regulations	EU/2016/424
5	**Construction Products Regulations (CPR)**	**EU/305/2011**
6	**Eco-design of energy related products (ErP) Directive**	**2009/125/EC**
7	**Electromagnetic Compatibility (EMC)**	**2014/30/EU**
8	Explosives for civil use	2014/28/EU
9	**Hot-water boilers**	**92/42/EEC**
10	In vitro diagnostic medical devices	98/79/EC
11	**Lifts**	**2014/33/EU**
12	**Low Voltage Directive (LVD)**	**2014/35/EU**
13	**Machinery**	**2006/42/EC**
14	Measuring Instruments	2014/32/EU
15	Medical Devices Directive (MDD)	93/42/EEC
16	Noise emission in the environment	2000/14/EC
17	Non-automatic weighing instruments	2014/31/EU
18	**Personal protective equipment**	**EU/2016/425**
19	**Pressure Equipment Directive (PED)**	**2014/68/EU**
20	Pyrotechnics	2013/29/EU
21	**Radio Equipment**	**2014/53/EU**
22	Recreational craft	2013/53/EU
23	**Restriction of Hazardous Substances in Electrical and Electronic Equipment**	**2009/48/EC**
24	Safety of toys	2009/49/EC
25	Simple Pressure Vessels Directive (SPVD)	2014/29/EU

Table 1. CE Marking Regulations and Directives

It is noted that Regulation (EU) 2023/1230 repeals Directive 2006/42/EC listed in the table above. The 2023 EU Machinery Regulation becomes legally binding in all EU member states on 20 January 2027. See the NSAI update.

(vii) In addition to the schemes above, the European Union for technical approval in construction (UEAtc) is a de-facto partnership, which brings together, on a voluntary basis, national institutes, centres or organisations that are engaged in the issuing of technical approvals.
UEAtc members develop and maintain a proficient voluntary technical approval process supporting innovation in the building and construction sector, share experiences and try to avoid, whenever possible, repetition of activities to the benefit of the stakeholders involved in the process. In addition, the members may carry out other specific activities such as research, testing, certification and development of specifications (UEAtc, Accessed 2023).

UEAtc has published a position paper which describes the different technical approval terms used across EU member states (UEAtc Position Paper, Accessed 2023). The paper states third-party technical fitness for purpose declarations are generally referred to as Approvals, but these may also be referred to by terms such as Agrément certificates, Avis Techniques, Zulassungen, Documento de Idoneidad Tecnica, Technical Approval, Agrément Techniques etc. NSAI is a member of UEAtc.

UEAtc is a member of the European Council for Construction Research, Development and Innovation (ECCREDI). ECCREDI was created in Brussels on 19 December 1995 with the signing of a Memorandum of Understanding by representatives of European federations concerned with construction in its widest sense (ECCREDI, Accessed 2023).

At a global level, WFTAO is the World Federation of Technical Assessment Organisations, a worldwide network for co-ordinating and facilitating the technical assessment of innovation in the construction field. The list of members is available on their website (WFTAO, Accessed 2023).

4. MMC drivers & policy considerations

This section outlines the current drivers that will stimulate demand for NSAI – MMC Agrément certification, which may require a balancing of resources to meet the changing needs or additional certification requirements of existing NSAI customers. NSAI expects new entrants to the MMC market based on international enquiries received to date.

- EU directives
  - Energy Performance Building Directive (EPBD)
  - EU Green Deal
  - RePowerEU
  - ERP Directive
  - CSRDD Corporate Sustainability Due Diligence Directive
  - CSRD Corporate Sustainability Reporting Directive
- National Development Plan (NDP) – Project 2040
- Climate Action Plan 2024 (and subsequent revisions)
- Circular Economy Act 2022

- Guidance Towards the Circular Economy for the Irish Construction Sector – due to be published shortly in Q1, 2024 (as led by DECC)
- Housing for All – A New Housing Plan for Ireland is the government's housing plan to 2030 (DHLGH, Housing for all, Accessed 2023).

The country-specific details, as reported in Section 3 above, demonstrates that sustainability is intertwined with building regulations and therefore will be a key driver. The EU sustainable buildings framework promotes the use of life cycle assessment (LCA) and life cycle costing (LCC) to help understand the quantities and timings of environmental impacts. The life cycle analysis approach, as illustrated in Figure 22, will influence the design of MMC systems (One Click LCA, Accessed 2023).

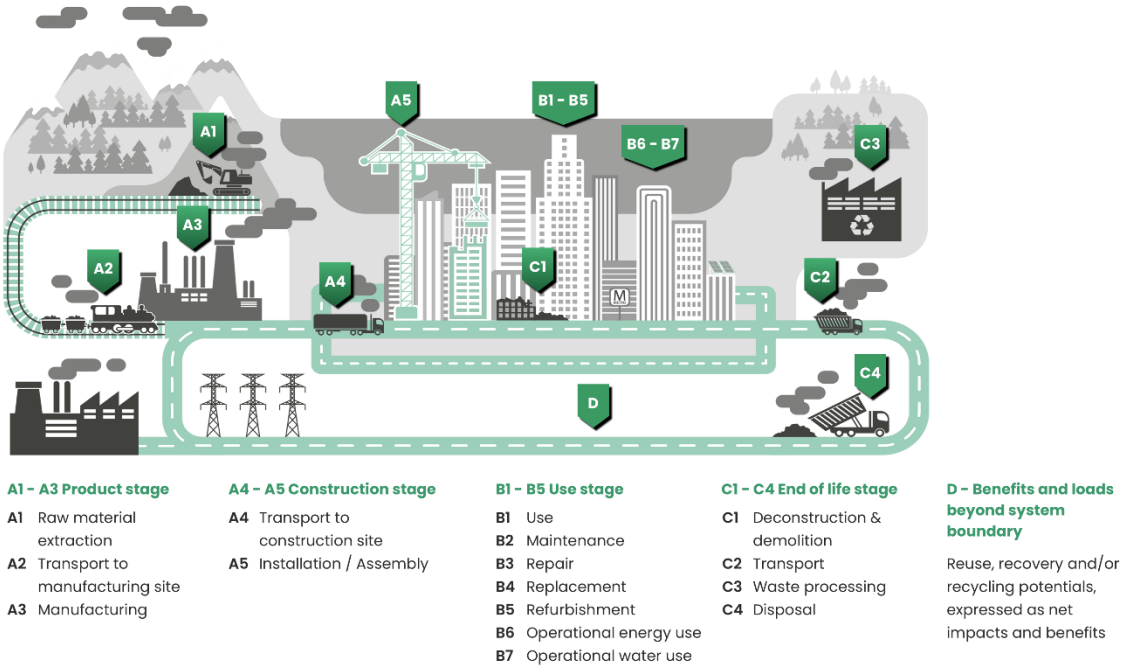

Figure 21. Life cycle of a building. Source: (One Click LCA, Accessed 2023)

5. NSAI MMC Agrément process and MMC guidance document

NSAI Agrément is responsible for Irish Agrément assessment and certification. Formerly the Irish Agrément Board (IAB), it now operates as part of NSAI (National Standards Authority of Ireland).

Agrément certification is designed specifically for new building materials, products and processes that do not yet have a long history of use and for which published national standards do not yet exist. NSAI Agrément assesses, specifies testing and, where appropriate, issues Agrément certificates for such products.

In response to the Housing for All initiative (DHLGH, Housing for all, Accessed 2023), the NSAI MMC Agrément offering has been established to certify MMC, such as offsite construction, modular construction panels and structural insulated panels. The aim is to enhance the certification process for MMC and provide a clear pathway for system manufacturers on the assessment process for Agrément certification.

Agrément certification is voluntary and is one of the routes for evidencing 'proper materials' as defined in Technical Guidance Document, Part D, as per the extract in Figure 5 above. Irish Agrément is therefore an option for new innovative building materials, products and systems that do not yet have a long history of use and for which there may be no national standard, harmonised European product standard (hEN) or European Technical Assessment (ETA).

The advantage in Irish Agrément certification, relative to an ETA, is that the certified MMC system will satisfy all relevant parts of the Irish Building Regulations with associated consideration of Irish environmental conditions. The certification confirms the products and systems are fit for purpose for use in the Republic of Ireland, when installed with due regard to the limitations contained within their Agrément certificate.

A description of the current NSAI Agrément certification process and a 46-page *Guide to Agrément Certification for Modern Methods of Construction (MMC)* document can be accessed via the weblinks in the bibliography section: (NSAI Agrément Certification), (NSAI MMC Guide), (NSAI Flowchart)

This *Guide to Agrément Certification for MMC* document, sets out the 15-step process for applying for and achieving NSAI Agrément certification for MMC/modular construction.

NSAI is developing a series of supporting MMC infographics for wider MMC stakeholder engagement and further understanding of the current NSAI Agrément certification process.

Figure 22 and 23 detail the NSAI Agrément certification process from application and product evaluation stages to FPC, followed by the award of a certificate and annual surveillance over the five-year cycle.

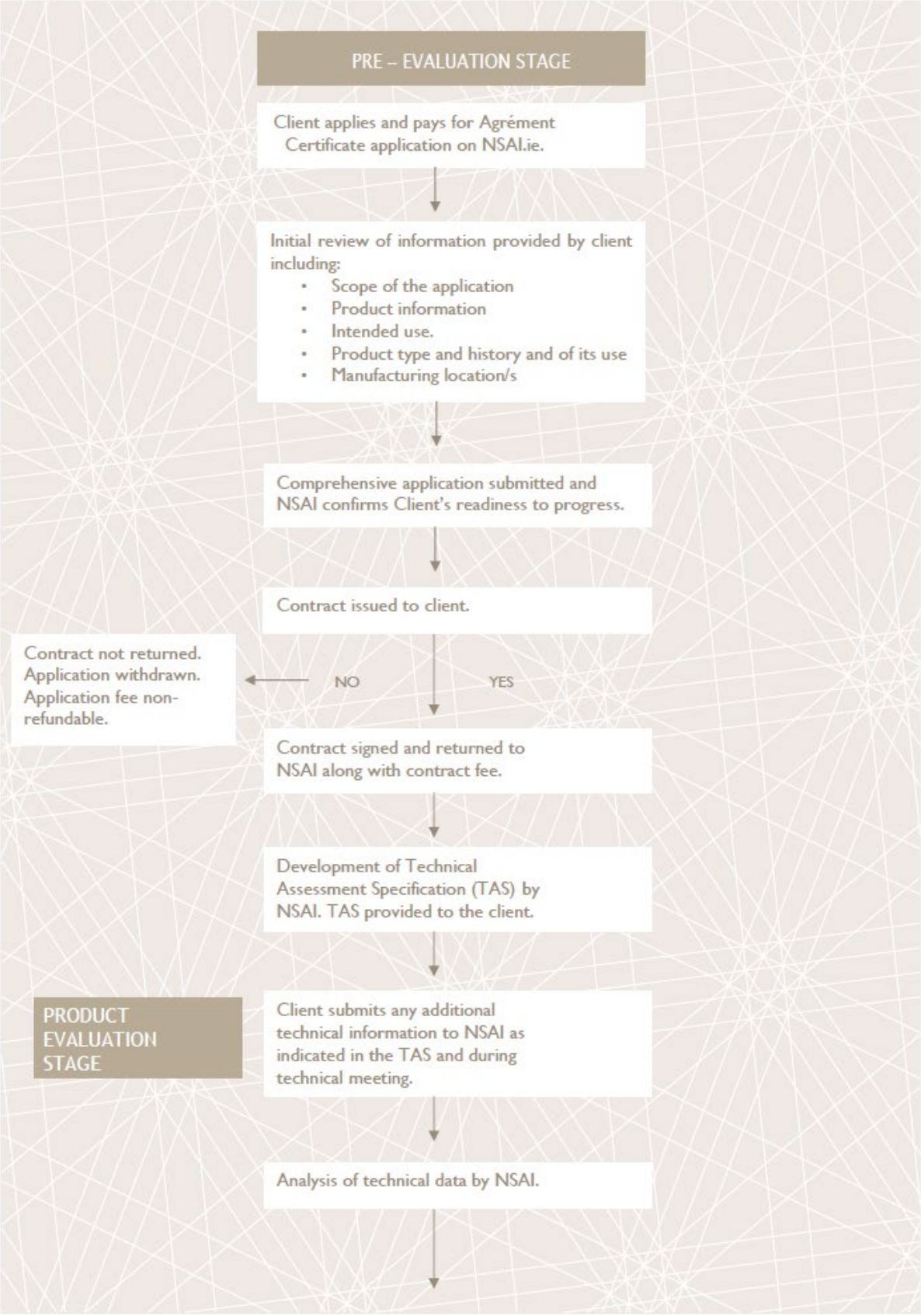

Figure 22. NSAI Agrément certification process (application and product evaluation stages). Source: NSAI.

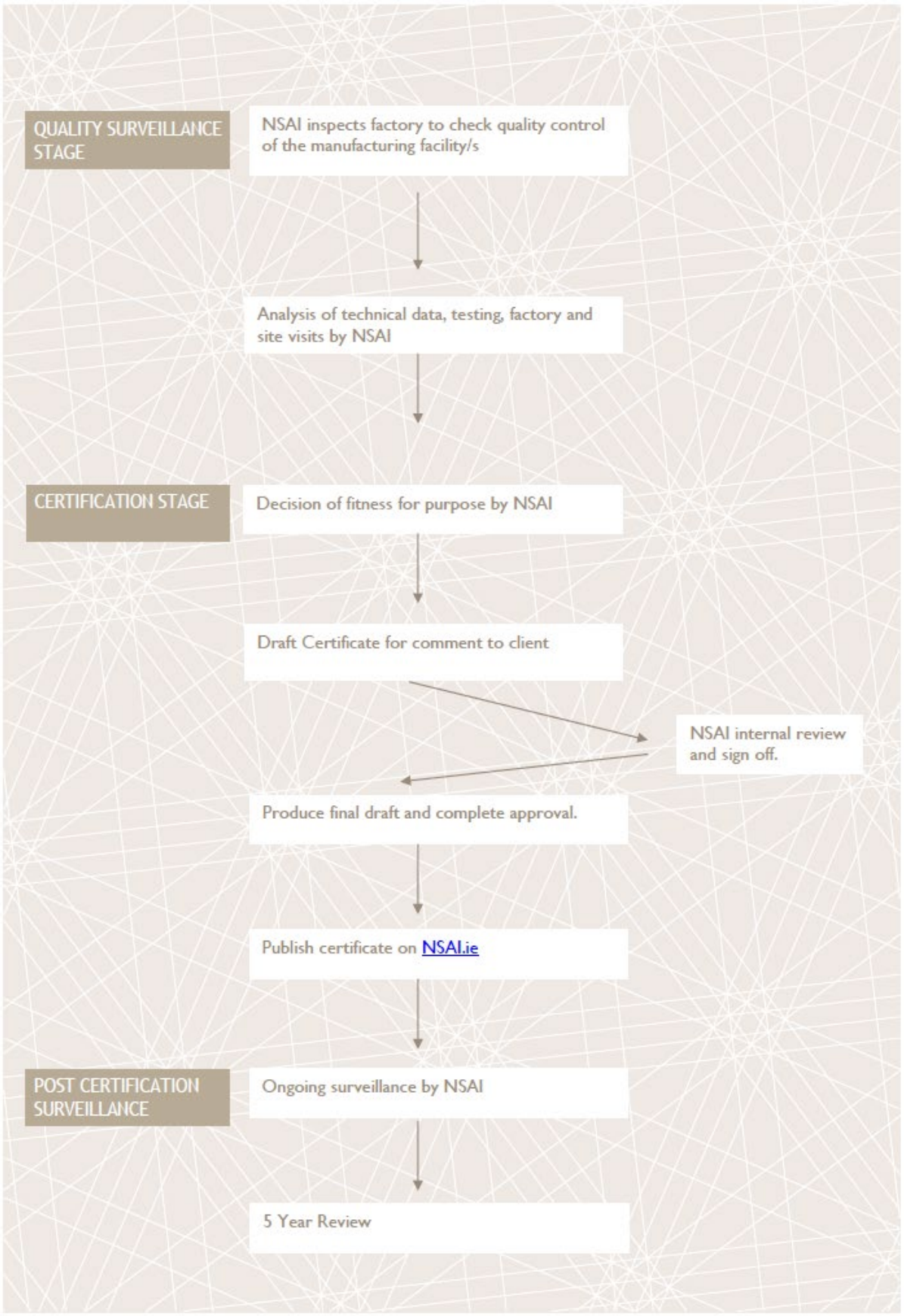

Figure 23. NSAI Agrément certification process (FPC, certification and surveillance stages). Source: NSAI.

The current NSAI *Guide to Agrément Certification for MMC* document, dated December 2021, includes the responsibilities in respect of surveillance audits and the validity of certificates (as extracted in Figure 24 below):

12. Maintaining Certification

In order to maintain the Certification and ensure continued adherence of the system to that certified, NSAI have implemented a surveillance audit programme.

In addition, Agrément certificates have a validity of five years from date of issue or date of latest revision. Before the certificate expires, it will be reviewed to ensure the product/system meets all current regulations and that the processes, specification are in accordance with NSAI requirements.

Responsibilities for both the Agrément certificate holder and NSAI to support and maintain the certification process are outlined below.

14. NSAI Responsibilities

NSAI shall:

- Ensure that the assessment/surveillance/5 year reassessment is undertaken by personnel who are adequately trained and experienced in the technology to enable them to assess compliance;
- Ensure that surveillance audits and 5 year reassessments are conducted within the relevant time period;
- Treat all information in respect of the certificate and certificate holder are treated in strictest confidence;
- Maintain an up-to-date list of Agrément certificates on the NSAI website www.nsai.ie.

Figure 24. NSAI Agrément certification responsibilities. Source: NSAI.

Specific certification schemes to support the timber Industry

Separate to Irish Agrément certification, NSAI supports the timber industry through product certification and inspection schemes. These include:

- **Roof Truss Manufacturers Approval Scheme**, which certifies manufacturers to I.S. EN 14250:2010 entitled 'Timber structures - product requirements for prefabricated structural members assembled with punched metal plate fasteners.'

- **Timber Frame Manufacturers Approval Scheme** for the purpose for which it is intended, the conditions in which it is used and the requirements of I.S. 440. A certificate may include evidence of conformity with a European Tec, which certifies manufacturers to I.S. 440:2009+A1:2014 which is entitled 'Timber frame construction, dwellings and other buildings (including amendment 1, consolidated).'

- A scheme certificate demonstrates that the material is fit for the purpose for which it is intended, the conditions in which it is used and the requirements of I.S. 440. A certificate may include evidence of conformity with a European Technical Approval, Agrément certification or approval issued by a notified body.

NSAI inspection service & ancillary certification

The NSAI MMC ancillary certification offering will address the inspection component of milestone No. 13 of the roadmap as detailed in Section 6.1 below. The service will consider the building regulations and the government guidance documents, specifically S.I. 9 BCAR legislation (BCAR, 2014) and the associated *Code of Practice for the Inspection & Certifying of Buildings in Ireland* document (DHLGH, 2016) .

The NSAI ancillary certificate will support the existing certification roles as defined in the guidance documents and meet any additional inspection requirements, subject to resource requirements. The scope of the ancillary certificate will be agreed between NSAI and the client, based on a review of the client's inspection and certification requirements.

The Code of Practice, listed above, defines an ancillary certificate as follows:

"A certificate other than a statutory certificate of compliance as prescribed in the Building Control Regulations given by a competent person to confirm compliance of elements of the building, design or works with Building Regulations; and 'Ancillary Certifier' means a person proposed to issue such a statement. (Note: a 'person' also includes a company)."

Sections 3.3, 3.4 and 3.5 in the Code of Practice should be consulted for detail on the scope of the statutory roles. Section 3.5 details the Assigned Certifiers role. Limited extracts (specific bullets) of Sections 3.3 and 3.4 are included below in respect of builders and designer roles. The NSAI ancillary certificate will be non-statutory and will primarily support the Assigned Certifier, within the contract scope agreed by NSAI and their client.

> *"3.3 Builders role includes:*
> *(i) ensure the coordination and provision of all test certificates and confirmations to the satisfaction of the Assigned Certifier or other designated inspectors or certifiers providing ancillary certificates; and*
> *(j) maintain records.*
>
> *3.4 Designer's role includes:*
> *(d) as agreed with the Assigned Certifier, carry out work inspections which are pertinent to their elements of the design, and liaise with the Assigned Certifier in terms of this and the required ancillary certification;*
>
> *(f) provide the ancillary certificates when required by the Assigned Certifier and Design Certifier; and*
>
> *(g) maintain records of inspection."*

.....

6. NSAI activity and metrics update

6.1 NSAI roadmap actions update

The NSAI has completed all actions below as included in the July 2023 publication entitled *Roadmap for increased adoption of MMC in public housing delivery)* (gov.ie, 2023), reproduced in Figure 25.

11	Strengthened capacity within the NSAI to support an efficient Agrément process.	Q2 2023	NSAI
12	Assessment of the efficiency of current Agrément Certification process in an international comparative context.	Q3 2023	NSAI
13	Communication about NSAI Agrément Certification and Inspection in the context of the broader regulatory system for residential construction.	Q3 2023	NSAI
14	Stakeholder engagement and contribution to related international and European standards developments, and consultation on specific national needs, if any, and progress as appropriate.	Ongoing	NSAI

Figure 25. Extract of NSAI actions arising from the MMC roadmap.

The Housing for All Q3 2023 update (HfA, Q3, 2023), includes Action 61 for delivery in Q3 2024 as shown in Figure 26.

No.	Action	Delivery Date	Reporting Dept
61.	Drive further process improvements and cycle time efficiencies in NSAI Agrément certification for MMC in residential construction, including development of information supports to assist applicants to prepare for the certification process.	Q3 2024	DETE

Figure 26. NSAI Action 61, as included in the Housing for All Q3 2023 update.

6.2 NSAI information supports

The recent Housing for All update (HfA, Q3, 2023) includes Action 61, which states that NSAI is developing information supports to assist applicants for certification processes. This study of international construction quality assurance and certification schemes, including MMC-specific schemes, has been completed. Other resources are in development and will be shared online.

6.3 NSAI contribution to metrics

In addition to the NSAI specific milestones listed above, NSAI will have a role in supporting other stakeholders. Enhancement of MMC metrics is being addressed at multiple levels; The *Housing for All Q2 2023 Progress Report* (Gov, Q2, 2023) confirms progress on Action 13.12, entitled 'Develop a dashboard of MMC metrics to benchmark, and subsequently track, levels of MMC adoption in Ireland,' which has been progressed by DETE.

This project will deliver:

(i) a short interim report detailing examples of international best practice in the collection of MMC/construction innovation data
(ii) an agreed set of metrics to benchmark and track MMC
(iii) the results of a survey to collect data.

In parallel, NSAI is now recording key metrics in respect of MMC clients, which are then aggregated to reflect national production capacity. This protects the confidentiality of individual clients. There are numerous MMC stakeholders within the engineering and construction sector in Ireland, including the potential end users/occupants of modular building systems. The NSAI MMC inspection team are uniquely placed among these stakeholders to record key metrics and validate milestones on the MMC roadmap.

According to McKinsey & Company, in their *Modular construction: From projects to products*, June 2019 report, a key determinant for the increased adoption of modular construction is regulation. They state that:

> *"Quality certification standards and warranties are big drivers that can inform customers and give them confidence. These certifications and warranties also facilitate the provision of financing as development financiers and mortgage providers need them to agree loans. Financing will also become easier as scale is achieved, and insolvency risk is alleviated."*

McKinsey & Company determined in 2019 that:

> *"Governments can additionally help to drive adoption by including offsite manufacturing targets in public projects. In Singapore, for example, all government housing projects must use prefinished volumetric modules."*
>
> *"Sustainability requirements and incentives will also help to drive the industry toward the most carbon neutral products and practices. Another option is to support mortgages for the purpose of offsite manufactured homes. Similarly, building standards will have an important role in driving the uptake of modular construction. The more that they can move towards harmonisation across different geographies and sectors, the more that suppliers will be able to drive scale into their pipeline."*

7. Conclusion

Thirty international construction quality assurance initiatives have been reviewed from August 2023 to January 2024 ranging across standards, technical approval and certification schemes.

All schemes have elements common to Irish Agrément, with most based on substantially similar processes and technical assessment stages. The common elements of the schemes outlined above, and summarised below, demonstrate that the NSAI Agrément process is closely aligned with global certification schemes in relation to:

System/product & certification scope	Factory production control
• organisational structure • competency management • training • system manual • quality policy & implementation • design methodology • test reports • material specifications and certificates • factory production control documents • approved construction details • system configuration management • supply chain quality control	• quality & risk management • contracts • document control • project record methodology • design and process control • offsite manufacturing process • onsite assembly process • competency records • process control • performance monitoring • continuous improvement • project completion and handover

Currently, the NSAI Agrément timeline is nine to 18 months for building systems certification. Benchmarking of NSAI Agrément timelines against equivalent schemes is challenging as, in general, certification providers do not publish typical timelines for certification.

Only BOPAS, BRANZ and EOTA provide indicative timelines ranging from nine to 12 months without specifying the impact of product or system complexity. However, this has been highlighted as subject to timely technical documentation, including test data, records and other evidence as inputs from the product or system manufacturer.

NSAI has directly contacted four certification scheme providers in the UK, of which two provided some high-level information on project cycle times. Both responses stated that timelines will vary significantly with complexity and level of client engagement. However, a range of six to 12 months was indicated for low complexity projects, that is, building component level as opposed to full system certification. It is evident from the study that there is scope for some reductions in the NSAI Agrément timeline but the level of engagement from clients has been identified as a key parameter in the feedback received from other certification bodies.

Arising from this study, and in alignment with the Housing for All actions identified in Section 6 of this report, the following actions are underway at the NSAI to improve efficiency:

1. In depth review of best-in-class MMC technical approval schemes
2. Enhanced communication with prospective clients including infographics on pre-application requirements
3. Update technical requirements checklists to assist MMC clients in determining internal readiness for certification
4. Continuously improve standardised assessment templates specific to MMC building systems
5. Engagement with consultants in respect of a report on *Skills gaps and required training needs/courses for Modern Methods of Construction* as commissioned by DETE
6. Engagement with consultants in respect of the project entitled *Develop a dashboard of MMC metrics to benchmark, and subsequently track, levels of MMC adoption in Ireland* as commissioned by DETE and summarised in section 6.3 above
7. Quarterly metrics of Agrément certification of building systems to DETE
8. Quarterly updates of Agrément certification of building systems to CSG
9. Updates provided to the MMC Leadership & Integration Group (MMC-LIG).

In conclusion, further study is required in respect of the Australian and New Zealand schemes, which are emerging as best in class in terms of processes with conformity assessment for MMC certification, based on the schemes summarised above. It is noted that these schemes may inform optimisation of the NSAI Agrément scheme, but will need adaptation for the current Irish building regulations.

This study has also included the alternative approaches to Irish Agrément, for evidencing proper materials in compliance with Part D of the building regulations. Agrément certification is designed specifically for new building materials, products and processes that do not yet have a long history of use and for which published national standards do not yet exist.

NSAI is aligned to the EU initiatives for maintaining a proficient voluntary technical approval process, via UEAtc, and is also a member of the World Federation of Technical Assessment Organisations, as detailed above.

8. Appendix 1 – Table of schemes by country.

Appendix 1. International Construction Quality Assurance Standards & Certification Schemes by Country (Jan 2024)

Country	Scheme Title	Scheme Operator	Certifier	Process duration (Approx* months)	Scheme details	Cert / Review cycle (Yrs)	Comparision with NSAI Agrément	WebLink	Report Section Ref.
Republic of Ireland	Agrément Certification	National Standards Association of Ireland	NSAI	12-24	Scheme booklet online.	5	N/A	https://www.nsai.ie/certification/agrement-certification/	5
United Kingdom	Agrément Certification	British Board of Agrément	BBA	12-18	Scheme booklet online.	3	Directly comparable technical requirements & process map.	https://www.bbacerts.co.uk/	3.1
United Kingdom	NHBC ACCEPTS certification	National House Building Council	NHBC	-	Scheme details online.	1	Good alignment	https://www.nhbc.co.uk/builders/products-and-services/techzone/accepts	3.1
United Kingdom	Build Offsite Property Assurance Scheme	BLP Technical Services (UK) Ltd.	BOPAS	12	Appendix 5, BOPAS guide details the BLP technical review procedure. Appendix 6, process flowchart.	3	Directly comparable technical requirements & process map.	https://www.bopas.org/	3.1
United Kingdom	BPS 7014	Building Research Establishment	BRE	-	**Draft** standard (2019) available online.	-	Directly comparable technical requirements & process stages.	https://bregroup.com/expertise/innovation/modular-construction/	3.1
United Kingdom	BDA Agrément	Kiwa UK	BDA	-	Scheme details online.	1	Good alignment	agrements/pdf/	3.1
United Kingdom	Product Certification	Steel Construction Institute	SCI	6-9	Scheme details online.	1	Good alignment	tsd005-2023.pdf (scicerts.com)	3.1
United Kingdom	Technical Approval	CARES	CARES	-	Scheme details online.	-	Good alignment	https://www.carescertification.com/certification-schemes/technical-approvals	3.1
United Kingdom	PAS 8700	British Standards Institution	BSi	-	Standard under development	-	Draft unavailable	British Standards Institution - Project (bsigroup.com)	3.1
United Kingdom	LPS 1501	Building Research Establishment	BRE	-	standard (2014) available online	-	Applies to fire test & performance	https://fireacademic.com/lps-1501-issue-1-1-fire-test-and-performance-requirements-for-innovative-	3.1
EU	EN 1090	Multiple CB	CB#	3-9	Scheme requirements online	1-3	Separate but can support an Agrément application	Harmonised Standards - European Commission (europa.eu)	3.1
EU	ETA	EOTA	TAB+	9+	ETA process detailed online	indefinite	Separate but can support an Agrément application	https://www.eota.eu/faqs https://www.eota.eu/tabs	3.3
Germany	Structural Design Approvals	Deutsches Institut für Bautechnik	DIBt	-	Scheme details online.	5	Good alignment	https://www.dibt.de/en/we-offer/structural-design-type-approval	3.2

Sweden	National Technical Approvals	Boverket	Swedac	-	Limited detail available	-	-	https://www.boverket.se/	3.3
Norway	Norwegian Building Authority	Norwegian Building Authority	DiBK			-	Poor alignment, administrative focus.	https://www.dibk.no/sentral-godkjenning/central-approval-in-english/about-central-approval/	3.4
Netherlands	BDA Agrément	Kiwa N.L.	BDA	-	Scheme details online.	1	Good alignment	https://www.kiwa.com/nl/nl/markten/bouw-en-	3.5
Netherlands	VCA	Multiple CB	CB						
France	Atec (l'Avis Technique)	Commission Chargée de Formuler des Avis Techniques	CCFAT	-	Scheme details online.	-	Differs from Agrément (Atec compiled by advisory groups)	https://www.ccfat.fr/	3.6
France	Contrôle Technique de la Construction	apave	CTC	-	Scheme details online.	-	Good alignment	https://infrastructures-	3.6
Austria	Construction Engineering Approvals (BTZ)	Austrian Institute for Building	BTZ	-	Scheme details online.	-	Good alignment	https://www.oib.or.at/en/node/209397 https://www.oib.or.at/	3.7
New Zealand	BuiltReady MMC specific scheme	(MMC specific)	BuiltReady	-	Scheme details online.	-	Good alignment	https://www.building.govt.nz/building-code-	3.8
New Zealand	MultiProof	Standard designs	MultiProof	-	Scheme details online.	-	Good alignment	https://www.building.govt.nz/building-code-	3.8
New Zealand	Appraisal scheme	Building Research Association of N.Z.	BRANZ	6-12	Scheme details online.	-	Good alignment	https://www.branz.co.nz/	3.8
Australia	BCA Compliance Appraisal	Engineered Wood Products Assoc.	EWPAA	-	Scheme details online.	-	Aligns with the NSAI I.S. 440 scheme	https://ewp.asn.au/	3.9
Australia	BCA Compliance Appraisal	Milestone	Milestone	-	Scheme details online.	-	Good alignment	http://www.milestonebc.com.au/services/new-technology-and-building-material-appraisals.aspx	3.9
United States	Validation and QA	ICC Evaluation Services	ICC ES	-	Scheme/Certification details online.		Good alignment	https://icc-es.org/	3.10
Canada	CSA A277 certification standard	Quality, Kentucky	CB	-	Scheme details online.	-	Good alignment	https://qai.org/A277/#:~:text=CSA%20A277%20applies	3.11
Brazil	National system of technical approvals.	Ministry of Cities	Assessment Body	-	Scheme details online.	-	Good alignment	https://www.researchgate.net/publication/324824419	3.12
China	Nat. Standards for Assessment of Industrialised building	State Council of China	CB	-	limited detail online	-	Insufficient detail available	-	3.13

*subject to MMC category type, system complexity & client engagement.

#CB : Certification Body

+TAB: Technical Assessment Body

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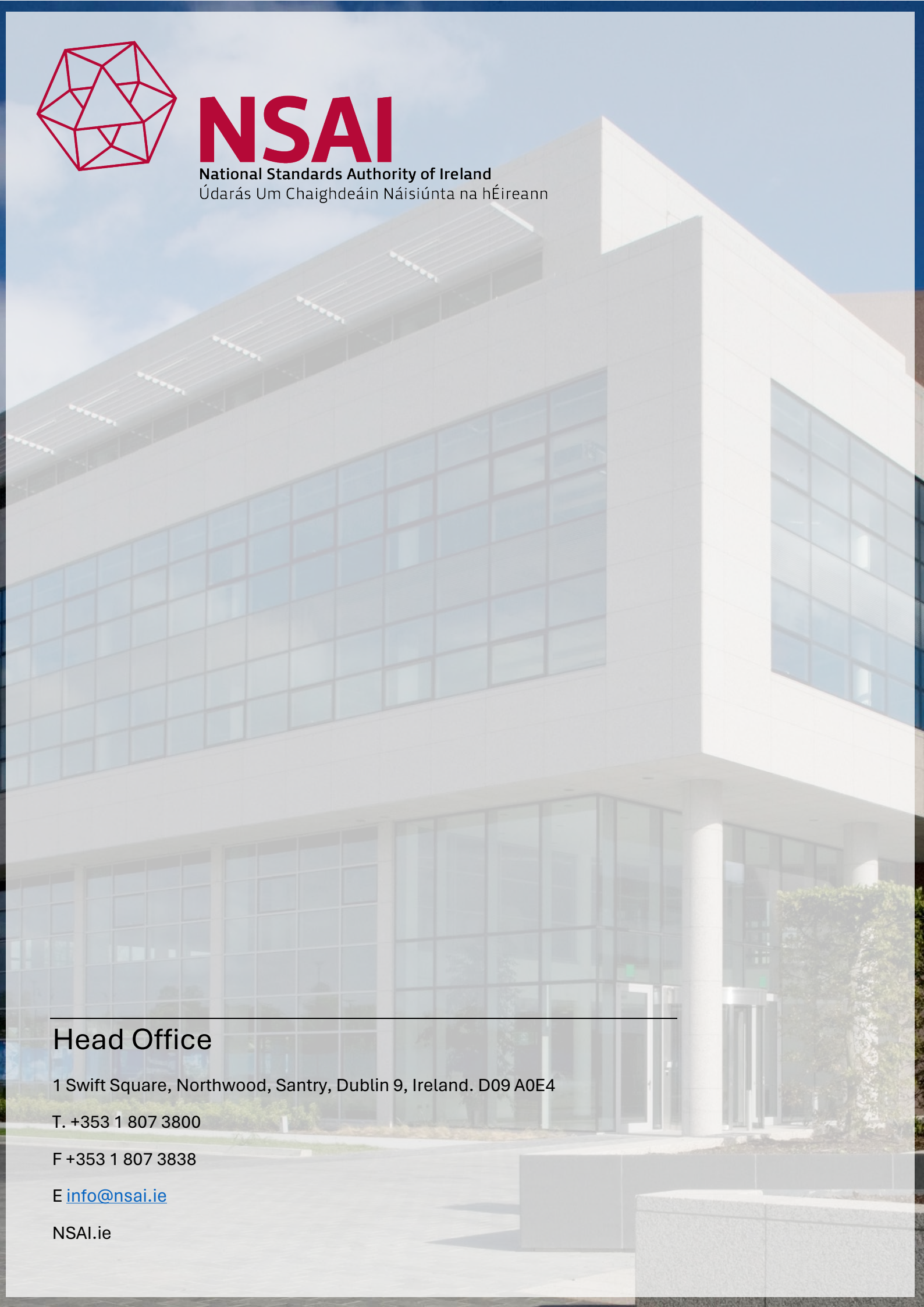

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