WP2 Analysis of the **industrialised systems** in the construction industry

Report of GZS&Pedmede

Leading Organizations

PEDMEDE- Panhellenic Association of Engineers Contractors of Public Works (GREECE)

GZS ZGIGM - Chamber of Commerce and Industry of Slovenia Chamber of Construction and Building Materials Industry of Slovenia - CCBMIS (SLOVENIA)

Contributing Organizations:

PEDMEDE- Panhellenic Association of Engineers Contractors of Public Works (GREECE)

GZS ZGIGM - Chamber of Commerce and Industry of Slovenia Chamber of Construction and Building Materials Industry of Slovenia - CCBMIS (SLOVENIA)

FLC - Fundación Laboral de la Construcción (SPAIN)

IIPLE - Istituto per l'istrucione professionale dei lavoratori edili della provincia di Bologna (ITALY)

K&S Skopje - Knowledge and skills management center (REPUBLIC OF NORTH MACEDONIA)

Associated partner

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1. Methodology

1.1. Research Methodology for Industrialized Construction Analysis

Introduction

The research methodology prepared by PEDEME and GZS ZGIGM and employed by the BuildOffsiteEU consortium members in five countries: (Spain, Slovenia, Italy, Greece and North Macedonia) underlines their commitment to developing innovative training paths and tools for bridging the skills gap between traditional and "new" occupations in industrialized construction. This methodology, encompassing two primary activities within work package 2 (WP2), aims to analyse various facets of industrialized building systems. Through interviews, focus groups, and expert validation, the consortium members collectively address essential aspects of this transformative construction approach.

Activity 2.1 - Experts' Interviews: Conducted in each country, this activity involves individual interviews with both workforce representatives from industrialized construction companies and experts in building sectors focusing on energy efficiency and circular economy. A total of three interviews per country are planned, resulting in 15 interviews overall. These interviews seek to gather first-hand insights into different industrialized construction systems, the significant procedures, tasks, and activities within them, and the crucial criteria determining their compatibility with energy efficiency and circular economy principles. Participants include employers, managers, employees of industrialized construction firms, and experts in the energy efficiency and circular economy realms. By delving into their perspectives, this approach aims to offer a comprehensive view of the industrialized construction landscape.

Activity 2.2 - Focus Groups: Complementing the interviews, focus groups are set to take place with the same participant categories as in the interviews. These focus groups intend to further explore the nuances of various industrialized construction systems, discerning the key procedures, tasks, and activities involved. Similar to the interviews resulting in 20 participants overall, will contribute to discussions. The focus groups delve into the compatibility of industrialized construction systems with energy efficiency and circular economy principles, aiming to identify the necessary skills for upgrading existing competences. These collaborative sessions provide a platform for in-depth exploration and insightful contributions.

Through a structured methodology involving interviews, focus groups, and expert validation, the consortium strives to comprehend the practical implications of industrialized construction systems, their alignment with sustainability principles, and the competences required for their successful implementation. By combining expertise and perspectives from various stakeholders, this research methodology serves as a crucial step towards fostering a more skilled, informed, and adaptable construction workforce capable of meeting the demands of the evolving industry.

Welcome to the comprehensive research report on the Desk and Terrain Analysis of Industrialized Construction Systems conducted under the ambit of the European project BuildOffsiteEU. Spanning the spring and summer of 2023, this extensive research initiative delved deep into the nuances of industrialized construction across diverse terrains in Europe. By scrutinizing the integration of offsite construction practices, technological advancements, and educational paradigms, this report serves as a beacon guiding the evolution of the construction industry towards greater sustainability and efficiency. Our findings underscore the pivotal role of collaborative efforts in shaping the future of construction in Europe and beyond.

2. The industrialized construction systems

2.1. Introduction and Description

Industrialized construction systems revolutionize traditional building processes by utilizing advanced manufacturing techniques and prefabrication methods. These systems encompass both onsite and offsite approaches, each offering distinct advantages in terms of efficiency, quality, and sustainability. Here are listed most common industrialised construction system:

Modular Construction: buildings are constructed using standardized modules that are manufactured offsite and then assembled on-site like building blocks.

Panelised Construction: walls, floors, and roofs are prefabricated as panels in a factory and then transported to the construction site for assembly.

Volumetric Construction: entire rooms or sections of buildings, known as modules or “volumetric units,” are manufactured offsite and delivered to the site for stacking or arrangement.

Hybrid Construction: a combination of traditional on-site construction and prefabricated components, offering flexibility in design and construction methods.

Precast Concrete Construction: concrete elements, such as columns, beams, and panels, are precast in a factory and transported to the site for assembly.

Steel Framing Systems: steel components, such as beams and columns, are manufactured offsite and assembled on-site to create the building’s structural frame.

Timber Framing and Prefabrication: wood-based construction using premanufactured timber components, such as trusses and panels, for quick on-site assembly.

3D Printing: additive manufacturing techniques are used to construct buildings layer by layer, offering design freedom and reduced construction time.

Offsite MEP (Mechanical, Electrical, Plumbing) Systems: prefabricated building service components, like HVAC systems and electrical panels, are manufactured offsite for efficient on-site installation.

Pre-engineered Metal Buildings: steel buildings are designed and manufactured offsite as complete structures and assembled on-site using standardized components.

Pre-assembled Cladding Systems: exterior cladding elements, such as curtain walls and façade panels, are premanufactured and then attached to the building structure.

Pre-insulated Wall Systems: wall panels with integrated insulation are produced offsite, enhancing energy efficiency and thermal performance.

Pre-finished Interior Systems: prefabricated interior components, like wall panels and ceiling systems, are manufactured offsite with finishes and details.

Bathroom Pods and Kitchen Units: prefabricated bathroom and kitchen units are manufactured offsite with all fixtures and finishes, then installed in the building.

There are three industrialized construction systems, depending on the degree of compatibility of their elements with the system units produced by other manufacturers:

- Closed industrialisation: all elements are produced by the same manufacturer, who is responsible for assembly and sometimes also for finishing on site.
- Open industrialisation or through “compatible components”: the elements are compatible with those of other manufacturers and can be combined on site and integrated into traditionally solved elements.
- Hybrid solutions: they combine traditional construction with industrialisation of all types of units.

There are seven categories of **Modern Methods of Construction (MMC):**

1. 3D primary structural systems.

2. 2D primary structural systems.

3. non-systematised primary structural components.

4. Additive components, on site, with low industrialisation index.

5. Non-structural components and sub-components.

These are isolated elements that are part of the various systems, prefabricated components and non-structural sub-components: 3D volumetric components (bathrooms, kitchens, appliances and furnishings); 2D panelled components (façades, roofs). They have a significant industrialisation index when multiple subcomponents are included.

6. Traditional substitute products. Use prefabricated materials to replace traditional (or large-scale) materials. They have a lower impact on industrialisation because they are manufactured locally.

7. Traditional substitute processes that allow digitised tools to be put to work: a robot that puts bricks to work, use of tablets with RA and RV, exoskeletons.

2.2. Offsite vs. Onsite Construction

The differences between traditional onsite and industrialized offsite construction cover construction process, labour needs, quality control, environmental effects, and overall effectiveness. These disparities highlight the benefits of industrialized construction, such as waste reduction, improved quality, and fewer disruptions. Project requirements, budget, timeline, and other considerations determine the choice between onsite and offsite methods. While onsite construction is conventional, offsite construction is becoming more popular for its potential to enhance efficiency, save costs, and decrease environmental impact. Read about each possible approach here.

Offsite Industrialized Construction: Offsite industrialized construction, often referred to as prefabrication or modular construction, shifts a significant portion of the building process to controlled factory environments. Here, building components or entire modules are manufactured with meticulous precision using automated systems. These components (prefabricated elements) are subsequently transported to the construction site, where they are assembled with remarkable speed and accuracy. Offsite construction minimizes on-site disruptions/disturbances, optimizes/improves quality control, and reduces waste generation as well as on-site labour. Moreover, it lends itself well to sustainable practices, as controlled manufacturing allows for efficient use of resources and

environmentally friendly materials. This approach minimizes the need for traditional assembly methods and reduces construction timelines.

Onsite Industrialized Construction: The opposite of offsite construction is onsite construction, often referred to as traditional construction or conventional construction. Onsite industrialized construction entails the integration of modern technology and techniques directly at the construction site. It involves the use of advanced machinery, such as robotic systems and 3D printing, to fabricate building components in real-time. Onsite industrialization fosters adaptability, allowing for immediate adjustments to the project as it progresses. It also enhances the utilization of local materials and streamlines logistics, thus curbing transportation-related environmental impacts. This is the traditional method of building, where materials like bricks, concrete, steel, and wood are brought to the construction site, and the building is constructed piece by piece on the spot. This method requires extensive on-site labour and management, and the construction timeline can be longer compared to offsite construction.

Differences between onsite (traditional) and offsite (industrialized) Construction:

1. Location of Construction:

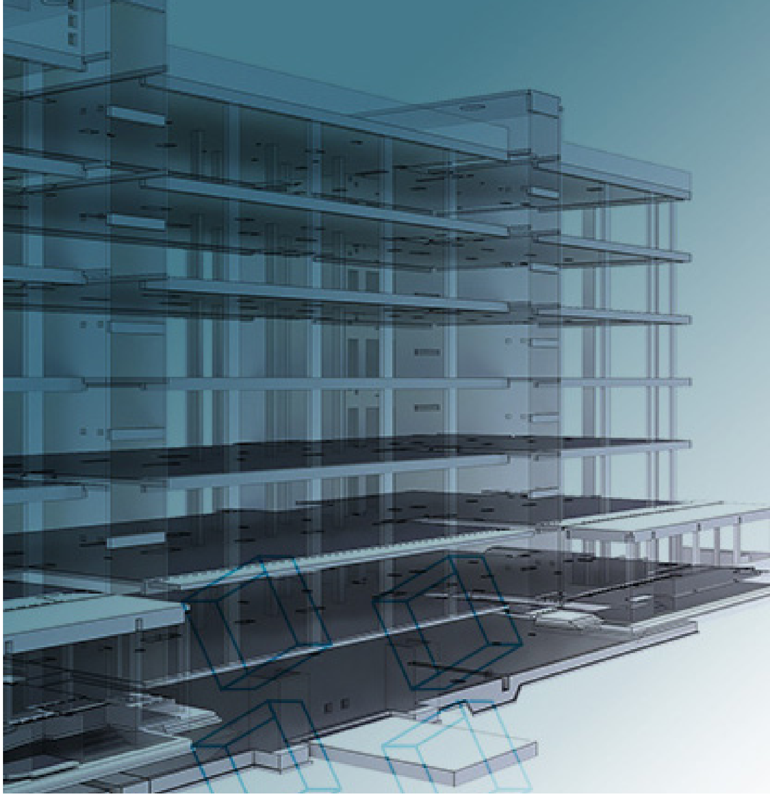
- Onsite Construction: entire process at the actual site.
- Offsite Construction: components manufactured off-site, then transported for assembly.

2. Construction Process:

- Onsite Construction: sequential process, each component built on-site.
- Offsite Construction: simultaneous component manufacturing, quicker on-site assembly.

3. Labour Requirements:

- Onsite Construction: demands significant on-site labour force with various trades.
- Offsite Construction: requires fewer on-site workers due to prefabrication.



4. Weather Dependency:

- Onsite Construction: prone to weather-related delays and quality issues.
- Offsite Construction: less weather-dependent as components produced indoors.

5. Quality Control:

- Onsite Construction: quality challenges due to on-site variables and weather.
- Offsite Construction: offers better control, higher quality, and consistency.

6. Construction Timeline:

- Onsite Construction: longer timelines due to sequential processes and weather.
- Offsite Construction: faster due to concurrent manufacturing and on-site assembly.

7. Site Disturbance:

- Onsite Construction: disruptive noise, dust, and traffic in the vicinity.
- Offsite Construction: reduces on-site disturbances and environmental impact.

8. Waste Generation and Sustainability:

- Onsite Construction: increased waste and environmental impact.
- Offsite Construction: optimized raw material use and waste minimization.

9. Actors Involved in Construction:

- Onsite Construction: individualized work in a hierarchical model with less collaboration.
- Offsite Construction: collaborative work in a factory setting with a flatter hierarchy.

10. Workforce:

- Onsite Construction: high turnover of workers and temporary jobs with limited specialization.
- Offsite Construction: regular partner companies, low turnover, job stability.

11. Procedures:

- Onsite Construction: manual work on-site, wet jointing of elements.
- Offsite Construction: factory units assembled on-site with dry joints.

12. Costs:

- Onsite Construction: possible cost overruns due to delays.
- Offsite Construction: reduced labour costs and enhanced cost predictability.

13. Sustainability:

- Onsite Construction: higher waste generation, greater water, and energy usage.
- Offsite Construction: raw material and water optimization, waste minimization.

ASPECTS

Traditional construction	Aspect	Industrialised construction
Personalisation and uniqueness. Modifiable on site	Desing	Design of repeated units to be assembled on site. Standardization of the project
Individualised work	Agents	Collaborative work
Constant flow of subcontractors. Rotation of workers. Low-skilled temporary jobs	Labour	Regular partner companies. Low turnover of workers, job stability
Manual work on site. Joining of elements and components by means of a wet jointtemporary jobs	Procedures	Construction of factory units that are assembled on site by dry-jointing
It depends on the site management and the professionalism of the tradesjointtemporary jobs	Quality	The quality is verified in the factory under control and qualified
Variable according to climatic conditions and trades coordination	Time frames	Optimised, without the variables of the traditional model
Potential cost overruns due to delays	Costs	Reduction of labour costs
Increased waste generation, water and energy use	Sustainability	Optimisation of raw materials and water, minimisation of waste

3. The industrialized offsite construction systems

3.1. The overview

Industrialised offsite construction methods/ systems, which are the focus of this Erasmus+ project BuildOffsiteEU, encompass a range of innovative approaches designed to improve the efficiency and sustainability of construction. Some prominent examples are:

- **Prefabricated Construction:** At the core of industrialized construction lies the concept of prefabrication. This entails the meticulous manufacturing of building components or modules within a controlled environment, distinct from the final construction site. These prefabricated elements, which encompass walls, floors, roofs, and other building constituents, are typically crafted in dedicated factories or production plants. Their subsequent assembly onsite ushers in a swifter and more efficient construction process when juxtaposed with the conventional method of onsite construction. This modular and streamlined approach to building yields enhanced precision, minimized wastage, and expedited project timelines.

- **Modular Construction**: This method involves creating individual building modules within a factory setting. These modules can be entire rooms, sections of a building, or even standalone structures. Once manufactured, they are transported to the site and assembled into the final structure. The modular approach allows for consistency in production and quality, enabling rapid on-site assembly. Modular construction is a specific type of prefabricated construction where buildings are constructed using standardized, pre-engineered modules or units. These modules are typically assembled into larger structures on-site. Modular construction offers a high degree of flexibility and can be used for a wide range of building types, from residential and commercial to institutional structures. The use of standardized modules allows for easier scalability, cost-effectiveness, and reduced construction time.

- **Prefabricated Structural Systems**: Certain companies specialize in crafting prefabricated structural systems, encompassing components like columns, beams, and trusses, away from the construction site. These elements are meticulously manufactured offsite and subsequently transported to the designated location for assembly. This approach significantly diminishes the necessity for extensive onsite formwork and concrete pouring.

- **Precast Masonry Construction**: Precast construction is another form of prefabricated construction in which concrete elements such as walls, columns, beams and slabs are manufactured off-site in a controlled environment. These prefabricated elements are cured and then transported to the construction site where they are assembled. Precast construction offers advantages such as improved quality control, faster construction time and less labour on site.

- **Lightweight Concrete Systems:** Lightweight concrete systems use lightweight aggregates such as expanded clay or polystyrene balls to reduce the weight of the concrete elements. These systems are particularly suitable for the construction of multi-storey buildings where a lower load is desired. Lightweight concrete systems often consist of prefabricated elements.

- **Timber Construction Systems**. These systems use prefabricated timber components such as panels, beams and frames that are manufactured off-site and assembled on-site. Timber construction offers advantages in terms of sustainability and can convey a warm and natural aesthetic.

- **Panelised Systems**: In this method, building components such as walls, floors, and roofs are prefabricated in factories as panels. These panels are then transported to the site and assembled to create the structure. Panelised systems offer a high degree of customization and adaptability.

- **Volumetric Modules:** These are fully finished, three-dimensional units manufactured offsite and transported to the construction site for assembly. They can include complete rooms or even entire apartments, complete with fixtures, finishes, and MEP (mechanical, electrical, plumbing) systems.

- **Bathroom Pods:** Bathroom pods are self-contained units that include all bathroom fixtures and finishes. They are manufactured offsite and then transported and installed in the building. Bathroom pods can significantly accelerate construction timelines and improve quality control in a critical area of the building.

- **Facade Systems:** Prefabricated facade systems, including curtain walls and cladding, can be produced offsite with high precision. This approach can enhance building aesthetics and performance while reducing the need for extensive onsite finishing.

- **Service Distribution Modules:** These modules contain the building's services, such as electrical, plumbing, and HVAC systems. They are manufactured offsite and then integrated into the building, minimizing the need for extensive onsite coordination and installation.

- **Podium Construction:** Commonly used in mixed-use developments, podium construction involves building the ground-floor or lower levels using traditional methods while utilizing offsite construction for upper levels. This approach optimizes the use of space and construction techniques.

- **Flat-Pack Systems:** Inspired by flat-pack furniture, this approach involves producing building components in flat pieces that can be easily transported and assembled onsite. It's particularly suitable for lightweight structures.

- **Hybrid Systems:** Combining onsite and offsite construction, hybrid systems utilize the strengths of both approaches. Some parts of the building may be constructed traditionally onsite, while others are prefabricated offsite. This approach can offer a balance between efficiency, adaptability, and construction quality-

It is important to note that these systems can be used individually or in combination with each other, depending on the specific requirements of the project. In addition, the choice of building system may depend on factors such as building type, size, budget, regional regulations and traditions of the particular region or area.

More detailed explanation of specific terms to differ among common offsite system:

Prefabricated Construction vs. Modular Construction: While both are forms of offsite construction, the main difference lies in the level of customization and flexibility. Prefabricated construction involves producing various building components offsite, which may or may not be standardized, while modular construction uses pre-engineered units that are highly standardized and easily interchangeable. Modular construction is particularly well-suited for repetitive building layouts or projects with strict design guidelines.

Prefabricated Construction vs. Precast Construction: The primary distinction is in the material used. Prefabricated construction is a broader term that encompasses various building materials, including steel, wood, and concrete. Precast construction, on the other hand, specifically refers to manufacturing concrete elements offsite. While prefabricated construction can involve different materials, precast construction focuses exclusively on concrete components.

Prefabricated Construction vs. Offsite Construction: Prefabricated construction is a subset of offsite construction. Offsite construction includes any method where building components are partially or entirely prepared away from the construction site. Prefabricated construction is one of the specific techniques used in offsite construction, along with other methods like panelised construction and volumetric modular construction.

3.2. Impact, Advantages and Effects on People, Environment and Construction Industry

- This chapter looks at the benefits and impacts of industrialised offsite construction systems on people, the environment and the construction industry. From reduced construction times and improved quality of life for residents to environmental benefits such as waste reduction and lower CO2 **emissions, the chapter also looks at the streamlined quality control and improved building value that modular construction brings to the industry.**

- **People:**

- **Reduced Construction Times:** Modular construction significantly shortens project completion times, providing quicker access to housing and buildings.

- **Less Disturbance and Noise:** As construction activities relocate to factories, noise and disruptions in nearby areas decrease, enhancing the quality of life for residents and workers.

- **Customization and Flexibility:** Modular construction offers greater interior design customization and flexibility, enabling tailored environments to match individual needs and preferences.

- **Quality of Materials and Comfort:** Industrialized buildings boast superior material quality and comfort compared to traditional construction, offering higher value.

- **Streamlined Project Communication:** Offsite construction involves precise planning and coordination at every stage, leading to clearer communication among project stakeholders. The standardized processes and detailed documentation enhance collaboration and ensure that everyone involved is aligned with project objectives.

- **Streamlined Project Communication:** Offsite construction involves precise planning and coordination at every stage, leading to clearer communication among project stakeholders. The standardized processes and detailed documentation enhance collaboration and ensure that everyone involved is aligned with project objectives.
- **Safer Work Environment/conditions:** By relocating many construction activities to factories, the risks associated with on-site work are minimized. This leads to improved worker safety and reduced incidents on construction sites. Factory-based manufacturing leads to safer conditions, reducing accidents and hazards on construction sites.
- **Skilled Labour Utilization:** Offsite construction may require a different set of skills compared to traditional on-site construction. It provides an opportunity to utilize skilled labour in a factory setting, attracting a wider range of professionals to the construction industry.
- **Improved Construction Site Conditions:** Since the majority of construction activities occur in controlled factory environments, the amount of on-site labour and related disturbances are significantly reduced. This leads to cleaner, quieter, and safer construction sites, minimizing disruptions to nearby communities and improving overall construction site conditions.

Environment:

- **Reduction of Waste**: Efficient production processes in modular construction led to better resource management and reduced waste of building materials.
- **Lower CO2 Emissions**: Industrialized construction's reduced on-site time and resource use contribute to lower CO2 emissions associated with building activities.
- **Recoverability:** Prefabricated modules are recyclable or reusable, promoting resource efficiency and sustainability.
- **Energy Efficiency:** Modular construction excels in energy efficiency, aligning with regulations for nearly zero-consumption buildings.
- **Sustainable Materials:** Innovative processes and materials prioritize environmental concerns, resulting in eco-friendly and sustainable buildings.
- **Sustainability and Reuse:** Offsite construction aligns well with sustainable building practices. By optimizing material use, reducing waste, and minimizing energy and water consumption during the manufacturing process, offsite construction contributes to a reduced environmental footprint. Additionally, the ability to disassemble and reuse prefabricated elements in other projects promotes a circular economy and minimizes construction-related waste. Containment of the environmental impact of the buildings

Construction industry:

- **No or Reduced Weather Dependency:** Industrialized construction is not weather-dependent, minimizing project delays due to weather conditions. Prefabrication in a controlled environment significantly reduces weather-related delays and disruptions that can often impact traditional construction. This results in greater project predictability and reduced schedule risks.
- **Streamlined Quality Control:** Modular construction's-controlled factory environment ensures consistent material

quality and workmanship. Strict quality control during factory-based construction ensures consistent quality throughout the building process.

- **Improved Building Quality**: Offsite construction facilitates the production of prefabricated elements under controlled conditions within specialized production facilities. This controlled environment allows for better quality control, ensuring that the building components meet stringent standards. As a result, the completed building exhibits higher overall quality and performance, enhancing occupant satisfaction and long-term durability.

- **Efficient Manufacturing:** The assembly of prefabricated modules in factories is more efficient, with less waste and better resource management.

- **Cost and Time Savings:** The thorough planning and preparation in offsite construction contribute to fewer unforeseen costs and changes during implementation. This reduces the likelihood of costly delays and budget overruns. Additionally, the shorter construction timelines due to faster assembly of prefabricated elements result in significant time savings, enabling quicker project completion and potential cost savings. Increased profitability of projects. Reduction of execution times and construction costs of building.

- **Enhanced Building Value:** Industrialized buildings retain higher value due to material quality and recyclability, contributing to their long-term worth.

- **Certified Acoustic Comfort:** Industrialized construction produces buildings with guaranteed acoustic comfort and energy efficiency, complying with regulations.

- **Optimized Energy Performance:** Industrialized residential and commercial buildings exhibit superior energy performance and ventilation.

- **Material Reusability**: Industrialized buildings function as material banks, enabling reusability, replacement, and recyclability integration.

- Thoughtful and Efficient Construction: Offsite construction involves detailed planning and preparation before construction begins. As the project is defined down to the last detail, it allows for a more systematic and organized approach to building. This results in reduced waste, efficient use of materials, and optimized construction processes, leading to a more thoughtful and well-executed project.

- **The optimisation of the execution phase:** the first tangible benefit of industrialised construction, requires a transformation of the entire value chain and therefore brings with it a whole range of other advantages.

- **Innovative Technology Integration:** Offsite construction encourages the integration of advanced technologies and automation into the manufacturing process. This technological innovation can result in enhanced precision, consistency, and efficiency in building components.

- **Enhanced Flexibility**: Offsite construction offers greater flexibility in design and customization. With standardized modules or components, architects and designers can create versatile building layouts and configurations, meeting specific project requirements and accommodating various spatial needs. This adaptability enhances the overall functionality and suitability of the building for its intended use.

- **Overcoming Geographic Constraints:** Offsite construction provides a solution for projects located in challenging geographic locations. In areas that are difficult to access or have limited logistical infrastructure, such as remote marine and sea areas in the Mediterranean or densely populated urban spaces, offsite manufacturing can alleviate transportation challenges. By producing prefabricated components in controlled environments and then transporting them to these sites, construction becomes feasible even in otherwise inaccessible or confined locations. This capability opens up new possibilities for development and construction in areas that were previously considered impractical or unfeasible.

3.3. Disadvantage and Limitations Compared to Conventional Construction

In this chapter, some disadvantages of industrialised offsite construction systems compared to conventional construction are shown. While offsite construction offers numerous benefits, it's important to acknowledge its limitations. Some of the key disadvantages include challenges related to project complexity, technology integration, customization limitations, initial investment, workforce transition, job displacement, quality control issues, cultural acceptance, architectural aesthetics, transportation impact, complex logistics, site restrictions, storage requirements, limited spatial span, design complexity constraints, construction site preparation, waste generation, maintenance and repairs, local material availability, and regulatory approval and zoning. Understanding these drawbacks is essential for a comprehensive assessment of offsite construction's applicability in various contexts.

- **Project Complexity:** Highly intricate projects with complex spatial arrangements, intricate detailing, or unconventional designs might face challenges in adapting to the constraints of offsite construction.

- **Technology Integration:** Integrating advanced technologies or systems into prefabricated elements might require additional planning and coordination, potentially leading to higher costs or delayed implementation.

- **Limited Customization**: Offsite construction often involves standardized modular components, which can limit the level of customization and unique design features that can be incorporated into the building. Limited customization compared to traditional construction methods. While standardization can lead to efficiency, it can also impose constraints on design creativity. Customizing prefabricated components beyond established standards might result in additional costs or technical difficulties.

- **Initial Investment:** Setting up manufacturing facilities and implementing offsite construction methods might require a significant initial investment, which can be a barrier for smaller companies or projects.
- **Workforce Transition:** Transitioning from traditional construction to offsite methods might require retraining and reskilling of the workforce, leading to temporary displacement or skill gaps in the industry.
- **Job Displacement:** Offsite construction may require fewer on-site labourers, potentially leading to job displacement in the construction industry, particularly for trades focused on on-site work.
- Quality Control Challenges: Ensuring consistent quality across all prefabricated elements can be challenging. Defects or errors in manufacturing might not be identified until assembly on-site, leading to additional costs and delays.
- **Cultural Acceptance:** In some regions or cultures, offsite construction methods might face resistance due to traditional construction practices or a lack of familiarity with the approach.
- **Architectural Aesthetics**: Achieving certain architectural aesthetics or distinctive features might be more challenging within the constraints of offsite construction. Unique design elements could be compromised in favour of standardization.
- **Transportation Impact:** Transporting large, prefabricated elements to the construction site can have a significant environmental impact due to increased road traffic, fuel consumption, and emissions. Transport of prefabricated elements to the construction site impacts costs and feasibility.
- **Complex Logistics:** Coordinating transportation, delivery, and assembly of various prefabricated components requires intricate logistical planning, which can be costly, challenging and time-consuming.
- **Site Restrictions:** Site limitations, such as access restrictions for large, prefabricated components, can impact the feasibility and practicality of offsite construction methods.
- **Storage Requirements:** Storing prefabricated components before installation might require additional space, leading to temporary land use and potential environmental concerns.
- **Limited Spatial Span:** The modular nature of prefabricated components can lead to limitations in the size and span of spaces that can be created, which might not align with certain architectural or functional requirements.
- **Design complexity:** constraints due to repeatability of elements and standardization. Design errors in one element can affect other manufactured elements. Meeting static, fire, thermal, and acoustic requirements can lead to additional costs. Initial Design Investment: Creating detailed designs for prefabricated components requires upfront investment in time and resources, which can impact project timelines and costs. The need for standardization and repeatability of elements in offsite construction can sometimes limit the complexity of architectural and structural designs. Unconventional

shapes or intricate designs might be harder to achieve within the confines of prefabricated modules. Design alterations or unexpected changes during the construction process might be harder to accommodate in offsite construction due to the replanned and prefabricated nature of components. Offsite construction may have limitations in adapting to dynamic design changes during the construction process, especially after prefabricated elements have been produced.

- **Construction Site Preparation:** While offsite construction reduces on-site labour, it requires meticulous site preparation to ensure that the prefabricated elements fit seamlessly during assembly. Any discrepancies in site preparation can lead to challenges during installation.
- **Waste Generation**: While offsite construction aims to minimize waste during manufacturing, some waste might still be generated during the assembly and installation process on-site.
- **Maintenance and Repairs:** The modular nature of offsite construction might pose challenges for maintenance and repairs in the long term. Accessing and replacing specific components within a prefabricated structure could be more complex than traditional construction.
- **Local Material Availability:** Offsite construction might rely on specific materials that are available regionally, limiting the choice of materials in certain locations. This could affect the architectural and functional aspects of the building.
- **Regulatory Approval and Zoning:** Certain regions may have regulations or zoning restrictions that limit the use of offsite construction methods. Local authorities might need to adapt their guidelines to accommodate this approach, leading to additional administrative efforts and delays.

3.4. Processes and Phases

Offsite construction processes encompass all stages from project initiation, design, and production to transportation, assembly, and even considerations for the end of the element's lifecycle. The focus on quality control, efficiency, and sustainability is key throughout each phase.

Offsite Construction Processes identified via this project research were recognized as following:

1. Project Initiation and Planning:

- Definition of client's requirements and terms of reference.
- Design and cost analysis in comparison to conventional construction methods.

2. Design and Documentation:

- Creation of detailed design plans for prefabricated elements.
- Preparation of shop drawings for execution in the production plant.
- Preparation of workshop documentation and installation plans.

3. Manufacturing and Production:

- Procurement of building materials for production.
- Manufacture of modules or prefabricated elements in the production plant.
- Implementation of quality control (QC), marking, and traceability processes.

4. Assembly and Transportation:

- Loading of prefabricated modules onto transportation means.

- Transport or delivery of modules to the construction site.
- On-site assembly of prefabricated elements.

5. Installation and Finishing:

- Installation of prefabricated modules according to the installation plan.
- Supervision of installation to ensure accuracy and quality.
- Completion of finishing touches and integration with on-site components.

6. Quality Check and Approval:

- Creation of sample models for client review and approval.
- Checking and approval of the sample model by the client.

7. Use, Maintenance, and Lifespan:

- Use of the constructed building or component in the intended manner.
- Regular maintenance to ensure longevity and performance.
- Possibility of repair or replacement as needed.

8. End-of-Life Considerations:

- Recycling or disposal plans for the prefabricated elements at the end of their lifecycle.

3.5. National Context, Best Practices, Manufacturers

In the exploration of Industrialized Offsite Construction Systems, this chapter unveils the National Context, Best Practices, and Manufacturers involved in this transformative approach. Delving into the specific contexts of Slovenia, Spain, Northern Macedonia, Italy, and Greece, the chapter elucidates the prevalent industrialized construction systems, best proven practices, and key manufacturers that shape each country's landscape.

Slovenia

MOST COMMONLY USED INDUSTRIALISED BUILDING SYSTEMS

Between 1955 and 1985, the largest number of apartments in Slovenia was built by architect Ilija Arnautović. He was born in Niš, Kingdom of Yugoslavia, in 1924 and died in Ljubljana in 2009. He studied architecture in Prague (1945-48) at the Technical College and continued his studies in Ljubljana (1948-52) at the Edvard Ravnikar Seminar. Arnautović's design is characterised by economy and speed of construction with the possibility of industrial production of individual building elements (industrialisation and prefabrication of building elements), he researched various possibilities of prefabricated construction, used prefabricated façade elements (large-panel prefabrication systems, heavy and light assembly methods). He is one of the pioneers of prefabricated construction in Slovenia.

Danilo Fürst, who developed the Quick-build system, is considered to be the pioneer of prefabricated construction in Slovenia, and he was also the author of the first prefabricated house, which was erected in eight days, complete with all the interior fittings. The architect Danilo Fürst, a representative of the Plečnik school, introduced technical innovations into Slovenian architecture, among which the plans for standard and prefabricated construction and the use of curved ceilings and pre-stressed concrete roofs stand out.

As early as 1955, the company Jugomont was founded in Zagreb, Croatia, to produce elements for prefabricated building systems throughout the former Yugoslavia. In Ljubljana, the system was perfected by engineer Ervin Prelog and brought into line with anti-flood requirements.

BEST PRACTICE

The National Housing fund (SSRS) recommends and requires designers to incorporate prefabricated products where rational in residential building projects. Ready-mixed elements like lightweight concrete installation shafts, sanitary cabins, and other concrete products are commonly installed in projects, streamlining the construction process. However, precast systems are not employed for primary structures, with prefabricated timber systems planned for specific projects. Marles, a prefabricated house company from Maribor, is actively helping to find solutions for the destroyed and destroyed residential buildings and the rehabilitation of the buildings flooded in August 2023. In addition to prefabricated houses, the company's programme also includes modular buildings, which allow for quick implementation and, at the same time, a comfortable and high-quality stay for the citizens of Slovenia, as well as a temporary solution to the housing problems of some of the inhabitants whose homes have been destroyed by the weather storm. Trimo group containers can be used to build temporary housing, temporary office buildings, kindergartens. It is a modular prefabricated construction. As part of the reflection, common standards should be set, as is the case for example in the software sector, so that clients can assemble products from different manufacturers, which would allow healthy competition and development in this area.

A good practice in the country is to promote projects with prefabricated elements (concrete safety barriers on the motorway, noise barriers on the motorway and railway, concrete thresholds on the railway, etc.).

MANUFACTURERS OF INDUSTRIALIZED OFFSITE CONSTRUCTION SYSTEMS

Varis Lendava: produces bathroom modules (finished bathrooms) made of concrete and wood. https://www.varis-group.com/

Sigmanova: installation shafts and chimneys http://www.sigmanova.si/

CGP: manufacturers of concrete elements for prefabricated buildings elements (for residential use) https://www.cgp.si/Dejavnosti/Proizvodnja

Pomgrad ABI: manufacturers of concrete elements for prefabricated industrial halls https://www.pomgrad.si/stik

Arcont: manufacturer of modular living units and prefabricated buildings https://www.arcont.si/si/sl/proizvodi

Trimo Group: one of the leading providers of modular space solutions, with over 30 years of experience and almost 100.000 units manufactured and supplied worldwide to-date. Modular solution for Commercial, Hospitality, Education, Industrial, Government

https://www.trimo-group.com/en/products/modular-space-solutions

CBD: timber massive construction elements https://www.cbd.si/lesena-masivna-gradnja

Slovenian manufacturers of prefabricated wooden residential houses/ buildings:

JELOVICA HIŠE, from Škofja Loka https://www.jelovica-hise.si/vecji-objekti/

MARLES HIŠE, from Limbuš https://www.marles.com/hise/konfigurator

RIHTER, from Ljubno ob Savinji https://www.rihter.si/hise/klasicne-hise/

RIKO HIŠE, from Ljubljana https://www.riko-hise.si/sl/ponudba/konstrukcijski-sistemi/

Italy

MOST COMMONLY USED INDUSTRIALISED BUILDING SYSTEMS

All the experts in the focus group agree that modular construction in Italy is still under development and is not yet as widespread as the traditional construction method. Modular buildings in Italy are in fact mainly used for industrial structures, mall, offices, schools, recreational and sports facilities. In the residential sector, the use of modular structures is not particularly widespread.

Modularity means using the same module in multiple solutions, allowing for a wide variety of designs without using many different module types. This brings numerous advantages, first of all the economic one. Modularity is particularly advantageous when the project is relatively large. Thanks to the modularity, various designs can be realized, resulting in low development costs t.

BEST PRACTICES

Some good practices of Italian companies, in the construction chain, which adopt products with eco-labels, are reported:

- Permasteelisa Group: Italian company specialized in the design and construction of glass and aluminum facades, has obtained the EU Ecolabel for its range of eco-sustainable aluminum products.
- GranitiFiandre: manufacturer of porcelain stoneware floors, has obtained the EU Ecolabel for its “Ecolight” product line which uses recycled materials and reduces the environmental impact in production.
- A2A Calore & Servizi: provides heating and cooling services for buildings, uses EU Ecolabel certified heat pumps and cogeneration systems to reduce environmental impact.

- Fassa Bortolo: manufacturer of plasters, mortars and coatings for the building industry, has obtained the EU Ecolabel for its "EcoMalta" product line which uses natural materials and reduces the environmental impact in production.

- Edilclima: deals with low energy consumption buildings and uses EU Ecolabel certified products for its projects, for example the heating and cooling systems of buildings.

Many other companies are gradually adopting eco-certified products to build more efficient and sustainable buildings.

MANUFACTURERS OF INDUSTRIALIZED OFFSITE CONSTRUCTION SYSTEMS

Even in Italy there are industrialized off-site construction systems, also known as prefabrication or modular construction systems. These systems are gradually gaining popularity in the Italian construction sector, as they offer numerous advantages in terms of construction efficiency, product quality and sustainability.

Some examples of industrialized off-site construction systems popular in Italy include:

- Modular Constructions for which there are Italian companies specialized in the design and production of prefabricated modules for residential, commercial and industrial use. These modules can be used for the rapid construction of buildings and structures.

  Prefabrication techniques are often used to create building components, such as walls, floors, floors and beams, in controlled factory environments. These components are subsequently transported to the construction site and assembled.

- Dry Construction Systems: The dry construction approach, often using steel materials, has been adopted in Italy to construct buildings efficiently and sustainably.

  Dry steel constructions, unlike the "wet" construction processes of the last century, constitute integrated systems of components, both structural and complementary pre-worked. The construction site becomes the site where highly competitive building components are assembled in the shortest possible time and according to predefined and simplified methods, pre-assembled in the workshop where checks, tests and quality standards of absolute reliability are guaranteed. The risks due to environmental factors and conditions typical of construction on site are thus reduced.

Industrialized metal carpentry construction is divided into two main macro-categories:

- Metal constructions in heavy carpentry, with a structure in laminated profiles, floors in mixed or entirely dry structure, and dry infill and roofing, represent a specific approach to construction that exploits the use of steel for key components.

- Lightweight carpentry metal constructions are distinguished by the use of cold-formed thin profiles as the main element of the structure. These thin profiles are made using cold-forming steel processes, making them lighter than rolled profiles used in heavy carpentry construction. This type of construction is often employed in a range of applications, including residential, commercial, industrial buildings and even temporary structures such as warehouses or exhibition stands.

The construction landscape in Italy is changing and new initiatives and technologies are constantly emerging.

Spain

MOST COMMONLY USED INDUSTRIALISED BUILDING SYSTEM

Each system has its merits and there is no single criterion that determines the suitability of using one or the other. Indirectly, logistics (transport) can be considered the variable that determines the use of each one. Also items that may affect sustainability (e.g. CO2 embedded) can be considered as a variable.

MANUFACTURERS OF INDUSTRIALIZED OFFSITE CONSTRUCTION SYSTEMS

In Spain, the only materials with certified industrialised proposals at present are the following: structural timber (MET) (laminates, cross-laminated timber); timber framing (TF); light galvanised steel (LGS) (steel frame); hot-rolled steel (HRS) (heavy steel structures); concrete and cement (C) derivatives (C) (concrete and cement).

These materials can be hybridised to produce different combinations. For example, hot rolled steel can be combined with light galvanised steel; if timber frame is combined with concrete, the result is TFC; and if concrete is combined with light galvanised steel (steel frame), the result is called LGSC. These combinations include all the technical proposals that exist in Europe.

North Macedonia

MOST COMMONLY USED INDUSTRIALISED BUILDING SYSTEM

In the Macedonian construction sector the use of traditional construction materials is still on the leading level as the most common types of building materials which are used are conventional materials. Current most common types of building materials used by construction sector in North Macedonia are concrete, bricks and steel, as part of traditional construction process. As the material used for carpentry varies between PVC and wood. Additionally, the materials for thermal insulation usually represent a synthetic material.

When we are speaking of Industrialised construction, the main industrialized construction systems used are Concrete Systems, Steel Framing Systems, Modular Construction: Modular and Lightweight Construction Systems and prefabricated construction elements.

In terms of industrialised construction, in MK it is mostly present in final phase like using prefabricated facades, windows etc. Very rare there are prefab concrete slabs used in construction. Some companies offer prefabricated houses, but mainly for vacation use on remote places or for industrial objects. Rarely this is chosen for constructing housing buildings.

BEST PRACTICES AND MANUFACTURERS OF INDUSTRIALIZED OFFSITE CONSTRUCTION SYSTEMS

The whole process of industrialised construction refers to producing prefabricated elements far from the site (off-site) that are then transported to the site and assembled. These elements mainly are from concrete, wood, or entire blocks for façade assembling.

Best practices related to industrialized construction systems in Macedonia are:

- Construction of concrete face slabs for dam Loshana, Delchevo
- In the past there were industrialized buildings called Russian buildings. There was a company Karposh producing prefabrikated elements from concrete. There are prefabricated wooden hauses in Radishani produced in Treska. The facade of Dzevahir are from prefabricated elements in their own production.
- Some companies offer prefabricated houses, but mainly for vacation use on remote places or for industrial objects. Rarely this is chosen for constructing housing buildings.
- KEN panel, HOT-HOT houses.

Greece

MOST COMMONLY USED INDUSTRIALISED BUILDING SYSTEM

The most common industrialized construction systems in Greece are related to pre-cast concrete structural elements: concrete blocks for marine projects, concrete beams/columns for buildings, special-type construction concrete systems in industrial facilities etc. The reason is that the construction industry in Greece demands that kind of concrete items and in addition, the public works price catalogue includes that kind of cost items.

Other main industrialized systems in Greece as referred to by the participants are:

- Steel and timber structure frames. Steel beams, columns, and trusses are often used to create the structural framework, with metal cladding or other wall and roof materials. Timber frame structures are more common in rural areas with high altitudes. The main advantages of these are the ease of erection and also, small timber buildings are excluded from building permit application.
- Prefabricated concrete panels. These panels are manufactured off-site in controlled factory conditions and then transported to the construction site for assembly. They offer faster construction times and can be customized according to design requirements. The main source of applications includes concrete beams for bridges, and industrial projects.
- Insulated Concrete Formwork (ICF): consisting of blocks of expanded polystyrene (EPS) or polyurethane (PUR). The primal application of these systems is the insulation of the building frame. The main advantage is the insulation of the building and the ease of erection.

In Greece, mainly industrial areas, hotels, new school buildings and bridges are built using the method of heavy prefabrication. Prefabrication is mainly based on the standardization of raw materials and production methods, the mechanization of production, transportation and project execution processes and the systematization of all operations, from the stage of study, design and construction budget, to transportation, the placement and assembly of its structural elements. Due to the above, the main goals of industrialized building are the solution of structural problems that the classical method cannot deal with, the speed of meeting construction needs, the reduction of production costs, the control and improvement of construction quality, the exploitation of technological properties and the reduction of site work with a parallel increase of the corresponding factory work.

BEST PRACTICES RELATED TO INDUSTRIALISED CONSTRUCTION SYSTEMS

- Thorough planning and design processes that consider the specific requirements of industrialized construction systems can optimize efficiency, cost-effectiveness, and quality.
- Effective collaboration among stakeholders, including architects, engineers, contractors, and manufacturers, is essential for seamless integration of different components and successful implementation of industrialized construction systems.
- Developing standardized processes, components, and quality control measures ensures consistency, reliability, and efficiency in manufacturing and assembly.
- Leveraging technology such as Building Information Modelling (BIM), digital fabrication, robotics, and automation can enhance accuracy, productivity, and communication throughout the industrialized construction process.

BEST PRACTICES FROM COMPANIES IN GREECE ON INDUSTRIALISED BUILDINGS

Use standardized components: This help to reduce costs and improve efficiency, as the components are mass-produced in a factory.

Use prefabrication: This means assembling building components in a factory before transporting them to the construction site. This can improve quality, reduce waste, and speed up construction time.

Use modular construction: This means assembling a building from prefabricated modules that are transported to the construction site and stacked together. This can offer similar benefits to prefabrication, but it can be even more efficient.

Use precast concrete: This means casting concrete in a factory before transporting it to the construction site. Company Lafarge Holcim uses precast concrete to create a variety of building components, such as walls, floors, and roofs.

Use Building Information Modelling (BIM): This is a process that uses computer software to create a digital model of a building.

Use lean construction principles: This is a set of principles that focus on waste reduction and continuous improvement. These principles help to improve efficiency and productivity in a construction project.

The Athens Olympic Village was built using modular construction techniques. The modules were prefabricated in factories and then transported to the construction site, where they were stacked together to create the buildings.

MANUFACTURERS OF INDUSTRIALIZED OFFSITE CONSTRUCTION SYSTEMS

In Greece there are several manufactures of Industrialized Offsite Construction Systems. Some of them are:

EUROtrade S.A. Bulletproof Constructions & Modular Buildings: modular buildings range from a one-man cabin (guard posts) to relocatable classrooms, entire schools, hospitals, commercial warehouses and hagars, worksite offices, press boxes, changing rooms.

PAUL KALFAGIAN is a Manufacturer/ Producer, which operates in the Buildings, modular industry.

The company EUROPA CRETE PROPERTIES S.A. REAL ESTATE DEVELOPMENT AND CONSTRUCTIONS is a Manufacturer/ Producer, which operates in the Buildings, modular industry.

ARMOS precast construction is provider of industrial prefabrication of precast concrete elements and precast fencing systems as well as the reinforced concrete prefab.

The company IG Kallergis Ltd. it is a pioneer in the construction of prefabricated buildings.

The company Androulakis, a leader in prefabricated houses in Greece, implements technologies mandated by green construction. The primary structural material for their constructions is Swedish and Scandinavian wood.

METALBOX is a company in the field of polyester and metal constructions. The main business is modular buildings in all sizes, polyester or metal such as in portable cabins, Polyester portable WC & Mobile accessible toilets, prefab mobile offices, Guardhouses & Bulletproof security booth, ticket offices.

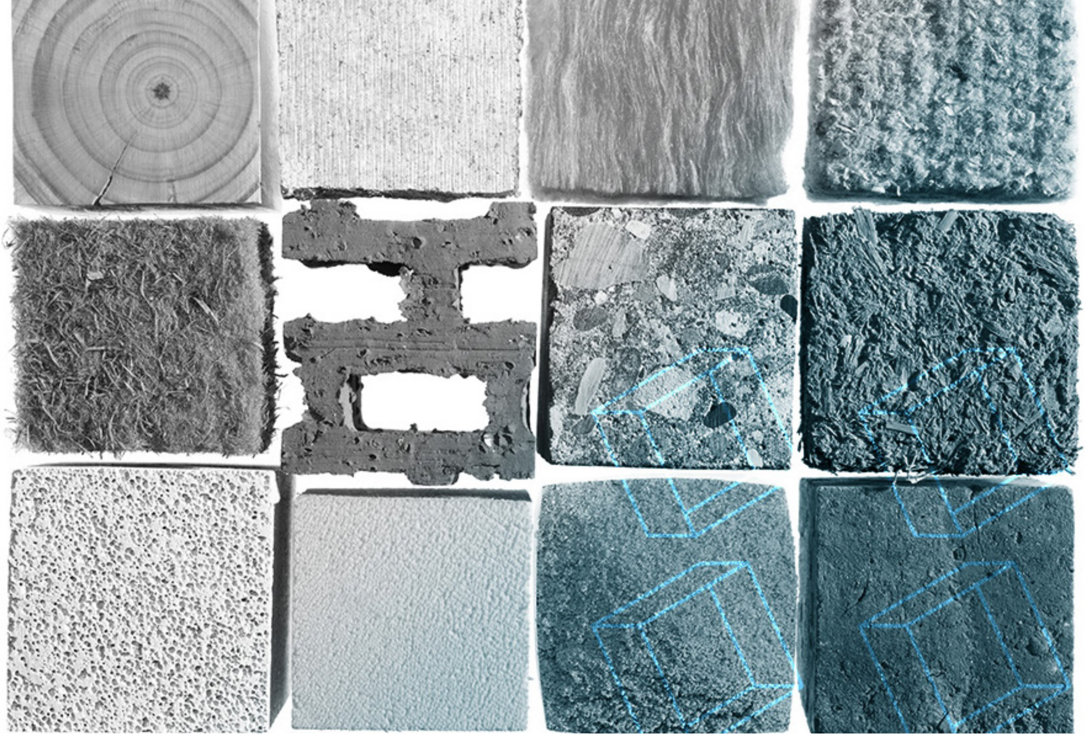
3.6. Link between industrialised construction and EE&CE

Industrialised construction plays a central role **in supporting the clean energy transition and accelerating the decarbonisation of the built environment**. The inherent benefits of this approach, including rigorous quality control, preparation in controlled environments, control of waste management, reduced raw material consumption, minimised reliance on on-site labour and reduced negative impacts of transportation, are consistent with clean energy and environmental sustainability goals. **The introduction of circular economy and energy efficiency principles into industrialised building systems is applicable to a variety of methods**. The selection of the optimal system depends on factors such as demand, availability of raw materials, economics and transport options. Certain systems, especially those that use locally produced materials and renewable resources such as wood and aggregates, are more suitable in this respect.

Certain industrialised building systems are compatible to varying degrees with the principles of the circular economy and energy efficiency. Criteria such as control of raw material and energy consumption, design based on recycling and end-of-life considerations, and stakeholder involvement in project preparation are of paramount importance. These criteria serve as crucial reference points to ensure that systems comply with the principles of sustainability.

Modular prefabrication is a common option in industrialised building systems. This approach offers several opportunities to promote energy efficiency and the circular economy. **Prefabricated modules can be designed to maximize thermal insulation, reducing thermal bridges and ensuring better airtightness.** Furthermore, the prefabricated modules can be disassembled and reused in other constructions, reducing material waste and promoting material circularity. It is also important to consider intelligent building management and monitoring. Industrialised building systems can integrate technologies that allow the control and optimization of energy consumption, the automation of lighting and air conditioning systems, as well as the efficient management of water and waste. This approach aims to reduce energy waste and optimize the use of resources.

The experts involved state that industrialised building systems can be partly designed and built in accordance with the principles of energy efficiency and circular economy, integrating specific criteria. One of the key aspects is the energy efficiency of buildings. **Industrialised building systems may include features that improve thermal insulation**, such as adequate insulation and energy-efficient windows. Furthermore, they **can integrate controlled ventilation systems and renewable energy sources** such as solar or geothermal energy, with the aim of reducing energy consumption and creating comfortable and energy-efficient interior environments.



Industrialised construction systems can facilitate the use of materials with low environmental impact. Industrial construction in line with the principles of circular economy and energy efficiency proves beneficial when materials are sourced locally. The emphasis on raw materials such as **timber and aggregates at the production site**, combined with the **ability to recycle concrete**, demonstrates a commitment to sustainable practises and reduced environmental impact. Key criteria for industrialised construction include the prudent use of local materials to minimise transportation and environmental impact. The use of environmentally friendly materials, reduced energy consumption in production and installation, and improved energy efficiency together contribute to sustainability in industrialised construction. This could include **using recycled or recyclable materials**, such as wood from sustainably managed forests or low-carbon concrete. Furthermore, **the use of local materials can be promoted** to reduce the impact of transportation and benefit the local economy.

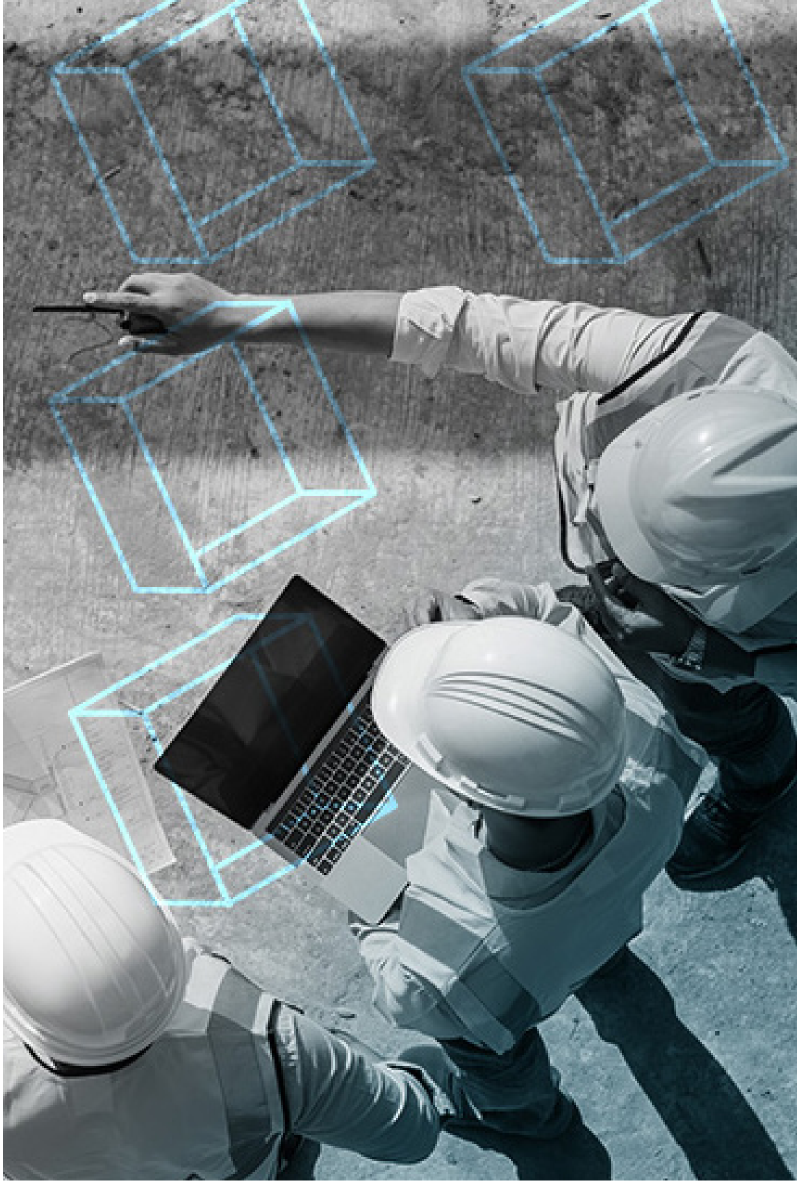
The prospect of implementing green criteria and standards in industrial building systems is promising. There are several green criteria and standards related to sustainability that are applicable to industrialised construction systems. The best known globally and also widespread are **following certification schemes**: LEED, BREEAM, DGNB, WELL Building Standard, Passive House Standard.

Adapting these criteria to specific projects is crucial, with modular construction offering potential cost benefits and energy efficiency improvements in certain scenarios. Implementation often depends on legislative support and collective industry cooperation. While designers advocate for policy to introduce green criteria and standards for public projects, they also recognise the role of manufacturers in implementation, as well as the role of investors and public procurement specifications. These manufacturers and investors can extend and strongly support the reach of sustainable building practises.

When designing industrialised building systems, the life cycle of buildings can also be taken into account. This implies the choice of **long-lasting and low-maintenance materials, flexible, adaptable and sustainable design** (design for deconstruction, design for functional adaptation, design for sustainability) that allows for the **redevelopment of spaces over time and planning for the efficient management of construction and demolition waste**. The goal is to minimize the environmental impact throughout the life of the building.

Implementing these principles requires holistic design and collaboration between different stakeholders, such as **designers, engineers, builders and material suppliers**. Furthermore, it is important to consider local environmental regulations and standards to ensure compliance with best practices and maximize the positive effect of industrialised buildings on energy efficiency and the circular economy.

Education and awareness raising within the construction sector remains critical to shaping a sustainable future. The mantra “act locally, think globally” underlines the need for a united front to protect the environment. The use of local materials, reduced energy consumption, environmentally friendly materials and increased energy efficiency underline the importance of collaboration across the industry.



4. The industrialized construction systems' competences

4.1. Workers` Competences

To advance industrialized construction systems and offsite construction practices, upgrading competences is crucial. Education and training play a significant role in developing a skilled operational workforce capable of implementing these modern construction methods.

Additionally, fostering technical and design expertise is essential for architects, engineers, and construction professionals to effectively leverage the benefits of prefabricated and modular construction. Upgrading technical and design expertise is crucial for successfully implementing industrialized construction systems. Architects, engineers, and construction professionals need to familiarize themselves with the principles, techniques, and best practices of prefabricated and modular construction. This includes understanding how to design for modular components, coordinate with manufacturers, and optimize building processes to take advantage of the benefits that offsite construction offers.

To promote the adoption and implementation of industrialized construction systems, there is a need to upgrade competences in the field of construction education and training. This includes incorporating teaching about industrialized construction into secondary schools, higher schools and faculties as well in cVET.

There are several alternatives for defining training that ensures the (re)qualification of the workforce in this constructive ecosystem:

- Adapt training contents from traditional to industrialised construction.
- Adapt training contents from industrial to industrialised construction.
- Design new training content directly for industrialised construction.

4.2. Areas of Competences

In the context of enhancing skills to implement optimal practices in industrialized construction offsite systems across the five European countries engaged in the BuildOffsiteEU project, crucial areas of competency have been identified based on insights from interviews and focus groups:

Elevating expertise in architectural design and engineering is paramount to conceive modular designs that encompass both structural robustness and aesthetic appeal, while also being efficient to fabricate and assemble. This entails proficiency in modular design principles, parametric modelling, and Building Information Modelling (BIM). The workforce should enhance their digital skills to adapt to Industry 4.0 technologies, including the use of advanced construction software, Building Information Modeling (BIM), and other digital tools. Competence in utilizing these technologies enables better coordination, communication, and efficiency in industrialized construction projects.

Developing proficiencies in off-site manufacturing techniques and processes is fundamental to ensuring efficient and top-quality production of modular components. This encompasses training in advanced manufacturing technologies, such as computer-controlled cutting, robotic assembly, and 3D printing, combined with the implementation of lean manufacturing principles.

Proficiencies in logistics and supply chain management are indispensable for orchestrating the transportation, delivery, and installation of modular components. This encompasses optimizing transportation routes, inventory management, and guaranteeing the timely delivery of materials to the construction site.

In order to align with circular economy principles, it is essential to provide the workforce with training in sustainable construction practices and materials associated with offsite construction. Proficiencies in selecting environmentally friendly materials, recycling, and waste reduction are critical for ensuring the long-term sustainability of industrialized construction. Additionally, mastering the skills required for the external assembly of offsite elements holds significant importance. This is because the installation and finishing of structures can often be intricate and specific to the product or project, necessitating prior training or on-site demonstrations with the construction team involved.

Elevating project management competencies is essential for effectively planning, executing, and monitoring modular construction projects. This encompasses skills in scheduling, cost control, risk management, and stakeholder coordination. Moreover, familiarity with project management tools and methodologies specific to modular construction can confer additional advantages.

Ensuring unwavering quality throughout the manufacturing and assembly processes is of paramount significance. Proficiencies in quality assurance and control entail implementing standardized procedures, conducting inspections, and instituting quality management systems to adhere to regulatory stipulations and industry benchmarks.

Enhancing client relationship skills and communication abilities is essential for professionals involved in industrialized construction. Effective communication with clients, understanding their needs, and educating them about the benefits of industrialized construction contribute to successful project engagements and long-term partnerships.

Effective collaboration between various disciplines is vital in industrialized construction. Training employees, employers, and managers in interdisciplinary collaboration fosters better coordination, communication, and teamwork, leading to smoother project execution and improved project outcomes.

The workforce should enhance their digital skills to Continuous Learning and Adaptability (Digital Skills and Industry 4.0 Competences). The workforce should be encouraged to embrace continuous learning and stay updated with the latest advancements in industrialized construction. Being adaptable to evolving technologies and industry practices allows individuals to remain competitive and efficient in their roles.

4.3. Challenges on Technical Competencies

Industrialized systems hold great potential for circular economy principles and energy efficiency in the construction industry. However, several technical challenges and barriers must be overcome to fully realize these benefits. Workforce skills play a vital role in addressing these challenges. Professionals need expertise in advocating for standardization and common principles, converting traditional building designs into modular solutions, and closing the knowledge gap in industrial construction design. Furthermore, only skilled individuals can effectively communicate the advantages of industrialized construction to clients and promote awareness of its possibilities. Equally important is the knowledge of environmentally friendly materials and digitalization to ensure that industrialized systems align with sustainability goals and energy efficiency objectives. By empowering the workforce with the necessary skills and knowledge, the construction industry can embrace industrialized systems that drive a more sustainable and efficient built environment.

In the context of complying with circular economy and energy efficiency principles, industrialized construction companies, their staff, employers, and managers encounter several technical challenges and barriers. Some key issues include the following:

Lack of Awareness and Knowledge: One of the foremost challenges is the lack of awareness and knowledge about the existence and benefits of industrialized construction systems. The advanced tools and digital capabilities available for anticipating and planning every detail during the design phase are often underutilized due to a lack of understanding. Another problem is that clients are not familiar with industrial construction and its possibilities. Shortly, key problem is poor knowledge of the benefits of industrial production of building elements on the part of designers and clients.

Stakeholders Perception: Production of building elements involves collaboration between designers, clients, contractors, and builders. However, a challenge lies in altering the perception of industrialized construction. Misconceptions that associate it with lower quality assets persist. In certain design and build (DB) projects, contractors grapple with technical complexities, especially in residential building designs that are originally intended for traditional construction.
As a result, redesigning projects for manufacturing facilities becomes necessary, consuming time, financial resources, and human efforts. Investors often avoid such processes. Exceptions are observed in projects like production halls, warehouses, and shops, where industrial construction is the primary focus. An underlying issue is that designers lack adequate knowledge in designing for industrial construction due to educational gaps. Notably, exceptions exist among designers who have experience in a production plant context, enabling them to understand the nuances of industrial construction. Addressing this knowledge gap is crucial for smoother integration of industrialized construction practices.

Lack of Skilled Labour Workforce: A critical bottleneck is the lack of skilled labour specialised in industrial construction. The special nature of these facilities requires a new set of skills that are currently lacking, making it difficult to find qualified people to carry out these projects effectively.

The lack of skilled labour also hinders the development of the construction sector, as there are not enough training opportunities for young workers.

Knowledge Transfer: Transitioning to industrialized construction often involves the digitization of information within the Building Information Modelling (BIM) environment. While the potential benefits are significant, a barrier arises from not fully comprehending how to effectively transfer this knowledge into practical implementation. Loss of knowledge on industrial production of building elements from previous generations/ past projects, too few or no professional staff with competences or experience.

Minimal/Poor Industry-Academia Collaboration: Effective collaboration between the construction industry and academia is integral for fostering innovation and progress. However, the lack of significant partnerships between these sectors hampers the transfer of knowledge, hindered by a gap between theoretical education and practical implementation.

Skill Shift: Industrialized construction requires a workforce that excels in process management rather than traditional craftsmanship. Emphasis on procedural processes, reduced specialization time, and a different skill set poses challenges for training and upskilling.

Financing and Certification: Obtaining financing for industrialized element production remains a hurdle for many clients. Furthermore, the need for standardization and certification is vital to ensure quality guarantees, yet it presents an initial challenge.

Cultural Resistance and Skill Gap: In some regions, the construction industry holds a conservative culture that resists change. Industrialized systems demand a transformation of traditional processes, which can be met with resistance. Additionally, a shortage of skills and knowledge in designing and managing construction processes for industrialized systems poses a significant barrier.

Complex Skill Requirements: Implementing circular economy and energy efficiency principles in industrialized construction necessitates specific and complex skills. The intricate nature of these principles means that technicians may possess expertise in one area, either circular economy or energy efficiency, rather than both.

Expensive Overall Costs: The substantial costs associated with industrialized construction often pose a significant challenge. The initial investment required for specialized equipment, digital technologies, and training can be substantial, deterring some companies from embracing these innovations. In small countries they are too small a market for most products to cover the costs of development and production.

Lack of common EU Standardization and Principles/Approach: The lack of comprehensive compliance standards and regulations tailored to industrialised construction systems creates uncertainty. Clear guidelines and regulations are essential to ensure consistency, safety and quality across all projects and their absence can prevent industry-wide adoption. There are no common EU standards and principles, and no offsite engineer or architectural approach prior to actual construction. The lack of standardised principles is a challenge for industrialised systems. To remedy this, the workforce needs to be able to develop and advocate for common standards and solutions, much like ancient Rome did when it came to uniform standards for infrastructure.

4.4. Lack of Technological Skills

In the rapidly evolving landscape of industrialized construction, continuous learning and upskilling are fundamental. Workers must be equipped to certify their training, and this certification should hold universal recognition. Ultimately, the construction industry's future success hinges on its ability to embrace change, cultivate expertise, and keep pace with technological advancements.

The comprehensive approach to industrialized construction encompasses three critical dimensions: training, digitalization, and maintenance. Within this framework, the adaptability and versatility of construction workers emerge as paramount factors. Workers need to embrace change without hesitation and readily adjust to the evolving demands of their roles in the construction industry.

When it comes to training in industrialized construction, various options exist for requalifying workers within this construction ecosystem. Among these options, the most suitable approach involves tailoring training to the specifics of industrialized design and processes. There are several pathways to consider:

1. Adapting Traditional Content: One approach involves the adaptation of existing training content from traditional construction to align with the requirements of industrialized construction. This strategy leverages the foundation of traditional construction knowledge and modifies it to suit the industrialized context.

2. Optimizing Industrial Content: Alternatively, existing industrial construction training content can be refined and updated to cater to the nuances of industrialized construction. This approach acknowledges the relevance of industrial processes while fine-tuning them for the industrialized paradigm.

3. Developing New Curriculum: A more forward-looking strategy involves the creation of entirely new training content designed specifically for industrialized construction. This approach acknowledges that industrialized construction is a distinct field with its own set of principles and practices.

In conclusion, the identification of competencies and the imperative for "new training" in industrialized construction call for a multifaceted approach:

- **Defining Competences:** Clearly defining job competencies and professional profiles is foundational to effective training.

- **Industry Partnerships:** Collaborating with construction companies to tailor training to their evolving needs is essential. Training programs must be dynamic and responsive to changing industry requirements.
- **Digital Literacy:** In the era of Industry 4.0, digitalization is paramount. Training should encompass digital skills, including proficiency in Building Information Modelling (BIM), Virtual Reality, and Augmented Reality, to enable construction professionals to navigate the digital landscape effectively.
- **Customized Short Courses:** Short courses should cater to various construction systems, from 2D and 3D structures to panelling and modular construction. This ensures that workers are well-versed in the specific methods and technologies relevant to their projects.
- **Industry Collaboration:** Encouraging collaboration among companies is vital. Each firm can contribute its specialized knowledge of construction systems, fostering a collective learning environment.
- **Certification:** Leveraging certifications offered by industrialized construction companies can serve as a valuable resource for training skilled professionals in the industry.
- **Continuous Learning:** Training must be ongoing and adaptive, tailored to the unique needs of companies and their workforces. Establishing a common baseline of training needs is the first step in developing effective training pathways.

4.5. Competences For Operating On-Site

Targeted competences to be upgraded by operational workforce

The enhancement of skills for employees, employers, and managers in industrialized construction systems, with a specific focus on complying with circular economy and energy efficiency principles, is a multifaceted endeavour. A holistic approach that encompasses training, digitalization, and maintenance is imperative for the successful integration of these principles. The challenges and barriers encountered in this journey underline the need for strategic planning and a comprehensive skill development strategy.

Assembling on-site Construction: One critical aspect is the efficient assembly of prefabricated elements on-site. This entails mastering the precise installation of components to achieve structural integrity, durability, and energy efficiency. Professionals need the ability to seamlessly integrate prefabricated elements into the overall project, ensuring that the on-site construction process aligns with the design intent and efficiency goals.

Alignment with Project Design and Avoidance of Frequent Team Changes: Professionals must meticulously follow project designs to ensure the precise implementation of all elements. This involves translating design blueprints into tangible structures, leaving no room for deviation. Adopting a holistic perspective—globalizing competences—is essential for assembly and integration. This minimizes the need for frequent changes in work teams, leading to smoother processes and consistent project outcomes.

Material Properties Understanding and Proper Installation: Profound knowledge of material properties is indispensable. Understanding how different materials interact with energy, the environment, and each other allows professionals to make informed decisions that align with circular economy and energy efficiency principles. Additionally, mastering the proper installation of prefabricated elements guarantees their optimal performance and longevity, reducing the likelihood of maintenance issues.

Correct Conjunctions and Thermal Bridge Avoidance: Ensuring correct conjunctions of construction elements is pivotal for achieving structural integrity and energy efficiency. Proficiency in this area guarantees that all components fit seamlessly, and interconnect as intended. Special focus on avoiding thermal bridges—areas of elevated heat transfer—enhances energy efficiency by preventing unnecessary energy loss.

Specialized Training from Industry Professionals: Specialized training from experienced professionals who are well-versed in industrialized construction is crucial. This training imparts practical insights, best practices, and context-specific knowledge that textbook learning often lacks. It encompasses a wide spectrum, including organizational and management skills to effectively oversee complex projects and communication skills to facilitate seamless coordination among diverse stakeholders.

Strict Control Process of Industrialized Products: Implementing a stringent control process for industrialized products is paramount. Professionals must be skilled in conducting meticulous inspections and quality assessments at every stage of production. This involves rigorous adherence to established standards, ensuring that each component meets specified criteria for performance, safety, and sustainability.

Technical Competences for Technicians: Technicians require a solid grasp of various technologies, materials, and regulations. They must excel in translating project requirements into technical drawings, managing production activities, and ensuring quality throughout the process. Additionally, context-specific skills, such as working with precast concrete, add to their proficiency.

Operational Proficiency: Operational roles demand practical skills, from utilizing equipment and tools to deciphering intricate technical drawings. Precision in assembly, installation, problem-solving, and teamwork are cornerstones of operational proficiency.

Technical Competences for Managers and Entrepreneurs: For managerial and entrepreneurial roles, a blend of technical and management skills is paramount. An in-depth understanding of the construction sector, project management prowess, leadership skills, and quality management expertise are crucial. Proficiency in technologies like BIM and mastery over digital solutions are increasingly vital.

GENERAL COMPETENCES TO BE UPGRADED BY OPERATIONAL WORKFORCE

Adaptability and Versatility: Central to this progression is the adaptability and versatility of the workforce. The ease of embracing change and swiftly adjusting to the evolving needs of the company is vital. Workers must be empowered to overcome any initial resistance to new methods and be ready to embrace innovative practices.

Training Strategies: In the realm of training, a variety of strategies can be considered for equipping the workforce with the requisite skills. The process of (re)qualifying workers in the industrialized construction ecosystem demands thoughtful approaches. These include adapting traditional content to industrialized design and processes, transitioning existing industrial content to industrialized applications, or even designing entirely new content tailored for industrialized construction.

Collaborative Development: Collaborative approaches are key. Crafting job competences and professional profiles should involve partnerships with companies to ensure training aligns precisely with real-time industry needs. Furthermore, digitalization should be emphasized across all levels, equipping all participants in the production process with the ability to adeptly navigate digital tools and platforms.

Strategic Planning: Addressing these skills gaps necessitates a strategic sector-wide planning approach. Collaborative synergies between companies, a strong emphasis on continuous up-to-date training, and the introduction of training mandates are essential.

Promoting Awareness: Beyond skills enhancement, raising awareness and promoting industrialized construction at a societal level is crucial. Integrating industrialized construction education into the school system and fostering a culture of innovation are pivotal for long-term transformation.

The journey towards aligning industrialized construction with circular economy and energy efficiency principles requires coordinated efforts from employers, employees, managers, educational institutions, and the broader society. It's a shared mission to equip the workforce with the competencies needed for a sustainable and efficient future.

5. Training In VET systems

The integration of industrialized construction into Vocational Education and Training systems in the construction sector varies among the mentioned countries—North Macedonia, Slovenia, Italy, Spain, and Greece. The following insights provide a comprehensive overview:

North Macedonia: Education centres of material manufacturers represent a good practice in this regard. There is partial integration, particularly in certain subjects' curricula within the 1st and 2nd cycles of studies at the Civil Engineering Faculty, Skopje, UKIM. So some integration exists in educational systems, specifically in Vocational Education and Training (VET) schools/centres. However, the focus is mainly on providing informative content without significant practical application. Integration is partially also present in the formal higher education system, although this is more common in other subjects. Nonformal training offerings are sparse, and industrialized construction is mainly addressed in the context of installing PVC carpentry.

Slovenia: Industrialized construction, particularly in the field of building systems, is not or only minimally included in the education system. There seems to be a gap in directly addressing this topic, but certain related aspects might be touched upon in subjects like computer science. Experts emphasize the necessity of legislative action

to make mandatory compulsory training for clients, designers (especially those with an IZS license), and contractors. This approach aims to create a shared language and a comparable level of knowledge. Industrialized construction's inclusion in education is considered essential, but it's the direct integration (inclusion) appears limited.

Greece: There is still much to be done in this respect. However, universities in Greece and the prefabrication ecosystem are implementing some education and qualification programmes to improve the skills of managers. In addition, many faculties of civil engineering in Greece, such as the National Technical University and the University of Patras, have included a prefabrication module (related to prefabrication materials and design) in their curriculum. At Master's level, there is no specific curriculum for industrialised building systems.

Spain: Training is an imperative for transformation, providing insight into the industrialization environment and the requisites across stages: design, processes, standardization, and sustainability metrics. This fosters investment in technology, materials, and system development, thereby enhancing comprehension of the industrialization ecosystem. Notably, Environmental, Health & Safety (EHS) aspects are integral in industrialized construction training curricula, requiring regular updates and mandatory inclusion in formal education. Ensuring workers possess foundational knowledge in these areas before commencing work is crucial, aligned with construction industry conventions.

Italy: Within Italy's VET systems, integrating industrialized construction into education would involve updating curricula in disciplines like civil engineering, architecture, and construction technology. Establishing simulation labs equipped with machinery used in prefabrication processes enhances practical skills. Collaborations between educational institutions and industry experts will be crucial, offering consultation, real-world projects, and internships. Programs for educators ensure they're updated on latest trends. Leveraging ongoing research enriches students' understanding of innovative construction solutions.

Common Strategies for Integration:

1. Curricular Updates: Education institutions are encouraged to review, discuss and update their curricula to encompass construction industrialization topics, possibly through dedicated modules or courses.

2. Practical Simulations: Establishing laboratories and showrooms or special VET facilities equipped with machinery and tools used in prefabrication processes can provide students / trainees with hands-on experience and operational skills.

3. Collaboration with Industry: Industry partnerships are vital for consultancy, practical exercises, case studies, internships, and apprenticeships.

4. Teacher and Trainer Programs: Offering training programs to educators keeps them updated on the latest trends and technologies in industrialized construction. The issue is how to deal with this, temporary work rotation of VET staff among VET centres and companies?

5. Leveraging R&D Results: The outcomes of research and development programs can improve knowledge and awareness of innovative solutions in the industrialized construction sector.

In summary, while the integration of industrialized construction into Vocational education and training systems varies, there is a shared recognition of the importance of enhancing education to align with the evolving construction landscape. The strategies identified aim to bridge the gap between traditional education and the requirements of modern construction practices.

Recommendations for identifying competences and the need for 'new training':

- Define competences based on jobs and professional profiles.
- Work continuously with companies to define these training courses that meet their needs and look for synergies between the different construction systems.
- Digitalisation at all levels as a key point. It is important that all those involved in the production process, all profiles are trained to know how to "read" digital. Training in digital skills linked to Industry 4.0 methods: BIM -Virtual Reality-Augmented Reality should be included.
- Design short-term training activities tailored to the characteristics of each building system (2D-3D structures, panels, modules).
- Use the certification processes of industrial companies in the construction sector as a "nucleus" for trained professionals.
- Give validity and recognition to the certification acquired through training in order to provide workers with tools that facilitate their labour mobility in the industrialised construction sector.

5.1. Status Of Teachers/Trainers

Slovenia: The training of educators in industrialized construction systems is lacking, with historical expertise fading. During the former Yugoslavian era, there was more emphasis on these topics, resulting in more skilled educators. Presently, there seems to be no specific training requirement within the education system for these educators. Knowledge appears outdated, and further education is largely driven by individual motivation.

Spain: In Spain, training for teachers and trainers in industrialized construction systems should involve collaboration with innovative companies in the industrial construction sector. The evolving nature of construction requires proactive training to anticipate changes. Certification by companies engaged in industrialized construction could play a significant role in keeping educators up to date. Short courses in collaboration with construction companies could provide specific training based on current industry needs.

Italy: Experts in Italy indicate a lack of easily accessible training in "industrialized construction systems." While discussions often revolve around prefabrication and dry assembly techniques, training in this area remains scarce. Adequate training, especially in dry prefabrication and digital sustainability aspects, is essential for various profiles within the construction sector. Some training is offered by manufacturers of prefabrication components, but there's a need for broader coverage, including digitization and sustainability aspects.

North Macedonia: Information about the training of educators in industrialized construction systems is limited. Self-education through online resources seems to be a common approach. There's a need to align educators' training with the latest products and technologies in the market, as the current training might not correspond to new offerings.

Greece: In Greece, educators in industrialized construction systems often require further improvement and upskilling. Collaborations between educational institutions and industry partners are proposed to enhance training relevance. Such partnerships provide exposure to real-world projects, industry practices, and emerging technologies. These collaborations ensure educators remain current on the latest trends, challenges, and solutions within industrialized construction systems.

Offsite construction is rapidly evolving, driven by technological advancements and sustainability imperatives. In Europe for trainers and teachers, upgrading their competences is crucial to effectively prepare the workforce for the future of construction. The rapid evolution of offsite construction demands proactive and continuous efforts from trainers and teachers to upgrade their competences. By staying informed, embracing new technologies, and engaging with industry partners, educators can effectively equip the future workforce with the skills needed for success in the evolving construction landscape.

Given the dynamic nature of offsite construction, trainers and teachers should aim to upgrade their competences at least once a year. Regular attendance at industry events, workshops, and webinars ensures that educators remain up to date with the latest trends, technologies, and practices. Collaboration with industry partners can facilitate access to practical experience, allowing trainers to incorporate real-world scenarios into their teaching.

6. Sources and literature

Greece

(input received by PEDMEDE):

The Greek study engaged the expertise of various key representatives from the construction sector. A total of six participants took part, involving a combination of three in-person interviews and a focused group discussion with three participants. The participants' composition included five male and one female experienced civil engineers, all with substantial backgrounds in construction and energy projects. The study commenced with an introductory overview of the project's scope and objectives, providing a clear context for the subsequent interviews and discussions. The methodological approach employed for the study reflects a blend of online interviews and face-to-face interactions during a focus group session. This dual approach allowed for a comprehensive examination of the subject matter, encompassing the digital realm and fostering insightful in-person dialogues. This was executed during the month of June in the year 2023, facilitating an efficient and focused exchange of perspectives.

The engagement of representatives from diverse construction entities provided a holistic view of the industry's standpoint on industrialized construction. Companies actively involved in the focus group and interviews include:

- TEKAL S.A., a versatile general contractor established in Greece participating in both private and public projects. Despite its involvement in numerous projects, TEKAL has yet to venture into the realm of industrialized construction.
- G.E.M.E.K., a well-established construction company headquartered in Distomo, Livadia, Greece. Founded in 1979, the

company boasts an extensive project portfolio spanning various sectors such as building, hydraulic, environmental, industrial, and energy. Its recent endeavours also include Construction and Demolition recycling, concrete production, and steel reinforcement.

- Odos ATE, a technical powerhouse with over four decades of experience in Greece's public works sector. Specializing in construction public works brings a wealth of expertise to the study.
- DEKTOR S.A., a company with a broad spectrum of involvement in construction and energy sectors, undertaking projects both domestically and internationally. Their experience spans across Construction, Hydraulic, Industrial, Electromechanical, Energy, Port, and Road projects.
- LAZAROU IKE, a small-scale company engaged in the construction of private and public works, contributing valuable insights from their unique perspective.
- AVAX S.A., a construction industry heavyweight, recognized as one of Greece's largest construction groups. Renowned for its successful projects, infrastructure works, and contributions to the economy, AVAX S.A.'s involvement underscores the study's significance.

Italy (input received by IIPLE):

The Italian study encompasses a group of experts who actively engaged in both round table discussions and interviews, representing diverse professional backgrounds and areas of expertise. The expert panel and participants featured a total of six persons, in addition to the IIPLE staff who facilitated the study's progress. Among these participants, five identify as male, while one is female, offering a balanced representation.

Profiles of the participants showcase a rich diversity of skills and knowledge:

- ffA male Civil and Plant Engineer whose role within a company specializing in eco-sustainable living centers around integral planning. His expertise covers areas such as architectural and sustainable urban design, building energy systems, structural engineering, and applied research in energy-saving technologies and environmental control for built environments.
- A male Surveyor and Construction Management Specialist whose work as a freelancer involves the management of building practices and renovation works. With a strong training background, he serves as a skilled trainer in construction

operator qualification courses, imparting knowledge on construction techniques, site management, and the use of sustainable materials.

- An Entrepreneur in Residential Civil Construction who is actively involved in the field. His exploration of innovative techniques in industrializing both structural and building completion elements sets him apart in the study.

- A male Civil Engineer specializing in Wooden Prefabrication, serving as a construction site technician within a company specializing in wooden buildings. His expertise lies in the efficient management of building orders, particularly focusing on the assembly of prefabricated components and maintaining site safety.

Slovenia (input received by GZS ZGIGM):

The Slovenian study examines offsite construction in Slovenia through three interviews and a focus group with three stakeholders. Eight people participated, three online interviews were conducted with a total of five people (1 x architect, 1 x learning centre, 3 x manufacturer) and 1 face-to-face focus group with 3 participants from the National Housing Fund.

The study explores the state, challenges, and opportunities of offsite construction in addressing labour shortages, construction waste, and logistical issues. The interviews were conducted online from June to July 2023, and the focus group in August 2023 at the Housing Trust premises.

Key contributors include:

- The Director of GZS VET CENTER -CPU .

- The Slovenian Manufacturer Team of POMGRAD GROUP

- The Director of architectural bureau AMPL d.o.o..

- The Housing Fund of the Republic of Slovenia, represented by three project managers (architects, construction engineers), also participated in the round table.

Spain (input received by FLC):

The Spanish study featured a gender-diverse participation of seasoned experts. The study, guided by the project's objectives, emphasized collaboration, sharing of knowledge, and a comprehensive exploration of the challenges and benefits of industrialized construction. The study sessions were conducted using a mix of online interviews and face-to-face focus group meetings. This enabled a thorough examination of the subject matter while fostering meaningful discussions among participants.

This study involved an array of experts from diverse sectors of the construction industry, providing valuable insights into the realm of industrialized construction. Eight persons in total provided their answers:

- Director of Industrialization at Viuda de Sainz, the Managing Director of Enerblock S.L., and the President of the Asociación Española de Construcción Industrializada (OCH), a newly founded entity dedicated to promoting industrialized construction in Spain.
- Head of the Technical Office and Industrial Process Development at Sant Gobain, a prominent figure with extensive experience in various departments.
- Director of Zero Housing, two members of the Colegio de Aparejadores y Arquitectos Técnicos de Sevilla (COAAT).
- Professionals from companies like CIMPRA and Construcciones Felipe Castellano.

North Macedonia (input received by Knowledge and Skills Management Centre- K&S Skopje):

The study In North Macedonia encompasses a series of interactions, including three individual interviews and a focused group discussion. The interviews, totalling three in number, were conducted through both online platforms and face-to-face meetings, six persons in total. Participants in these interviews comprised a diverse group, encompassing an academic representative, an NGO professional specialized in energy, and a construction industry expert. Among them, there were two male participants and one female participant. Organized by the Knowledge and Skills Management Centre-K&S Skopje, this study occurred on June 19th, 2023, in the city of Skopje, North Macedonia.

The individual interviewees brought a wealth of experience and perspectives to the study:

- Stevco Mitovski, holds the position of Associate Professor at the Faculty of Civil Engineering, University Ss Cyril and Methodius in Skopje.
- Risto Ivanov operates as a Project Manager at Kreacija, an NGO.
- Zhanina Stamenkova, works as a Civil Engineer in the construction company Delta proekt.

The study further included a focus group discussion, 26 June 2023, involving three individuals from the workforce of industrialized construction companies and experts specializing in energy efficiency and circular economy within the building sector. One participant represented academia, another was an energy expert, and the third was actively involved in the construction industry. Among the focus group participants, there were two male members and one female members. All together nine persons were involved in the research.

7. Validation process

The validation process of BuildOffsite's national inputs from five European countries aims to verify the key findings obtained from interviews and focus groups. This validation is conducted in collaboration with national and international external experts to ensure the relevance and applicability of these findings within the context of the off-site construction industry.

The validation process involves the distribution of an online questionnaire, which serves as a tool to validate the insights gained from the interviews and focus groups. The online survey is designed to be comprehensive and is sent via email to a target group of experts. This group includes professionals from industrialized construction companies, as well as experts specialized in energy efficiency and circular economy aspects within the building sector.

Three experts from each participating country, totalling 15 experts, are invited to participate in the validation process. Before sending out the online questionnaire, all partners are required to provide the results of their respective interviews and focus groups, which allows the experts to familiarize themselves with the findings. The questionnaire itself can be prepared using platforms like Google Forms or other suitable means, ensuring consistency in the question order across all partners.

To maximize understanding, translation of the questionnaire into the local language of each partner is optional, depending on what enhances clarity for the respondents. Throughout this process, data protection policies applicable to each partner's organization should be respected and upheld.

The validation tools include Annex, which offers a synthesis of the findings from interviews and focus groups in the national context, and Annex, providing the actual online questionnaire designed for the experts. This comprehensive validation process ensures that the insights garnered from interviews and focus groups are rigorously examined and confirmed by external experts, further enhancing the credibility and utility of the study's outcomes.

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Annexes

The research questionnaire

1. Could you briefly describe your business, the type of services you offer and your role? Please also indicate if you are actively involved in industrial construction.

2. How familiar is your company/organisation with industrialised construction? Could you please indicate which industrialised construction systems are used in your country? Which are the most widely used in your country? And why? What are the main differences between these systems?

3. What are the main advantages and benefits of prefabricated/offsite construction? What are the differences or limitations compared to conventional construction?

4. What elements make up the different processes, phases, and activities of each of these systems? What are the most common building materials currently used in your country/company?

5. Can you briefly describe the term modular/offsite/prefab construction"?

6. Are you familiar with the benefits and impacts of modular/offsite/prefab construction on people, the environment and the construction of the building?

7. Do you know best practises in your country/company related to industrialised construction systems? What are the main competences that need to be improved in industrialised construction systems?

8. In your opinion, what are the technical challenges and barriers faced by staff/employers/managers of industrialised construction companies in terms of compliance with circular economy and energy efficiency principles? How do you deal with this within your company/organisation?

9. Do you think that employers, employees, and managers have enough skills and competences to deal with the challenges and needs addressed in this research?

10. What do you think are the most important skills that workers specialised in industrial construction should improve through training? How do you deal with this need in your company/organisation?

11. How is the subject of industrialised construction being integrated into education systems in the construction sector?

12. How are these educators trained in industrialised construction systems? What is the status of this training? (i.e. updated, outdated, etc.)

13. Can industrialised construction support the transition to clean energy, accelerate the decarbonisation of the built environment and attract a workforce for energy efficiency?

Do you think that some industrialised building systems are better than others in terms of circular economy and energy efficiency principles? Which are they and to what extent?

In your opinion, what are the most important criteria in industrialised construction that should be taken into account in order to comply with the principles of energy efficiency and the circular economy? How do you deal with these criteria in your company/organisation?

14. Do you foresee specific green criteria and standards related to sustainability for industrial building systems?

The validation questionnaire

Personal Information

Please specify the type of your organization/ company.	Construction Company
	Consulting Company
	Engineering Company
	Non-Profit Private Organisation
	For-Profit Private Organisation
	Other (please specify):
Please indicate the areas in which your organization belongs.	Construction Sector (NACE F - 42)
	Building sector (NACE F- 41, 43)
	Energy efficient sector (M 71.-consultancy)
	Environmental sector (M 71.-consultancy)
	Other (please specify): ________________
Are you aware of the main different industrialized construction systems in your country?	Yes
	No
	If yes, please specify: ________________

Evaluation of findings regarding the report from interviews and focus groups.

Please indicate from a Scale from 1 to 4 (where 1=bad, 2=good 3=very good 4 =excellent) your view on project's findings regarding industrialized construction systems.

Quality Criteria: Relevancy	1	2	3	4	COMMENTS
The findings are satisfied regarding the needs of industrialized systems					
Based on the need of the target group is the content relevant and up-to date					
Quality Criteria: Effectiveness					
The output matches the description given					
The output can be easily used by its intended target group					
The areas of investigation are relevant regarding the content					
Quality Criteria: Consistency					
The overall content of the findings is presented in a logical and to the point manner					
No grammar, spelling, and punctuation errors exist					
Quality Criteria: Efficiency					
The findings provide the basis to ensure the "new competences" of the workers in the industrialized systems					
Quality Criteria: Impact					
Can these findings contribute to reaching higher level objectives, i.e identification of key competences in the industrialized systems					

Conclusion	Mark with X the appropriate line
no changes required	
changes required	

BuildOffsiteEU