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CONSTRUCTION & ENERGY

OFF-SITE ENGINEERING SOLUTIONS
MODULAR & PREFABRICATION CONSULTANTS

Sayram Construction & Energy Modular Systems Study

Synergies Between Tunnelform & Modular Construction

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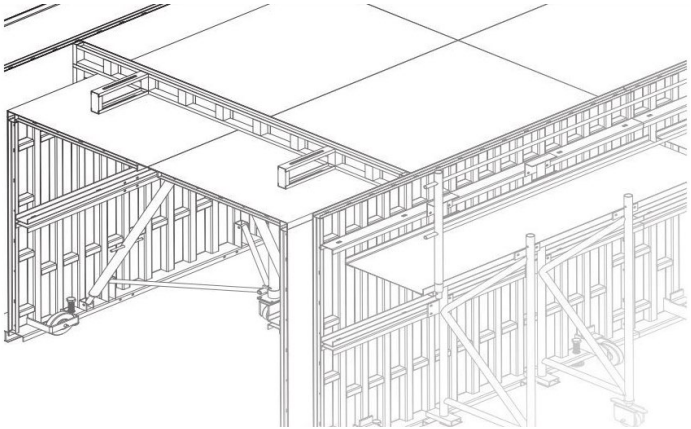

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4. A forward-looking overview of the future developments and direction of the modular construction and tunnel form sectors.
5. The geographical areas to be included in the report are to be global and inclusive of Europe and North America
6. A breakdown of the geographical relevance and adoption of different proprietary systems within the modular construction and tunnel form sectors
7. Regulatory and market entry issues related to modular and tunnel form systems in different geographies
8. Clear and Actionable Conclusions and recommendations on the commercial viability of the hybrid approach. (Using tunnel form as part of a modular construction system.)

This will include the cost benefit of the hybrid system compared to traditional construction. We will also provide additional data or insights related to global turnover, demand trends, and benchmark pricing metrics (e.g., €/m²) that can further support a preliminary evaluation by management.

DELIVERABLE 1:
An overview of current applications and technological advancements in the off-site engineering and modular construction sector

1. Applications of Modular Construction. In general, offsite engineering and modular construction are best deployed on projects that have scale and repetition. These are the types of buildings and sectors where modular/off-site construction is currently being applied:
    - Residential Single-family housing
    - Multi-family housing
    - Disaster Response/Rapid Response Shelters
    - Secure Structures, Ballistic Shelters, Hangers & Logistics Structures
    - Commercial Offices
    - Hotels & Apartment Buildings
    - Institutional: Schools & Hospitals
    - Industrial Power Plants & Factories
    - Infrastructure, Bridges & Tunnels
    - Bathroom & Kitchen Pods
    - Prefabricated MEP Modules

Building The System

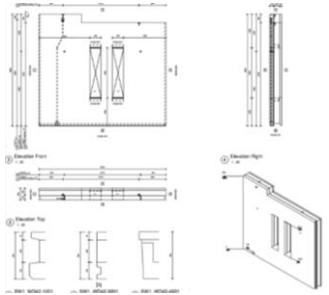
Synergies Between Modular Construction & Tunnelform

DELIVERABLE 1: Continued.

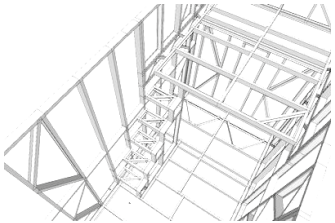
2. Technological Advancements in Off-Site Engineering. These advancements are enabling greater efficiency, predictability, quality and scalability of modular construction projects while reducing risk at the same time:
    - Building Information Modelling (BIM): Integrated design and manufacturing, Clash detection
    - Digital Twin Technology: Realtime monitoring & Lifecycle optimization
    - Robotics and Automation: Automated fabrication & Robotic welding/assembly
    - 3D Printing: Component production & Concrete extrusion (Not a fully mature technology currently)
    - IoT (Internet of Things)Smart sensors for quality and productivity & Equipment tracking
    - Advanced Materials: High-performance insulation & Lightweight composites
    - Structural Insulated Panels (SIPs): Now seeing much greater usage due to high strength & light weight

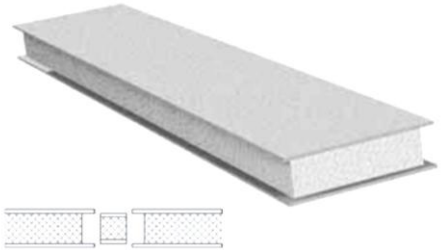
DELIVERABLE 1: Continued.

3. Manufacturing Approaches. Different production strategies used in off-site manufacturing:
   - Volumetric Construction: Complete modules (e.g., hotel rooms, apartments, villas, ballistic shelters)
   - Panelized Systems: Walls, floors, roofs pre-fabricated
   - Hybrid Systems: Combination of volumetric and panelized
   - Sub-assemblies: MEP racks, Bathroom and kitchen Pods



4. Basic Systems Make-Up and Materials
   - Precast Concrete
   - Light Gauge Steel (LGS)
   - Hot Rolled Steel
   - Hybrid Systems (Hot rolled frame with LGS or SIP panel infill walls, concrete floors)
   - Predominantly SIP panel modules with hot rolled steel floor and roof perimeter frames





DELIVERABLE 2:
An overview of the latest applications and technological advancements in the tunnel form usage within the construction industry

Introduction: Tunnel form construction was first developed and used in Europe in the 1960s, particularly in France, as a fast and efficient method for building repetitive, load-bearing wall and slab structures such as apartment blocks, hotels, and dormitories.

Key Milestones:

- 1960s (France): The technique emerged as a solution for mass housing, particularly in post-war reconstruction efforts. The method was driven by the need for speed, labor efficiency, and improved structural integrity.
- 1970s–1980s: Tunnel form gained popularity in other parts of Europe and the Middle East, particularly in Turkey and the Gulf, where it was used extensively for security structures, low-cost housing and high-rise apartments.
- 1990s–2000s: Adoption spread to Asia (notably Singapore and South Korea), as governments pushed for industrialized construction methods to support rapid urbanization.
- 2000s–Present: It continues to be refined with automation, higher-precision steel forms, and integration with BIM and prefabrication techniques, supporting large-scale housing, security structures and infrastructure projects worldwide.

DELIVERABLE 2: Continued.

1. **Tunnelform construction** is well known and well tested over many years on thousands of projects world-wide. The first common thread linking all projects is the deployment on projects of relatively large scale with great repeatability of tunnelform cells. For this reason, hotels, apartments, multi-family homes and security shelters are a great target for tunnelform construction. The second common factor is the usage of reinforced in-situ poured concrete as the primary building material. Where these two project attributes are present, tunnelform construction is often the most viable method of construction and this has been the case since the technology was first used in the 1960s.
2. **Digital Design & Simulation:** Tunnelform platform and formwork design has significantly benefited from developments in BIM (Building Information Modeling) and digital simulation tools thus enhancing design accuracy, coordination, and clash detection in construction projects. The use of BIM results in streamlining planning, coordination and error reduction.
3. **The Use of Advanced Materials**: Notably next-gen steel, aluminum, and composites. This is improving formwork durability, sustainability, and performance of reuseable tunnelform systems.
4. **Inspection, Measurement & Monitoring**: Integrating 3D point-cloud scanning for formwork spacing inspection is a developing solution to replace manual measurement, improving precision, tolerance and enabling autonomous and digitally reportable quality assurance

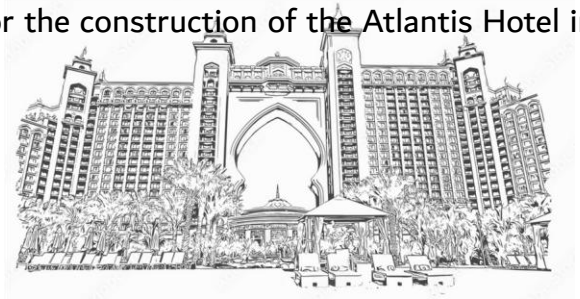
DELIVERABLE 3:

An analysis of the synergies and existing intersections between the modular construction and tunnel form industries.

Tunnel form construction and volumetric modular construction are often viewed as distinct methodologies, one being a site-based cast-in-place method, the other an off-site prefabrication strategy. However, they can offer valuable synergies when strategically combined, especially in mid- to high-rise residential, hospitality, and worker accommodation projects.

Below is a breakdown of the key synergies between the two technologies:

1. Structural Synergy: Hybrid Systems
    - Tunnel form excels in casting repetitive, load-bearing wall and slab systems, which can form the structural skeleton" of a building.
    - Volumetric modules (e.g. bathrooms, kitchens, MEP-heavy rooms) can be inserted into this structure as non-structural fit-outs, reducing on-site complexity.
    - Use case: Cast core and shell with tunnel form; drop in fully finished bathroom/kitchen pods made offsite. This was the case for the construction of the Atlantis Hotel in Dubai which can be considered a perfect case study.



DELIVERABLE 3: Continued.

An analysis of the synergies and existing intersections between the modular construction and tunnel form

2. Accelerated Construction Timelines
    - Tunnel form allows for fast-track vertical progression (one floor per day or two with a large team).
    - In parallel, volumetric modules are manufactured off-site, allowing concurrent workflows.
    - Result: Significant reduction in total construction time—structure and fit-out progress simultaneously.

3. Repetition & Standardization
    - Both methods thrive on standardized, repetitive layouts
    - Ideal for hotels, apartments, hostels, dormitories, ballistic shelters and secure structures.
    - Standard room layouts can be cast using tunnel form
    - Service spaces can be built as volumetric modules.

4. Cost Efficiency at Scale
    - Tunnel form offers low per-unit cost for structural elements once the formwork system is in place.
    - Volumetric units benefit from factory economies of scale and reduced site labor.
    - Integration optimizes CAPEX and OPEX through lifecycle savings in construction, maintenance, and rework.

DELIVERABLE 3: Continued.

An analysis of the synergies and existing intersections between the modular construction and tunnel form

5. Integration of MEP Systems
    - Tunnel form provides clean, robust service shafts and structural cores.
    - Modular MEP rooms (plantrooms, bathrooms, utility closets) can be prefabricated with plug-and-play services, reducing site congestion and coordination issues.
6. Quality Control
    - The in-situ concrete of tunnel form ensures robust acoustic, fire, and thermal separation.
    - Volumetric units manufactured in controlled environments offer high-quality finishes and consistent tolerances.
    - Together the combination gets the best of structural permanence and interior quality
7. Design Flexibility Through Partial Modularity
    - Not all areas of a project benefit from full modularization.
    - Tunnel form can be used where site-cast systems are more cost-effective, while volumetric units can focus on areas where labor is more intensive or finishing is critical.
8. Logistics & Site Constraints
    - Tunnel form is better for tight urban sites with limited crane space or lifting access.
    - Volumetric units can be delivered just-in-time, minimizing storage needs and allowing for phased occupation. Ideal for rapid deployment ballistic structures and storage shelters.

DELIVERABLE 3: Continued. (CASE STUDY)
Hybrid Construction for Worker Accommodation in Singapore

Project Overview:

- Project Name: Westlite Dormitory @ Mandai
- Location: Singapore
- Type: Purpose-built worker accommodation
- Height: 7 storeys
- Units: 4,100 beds across multiple identical blocks (Phase 1)
- Client: Centurion Corporation
- Timeline: 13 months from site clearance to occupancy
- July 2008 – September 2009

DELIVERABLE 3: Continued. (CASE STUDY)
Hybrid Construction for Worker Accommodation in Singapore

Construction Methodology
1. Tunnel Form – Structural Frame
- Tunnel formwork to cast in-situ reinforced concrete walls & slabs in repetitive bedroom units & corridors.
- Each block had typical floor plans with mirrored layouts, ideal for tunnel form.
- Cycle time: 2–3 days per floor with a rotating crew.

2. Volumetric Modular – Wet Areas
- Precast bathroom pods built offsite in a factory with:
- Fully tiled walls and floors
- Pre-installed WC, shower, sink, lighting, exhaust
- Integrated MEP risers
- Delivered just-in-time and craned into structural frames after tunnel casting.
- MEP connections standardized to match in-situ stub-outs cast into tunnel form walls

DELIVERABLE 3: Continued. (CASE STUDY)
Hybrid Construction for Worker Accommodation in Singapore

Synergies Achieved

Category	Tunnel Form Advantage	Volumetric Advantage	Synergy Outcome
Speed	Rapid floor-to-floor casting	Parallel off-site pod manufacturing	30% faster overall build time
Labor Efficiency	Reduced on-site labor for structural work	Minimal site labor for finishes	40% fewer skilled workers required
Quality	Durable RC structure, great for fire/acoustics	Factory-controlled finish in pods	High, uniform build quality
Cost Control	Low structural cost per m^2	Predictable factory cost per pod	Budget certainty
Site Management	Clean, repeatable structural zones	Fewer on-site trades	Less congestion, fewer safety risks

DELIVERABLE 3: Continued. (CASE STUDY)
Hybrid Construction for Worker Accommodation in Singapore

Implementation Notes
- Careful coordination between MEP designers and civil engineers ensured service routes aligned between in-situ and modular elements.
- Tunnel form used precast floor openings and sleeves to simplify pod integration.
- Crane planning was key to avoid delays in pod installation

Results
- Total duration: Reduced from 18 months (traditional) to 13 months.
- Snagging time: Cut by 50% due to pod quality.
- Lifecycle savings: Energy and water-efficient pods also reduced operating costs

Key Lessons
- Standardization is critical. Align all designs to tunnel form and pod manufacturing constraints early.
- Early collaboration between structural, MEP, and modular suppliers prevents clashes later.
- Hybrid methods allow flexibility: Use tunnel form where cost-effective, and volumetric where value-added (e.g., bathrooms, kitchens, or clinical spaces)

DELIVERABLE 4: A Forward-Looking Overview of the Future Developments and Direction of the Modular Construction and Tunnel Form Sectors

1. Introduction

The global construction industry is undergoing a period of rapid transformation driven by technological innovation, urbanization, sustainability imperatives, and labor shortages. Both modular construction and tunnel form construction are positioned as key methodologies that can address cost, speed, and efficiency challenges while aligning with future demands for sustainable and resilient infrastructure.

2. Technological Advancements - Prefabrication

As highlighted previously in Deliverable 2, some of the important Technological Advancements in Off-Site Engineering are reviewed below. These advancements are enabling greater efficiency, predictability, quality and scalability of modular construction projects while at the same time reducing risk:

- Building Information Modelling (BIM): Integrated design and manufacturing, Clash detection
- Digital Twin Technology: Realtime monitoring & Lifecycle optimization
- Robotics and Automation: Automated fabrication & Robotic welding/assembly
- 3D Printing: Component production & Concrete extrusion (Not a fully mature technology currently)
- IoT (Internet of Things)Smart sensors for quality and productivity & Equipment tracking
- Advanced Materials: High-performance insulation & Lightweight composites
- Structural Insulated Panels (SIPs): Now seeing much greater usage due to high strength & light weight

DELIVERABLE 4 Continued.

3. Market Growth Drivers - Prefabrication

- Urbanization & Housing Demand: Modular housing for affordable housing schemes, student housing, and urban infill projects.
- Need for rapid response shelters and blast resistant structures in strategic locations with limited availability of labour and resources.
- Healthcare & Education: Rapid-deployment modular hospitals, clinics, and schools are expected to grow significantly post-pandemic.
- Corporate ESG Commitments: Modular construction supports net-zero targets through material efficiency and reduced waste.

4. Strategic Shifts - Prefabrication

- Hybrid Construction Models: Combination of modular units with traditional methods for high-rise and complex structures.
- Global Supply Chains: Standardized modular components enabling international trade and offshore fabrication.
- Sustainability First: Full traceability of materials, circular economy approaches, and carbon-neutral factories. Ignore this issue at your peril, big investors are beginning to demand this in measurable KPIs

DELIVERABLE 4 Continued: Tunnel Form Construction: Future Developments and Direction

5. Technological Advancements - Tunnelform

- Automation in Formwork: Mechanized and robotic formwork systems to reduce reliance on manual labor.
- Improved Concrete Technologies: High-performance self-compacting concrete, ultra-low carbon mixes, and faster curing methods.
- Digital Monitoring: IoT sensors embedded in formwork for structural monitoring and curing optimization

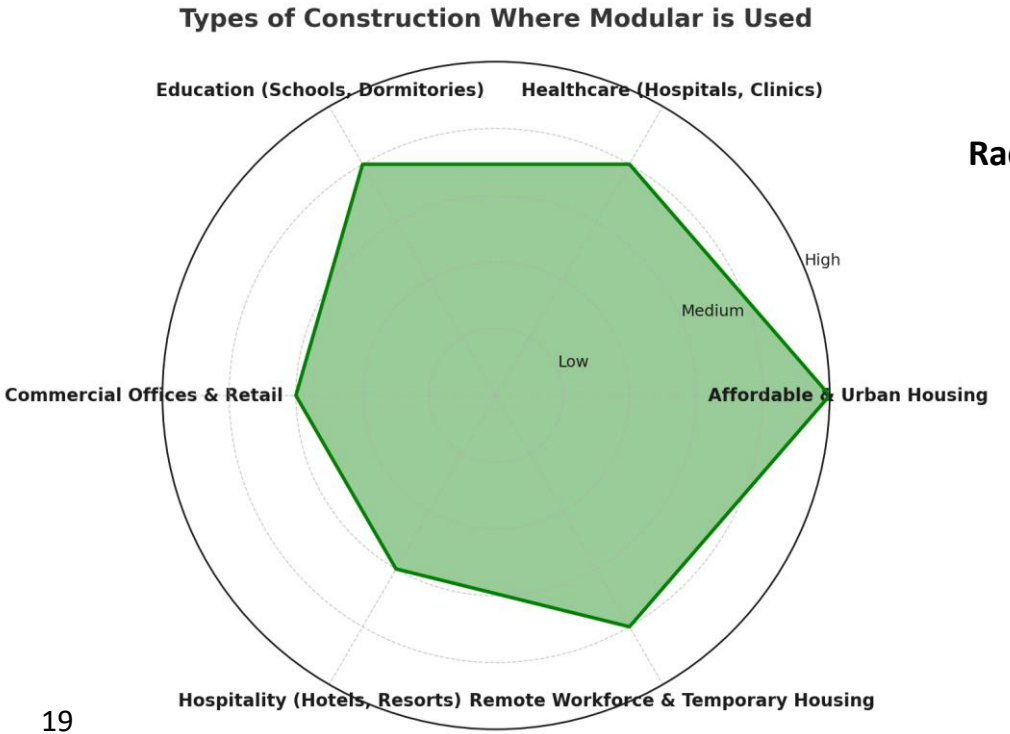
6. Market Growth Drivers - Tunnelform

- High-Density Urban Housing: Tunnel form remains attractive for repetitive high-rise residential and hotel developments.
- Infrastructure Needs: Application in mass housing programs across emerging markets (e.g., Middle East, Africa, Asia) and Rapid response to disaster and security shelter
- Durability & Lifecycle Efficiency: Tunnel form construction aligns with governments' push for long-life, low-mainten situations.ance housing.

7. Strategic Shifts - Tunnelform

- Integration with Modular Systems: Hybrid developments where tunnel form cores integrate with modular units for façade or fit-out.
- Sustainability Push: Emphasis on greener cements, recycled aggregates, and reduced site waste
- Digital Workflows: BIM integration for design precision, logistics planning, and clash detection

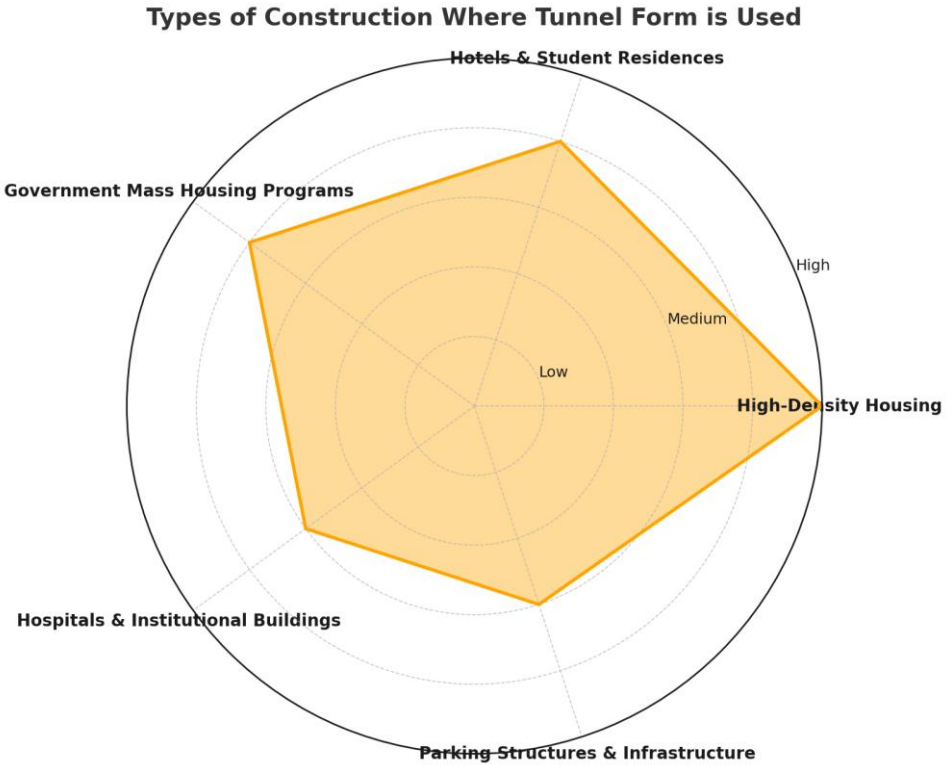
DELIVERABLE 4 Continued: Tunnel Form Construction: Future Developments and Direction



Radar chart for Modular Construction applications:

- Affordable & Urban Housing (highest adoption)
- Healthcare (Hospitals, Clinics)
- Education (Schools, Dormitories)
- Commercial Offices & Retail
- Hospitality (Hotels, Resorts)
- Ballistic and Security Rapid Response Structures
- Remote Workforce & Temporary Housing

DELIVERABLE 4 Continued: Tunnel Form Construction: Future Developments and Direction



Radar chart showing the main types of construction where tunnel form is commonly used:

- High-Density Housing (highest adoption)
- Hotels & Student Residences
- Government Mass Housing Programs
- Hospitals & Institutional Buildings
- Ballistic & Security Structures
- Parking Structures & Infrastructure

DELIVERABLE 4 Continued: Synergies Between Modular and Tunnel Form

8. **The convergence of modular and tunnel form construction is likely to accelerate as both methods seek efficiency and sustainability.**
   - Hybrid Structural Systems: Tunnel form for structural cores and repetitive floors, modular units for MEP modules, bathrooms, and façades.
   - Cost and Time Optimization: Combining speed of modular with durability of tunnel form for high-rise housing and commercial projects.
   - Sustainability Gains: Reduced material waste, improved energy efficiency, and carbon reduction across the project lifecycle.
9. **Challenges and Risks**
   - Regulatory Barriers: Codes and standards lagging behind technological innovations.
   - Capital Investment: High upfront costs for modular factories and advanced tunnel form equipment.
   - Supply Chain Dependencies: Modular construction is vulnerable to shipping delays and geopolitical trade disruptions.
   - Labor Market Transition: Upskilling required for workers to operate in digitally enabled and factory-driven environments.

DELIVERABLE 4 Continued: Synergies Between Modular and Tunnel Form

10. Outlook: 2025–2035

- Mainstream Adoption: Modular construction expected to grow at 5–7x faster rate than traditional construction in certain markets.
- Tunnel Form Resurgence: Particularly in affordable housing and large-scale government programs.
- Integration of Offsite & Onsite: Hybrid approaches becoming the norm for high-rise and mixed-use developments.
- Green Construction Leadership: Both sectors will be pivotal in achieving net-zero targets through energy-efficient design, low-carbon materials, and reduced site waste.

11. Conclusion

The modular and tunnel form construction sectors are on converging paths toward greater efficiency, sustainability, and digital integration. Modular construction will lead in flexibility and adaptability, while tunnel form will maintain its dominance in repetitive, high-density housing. Together, they represent a future-ready toolkit for meeting global housing, infrastructure, and sustainability challenges. Challenges and Risks

DELIVERABLES 5 & 6: The geographical areas to be included in the report are to be global and inclusive of Europe and North America. A breakdown of the geographical relevance and adoption of different proprietary systems within the modular construction and tunnel form sectors

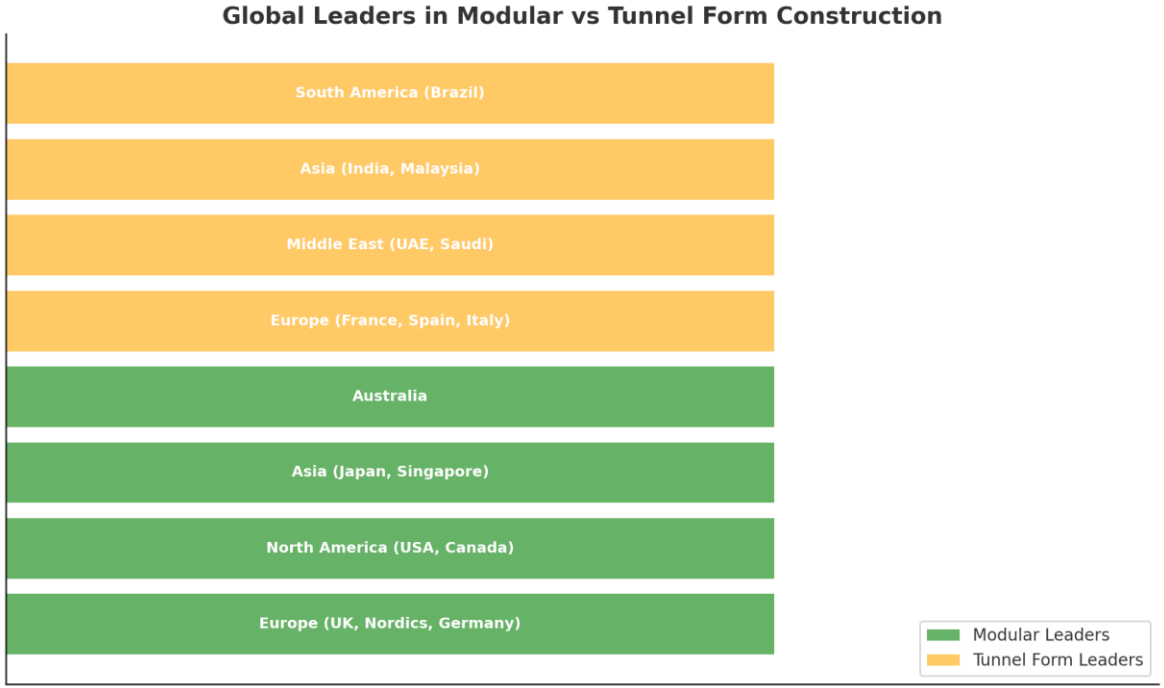
1. **Global Overview**

   The adoption of modular construction and tunnel form technologies varies significantly across regions, shaped by local building codes, labor dynamics, real estate pressures, and government policies. While modular construction is advancing rapidly in Europe, North America, and Asia-Pacific, tunnel form remains a mainstay in Europe, the Middle East, and parts of Asia where mass housing programs dominate. There is no doubt, however, that the Middle East is rapidly catching up and may shortly become the epi-center of modular construction worldwide.

2. **Modular Construction by Region**

   - **Europe:** Strong adoption of modular housing and public sector buildings, driven by net-zero policies, high labor costs, and urban housing demand. UK, Sweden, Finland, and Germany are leaders.
   - **United States/North America:** Growing but fragmented adoption, particularly in multifamily housing, student accommodation, and affordable housing. Strong interest in “disruptive” low-cost housing.
   - **Asia Pacific:** Leading in scale and innovation. Singapore pioneered PPVC (Prefabricated Prefinished Volumetric Construction). Japan is mature with prefab homes. Australia is growing in modular for mining camps and healthcare.
   - **Middle East/GCC:** Adoption accelerating under housing programs and mega-projects (Saudi Arabia’s Vision 2030, UAE smart cities). Modular is being used for hotels, worker housing, and infrastructure.

DELIVERABLES 5 & 6: The geographical areas to be included in the report are to be global and inclusive of Europe and North America. A breakdown of the geographical relevance and adoption of different proprietary systems within the modular construction and tunnel form sectors



DELIVERABLES 5 & 6 Continued

3. **Tunnelform Construction by Region**
   - **Europe:** Birthplace of tunnel form (France, Spain, Italy). Widely used in high-density housing, hotels, and institutional buildings. Mature market with highly engineered formwork solutions.
   - **United States/North America:** Limited adoption compared to Europe. More common in Florida, Texas, and California for repetitive high-rise housing and student residences.
   - **Asia Pacific:** Significant use in India, Malaysia, and Indonesia for mass housing projects. China uses alternatives like large panel precast but is experimenting with tunnel form.
   - **Middle East/GCC:** Very strong adoption for large-scale housing, especially in UAE, Qatar, and Saudi Arabia. Governments favor tunnel form for speed and durability in mass housing.
4. **Comparative Insights**
   - **Europe**: Leads in both modular and tunnel form adoption, but for different segments—modular for sustainability and flexibility, tunnel form for durability and housing programs.
   - **North America:** Modular is gaining traction faster than tunnel form, as tunnel form adoption remains niche.
   - **Asia-Pacific:** A dual leader—Japan and Singapore in modular innovation; India and Malaysia in tunnel form mass housing.
   - **Middle East:** Tunnel form is dominant today, but modular is expected to rise sharply with giga-projects and sustainability mandates.

DELIVERABLES 5 & 6 Continued

5. Key Takeaways

- **Modular** construction is scaling globally as the future-facing system for sustainability and flexibility.
- **Tunnelform** remains entrenched in regions needing mass housing at scale, especially in government-driven programs. Automation in formwork, high-performance concrete, and IoT monitoring will define tunnel form's future. Its use remains strong in mass housing, especially in Europe, the Middle East, and Asia..
- **The most advanced markets** (Europe, North America, Asia-Pacific) are now experimenting with hybrid approaches, combining tunnel form structural cores with modular units (bathroom pods, MEP modules, façade systems similar to the Atlantis Dubai hotel case study)

6. Summary Insights

- **Global Leaders in Modular Construction:** Europe (UK, Nordics, Germany), North America (USA, Canada), Asia (Japan, Singapore), Australia.
- **Global Leaders in Tunnel Form Construction:** Europe (France, Spain, Italy), Middle East (UAE, Saudi), Asia (India, Malaysia), South America (Brazil)
- **Hybrid Adoption Zones:** UK, Singapore, UAE, Saudi Arabia: markets where modular and tunnel form converge (e.g., tunnel form cores + modular pods/facades).

DELIVERABLE 7: Regulatory and Market entry issues related to modular and tunnel form systems in different geographies including Luxembourg

1. Introduction

Here we have provided a field guide to the regulatory and market-entry realities for modular (volumetric/2D) and tunnel-form (in-situ RC) systems across key regions—followed by concrete, go/no-go recommendations on the commercial viability of a hybrid: tunnel-form primary structure + modular pods/corridor/room units

2. The Regulatory Landscape

- The hybrid approach is commercially viable where you have repetitive layouts (hotels, student resi, key-worker, mid-rise BTR), tight programs, and constrained sites. It de-risks crane time and transport by keeping big RC elements in situ (tunnel form), while shifting MEP/fit-out off-site. Daily tunnel-form cycles are achievable in practice; Singapore/HK regulators already support modular with clear pre-acceptance schemes. Concrete CentreBCA CorpCIC MiC
- Regulatory certainty is highest in Singapore (PPVC IPA/MAS), Hong Kong (MiC practice notes), UK (NHBC Accepts/BOPAS + new BSR regime), Canada (CSA A277), Australia/NZ (NCC + MultiProof/BuiltReady). The US is viable but state-by-state and public work is now shaped by Buy America domestic-content rules. BCA CorpCIC MiCNHBCbopas.orgyoussry salehThe White HouseNational Construction CodeBuilding.govt.nz

DELIVERABLE 7: Regulatory and Market entry issues related to modular and tunnel form systems in different geographies including Luxembourg

3. **Transport is the silent killer**: HK and Singapore enforce tight wide-load thresholds (typically ~2.5–3.0 m without special measures). Design your module SKUs and façade strategy around those limits (or go pods + 2D sub-assemblies). Transport Department+1OneMotoring

4. **In the EU, the new CPR (2024/3110)** introduces Digital Product Passports; get your component EPD/DoP house in order early. RICSInternal Market & SMEs

5. **GCC: Dubai's unified Building Code** is now the baseline; Abu Dhabi continues with ADIBC variants. Market entry hinges on local classification/partnering and early authority engagement rather than any anti-MMC stance. Dubai Development AuthorityDubai Municipality

6. **Caribbean (Cayman/Jamaica):** ICC-based regimes; approvals are straightforward if you treat modules as code-compliant components and manage site-specific foundations/wind exposure. Start with pods and MEP modules; scale to room modules once logistics tested. BCA Corp+1

DELIVERABLE 7: Regulatory and Market entry issues related to modular and tunnel form systems in different geographies including Luxembourg

7. **Luxembourg: Core Legal & Regulatory Context**
   National Energy Performance Requirements, Luxembourg enforces strict energy performance rules through its Grand Ducal Regulation on the Energy Performance of Residential Buildings. Permits require calculations of q_h (specific heat demand) and Q_p (specific primary energy demand), benchmarked against a reference building
8. **To achieve a building permit**: q_h and Q_p must not exceed reference values. This heavily influences modular design, especially envelope, insulation, and energy system choices.
   - "A" energy class: $Q_p \leq 45$ kWh/m²·y;
   - "A thermal class": $q_h \leq 22$ kWh/m²·y
   - Passive-house level ("AAA" / nZEB) requires even stricter metrics
9. **CE Marking & European Product Regulations** As an EU member, Luxembourg requires modular components to comply with EU Construction Products Regulation (CPR):
   - Products must hold CE marking to verify mechanical resistance, structural durability,
   - traceability, etc. Alho+10Wikipedia+10Built Offsite+10
   - Regulatory routes may include harmonized European Standards or European Technical Assessments (ETA)

DELIVERABLE 7: Regulatory and Market entry issues related to modular and tunnel form systems in different geographies including Luxembourg

10. National Policy Perspective & Institutional Oversight

Low-Carbon Construction Roadmap

- The government has launched a Low Carbon Construction Roadmap, part of the National Energy & Climate Plan
- Targets deep reduction in building-sector emissions (–64% by 2030 vs. 2005)
- Emphasizes life-cycle emissions—including embodied carbon of materials, construction processes, and transport.
- Modular construction aligns well with this push—especially systems favoring low-carbon materials such as timber hybrids.
- Tunnel form construction is not specifically mentioned but is clearly aligned with the national objectives and this bodes well.

11. Stakeholder Coordination via CNCD

- The Conseil National pour une Construction Durable (CNCD) brings together architects, engineers, material producers, developers, and public officials to implement sustainable building strategies, including emerging methods like modular and off-site systems. This is a very useful lobby group to be familiar with

DELIVERABLE 7: Regulatory and Market entry issues related to modular and tunnel form systems in different geographies including Luxembourg

12. Practical & Market Signals and Innovations Seen in Practice (Luxembourg specific)

- The CREE modular timber-hybrid system has recently gained traction in Luxembourg:
- Prefabricated timber, concrete slabs and glulam columns reduce concrete use and carbon output
- Modular units (~2.5–3 m wide) enable faster weatherproofing and interior fit-out in urban conditions.
- These innovations align closely with national goals, illustrating early regulatory openness to modular strategies.

13. Affordable Housing Using Modular Systems

Modular is being flagged in Luxembourg as a cost-effective solution for social housing and affordability challenges for all the usual and well-known reasons including: Off site production reduces labour intensity, speeds deployment, and improves flexibility—aligning with market demand and policy priorities.

DELIVERABLE 7: Key Takeaways: Regulatory Fit and Opportunities

Regulatory/Policy Area	Implications for Modular Construction
Energy Performance Rules	Modular units must meet strict thermal and energy targets—driving high-performance design in envelope and systems.
CE / CPR Requirements	Requires certification of components (CE marking, hEN/ETA) for compliance and traceability.
Sustainability Policies	Embodied carbon and LCA must be addressed—modular favored if using low-carbon materials and efficient methods.
Institutional Support	CNCD offers a collaborative pathway to align with sustainable building strategies and technical guidance.
Market Signals	Demonstrated interest via CREE system adoption and modular housing projects indicates both regulatory openness and commercial feasibility.

DELIVERABLE 7: Regulatory and Market entry issues related to modular and tunnel form systems in different geographies including Luxembourg

Practical Recommendations & Next Steps

14. Technical Design Strategy

- Prioritize module envelope design that meets "A" and nZEB energy thresholds (e.g., high insulation, airtightness, high-efficiency MEP, potential for PV integration)—in line with national calculation method (q_h, Q_p). Ministère de l'ÉconomieResearchGate+1

15. Certification Planning

- Ensure components or systems secure CE marking via a recognized CPR route (e.g., hEN or ETA), including documentation of materials and production traceability.

16. Sustainability & Embodied Carbon

- Incorporate life cycle assessment reporting and low-carbon materials (wood, prefabricated efficient designs).
- Consider engaging with CNCD for support, resources, and feedback loops. Built Offsite+5Ministère de l'Économie+5Built Offsite+5

DELIVERABLE 7: Regulatory and Market entry issues related to modular and tunnel form systems in different geographies including Luxembourg

Practical Recommendations & Next Steps

17. Pilot & Policy Engagement

- Evaluate the CREE timber-hybrid approach for pilot demonstration.
- Position affordability-focused modular solutions (e.g., for social housing) to align with public sector priorities.

18. Engage with Authorities Early

- Early consultation with building permit authorities and CNCD can help de-risk regulatory uptake and align expectations.

19. In Summary:

- Luxembourg's regulatory context is increasingly favorable to modular construction, especially when it delivers on high energy performance, lifecycle sustainability, and affordability. Its policy direction and institutional architecture suggest that modular strategies—especially low-carbon hybrids—can be smoothly integrated, provided design and certification align with national standards.

DELIVERABLE 8: Clear and Actionable Conclusions and recommendations on the commercial viability of the hybrid approach of using tunnel form as part of a modular construction system.

20. **Net project saving**: 2–5% of capex is achievable for mid-rise, repetitive assets (hotels, student residential or key-worker) when you combine tunnel-form daily cycles with off-site pods / 2D MEP. The win is schedule-driven (preliminaries + finance carry) and typically offsets a modest direct-cost premium on pods. (Information sourced from: Ischebeck Titan. Outinord. BCA Corp Singapore)

21. **Time = money:** credible regulator/industry sources show 20–40% manpower/time gains for volumetric elements. At a 24-month baseline, a 20–30% program cut yields prelim and interest savings that land in the 3–5% of capex range for typical financing. (BCA Corp Singapore)

22. **Worked example** (for a 15,000 m², ~250-key mid-rise) Assumptions (conservative and explicit):
    - Baseline construction cost (generic "building" basket, London): $4,473/m² ≈ €3,847/m² at 2025 average FX. Total ≈ €57.7m. Statista Spaces Exchange Rates
    - Hybrid program cut vs. conventional: 20–30% (supported by PPVC/MiC guidance). Finance: 8% p.a. construction loan; prelims 10% of capex. Pod premium tested at 0–20% (applied only to bathroom trade). (BCA Corp Buildings Department)

DELIVERABLE 8: Clear and Actionable Conclusions and recommendations on the commercial viability of the hybrid approach of using tunnel form as part of a modular construction system.

23. **Schedule-derived savings (prelims + interest):**
    - 20% faster (save 4.8 months): ≈ €2.08m (≈ 3.6% of capex).
    - 25% faster (save 6 months): ≈ €2.60m (≈ 4.5%).
    - 30% faster (save 7.2 months): ≈ €3.12m (≈ 5.4%).

24. **Pods direct-cost premium sensitivity** (if bathrooms ≈8% of capex):
    - +0% pod premium → net +3.6–5.4%.
    - +10% pod premium → net +2.8–4.6%.
    - +20% pod premium → net +2.0–3.8%.

25. **Interpretation:** even with a +10% pod premium, the hybrid still beats conventional by ~3–4% on total project out-turn due to prelim/finance compression alone. (Quality/rework reductions and earlier revenue improve this further but are not counted here.)

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26. Why it works

- Structure on a daily cycle (tunnel-form casting walls + slab together); follow with rapid craned-in pods/2D/room modules, compressing critical path while keeping tolerance control at interfaces.
- Regulator Friendly: Core/shell behaves like conventional reinforced concrete, modular elements are well known and pass-through established acceptance/warranty schemes (PPVC, MiC, NHBC, BOPAS)
- Transport Efficient: By reserving volumetrics for bathrooms/bedrooms within 2.5 – 3.0m envelopes (or switching to PODs + 2D panels) to avoid road escort and permit issues in most locations.

27. Bottom line

- Positive commercial viability: Use tunnel form for the repetitive structure and standardize the off-site scope (pods, corridor MEP, select room boxes within local transport envelopes).
- Win approvals fast by packaging your submission in the local acceptance language (NHBC/BOPAS in UK; PPVC/MiC in SG/HK; A277 in Canada; state programs + BABA screen in US; DBC/ADIBC in GCC; ICC in the Caribbean).
- Protect margins by locking interfaces/tolerances, designing for transport early, and aligning warranty/insurance up front.

DELIVERABLE 8: Clear and Actionable Conclusions and recommendations on the commercial viability of the hybrid approach of using tunnel form as part of a modular construction system.

28. Global modular market size:

- $103.6bn (2024); forecast CAGR ~7–8% to $162bn by 2030. Grand View Research
- Europe share: ~42% of global modular by revenue (2024). Precedence Research
- US modular (permanent + relocatable): $20.3bn in 2024 (~5.1% of total construction spend in covered segments); projected $25.4bn by 2029. modular.org

29. Cost climate:

- Global construction cost inflation easing toward 3.9% in 2025 on average. This will be helpful context when benchmarking premiums/credits
- Information source: publications turner and townsend.com

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30. Actionable Guidance:

- **Price-to-beat**: take your local €/m² baseline (table above or your QS data). Apply –3–5% for the hybrid on total out-turn if you can commit to: (a) tunnel-form 24-hr cycles, (b) standardized pods/MEP cassettes, (c) transport widths ≤2.5–3.0 m where needed.

- **Finance the schedule:** when selling to owners, quantify prelim + financing carry explicitly; many appraisals miss that time compression > direct cost parity. (Use the worked example as a template.)

- **Start pods then scale:** where logistics or acceptance are tight (HK/SG/urban EU), start with bathroom pods + corridor MEP, then add bedroom boxes if the transport envelope and lifting/cranage plan allow.

- **De-risk acceptance:** align submissions to local frameworks (PPVC/MiC in SG/HK; NHBC/BOPAS in UK; CSA A277 in CA; state programs in US). This preserves the time advantage that makes the business case work.

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31. Actionable Guidance and Recommended Next Steps

STEP 1

- Bring bathroom PODs into your product offering and begin offering tunnel form and PODs as a package
- Initially via subcontracting with a well reputed POD manufacturer (learning the system)
- Then bringing POD production in-house

STEP 2

- Integrate Tunnelform and internal PODs into Sayram business model
- Initially as traditional in-situ tunnelform structure with internal PODs
- Sell tunnelform + PODs as a package
- Offer PODs to third party contractors and developers

STEP 3

- Scale tunnelform manufacture technique as modular/prefabrication solution
- Tunnelform providing the transportable structural framework and shelter
- PODs providing internal fitout and living requirements

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32. Ideal Target Markets (Tunnelform Modules + Interior PODs)

Market 1

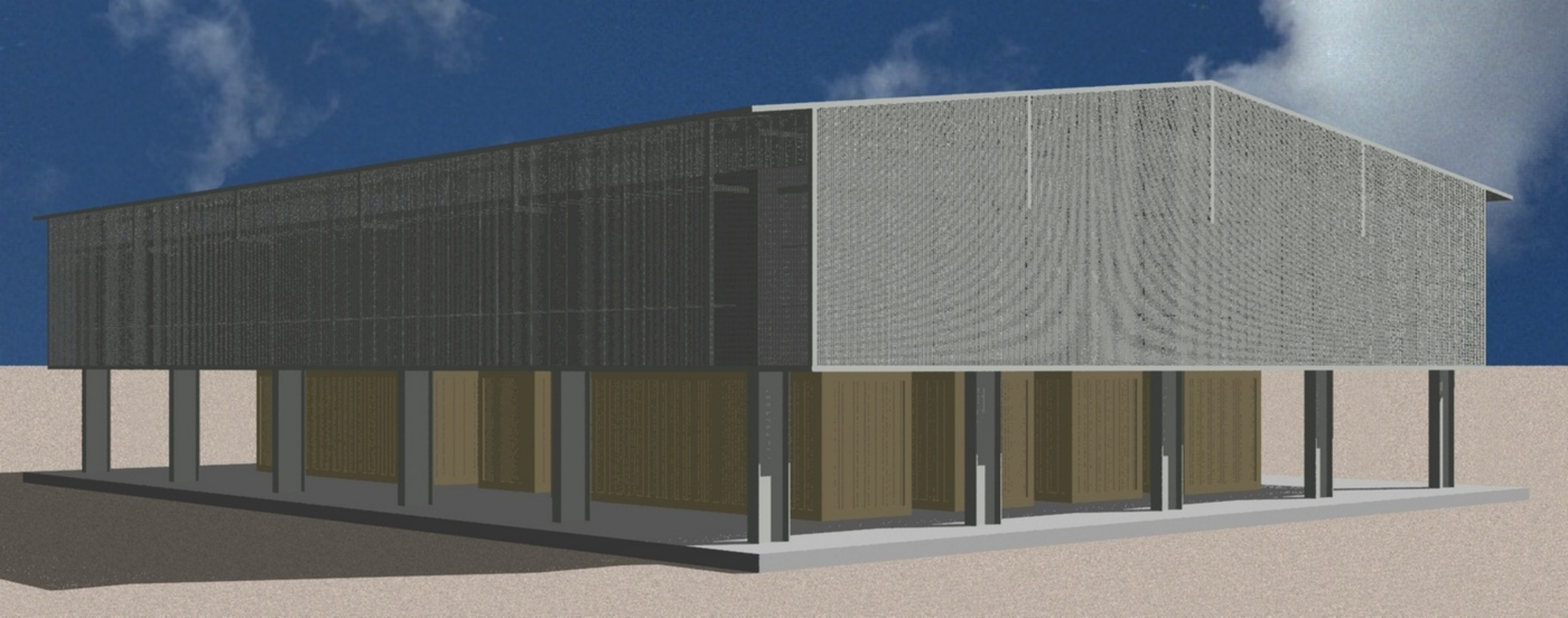
- Rapid response permanent or relocatable humanitarian shelters
- Blast resistant hangars, storage units and accommodation (permanent or relocatable)
- Armoury protection and ammunition storage (permanent or relocatable)

Market 2

- Affordable housing solutions (single dwellings and apartments)
- Multiple housing layouts and stackable multi-rise capability
- Compatible with multiple specifications, finishes and regulatory codes
- High energy rating capability, known and trusted building materials and system.

Market 3

- Hospitality and hotel developments up to five-star level
- Strip malls and commercial units (good shell and core opportunity)
- Any structure or building with repeatable design and interior spaces

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Generator Power Shelter Offload


WALTON


GENERATOR No. 1 CONTROL PANEL
GENERATOR No. 2 CONTROL PANEL


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