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Cargotecture (Container Housing): An Exploration of the Construction Mechanism

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Abstract: ***Container housing has emerged as a viable alternative in modern construction, offering a cost-effective and sustainable solution to address housing shortages and urbanisation challenges. This research explores the construction mechanisms involved in container housing, focusing on how shipping containers can be adapted as habitable spaces. The study analyzes four case studies: the Proposed Tech Hub at Heliu Health and Tourism District in Enugu, Nigeria; Container City in London, UK; Container House by Plannea Arquitectura in Chile; and KODA by Kodasema in Estonia. Each case demonstrates unique design elements, construction techniques, and modifications specific to local environmental and regulatory contexts. The findings reveal that container housing benefits from rapid construction timelines, affordability, and modular adaptability. However, challenges such as insulation, ventilation, and compliance with building codes require tailored solutions to ensure occupant comfort and regulatory approval. Recommendations include climate-specific modifications, integration of renewable energy sources, and the establishment of standardized building codes to support the growth of container housing. This study concludes that with thoughtful design and strategic implementation, container housing has the potential to provide sustainable, adaptable, and affordable housing solutions worldwide.***

Keywords: Container Housing, Construction Mechanisms, Thermal Insulation, Structural Integrity

1. Introduction

Container housing, also known as shipping container architecture or "Cargotecture" (which is coined from the words "Cargo and architecture"), has emerged as a transformative approach to addressing modern housing challenges, combining sustainability with potential cost-efficiency. The adaptability of shipping containers allows them to be repurposed into residential units, contributing to a reduction in construction waste and promoting eco-friendly building practices (Lim et al., 2013). This paper explores the construction mechanisms involved in container housing, evaluates its structural and thermal performance, and assesses its potential as a sustainable housing solution. The use of shipping containers in construction has increased significantly due to their availability, durability, and modular nature. Originally designed to withstand harsh sea conditions, containers possess the strength needed for multi-story construction and are structurally sound against natural disasters, such as earthquakes (Giriunas et al., 2012). The concept has seen practical applications worldwide, notably in Amsterdam's Keetwonen project, which successfully transformed containers into affordable student housing (Megahed & Ghoneim, 2022). Container housing not only reduces construction costs but also shortens build times, as most work can be completed offsite (Islam et al., 2016).

Despite its advantages, container housing faces several challenges that hinder its broader adoption. Concerns regarding insulation, rust prevention, and structural modifications necessary for habitable spaces require further study (Grosso, 2007). Converting a shipping container into a habitable unit involves insulation, structural reinforcement, and the addition of utilities such as plumbing and electricity (Megahed & Ghoneim, 2022). Container housing faces thermal challenges due to metal's high conductivity, which affects temperature regulation inside the units. Consequently, insulation materials and design modifications are crucial to making them livable (Islam et al., 2016; Tettey et al., 2019). Additionally, the environmental impact of repurposing containers—especially the embodied energy in steel production—raises questions about the long-term sustainability of this construction method (Bongiorno et al., 2017). Shipping containers are an appealing option due to their recyclability and cost-effectiveness, which can reduce both initial construction costs and ongoing maintenance expenses (Giriunas et al., 2012; Lim et al., 2013). There is a need to evaluate these aspects to establish container housing as a viable solution to urban housing shortages.

This research aims to explore and analyze the construction mechanisms involved in container housing and evaluate its potential as a sustainable and cost-effective solution to modern housing challenges. The aim will be pursued through these objectives;

1. To identify the key construction mechanisms required for converting shipping containers into habitable spaces.
2. To evaluate the thermal and structural performance of container housing in different climatic conditions.
3. To assess the sustainability and economic viability of container housing as a long-term solution for affordable housing.

This study contributes to the understanding of container housing by highlighting its potential to meet urban housing demands sustainably. With over twenty million unused containers globally, reusing them for construction can significantly reduce environmental waste while providing an affordable housing solution (Olivares, 2010). Furthermore, container housing aligns with sustainable building practices, minimizing material use, construction time, and energy consumption (Islam et al., 2016).

2. Literature Review

2.1 History and Evolution of Container Housing

Container housing originated in the mid-20th century with the invention of the shipping container by Malcolm McLean in 1956, primarily for the shipping industry (Container One, 2018). The idea of converting these containers into habitable spaces gained traction in the 1980s, with Phillip Clark filing the first patent in 1987 for a method to convert shipping containers into homes (Container One, 2018). The trend began to flourish in the early 2000s, particularly after the completion of the first container home in the U.S. by architect Peter DeMaria in 2007. This shift was further accelerated by the rising popularity of sustainable living and innovative architectural practices (Instant Living, n.d.). Container homes offer numerous benefits, including cost-effectiveness, durability, and sustainability. Their modular nature allows for quick assembly and minimal construction waste, making them an appealing choice for affordable housing (Instant Living, n.d.; Futurist Architecture, n.d.). However, challenges such as insulation, temperature control, and structural modifications pose significant hurdles in their construction and long-term livability (Instant Living, n.d.; Futurist Architecture, n.d.).

2.2 Overview of Shipping Containers as Building Materials

Shipping containers are constructed from Corten steel, which provides exceptional durability and resistance to extreme weather (Instant Living, n.d.). Their standardized dimensions and modular characteristics make them suitable for various building applications, from residential homes to community centers and commercial spaces (Futurist Architecture, n.d.). While containers provide robust structural integrity, modifying them for residential use requires careful consideration. Cutting out sections for windows and doors can compromise their strength, necessitating additional reinforcements (Instant Living, n.d.; Futurist Architecture, n.d.). Understanding these structural requirements is essential for successful container home design. The layout of container homes must consider their fixed dimensions and the need for efficient space utilization. Architects have become increasingly creative in designing multi-container structures that optimize space while ensuring aesthetic appeal (Instant Living, n.d.; Futurist Architecture, n.d.). Effective insulation is critical for maintaining comfortable temperatures within container homes. The metal construction can lead to significant heat loss or gain, making temperature control a key consideration during the design process (Instant Living, n.d.; Futurist Architecture, n.d.). Proper foundations and anchoring methods are essential for ensuring the stability and longevity of container homes. Various techniques, such as concrete pads or piers, can be used to anchor the containers securely (Futurist Architecture,

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n.d.). Different types of shipping containers, such as standard, high-cube, and refrigerated containers, have unique properties that can influence their suitability for various projects (Instant Living, n.d.; Futurist Architecture, n.d.). Adhering to local safety codes and building standards is crucial for container housing projects. This includes compliance with zoning laws, fire safety regulations, and structural requirements (Futurist Architecture, n.d.). The integration of multiple containers can create expansive living spaces or multi-functional structures. However, the assembly process must be carefully planned to ensure structural integrity and aesthetic harmony (Instant Living, n.d.; Futurist Architecture, n.d.). The installation of essential utilities in container homes requires strategic planning. Plumbing and electrical systems must be carefully integrated to ensure functionality and compliance with building standards (Instant Living, n.d.). The interior design of container homes often involves creative solutions to maximize space and ensure comfort. This can include innovative storage solutions, multifunctional furniture, and eco-friendly finishes (Futurist Architecture, n.d.).

3. Methodology

This study adopted a mixed-methods approach. The research began with a review of existing literature on container housing construction mechanisms. Field studies were then conducted, involving pilot observation of a Case study of a container housing project in Enugu. Other Case studies in various climatic regions were analyzed to assess their performance too

CASE STUDIES

1. PROPOSED TECH HUB AT HELIU HEALTH AND TOURISM DISTRICT ENUGU

The proposed Tech Hub at the Heliu Health and Tourism District in Enugu is part of an ambitious development aimed at creating a multifaceted community that combines healthcare, residential, and technology-focused facilities. This project is significant as it aims to position Enugu as a hub for technological and entrepreneurial growth within the region. Notably, the Tech Hub is planned to utilize shipping containers as the primary construction material, reflecting an innovative approach to flexible, modular building design. The hub will not only serve as a workspace but also as an educational and training center aimed at fostering technology skills among youth in the state(Heliu Residences). The image of the tech Hub is shown at Fig 1.0.

Fig 1.0: Image of the Tech Hub at Heliu Health and Tourism District, Enugu
Source: Author, 2024

***Unique Design Elements**: The project emphasized a modular design, allowing for flexibility in configuration while maintaining a low cost. The use of prefabricated containers enables quick assembly and can cater to various family sizes.*
- *Interior: Drywall finish (Gypsum board) well screwed to Aluminum tracks and profile, well screeded, insulated and painted.*
- *Exterior: Aluminum composite panel as shown at Fig 2.0*

Fig 2.0: Image of Exterior cladding panels-Aluminum Composite panels for the Tech Hub at Heliu Health and Tourism District, Enugu
Source: Author, 2024

- Ceiling finish: PVC coated suspended ceiling
- Windows: 1200mm x 1200mm white powder-coated aluminum framed burglary-proof

windows, tinted reflective glazing (with weather shield)

• Doors: 900mm x 2100mm external steel door (with weather shield), 900mm x 2100mm internal wooden flush door

• Floor finish: 600mm x 600mm vitrified Nigerian floor tiles.

Fig. 3.0 shows its image of mechanical-ventilation plans.

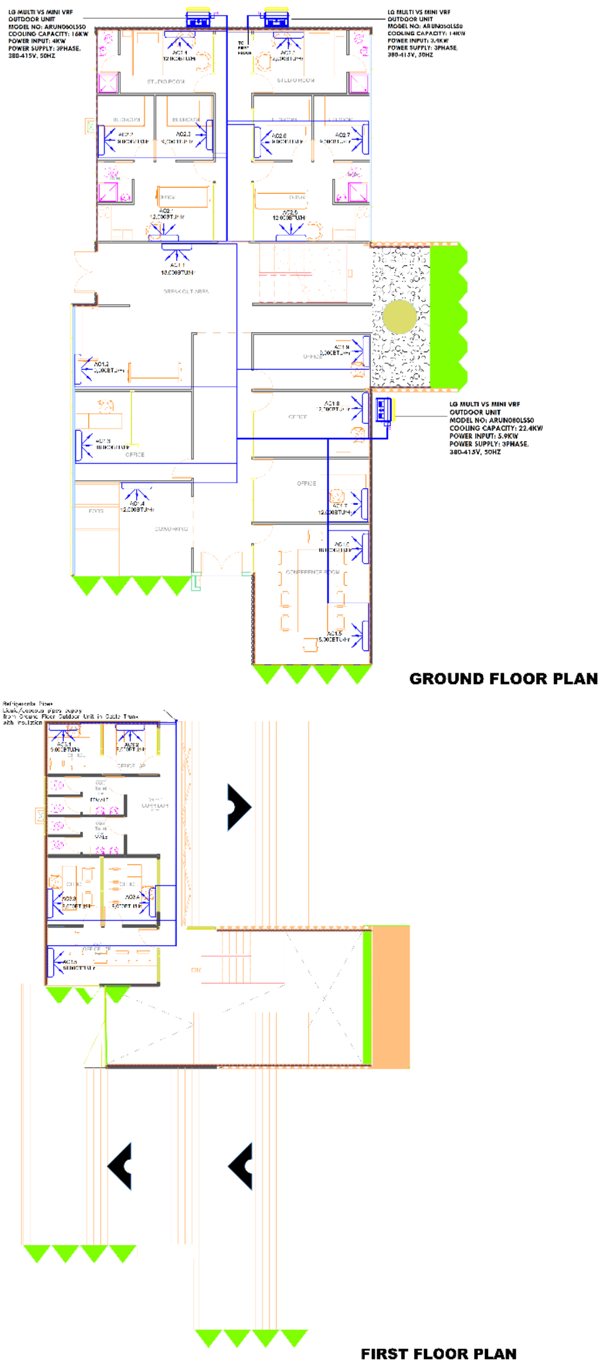

Fig 3.0: Image of mechanical – ventilation plan for the Tech Hub at Heliu Health and Tourism District, Enugu (a- ground floor plan, b-first floor plan)
Source: MNIGS NIG. LTD

Construction Methods: The construction involved standard practices of modifying containers by cutting openings for windows and doors and stacking them to create multi-story living spaces. This innovative approach reduces construction time significantly compared to traditional methods.

Modifications Required: Containers were modified for insulation and ventilation to ensure thermal comfort in the humid tropical climate of Enugu. Special attention was paid to proposing the addition of insulation materials and creating ventilation systems to manage heat.

2. *CONTAINER CITY (LONDON, UK)*

Container City, located in East London, represents one of the pioneering efforts in container housing and is shown in Fig 4.0. This project consists of modular units made from shipping containers, designed to provide flexible work and living spaces.

Fig 4.0: Image of the High School at the container City London, UK
Source: ArchDaily, 2020

Unique Design Elements

The project incorporates vibrant colors and artistic elements, emphasizing community interaction. The design promotes modularity, allowing for easy expansion and reconfiguration of spaces as needs change (ArchDaily, 2020).

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• Interior: Drywall finish (Gypsum board) well screwed to Aluminum tracks and profile, well screeded, insulated and painted.
• Exterior: Anti-rust paint over the metal panels of the shipping container.
• Ceiling finish: PVC coated suspended ceiling
• Windows: Circular windows, tinted reflective glazing (with weather shield)
• Doors: Curtain wall panel Doors
• Floor finish: Floor tiles

Construction Methods

The construction involved stacking and welding containers to create stable structures. Innovative techniques were employed to ensure that the aesthetic appeal did not compromise structural integrity.

Modifications Made to Containers

Containers were modified through cutting openings for windows and doors, enhancing natural light and ventilation. Stacking methods allowed for unique multi-level configurations (ArchDaily,2020).

3. CONTAINER HOUSE BY PLANNEA ARQUITECTURA (CHILE)

This project as shown in Fig 5.0, located in La Compania, Chile, showcases a dual-container design that serves multiple functions, from living space to creative studio.

Fig 5.0: Image of the container house in Chile Source: ArchDaily, 2021

Unique Design Elements

The house features a large overhanging roof that connects the two containers, creating an open, versatile space that blurs the lines between indoor and outdoor living (ArchDaily, 2021). This is described in plan and section in Fig 6.0.

• Interior: Well-polished cross-laminated timber
• Exterior: Well-polished cross-laminated timber.
• Ceiling finish: PVC-coated suspended ceiling
• Windows: Curtain wall panel windows, tinted reflective glazing (with weather shield)
• Doors: Curtain wall panel Doors
• Floor finish: Over-site mass concrete.

Construction Methods

The construction utilized prefabricated shipping containers, which were assembled on-site with minimal disruption. The integration of local materials further enhanced the construction efficiency.

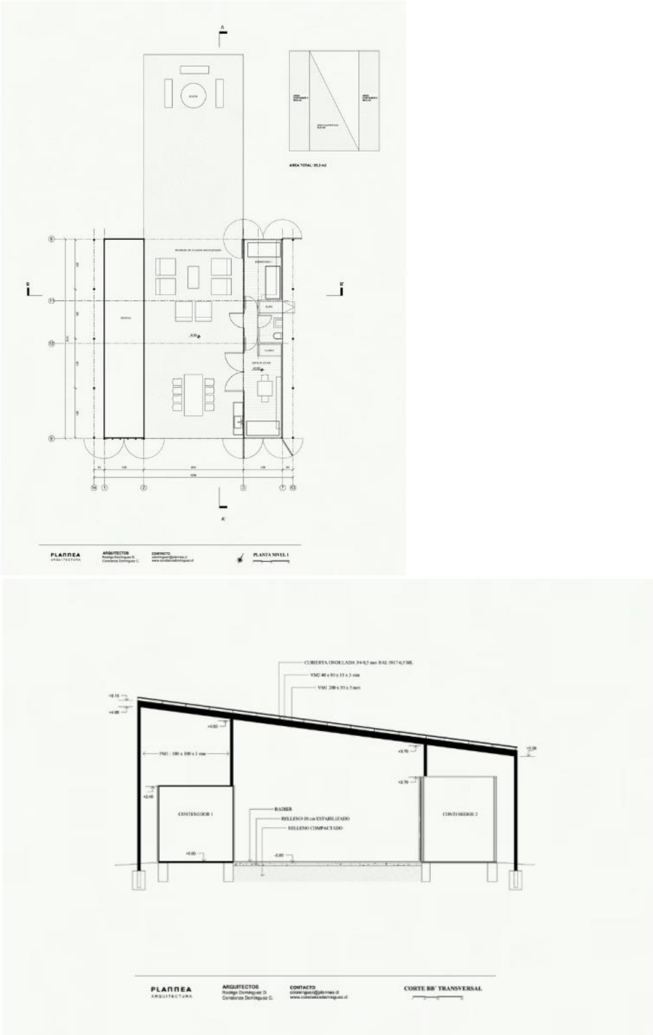

Fig 6.0: Image of the plan and section of the container house in Chile
Source: ArchDaily, 2021

4. KODA BY KODASEMA (ESTONIA)

KODA as shown in Fig 7.0, is a compact container home developed in Estonia that aims to provide affordable and sustainable living solutions.

Fig 7.0: Image of the Koda in Estonia
Source: ArchDaily, 2021

Unique Design Elements

The design features a minimalist aesthetic, large glass facades, and an innovative folding mechanism that allows the unit to expand on-site.

- Interior: Light-colored plywood
- Exterior: Vacuum-insulated concrete.
- Ceiling finish: Light plywood as the interior walls
- Windows: Quadruple-glazed windows
- Doors: Curtain wall panel Doors
- Floor finish: High-quality laminate.

Construction Methods

Constructed entirely off-site, KODA is designed for quick assembly. Its modular nature allows for easy transportation and installation in various locations. The plans and sections are shown in Fig. 8.0

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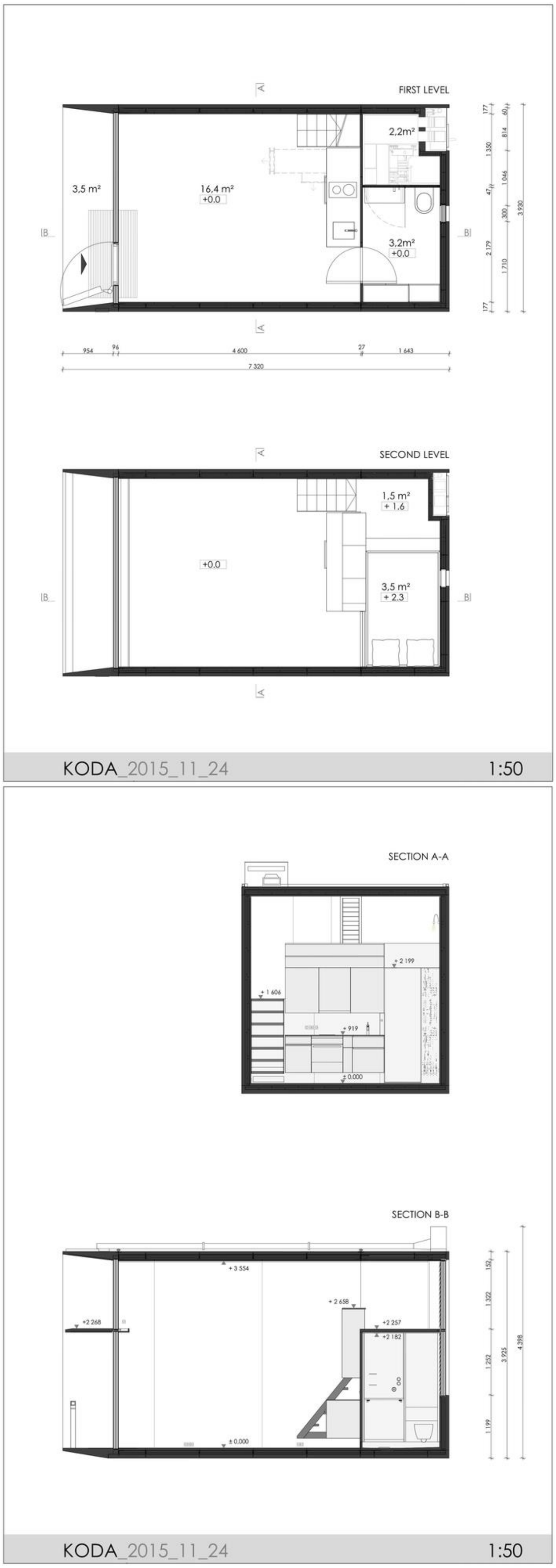

Fig 8.0: Image of the plan and section of the Koda in Estonia
Source: ArchDaily, 2021

Table 1: Container Housing Projects and their Design Features

Modifications Made to Containers

KODA utilizes custom-designed panels that extend from the container, transforming it into a spacious living area. Additionally, insulation materials were strategically placed to optimize energy performance (Rosenberg, 2023).

4. Results and Findings

Table 1.0 describes a structured comparison of the four container housing projects, based on their unique design elements/ features, construction methods, modifications, and finishes:

projects' construction mechanisms and material selections.

Case Study	Unique Design Elements	Construction Methods	Modifications	Interior Finish	Exterior Finish	Ceiling Finish	Windows	Doors	Floor Finish
Proposed Tech Hub, Enugu (Nigeria)	Modular design, with flexible configuration and low cost	Containers were stacked, cut for windows and doors, and insulated	Added insulation and ventilation to suit humid climate	Drywall (Gypsum board), insulated and painted	Aluminum composite panels	PVC-coated suspended ceiling	Aluminum-framed, tinted reflective glazing	Steel exterior door, wooden flush interior doors	Vitrified Nigerian floor tiles
Container City, London (UK)	Vibrant colors and artistic community emphasis	Containers stacked and welded; structural integrity preserved through stacking	Modified for light, ventilation, and stacking to multi-levels	Drywall (Gypsum board), insulated and painted	Anti-rust paint on metal panels	PVC-coated suspended ceiling	Circular, tinted reflective glazing	Curtain wall panel doors	Floor tiles
Container House by Plannea Arquitectura, Chile	Large overhanging roof connecting dual containers for indoor-outdoor space	Prefabricated containers assembled on-site	Cut-outs for larger windows, semi-enclosed space for airflow	Cross-laminated timber, polished	Cross-laminated timber, polished	PVC-coated suspended ceiling	Curtain wall panel, tinted reflective glazing	Curtain wall panel doors	Mass concrete
KODA by Kodasema (Estonia)	Minimalist design, large glass facades, modular and portable	Constructed off-site, assembled on-site quickly	Custom panels for space expansion, optimized insulation for energy	Light-colored plywood	Vacuum-insulated concrete	Plywood matching walls	Quadruple-glazed	Curtain wall panel doors	High-quality laminate

These case studies illustrate a variety of approaches to container housing, with each project incorporating specific design choices to address local climate, structural requirements, and aesthetic goals. Notably, the Proposed Tech Hub at Heliu Health District in Enugu focuses on rapid construction using prefabricated containers. At the same time, the Container City in London highlights community integration with vibrant colors and open spaces. In Chile, Plannea Arquitectura emphasizes an indoor-outdoor connection, whereas Kodasema in Estonia offers a minimalist, energy-efficient design for sustainable living. This comparative analysis provides insights into how different environments and requirements shape container housing

5. Conclusion and Recommendation

This research explored the construction mechanisms of container housing by analyzing various case studies. Container housing presents a promising alternative to modern housing, particularly in rapidly urbanizing areas where conventional construction costs and timelines can be prohibitive. The case studies of the Proposed Tech Hub at Heliu Health and Tourism District in Enugu, Container City in London, Container House by Plannea Arquitectura in Chile, and KODA by Kodasema in Estonia underscore the versatility of container housing across diverse environmental and cultural contexts.

In conclusion, the study finds that container housing offers multiple benefits, such as reduced construction times, cost-effectiveness, and adaptability to various needs. Each case exemplifies how container units can be customized to meet unique project requirements, from aesthetic design to structural modifications. However, challenges such as insulation, ventilation, and compliance with local building codes require careful consideration. The proper incorporation of insulation and climate-specific modifications, as seen in the Enugu Tech Hub and KODA projects, is essential for enhancing occupant comfort and achieving energy efficiency (Rosenberg, 2023; ArchDaily, 2020). Moreover, the ability to meet local safety codes and standards is vital to ensure the longevity and acceptance of container housing (Heliu Residences, 2023).

To maximize the potential of container housing, the following recommendations are proposed:

1. **Tailored Modifications for Climate Adaptation:** Given the variability in climate conditions, it is essential to adopt construction techniques that align with local climates. For example, utilizing insulation and natural ventilation systems can significantly enhance thermal comfort and energy efficiency, as demonstrated in the projects in Nigeria and Estonia (Rosenberg, 2023).
2. **Integration of Renewable Energy Solutions:** Incorporating renewable energy sources, like solar panels, can increase the sustainability of container housing. This approach not only lowers operational costs but also enhances the eco-friendliness of container-based projects, as evidenced in the KODA project, which feeds excess energy back into the grid (Divisare, 2023).
3. **Standardization and Compliance with Local Codes:** Given the increasing interest in container housing, governments and regulatory bodies should consider establishing guidelines specific to this construction method. Such regulations will help ensure safety, quality, and compliance while facilitating the broader acceptance of container housing as a viable solution for affordable housing (ArchDaily, 2021).
4. **Community-Centric Design and Aesthetics:** As seen in Container City in London, embracing design elements that foster community interaction can enhance the social acceptance and usability of container housing. Projects should consider including shared spaces and adopting aesthetics that reflect local culture and preferences (ArchDaily, 2020).

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