Foldable and Transportable House Unit: An Approach for a Socio-Environmental Model Design in Al-Araqib Village, Palestine

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***Abstract*—Palestine has been suffering from the occupation for a long time. Occupation authorities have practiced major persecution policies against Palestinian citizens; their homes and livelihoods have been destroyed, their land claims and historical rights have been denied, they've had restrictions enforced on their movement, access to their own water, land and other natural resources. Al-Araqib Village in southern Palestine is one of many villages whose homes are constantly being demolished by the occupation. That calls for the need to think about a collapsible building method that supports Bedouin life and reduces damage. This study aims to design a housing unit that can be folded, disassembled and transported, taking into account the social aspects and preserving the nature of Bedouin life. A virtual model for the proposed housing unit was made on Design Builder software, and a simulation was performed to ensure the expected approaches. The results revealed that the designed housing unit provides reasonable thermal performance for the dwellers. The deigned unit can be adopted as an effective housing unit in Araqip village and similar villages which will reduce the harm inflicted on them and enhance their existence. This unit can also be adopted in areas exposed to natural disasters or wars, such as Gaza.**

I. Introduction

Under the State Property Law of 1951, the occupation government inherited Land and property of the British Mandate government. 1950 The Absentee Property Law effectively gave the state control over the movable and immovable property of all Palestinian refugees. (53) Aside from legislation, land title settlement was another process A major tool of land expropriation, playing a major role in the Negev lands, there are only 494,157 dunams of land in the occupation government whose ownership remains precarious, especially in the Negev.57 During the 1950s and 1960s, the occupation government continued Britain launched the land titling process, starting in the north Area. Significantly new combination of legislative and judicial standards Restricting the ability of Palestinian landowners to prove or acquire land ownership [1]. Al-Araqib is a Palestinian village located north of Beersheba, in the Negev desert, in southern Palestine. It is one of the 45 Arab villages in the Negev that have not been recognized by the occupation authorities. "The Israeli authorities demolished the al-Araqib village for the 184th time," Aziz al-Touri, a member of the Committee for the Defense of al-Araqib, told Anadolu Agency. AL-Touri said the demolition was the ninth since the beginning of the novel coronavirus pandemic. The village was demolished last on Feb. 17 2021. Homes in Al-Araqib, which are inhabited by 22 Palestinian families, are built of wood, plastic, and corrugated iron. AL-Touri confirmed that the villagers intended to rebuild their destroyed dwellings and other structures. The village was first destroyed in 2010 and every time after it was rebuilt since then. the occupation government authorities claim that the site where it's located falls under "state land. "The Israeli Zochrot organization said in a recent report that al-Araqib village was first built during the Ottoman period and its lands purchased by residents. the occupation government authorities seek to seize control of the lands and expel its residents, with dozens of villages and Bedouin communities facing the same threat in the Negev area, according to Zochrot"[2]. The unrecognized Bedouin villages have not been identified on any official state maps, nor are they provided with any kind of infrastructure by the state, be it water, electricity or sanitation. At the beginning of the last decade, after years of neglect and neglect, the State of the occupation government. It intensified its efforts to impose illegal construction activities within the Bedouin community residing in the Negev. Desert. In fact, the occupation government authorities issued a demolition warrant for every additional building for the Bedouins Constructed without permission [3].

The primary objective of this paper is to empower the indigenous Bedouin communities in Al-Araqib and surrounding areas by supporting their resilience and minimizing the damages they suffer as a result of repeated demolitions by occupation authorities.

To achieve this overarching goal, the study sets out several specific objectives:

- Designing adaptable housing units using collapsible and transportable construction materials to enable quick dismantling and reassembly in the face of demolition threats.
- Preserving the traditional Bedouin way of life, with special consideration for sustaining their livelihoods, including sheep herding and poultry farming.
- Utilizing renewable energy and locally sourced materials to provide essential services in a sustainable and self-sufficient manner, tailored to the needs of the indigenous population.

II. Research Approach And Methodology

A seven-phase methodology was adopted to develop the design approaches for the project. In Phase (1) an inductive approach was employed to collect detailed information about

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978-9950-8599-0-6

the Al-Araqib area, including its political status, geographical location, population, as well as social, cultural, and climatic characteristics. Phase (2) involved reviewing relevant case studies, specifically examining the "Village in a Box" and "The Meir House" to draw inspiration and gather insights. In Phase (3) the focus shifted to the design of the housing unit, addressing the architectural and philosophical ideas, construction methods, selection of suitable building materials, and incorporation of environmental strategies. Phase (4) dealt with preparing comprehensive project plans, which included the general site layout of the village, individual plots for owners, detailed architectural drawings such as plans, facades, and sections, the unit's folding mechanism, and proposed environmental solutions. Phase (5) entailed simulation and verification of the housing unit's performance using the Design Builder and DIA Lux software to ensure thermal comfort for residents. Phase (6) focused on analyzing the simulation results to assess the effectiveness of the design. Finally, in Phase (7) conclusions and recommendations were made, which led to the adoption of the housing unit design after confirming thermal comfort, along with endorsing the selected construction method and building materials as appropriate for use in the region.

III. The Study context

Al-Araqib is a Palestinian Bedouin village situated north of the city of Beersheba, within the Negev Desert in southern Palestine. It is one of 45 unrecognized Arab villages in the Negev region, which means it is not acknowledged by the Israeli authorities and is consequently excluded from official maps and denied access to basic infrastructure and public services. [4]

The population of the area ranges between 300 and 1,000 individuals, primarily composed of Bedouin families known for their large household sizes, often consisting of seven or more members. The community is marked by a noticeable gender gap in education, with a higher percentage of educated men compared to women. Al-Araqib represents a simple and conservative society that continues to face substantial challenges, particularly due to the lack of access to essential public services such as water, electricity, healthcare, and education.

Al-Araqib experiences a semi-arid climate with hot, dry summers and cooler winters. Summer temperatures frequently rise above 30°C, with August being the hottest month. In contrast, winter daytime temperatures fall below 19°C, with the coldest day typically occurring around January 24. Humidity levels reach their peak on August 15, averaging 66%, and drop to their lowest around December 25.

Wind speeds exceed 7.5 mph from May to September, then decrease to around 6.9 mph for the remainder of the year. Seasonal shifts in wind direction are also evident—winds blow predominantly from the north between mid-April and mid-June, and from the west between mid-June and late August. Rainfall, though limited, is the main form of precipitation, with the highest likelihood—approximately 17%—occurring around January 18. The region endures a prolonged dry season lasting roughly 7.5 months, intensifying challenges related to water access and sustainability. [6]

The construction situation of Al-Araqib can be mentioned as the following:

- Existing Structures:
  The majority of buildings in the area consist of temporary or semi-permanent structures, including huts, tents, caravans, poultry shelters, and water tanks. These structures reflect the resourcefulness of the residents in the face of limited infrastructure and recurring demolitions.
- Construction material:
  The existing buildings are primarily constructed using basic and readily available materials such as bricks, leather, and corrugated metal sheets. These materials are chosen for their affordability, ease of assembly, and mobility.
- Construction Materials can be provided:
  - Concrete Reinforced concrete
  - Hollow concrete block
  - Autoclaved Aerated Concrete
  - Stable Soil Mass
  - Mass fly ash (mixed)
  - Mass fly ash (soil)
  - Stone
  - Expanded polystyrene.

IV. Related Case studies

A. Case study 1: Village in a Box

The "Village in a Box" case study presents a sustainable housing proposal in the Negev desert town of Mizpah Ramon, designed by architects Victor Heim Hajjaj and Jonathan Haran. The project aims to develop 200 modular, 120 m² monolithic dome homes using reusable inflatable molds. Each home includes a 250 m² garden, and the village infrastructure supports communal, industrial, and agricultural activities. The project emphasizes environmental sustainability through complete water recycling, waste treatment, rainwater harvesting, and 100% renewable energy powered by solar and wind, with lithium-ion battery storage and biodiesel backup. Smart-home systems enable real-time monitoring of water and energy use. A no-car policy promotes bicycles and scooters, with shared electric vehicles parked outside. The village is expected to achieve a negative carbon impact of about 3,800 tons of CO_2, serving as a model for affordable, self-sufficient, and eco-friendly living [7] (Figure 1).

B. Case study 2: The Meir House

The Meir House, designed by architect Isaac A. Meir between 1992–1994 in the Negev Desert, exemplifies sustainable residential design adapted to harsh arid climates. Built for the Meir family on the Sede Boqer Campus, the 208 m² home incorporates passive design strategies to optimize thermal comfort and energy efficiency. The house is oriented along an east–west axis with southern-facing living areas and strategically placed windows to promote natural lighting, cross-ventilation, and stack ventilation. It uses medium-weight exterior walls made from YTONG cellular concrete for thermal insulation, and heavy-weight internal partitions to regulate heat transfer. Additional features include shaded verandas, insulated rolling shutters, and durable aluminum-framed double-glazed windows with insect screens. Landscaping and architectural shading devices reduce solar heat gain, while reinforced concrete floors and roofs enhance thermal mass. Overall, the Meir House demonstrates an environmentally responsive layout and construction approach tailored to its desert environment. [8]

Figure 1. Village in a Box, Source (7)

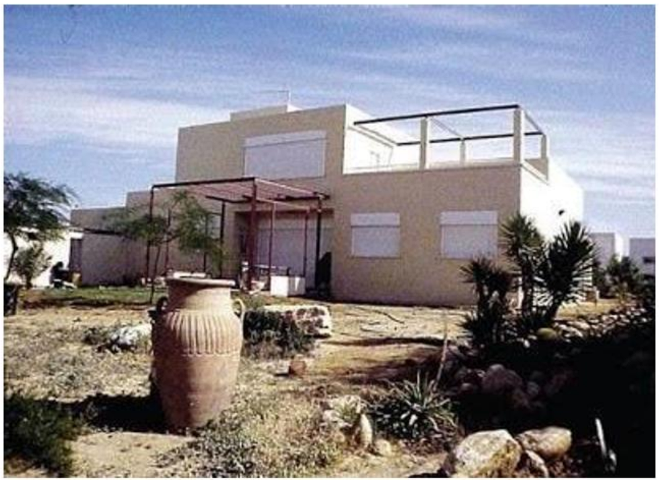

Figure 2.The Meir House, Source (8)

V. Conceptual Approach

The Folding and Transportable house model concept emerged from the urgent need to empower indigenous communities living in unrecognized areas, who frequently face the threat of home demolition. The aim is to develop retractable and transportable housing units that allow residents to preserve and relocate their homes, minimizing material and emotional loss each time demolition occurs. The design inspiration for the unit's form was drawn from the pill bug which remains extended in normal conditions but instinctively folds into a compact shape when under threat a natural defense mechanism that reflects the responsive, protective nature of the proposed unit.

The unit was designed to evolve through multiple development stages to achieve the optimal balance between functionality, comfort, and cultural relevance for the residents. The process carefully considers the social, cultural, and political complexities of the region. Additionally, the design aims to reduce dependence on municipal infrastructure by proposing alternative solutions for basic services such as electricity and gas services that are often denied or heavily restricted by the authorities. Strategies include the collection of rainwater reuse of graywater for irrigating crops, and integration of renewable energy sources. As part of the implementation strategy, the project also seeks financial and logistical support from humanitarian organizations such as UNRWA and UNICEF, with a specific focus on providing individual solar energy systems for each family to ensure independent and sustainable access to electricity (Figure 3).

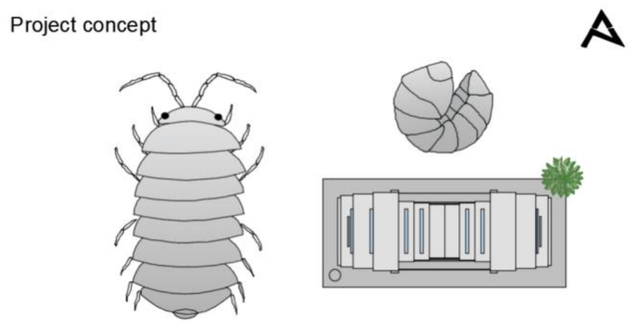

Figure 3. Project Concept (bio-mimicry)

A. Zoning

A residential unit with a total area of 53 square meters has been developed, incorporating three main interior zones: a master bedroom, a secondary bedroom, and a living room integrated with a kitchenette. To reflect and respect the traditional lifestyle of the local community, the bathroom was designed as a pre-fabricated external unit, aligning with common practices in the area.

In addition to the residential spaces, the design thoughtfully includes animal shelters, a food storage area, and a chicken coop, recognizing these elements as vital components of the local livelihood and economy. These supporting structures are designed to mirror the characteristics of the main housing unit, being both foldable and easily transportable, thereby ensuring the entire system is adaptable and responsive to the region's social, economic, and political challenges (Figure 4).

B. Environmental Solutions

The unit's roof and wall systems are constructed using polyurethane (PU) sandwich panels, selected for their low thermal conductivity and high insulation performance. Each panel measures 1 meter in width, up to 6 meters in length, and 0.10 meters in thickness, with a thermal conductivity of 0.22 W/m·°C. Polyurethane foam, known for its excellent thermal insulation properties, serves as the core insulating material.

The exterior faces of the panels are clad in stainless steel or aluminum sheets, finished in white-coated steel plates to enhance solar reflectivity and reduce heat absorption.

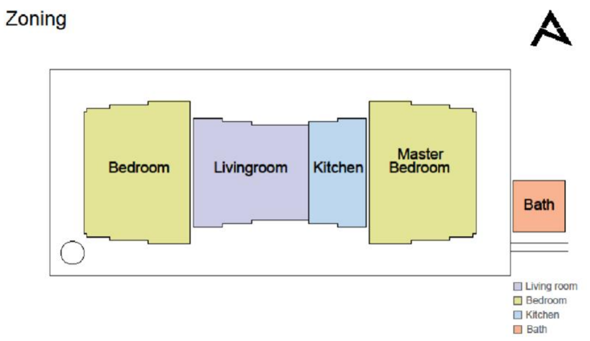

Figure 4. Zoon plan for residential unit

These sandwich panels significantly minimize heat transfer between the indoor and outdoor environments, effectively reducing the temperature differential. This contributes to maximum thermal efficiency and improves the cooling and heating performance of the unit, ensuring greater energy savings and thermal comfort for the occupants *(*Figure 5).

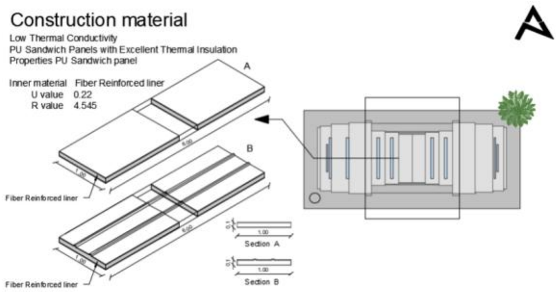

Figure 5. Constriction material Low thermal conductivity PU sandwich panels

1. Openings

Double-glazed, reflective, clear glass without external shading has been utilized to minimize solar heat gain while allowing sufficient daylight to enter the residential unit. This approach ensures that natural light is admitted at optimal levels, while thermal radiation is effectively blocked, contributing to improved indoor comfort and energy efficiency.

2. Solar Energy

Solar cells have been adopted to provide electrical energy.

3. Methane biogas unit (Natural gas production unit)

The presence of livestock has been utilized as a sustainable resource by converting animal dung into biogas for use in cooking and heating. The biogas production system consists of two interconnected water tanks—one with a capacity of 1,500 liters and the other 1,000 liters. In this process, 10 to 15 kilograms of animal manure are mixed with approximately 30 liters of water to form a slurry. This mixture is then fed into the tanks, initiating the anaerobic digestion process that generates methane-rich biogas.

Depending on the family's size and energy needs, this process is typically repeated two to three times daily. This system not only provides a sustainable and cost-effective energy source but also contributes to waste management and reduces dependence on external fuel supplies, making it particularly suitable for off-grid and vulnerable communities (Figure 6).

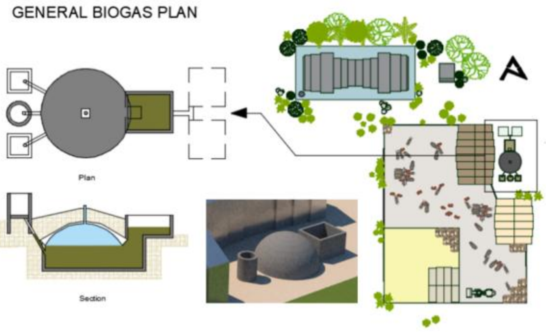

Figure 6. Methane biogas unit

4. Fertilizer -Methane Biogas Unit

The byproducts of the methane biogas unit are also efficiently utilized as liquid fertilizer. This nutrient-rich output is free from harmful bacteria and pathogens due to the anaerobic digestion process and is high in essential nutrients such as calcium and phosphorus. It serves as an eco-friendly, natural fertilizer that is safe and highly suitable for a wide range of agricultural applications, contributing to sustainable farming and soil enrichment.

5. Rain Water Harvesting

Rainwater is harvested from the building's surroundings and stored in underground tanks. Two tank options are available: a large 25,000-liter tank (D 3.05m, H 3.85m) and a smaller 5,000-liter tank (L 2.35m, W 1.70m, H 1.90m). The system supports water conservation for domestic, irrigation, and livestock use (Figure 7).

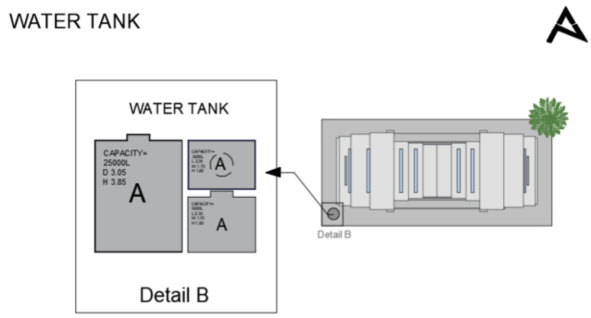

Figure 7. Water Tank

6. Gray-Water Reuse

It was proposed to implement a gray water separation system, allowing used water from sinks, showers, and laundry to be collected in dedicated tanks equipped with external pumps. This treated water can then be reused for irrigating plants, serving as an effective strategy to conserve water resources in response to the region's ongoing water scarcity (Figure 8).

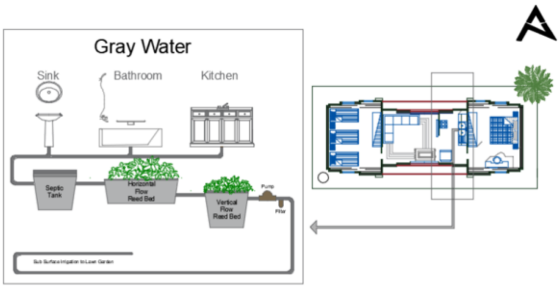

Figure 8. Gray Water Proses unit

7. Plants:

Preserving tree planting is of vital importance due to the numerous environmental and functional benefits it provides. Strategically planted trees enhance privacy for each residential unit and offer natural shading, which helps in lowering ambient temperatures and improving air circulation. These effects contribute to a reduction in energy consumption needed to maintain thermal comfort indoors. Additionally, trees play a key role in promoting energy efficiency and mitigating environmental impact by absorbing greenhouse gases, including carbon dioxide, sulfur dioxide, and nitrogen dioxide, thus supporting a healthier and more sustainable living environment. Figure (9).

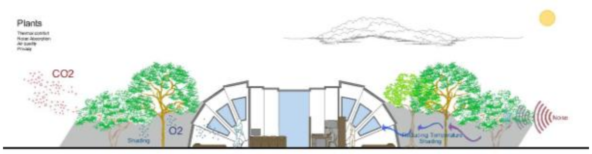

Figure 9. The effect of plants around the unit

8. The Bedouins' lifestyle

The Bedouin lifestyle has been thoughtfully preserved in the design approach, recognizing that most residents are livestock herders and maintain strong family cohesion without physical boundaries between households. The housing units are oriented along the east-west axis, strategically minimizing openings on the southern façade to limit solar heat gain while maximizing natural ventilation by capturing prevailing winds. Conversely, the barns are oriented north-south to ensure maximum exposure to sunlight, which helps prevent moisture accumulation and promotes efficient fluid drainage, keeping the interior dry and sanitary. This alignment respects both environmental conditions and the cultural traditions of the community.

9. Furniture

The furniture was carefully selected to align with the Bedouin way of life, emphasizing simplicity, functionality, and cultural relevance. Foldable and compact pieces were chosen to allow for easy assembly and storage within the unit once it is folded, thereby facilitating efficient transportation without compromising comfort or practicality.

VI. Model Design

The planning of the Bedouin village was guided by several key considerations, with site orientation and cultural sensitivity at the forefront. One of the most important aspects was the strategic distribution of residential units across the land in a way that respects the traditional Bedouin lifestyle. This included preserving grazing areas and ensuring that animal pens were positioned adjacent to the homes to support daily herding activities. Additionally, vegetated buffer zones were introduced between units to enhance privacy while maintaining a sense of community and openness that reflects the Bedouins' close-knit social structure (Figure 10).

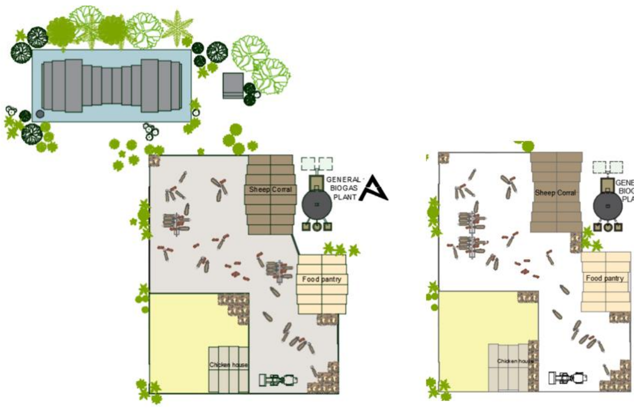

Figure 10. Site plan layout

VII. Details Of Folding The Housing Unit

Drawings illustrating the approved construction technique -folding and sliding- demonstrate a compact and efficient design. The unit can be folded to dimensions not exceeding 3.50 meters, enabling ease of transport and deployment. The structure incorporates the following key features:

- A robust and durable framework ensuring structural stability.
- Quick and simple assembly and disassembly, allowing for efficient relocation.
- A fully removable design, ideal for areas facing demolition threats.
- Sloped surfaces and detailing that prevent water accumulation.
- Fast anchoring system for secure installation on various ground types.
- Protection from direct sunlight, enhancing indoor thermal comfort.
- Resistance to harsh weather conditions, including wind and snow.
- Barrier protection against birds and wild animals, ensuring safety and hygiene.

VIII. Stages Of Relocation

1. Folding Stages

The folding stage marks the initial step in the unit's relocation process. During this phase, the side panels of the unit are carefully folded inward using the designated folding mechanism. This process reduces the overall footprint of the structure, allowing it to be compact and ready for transport, without compromising its integrity. Figure (11).

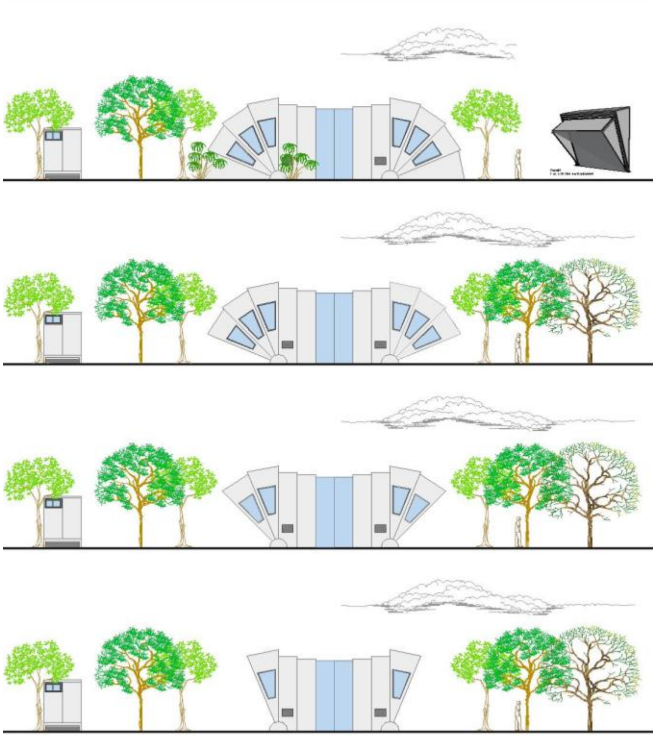

Figure 11. Folding Stages

2. Sliding Stages

The second stage involves sliding out the central section of the unit, which contains the main entrance and forms the living room and kitchen area. Once retracted, the unit reaches its most compact form, minimizing its footprint. This compact configuration allows for easy loading onto a transport vehicle, making relocation more efficient and manageable. (Figure 12).

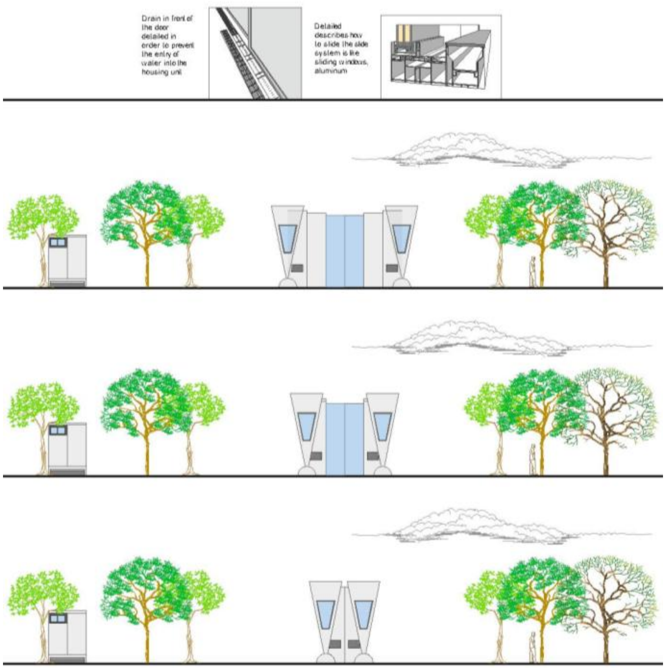

Figure 12. Sliding Stages

IX. Environmental Analysis

1. sun Path Analysis

The sun path analysis reveals that, due to the building's east-west orientation, sunlight penetrates the interior spaces extensively throughout the day. This exposure necessitated minimizing openings on the southern facade to reduce solar heat gain and glare, thereby preventing overheating and enhancing occupant comfort (Figure 13).

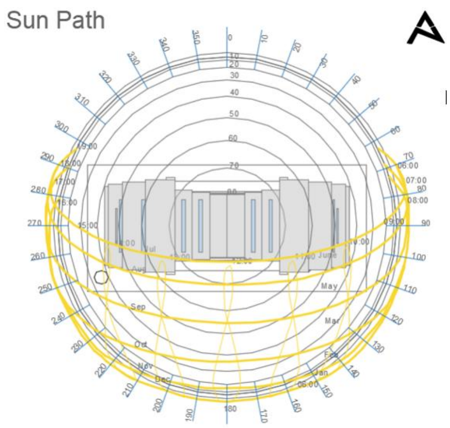

Figure 13. Sun Path

2. Ventilation Analysis

The air movement analysis demonstrates the use of natural ventilation by incorporating lower openings on the northern side to allow the entry of cooler air, while strategically placed upper openings on the southern side facilitate the exit of warm air. This design promotes automatic airflow circulation throughout the interior (Figure 14).

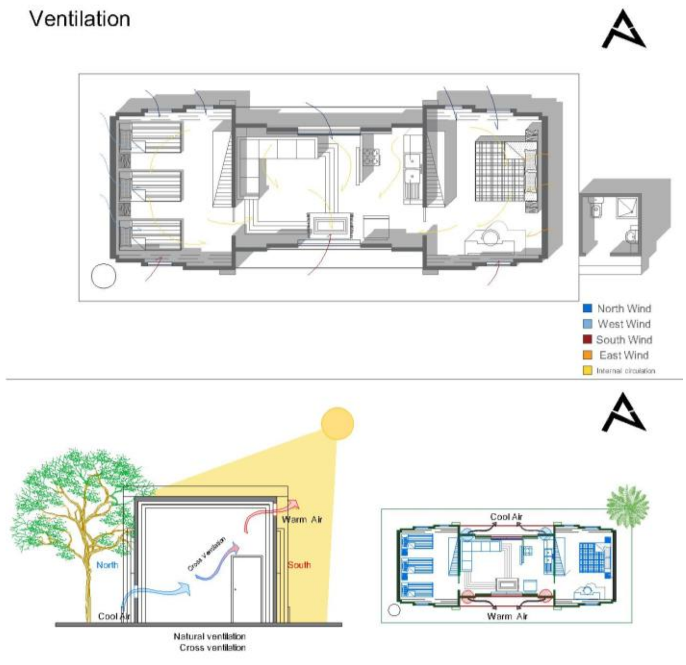

Figure 14. Ventilation

X. Simulation and Verification of the House Unit Status

Design Builder CFD enables both external and internal analyses. Internally, it maps the distribution of air velocity, pressure, and temperature throughout the building's interior spaces, providing valuable data to assess occupant comfort. Additionally, it evaluates the structural materials by detailing their thermal conductivity and resistance values. The analysis focused on the warmest week of the year, from August 15 to 21, chosen because the region experiences predominantly hot and dry conditions during this period, which are more critical than colder days.

1. *Daylight Simulation*

The DIA Lux program was utilized to evaluate the lighting levels within the residential unit. The results indicated that most areas receive between 300 and 500 lux, which falls within the optimal range required for performing typical household tasks effectively (Figure 15).

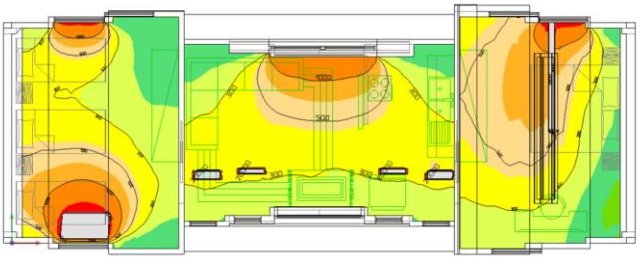

Figure 15. Daylight Chart

2. *Cooling Design*

The cooling design analysis demonstrates that the indoor air temperature within the housing unit was maintained at 25.4°C, while the outdoor temperature reached 33.8°C, resulting in a temperature difference of approximately eight degrees. This significant reduction confirms that the thermal performance of the building envelope successfully achieved its primary objective (Figure 16).

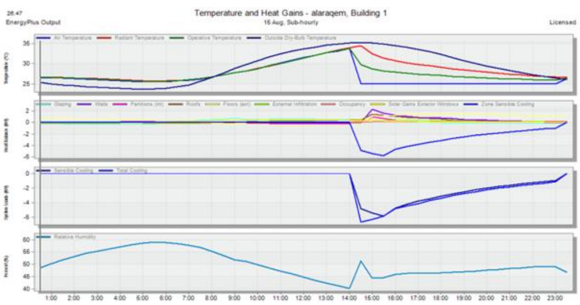

Figure 16. Cooling Design Chart.

3. *Heating Design*

The heating design analysis indicates that the indoor air temperature reached 21.00°C, with an operative temperature of 18.86°C, while the outdoor air temperature was recorded at 5.20°C, as illustrated in the corresponding (Figure 17).

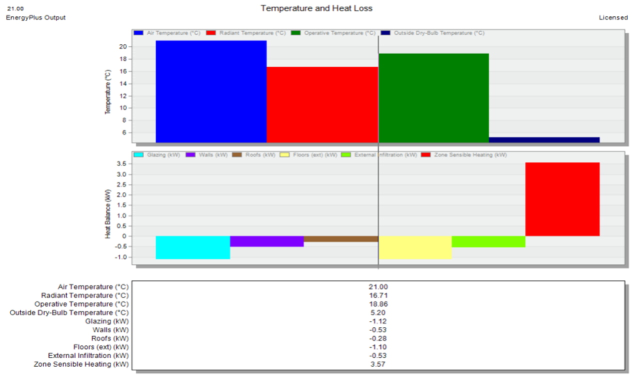

Figure 17. Heating Design

4. *Temperature Enhancement*

The internal CFD analysis revealed that the temperature in the master bedroom and kid's bedroom ranged between 18.45°C and 19.00°C. Meanwhile, the living room and kitchen experienced slightly higher temperatures, ranging from 19.54°C to 20.63°C (Figure 18).

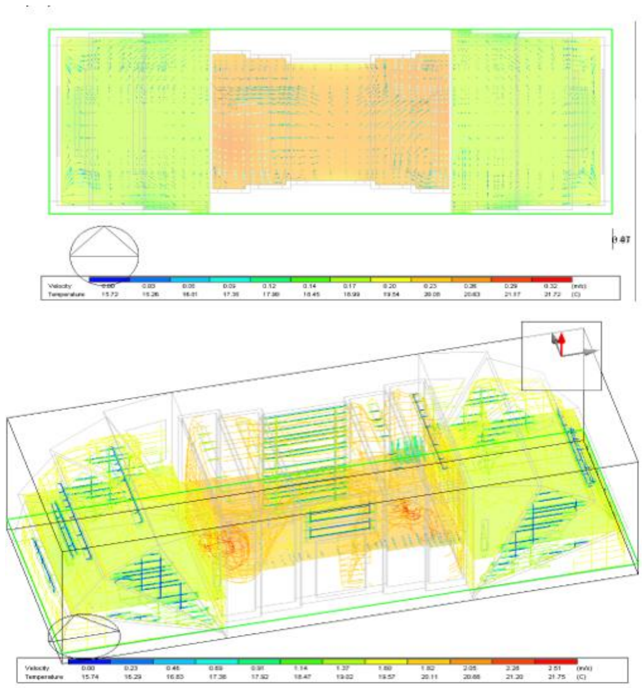

Figure 18. Temperature Chart

5. *Age of Air*

According to ASHRAE standards and referenced data on air age, the residential unit requires air changes between 6 to 9 times per hour. The age of air in the bedrooms ranged from 360 to 430 seconds, corresponding to 6 to 7 air changes per hour. In contrast, the living room and kitchen had an air age between 573 and 645 seconds, indicating a higher air change rate of 9 to 10 times per hour (Figure 19).

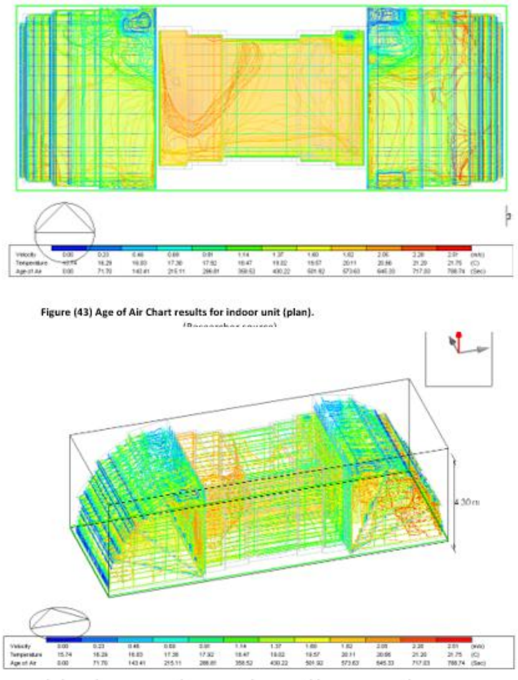

Figure 19 Age of Air Chart

6. PMV Result

According to the PMV chart based on ASHRAE 55 standards, the building's thermal conditions consistently remained within the optimal comfort range of -0.5 to +0.5, successfully ensuring thermal comfort for the occupants of the housing unit, as illustrated in (Figure 20).

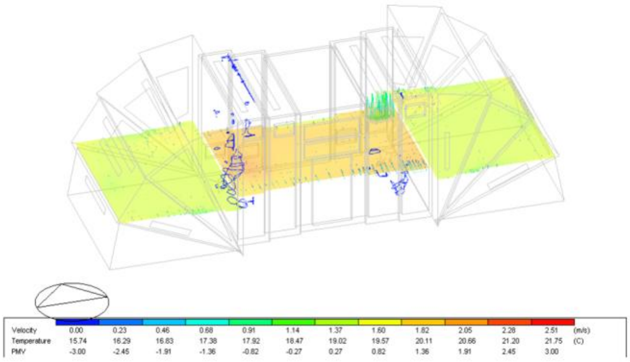

Figure 20. PMV Chart

7. PPD Result

The chart illustrates the predicted percentage of dissatisfied occupants (PPD) due to thermal conditions within the space. According to ASHRAE standards, all occupied areas should maintain a PPD below 20% to ensure thermal comfort. The chart indicates that the PPD values throughout the residential unit remain within this acceptable range, as shown in (Figure 21).

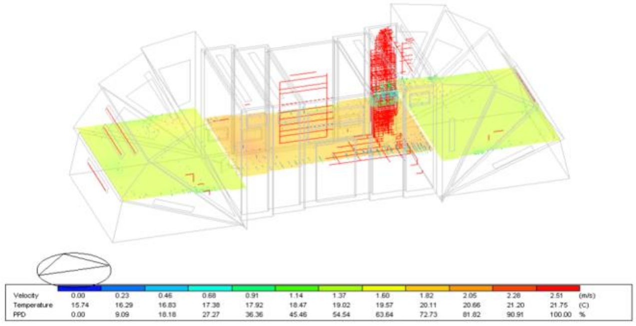

Figure 21. PPD Chart

XI. Conclusion

The study demonstrates the effectiveness of using sustainable construction techniques and insulating materials to reduce energy consumption, achieve thermal comfort, and maintain proper illumination levels within the housing unit. The findings also highlight the practicality and resilience of a foldable and dissemblable structural system in areas prone to demolition. This approach not only preserves the physical structure but also mitigates material and emotional losses, reinforcing the steadfastness of communities living under unstable conditions.

A housing unit and its complementary facilities were designed with a focus on empowering the local population and supporting their resilience. The constructive system—foldable, transportable, and easy to assemble—was paired with passive and active sustainability strategies to enhance thermal comfort and minimize reliance on external services.

Key sustainable measures include:

- Folding and removable insulation materials to reduce cooling and heating demands and provide psychological and economic security.
- Solar energy systems to generate electricity independently of municipal infrastructure.
- Gray water reuse systems for irrigation, addressing the scarcity of fresh water in the region.
- Methane biogas production units, which use livestock waste for cooking and heating, with the by-product repurposed as an organic fertilizer.
- Rainwater harvesting through sloped extensions around the building, directing water into underground storage wells.
- Preservation of vegetation and agricultural activity, which plays a vital role in enhancing environmental quality, supporting the economy, and reducing energy use.

Overall, the project provides a replicable model of resilient, sustainable housing that addresses environmental, economic, and socio-political challenges while respecting the lifestyle and traditions of the Bedouin communities.

XII. Recommendations

A set of recommendations can be highlighted, as there is a need of the following:

- Developing specialized construction materials that enable faster folding and dismantling processes, enhancing resilience and empowering communities living in threatened and unstable areas.
- Encouraging international organizations and human rights groups to intensify their support for such innovative housing projects, helping communities to safeguard their rights and preserve their homes.
- Prioritizing the adoption of passive design technologies to minimize energy consumption, protect the environment, and promote long-term sustainability.
- Invest in advancing technologies that harness natural resources -such as animal manure and organic waste- to provide essential services, including energy production and fertilizer, thereby supporting self-sufficiency within the population.

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