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Sustainable Solutions for Mass-Housing Design in Africa: Energy and Cost Assessment for the Somali Context

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Abstract: Today, the main issue of providing adequate and affordable housing is to go beyond the mere offer of basic shelters, intending to create sustainable and durable settlements. Due to the fragile and uncertain nature of its social, political and economic context, characterized by the lack of common shared legislative references and business strategies in the housing sector, Somalia is a challenging reality to be explored and improved. This paper describes the outcomes of the BECOMe project, intending to propose sustainable solutions for mass-housing design for new sustainable settlements in Mogadishu, involving local entrepreneurs, social organizations and renewable energy. In detail, social, environmental and economic key sustainability requirements (KSRs) for mass-housing are identified first. Then, the most appropriate climate-responsive design and construction technologies at the building level, tailored to the Mogadishu context, are selected; the outcomes are applied to a specific case-study building, assessing energy and cost performances to pave the way for implementation projects in Somalia.

Keywords: sustainable buildings; mass-housing; precast panels; passive design strategies; energy efficiency; Africa; Somalia

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1. Introduction

Developing regions are experiencing rapid urbanization, mainly characterized by population growth and migrations from rural to urban areas. In this respect, the African continent is a significant example: in fact, although Africa represents the most rural country in the world, with only 42% of the population concentrated in urban areas in 2018, it has been estimated that sustained rates of urbanization could drive more than half of the African population (59%) to live in cities by 2050 [1]. The capacity of cities to deal with population growth is challenged by problems of low development and poverty, which cause the rise of slums. This is rather evident from the data provided by UN-Habitat, which estimated that over half of the African urban population (62%) currently live in slums [2].

Housing programs in response to the shelter needs of the low-income African population either do not exist, are not affordable, or are insufficient in scale, compared to the demand; in addition, they have often proven to be inadequate, providing poor shelter standards in remote locations, with scarce regard to the lifestyle and livelihood strategies of the residents [3].

It should also be stressed that rapid housing developments create an amplified carbon footprint and further negative impacts on the environment. The building sector is one of the largest consumers of natural resources and energy since it uses 30–40% of all primary energy and natural resources over the building's lifespan (construction, operation, maintenance and demolition) and accounts for 30% of the global emission of greenhouse gases [4].

It is, therefore, evident that only through sustainable solutions is it possible to mitigate the tensions between urban growth, climate change and poverty reduction, offering affordable housing and access to quality residential services, clean energy and environmental conditions. This could also allow low-income housing to have the potential to improve the economic prosperity and social development of its occupants.

The achievement of sustainability in affordable housing has received increasing attention in the literature [5]. However, in recent years housing policies and practices for sustainable and affordable housing have been both insufficient and inefficient. In this context, a vital question is: how should sustainability be integrated into the design of affordable housing? To address this issue, a relevant research topic is to identify the key requirements that are useful to guide developing affordable housing, often also called "low-income housing".

First of all, it must be clarified that, in the literature, the expression *low-income housing* is usually associated with terms such as social, affordable and mass housing [6]. The overarching objective to which the different terms refer is to satisfy the housing needs of vulnerable and low-income households, with reference to social and economic aspects, respectively. However, a first assessment on the different possible definitions is reported below.

In detail, the expression "social housing" means a response to housing needs that, as the qualifier itself suggests, mainly takes into account the social aspect. The target group is households with low financial resources, and therefore, having problems in accessing decent housing on the market [7,8]. Since the social housing systems offer rents or prices lower than the general market, they are not self-sufficient, but they usually require some form of public or private subsidy [8,9]; there are various providers working with different incentives, but the major ones are public bodies and nonprofit organizations [9,10].

The expression "affordable housing", instead, takes into account the economic criteria and is generally used to refer to the relation of the housing cost with respect to the occupants' income. In this context, an interesting definition is that from Eurocities [11], which identified it as housing available to all individuals and families who require it, including low-income groups, without this causing a disproportionate burden on their disposable income [12]. Similarly, UN-Habitat [3] stated that affordable housing does not cost so much that it prevents its occupants from meeting other basic living costs or threatens their enjoyment of basic human rights. Although there is no universally agreed percentage, housing is generally deemed affordable when households spend less than 30% of their income for housing-related expenses [10].

Lastly, the term "mass-housing" mainly considers the design aspects and refers to a standardized approach to housing production, applied to meet the rapidly growing housing demand in most developing economies [13,14]. The term was inspired by the concept of mass production [14] and referred to standardized house-units, executed within the same project scheme, without reference to any specific customer, and usually located in the same area [13,15]. The main risk observed in mass-housing is the lack of attention to the quality-related issues due to the effort in time-saving and cost-effectiveness of the projects [16].

Within the above framework, the scope of the present work is to identify sustainable solutions for mass-housing design and construction, with a specific focus on Somalia. More in detail, the work analyses the context of Mogadishu, which in 2015 was ranked as the world's second-fastest-growing city, with a population of 2.1 million growing at a 6.9% rate [17]. Indeed, the civil war, together with the continued instability of the local governments, caused the suffering and overall poverty of the Somali people. However, after the '90 s the situation improved: citizens started to express their need for liberation and Mogadishu is now characterized by economic recovery, reconstruction and a strong sense of optimism [18]. However, the concurrence of these factors could cause a sudden and uncontrolled growth, with a consequent risk of speculation, as well as purely economic strategies, unable to include the social and environmental sustainability aspects, as a proper holistic view should.

It must also be noted that, during the past, Mogadishu's housing sector was affected by high levels of poverty, the destruction of the building stock, the displacement of people and the insecurity of the area; this resulted in an increase in housing demand [19]. Additionally, today the reconstruction mainly focuses only on high-level housing, without involving the low and medium levels.

For such reasons, but also for the specific urban and socio-economic situation of the postwar situation, Mogadishu is an interesting and representative case study for the purpose of addressing the mass-housing issue [20].

In this context, the present work describes a part of the results of the specific research project *Business ECOsystem design for sustainable settlements in Mogadishu* (BECOMe) [21]; the project aims to propose a new business ecosystem for sustainable settlements, developed through an integrated model that includes affordable housing, local entrepreneurship and social facilities, also exploring the exploitation of local stakeholders, in a circular economy approach. From the social point of view, the affordable housing model proposed is designed to target a predefined housing price that is affordable for an increasing proportion of the population. This could be achieved through the optimization of the entire construction process and using local renewable energies. On the other hand, from the economic and financial point of view, it suggests an investment plan, leveraging financial aids for local entrepreneurs as well as renewable production, showing the potential for a sustainable intervention by external investors. Furthermore, concerning environmental sustainability, it tries to offer a high-energy performance of buildings, with consequent adequate comfort levels through climate-responsive designs. At the same time, it aims to exploit the most appropriate construction materials and techniques. Thus, the research aims to raise awareness among local governments on the potential for providing affordable housing solutions to a larger part of the population, thus creating—through the involvement of local entrepreneurs—a lively and almost self-sustaining environment and the local community.

The present paper first identifies social, environmental and economic key sustainability requirements for mass-housing (Section 2), then selects the most appropriate design strategies and construction technologies/materials at the building level, tailored to the Mogadishu application context (Section 3). Subsequently, in Section 4, the outcomes are applied to a specific case-study district identified within BECOMe project; in detail, and energy and cost analysis is carried out on a reference building of the district, and one of the possible cost-optimal solutions is identified. In Section 5, a brief discussion about obtained outcomes is reported before the conclusions.

The work provides useful knowledge for developing building projects in Somalia while also paving the way for a more detailed assessment of the Somali construction sector.

2. Key Sustainability Requirements for Mass-Housing

To assess the sustainability condition of mass-housing, the definitions and descriptions of sustainable buildings were examined to assess which specific aspects of sustainability were discussed in the literature and to identify the relevant key sustainability requirements (KSRs). To this aim, a comprehensive review of the literature and an analysis of the most adopted rating systems for assessing the environmental impact of buildings [22] was conducted. The KSRs identified and selected based on their relevance to African specific context were grouped into 3 categories of sustainability, as shown in Table 1, and are described in the following paragraphs.

Table 1. List of KSRs for sustainable, affordable housing, together with their respective references.

Code	Key Sustainability Requirement	References
Economic sustainability		
KSR-1	Affordability	[5,23–25]
KSR-2	Good governance	[24,26]
KSR-3	Adequate funding	[5,24,26]
KSR-4	Effective legal frameworks	[24,26]
KSR-5	Cost-effectiveness	[5,13,23–27]
KSR-6	Time effectiveness	[13,25,26]
KSR-7	Flexibility and adaptability	[5,14,23,24,26,27]
KSR-8	Adequate transport infrastructure	[23–26]
KSR-9	Local economy development	[5,14,23,26,27]
KSR-10	Desirability	[5,25]
Environmental sustainability		
KSR-11	Minimize energy demand	[5,23–25,27]
KSR-12	Renewable energy sources	[23,27]
KSR-13	Minimize use of fresh water	[5,23,27]
KSR-14	Minimize pollution	[23]
KSR-15	Minimize waste	[5,23,27]
KSR-16	Minimize use of resources	[5,13,23,24,27]
KSR-17	Appropriate land use	[5,14,23,24,26]
KSR-18	Protect natural ecosystems	[5,13,14,23,25,27]
KSR-19	Good accessibility	[5,14,23,24,26]
KSR-20	Mitigation	[5,13,14]
Social sustainability		
KSR-21	Social equity	[5,14,23–27]
KSR-22	Social cohesion	[5,14,23,24]
KSR-23	Access to social services	[5,14,23,24,26,27]
KSR-24	Community's participation	[5,24–27]
KSR-25	Local culture	[5,13,14,23]
KSR-26	Housing quality	[5,13,14,23–27]
KSR-27	Skills acquisition/job opportunities	[5,14,23,24]
KSR-28	Wellbeing of workers	[5,14,23,27]
KSR-29	Security of tenure	[5,24]
KSR-30	Security of lives	[14,23–25]

2.1. Economic Sustainability

The main objective of economic sustainability is to enhance housing affordability (KSR-1) for low-income households by reducing the purchase/rental cost and the operational expenses (e.g., energy bills) to allow occupants to spend more of their limited income on non-housing needs. More specifically, it has been widely accepted that a house is affordable if a family can obtain it for 30% or less of their income [28].

Good governance (KSR-2) for promoting a stable political and macroeconomic system, which improves guarantees to developers, is also an important economic sustainability indicator [26]. In addition, governments should provide adequate funding (KSR-3) to empower the public and private sectors to provide affordable housing that meets housing needs [26], as well as effective legal frameworks (KSR-4) for enhancing an efficient implementation and control of social housing provision activities.

Economic sustainability should also consider two key elements: (i) the cost-effectiveness (KSR-5) of the projects for developers, which should be achieved by taking advantage of improved productivity of resources, resulting from the repetitive work involved or by adopting cost–reduction strategies (such as using regionally available materials and techniques), and not by cutting the quality of individual housing units; (ii) the time effectiveness (KSR-6) of the completion of the projects and the allocation of housing units to applicants, reducing the risks derived from long construction periods. Flexibility and adaptability (KSR-7) are important to allow the building to meet new requirements (e.g., future expansions) with minimum costs [5].

Integrating economic sustainability also requires considering the provision of adequate transport infrastructures (KSR-8) to meet business needs. This can enhance commercial viability, which in turn can create more employment opportunities, fostering local economic development (KSR-9). Ultimately, the desirability (KSR-10) of housing programs—which refers to how the programs meet the consumers' expectation and is related to the marketability of the housing facility, that is, whether people want to buy the product unless they need it [29]—is an important economic sustainability indicator to be taken into consideration.

2.2. Environmental Sustainability

Environmental sustainability highlights the issues of climate change and the reduction in greenhouse gas emissions. These macro-objectives can be achieved by minimizing the energy demand (KSR-11) of buildings through using passive design strategies and energy efficiency in the HVAC systems and that of renewable energy sources (KSR-12). The amount of embodied energy of construction material should also be considered and minimized [27].

Environmental sustainability also requires minimizing the use of water (KSR-13) since freshwater is a scarce resource; in buildings and construction processes, more effective use of water, through more efficient devices and water collection, is an important feature of sustainability. Minimizing the pollution (KSR-14) of the existing water systems by household sewage is another persistent problem in many poor areas, one, which needs to be prevented, as well as that of minimizing waste (KSR-15) through a well-designed waste management system.

Furthermore, buildings consume a significant amount of resources, particularly when building materials are evaluated from a life cycle perspective that takes into consideration their sourcing, processing and disposal. Minimizing using resources (KSR-16) is possible using less resource-intensive as well as and recycled or renewable materials.

Environmental sustainability requires ensuring appropriate use of land (KSR-17) through reasonable settlement densities in order to avoid the misuse and the excessive use of land [17]; in addition, the choice of building sites is often associated with negative impacts on natural ecosystems (KSR-18). The selection of locations that minimize the distances the building's users must travel will reduce the environmental burden [27]. Similarly, using mixed land is suggested to increases accessibility (KSR-19) and motivate the provision of adequate alternative transport modes (e.g., public transport, walking, cycling) to cut the environmental burdens imposed by excessive use of cars. Finally, special attention should be paid to the mitigation (KSR-20) of the risks associated with natural disasters, an issue, which requires adequate planning of land use to avoid any settlement in risky areas.

2.3. Social Sustainability

Social sustainability in affordable housing emphasizes social equity (KSR-21), which refers to the impartiality and transparency in the distribution of housing resources, meeting the needs of the society's less-privileged households and reducing the occurrence of disputes. It also highlights social cohesion (KSR-22); in this respect, the mixed development for residents with different economic, cultural and social backgroundsand the provision of diversified housing types can facilitate their interaction and improve the social relationships within the rest of the community [30].

Access to basic utilities (KSR-23), such as water and electricity, and services like public transport, health, education and commercial buildings, needs to be provided to ensure equity and promote social interaction. The importance of the community's participation (KSR-24) in the design process has been emphasized since not only it effectively improves social relationships but also satisfies the residents' needs [31]. Similarly, the local culture (KSR-25) should be integrated into the housing design. Developments should reflect the local heritage, and the use of local materials should be accepted by communities.

Social sustainability also emphasizes the importance of the quality of housing (KSR-26), on which the health of the occupants depends. It is important to meet the residents' needs, such as indoor air quality, noise abatement, lighting during daylight hours, adequate heating, cooling and ventilation, especially in climatic regions with extreme temperatures.

To facilitate social sustainability, a housing program needs to engage local skills during the construction and management phases and to contribute to skills acquisition and job opportunities (KSR-27) for the community. It is also important to ensure the wellbeing of workers (KSR-28), as well as providing them with fair compensation.

Ultimately, attention should be paid to the security of tenure (KSR-29), which is important for creating a sense of belonging and community stability [32], as well as the security of lives (KSR-30), thus creating a safe housing environment for the residents, one, which also prevents crime.

All the KSRs above have been considered in developing the BECOMe project, identifying specific solutions at the district and building levels. The latter is precisely defined in the following chapters, while the urban design will be the object of a further publication. The methodology used to integrate KSRs with the context analysis to propose sustainable building design solutions to be proposed for a reference building of a settlement in Mogadishu is summarized in Figure 1.

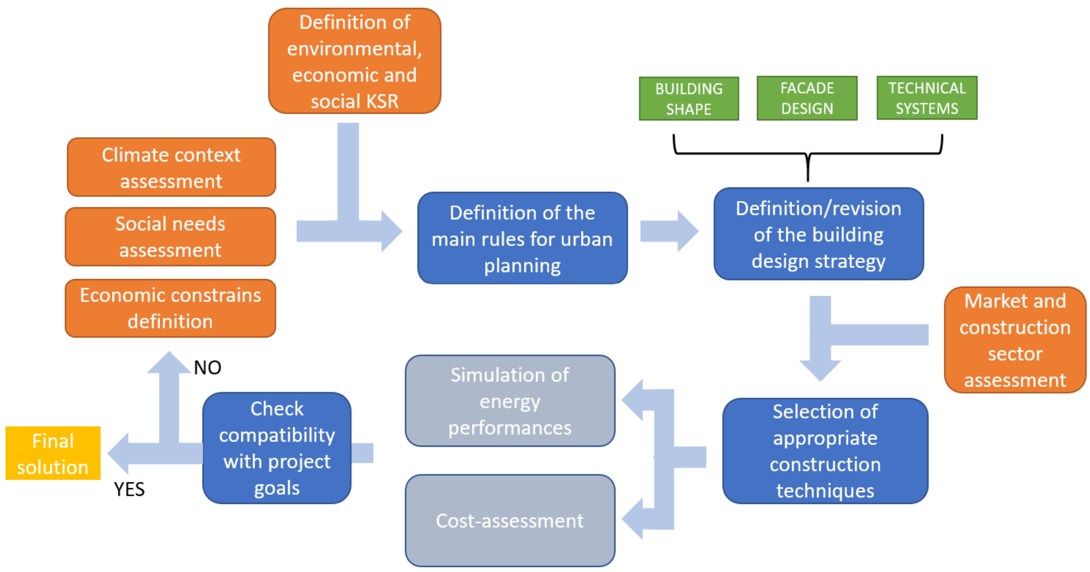

Figure 1. A flowchart about the main steps of the proposed methodology.

3. Identification of Main Rules for Climate-Responsive Design

Although sustainable building design is a process involving all three sustainability dimensions, due to the massive urban development ongoing in Africa, one of the main goals for the designer is the reduction in building energy consumption to consequently avoiding a dramatic increase in GHG emissions. For these reasons, in the next chapters, the methodology proposed in the present work will be focused more on the energy issue while also taking into account the economic and social aspects.

This challenge will require a transformation in the building design procedure that includes the analysis of the climatic context and the economic and social constraints, which allows the definition of the main principles and guidelines to be followed during the building's design.

3.1. Analysis of the Climate Context

This section presents the analysis of the climatic context of Mogadishu. The city is situated close to the equator, and the prevailing climate of the area according to the Köppen–Geiger climate classification system is BSh (hot semi-arid climate), as shown in Figure 2; however, since the city is on the sea, some features of the Aw climate (tropical savanna) are present.

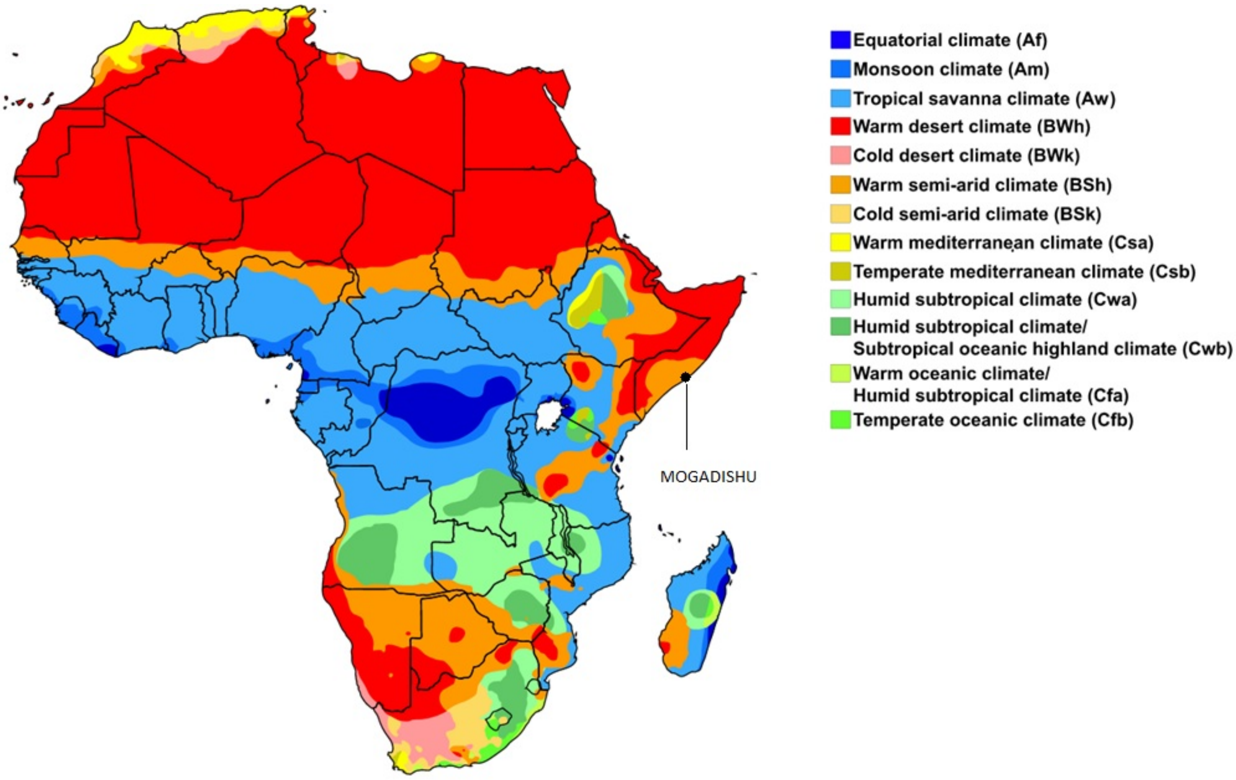

Figure 2. General climatic classification of Africa and position of the city of Mogadishu.

The typical meteorological year (TMY) weather file used to perform the analysis was constructed from weather data acquired between 1958 and 2017, and by selecting the most typical data for each month [33].

Through a climate analysis, it is possible to obtain important indications on bioclimatic strategies that allow a more adequate architectural and energy design. The results of the analyses performed (summarized in Table 2) are reported below [33].

Table 2. Reference climatic parameters.

Air temperature	Average	26–28 °C
	Average Min.	25 °C
	Average Max.	30 °C
Relative humidity	Average	77.8%
	Average Min.	70%
	Average Max.	83%
Solar radiation	Annual global irradiation	2240 kWh/m^2
Rainfall	Average annual precipitation	474 mm

The average monthly temperatures are almost constant throughout the year, between 26 and 28 °C. As for the average monthly maximum and minimum temperatures, there is a greater annual variability. In particular, the minimum average temperature reaches 23 °C in June, versus a peak of 26 °C in March, while the maximum mean monthly temperature is below 30 °C only in the period between June and October, with a minimum of 27 °C in July, versus a peak of 32 °C in March. With an average temperature of 28.0 °C, March is the hottest month of the year. A more comfortable season is experienced between June and September due to a small temperature drop; in particular, August has the lowest average temperature of the year, 26 °C.

The excursion between maximum and minimum average daily temperature varies between a minimum of 6 °C in July and a maximum of 8 °C in January.

The average relative humidity is very high throughout the year. In fact, this parameter shows minimal monthly variations. During the daytime, relative humidity reaches values that are generally 80% in the morning, then falls to 40–50% in the afternoon hours, to finally reach 60% after sunset.

Thus, the hot and humid climate suggests using medium to lightweight walls and a ventilated roof.

Global solar radiation over a horizontal surface is high in all months of the year; the annual average normal direct irradiance is higher than 400 W/m^2, while the global horizontal exceeds 500 W/m^2. Daily, the average total horizontal irradiation is about 6.1 kWh/m^2 per day, for a total of 2240 kWh/m^2 per year.

The average annual daylight illumination is very high, around 60,000 lux, of which less than half is due to direct solar radiation. The high contribution of natural illumination must certainly be taken into consideration for the design of the windows and the lighting and the shading systems.

The prevailing wind direction is from the east from November to March and from the southwest from April to October. To select the orientation of the buildings to maximize the natural ventilation, the eastern direction of the wind must be considered because of the higher temperatures during the period from November to March versus other months.

3.2. Climate-Responsive Building Design Strategies

This section describes some specific building design strategies to be adopted in climates, such as that of Mogadishu, to ensure good indoor comfort without the need for active cooling.

The considerations reported are based on studies recently carried out by the Politecnico di Milano in collaboration with UN-Habitat to identify the most adequate and effective strategies for sustainable buildings in tropical climates, with particular reference to the African context [34].

More in detail, site planning is the first choice in the design process; the second most important decision is related to the building's shape and envelope, together with windows design. Lastly, consideration about technical systems and renewable energy sources are reported.

3.2.1. Site Planning

Urban form plays a fundamental role both in mitigating the microclimate and in offering better conditions for the buildings and their inhabitants. In hot-humid climatic contexts, the main measures in terms of urban form concern implementing interventions for air movement and shading.

Improving ventilation is possible by locating the buildings according to a staggered pattern, in which each building should be oriented at an angle of about 20–30° concerning the prevailing wind direction. Furthermore, the distance between the opposite facades, that is, the depth of the building, should be limited, with large openings on the opposite external walls and with the rooms arranged in a row. Vegetation is also important and should be arranged to provide shade without interfering with natural ventilation.

To protect the buildings from the sun, orientation plays a key role. In particular, the east-west orientation (for the axis of the building) is to prefer to maximize the north and south-facing facades, which are easy to protect with small overhangs, and minimize the east- and west-facing ones, which are difficult to protect, to minimize heat gains. To maximize the internal comfort of the inhabitants, the living spaces should be arranged in the south and north portions of the building, while spaces, such as the stairs, should be located on the east and west facades. Furthermore, in this case, vegetation is important, together with overhead shades.

3.2.2. Building Shape and Envelope

The capability of a building to store or release heat is related to its volume, and thermal mass since losses or gains take place through its surfaces. At a constant volume, if we move away from a compact form, heat losses and gains increase. In hot-humid zones, where daily variations in temperature are minimal, and relative humidity is high, the shape should be open to allow natural ventilation.

The design of the building envelope should be done keeping in mind the need to reduce heat gains by minimizing the solar exposure of the building components (external walls, roof and windows) and improving natural ventilation; through airflow, it is possible to remove indoor heat and promote thermal comfort for the inhabitants.

Thermal insulation should be considered to minimize the flow of heat through a wall or a roof because of the solar radiation incident on it. However, insulating the building envelope is not always feasible because it is not economically beneficial in housing developments where affordability is a priority; for such a reason, cost-effective construction techniques with an insulation layer should be investigated.

The thermal mass's role is to absorb heat during the day and return it at night, helping maintain environmental conditions within the comfort range. If the daily temperature variation is low, using materials with medium-low thermal mass is preferable because the heat stored during the day from incident solar radiation would be released at night, negatively affecting comfort.

The design of the roof requires particular attention. To reduce heat gains due to solar radiation, the roof should be designed as much insulated, ventilated and reflective as possible. In hot-humid climates, the double-leaf roof design is to be preferred, with a ventilated double skin in which the outer skin shades the inner layer and absorbs the solar heat according to its reflectivity, which should be as high as possible. The obtained ventilation of the space between the roof and the ceiling would be essential for higher comfort.

The design of walls is important because they constitute the major part of the building envelope. Adequate protection from the sun is essential to avoid the transmission of heat inside a building. The walls facing north and south receive moderate radiation due to the strong angle of incidence of solar rays, while the walls facing east and west receive a much greater heat load, against which it is difficult to obtain effective sun protection with using overhangs. It is possible to limit the flow of heat through the most exposed walls through the adoption of measures, such as cavity structures, insulating materials, radiant barriers and light colors on the external surfaces, to favor the reflection of solar radiation, always taking into account the economic cost concerning affordability.

3.2.3. Windows Design

Windows also play an important role in improving the comfort conditions inside buildings. To allow proper ventilation, openings should be large; it would be better to expand them horizontally, and they should be placed on opposite walls. To control solar gains, they should be placed on the north and south walls, and glazing should not exceed 20% of the wall area. It is important to consider the prevailing wind direction concerning the openings; three different conditions can occur: openings aligned, parallel or oblique concerning the wind direction. In the first case, the airflow would cross the space, affecting a limited part of it, with modest induced air movements; in the second case, there would be no significant air movements; while in the third, the ventilation would involve a larger area, thus inducing a greater air movement. Lastly, a stack effect ventilation could be obtained with a fifth of the total openings at ceiling level and with some openings also positioned at floor level.

With shading devices (e.g., overhangs, curtains), it is possible to protect the openings of a building from direct and indirect solar radiation. Shading systems can be both internal and external, but the external ones are more effective in controlling solar gains. The shading elements to be used vary according to the orientation of the openings: horizontal elements should be used in the case of north and south orientation, while a mixed system of vertical and horizontal elements should be used on the windows facing east and west.

3.2.4. Technical and Renewable Energy Systems

Technical systems (e.g., HVAC systems) should be minimized to ensure affordability and reduce energy consumption. Therefore, if feasible, active cooling systems should be avoided, and only cost-effective solutions (e.g., small-size air–water heat pumps with integrated tank) for domestic hot water preparation should be considered. Ceiling fans can be adopted to effectively improve the thermal comfort in every type of building, avoiding air conditioning.

Artificial lighting systems should always adopt high-efficiency LED lamps, while underground concrete/PVC tanks should be used to collect and store rainwater from roofs to be reused for non-drinking purposes. A septic tank should always be provided if no district sewage treatment systems are present.

The production of renewable energy should be maximized, and in tropical climates, the most cost-effective solution for building application is typically photovoltaic technology. PV modules can be easily integrated into the building roof, with a subhorizontal tilt angle, also acting as a shading layer.

4. Assessment of a Case-Study

As already introduced, the BECOMe research is focused on Somalia, and in particular on its capital, Mogadishu, by applying a building ecosystem model to a new settlement to be developed in the city. More in detail, the optimal size of the settlement (1000–1200 inhabitants) was defined to make the operation attractive for the relevant investors (e.g., World Bank) and to reach economies of scale in the construction process. Then, the urban planning was carried out considering the specific structure of the city, assuming to occupy a piece of free land on the north side of Mogadishu. The basic idea is to host in the settlement not only affordable housing but also social services (e.g., schools, AID facilities, etc.) and small entrepreneurial activities. The economic feasibility is based on the assumption that the income of commercial/artisanal activities can ensure adequate revenue to cover the mortgage payment for purchasing housing units. A similarly innovative approach had already been experimented with in Somalia in the Heliwa IDP housing scheme, developed in 2019 [35]. Another form of revenue considered in the project is related to the selling to the grid of the renewable photovoltaic energy generated in the settlement.

Then, the work focuses on a reference building of the settlement to optimize its design and construction techniques according to the project objectives and the principles described in the previous chapters, as illustrated in detail below; first, the concept design of the building is presented, then an in-depth analysis of the construction techniques and materials is carried out, concluding with the energy and cost analysis, to identify the best option for the application context.

4.1. Concept Design of the Reference Building

In this section, the concept design of the reference building identified for the settlement is briefly described. The design is also the result of an optimization process to meet the selected KSR and project objectives, i.e., to minimize construction costs/time, ensure good indoor comfort conditions according to a climate-sensitive approach and consider the needs of the contemporary Somali population in terms of living spaces.

More in detail, the basic choice of having several two-story semi-detached units is linked both to the need to limit the height of the building, allowing to use any type of self-supporting construction technique, and to maintain the traditional local housing typology; this also guarantees social acceptability. Furthermore, such a structure will not preclude the subsequent vertical expansion typical of developing countries. In this sense, the housing unit is based on a fundamental concept: to provide a housing solution that can grow and change over time, together with its inhabitants (incremental housing solution). This possibility has been obtained from a floor arrangement that combines the paradigms of flexibility and adaptability of spaces and functions. All the services and primary systems are gathered in a nucleus that is the focal point of the project, around which every functional activity is organized. It contains the kitchen, two bathrooms, the staircase and a transition area for horizontal connections. Thanks to this nucleus, it is possible to access two other volumes, including the main rooms of the house. These spaces can be used and divided in different ways, depending on the needs of the family. The main idea is to allow assembling various parts of volumes to build houses shaped according to the economic possibilities and the individual needs of each family (use adaptability). The internal partitions can be easily modified before construction to better indulge these specific needs.

This solution may vary according to the number of people in the family unit, the composition of the family and their age. For example, simple additions to the volume of the house will allow accommodating a larger family or two relatives. An example of the incremental solution is that another room can be built closing the terrace area, allowing, if needed, to divide the house into two small apartments (flexibility of use).

The base unit can host an average Somali family (in about 100 m^2), dedicating a room of 13 m^2 on the street front for a small family business activity. The closed room could be a living area for the family, directly connected to the house's core with a separate entrance. On the other side, there is an extra room, which could be used as a bedroom or another living area. On the second floor, there is a second common area, two bedrooms and a terrace. The latter is a shaded area characterized by a higher wall with openings to allow ventilation and, at the same time, to guarantee privacy.

The stairs go up to the third floor, where a small room gives access to the roof where the water cisterns and a laundry sink are located.

Cheap but effective passive-design techniques (such as shadowing the roof, cross ventilation, overhangs, etc.) help improve the indoor climatic condition. The concept proposed can also be built with different materials and structural schemes.

In Figure 3, the plan view of a block of houses of the settlement and the axonometric view of the reference building are reported, highlighting the key elements.

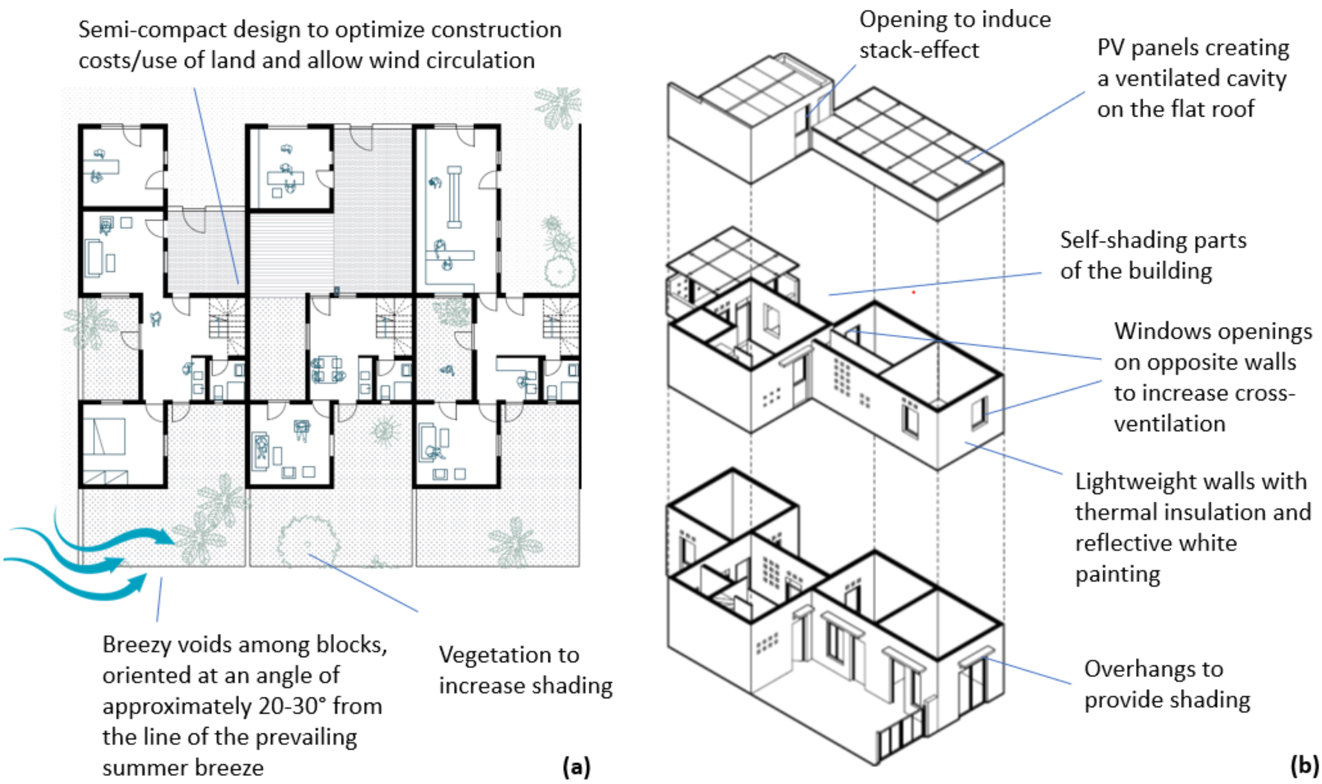

Figure 3. (**a**) Plan view of a block of houses of the settlement and (**b**) axonometric view of the reference building.

Concerning the technical systems, the building is equipped with a basic electric system to provide lighting and power in every room, a sanitary water plant in the central core, a rainwater collection system with a 3000 L underground tank, a domestic hot water producer with an air–source heat pump, and a sewage plant with a septic tank. Lastly, the roofs host a PV system with a minimum size of 2 kW_p/unit, which can be expanded up to 5 kW_p. It should be noted that the PV system will also allow to provide free power to the small business/craft activities but also to generate an income by selling surplus electricity to the national grid at the district level.

4.2. Construction Techniques and Materials

Today, most of the low-to-middle-income houses in Mogadishu are built using corrugated sheets, with wood structure and concrete blocks walls, whereas middle and upper-to-middle-income housings are characterized by a concrete frame, with an envelope made up of interlocking concrete blocks. While the former lack adequate services and equipment, with a price that is in any case outside the reach of the lowest incomes in the city, the latter also present problems related to the long construction times and overall high costs.

In this context, the BECOMe project aims to identify a series of technological solutions that, ensuring an adequate level of comfort, fit the environmental sustainability aspects and involve construction costs aligned with the project target.

In detail, a literature review and a market survey were carried out to identify all the possible construction solutions to be adopted for the case study. Indeed, concrete represents the most widely used construction material, both for the structure and for the envelope. Moreover yet, despite the easy casting procedures and the possibility to be shaped in infinite ways, its strong dependence on imported raw materials causes a pronounced variability in terms of costs and quality of construction. This, in addition to the long construction times, represents a weak point for the rapid and affordable urbanization of the entire zone.

Furthermore, it should be stressed that using high amounts of concrete still presents several sustainability issues due to the environmental burden of cement, assessed at around 800 kg of CO_2 released into the atmosphere per ton of cement [36,37].

Thus, natural construction materials have been investigated. In this regard, clay is commonly used in African countries in the form of different kinds of blocks, but since it is not locally available in the Mogadishu area, it has not been further investigated as a viable solution.

The case of the compressed straw panels wrapped in recycled paper was then analyzed [38,39]. A crucial aspect of these panels is their low embodied energy, together with the fact that similar products are currently produced in Rwanda with the deep involvement of local farmers in the production of straw [40]. While investigating using natural fibers, the possibility to employ blown-in straw, combined with a concrete basement and a steel frame structure, also has been studied. Today, similar technological solutions still have a niche application in Europe for one-floor structures [41–43].

However, both straw panels and blown-in straw solutions require an expensive concrete or steel structure, which is the reason why they have not been considered as the best option.

Subsequently, our research assessed the use of self-bearing precast panels; in fact, the use of precast elements in the African context has been already addressed, showing promising results [44]. Additionally, D. R. Joseph and Chippagiri et al. tested using these solutions as an innovative technology for the speedy construction of cost-effective residential housing [45,46].

Some manufacturers currently active in the precast panel sector already tested this technology in developing countries and also in settings similar to that of Mogadishu [47,48]. The proposed products generally vary from a single to a double panel, with two galvanized electro-welded meshes joined by connectors and separated by an EPS layer. The panel's thickness can vary according to specific requirements, and the panel can be used both as a partition wall or as a self-bearing wall for structures usually up to 4 floors. Differently from other solutions, these panels do not require a separate frame structure to be combined with; in fact, thanks to the possibility to be assembled with other modules (floor or stairs panels), a self-bearing structure can be obtained with various shapes, according to the specific needs. Furthermore, their simple assembly, together with their lightness and manageability, represents an added value for the purpose of this research [49–51]. They are industrially produced by setting up local plants and are then completed directly on-site with a layer of shotcrete, ensuring a low embodied energy, thanks to the reduced amount of materials. This also means increasing the job offer in the area since local production plants could be built to cover the needs of multiple settlements. By way of example, a pilot industrial plant [52], with a production capacity of 2000 m^2 of panels per 8 shift hours, requires an investment cost of around USD 3 million.

However, the presence of the EPS layer conflicts with the environmental sustainability goals. Therefore, since the structural requirements are mainly accomplished by the galvanized electro-welded mesh incorporated into the shotcrete, our research investigated the possibility of improving this technological solution using a layer of natural wood fibers instead of EPS. Due to the introduction of new material in the production process, during the experimental activities, some issues were observed, such as the malleability of the panel and its perforation by the connectors, which presented several implementation difficulties. This highlights the need to further investigate this opportunity at the industrial level, although the feasibility of the proposed solution can be confirmed.

It should be noted that previous studies already focused on using alternative and more sustainable materials than EPS, such as polylactic acid (PLA) core, although they are still under development.

In conclusion, due to their reduced construction costs and times, self-bearing panels with an insulation layer made with natural materials are a solution that potentially meets all the project objectives. For such a reason, in the following sections, energy and cost assessment are reported, comparing the current standard construction techniques with the alternative proposed.

4.3. Energy Analysis

In this section, the impact of the different building design strategies proposed will be simulated and assessed for the optimization of the reference housing unit in Mogadishu. The simulations are performed in free-floating conditions to check the comfort level without using active HVAC systems, as is necessary for the context of the analysis. More in detail, 3 options were simulated, a base case and 2 improved alternatives.

The base case (BC) configuration consists of the reference building with opaque walls with a *U*-value of 1.2 W/m^{2}K, made of 30 cm interlocking concrete blocks, 1.5 cm internal and external plaster and PVC windows with a *U*-Value equal to 2.7 W/m^{2}K. The flat concrete roof, made of 30 cm of lightened concrete slab with 1.5 cm internal and external plaster, has a *U*-Value of around 1.5 W/m^{2}K.

To optimize the energy performance of the building, in the first option (O1), an additional insulation layer, made of 4 cm of Rockwool with thermal conductivity of 0.045 W/mK, was applied to the base case on the wall and on the roof. In addition, the ventilated roof with the shading layer was applied, and the effect of natural ventilation driven by wind and stack effect was analyzed through the object". ZoneVentilation:WindandStackOpenArea" of the Energy Plus software, considering a ventilation shut-off when the indoor/outdoor temperature differential is below 0 °C.

To evaluate the energy performance related to the proposed construction technique, a second option (O2) was simulated; the same solutions of option 1 were assumed, but the standard concrete structure with concrete blocks was replaced with self-bearing precast panels and wood fiber insulation, with an overall U value of 0.42 W/m^{2}K.

The energy evaluations were carried out using the EnergyPlus simulation tool. Simulations were performed in free-floating conditions during the whole year; internal loads were set to 4 W/m^2 considering a constant people occupancy throughout 24 h. The results are summarized in Table 3.

Table 3. Main thermal features and performance of the reference building with standard construction techniques (base case) and 2 alternatives.

Options	**Characteristics**		**Thermal Transmittance (W/m^{2}k)**	**Summer Avg. Operative Temp. (°C)**
Base case (BC)	Concrete frame and interlocking concrete blocks	Wall Roof Windows	1.22 1.5 2.7	28.15
Option 1 (O1)	BC + insulated wall/roof + roof shading + Natural ventilation	Wall Roof Windows	0.55 0.72 2.7	27.00
Option 2 (O2)	O1 with precast panels with a wood fiber layer	Wall Roof Windows	0.42 0.42 2.7	26.72

According to the data reported, the summer average operative temperature of the base case is 28.15 °C, which means that daytime peak values are outside the comfort zone. The specific solutions adopted in options 1 and 2 decreases such values to 27 °C and 26.72 °C, respectively, showing the obtainable benefit in terms of an increase in indoor comfort. To better assess the obtainable results, Figure 4 reports the temperature values referred to March 15th (a typical hot summer day).

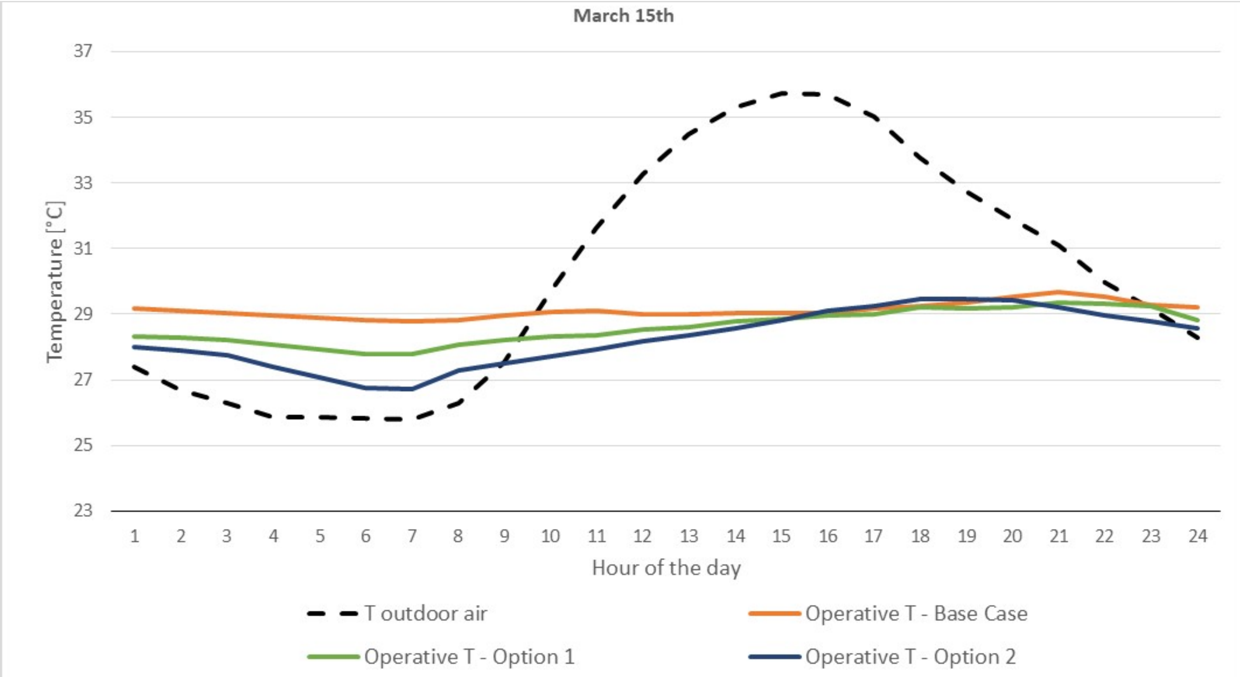

Figure 4. Comparison between outdoor air temperature and indoor operative temperature for the base case and the 2 alternatives during a typical hot summer day.

As it can be noted, the options proposed to allow to maintain better indoor comfort compared to the base case. The indoor operative temperature before noon and in the evening remains below 28 °C, which can be considered within the acceptability limit of adaptive comfort with high outdoor temperatures. During the afternoon, the temperature slightly rises to around 29 °C, which is, in any case, acceptable using ceiling fans. Particularly interesting is the performance of the insulated precast panels, which ensure better natural cooling at night.

4.4. Cost Analysis

In this paragraph, the cost of the above-described reference building is assessed, assuming to integrate all designed climate-responsive strategies and investigating the two proposed options (O1 and O2) as construction techniques.

In this regard, the lack of data on the Somali market referred to the construction costs represented one of the main challenges of our research; additionally, the few available data referred to other projects already completed in Africa show a pronounced variability of the rates due not only to the complexity of the context but also to the strong dependence on imported materials, as already mentioned before.

Thus, an accurate market survey has been developed to create a construction costs database to be used in the Somali context. For this purpose, several local construction companies have been interviewed, and, thanks to their expertise in the specific field, it was possible to estimate unitary costs both for urbanization and construction, according to the technologies currently adopted in the Mogadishu area. As for the proposed solution with precast panels, the cost analysis was carried out considering actual average construction costs related to two of the main industrial solutions available on the market [47,51] and adding the extra cost due to using a wood-fiber layer.

The bill of quantities (BoQ) obtained is reported in Table 4.

Table 4. Bill of quantities of the reference building with a total surface around 120 m^2.

	Option 1 (O1)		Option 2 (O2)	
	(USD)	(€)	(USD)	(€)
Excavations and foundations	9894	8212	9894	8212
Structure	26,016	21,594	14,392	11,945
Opaque envelope	5570	4623		
Finishes and interior works	25,222	20,935	11,714	9722
Windows	2000	1660	2000	1660
Electric system	2700	2241	2700	2241
Photovoltaic plant	2400	1992	2400	1992
Water and wastewater systems	2500	2075	2500	2075
TOTAL including unexpected costs (10%)	**83,934**	**69,665**	**50,160**	**41,633**
Cost per m^2	**688**	**571**	**411**	**341**
Urbanization costs	**1908**	**1584**	**1908**	**1584**
Urbanization costs per m^2	**15**	**13**	**15**	**13**

As can be noticed, adopting the current standard technological solutions (option 1) applied to the proposed reference building involves a cost of around USD 703/m^2, including urbanization costs. In this context, it should be stressed that the structure alone, assessed at around USD 180/m^2 due to the high price of the concrete itself, has a 31% incidence on the overall costs, underlining the need to identify alternative solutions to achieve better results.

Additionally, for the urbanization, it has been estimated a total expense roughly equal to USD 13 per square meter of the plot area, including the connection to the electric grid, water and wastewater district systems, and the landscaping of the surrounded area within the district.

Such costs have been compared with the proposed solution with self-bearing precast panels with concrete and wood fiber layers, obtaining a final overall cost of around USD 426/m^2, which is 39% lower than that of the standard solution.

5. Discussion

According to a review of the African housing finance markets, developed by the center for affordable housing finance in Africa (CAHF) in 2020 [53], today, only 4% of the Somali population can pay the housing rent. The purpose of this research is to increase that percentage up to at least 25%; this, according to the same document, corresponds to an annual income evaluated between USD 3600 and USD 5000. Thus, the BECOMe project starts from the assumption that an annual average income of USD 4300 should imply, considering a 30% residual (see Section 2.1), USD 1290 per year destined for home purchase/rent. This, assuming an average-size apartment of 60 m^2 (in the case of single-income households), or a 120 m^2 house (in the case of larger families with multiple incomes), corresponds to a maximum purchasing price of around USD 500/m^2; the calculation is done based on a 25 year loan.

Consequently, the overall price of an affordable house in Mogadishu must stay within such a threshold; as expected, this excludes the possibility to use traditional construction techniques applied to the proposed reference building, since the total construction cost is above USD 700/m^2; such a value is in line with the current price of upper-to-middle-income houses in the city. However, the adoption of precast panels with wood fiber insulation allows keeping the construction cost slightly above USD 400/m^2, thus ensuring a final market price definitely below the threshold defined, also including overhead and financial charges. The estimated cost includes the different climate-responsive design solutions that ensure good indoor comfort without air conditioning. Also, the minimum required urbanization works and even a photovoltaic plant to provide free electricity for domestic and small-business use.

6. Conclusions

The assessment carried out in the present work allowed to propose a specific design solution for housing settlements based on different context characteristics, intending to ensure economic, environmental and social sustainability. The analysis is based on the need to meet identified KSRs and, more precisely, on a specific climate-responsive design, on the optimization of shape and construction techniques and on social needs. The proposed methodology, applied in the context of Mogadishu, led to the definition of a concept design of a representative housing unit, which has been optimized from the energy, social and cost points of view.

In detail, the specific assessment of the possible construction techniques and materials allowed to observe that innovative solutions like the proposed precast panels are more in line with the target of the BECOMe project, due to their massive reduction in terms of costs and to their improved eco-profile versus common concrete solutions and EPS panels. From the point of view of thermal performance, they ensure good indoor comfort conditions, while the cost assessment demonstrated the possibility to remain below the target market price of USD 500/m^2, reaching the affordability threshold for at least 25% of the current population. However, the price of the proposed housing solution also includes a space for small business activities and the production of free power from solar energy; these two elements help increase the income of the households and support the overall sustainability of the settlement. Finally, the possibility of local industrialization of the construction techniques supports current entrepreneurs, reducing the uncertainties of construction cost and timing while triggering new business ecosystems for sustainable settlements.

The proposed solution meets several Sustainable Development Goals (SDGs), i.e., 3 (good health and wellbeing), 7 (affordable and clean energy), 9 (industry, innovation and infrastructure), 11 (sustainable cities and communities) and 13 (climate action).

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References

1. United Nations Department of Economic and Social Affairs. *World Urbanization Prospects: The 2018 Revision*; United Nations: New York, NY, USA, 2018.
2. UN-Habitat. *World Habitat Day 2014-Voices from Slums*; UN-Habitat: Nairobi, Kenya, 2014.
3. Majale, M.; Tipple, G.; French, M.; Sietchiping, R. *Affordable Land and Housing in Africa*; United Nations Human Settlements Programme (UN-HABITAT): Nairobi, Kenya, 2011.
4. *IEA World Energy Outlook 2016*; OECD: Paris, France, 2016; ISBN 9789264264946.
5. Gan, X.; Zuo, J.; Wu, P.; Wang, J.; Chang, R.; Wen, T. How affordable housing becomes more sustainable? A stakeholder study. *J. Clean. Prod.* **2017**, *162*, 427–437. [CrossRef]
6. Huang, Y. Low-income housing in Chinese cities: Policies and practices. *China Q.* **2012**, *212*, 941–964. [CrossRef]

7. Czischke, D. A policy network perspective on social housing provision in the European Union: The case of CECODHAS. *Hous. Theory Soc.* **2007**, *24*, 63–87. [CrossRef]
8. Granath Hansson, A.; Lundgren, B. Defining Social Housing: A Discussion on the Suitable Criteria. *Hous. Theory Soc.* **2019**, *36*, 149–166. [CrossRef]
9. Curoso, N. New Practice of Sosial Housing from a Definition to Recent Development. *Planum J. Urban.* **2013**, *2*, 34–39.
10. Raynor, K.; Panza, L.; Ordóñez, C.; Adamovic, M.; Wheeler, M.A. Does social mix reduce stigma in public housing? A comparative analysis of two housing estates in Melbourne. *Cities* **2020**, *96*, 102458. [CrossRef]
11. *EUROCITIES Position Paper on Affordable Housing*; Eurocities: Brussels, Belgium, 2009.
12. Stone, M.E. What is housing affordability? The case of the residual income approach. *Hous. Policy Debate* **2006**, *17*, 151–184. [CrossRef]
13. Ahadzie, D.K.; Proverbs, D.G.; Olomolaiye, P.O. Critical success criteria for mass house building projects in developing countries. *Int. J. Proj. Manag.* **2008**, *26*, 675–687. [CrossRef]
14. Karji, A.; Woldesenbet, A.; Khanzadi, M.; Tafazzoli, M. Assessment of Social Sustainability Indicators in Mass Housing Construction: A Case Study of Mehr Housing Project. *Sustain. Cities Soc.* **2019**, *50*, 101697. [CrossRef]
15. Kwofie, T.E.; Fugar, F.; Adinyira, E.; Ahadzie, D.K. Identification and Classification of the Unique Features of Mass Housing Projects. *J. Constr. Eng.* **2014**, *2014*, 927652. [CrossRef]
16. Kazaz, A.; Birgonul, M.T. The evidence of poor quality in high rise and medium rise housing units: A case study of mass housing projects in Turkey. *Build. Environ.* **2005**, *40*, 1548–1556. [CrossRef]
17. Where is the Fastest Growing City in the World? | Cities | The Guardian. Available online: https://www.theguardian.com/cities/2015/nov/18/where-is-the-worlds-fastest-growing-city-batam-niamey-xiamen (accessed on 23 March 2021).
18. Aisen, A.; Veiga, F.J. How does political instability affect economic growth? *Eur. J. Political Econ.* **2013**, *29*, 151–167. [CrossRef]
19. Chirisa, I.; Matamanda, A.R. Addressing urban poverty in Africa in the post-2015 period. Perspectives for adequate and sustainable housing. *J. Settl. Spat. Plan.* **2016**, *7*, 79–87. [CrossRef]
20. Bafana, B. Africa's cities of the future. *Africa Renew.* **2016**, *30*, 4–5. [CrossRef]
21. Bellini, O.E.; Campioli, A.; Del Pero, C.; Talamo, C.; Atta, N.; Dalla Valle, A. *BECOMe—Business ECOsystem Design for Sustainable Settlements in Mogadishu*; Springer: Cham, Switzerland, 2020; pp. 3–12.
22. Bernardi, E.; Carlucci, S.; Cornaro, C.; Bohne, R.A. An analysis of the most adopted rating systems for assessing the environmental impact of buildings. *Sustainability* **2017**, *9*, 1226. [CrossRef]
23. Williams, K.; Dair, C. A framework for assessing the sustainability of brownfield developments. *J. Environ. Plan. Manag.* **2007**, *50*, 23–40. [CrossRef]
24. Oyebanji, A.O.; Liyanage, C.; Akintoye, A. Critical Success Factors (CSFs) for achieving sustainable social housing (SSH). *Int. J. Sustain. Built Environ.* **2017**, *6*, 216–227. [CrossRef]
25. Chan, A.P.C.; Adabre, M.A. Bridging the gap between sustainable housing and affordable housing: The required critical success criteria (CSC). *Build. Environ.* **2019**, *151*, 112–125. [CrossRef]
26. Adabre, M.A.; Chan, A.P.C. Critical success factors (CSFs) for sustainable affordable housing. *Build. Environ.* **2019**, *156*, 203–214. [CrossRef]
27. Tessema, F.; Taipale, K.; Bethge, J. *Sustainable buildings and construction in Africa*; Federal Ministry for the Environment, Nature Conservation and Nuclear Safety: Bonn, Germany, 2009.
28. Adabre, M.A.; Chan, A.P.C.; Darko, A.; Osei-Kyei, R.; Abidoye, R.; Adjei-Kumi, T. Critical barriers to sustainability attainment in affordable housing: International construction professionals' perspective. *J. Clean. Prod.* **2020**, *253*, 119995. [CrossRef]
29. Pullen, S.; Arman, M.; Zillante, G.; Zuo, J.; Chileshe, N.; Wilson, L. Developing an Assessment Framework for Affordable and Sustainable Housing. *Constr. Econ. Build.* **2010**, *10*, 48–64. [CrossRef]
30. Winston, N.; Pareja Eastaway, M. Sustainable housing in the urban context: International sustainable development indicator sets and housing. *Soc. Indic. Res.* **2008**, *87*, 211–221. [CrossRef]
31. Ross, N.; Bowen, P.A.; Lincoln, D. Sustainable housing for low-income communities: Lessons for south africa in local and other developing world cases. *Constr. Manag. Econ.* **2010**, *28*, 433–449. [CrossRef]
32. De Azevedo, N.J.D.; Silva, J.J.; Silva, P.M.W. Definition of indicators for sustainable social housing: In search of a model. *Int. J. Hous. Sci.* **2010**, *34*, 79–92.
33. Climate-Data.org Database. Available online: https://en.climate-data.org/africa/somalia/banadir/mogadishu-856/ (accessed on 20 March 2021).
34. Butera, F.; Adhikari, R.S.; Aste, N. *Sustainable Building Design for Tropical Climates*; United Nations Human Settlements Programme (UN-HABITAT): Nairobi, Kenya, 2014; ISBN 9789211326444.
35. UN-Habitat: IDP Integration Spatial Planning: Mogadishu, Somalia. 2020. Available online: https://data2.unhcr.org/en/documents/details/79307 (accessed on 23 March 2021).
36. Meyer, C. The greening of the concrete industry. *Cem. Concr. Compos.* **2009**, *31*, 601–605. [CrossRef]
37. Federico, L.M.; Chidiac, S.E. Waste glass as a supplementary cementitious material in concrete—Critical review of treatment methods. *Cem. Concr. Compos.* **2009**, *31*, 606–610. [CrossRef]
38. Díaz Fuentes, C.X.; Pérez Rojas, M.C.; Mancilla, J.J. Physical-thermal straw properties advantages in the design of a sustainable panel-type construction system to be used as an architectural dividing element. *J. Phys. Conf. Ser.* **2020**, *1587*, 012032. [CrossRef]

39. Dahy, H. Efficient Fabrication of Sustainable Building Products from Annually Generated Non-wood Cellulosic Fibres and Bioplastics with Improved Flammability Resistance. *Waste Biomass Valorization* **2019**, *10*, 1167–1175. [CrossRef]
40. Strawtec. Available online: https://www.strawtec.com/panels (accessed on 23 March 2021).
41. Yearbook 2019: Blown-in-Straw Technique | Interreg NEW. Available online: https://www.nweurope.eu/projects/project-search/up-straw-urban-and-public-buildings-in-straw/action-activity/yearbook-2019-blown-in-straw-technique/ (accessed on 23 March 2021).
42. Teslík, J.; Labudek, J.; Valová, B.; Vodičková, M. Settlement of Crushed Straw. *Adv. Mater. Res.* **2014**, *1041*, 55–58. [CrossRef]
43. Mitterpach, J.; Igaz, R.; Štefko, J. Environmental evaluation of alternative wood-based external wall assembly. *Acta Fac. Xylologiae Zvolen* **2020**, *62*, 133–149. [CrossRef]
44. Kanyemba, J. Enhancing Housing Delivery using a Simple Precast Construction Method. In *Structural Engineering, Mechanics and Computation*; Elsevier: Amsterdam, The Netherlands, 2001; pp. 1471–1479.
45. Chippagiri, R.; Gavali, H.R.; Ralegaonkar, R.V.; Riley, M.; Shaw, A.; Bras, A. Application of Sustainable Prefabricated Wall Technology for Energy Efficient Social Housing. *Sustainability* **2021**, *13*, 1195. [CrossRef]
46. Daniel Ronald Joseph, J. Precast Concrete Sandwich Panels for Mass Housing Systems: Plan and Design Strength Requirements. *J. Inst. Eng. Ser.* **2021**, *102*, 359–368. [CrossRef]
47. Sneha, K.; Tezeswi, T.P. A Comparative Study of Construction Using Schnell Concrewall® pre-cast sandwich composite panel and RC moment frame with brick infill. *Int. J. Civ. Eng. Technol.* **2016**, *7*, 110.
48. Hope Housing Africa. Available online: http://www.unitedcaribbean.com/homesofhopeafrica.html (accessed on 23 March 2021).
49. Khursheed, S.; Paul, V.K.; Akbari, M.A. Cost feasibility and performance assessment of expanded polystyrene sheet over conventional method: A case study in Bhubaneswar. *Asian J. Civ. Eng.* **2019**, *20*, 659–667. [CrossRef]
50. Ferdous, W.; Bai, Y.; Ngo, T.D.; Manalo, A.; Mendis, P. New advancements, challenges and opportunities of multi-storey modular buildings—A state-of-the-art review. *Eng. Struct.* **2019**, *183*, 883–893. [CrossRef]
51. Li, Z.; Shen, G.Q.; Xue, X. Critical review of the research on the management of prefabricated construction. *Habitat Int.* **2014**, *43*, 240–249. [CrossRef]
52. Emme2 Pilot Plant. Available online: https://www.mdue.it/en/plants (accessed on 20 March 2021).
53. Centre for Affordable Housing Finance in Africa, Housing Finance in Africa. Housing Finance in Africa Yearbook. 2020. Available online: https://housingfinanceafrica.org/documents/2020-housing-finance-in-africa-yearbook-11th-edition (accessed on 23 March 2021).