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Developing building roofs as an entry point to a sustainable economy

(Case study: Jannah residence in New Damietta)

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ABSTRACT

Building roofs are an integral part of the building envelope, and their environmentally friendly exploitation is one of the most prominent practices aimed at achieving sustainability in buildings worldwide. The research problem is that cities in Egypt - especially in coastal areas such as Damietta - suffer from a lack of green spaces, which negatively affects the environment and human health and leads to increased pollution, climate change problems, and global warming. Also, the greatest health damages related to buildings are the lack of thermal comfort for residents of the top floors of buildings, which leads to the occurrence of sick building syndrome, because roofs treated with the proposed solution contribute to saving energy by increasing the quality of thermal insulation properties. In addition, the proposed model in the research enhances environmentally friendly sewage systems in water consumption and recycling, and this solution supports the consumption of edible crops free of pesticides and the consumption of healthy fish. The problem also lies in the fact that not exploiting the roofs of residential buildings for growing plants, raising fish, or solar cells deprives residents of many sustainable economic, social, and environmental benefits. This research aims to evaluate the possibility of applying the integration of agriculture with fish farming on the roofs of existing residential buildings and applying the concept of green and blue economy and circular economy to achieve a sustainable economy and reduce the carbon footprint in New Damietta City, and evaluate the possibility of developing building roofs in terms of the possibility of exploiting them to increase energy efficiency and save water and determine the needs of building roofs in the field of developing them to serve the sustainable economy. The research discussed increasing green spaces through rooftop cultivation, in a project to exploit the roofs of existing buildings by simulating a model project in Damietta, and the type of systems used in agriculture, types of fish, types of plants used, natural and industrial water supply systems, water recycling between fish ponds and irrigation of crops (aquaponics) were studied. The research discussed the use of a building simulation program, Revit, to study the impact of the proposed system on energy saving on the last floor of the building. The selected buildings in the study case were evaluated according to the criteria of the Egyptian Green Pyramid Evaluation System (GPRS), and the impact of this proposal on roof performance was studied in terms of energy saving, reducing carbon emissions, improving air quality, reducing the carbon footprint and improving the quality of life for residents of those buildings. The simulation results showed that the roofs of these buildings after applying the proposed model can contribute significantly to achieving the sustainability goals referred to in the research, as they can reduce electricity consumption by approximately [30%] in the apartments of the top floor due to the thermal comfort provided by good thermal insulation, and the results also showed a reduction in carbon emissions by approximately [20%] for these buildings, and the results also showed that the percentage of achieving GPRS standards in buildings after applying the proposed model can achieve the golden pyramid in GPRS evaluation. However, these projects face some challenges, such as high initial costs and challenges of maintaining the irrigation system and plants and preserving fish life, and it has been proposed to supply renewable energy to the roofs of buildings through solar pane.

DOI :

تطوير اسطح المباني كمدخل للاقتصاد المستدام

) حالة الدراسة : مباني التجمعات السكنية (جنة) بدمياط الجديدة(

الخلاصة :

تعتبر أسطح المباني جزء لا يتجزأ من غلاف المبنى ، ويعد استغلالها بشكل يراعي البيئة من أبرز الممارسات التي تهدف إلى تحقيق الاستدامة في المباني على مستوى العالم . وجاءت المشكلة البحثية في أن المدن في مصر - خاصة في المناطق الساحلية منها بدمياط – تعاني من نقص المساحات الخضراء، مما يؤثر سلباً على البيئة وصحة الإنسان و يؤدي لزيادة التلوث و مشاكل التغير المناخي و الاحتباس الحراري. و أيضا تتمثل أكبر الأضرار الصحية المتعلقة بالمباني من عدم توفير الراحة الحرارية لسكان الدور الأخير بالمباني ، مما يؤدي لحدوث متلازمة المباني المريضة ، لأن الأسطح المعالجة بالحل المقترح تساهم في توفير الطاقة من خلال ارتفاع جودة خصائص العزل الحراري. بالإضافة إلى ذلك، فإن النموذج المقترح في البحث يعزز أنظمة الصرف الصحي التي تراعي البيئة في استهلاك المياه و إعادة تدويرها، ويدعم هذا الحل تناول المزروعات المأكولة الخالية من المبيدات و تناول الأسماك الصحية. و تكمن المشكلة ايضا في ان عدم استغلال أسطح المباني السكنية لزراعة النباتات أو تربية الأسماك أو الخلايا الشمسية يحرم السكان من فوائد عديدة اقتصادية واجتماعية وبيئية مستدامة. و يهدف هذا البحث إلى تقييم إمكانية تطبيق تكامل الزراعة مع تربية الأسماك على اسطح العمارات السكنية القائمة و تطبيق مفهوم الاقتصاد الأخضر و الأزرق و الاقتصاد الدوار لتحقيق الاقتصاد المستدام و تقليل البصمة الكربونية بمدينة دمياط الجديدة، و تقييم إمكانية تطوير أسطح المباني من حيث إمكانية استغلالها لزيادة كفاءة الطاقة وتوفير المياه و تحديد احتياجات أسطح المباني في مجال تطويرها لخدمة الاقتصاد المستدام. و ناقش البحث زيادة المساحات الخضراء من خلال زراعة الأسطح، في مشروع لاستغلال أسطح العمارات القائمة من خلال محاكاة مشروع نموذجي في دمياط ، وتم دراسة نوع الأنظمة المستخدمة في الزراعة و انواع الأسماك و أنواع النباتات المستخدمة ونظم الامداد بالمياه الطبيعية و الصناعية وإعادة تدوير المياه بين أحواض السمك و ري المزروعات (الأكوابونيك)، و تم بالبحث مناقشة استخدام برنامج لمحاكاة البناء وهو الـ Revit لدراسة تأثير النظام المقترح على توفير الطاقة في الدور الأخير بالمبنى و تم تقييم المباني المختارة بحالة الدراسة بمعايير نظام التقييم الهرم الأخضر المصريGPRS ، و دراسة تأثير ذلك المقترح على أداء السطح من حيث توفير الطاقة وتقليل انبعاثات الكربون وتحسين جودة الهواء و تقليل البصمة الكربونية وتحسين جودة الحياة لسكان تلك المباني . وأظهرت نتائج المحاكاة أن أسطح تلك المباني بعد تطبيق النموذج المقترح يمكن أن تساهم بشكل كبير في تحقيق أهداف الاستدامة المشار اليها بالبحث، حيث يمكنها تقليل استهلاك الطاقة الكهربية بنسبة [٣٠%] تقريبا في شقق الدور الأخير نتيجة للراحة الحرارية المتوفرة بسبب العزل الحراري الجيد، وأيضا أظهرت النتائج تقليل انبعاثات الكربون بمقدار [٢٠%] تقريبا لتلك المباني، كما اظهرت النتائج أيضا ان نسبة تحقق معايير GPRS في المباني بعد تطبيق النموذج المقترح يمكن ان تحقق الهرم الذهبي في تقييم الـ GPRS. ومع ذلك، تواجه هذه المشاريع بعض التحديات، مثل التكاليف الأولية المرتفعة و تحديات صيانة نظام الري و النباتات و الحفاظ على حياة الأسماك، ولقد تم اقتراح امداد الطاقة المتجددة لأسطح المباني من خلال الواح الطاقة الشمسية .

1.1 Problem

- Lack of Green Spaces: Cities suffer from a shortage of green spaces, negatively impacting both the environment and human health, leading to increased issues related to climate change and global warming.

- Health Issues Due to Insufficient Thermal Comfort: The lack of thermal comfort for residents, particularly those living on the top floors, results in various health issues.

- Underutilization of Rooftops: Residential rooftops in Egypt are not being used for planting crops or fish farming, missing out on the potential for sustainable economic, social, and environmental benefits.

- Avoiding Health Risks from Unsafe Food Sources: Health risks arise from consuming crops treated with chemical pesticides or fish sourced from unsafe environments.

1.2 Target

- Evaluate the feasibility of developing the selected building rooftops to enhance energy efficiency and water conservation.

- Identify the developmental needs of building rooftops to better serve residents and the environment.

- Expand green spaces in the selected area through rooftop gardening, contributing to improved air quality and temperature reduction.

- Provide food sources through the cultivation of plants and fish farming, offering a safe source of edible plants and protein while reducing organic waste.

- Achieve integration between nutritional elements (certain plants and fish) to reduce the city’s environmental footprint and enhance resource efficiency.

- Enhance the quality of life for New Damietta's residents by partially achieving food self-sufficiency for Egyptian families.

- Create new job opportunities related to the installation and maintenance of the proposed integrated system.

- Strengthen collaboration between residents and local authorities by training residents to oversee plant cultivation and fish tanks.

- Assess the potential of applying green, blue, and circular economy concepts on rooftops in coastal cities as a case study, measuring their impact on sustainable economic development through GPRS standards.

- Use a building simulation model to evaluate the impact of various elements, such as the type of agricultural system, plant types, and systems for water collection and recycling between fish tanks and irrigation.

- Identify obstacles and challenges that prevent rooftop development in residential communities.

• Propose practical solutions for rooftop challenges and study the costs involved in implementing these recommendations.

1.3 Limits

The research is conducted within a specific scope in Damietta Governorate, Egypt, located in the Mediterranean coastal region, characterized by a rainy winter and a mild, humid summer climate. It focuses on a residential complex called Jannah in New Damietta, consisting of 20 buildings.

1.4 Significance

• Highlighting Health and Comfort Solutions: Emphasizes solutions that enhance human comfort and health through the GPRS evaluation.
• Ensuring Psychological and Physical Stability: Supports mental and physical well-being for residents, particularly those on top floors, by maintaining health (thermal comfort and access to uncontaminated food), thereby helping to prevent the "sick building syndrome."
• Contributing to Egypt's 2030 Sustainable Development Goals: Aligns with specific sustainable development goals, including Goal 1 (No Hunger), Goal 3 (Good Health and Well-being), Goal 11 (Sustainable Cities and Communities), and Goal 13 (Climate Action).
• Supporting Egypt's National Climate Change Strategy 2050: Contributes to the strategic objectives of Egypt's 2050 Climate Change Strategy.

1.5 Research Hypothesis

The researcher hypothesizes that there are promising opportunities to achieve a sustainable blue, green, and circular economy in coastal areas compared to other non-coastal regions in Egypt.

1.6 Research Tools

The data for this research was obtained using a set of tools as follows: exploratory study through field visits to the selected building, documents and records related to architectural and structural aspects of the sample buildings, interviews with experts and specialists in the field, and survey questionnaires.

1.7 General Description of Survey Forms

The research includes two types of questionnaires. The first questionnaire contains survey questions for residents of the selected area, designed by the researcher to assess various aspects related to economics, environment, and sustainability. The second questionnaire is based on the Egyptian Green Pyramid rating for existing residential buildings, measuring criteria related to environmental and sustainability aspects in housing. The target group for these surveys consists of residents of the residential building (the top-floor units) from families of the four apartments.

1.8 Research Methodology

The research followed procedural methodological steps based on a comparative descriptive causal approach, focusing on the inductive method in the theoretical section and the deductive and analytical approach in the practical section to achieve the research results.

1.9 Research Boundaries:

The research is conducted within a specific scope in Damietta Governorate, Egypt, located in the Mediterranean coastal region, characterized by a rainy winter and a mild, humid summer climate. It focuses on a residential complex called Jannah in New Damietta, consisting of 20 buildings.

2 Introduction

Over the past decade, green architecture has developed to create buildings that address global environmental issues, minimizing

harm to both internal and external environments. However, some existing buildings, particularly residential complexes, do not adhere

to environmental architecture standards. This research paper proposes environmental treatments to improve these conditions.

In Egypt, residential buildings in complexes often lack key environmental architecture standards, necessitating certain treatments to enhance environmental performance, specifically in Damietta.

3 Definitions

3.1 Green Roof:

Green roofs represent an innovative approach in green architecture, providing substantial energy savings through high-quality thermal insulation. This reduces heating and cooling demands, supports effective drainage systems, mitigates the urban heat island effect, and fosters biodiversity. Green roofs help reduce air pollution and greenhouse gas emissions by lowering cooling requirements and beautifying the environment. Additionally, they create habitats for various species and help in rainwater retention. By reducing heat transfer, green roofs enhance interior comfort, contributing to a more consistent and comfortable indoor temperature. Figure 1 following illustrates various methods for utilizing rooftops through agricultural and solar panel applications.

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Figure “1” illustrates various methods for utilizing roof

It is noteworthy that there are only a limited number of "pathways" through which heat is gained or lost between the internal and external climates. Figure 2 following illustrates the energy exchange pathways within the local building climate.

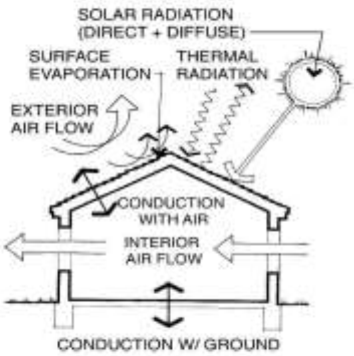


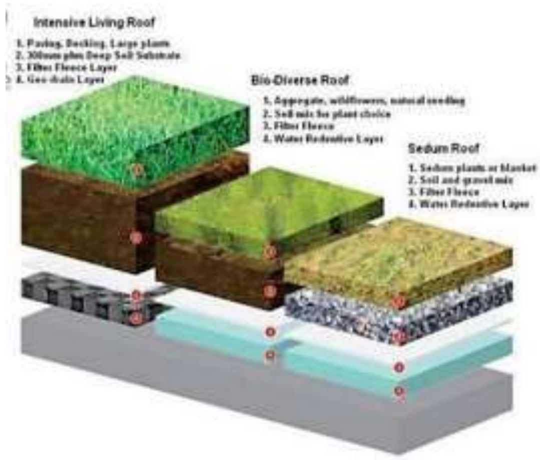
Figure “2“ illustrates the energy exchange pathways within the local building climate

Green Roof Types

types of environmental roofs for rooftop gardening, which are divided into three categories:

Intensive -Biodiverse -Sedum.

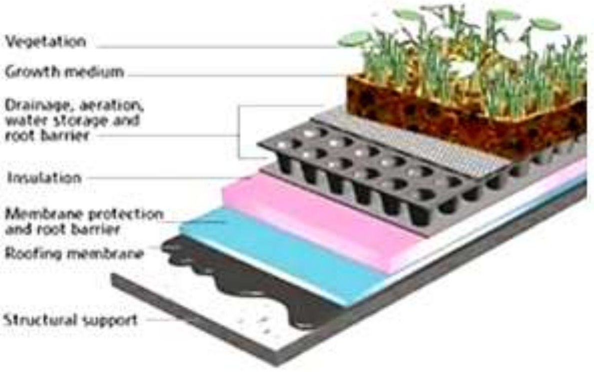
Figure 3-A following illustrates types of environmental roofs.



Figure“ 3-a “ illustrates the types of environmental roofs

Figure 3-B following shows the components of building rooftops when utilized for gardening, including: plants, growth medium,

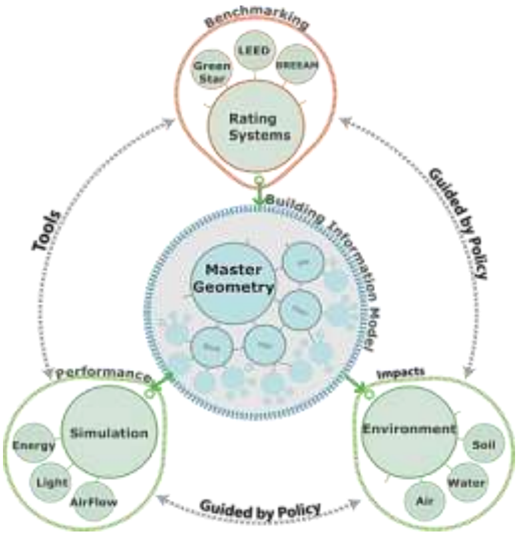
drainage and ventilation, water storage, root barriers, insulation, membrane protection, roofing membrane, and structural support.



Figure“ ٣-b “ illustrates the types of environmental roofs

3.1 Sustainability Evaluation Systems:

Classification systems for evaluating and measuring sustainability are continually evolving. Figure 4 below following illustrates the relationship between these classification systems, simulation programs, and environmental standards.



Figure“ 4“ illustrates the relationship between these classification systems, simulation programs, and environmental standards.

3.2 The Green Pyramid Rating System (GPRS):

The GPRS certification classifies projects based on the following scale:

- Certified: 40 - 49 points
- Silver Pyramid: 50 - 59 points
- Golden Pyramid: 60 - 79 points
- Green Pyramid: 80 points and above .

Projects that score below 40 points are rated as “Not Certified.” Certifications issued by HBRC are valid for five years, after which a re-application under the GPRS for existing buildings is required.

3.2.1 Calculation of the Green Pyramid Rating

The GPRS is recommended for use in the Egyptian construction market to encourage both public and private sector adoption. Table 1 illustrates the GPRS criteria, while Table 1 following details the point distribution for each GPRS standard - It evaluates buildings based on seven main categories:

- Sustainable Sites .
- Energy Efficiency
- Water Efficiency
- Materials and Resources
- Indoor Environmental Quality
- Management and Construction .
- Innovation .

Table“ 1 “illustrates the GPRS criteria, while Table 2 details the point distribution for each GPRS standard

Category	Category Weight
Category 1: Sustainable Sites	**8%**
Category 2: Energy Efficiency	**30%**
Category 3:Water Efficiency	**30%**
Category 4: Materials and Resources	**12%**
Category 5: Indoor Environmental Quality	**12%**
Category 6: Management Protocols	**8%**
Category 7: Construction and Innovation	**5% (Bonus)**

<u>Focusing on Specific Standards</u>:

Category 2: Energy Efficiency Standards

The Energy Efficiency category is divided into the following sub-criteria ,Table 2 following:

Table“ 2 “illustrates the Energy Efficiency category

Item	Criterion	Score	Weight
EE.01	Energy Efficiency Improvement	10	6%
EE.02	Passive External	10	6%

Item	Criterion	Score	Weight
	Heat Gain Reduction		
EE.03	Energy Efficient Appliances	5	3%
EE.04	Vertical Transportation Systems	5	3%
EE.05	Renewable Energy Sources	10	6%
EE.06	Environmental Impact	4	2.4%
EE.07	Operation and Maintenance	2	1.2%
EE.08	Optimized Balance of Energy and Performance	4	2.4%
Total		50	30%

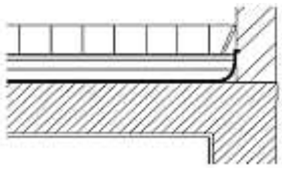
٣.٢.2 Reducing Energy Consumption and Lowering Carbon Emissions

This objective can be achieved by integrating strategies focused on the building envelope design, including:

- **Wall Types and Insulation**: Employing materials and designs that enhance thermal insulation.
- **Roof Insulation**: Ensuring roofs are well-insulated to reduce heat transfer.
- **Roof Shading**: Applying shading elements on the roof to minimize heat gain.
- **Window Types and Glass**: Selecting efficient window types and glass that offer better thermal performance.
- **Window Shading**: Utilizing shading solutions to block excessive sunlight, reducing indoor heat.

In the proposed solution, the research will concentrate specifically on **roof insulation and shading** as key interventions. The following table 3 outlines the evaluation criteria related to improving energy efficiency.

Table“ 3 “illustrates outlines the evaluation criteria related to improving energy efficiency.

ITEM	ASSESSMENT CRITERIA	DETAIL POINTS		Average
EE1	**Improve energy efficiency**			
	A maximum of 10 points can be obtained by improving energy saving compared to the base state shown in the following figure	>10 %	2	10
	Base case main surfaces definition Roof 	>20 %	4	
		>30 %	6	
		>40 %	8	
		>50 %	10	

٣.٣ Base Case Definition in Green Pyramid Standards (GPS):

Characteristics:

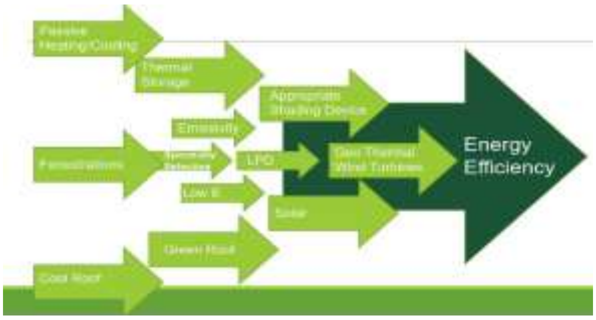
- Minimize external passive heat gain.

- Reduce heat gain through building envelopes.

- Achieve thermal comfort within the indoor space by employing passive design with minimal dependency on mechanical systems.

- Decrease energy consumption over time by integrating passive design strategies.

Figure (5) following illustrates how sustainable roofs are essential components for enhancing building performance.



Figure“ ٥“ illustrates how sustainable roofs are essential components for enhancing building performance

3.4 Passive External Heat Gain Reduction: Minimizing heat absorption through building envelopes.

• Reduction of Heat Gain through Building Envelopes: Decreasing the transfer of external heat into the structure.

• Thermal Comfort Achievement: Ensuring indoor thermal comfort through passive design strategies, thereby minimizing reliance on mechanical systems.

• Reduced Energy Consumption: Lowering future energy needs by integrating passive design strategies.

Table 4: GPRS Evaluation Criteria

<table>
<tr><th>ITEM</th><th colspan="2">ASSESSMENT CRITERIA</th><th>DETAIL POINTS</th><th>Average</th></tr>
<tr><td>EE 2</td><td colspan="4">Reduction of negative external heat gain</td></tr>
<tr><td rowspan="6"></td><td rowspan="6">A maximum of 10 points can be earned by improving energy savings compared to the base state described in the criteria</td><td>5-10%</td><td>2</td><td rowspan="6">10</td></tr>
<tr><td>11-16 %</td><td>4</td></tr>
<tr><td>17-22 %</td><td>6</td></tr>
<tr><td>23-28%</td><td>10</td></tr>
<tr><td>23-28%</td><td>8</td></tr>
<tr><td>≥29 %</td><td>10</td></tr>
</table>

4. Photovoltaic Solar Energy Systems:

Solar energy serves as the primary renewable source for zero-energy buildings. Installing photovoltaic panels on rooftops or open spaces generates electricity from sunlight. In Damietta, solar panels are extensively utilized to capitalize on the abundant solar energy available in the region. These photovoltaic systems are integrated into building designs to maximize sunlight exposure, ensuring optimal energy generation throughout the day.Figure 6 illustrates the components of a residential building solar energy system.

Figure“ 6“ illustrates the components of a residential building solar energy system

5. Aquaponics System:

Aquaponics is a balanced system that mimics natural interactions between agricultural and aquatic environments. It consists of a planting basin and a fish tank, where plants derive nitrogen from fish waste, and fish benefit from filtered, nutrient-rich water.

•<u>Process:</u>

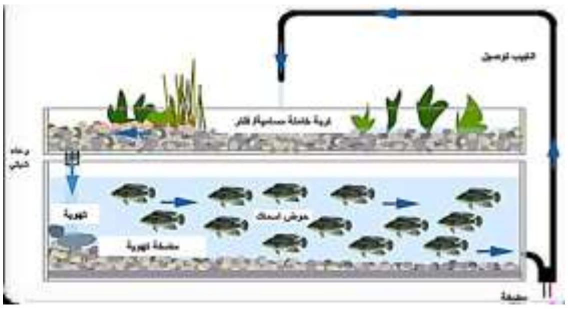
o Initially, fish are fed with floating feed. The nutrient-rich water is then circulated through pipes towards the plant basin using a pump, allowing plants to grow without soil or in an inert medium like glass wool, vermiculite, or perlite.

o After flowing through the plant basin, water returns to the fish tank, completing the cycle.

• *Advantages:*

o The soilless method reduces water usage and accelerates plant growth compared to traditional farming.

Figure 7a following shows a cross-section of the proposed aquaponics system on rooftops.



Figure“7-a “shows a cross-section of the proposed aquaponics system on rooftops.

Figure 7b following displays an actual model of the aquaponics setup on rooftops.

Figure“7-b “displays an actual model of the aquaponics setup on rooftops

Aquaponics combines hydroponic (soilless plant cultivation) and aquaculture (fish farming) systems, resulting in a cycle where both plants and fish benefit. The outputs are pure, pesticide-free produce, and the system does not require harmful chemicals. The essentials of an aquaponics system include fish tanks, a solid waste filter, biological filters, and a hydroponic unit. Fish produce ammonia in their waste, which is toxic to them. This is removed through the biological filter to ensure a safe environment.

Proposed Rooftop Agriculture Systems:

the proposed system will utilize closed systems, vertical farming setups, and planting in inert mediums, maximizing space and efficiency. Figure 8 a- b following illustrates sample rooftop-grown crops (Cucumber, tomatoes, leafy vegetables and strawberries) , such as tomatoes and cucumbers.

Figure“8 -a “ Figure“8 -b “

Example: Environmental Requirements for Tilapia Fish

- Optimal Temperature: 28 - 32°C
- Dissolved Oxygen Concentration: Above 3 mg/L
- Carbon Dioxide Level: Less than 15 mg/L
- Salinity: Up to 28 g/L
- pH Level: 6 - 8.5
- Alkalinity: 50 - 700 mg/L
- Ammonia: Less than 0.5 mg/L

These parameters ensure a healthy environment for tilapia, promoting growth and minimizing stress in an aquaponics system. Figure 9 illustrates examples of fish species cultivated on rooftops

Figure “9“ illustrates examples of fish species cultivated on rooftops

Core Components of the Aquaponic System:

- **Fish Farming Unit**: A tank designated for fish rearing.
- **Plant Containers**: Reusable plastic pots for growing plants.
- **Smart Water Quality Monitoring**

System: Ensures optimal conditions for fish and plants.

- **Oxygen Pump**: Maintains adequate oxygen levels in the water.
- **Plant Bed**: A reservoir specifically for planting.
- **Filtration System**: Removes waste and maintains water clarity.
- **Piping Network**: Connects various components, enabling water circulation.

<u>Advantages of the Aquaponic System:</u>

- **Soil-Free Farming**: Allows for efficient, soil-free plant cultivation.
- **Reduced Water Usage**: Utilizes 90-98% less water compared to traditional agriculture.
- **Job Creation**: Generates employment opportunities for installation and maintenance.
- **Eliminates Traditional Unwanted Tasks**: Reduces the need for weed removal and other conventional tasks.
- **Twice the Yield at Higher Quality**: Produces twice as fast with 100% organic quality.
- **Utilizes Unconventional Spaces**: Makes productive use of otherwise unusable areas like rooftops.
- **Ease of Implementation and Sustainability**: Operates year-round with longevity and minimal maintenance.
- **Scalable for Individuals and Institutions**: Can be adopted at various scales, from personal to organizational.
- **Environmentally Friendly**: Supports climate change adaptation and mitigation.
- **Air Quality Improvement**: Expands green areas that act as natural air filters, reducing pollution.
- **Reduction in Chemical Use**: Lowers the need for harmful pesticides and fertilizers, minimizing their environmental impact.

Figure “10“ illustrates the circular economy's relationship to both the green and sustainable economies

Marine Aquaculture and Fish Farming

Aquaculture refers to the cultivation of certain marine organisms, such as fish and other aquatic species, under controlled conditions and human supervision. Fish farming constitutes one integral part of aquaculture.

6.Carbon Footprint :

Carbon Footprint is a measure of the amount of carbon dioxide (CO_2) and other greenhouse gases emitted directly or indirectly as a result of a specific activity or the production of a product or service. The concept of the carbon footprint aims to provide a standardized means to assess the impact of human activities on climate change.

7.Global Per Capita Carbon Footprint:

The following figure (11) illustrates the sources of carbon footprint by sector .

figure “11“ illustrates the sources of carbon footprint by sector.

4. Previous Studies:

Examples of Residential Building Rooftops from Various Countries:

- **Germany:** Germany is a leader in renewable energy, where the government strongly promotes the installation of solar panels and green roofs, providing generous financial incentives for citizens and companies. Numerous German cities have also initiated successful pilot projects for green roofs.
- **Switzerland:** Switzerland is known for its strict environmental standards in construction, with many new and existing buildings featuring green roofs and solar panels.

- **Norway:** Norway is a leader in renewable energy, largely relying on hydropower but also advancing solar energy by promoting rooftop solar panel installations.
- **United States:** The U.S. solar market is rapidly expanding, with several states offering financial incentives for solar installations. Some cities have also enacted regulations mandating green roofs on new buildings.
- **Canada:** Canada is at the forefront of renewable energy, with government support for solar panel installations and green roofs, offering financial incentives to citizens and businesses.
- **Japan:** Japan applies strict environmental standards in construction, with green roofs and solar panels featured on many new and older buildings.
- **Singapore:** Facing a scarcity of green space, Singapore's government encourages the installation of green roofs to increase green areas throughout the city.
- **Latin American Countries:** Some Latin American countries, such as Brazil and Mexico, are experiencing rapid growth in the solar energy market, with governments encouraging the installation of solar panels and green roofs. Notably, governmental policies and incentives vary across countries, influencing the rate at which these technologies are adopted. Each nation also faces unique challenges in implementing these techniques, which are influenced by specific climate, economic, and cultural conditions.

Case Study - Janna Housing Project

Reason for Area Selection: The Case Study in Damietta as follows:

• Urban Context: Damietta is a coastal city in Egypt with rapid population growth and limited available land. This makes rooftop space a valuable resource for sustainable development.

• Challenges: Challenges in Damietta include a shortage of freshwater, limited access to pesticide-free crops, and reliance on non-renewable energy sources. Proposed rooftop solutions can address these issues by creating a clean, sustainable source of local food production, reducing water consumption, and decreasing reliance on non-renewable energy.

• Potential: Damietta’s climate and infrastructure provide a suitable environment for integrated rooftop systems. The coastal city’s climate allows for ample rainfall in winter, which can be utilized in the proposed agricultural system. Figure (12) shows the location of New Damietta City in Damietta Governorate, Egypt.

Figure “12“ shows the location of New Damietta City in Damietta Governorate, Egypt

Environmental Analysis for New Damietta City

<u>JANNA Residential Project:</u>

- In its effort to provide housing for all social segments, the New Urban Communities Authority aims to supply fully finished residential units, totaling 10,872 units across several cities: Sheikh Zayed, Sixth of October, New Cairo, New Mansoura, New Mallawi, and New Damietta.
- The JANNA housing project specifically targets the housing needs of higher-income families in New Damietta, offering fully finished residential units with various models, security, a community building, and swimming

pools, making it a well-serviced project in coastal areas near main roads.

- The project comprises 16 residential blocks with different models, including 815 residential units: two-bedroom units with 519 units measuring 65 m², 156 units measuring 72 m², and three-bedroom units with 56 units measuring 82 m² and 84 units measuring 90 m².
- Each building consists of a ground floor and four additional floors, with four residential units on each floor. The building models include single-type models, referred to as Model A buildings, like those selected in the case study (20 buildings, illustrated in Figure 13). There are also dual-type models called Model B buildings, which are not part of the case study.

Figure“ 13“ illustrated selected in the case study

Figure (14) following illustrates the map location of the JANNA project in New Damietta, showing its proximity to the Mediterranean coast. It also highlights the buildings selected as case study examples within New Damietta.

Figure “14“ illustrates the map location of the JANNA project in New Damietta

Figure (15) following presents a ground floor plan for Model A buildings within the JANNA project, while Figure (16) illustrates the layout of the repeated floors in the same model.

Figure “15“ presents a ground floor plan for Model A buildings within the JANNA project

Figure “16“ illustrates the layout of the repeated floors in the same model.

Figure (17) following shows the façade of the building in the case study before implementation, Model A in the JANNA project, while Figure (18) illustrates the façades of the buildings in the case study after implementation.

Figure “17“ shows the façade of the building in the case study before implementation

Figure “18“ illustrates the façades of the buildings in the case study after implementation

Discussion :

Simulation for block in (Revit)

A simulation of the building was conducted using Revit software to perform energy analysis on the rooftop and fifth floor. Figure (19) following displays the simulation of the building's exterior envelope, along with a three-dimensional section in Revit.

Figure “19“ displays the simulation of the building's exterior envelope

Figure “20“ following illustrates a section of the building in Revit .

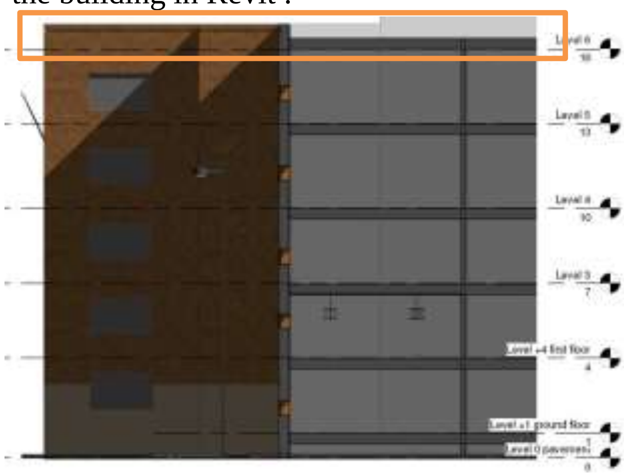


Figure “20“ illustrates a section of the building in Revit

Figure (21) following displays the energy analyses conducted in Revit for the top floor.

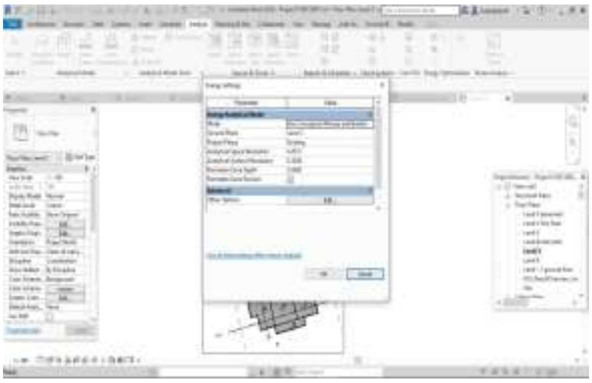


Figure “21“ displays the energy analyses conducted in Revit for the top floor

Simulation of Residential Building Project in New Damietta Using Revit and Energy Analysis:

Steps Followed for Creating a Detailed Revit Model:

- **Model Creation:** Develop an accurate three-dimensional model of the building, focusing on the details of the fifth floor and the roof.
- **Openings:** Precisely define all openings (windows and doors), including their dimensions and orientations.
- **Materials:** Select appropriate materials for each building element (walls, ceilings, floors, windows, doors) and define their thermal properties.
- **Systems:** Create different system elements such as lighting, heating, cooling, and ventilation systems.

Project File Preparation:

- **Location:** Accurately determine the project's location in New Damietta to assess the climatic conditions.
- **Time Frame:** Specify the time period to be analyzed (3 months).
- **Climatic Conditions:** Assign local climate data for New Damietta (temperature, humidity, solar radiation, wind speed).

Factors to Consider in the Analysis:

- **Impact of Aquaponics:**
  - **Thermal Insulation:** Evaluate the ability of the soil layer and plants to insulate the building.

 Natural Ventilation: Evaluate the effect of plants on improving indoor air quality and reducing the need for air conditioning.
 Additional Weight: Assess the impact of the extra weight from soil and plants on the building's structure.

2. **Climate Conditions in New Damietta**

- **Solar Radiation:** Assess the impact of solar radiation on the building and determine the need for shading or solar insulation.
- **Winds:** Evaluate the influence of winds on the building and identify the necessity for wind barriers.

Building Design Considerations

- **Orientation:** Evaluate the effect of the building's orientation on heat gain.
- **Openings:** Assess the size and number of openings and their impact on ventilation and natural lighting.
- **Thermal Insulation:** Evaluate the thickness and insulation of materials used in walls, roofs, and floors.

Outputs

- **Detailed Reports:** Provide analysis on energy consumption in the building.
- **Thermal Drawings:** Include thermal drawings that highlight areas suffering from heat loss or gain.
- **Energy Improvement Suggestions:** Offer recommendations to enhance energy efficiency in the building.
- **Targeted Levels for Analysis:** Focus on the fifth floor and the roof.
- **Roof Area:** 520 square meters (excluding cores, elevators, and light wells).
- **Required Analysis:** Conduct a comprehensive energy analysis of the building, focusing on the impact of the aquaponic system.

Detailed Proposals

1. **Revit Modeling:**
   - **Detailing Accuracy:**
     - **Aquaponic System:** Create a custom family to represent aquaponic planting beds, specifying the thickness of various layers (soil, plants, insulating materials) and their thermal properties.
     - **Additional Elements:** Develop families to represent irrigation and recycling systems, water collection systems, and any other related components.
     - **Openings:** Precisely define the type and size of each opening (windows, doors, ventilation openings) and their distribution.

Project File Preparation:

- **Climate Data:** Acquire accurate climate data for New Damietta from reliable sources (such as meteorological services) to determine temperature, humidity, solar radiation, and wind speed.
- **Operational Conditions:** Define the expected operating hours for air conditioning systems, lighting, and other electrical devices.

Energy Analysis:

- **Energy Simulation:** Run the energy simulation to assess the building's performance in terms of energy consumption.
- **Detailed Analysis:** Analyze the results to identify sources of thermal loss and gain, as well as the efficiency of heating and cooling systems.
- **Aquaponic System Evaluation:** Assess the impact of the aquaponic system on the building's thermal insulation and natural ventilation performance.
- **Dynamic Simulation:** Utilize dynamic energy simulation to obtain more accurate results, as this simulation accounts for changes in climatic conditions throughout the day and year.

- **Comprehensive Analysis:** Analyze the energy consumption of each system individually (heating, cooling, lighting) to identify weaknesses.
- **Evaluation of the Aquaponic System:**
  - **Thermal Insulation:** Measure the impact of the aquaponic system on reducing heat loss during winter.
  - **Evaporative Cooling:** Assess the ability of the aquaponic system to cool the indoor air during summer.
  - **Air Quality:** Evaluate the effect of plants on improving indoor air quality.

Design Optimization

- **Solar Orientation:** Optimize the building's orientation to maximize solar radiation in winter and minimize heat gain in summer.

- **Shading:** Utilize shading elements such as balconies and awnings to reduce heat gain from solar radiation.
- **Natural Ventilation:** Harness seasonal winds to enhance the building's natural ventilation.
- **Thermal Insulation:** Increase the thickness of thermal insulation in walls, roofs, and floors.
- **High-Performance Windows:** Use windows with high-performance glass and thermal insulation. Figure (16) illustrates images of the exterior envelop of selected buildings in the area.

Figure “16 “illustrates images of the exterior envelop of selected buildings in the area

Existing Issues in the Residential Area :

Among the existing problems in the residential project is the occurrence of some efflorescence due to humidity and water leakage from the roofs of the residential units during rainfall. Figure 17 a-b following illustrates some instances of humidity efflorescence and water leakage from the roofs.

Figure“ 17-a “ illustrates some instances at interior

Figure“ 17-b “ illustrates some instances At elevation

Analyses and Discussion

The analysis of the questionnaires was conducted as follows:

Part One: The application of the Egyptian Green Pyramid Questionnaire mentioned in the previous sections of the research for assessing existing housing according to all its criteria. Table 5 illustrates the Egyptian Green Pyramid Questionnaire for evaluating existing housing standards.

Part Two: A survey questionnaire targeting the residents of the JANNA housing project. The first field visit to the buildings took place on November 20, 2023, from 10 AM to 12 PM, and the second visit occurred on February 10, 2024, at the same time as the first visit. During this second visit, photography was completed, and the remaining questionnaires were answered by 30 families in different buildings within the area.

It is worth mentioning that a physical model of a building in the selected area was created, and a proposal for the aquaponics system was established as small tanks. This is the second proposed system in the research. Solar panels were added to supply renewable energy to the aquaponics system primarily, with any surplus potentially used for elevators as an alternative during power outages in the building. Figure X shows a horizontal floor plan for the roof with the proposed distribution of the aquaponics system and solar panels in the Model A buildings of the JANNA project in New Damietta. Figure 18 following illustrates a three-dimensional simulation model of a building n the JANNA project in New Damietta.

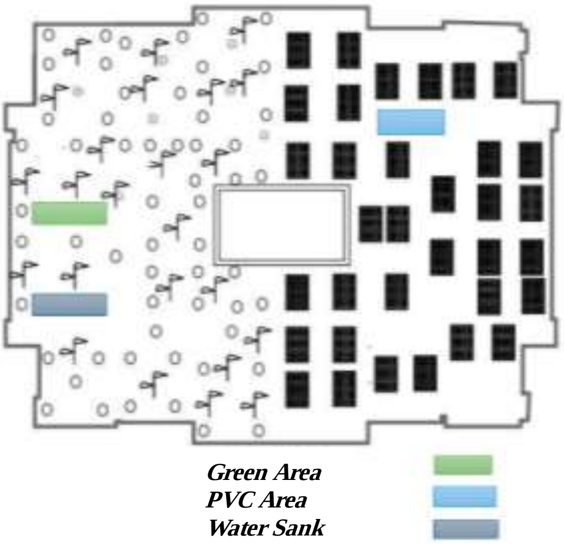


Figure " 18 " illustrates a three-dimensional simulation model

Figure 19 following illustrates a three-dimensional simulation model of a building in the JANNA project in New

Damietta.

Figure" 19" illustrates a three-dimensional simulation model of a building in the JANNA project

<u>The research yielded the following results, which align with its objectives:</u>

First: The simulation results indicated that green roofs can significantly contribute to achieving sustainability goals, with the potential to reduce electrical energy consumption by **30%** and decrease carbon emissions by **20%**. However, these projects face challenges, such as high initial costs, maintenance of the irrigation system and plants, and ensuring the sustainability of fish life Figure 20 illustrates the data regarding the environmental and economic impact-analysis of project data on the reduction of energy consumption and carbon emissions and their effects. Figure 26 illustrates the data regarding the environmental and economic impact-analysis of project data on the reduction of energy consumption and carbon emissions and their effects.

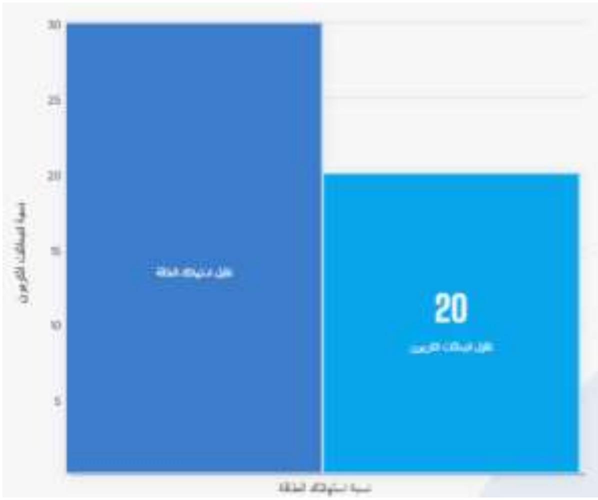
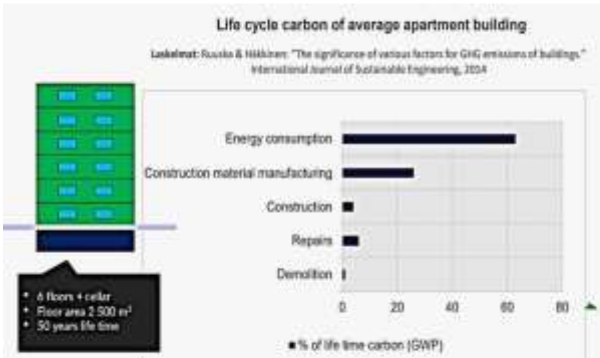


Figure " 20 " illustrates the data regarding the environmental and economic impact

Figure 21 illustrates the carbon lifecycle for an average apartment in the building.



Figure" 21" illustrates the carbon lifecycle for an average apartment in the building

Figure 22 following illustrates the technologies utilized in the project to enhance economic sustainability include (Green roof System, PVC Use , Collection Systems For rain water, Recycle water between green sank) .

Figure" 22" illustrates the technologies utilized in the project to enhance economic sustainability.

Analysis of Field Study Results:

Results of the Questionnaire Application:

i. **GBRS Evaluation:** The following table illustrates these results. Table (5) shows evaluation points in GBRS .

Table (5) shows evaluation points in GBRS

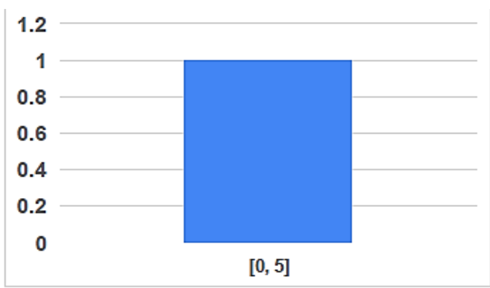
Green Pyramid Category	Credits Availabl	Credits Achieved	% Credits Achieved	Category Weight	Category Score
1: Sustainable Site, Accessibility, Ecology	10	*5*	**50%**	15%	7.5
2: Energy Efficiency	50	*30*	80%	25%	20
3: Water Efficiency	70	*35*	50%	30%	15
4: Materials and Resources	20	*10*	50%	10%	5
5: Indoor Environmental Quality	20	*10*	50%	10%	5
6: Management	20	*10*	50%	10%	5
7: Innovation and Added Value	10	*5*	50%	Bonus	5
TOTAL	(62.5)				
GREEN PYRAMID RATING	gold				

The previous table shows the weight of the criteria achieved in the evaluation as follows:
The total availability of a set of criteria for the selected building site, including Sustainable Site, Accessibility, and Ecology, is 15% of the total set of these criteria. Meanwhile, the set of criteria for good thermal environmental conditions for the building is available at 25% for the case study, while the remaining percentage reflects the criteria that are not available.
For the Water Efficiency criteria, they are available at 30% for the case study, and the Materials and Resources criterion is available at 10% for the case study. The Indoor Environmental Quality criterion is also available at 10% for the case study, while the Management criterion is available at 10% for the case study, and the Innovation and Added Value criterion is provided as a Bonus for the case study.

The Residents' Survey Results for the Selected Sample:

The following figures illustrate some analyses resulting from a group of residents in the selected area:

Figure 23 shows residents' expectations regarding the reduction in electricity consumption and the utilization of green space on the roof.
Figure 24 illustrates how much importance residents place on environmental aspects and sustainability in housing projects.
Figure 25 depicts residents' comfort level with the use of technology.
The new system in their home for monitoring the aquaponics on the roof.
Figure 26 illustrates the percentage evaluation of the selected sample of residents regarding green spaces.



Figure" 23" illustrates the percentage evaluation of the selected sample of residents regarding green spaces

Figure 24 illustrates residents' expectations regarding the reduction of electricity consumption and the utilization of green spaces on rooftops.

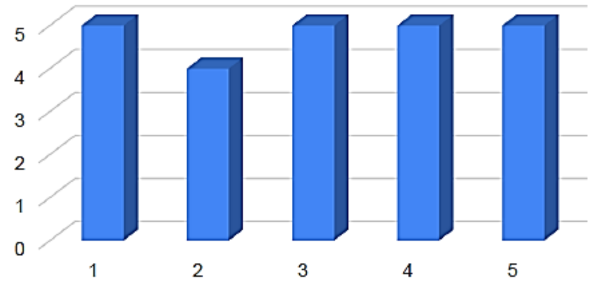


Figure “24“ illustrates residents' expectations regarding the reduction of electricity consumption and the utilization of green spaces on rooftops

Figure 25 illustrates the extent to which residents prioritize environmental aspects and sustainability in housing projects.

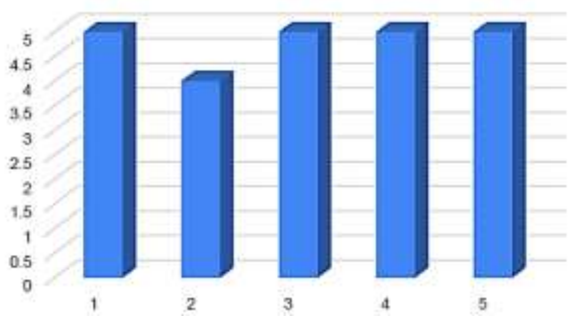
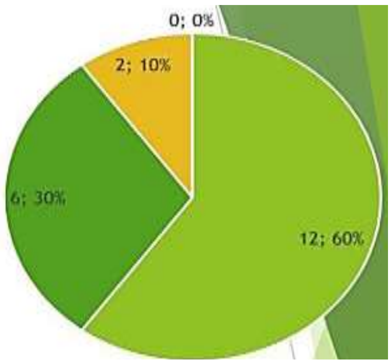


Figure “25 “ illustrates the extent to which residents prioritize environmental aspects

Figure 26 shows the level of satisfaction among residents regarding the use of new technology in their homes to monitor the aquaponics systems on the rooftops.



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راضي جدا ■ راضي ■ مقبول ■ غير راضي

Figure“26“ illustrates the extent to which residents prioritize environmental aspects

The previous figures indicate the following:

- Figure 23 illustrates residents' expectations for a 90% reduction in electricity consumption and the utilization of green spaces on the rooftops.
- Figure 24 demonstrates the importance residents place on environmental aspects and sustainability in housing projects, with a percentage of 85%.
- Figure 25 reflects the level of satisfaction among residents regarding the use of new technology in their homes to monitor the aquaponics systems on the rooftops.
- Figure 26 shows the evaluation percentages from the selected sample of residents regarding green spaces, indicating that the majority are satisfied with the green areas, with a percentage of 60%.

<u>Challenges of Solar Panels:</u>

- Cost: Despite the significant reduction in the cost of solar panels in recent years, they still represent a substantial investment for citizens.
- Space: Solar panels require a large area to produce sufficient energy to meet the building's needs, which can be a challenge in buildings with limited space.
- Shade: Shadows from adjacent buildings or trees affect the efficiency of solar panels, reducing energy production.

• Maintenance: Solar panels require regular maintenance to ensure optimal performance, such as cleaning the panels from dirt and debris.

Common Challenges:

• Regulations and Laws: Many countries lack clear and comprehensive regulations governing the design and implementation of green roofs and solar panels, complicating matters and delaying the adoption process.

• Awareness: Many people lack sufficient awareness of the benefits of green roofs and solar panels, limiting their willingness to adopt these technologies.

Mechanisms to Overcome Challenges:

• Feasibility Studies: Conduct comprehensive feasibility studies to assess the economic and environmental viability of implementing these technologies in each building individually.

• Government Incentives: Provide financial and promotional incentives to encourage citizens to adopt these technologies, such as tax exemptions and subsidized loans.

• Cross-Sector Collaboration: Enhance cooperation among government, private, and academic sectors to develop innovative solutions to these challenges.

• Awareness Campaigns: Organize extensive awareness campaigns to educate the public about the benefits of these technologies and how to utilize them effectively.

Challenges in Implementing the Proposed Project:

The following figure (27) following illustrates the challenges facing the implementation of the proposed project, such as high initial costs, maintenance of irrigation systems and plants, and the preservation of fish life.

figure“ 27“ illustrates the challenges facing the implementation of the proposed project

Figure (28) illustrates following the future perspectives for sustainable economy through the role of rooftop projects, agricultural innovation, renewable energy, and aquaculture.

Figure “28“ illustrates the future perspectives for sustainable economy

Results:

It is evident from the Green Pyramid Evaluation Criteria table that the total score in the assessment has reached the Golden Pyramid rating, falling within the permissible score range of the Egyptian Green Pyramid classification, which is 60-79 points. Figure 35 illustrates the symbols of the Egyptian Green Pyramid certificate, highlighting the Golden Pyramid achieved by the proposed model's evaluation. figure “29 “following illustrates the symbols of the Egyptian Green Pyramid certificate

figure “29 “ illustrates the symbols of the Egyptian Green Pyramid certificate

Objective of the Building and Innovation Standard:

The Building and Innovation Standard aims to enhance the environmental conditions of the building not only during the design phase but also throughout the construction phase. Bonus points are awarded to projects that strive to mitigate environmental impacts through the construction phase by improving construction site practices and enhancing the sustainability aspect of the building through the adoption of innovative designs. The following factors are considered in the Building and Innovation section to mitigate the environmental impacts of the building during the construction phase and to improve the building's sustainability:

1. Provision of Systems and Procedures for addressing and managing potential environmental impacts associated with construction activities.
2. Encouragement of Innovative Technologies and Methods to enhance the sustainability aspect of the building.

Green roofs and solar cells are among the most important tools for achieving environmental sustainability in buildings; however, they face numerous challenges that require concerted efforts to overcome. By implementing supportive policies and legislation and providing necessary funding, the pace of adopting these technologies can be accelerated, leading to a more sustainable future.

Research Hypothesis Affirmation:

The positive affirmation of the research hypothesis has been established, indicating that there are many promising opportunities to achieve sustainable development in coastal areas if resources are managed properly. This project serves as a model for initiatives contributing to the Sustainable Development Goals and Egypt's Vision 2030. By integrating various environmental, economic, and social elements, this project can help build more sustainable and resilient cities in the face of environmental challenges.

Recommendations:

1. Developing Rooftops: The development of building rooftops as an entry point to a sustainable economy represents a promising opportunity for urban transformation.
2. Introducing New Technologies: It is crucial to incorporate new technologies and create financial incentives to encourage the development of building rooftops.
3. Future Research Focus: Future research should concentrate on replicating this approach and expanding its scope in other urban areas, addressing challenges, and developing innovative solutions.
4. Evaluation of Buildings: The importance of evaluating buildings using the Egyptian Green Pyramid system and similar systems.
5. Supportive Policies Development: Establishing supportive policies is essential.
6. Comprehensive Feasibility Studies: Conducting comprehensive feasibility studies to evaluate the economic and environmental viability of the project before implementation.
7. Selecting Suitable Species: Choosing plant and fish species that are suitable for the climatic and environmental conditions of the area is necessary.
8. Smart Irrigation Systems: Utilizing smart irrigation systems to minimize water waste.
9. Environmentally Friendly Materials: Using eco-friendly building materials in the construction of these systems.
10. Community Awareness: Raising awareness in the community about the importance of these projects and how to participate in them.

Additional Outputs from Energy Simulation:

- Life Cycle Cost Analysis: Analyzing the total cost of the project over its lifespan, including construction, operation, and maintenance costs.
- Sustainability Assessment: Evaluating the environmental sustainability of the project by analyzing carbon emissions and the use of sustainable materials.

Important Additional Points:

- Collaboration with Specialists: Collaboration with HVAC specialists and agricultural engineers specializing in aquaponics may be needed to achieve the best results.
- Continuous Updates: Regularly updating the Revit model throughout the design and construction phases to ensure accurate analysis.
- Utilizing Advanced Simulation Tools: Many advanced tools available in Revit can be used for a more detailed performance analysis of the building.

Conclusion:

The new Damietta project serves as an excellent case study for achieving energy-free buildings through green architectural strategies. It highlights the importance of passive design, renewable energy systems, energy-efficient heating, ventilation, and air conditioning (HVAC), sustainable materials, and monitoring for optimal energy consumption. With the growing global focus on sustainability, projects like Damietta pave the way for a greener and more energy-efficient future.

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