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The role of sustainable buildings in promoting energy consumption efficiency

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دور المباني المستدامة في تعزيز كفاءة استهلاك الطاقة

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Abstract:
The global community is increasingly prioritizing environmental conservation and sustainable development. Over the past three decades, a growing consensus has emerged that prevailing development models are unsustainable, as consumer-driven lifestyles have precipitated severe environmental crises. Empirical evidence suggests that humanity faces two critical challenges: the imminent depletion of essential natural resources and the escalating pollution caused by significant industrial and urban waste. Consequently, these challenges—compounded by resource scarcity and rising global toxicity—have positioned environmental sustainability, particularly through energy rationalization, at the center of intellectual, policy, and architectural discourse. Contemporary approaches to sustainable architecture emphasize the efficient management of natural resources throughout a building's entire life cycle, balancing functional, environmental, and aesthetic requirements. This research explores the role of green buildings in mitigating resource consumption and enhancing public health. Specifically, it examines strategies for implementing sustainable building practices that integrate traditional architectural principles with modern technological advancements to achieve energy efficiency.

Keywords: Green Building, Energy Conservation, Sustainable Development.

الملخص:
يعطي المجتمع العالمي أولوية متزايدة للحفاظ على البيئة وتحقيق التنمية المستدامة. وعلى مدى العقود الثلاثة الماضية، برز إجماع متزايد على أن نماذج التنمية السائدة لم تعد مستدامة، حيث أدت أنماط الحياة الاستهلاكية إلى تفاقم أزمات بيئية حادة. وتشير الأدلة التجريبية إلى أن البشرية تواجه تحديين حاسمين: النضوب الوشيك للموارد الطبيعية الأساسية، والتلوث المتصاعد الناجم عن كميات كبيرة من النفايات الصناعية والحضرية. ونتيجة لذلك، وضعت هذه التحديات – التي تفاقمت بسبب ندرة الموارد وارتفاع معدلات التلوث العالمي – الاستدامة البيئية، لا سيما من خلال ترشيد استهلاك الطاقة، في صلب النقاشات الفكرية والسياسية والمعمارية. وتؤكد المناهج المعاصرة في العمارة المستدامة على الإدارة الكفؤة للموارد الطبيعية طوال دورة حياة المبنى، مع الموازنة بين المتطلبات الوظيفية والبيئية والجمالية. يستعرض هذا البحث دور المباني الخضراء في تخفيف استهلاك الموارد وتعزيز الصحة العامة، ويبحث تحديداً في استراتيجيات تطبيق ممارسات البناء المستدام التي تدمج بين المبادئ المعمارية التقليدية والتطورات التكنولوجية الحديثة لتحقيق كفاءة الطاقة.

الكلمات المفتاحية: المباني الخضراء، ترشيد الطاقة، التنمية المستدامة.

1. Introduction

There are no longer clear boundaries between the environment and the economy since the emergence and widespread adoption of the concepts of green buildings and sustainable development. Ensuring the continuity of economic growth cannot be achieved while the environment is threatened by pollutants, waste, and the depletion of its natural resources.

Green buildings reinforce this close relationship between the environment and the economy. Proper green building design is achieved through the integration of traditional architectural principles with modern technological systems and methods. This contributes to energy consumption reduction by preserving natural construction materials and energy sources, increasing building durability, providing comfort for occupants, reducing operational costs, and minimizing pollution and waste through reuse and recycling practices. Studies indicate that green buildings can reduce electricity and water consumption by approximately 15% to 20%(2014), in addition to extending the building's lifespan [14].

Therefore, protecting the rights of present generations, ensuring a healthy and decent life, and safeguarding the rights of future generations represent a major challenge in the twenty-first century. Green and sustainable construction is considered one of the most important modern approaches that contributes to energy production and efficient energy use in a renewable manner.

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Hence, this research highlights the role of green buildings as one of the contemporary trends in architectural thought, which focuses on the relationship between buildings and their environment - whether natural or man-made - and their role in reducing energy consumption.

1.1 Research Problem

Studies indicate that the construction sector alone consumes a significant share of global energy, estimated at about (40 - 50%) of the world's energy consumption according to [14].

Moreover, more than half of the world's primary natural resources (approximately three billion tons annually) are used in construction activities. Traditional buildings are responsible for approximately one-third of greenhouse gas emissions. This situation calls for a more balanced approach to environmental interaction, particularly from architects, by seeking alternative design solutions and benefiting from natural and renewable energy sources in order to construct green buildings that contribute to energy conservation.

1.2 Research Objective

This research aims to identify the most important modern systems and design principles of green buildings, and to determine the key technical and engineering standards of sustainable construction. It also seeks to benefit from previous experiences, particularly the Dubai experience in green building implementation, and to apply these practices in Libya and other Arab countries.
In addition, the study aims to promote the use of natural and renewable energy sources and highlight their role in reducing energy consumption in Libya.

1.3 Research Methodology

The study adopts a descriptive-analytical approach by Examining the general principles of green building design, conducting an analytical study of Dubai experience in implementing green building systems through the Dubai Green Building Regulations issued by the Dubai Municipality, reviewing global experiences in the design and construction of green buildings and their role in reducing energy consumption and attempting to apply these experiences in Arab countries, particularly Libya. The overall structure of the research is illustrated in the following figure.

Role of Green Buildings in Optimizing Energy Consumption
General Principles of Designing Green Buildings
Dubai's Experience in Green Building Construction
International Experiences in Green Building Construction
Results - Recommendations

Figure 1: Research Methodology
Source: Researcher

2. General Principles of Green Building Design

Green buildings are those that are designed, constructed, and maintained to be environmentally and socially friendly. They respect the natural order of things and lead to efficient use and conservation of resources such as energy, water, and materials. They also aim to reduce negative impacts on human health through optimal site selection and the use of building materials and modern technologies that contribute to energy conservation and make use of natural and renewable energy sources. Figure 2 illustrates the general concepts of green buildings [16].
This includes the commitment to applying thermal insulation systems and reducing energy consumption through automated programmable thermostats in all air-conditioned buildings, equipping central exhaust fans with energy recovery units, and implementing control systems to reduce outdoor air intake when not needed. It also involves using light and reflective colors, especially on façades and roofs, installing rooftop gardens for thermal insulation, maintaining regular maintenance, and using alternative energy sources such as solar energy. In addition, it limits the use of ozone-depleting substances in air-conditioning systems or building materials such as asbestos and polystyrene [4].
Green buildings aim to:

a. Utilize natural resources available on-site as sources of renewable energy (solar and wind energy), as well as site components (plants, water, soil, geological formations).
b. Maintain public health, the surrounding environment, and the planet as a whole.
c. onserve energy, water, and other natural resources, and use renewable energy and environmentally compatible building materials.
d. Achieve the concept of sustainability in buildings and reduce costs of construction and maintenance.

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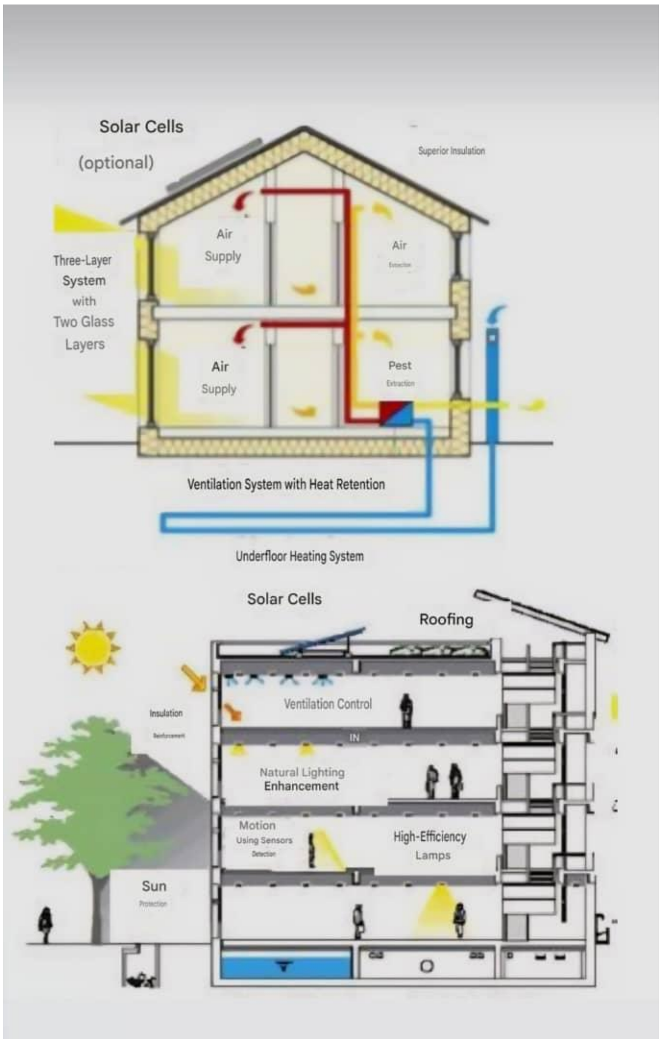
e. Use materials that have no negative environmental impact during production, use, maintenance, or disposal, while minimizing human exposure to toxic or harmful substances and reducing the environmental life-cycle impact through the efficient use of construction materials.
f. Proper waste disposal in a way that does not negatively affect the environment and treating waste in a manner that supports the ecological system.
g. Encouraging reduced car usage and promoting walking and bicycle use.



High-Efficiency Heating Equipment Rainwater Harvesting System

Figure 2: General Concept of Green Buildings

Source: http://www.derbyearth.com

2.1 Principles of Green Buildings

From this definition, it can be observed that the concept of green buildings represents a general goal that has been translated by several institutions into clear objectives and specific categories to facilitate its implementation. This has led to the emergence of the concept of sustainability in green buildings, whose main objective is to reduce energy consumption and maximize the use of natural and renewable energy sources. Among the most important institutions involved are:

a. The U.S. Green Building Council (USGBC), which developed the Leadership in Energy and Environmental Design (LEED) system [17].
b. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).
c. The Building Research Establishment (BRE), which supports environmental assessment and serves the United Kingdom, Europe, and Canada.
d. The Emirates Green Building Council (EGBC), which adapted the Leadership in Energy and Environmental Design (LEED) system to suit the environmental conditions of the United Arab Emirates.

Despite the differences and diversity among sustainable and green building systems, they all focus on the same goals and principles, which aim to reduce energy consumption and provide comfort for occupants without negatively affecting the environment. The principles, standards, operational systems, and modern construction technologies of green and sustainable buildings across these organizations can be summarized in Table 1 as follows:

Table 1: Modern Standards and Technologies of Green Buildings

Modern Principles and Technologies of Green Buildings		
Site and Design	**Environmental Design and Energy Conservation**	**Energy Management**
Indoor Environmental Quality	**Materials and Waste Management**	**Water and Wastewater Management**

Source: Researcher

LEED is considered one of the main systems in promoting building design and implementation. The word LEED stands for *Leadership in Energy and Environmental Design*, and its main objectives include:

a. Defining green buildings through standard specifications.
b. Promoting integrated design practices.
c. Encouraging leadership in the construction industry.
d. Encouraging competition among project owners.
e. Raising community awareness of the benefits of green buildings.
f. Increasing the economic efficiency of sustainable buildings.
g. Evaluating building performance throughout its entire life cycle.

LEED certifications are divided into **four levels**: (Certified, Silver, Gold, and Platinum). To obtain certification, it is necessary to meet the minimum requirements of the rating system - Fulfill all mandatory prerequisites - Achieve the required total points based on performance credits). The following table presents an analysis of the distribution of points for LEED criteria for buildings:

Existing Buildings			Assessment Points
Sustainable Site	26	Site Selection	4
		Exterior Building Assessment and Site Landscaping Works	1
		Site Management and Erosion Control	1
		Alternative Transportation	3:15
		Site Development and Protection or Restoration of Open Spaces	1
		Stormwater Management – Quantity Control	1
		Heat Island Effect – Non-Roof Surfaces	1
		Heat Island Effect – Roofs	1
		Reducing Light Pollution	1
Water use efficiency	14	Minimizing and optimizing the installation of sanitary fixtures within buildings	Mandatory
		Water Use Efficiency	1:2
		Innovative Wastewater Technologies	1:5
		Water Efficiency in Green Spaces	1:5
		Water Use For Cooling Towers	1:2
Energy and Atmosphere	35	Basic Planning For Building Energy Systems	Mandatory
		Minimum Energy Performance	Mandatory
		Basic Planning For Cooling Management	Mandatory
		Optimal Energy Performance	1:18
		Renewable Energy - Monitoring And Analysis	2
		Renewable Energy - Post-Implementation Costs	2
		Renewable Energy - Current Costs	2
		Building Performance Measurement - Automation Systems Integration	1
		Building Performance Measurement - Standard System Level	1:2
		On-Site and Off-Site Renewable Energy	1:6
		Enhanced Chiller Management	1
		Reporting for Emission Reduction	1
	10	Sustainable Procurement Policy	Mandatory
		Solid Waste Management Policy	Mandatory
		Sustainable Materials - Current Consumables	1
		Sustainable Materials - Electrically Powered Appliances	1
		Sustainable Materials - Furniture	1

Materials and Resources		Sustainable Materials - Facilities Modifications and Additions	1
		Sustainable Materials - Reducing Mercury Consumption in Light Bulbs	1
		Sustainable Materials - Food	1
		Solid Waste Management - Electricity Waste Statement	1
		Solid Waste Management - Current Consumables	1
		Solid Waste Management - Durable Goods	1
		Solid Waste Management - Facilities Modifications and Additions	1
Internal Environmental Quality	15	Minimum Indoor Air Quality Performance	Mandatory
		Environmental Control of Tobacco Smoke	Mandatory
		Green Cleaning Policy	Mandatory
		Indoor Air Quality Management Plan - Indoor Air Quality Management Programs	1
		Indoor Air Quality Management Plan - Monitoring Air Transferred from Outside to Inside	1
		Indoor Air Quality Management Plan - Increasing Ventilation	1
		Indoor Air Quality Management Plan - Reducing Particulate Matter in Air Distribution	1
		Indoor Air Quality Management Plan - Modifications and Additions to the Facility	1
		User Comfort - User Survey	1
		Controllable Systems - Lighting	1
		User Comfort - Continuous Thermal Comfort Monitoring System	1
		Daylight and Visibility	1
		Green Cleaning - Cleaning Performance Programs	1
		Green Cleaning - Evaluating Guard Effectiveness	1
		Green Cleaning - Purchasing Sustainable Cleaning Products and Materials	1
		Green Cleaning - Sustainable Cleaning Equipment	1
		Green Cleaning - Controlling Pollutants and Chemicals in Indoor Spaces	1
		Green Cleaning - Integrated Pest Management in Indoor Spaces	1
Design Creativity	6	Design Creativity: A Specific Topic	1
		Design Creativity: A Specific Topic	1
		Design Creativity: A Specific Topic	1
		Design Creativity: A Specific Topic	1
		LEED Certified Professionals	1
		Documenting the Impacts of Sustainable Construction Costs	1
Geographic Priorities	4	Geographical Priority: A Specific Topic	1
		Geographical Priority: A Specific Topic	1
		Geographical Priority: A Specific Topic	1
		Geographical Priority: A Specific Topic	1

2.1.1 Modern Standards and Technologies of Green Buildings

2.1.1.1 Site and Design

This axis focuses on the following aspects to achieve the highest levels of resource efficiency in green buildings [1]:

a. Increasing vegetation density around buildings, which helps improve the indoor environment, provides shading, reduces winter heat loss, and enhances cooling in summer through evaporation and shading.
b. Reusing buildings and sites to protect land and reduce the environmental impact of new expansions, especially brownfield sites affected by previous uses such as industrial areas.
c. Controlling pollution resulting from surface runoff and lighting, and reducing heat increase in urban heat island areas caused by replacing natural vegetation with concrete and paved surfaces.
d. Maximizing the use of the surrounding environment by selecting building sites that serve environmental objectives and reduce consumption through direct and indirect use of natural elements such as sunlight and shading.

Figure 3 illustrates multiple technologies for harnessing solar energy in generating electricity for green buildings.

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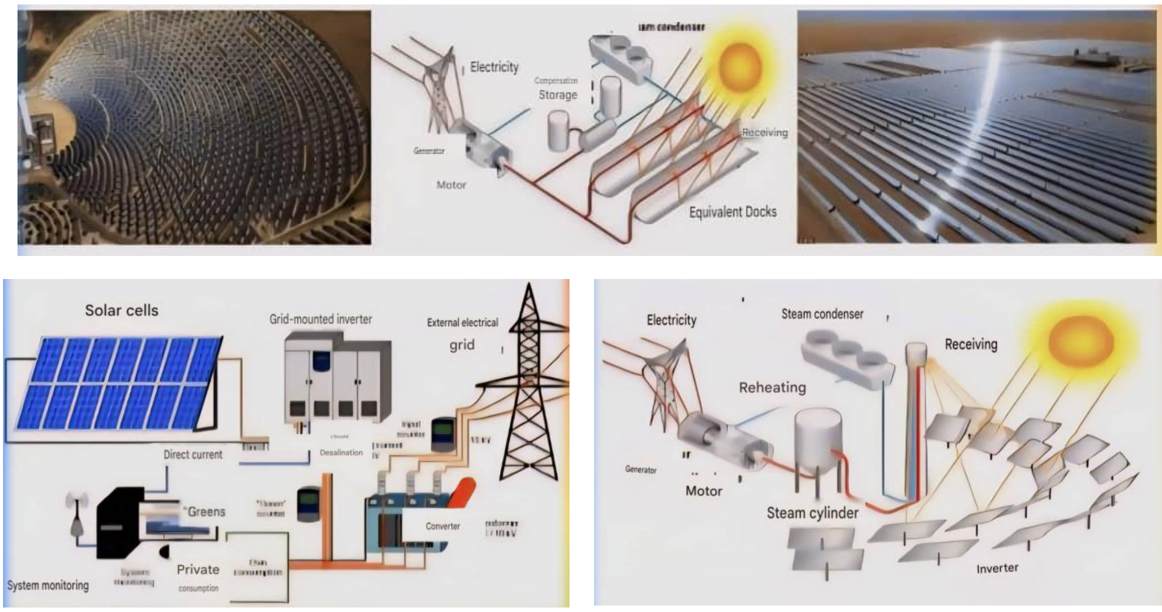

Figure 3: The Various Technologies for Harnessing Solar Energy to Generate Electricity using Solar Cells for Green Buildings
Source: http://news.travelerpedia.net

2.1.1.2 Environmental Design and Energy Conservation

The main objective of this axis is to utilize the local natural environment in a way that benefits the building from several aspects, as well as to exploit building components to support other performance characteristics.

a) Integrated Building Design:

This involves linking all aspects related to the building and making the design beneficial in multiple areas (such as lighting, air conditioning, interior design, and construction). Although these aspects may appear unrelated, it is possible to create opportunities by using one aspect to support another. This is achieved by bringing together specialists to identify key common points that can be utilized during the design process. The success of integrated design increases the building's effectiveness in reducing energy consumption [1].

One of the most important of these opportunities is:

b) The Use of Natural Daylight:

By balancing the need for electric lamps and the heat they generate, and the natural daylight system by reducing the number of lighting fixtures and increasing the number of windows, where sunlight can be controlled through the shape and location of the building and the development of effective strategies for using glass in terms of size, location and orientation in a more artistic than engineering way, as illustrated in Figure 4. "Light transmission through indirect pipes and utilizing the sun as a source of heat and ventilation" [8].

c) Light transmission via pipes for natural lighting:

Natural light is transmitted through curved and straight pipes, relying on reflections in prisms or optical fibers to reach interior spaces not directly exposed to sunlight [8].

d) Natural ventilation:

Temperature or air pressure differences are used to create airflow in the building. This process is based on two basic principles: the buoyancy of air due to temperature differences and air flow (due to air pressure differences). It is one of the most important indirect cooling strategies.

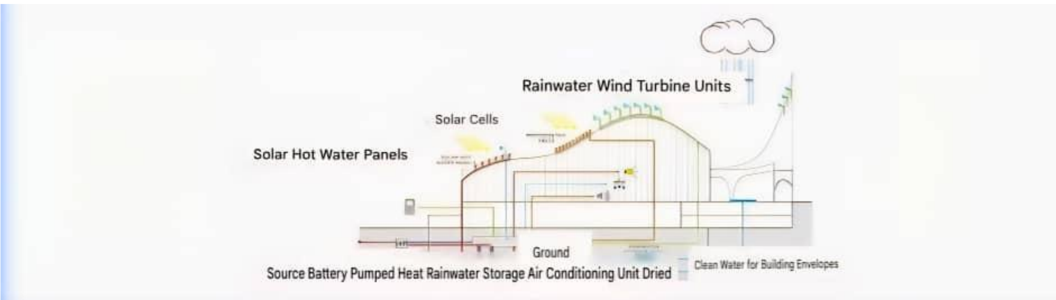

Figure 4. A Perspective View illustrating Indirect Light Transmission via Tubes and utilizing the Sun as a source of Illumination and Natural Ventilation.
Source: www.bigfoto.com

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e) Indirect Solar System:

By using the sun as a heat source for heating, water heating and ventilation, it also helps to reduce cooling loads. This is done by integrating a number of building elements such as exterior walls, windows and building materials to be used for daylighting and reducing electric lamps, and thus reducing the heat emitted from the lamps, which reduces the need for cooling and thus reduces the size of air conditioning units, and reduces the initial cost and consumption cost of the facility, i.e. it improves the performance of the building and works to rationalize energy consumption [6].

f) The building Shell

It is the envelope that separates the building's interior and exterior environments. An efficient building envelope design significantly reduces cooling and heating loads, thus minimizing the size of installed equipment and its future energy consumption. Figure 5 illustrates this, showing the utilization of exterior walls and roofs by installing solar cells as a power generation source at Seoul Airport in Korea.

Figure 5: Utilizing Exterior Walls and Roofs by Installing Solar Panels as a Power Generation Source
Source: www.google.com

g) Thermal Insulation

Thermal insulation is considered one of the best long-term methods for saving energy and improving indoor air quality in buildings. Insulation can be achieved through materials such as felt, lightweight filling granules, and foams, which reduce heat transfer from inside the building to the outside or vice versa. The largest portion of heat loss occurs through windows, walls, roofs, and ventilation openings. It is estimated that about 70% of the heat lost from the building envelope is the heat that must be removed by air-conditioning systems [9].

There are also various types of insulating materials, including organic materials such as wool, fibers, and cellulose-based materials; inorganic materials such as glass wool and rock wool; synthetic materials such as rubber and polystyrene foam; and reflective materials such as aluminum, steel sheets, reflective paper, and reflective paints. These materials are used to support the sustainability of buildings, improve their long-term efficiency, and reduce energy consumption.

h) Walls and Roofs:

Internal reflective surfaces and shading materials are used for walls, such as trees with dense shade and shading devices, which reduce cooling loads [15]. Figure 6 elucidates the use of trees as a shading source to reduce thermal loads and their impact on energy conservation.

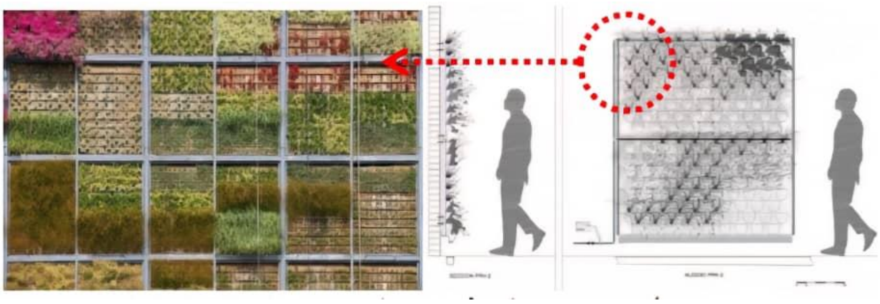

Figure6: Using trees as a shading source for walls to reduce thermal load
Source: news.travelerpedia.net

i) Green Roofs:

New lightweight and dense soil-like materials called "*Bafkal*" have been developed for use in rooftop planting. Ordinary soil can also be used to reduce building heat significantly. These materials can retain water and absorb a large portion of rainwater or hold it until it evaporates, helping to reduce pollution effects. Figure 7 shows rooftop and façade greening. [6]

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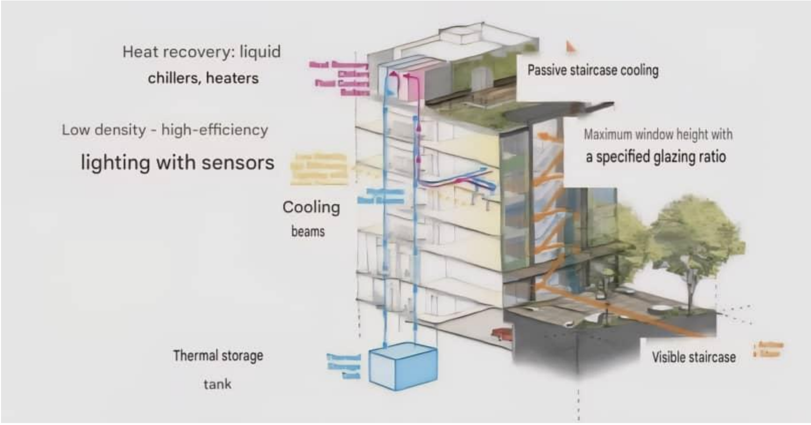

Figure 7: Illustration of Rooftop and Façade Greening
Source: www.digitalapoptosis.com

j) Windows and Glass:

They have a significant impact on energy consumption and indoor temperatures. Although natural daylight entering through windows is important, the thermal impact of solar radiation must be reduced through shading and thermal insulation techniques. This allows beneficial solar radiation to pass through while reducing unwanted heat gain. Double or multi-layer glazed windows are used, with the spaces between the layers filled with an inert gas such as argon, which prevents heat transfer through the glazing. It is also preferable to use window frames made from thermally insulating materials such as wood and vinyl. Figure 8 illustrates the use of double glazing with gas filling to reduce thermal load within the space.

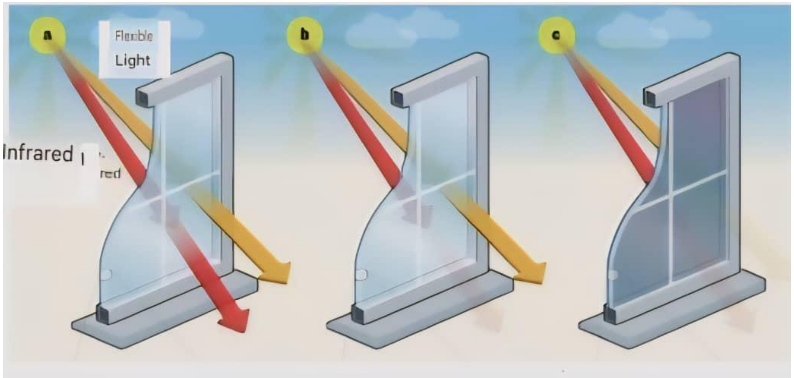

Figure 8: Use of Double Glazing with gas-filled Spaces to reduce Thermal Load
Source: http://www.mjhar.com

i) Energy Management:

The integrated building design mentioned earlier significantly supports energy management [17]. Building design can be optimized to reduce energy consumption by using modern construction systems, such as harnessing wind energy to generate electricity, as seen in the Bahrain World Trade Center. Figure 9 illustrates the use of wind turbines as a source of electrical power generation.

Figure 9. Using Wind Turbines as a Source of Energy Generation
Source: http://www.almaniah.com/tourism

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k) Indoor Environmental Quality:

Indoor environmental pollution results from mistakes made during different stages of construction and operation, leading to serious health concerns. However, it can be avoided at any stage of building design, construction, and operation as follows:

- **Ventilation and smoking control:** Smoking should be controlled in buildings by designating specific smoking areas equipped with air filters, or by completely banning smoking indoors.
- **Organic pollutants:** These include bacteria and dust caused by leakage and moisture infiltration. Therefore, indoor humidity should not exceed 50%, using moisture-absorbing materials and proper humidity control systems.

l) Water and Treated Water Management

In this section, the focus is on encouraging water recycling through various methods in order to rationalize water consumption, as follows:

- **Effective Water Management:**

This is achieved by reducing water losses through leakage control, repairing pipelines, and using low-flow fixtures such as toilets, sinks, showers, and drinking fountains that reduce water consumption [7]. These devices are equipped with narrow-opening spray heads that provide the same performance as high-flow systems (spray jets).

- **Faucets and Drinking Fountains:**

Several technologies are used, such as automatic control systems, sensor-based operation, or devices that deliver a predetermined amount of water before shutting off automatically. These methods help significantly reduce water consumption.

- **Greywater Reuse:**

Greywater refers to water generated from showers, bathtubs, bathroom sinks, washing machines, drinking fountains, and even water from air conditioners and refrigerators.

It can be directly reused for applications such as irrigation, cooling, industrial purposes, toilets, and fire-fighting systems [18]. However, it should not be used for irrigating vegetables or fruits. One of its drawbacks is the need for a separate plumbing system from blackwater and other wastewater sources. It must also be filtered and regularly tested to ensure safety, using self-cleaning or easily maintained filters. Figure 10 illustrates modern methods of greywater reuse and its role in reducing water consumption.

- **Effective Management of Treated Water:**

Greywater and blackwater (from toilets and industrial uses) are treated through dedicated systems. Facilities with high water consumption, especially industrial ones [7], are encouraged to install on-site treatment units to support recycling and reduce water demand.

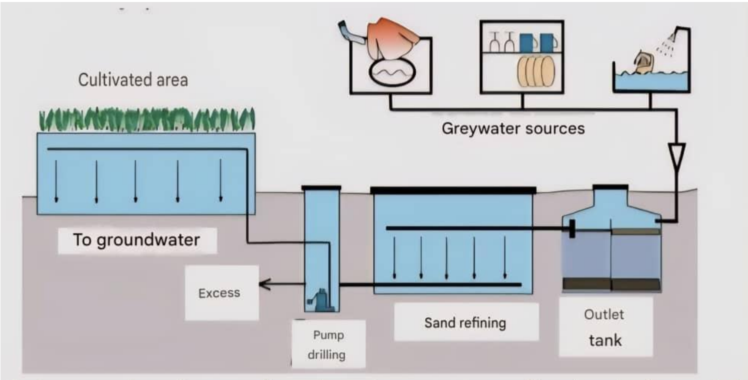

Figure 10: Modern Methods of Greywater Reuse and Its Role in Water Conservation
Source: http://www.derbvearth.com

- **Stormwater Harvesting:**

Stormwater / Rainwater can be collected, stored, and purified before use for drinking to ensure safety. Harvesting rainwater has multiple environmental benefits, including reducing floods and decreasing pressure on limited water resources [7]. Rainwater is generally of better quality compared to other sources due to its low mineral content and lower levels of contaminants such as arsenic and naturally occurring toxins found in groundwater.

3. Dubai's Experience in Green Building Development

The United Arab Emirates continues to make ongoing efforts to build sustainable communities and an environmentally friendly economy for sustainable development. It has implemented several measures to reduce greenhouse gas emissions, aiming to support the design and construction of sustainable communities and create a healthy environment and stable economy for both present and future generations. These will be well-planned communities, built and operated to provide citizens and residents with a safe place to live and work.

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The Government of Dubai has launched a sustainable development initiative aimed at creating sustainable communities that protect the environment and its natural resources. Accordingly, green building specifications have been mandated for all buildings and facilities in the Emirate of Dubai, in line with the best international environmentally friendly standards adapted to local conditions.

The goal is for Dubai to remain a healthy city that follows the highest environmental sustainability standards, with a clean environment free from pollutants, directly contributing to rationalizing energy consumption. Table (2) illustrates the main pillars of the Green Building Regulations.

At the beginning of 2014, the application of Dubai Green Building Standards became mandatory in both the public and private sectors. It is well known that more than 50% of the world's population lives in cities, and this percentage is continuously increasing. We live in an era where human activities increasingly negatively affect nature and its resources, which in turn impacts current lifestyles. Since cities generate about 80% of the global GDP [2], it has become essential to implement strategies that create safe and comfortable communities with good governance and simultaneous economic growth.

This is achieved by improving building performance in Dubai through reducing the consumption of energy, water, and materials, and improving public health and safety by enhancing planning, implementation, and operation processes. This helps create a distinguished urban environment that provides quality of life and success factors. The regulation also aims at the practical application of sustainable building development throughout the entire building life cycle - from site selection, design, construction, operation, and maintenance, to demolition and recycling.

The Green Building Regulation also seeks to rationalize energy consumption through:

a. Setting clear goals and targets such as reducing energy and water consumption in buildings, minimizing waste, and converting it into resources.
b. Assisting developers in accessing the necessary resources to create sustainable communities.
c. Establishing a set of standards for resource-efficient model cities.
d. Providing technical expertise to investors and developers.
e. Connecting companies, suppliers, and relevant organizations with each other.

Table 2: Main Pillars of the Green Building Regulations
Source: Dubai Municipality Green Building Regulations, p. 6, published on the official website of the Government of Dubai www.dm.gov.ae

Energy	Encouraging the use of high-quality insulation systems, improving window performance, reducing energy used in lighting, and using high-efficiency air conditioning systems.
Water	Encouraging the use of devices that reduce water consumption and improve water purification efficiency.
Resources	Encouraging the use of recycled materials.
Indoor Environment	Encouraging the use of non-harmful materials that do not cause respiratory diseases, such as low-emission materials and formaldehyde-free products.
Design	Encouraging the creation of larger internal open spaces.

Table 3: Buildings Subject to the Green Building Regulations

Buildings Subject to the Green Building Regulations			
Residential Villas	**Residential and Commercial Buildings**	**Public Buildings**	**Industrial Buildings**
Investment Villas - Private Buildings - Traditional Arab Housing	Residential apartments, workers' accommodation, and student housing - Hotel establishments, hotels, hostels, and hotel apartments - Laboratories and offices - Resorts and restaurants	Banks and Financial Institutions - Theaters and Cinemas - Educational Buildings - Government Buildings - Health Buildings and Facilities - Historical and Heritage Buildings - Museums - Petrol Stations - Post Offices - Retail Stores - Shopping Centers - Mosques and Places of Worship	Factories and Workshops - Warehouses - Workshops and Plants

Source: Dubai Municipality Green Building Regulations, p. 6, published on the official website of the Government of Dubai www.dm.gov.ae

3.1 Requirements and Specifications of Green Buildings in the Emirate of Dubai

In line with achieving the objectives of the Dubai Strategic Plan and the efforts of Dubai Municipality to preserve the environment and natural resources, and in reference to Administrative Resolution No. 344 of 2011 issued on 27/11/2011 regarding the approval and implementation of the Green Building Regulations and Specifications in the Emirate of Dubai, the regulation addresses the following five main pillars:

3.1.1 First Axis: Building Design and Environment

This axis focuses on entrances and mobility accessibility in terms of: (dedicated parking spaces / accessibility for people with special needs / bicycle parking) [2], it also includes site landscaping using native plants, and improving the surrounding climatic comfort of the building by addressing:
Urban heat island effects / green roofs / use of light colours in façades / impact of construction and demolition activities / environmental impact assessment, green building regulations.

3.3.2 Second Axis: Building Vitality and Human Comfort (Building Health)

This axis studies the building's role in reducing energy consumption and its impact on human health through three main aspects:

- **Ventilation and Air Quality:**

Minimum ventilation requirements to ensure indoor air quality / indoor air quality during construction, renovation, or interior finishing / air intake and exhaust outlets / isolation of pollution sources / ensuring indoor air quality in new and existing buildings / smoking regulation in public spaces.

- **Thermal and Acoustic Comfort:**

Sound control and acoustic insulation.

- **Hazardous Materials:**

Low-emission materials (paints and coatings) / low-emission adhesives and sealants.

- **Natural Lighting and Visual Comfort:**

Provision of natural daylight / visual access and views.

- **Water Quality:**

Water systems and Legionella bacteria control / quality of water used in decorative water features.

3.3.3 Third Axis: Energy Efficiency

This axis focuses on energy efficiency in buildings and its role in reducing energy consumption through three key aspects:

- **Efficiency and Conservation (Building Shell):**

Minimum performance requirements for the building shell / thermal bridges / heat load limitations / air leakage / loss of air through entrances and exits.

- **Energy Efficiency – Building Systems**

This axis focuses on energy efficiency in buildings through the optimal use of systems and equipment, including: Energy-efficient use / air-conditioning units and systems / demand-controlled ventilation systems based on occupancy levels / lighting density and external electric lighting power control / electronic ballasts and lighting control devices / heating, ventilation, and air-conditioning (HVAC) control systems / pipe and duct insulation / thermal energy storage for district cooling systems / air leakage in ducts / maintenance of building services.

Energy Management

This includes the commissioning of building services and energy monitoring systems, such as: electricity meters / air-conditioning consumption meters / centralized monitoring and control systems / (Renewable Energy Generation): on-site renewable energy systems / small and medium-scale generators / external lighting / solar water heating systems.

3.3.4 Fourth Axis: Water Efficiency

This axis focuses on rationalizing water use in buildings and recycling it through various methods to enable reuse, including: (Rationalization and Efficiency): high-efficiency water fixtures and systems / air-conditioning condensate drainage reuse / water metering systems / wastewater reuse systems / use of water in heat exchange systems.

3.3.5 Fifth Axis: Resource Efficiency and Waste Management

This axis focuses on recycling construction materials and waste, and using sustainable and environmentally friendly building materials through two main areas:

- **Materials and Resources:** Thermal and acoustic insulation materials / materials containing asbestos / materials containing lead or heavy metals / ozone-depleting substance management materials / recycled materials / locally available materials / composite wood products.
- **Waste Management:** Construction and demolition waste / collection of bulky waste / waste disposal areas / facilities for managing recyclable materials.

4. International Experiences in Green Building

This section analyzes two international projects that apply advanced green building technologies and demonstrate their impact on energy efficiency. These examples provide valuable lessons for future projects.

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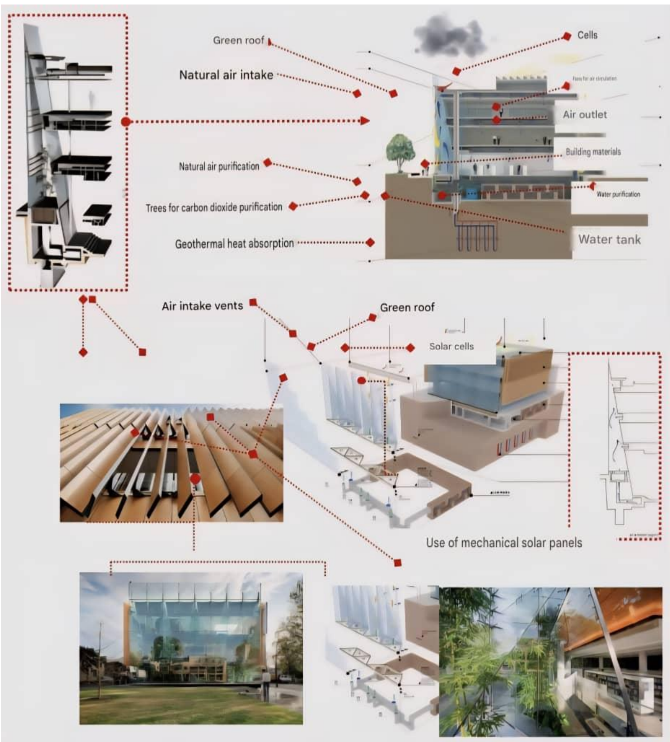
Surry Hills Library Project
Architects: Francis-Jones Morehen Thorp, **Location:** Surry Hills, New South Wales, Australia,
Project Year: 2007–2009

Energy-saving technologies used in the building (as shown in Figure 12):

- Efficient use of environmental resources and sustainable building materials to reduce annual costs
- Rainwater harvesting system stored in underground tanks with a capacity of 620,000 liters, used for cleaning, toilets, and irrigation of indoor and outdoor plants, as well as for cooling the building [20].
- Automatic sun-shading devices that adjust according to light intensity.
- Roof openings integrated with plants to naturally filter and cool the air.
- Installation of solar panels on the roof of the building and converting solar energy into electrical power.
- Utilization and greening of rooftops to reduce the thermal load on the upper floors.
- Harvesting rainwater and storing it in underground tanks beneath the building. Rainwater is then circulated through pipes throughout the building, with fans installed alongside the pipes to cool the indoor spaces.
- Creating openings near the staircase to allow hot air to escape.
- Using white color for interior finishes, which enhances the perception of spaciousness within the interior spaces.



Maximizing Natural Light *Airflow through the front facade, passing through planting beds behind the facade to convert carbon dioxide into oxygen*

Figure 12: Technologies Used in the Surry Hills Library Project
Source: https://www.archdaily.com

Jacobs Institute for Design Innovation; Berkeley, CA 2016
Leddy Maytum Stacy Architects

a- Design and Innovation

The mission of Hakous Institute is to expand the role of design in engineering education at all levels and to enable young engineers to create innovative solutions to major societal problems. The design and implementation of the project help reduce carbon dioxide emissions in outdoor spaces, reflecting the sustainable values of the institute and the university. The project design and execution have achieved our

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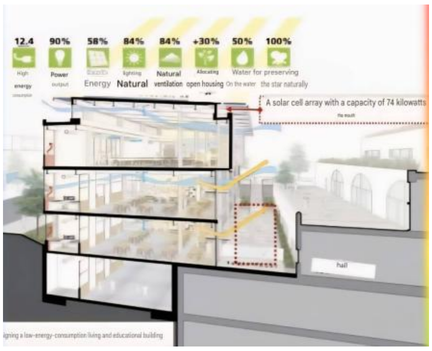
economic strategy by using 90% less energy than the average university buildings [19], in line with the 2030 AIA goals (American Institute of Architects 2030 vision).

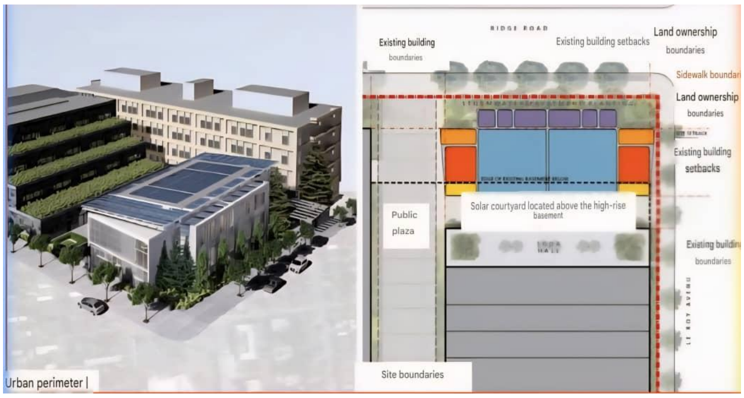


The American Institute of Architects
Designing a low-energy living and learning environment

Figure 12 Illustrates the Main Ideas for achieving the Principles of Green Architecture and Its Positive Impact on Energy Conservation
Source: https://www.aia.org
American Institute of Architects

b. Community Design (Regional community)

It is a multidisciplinary center affiliated with University of California, Berkeley, for students, educators, and practitioners working on research that combines design and technology. The building is located at the northern corner of the campus and serves as a new gateway to the university and a "beacon of innovation" that attracts students at all times. Northern solar cells were placed as projections on the roofs and oriented toward the north to express the ambition of youth toward the future. All staircases are directed outward to create a sense of welcoming visitors into the building, and the façades consist of transparent glass that lights up at night.



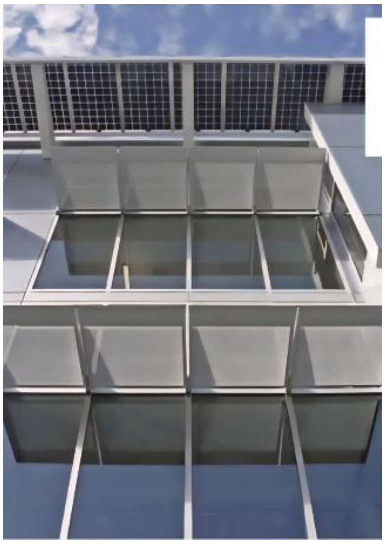
Urban perimeter

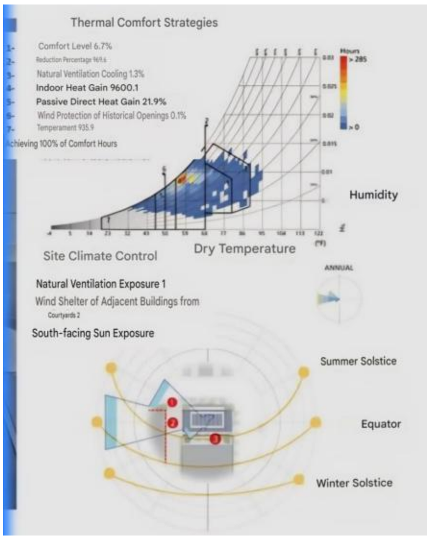
Site boundaries

Figure 13 Shows the Use of the Site and Building Roofs to install a Large Number of Solar Cells for Energy Generation, Contributing to Shading Part of the Façade as well as serving as an Aesthetic Element
Source: https://www.aia.org
The American Institute of Architects

c- Orientation

The building is oriented along an east–west axis to maximize solar benefit, which created a sunlit courtyard exposed to warm winds, as well as continuous daylight availability and natural ventilation in the external courtyard and most internal and external spaces on the ground floor. Figure 14 illustrates thermal comfort strategies and the effect of the external envelope on shading inside the building.





High-Efficiency Building Envelope with Integrated Shading Systems

Figure 14 shows the building orientation to benefit from the maximum possible solar gain, daylight, and natural ventilation, along with solar shading devices

Source: https://www.nia.org / American Institute of Architects

d- Lighting and Air

- **Daylight**
  The proximity of buildings on the ground floor in the southern side created shading on façades while allowing the enjoyment of natural daylight. Large windows facing north, along with internal glazing, help reduce internal glare. This resulted in achieving natural daylight throughout most of the day in 100% of educational spaces above the basement level and 85% of all occupied spaces. Figure 15 illustrates the impact of daylighting and natural ventilation on interior spaces [19].
- **Biophilic Benefits**
  Biophilic design benefits were also studied in relation to daylight within the design, ensuring activation of public spaces throughout the day.
- **External Views**
  Transparency is a key strategy used in the project to enhance a healthy learning community and well-being. It provides 100% of educational spaces above the basement level and 85% of all occupied spaces with visual access to outdoor courtyards.
- **Air**
  The building achieves 100% of educational spaces above the basement level and 85% of all occupied spaces with regular natural ventilation. Mechanical ventilation provides additional fresh air when windows are closed, supplying 30% additional outdoor air above the requirements of U.S. educational building ventilation codes.
  Paints free from volatile organic compounds (VOCs), adhesives and sealants, as well as materials free from formaldehyde, are used to ensure healthy indoor air quality and a safe, non-toxic indoor environment.

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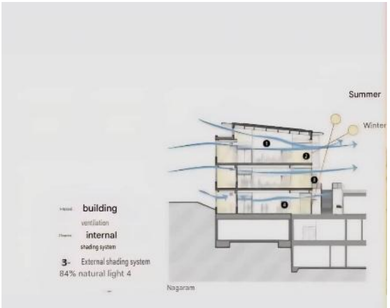


Use of double glazing to separate spaces

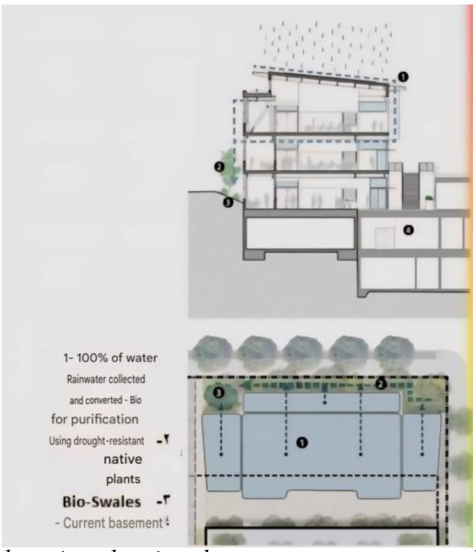
Figure 15. 100% of the learning spaces benefit from natural daylight and ventilation

Source: https://www.aia.org / American Institute of Architects

e- Water Cycle

The project is located in a semi-arid climate that suffers from continuous drought periods. It reduces potable water consumption by 50% and treats 100% of roof runoff within the confined small site. Figure 16 illustrates the utilization of rainwater and its reuse.

- **Building Water Use:**
  The use of low-flow sanitary fixtures contributes to reducing water consumption by 50%.
- **Landscape Water Use:**
  Drip irrigation systems and sensors are used in irrigation devices, which help reduce water usage by 50% compared to conventional methods [19]. In addition, drought-tolerant plant species that require minimal water are used.
- **Stormwater Management:**
  100% of rainwater is collected through a dedicated piping system that gathers rainfall from building roofs [19]. The collected water is then distributed to green areas and treated through Bio-swale.



Plant and section showing the rainwater harvesting system

Naturally treating rainwater using Bio-Swales

Figure 16. Rainwater Harvesting and Reuse

Source: https://www.aia.org / American Institute of Architects

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f- Energy Flows & Energy Future

The project aims to achieve the AIA 2030 Vision (United States) by attempting to reduce energy consumption by 90% compared to the average energy use of university buildings, according to targeted environmental protection agency reports [19].

- **High-Performance Envelope**
  The building's external envelope includes additional insulation, solar shading systems, cool roofs, high-performance glazing, and daylighting strategies. All these systems work together to reduce thermal loads and contribute to passive cooling, heating, and lighting, thereby significantly reducing overall energy consumption.
- **Ventilation**
  The building is naturally ventilated and supplemented by mechanical ventilation in interior spaces and basement levels. It provides 30% more outdoor air than ASHRAE standards, improving indoor air quality when windows are closed [19].
- **Thermal Comfort**
  The building utilizes surplus hot and chilled water for air conditioning systems to enhance thermal comfort and improve energy efficiency.
- **Renewable Energy**
  Solar photovoltaic panels supply approximately 58% of the building's energy demand [19], while also serving as an aesthetic feature on the façade.

South Façade Treatment and

Figure 17: Utilizing the Exterior and Natural Ventilation to Reduce Energy Consumption

Source: https://www.aia.org / American Institute of Architects

g- Materials & Construction

- **Resource Reduction**
  Resource use was reduced through the design of simple architectural models using a basic structural system and standard construction dimensions.
- **Materials**
  Economical, durable, and 50% recyclable building materials were selected.
- **Health**
  Special attention was given to ensuring a healthy indoor environment, including the use of materials free from volatile organic compounds (VOCs), and free from vinyl, and formaldehyde. Indoor Air Quality (IAQ) management plans were implemented during construction and pre-occupancy phases.
- **Waste Reduction**
  Approximately 1,595 tons of construction and site waste (97%) were recycled and diverted from landfills. Recycling and composting stations throughout the building support ongoing waste management practices.

4. Results

- Green buildings reduce energy consumption by 24 - 50%, while conventional buildings consume about 40% of global energy.
- Green buildings reduce carbon dioxide emissions by 39.9%, whereas conventional buildings are responsible for approximately 35% of greenhouse gas emissions.
- Solid waste generation is reduced by 70% in green buildings, while conventional buildings contribute about 28% of solid waste and occupy up to 20% of landfill capacity.

- Electricity consumption in green buildings is less than 100 kWh/m²/year, compared to approximately 200 kWh/m²/year in conventional buildings.
- Water savings in green buildings are achieved through simple investments and behavioural changes in consumption.
- Energy savings are achieved through behavioral changes and the use of low-cost available technologies.

5. Recommendations

- In designing building there should be considered climatic factors such as heat, wind, and rainfall, with emphasis on natural lighting and ventilation, and encouraging the use of renewable energy for heating and cooling systems, as well as water conservation.
- Implementation of energy efficiency codes in buildings should be enforced.
- Designers should be encouraged to reuse waste materials and recycle water for irrigation and cleaning purposes.
- Efficient land use should be promoted to reduce required land areas and minimize travel distances.
- Adoption of modern technology in residential infrastructure and integration with urban and neighborhood networks is essential.

- Building regulations, infrastructure systems, and local management systems must be developed to align with sustainable city requirements.
- Planning systems and building codes should be flexible and adaptable to accommodate sustainable development proposals.
- Building codes should be expanded to cover all aspects of architecture in order to accommodate modern technologies, energy-saving strategies, and green architecture requirements.
- There should be an emphasis on the use of renewable energy sources through advanced and cost-effective methods, such as solar energy, wind energy, bioenergy, hydropower, and geothermal energy, while also benefiting from Dubai's experience in green building practices.
- Benefiting from Dubai's experience in laying out strategic visions to activate green building concepts.
- Use of recyclable building materials.
- Reuse of water within buildings.
- Optimization of building orientation with photovoltaic panels installed on rooftops.
- Utilization of rainwater harvesting and reuse systems as demonstrated in research examples.
- Dependence on natural lighting and maximizing its use.
- Use of paints free from volatile organic compounds (VOCs), low-emission adhesives, sealants, and formaldehyde-free materials.
- Installation of low-flow sanitary fixtures in bathrooms and kitchens.
- Drip irrigation systems for green landscapes.
- Use of glazing systems that reduce thermal loads within interior spaces.

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