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Nurturing Sustainable Urban Space: Integrating Smart City Innovations and Earthship Design Principles for Eco-Friendly Futures

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Abstract:

This research delves into the convergence of smart cities and Earthship design principles to explore the potential for creating sustainable, eco-friendly urban environments. Smart cities leverage innovative technologies to enhance efficiency, while Earthship design embraces sustainable building practices, renewable energy, and resource conservation. By combining these approaches, this study aims to highlight the benefits and challenges of integrating smart technologies and Earthship design concepts to build resilient and sustainable cities of the future. This study investigates how to develop metropolitan areas that are resilient, environmentally friendly, and energy-efficient by combining smart city technologies with Earthship design concepts. By applying Earthship concepts to the larger urban landscape, smart cities can incorporate biophilic design components, green areas, and integrated waste management systems. Earthship principles can be incorporated into smart city infrastructure to promote active community involvement and foster a sense of environmental responsibility among urban residents. Finally, the intersection of smart cities and Earthship architecture offers a cutting-edge solution to the urgent worldwide problems of urbanization and environmental deterioration. Cities may advance toward sustainable urban projects that prioritize environmental preservation, human well-being, and resilience in the face of an uncertain future by utilizing the power of technology and nature-inspired design approaches.

Keywords:

Smart cities, Earthship design, Sustainable urban developments, Internet of Things (IoT), Environmental sustainability.

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1. Introduction:

The search for sustainable solutions to sculpt the cities of the future has become necessary due to the problems posed by climate change and resource depletion. Two cutting-edge ideas—smart cities and Earthship design—have emerged as possible routes toward sustainable urban development in response to this urgent demand. Smart cities use cutting-edge technologies and data-driven strategies to optimize resource management and boost the effectiveness of their urban infrastructure. On the other side, the Earthship design, which draws its inspiration from nature's self-sustaining systems, promotes eco-friendly practices and self-sufficient living through the use of natural and recyclable resources.

Through the combination of the Internet of Things (IoT), artificial intelligence (AI), and real-time data analytics, smart cities change urban life. Cities can now gather and analyze enormous volumes of data thanks to these technologies, which helps them make wise decisions and optimize their transportation, waste management, and energy usage. Therefore, smart cities have the potential to promote environmental sustainability, support economic growth, and improve the quality of life for those who live there.

An architect, Michael Reynolds invented the Earthship concept, presenting a novel but useful way to sustainable living in an urban setting. For self-sufficiency, these autonomous, off-grid homes rely on passive solar energy, rainwater collection, and wastewater recycling. Earthships are a prime example of peaceful coexistence with nature and the reduction of environmental effects since they incorporate biophilic design elements and emphasize the use of recycled and natural materials. A paradigm shift towards more holistic and regenerative urban planning will be achieved through the combination of smart city technology with Earthship design concepts.

1.1 Research objective

The main objective of the research on Smart Cities and Earthship Design: Towards Sustainable Urban Development is to develop a holistic and innovative approach to urban planning and development that prioritizes sustainability, self-sufficiency, and eco-conscious living practices. This research aims to explore, synthesize, and promote a model of urban development that integrates Earthship design principles and smart city technologies to create sustainable, resilient, and livable urban spaces.

1.2 Research Aim

This research seeks to provide a comprehensive understanding of the integration of smart city technologies and Earthship design principles to promote sustainability and resilience in urban environments. By harnessing the power of advanced technologies while embracing Earthship's sustainable building techniques, cities can move towards a more harmonious relationship with nature, reduce their ecological footprint, and enhance the well-being of their residents.

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1.3 Research Methodology

This methodology aims to create a robust foundation for investigating the integration of smart city innovations and Earthship design principles, incorporating diverse perspectives to nurture sustainable urban spaces for eco-friendly futures in these steps:

- Case Studies: Identify and analyze case studies of cities that successfully integrate smart city innovations and Earthship design principles into their urban fabric. understand the similarities, differences, and outcomes of these integration efforts.

-Establish focus groups: comprising diverse participants to facilitate discussions on potential conflicts, opportunities, and collaborative strategies.

-Earthship and Smart City Design Prototype: Create a conceptual design prototype showcasing the incorporation of Earthship principles in urban architecture.

-Analysis Framework: Develop an analytical framework to identify and evaluate integration points between smart city innovations and Earthship design principles.

-Synthesis and Conclusions: Derive conclusions and provide actionable recommendations for urban planning, policy development, and architectural design.

2. Literature Review

From the analysis of previous studies where information about smart cities, Earthship design, and sustainable urban development is found, and by using these sources, information can be accessed, namely:

Smart Cities Council: Their website offers numerous reports, case studies, and resources on smart city initiatives worldwide, and often publishes reports and analyses on smart city trends, technologies, and best practices [1].

How to Build Your Own" by Michael Reynolds: This book is a comprehensive guide to Earthship design principles and construction methods, also Michael Reynolds' organization, Earthship Biotecture, provides valuable information, case studies, and examples of Earthship projects [2].

World Green Building Council: This organization focuses on sustainable building and urban development practices. Their website publishes reports and resources on sustainable urban development goals and strategies [3].

2.1 Background on Smart Cities

A smart city is an urban area that employs technology, data, and innovation to improve people's quality of life, urban services, and operations, and to promote sustainability and efficiency in different facets of urban

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living. The concept of a "smart city" refers to incorporating digital technology, communication networks, and data analytics into various components of a city's infrastructure and services to create a more connected, responsive, and intelligent urban environment. Smart cities seek to overcome the problems of growing urbanization by harnessing technology to optimize resource allocation, improve urban planning, and increase citizens' well-being [4].

2.2 Earthship Design: A Sustainable Building Approach

The idea began in the seventies and its founder is Mike Reynolds. The goal is to create a home that will do three things; First, it will be sustainable, using materials that are entirely native to the planet and recycled. Second, homes depend on natural energy sources and are independent of the “grid,” thus being less vulnerable to natural disasters and free of power and water lines. Third, it would be economically possible for the average person without specialized building skills to be creative. Reynolds' vision of the material with thermal mass potential, such as concrete, adobe, or stone could theoretically be used to construct a ship on Earth [2].

3. Smart Cities: Definition and Core Components of Smart Cities

- Definition of Smart Cities: A smart city is a city that combines technology, data, and innovative solutions to improve the quality of life for its citizens, urban services, and operations, and to promote sustainability and efficiency in different facets of urban living [4]. Smart cities collect and analyze data from numerous sources using digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), data analytics, and communication networks, enabling better decision-making, resource allocation, and overall urban management. The goal of a smart city is to create a connected, responsive, and sustainable urban environment that addresses urbanization concerns while boosting citizens' well-being and satisfaction [5]

- Core Components of Smart Cities: Smart cities seek to improve the quality of life for their citizens, promote urban sustainability, and maximize the efficiency of municipal operations by leveraging technology, data, and innovation. The following are the primary goals of smart cities as in Figure 1:

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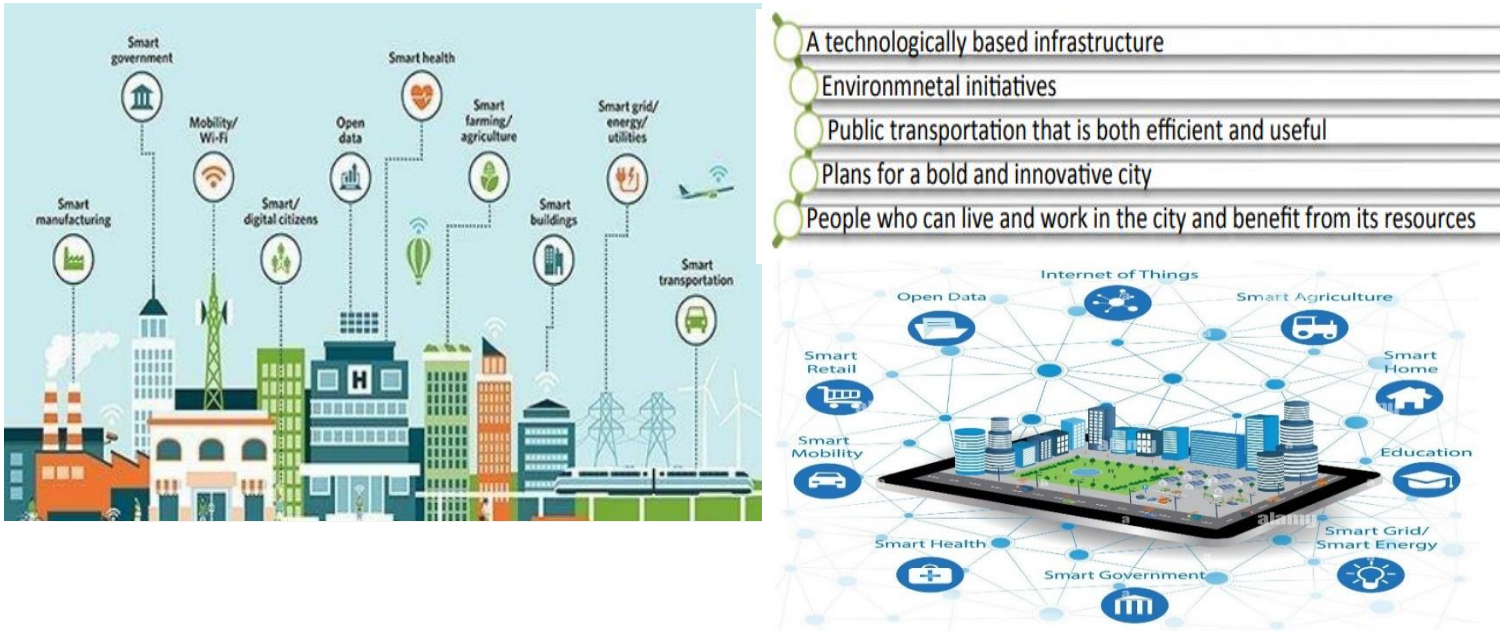

Figure 1. *Importance and Application of Smart City [1,8]*

Sustainability: The goal is to reduce urban areas' carbon footprint and overall environmental impact. by incorporating energy-saving technologies, renewable energy sources, effective waste management, green spaces, and environmentally friendly transportation options [6].

Efficient Mobility: Smart cities reduce traffic congestion, shorten commute times, and provide efficient transportation options. This includes encouraging the use of public transit, car-sharing services, bike lanes, pedestrian routes, and the integration of transportation systems using data-driven solutions [7].

Quality Public Services: Smart cities strive to deliver high-quality public services to inhabitants, such as healthcare, education, safety, and emergency response.

Citizen Engagement: Smart cities use digital platforms and technologies to engage citizens in decision-making processes. This includes obtaining input, administering surveys, and involving locals in molding the city's destiny [8].

Improved quality of life: Better public areas, cultural offerings, access to education and healthcare, less pollution, and increased safety can all contribute to a better Life.

Disaster management and resilience: Improving resiliency to emergencies and natural disasters by utilizing technology for early warning systems, efficient evacuation planning, and disaster response.

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Innovation and Technology Adoption: Smart cities encourage innovation by embracing cutting-edge technologies like the Internet of Things (IoT), artificial intelligence (AI), and data analytics [9].

3.1 Smart Cities Require the Following Ingredients for Success

The improvement of city life makes the city smarter, and the achievement of this transformation necessitates Government and community support, A distinct strategic vision, caring for research institutes and universities to promote smart city innovation, raising awareness, and teaching citizens about the project's value, as well as providing public lectures on the extension's primary areas of applicability [10].

3.2 Internet of Things (IoT) and Smart Infrastructure

The Internet of Things (IoT) is a network of interconnected gadgets and sensors that collect and share data over the Internet. These systems can become smarter, more responsive, and more efficient. Here are some examples of how the Internet of Things can benefit smart city infrastructure as in Figure 2 [11,12].

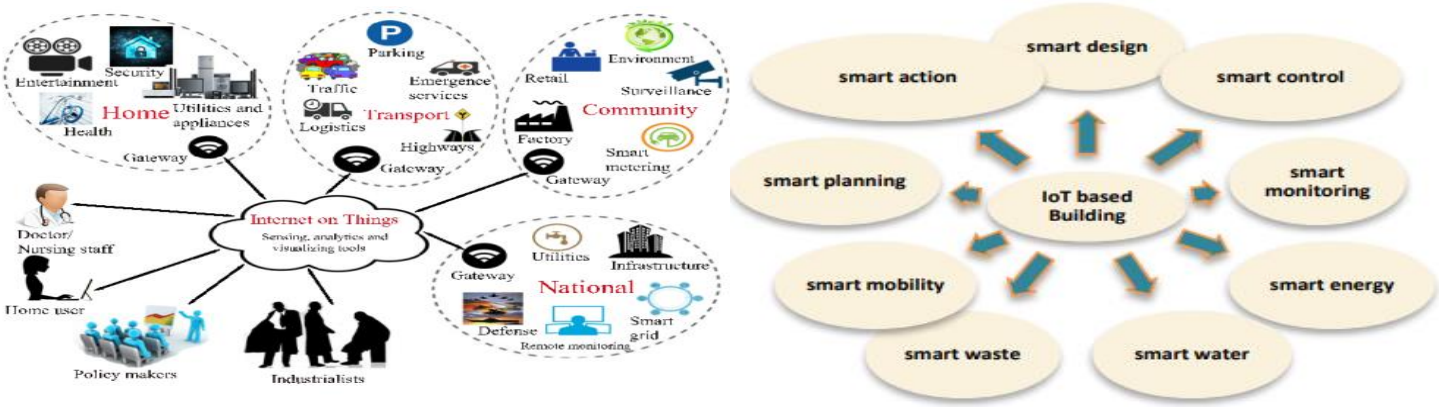

Figure 2. *Elements of IoT Building and Smart Infrastructure [11].*

Data collection and monitoring: IoT sensors capture data about, for example, energy consumption, air quality, trash levels, and traffic flow.

Remote Monitoring and Control: Saves energy by changing heating, lighting, and cooling based on ambient conditions and occupancy.

Efficient resource management: Intelligent lighting systems can change brightness based on ambient light or foot traffic, reducing energy use. Intelligent waste management systems can optimize garbage collection methods based on real-time fill-level data.

Transportation and traffic management: Cameras, traffic lights, and IoT-connected vehicle sensors can be used to regulate traffic flow and ease congestion. It is used to redirect traffic, shorten travel times, and improve public transportation routes [13].

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Energy Efficiency and Sustainability: IoT-enabled devices can monitor and control energy consumption in buildings, utilities, and street lighting. It can better balance energy supply and demand by integrating renewable energy sources and improving distribution.

Predictive Maintenance: Internet of Things sensors can monitor the health of infrastructure components such as bridges, highways, and utility systems. reducing costly failures and disruptions.

Safety and security: Enhanced via IoT-connected surveillance cameras, access control systems, and emergency response devices. Aids in the detection and response to incidents.

Public Services and Citizen Engagement: IoT-powered kiosks, mobile apps, and smart displays can provide citizens with real-time information on transportation, events, weather, and other issues.

Waste Management: IoT sensors in garbage cans and recycling bins can monitor fill levels, improving waste collection routes and eliminating unnecessary pickups.

Water management: comprises monitoring water quality, finding leaks, and controlling water distribution, all while encouraging efficient water usage and conservation.

3.3 Smart Mobility and Transportation

Smart mobility and transportation in smart cities comprise the use of technology and data-driven solutions to create efficient, sustainable, and integrated transportation systems. Here are some examples of smart mobility in modern urban settings as in Table1, [14,15]:

Table 1: How Intelligent Technology Might be Used in Smart Cities

	How Intelligent Technology Might be Used in Smart Cities	
Intelligent Traffic Management	Sensor-equipped traffic lights	change signal timings in response to real-time traffic flow, reducing congestion and improving traffic flow.
	Changes in digital signs and indicators	in response to maximizing lane utilization, traffic conditions, and easing congestion.
Enhancement to	Real-time Transit Tracking	Smartphone applications display on train and bus arrivals, and mobile applications allow switching between modes of transit.
Public Transit	Ride-sharing and Carpooling	By enabling users with comparable paths to share ride applications like Lyft and Uber help to cut off trip time and dela expenses.
Self-Driving and Electric Cars	Infrastructure for Electric Car Charging	Set up charging stations to increase the usage of electric vehicles and reduce pollution and air pollution.
	Self-Driving Cars	It is integrated into metropolitan transportation systems, with the potential to reduce accidents and congestion.

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Micro Mobility and Bike-Sharing	Cities Provide Easily	Available bikes for short trips, eliminating the need for cars and promoting environmentally responsible transportation.
	Electric Scooters	Can be rented via applications, providing a convenient last-mile mobility option.
Intelligent Parking Solution	Parking Sensors	Assist vehicles in finding parking faster and minimizing gridlock generated by circling for spots.
Transportation Planning	Cities use Traffic Analytics	To plan road improvements, ease bottlenecks, and optimize transit routes by analyzing traffic patterns and congestion data.

4 Earthship Design Principles

Earthships are creative and sustainable house designs that emphasize the use of ecologically friendly building materials and techniques. Here are some specific sustainable building materials and practices that are often used in Earthship construction. Reynolds' design eventually evolved into the U-shaped mud-tire frame houses popular today, as in Fig.4. The Earthship concept wasn't limited to tires; Several recycled materials, including plastic bottles and cans, filled with a thick material with potential thermal mass, such as concrete, clay, or stone, could theoretically be used to build a gabion. On the other hand, the land-frame variant of the Earthship is today the most widespread design and is usually the only construction referred to as an "Earthship" as Figure 3 [16].

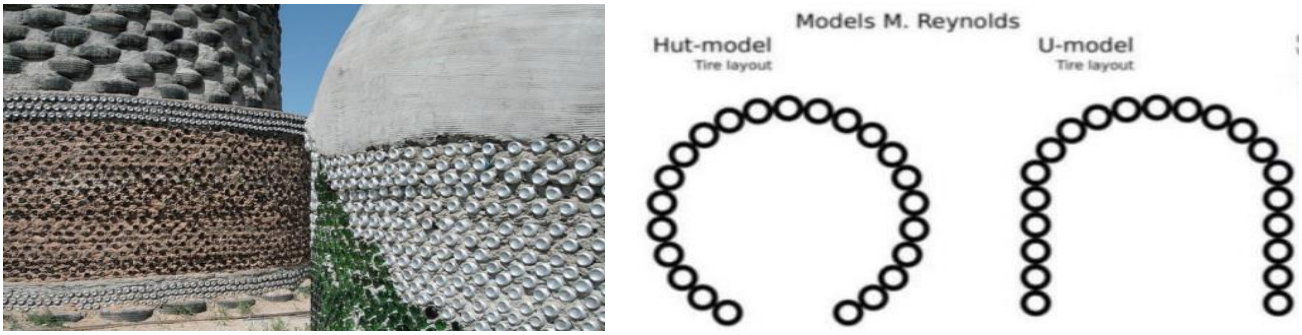

Figure 3. *The U-shaped and Hut-shaped mud-tire Frame Houses in Earthship design [2].*

4.1 Sustainable Building Materials and Techniques

Reuse Materials: Old tires filled with earth to build thick, thermally substantial walls. These walls absorb heat during the day and gently release it at night, helping to manage indoor temperatures.

Natural and local earth materials: Such as adobe, cob, and rammed earth are frequently utilized to construct internal and external walls. These materials have a low environmental impact, provide insulation, and contribute to the thermal mass of the building.

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Recycled and Salvaged Materials: Earthships combine recycled and salvaged materials into their walls, providing vibrant and aesthetic characteristics. To reduce waste and environmental impact, recycled lumber, doors, windows, and metal are widely employed.

Glass Bottles and Aluminum Cans: The earth ship walls are built from recycled aluminum tins mixed with mud. The mud is made out of sifting clay, sand, straw, and water. Then, to assist in stabilizing the can wall, a few pieces of plaster lathe are tacked to the wood frame. The aluminum cans are crushed into a layer of mud that has been placed down. Pouring mud between and above the aluminum cans [17].

Figure 4*. Construction using Tires, and Plastic Bottles [17].*

4.2 Design for Passive Solar and Thermal Mass

Solar radiation striking a structure can be transmitted, and reflected by building components. For these environmentally friendly homes, Earthship architecture combines thermal mass and passive solar design concepts to ensure a comfortable interior. It is the source of the following concepts [18]:

Design for Passive Solar: The goal is to maximize solar heat gain during the winter and minimize it during the summer. The demand for mechanical cooling and heating systems, as shown in Figure 5, is reduced when solar energy is used for the passive cooling and heating of a structure.

For this Orientation: The south-facing wall of an Earthship is often built with a great number of windows. In the winter, when the sun is lower in the sky, this orientation enables it to get the greatest sunlight [19].

South-Facing Windows: Contribute to the greenhouse effect. Through the windows, sunlight penetrates the building and warms all of the interior surfaces, including the thermal mass (clay floors and walls). When the interior temperature drops, the thermal mass collects onto heat, reflecting it into the living area.

Overhangs and Shading: To reduce summer overheating when the sun is higher in the sky, the design includes overhangs or shading elements that block direct sunlight from entering the structure.

Night Cooling: During the night, the thermal mass's stored heat is released, making it simpler to maintain an equal temperature and lowering the need for further heating.

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Figure 5. *Earthship with Natural Ventilation [16,18].*

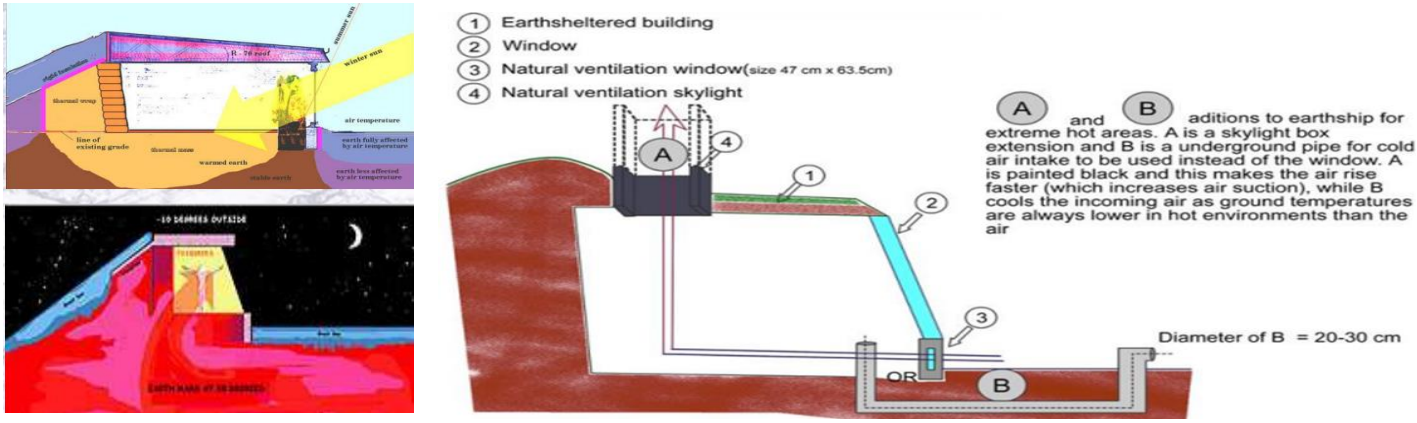

Figure 6*. Photovoltaic Cells Produce Electricity Directly from Sunlight [20].*

4.3 Energy Production for Self-Sufficiency and Sustainability in Earthship Architecture:

Solar Panels: To absorb sunlight and turn it into power, photovoltaic (PV) solar panels are frequently used in Earthship designs. These panels can be built into the walls or put on the roof as in Figure 7,[20].

Small wind turbines: may be utilized in some Earthship designs to capture wind energy, particularly in regions with predictable wind patterns.

Examining the use of Energy-efficient: building techniques and materials to reduce energy usage[21].

Energy Storage: Practical strategies for storing extra energy produced, such as battery and thermal storage.

Environmental Impact: Take into account elements like decreased dependency on non-renewable resources and decreased carbon emissions.

4.4 Rainwater Harvesting and Water Conservation

Rainwater collection and water conservation are essential components of Earthship design, harmonizing with the eco-friendly dwellings' sustainable and self-sufficient philosophy. Here's how rainwater collection and water conservation work together as in Table2,[22]:

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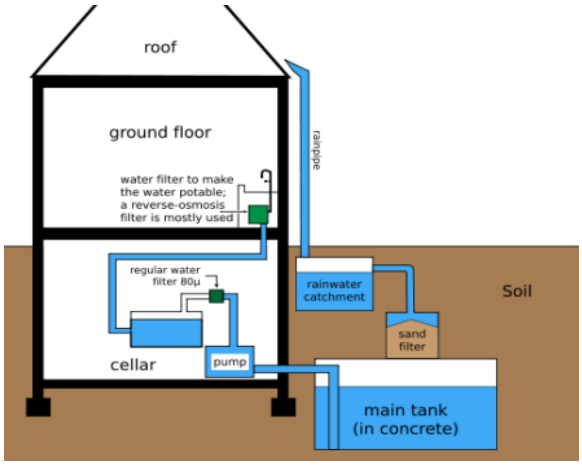
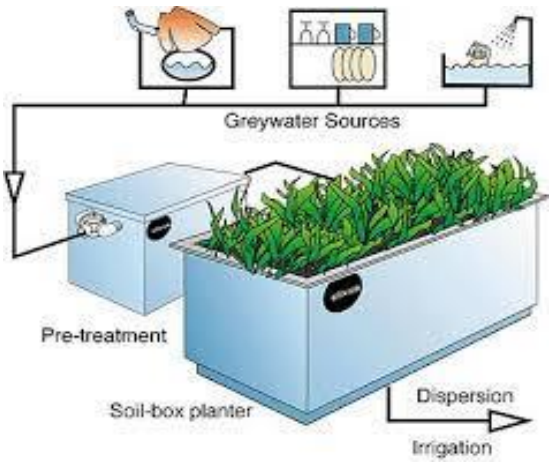
Table 2: Rainwater Harvesting and Water Conservation System.

	Rainwater Collection	Water Conservation
Definition	Earthships their reliance on local water resources by combining rainwater gathering and water saving. These behaviors not only help with sustainability but also strengthen the connection to natural resources and promote water management [24].	Greywater recycling: is the treatment of wastewater from sinks, showers, and washing machines for reuse. This recycled water is used to flush toilets and water indoor and outdoor plants, and it is non-potable [22].
The Description	Rainfall Harvesting: Roof Collection: An Earthship's broad, sloped roof is designed to channel rainfall into gutters and drains. Rainwater is collected and sent to storage tanks or cisterns.	Water-Saving behaviors: The Earthship concept is urged to develop water-saving behaviors such as swiftly repairing leaks, avoiding excessive water usage, and being careful of water consumption [23].
	Cistern Storage: Large underground or above-ground cisterns are used to store rainwater. These storage tanks can contain large amounts of water.	Efficient Plant Watering: Greywater is frequently utilized for irrigation in indoor and outdoor planters, encouraging water saving while fostering plant growth
	Filtration and purification: Before being utilized, rainwater is filtered to remove debris and pollutants.	Low-Flow Fixtures: Earthships have low-flow faucets, showerheads, and toilets that save water without losing functionality.
Pictures for Example	 Rainwater Collection System [25].	 Greywater Recycling System [24].

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4.5 On-Site Wastewater Treatment

Safe wastewater treatment is another crucial aspect of Earthship designs. We construct homes that offer you all the necessities permanently, free of charge. Gray water waste enters the inner plant cells where it is used and cleaned by the plants until it is clean enough to gather in a well at the end of the bowl and be pumped, as needed, into the toilet tank for flushing. Toilet flushing accounts for 40% of the water consumed in a typical home. The sewage from the toilet then enters a conventional septic tank, which overflows into a rubber-lined plant cell outside that is filled with outdoor landscaping plants. Each drop of water that touches the surface of the Earth is utilized four times to sustain the buildings as in Figure 8 [25,22].

Figure 7*. Indoor Water Storage, and Outdoor Water Storage Systems [22,23].*

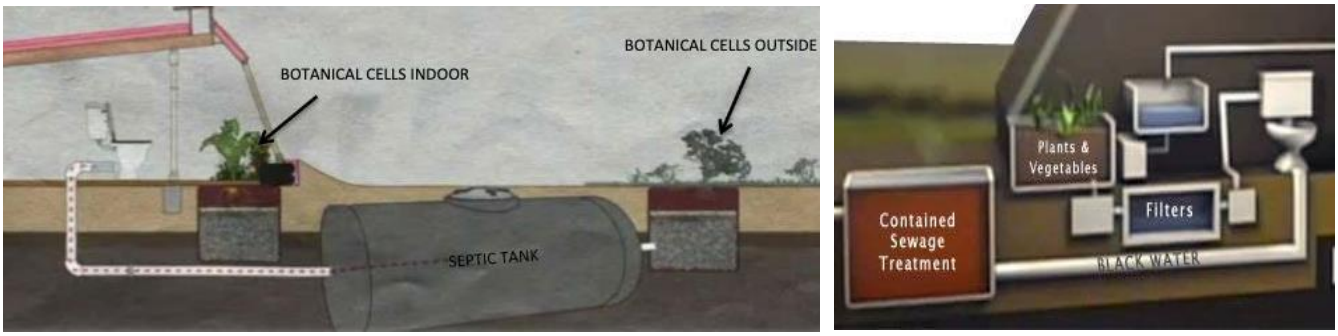

Figure 8. *Wastewater Treatment is Another Important Aspect of Earthship Designs [22].*

4.6 Off-Grid Energy Systems: Solar, Wind, and Geothermal

Off-grid power solutions are an essential part of sustainable living in Earthship dwellings. To be self-sufficient, ecologically responsible, and adaptable Earthship houses frequently rely on renewable energy sources including solar, wind, and geothermal energy. An overview of off-grid housing is provided here [26]:

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You are not physically connected to the utilities via wires, pipes, or cables if you live off the grid. Off-grid dwellings are therefore totally dependent on their energy sources, which are frequently renewable energy sources like the sun and wind. In essence, Earthship houses are self-sufficient, off-the-grid living spaces built using a mix of renewable energy sources, energy-efficient design principles, and sustainable behaviors. These houses are proof that it is possible to live comfortably while having less environmental impact.

4.7Food production

The Earthship design idea is to produce organic food within the housing. A plant expert with Earthship Biotecture has tested the best plants for graywater endophyte cells. This increased the vertical growth area in the greenhouses and produced huge crops of herbs. Where employees often consume fresh fruits and vegetables straight from the vine. The newest terrestrial vessel contains aquatic plant systems that use fish and nutrients from their waste to increase food production [22].

5 Case Studies of Smart Earthship Projects

Examining case studies of smart Earthship projects reveals innovative and sustainable approaches that seamlessly integrate cutting-edge technology with Earthship design principles, showcasing the potential to create eco-friendly and energy-efficient structures for a sustainable future.

5.1 World Earthship Community. Taos, New Mexico, Birthplace of Earthships

A sustainable community contributes to the larger world and continually bolsters the power of its existence. This community is of unique significance since it is a conglomerate cohousing, whereas the majority of Earthships have a single concentration on sustainability.

• Taos, New Mexico, 634 acres in size, natural parkland that was originally abandoned and useless.
• 130 housing sites, including 9 home/light commercial sites and 79 standard home sites (5 acres on average).
. • First and only approved utility-free subdivision in the developed world (totally "off-grid"), to be constructed in 4 phases over 20 years.

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The larger goal of the project is to reduce the economic and institutional barriers between people and sustainable housing while reversing the traditional negative impact of dwelling on the planet. It aims to interface the economy and the environment in a tangible way that impacts current stress and problems of current lifestyles as in Figure 9,10 [26,27].

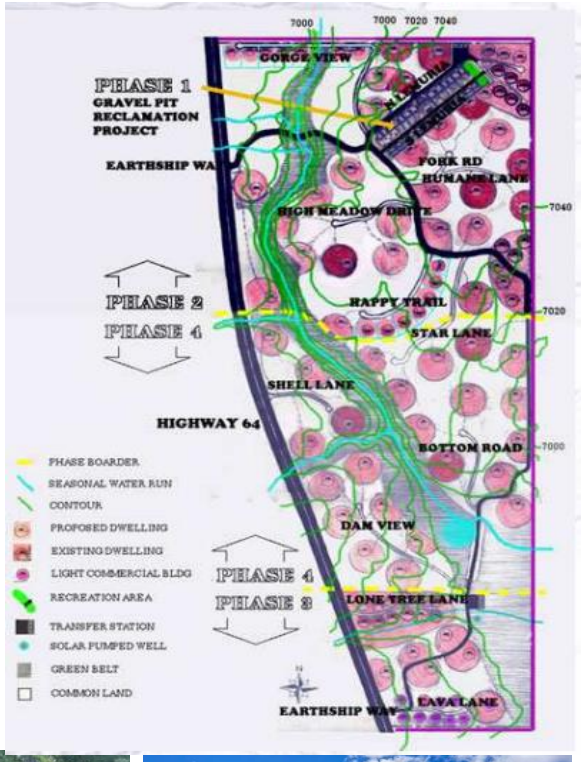

Figure 9. *Greater World Earthship Community Taos, New Mexico [27].*

Figure 10. *Taos, New Mexico, Birthplace of Earthship.*

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Figure 11. *Recycled Bottles and Cans Create a Stained-Glass Effect [29,30].*

Figure 12. *Architectural Inspiration from Nature [28].*

Table3: *Project Success Factors*

	Project Success Factors
Social Factors	*Lands are administered by a board of directors elected by the community as a whole.*
	Privately owned land provides a sense of community while preserving personality identification.
	A livelihood that can be achieved through the owner's participation in setting up his own unit and growing his food.
Economic Factors	*Providing customized, high-quality, affordable housing.*
	A light commercial area to promote and encourage "home" industries and office/studio space to adapt to future growth.
	No public funding - actual community employment generated from an area that caters to the world's largest.

5.2 Toki Rapa Nui School of music and arts

The NGO Toki Rapa Nui, a non-profit organization, was established in 2012 on the initiative of nine young professionals from Rapanui who wished to use their newfound expertise for the good of the island. The School of Music and Art in Rapa Nui is the group's first great achievement. This integrated development

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center promotes environmental protection and cultural heritage preservation activities to support sustainable development in four areas [31]:

*1. School of Arts and Music, 2. Preserving the environment, 3. Social Security,*4 *. Protecting the material and moral heritage of the ancestors*

"Toki" refers to the famous rock carvings on the island. He intended to provide a cultural environment where the music, arts, and traditions of Rapa Nui could be preserved and work for a better future. The goal of establishing a free school of music was achieved that year thanks to the donation of some musical instruments and, therefore [30]. The school was created by building engineer Enrique Icka and was based on the Earthship design. The building was designed to be accessible to the community and provide the groundwork for a self-sustaining building in Rapa Nui. Ten tons of cartons, 1,500 tires, 20,000 glass bottles, six pellets, and 30,000 aluminum cans, were used to construct the Toki School. It is a self-sufficient, environmentally responsible building. Electricity is produced by solar panels, while rainwater is recycled using plant cells and storage tanks [33].

Figure 13. *Toki Rapa Nui School of music and arts [30].*

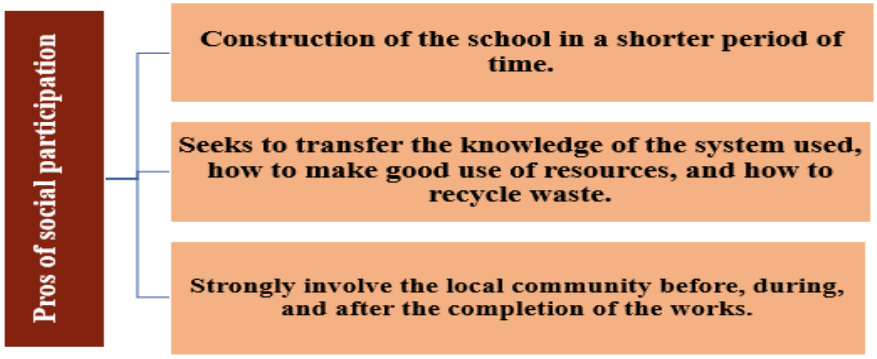

Figure14. *Earthship Design: Global Model, Pros of Social Participation.*

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More than 400 volunteers from different countries worked together to erect the eight-petalled flower-shaped school. These volunteers were instructed in the use of recyclable materials and environmentally friendly construction methods. As seen in Figure 14, they will be able to deal with environmental issues including excessive pollution and a lack of building materials [31]. Toki School has had a daily stream of tourists who are interested in sustainable travel since the building began. Toki School advertises aggressively promoting sustainable tourism that has a minimal detrimental impact on the local ecology and culture [31].

Figure 15. *Interior, and Exterior Walls Construction of Recycled Bottles and Cans [29].*

Food production: *Establishing an agricultural innovation fund and using the latest agricultural technologies to produce more agricultural products with better quality and fewer resources. They have developed a toki farming program on 1.5 hectares of land, where they grow and harvest local produce for the island and other community consumption using cutting-edge technologies as in Figure 16 [33]*

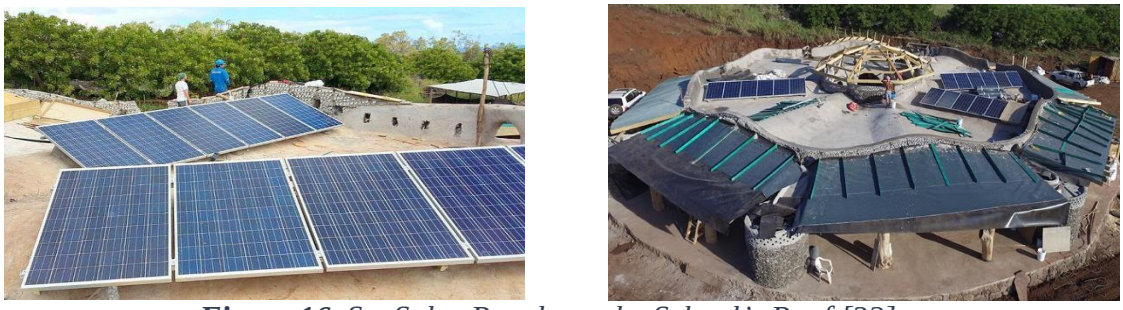

Figure 16. *Set Solar Panels on the School's Roof [32]*

6 Smart Technologies in Earthship Design

The integration of smart technologies in Earthship design empowers sustainable and energy-efficient structures, leveraging innovative solutions to harmonize with the environment and enhance the overall efficiency of the built environment.

6.1 Integration of Smart Technologies in Earthship Design

Smart technology may improve the overall sustainability, and usefulness of Earthship designs. These innovations can boost energy efficiency, enhance resource management, and offer convenience to locals. Here are some examples of how intelligent technology might be used in Earthship design as in Table 4:

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Table 4: *How Intelligent Technology Might be Used in Earthship Design*

	How Intelligent Technology Might be Used in Earthship Design	
1-Energy Administration	*Smart Thermostats*	*These devices contribute to energy savings by adjusting heating and cooling systems by occupancy and weather.*
	Energy Tracking	*Real-time monitoring of energy usage by smart meters and sensors enables communities to identify areas that consume less energy.*
	Automated lighting	*To use less energy, smart lighting systems may turn off and dim the lights in vacant places.*
2-Renewable Energy Optimization	*Solar Tracking Systems*	*Automated solar panel tracking systems can maximize electricity production by following the movement of the sun.*
	Wind Turbine Monitoring	*Sensors may track wind direction and speed to make sure wind turbines are operating as efficiently as possible.*
3-Water Management	*Smart Irrigation*	*Can maximize outdoor watering and cut down on water wastage by using soil moisture sensors and meteorological information.*
	Monitoring water quality	*Sensors can evaluate the water's quality and make sure it complies with requirements for bathing and drinking.*
4-Waste Management	*Composting Sensors*	*Sensors for composting may keep an eye on the temperature and moisture content of compost*
	Systems for sorting garbage	*Smart bins can help in the separation of organic and recyclable waste, encouraging recycling and lowering landfill waste.*
5-Air Quality Indoors	*Air Quality Sensors*	*With the use of these instruments, ventilation systems may be changed to ensure that only clean air is circulated throughout a structure.*
	Controlling Humidity	*The correct relative humidity for comfort and health may be maintained in the air by sophisticated dehumidifiers and humidifiers.*
6-Security	*Smart Locks*	*Residents can control access to their Earthship using smartphone applications to improve security.*
	Smart Cameras	*And surveillance systems with motion detectors can provide real-time security monitoring*
	Devices that use less Power	*Smart devices may be set to only turn on when power demand is low*

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7-Electronics and Appliances	*Smart Home Controllers*	*May be managed by centralized control systems, enabling people to plan their daily activities in an energy-efficient manner.*
8-Water Recuse	*Gray Water Systems*	*Sophisticated gray water recycling systems can treat and distribute gray water for irrigation and other non-potable purposes.*
9-Food Production	*Indoor Gardening Systems*	*Automated hydroponic or aquaponic systems can help with indoor food production. Indoor gardening systems.*
	Plant Monitoring	*Smart sensors can monitor plant growth and health and alert occupan to maintenance needs.*
10-Waste-to-Energy	*Biogas Systems*	*Smart biogas digesters can effectively transform organic waste in useable biogas that can be used for cooking and heating.*
11-Analytics of data	*Energy and Resource Management Software*	*Use data analytics platforms to monitor and optimize their resource consumption and make knowledgeable decisions about energy and water conservation*
12-Remote Control and Monitoring	*Voice-Activated Systems*	*Residents may use voice commands to manage a variety of Earthship features, increasing convenience.*
	Using Smartphone Apps	*Residents can check on and manage different systems in their Earthship remotely, ensuring everything is running well even when they aren't there.*
13-Community Involvement	*Community-Wide Systems*	*To manage shared resources like community gardening, water collecting, and energy distribution, smart technology may be included at the community level.*

6.2 Benefits of Smart Earthship Cities

Future urban living that is sustainable and self-sufficient is envisioned in Smart Earthship Cities. These cities will incorporate cutting-edge infrastructure and technology with Earthship design concepts to provide livable spaces that are both incredibly efficient and ecologically beneficial. The advantages of these cities include the following as in Table 5

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Table 5: *Benefits of Smart Earthship Cities*

	Benefits of Smart Earthship Cities	
1- Environmental Resilience	*Zero Carbon Emissions*	*To reduce or perhaps eliminate carbon emissions, the generation of energy in smart terrestrial cities will mostly rely on renewable energy sources like solar and wind power.*
	Resource Efficiency	*The efficient use of resources and reduction of stress on neighboring ecosystems are encouraged by Earthship design including wastewater treatment and rainwater collection.*
2-Energy independence	*Renewable Energy*	*Have less need for fossil fuels and centralized power networks since they will be able to generate large volumes of solar and wind energy.*
	Energy Storage Technologies	*Such as massive batteries and cutting-edge thermal storage systems, can deliver on-demand electricity even when the generation of renewable energy is low.*
3- Resilience	*Natural Disaster Resistant*	*Earthship homes are built to withstand extreme weather events, making them resilient to hurricanes, earthquakes, and wildfires*
	Off-the-grid capabilities	*Designs of Earthship are self-contained, hence these*
4-Enhanced Quality of Life and Well-Being	*Sustainable design, intelligent technology,*	*A focused approach can increase inhabitants' quality of life. An environment that is healthier and more fun to live in may be achieved by reducing pollution, using resources more effectively, and having access to green places.*
5-Community Participation, & Empowerment	*Community Cohesion*	*Strong relationships are fostered by Earthship Communities. The community is helpful because residents frequently work together on various initiatives and pool resources.*
	Skills Development	*Learning how to design, manage, and debug Earthship systems and sustainable technology gives inhabitants useful skills that can open up job prospects.*
	Food Production and Security	*Many Earthship communities engage in local food production, which may require people to engage in farming and gardening tasks. Additionally, the population gains the knowledge and abilities necessary to attain food security as a result.*
6-Economic Opportunities, & Job Creation	*Construction and Upkeep*	*Skilled labor is necessary for building and maintaining Earthships. Residents can get training and employment in a variety of construction and maintenance positions, fostering the community's economic independence.*

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	Renewable Energy Sector	*Generating work in the field of renewable energy, such as power system management, wind turbine repair, and solar panel installation.*
	Sustainable Agriculture	*Increasing local food production will open up chances for agricultural and food-related in Earthship's communities.*
	local Entrepreneurship	*Emphasis on eco-friendly manufacturing, green consultancy, or start-ups in sustainable technology*

7 Towards the Future: Smart Earthship Cities concept of Cities envisions

integrated urban environments that harmonize advanced technologies with Earthship design principles, fostering sustainable, resilient, and eco-friendly urban living.

7.1 Scalability and Replicability of Smart Earthship Projects

A sustainable future requires scalability and replication of Smart Earthship projects. To handle greater populations and various geographic areas, Important factors for replication and scalability include:

- Modular Structure: Create Earthship systems that are simple to copy in other locations, cutting down on building costs and time. and Earthship designs while upholding fundamental sustainable principles to accommodate regional climate, resource availability, and cultural preferences.

- Community Engagement: Promoting community involvement in project development and execution that Smart Earthship Cities represent the requirements and goals of its inhabitants.

- Government Support: Working with the government in the process, offer financial incentives for environmentally friendly architecture, to create buildings with Earthship design concepts.

- Education and Training: To enable the replication of Smart Earthship designs and technology, training courses and instructional materials are made available to architects, builders, and residents.

-Establishing monitoring: Methods to track the effectiveness and impact of Smart Earthship Cities will help to ensure that sustainability objectives are achieved.

7.2 Advancements in Technology and Materials

The development of Smart Earthship Cities requires ongoing technological and material improvements. This comprises:

- Innovations in materials: Developing locally produced, recyclable, and environmentally friendly building materials to lessen the impact of construction.

- Energy Storage: Improving battery systems and other energy storage technologies to increase the resilience and energy independence of Smart Earthship Cities.

- Artificial Intelligence (AI): utilizing AI and data analytics to improve system efficiency, forecast energy and water use, and optimize resource management.

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- Green Transportation: Including electric cars and environmentally friendly transportation systems in Smart Earthship Cities to cut emissions and promote greener modes of transportation.

- Biotechnology: Investigating biotechnology uses to improve sustainability, such as biodegradable construction materials and wastewater treatment utilizing natural processes.

- Using 3D printing technology: To build Earthship components quickly and with the least amount of waste.

7.3 Collaboration and Knowledge Sharing

The development of Smart Earthship Cities depends on collaboration and knowledge sharing since they enable the interchange of ideas, innovations, and best practices:

-Global Networks: Creating networks at the international level for Smart Earthship practitioners, researchers, and supporters to exchange ideas.

- Open-Source Platforms: Promoting the creation of open-source plans, designs, and software for the building of Earthships and the administration of smart cities.

- Research & Development: Investing in sustainable research and development projects with a focus on integrating smart technologies with Earthship concepts.

-Public Awareness: Supporting public awareness efforts to inform the general public about the advantages of Smart Earthship Cities and to rally support for environmentally friendly urban planning.

-Collaboration across sectors: Establishing alliances across the public and corporate sectors, as well as with institutions of higher learning and nonprofit organizations, to pool resources and funds for initiatives like the Smart Earthship City.

8 Conclusion

1. Synthesis of Smart Cities and Earthship Design

To build urban environments that are both environmentally conscious and technologically cutting edge, smart cities and Earthship design represent a harmonious fusion of sustainability and technology. While Earthship design emphasizes self-sufficiency, renewable resources, and low environmental effects, smart cities use cutting-edge technologies to improve efficiency, convenience, and quality of life for residents. These ideas are combined to form the idea of "Smart Earthship Cities."

The importance of sustainable living is highlighted in Smart Earthship Cities. To maximize resource management, energy efficiency, and comfort, these communities combine Earthship principles like passive solar design, natural resource usage, and self-sufficiency with smart technologies. The result is an urban development paradigm that not only lessens ecological damage but also gives locals more control over their environmental influence.

Renewable energy production (solar, wind), improved water management (rainwater collection, greywater recycling), waste reduction and recycling techniques, sustainable agricultural practices, and community

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involvement are important components of Smart Earthship Cities. Smart technologies, such as IoT gadgets, data analytics, and automation, are crucial for keeping an eye on and managing these systems to ensure optimal effectiveness.

2. The Path to Sustainable Urban Development

The Smart Earthship Cities model of sustainable urban development offers a possible road map for tackling the complicated problems our increasingly urbanized society faces. This route is distinguished by several fundamental ideas and techniques:

- Planning holistically: This is essential for sustainable urban growth since it takes into account economic, social, and environmental factors. This all-encompassing strategy is demonstrated by the incorporation of smart technology and Earthship design principles.
- Resource Efficiency: A key component of sustainability is maximizing resource efficiency. This entails lowering energy and water usage, improving trash disposal, and encouraging the production of local foods.
- Renewable Energy: Utilizing renewable energy sources, such as solar and wind power, is crucial for cutting greenhouse gas emissions and fostering energy independence.
- Community Engagement: Getting locals involved in sustainable habits encourages a sense of ownership and accountability, which advances sustainability over the long haul.
- Resilience: It's critical to develop resilience to climate change and other difficulties. The resilience of a society is aided by self-sufficiency and decentralized systems, as evidenced in the design of Earthships.
- Innovation: By maximizing resource use and enhancing quality of life, embracing innovation and emerging technologies, such as IoT, can increase sustainability initiatives.
- Education: Is the key to bringing about long-lasting change through increasing public awareness and knowledge of sustainable living practices. It enables people to make decisions.
- Collaboration: To implement effective policies and programs, sustainable urban development frequently involves collaboration between the government, corporations, and communities.
- Adaptation: To address changing environmental and socioeconomic concerns, urban planning must be flexible and adaptable.

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VOLUME 6, ISSUE 2, 2023, 376 - 400

References:

[1] https://smartcitiescouncil.com/
[2]https://earthshipglobal.com/
[3]https://www.worldgbc.org/
[4] Harmon RR, Castro-Leon, "Smart cities and the Internet of Things". In: PICMET annual conference proceedings, 2015. https://doi.org/10.1109/PICMET.2015.7273174
[5] Toli AM, Murtagh N , 2020, The concept of sustainability in smart city definitions. Built Environ. https://doi.org/10.3389/fbuil.2020.00077
[6]A Saker. Mohamed, "Towards Developing Sustainable Design Standards for Open Spaces", International journal of architectural engineering and urban research, ONLINE ISSN 2785-9673 Volume 6, ISSUE 1, 2023, 167 – 186.
[7] Amany Saker, Vitta Ibrahim, 2024, "Towards a Sustainable Future: Exploring the Integration of Architecture Education, Innovation and Sustainability", SVU-International Journal of Engineering Sciences and Applications, 5(1): 49-63, Print ISSN 2785-9967 | Online ISSN 2735-4571, DOI: 10.21608/SVUSRC.2023.224923.1143.
[8] Abou El Seoud T, 2019, "Towards sustainability: smart cities in the Egyptian environment how much smart to be smart?", J Urban Res 31.
[9] Al-Qadi ANAH, "The characteristics of smart cities and their role in the transition to the sustainability of the Egyptian city".2018, Academic Research Community, Al-Iraqi MI, IEREK Press.
[10] https://smartcitiesconnect.org/why-singapore-is-the-smart-city-of-2018.
[11] Ghonimi I, 2021 ,"Smart city: a question of social sustainability in Urban Spaces? Assessing the impacts of ICT on urban behavioral patterns in urban spaces of Madinaty,Egypt.", J Urban Res 42.
[12] Abdoullaev A, 2011 "A smart world: a development model for intelligent cities—the trinity world of trinity cities". In: The 11th IEEE International Conference on Computer and Information Technology, ,http://www.cs.ucy.ac.cy/CIT.
[13] I. R. Mihai, N. Cristina, S and M. Angela, 2021, "Internet of Things (IoT) and Sustainability, 7th BASIQ International Conference on New Trends in Sustainable Business and Consumption. Foggia, Italy. Bucharest: ASE, pp. 346-352 DOI: 10.24818/BASIQ/2021/07/044, Jun.
[14] Kehinde Lawala, Hamed Nabizadeh Rafsanjanib, "Trends, benefits, risks, and challenges of IoT implementation in residential and commercial buildings", Energy and Built Environment, KeAi, Volume 3, Issue 3, pp. 251-266, 2022.
[15] A. Faris, H. A. Saeed Hamood, S. Radhya,2021, "Green IoT for Eco-Friendly and Sustainable Smart Cities: Future Directions and Opportunites", Mobile Networks and Applications, Springer.
[16] Karunakaran K, Shanmugasundaram N, Pradeep Kumar, "Analysis of smart energy supply to smart city—review". Int J Pure Appl Math 118(20):757–762. ISSN: 1311-8080; ISSN: 1314-3395 (online version) http://www.ijpam.eu Special Issue 2018.
[17] Lacinák M, Ristvej J, "Smart city, safety, and security. In TRANSCOM: international scientific conference on sustainable, modern, and safe transport", Procedia 192, 2017. www.sciencedirect.com
[18] Divyashree, C. P., "Earthship – Scrap Materials Recycling in the Building Design", 2012.
[19] A Saker. Mohamed, 2023 "Harmonizing Human Needs and Sustainability in Islamic Architecture: A Case

INTERNATIONAL JOURNAL OF
ARCHITECTURAL ENGINEERING AND URBAN RESEARCH
PRINT ISSN 2785-9665 ONLINE ISSN 2785-9673

VOLUME 6, ISSUE 2, 2023, 376 - 400

Study of Zenab Khatoun House" FACULTY OF ENGINEERING – SOHAG UNIVERSITY. Sohag Engineering Journal (SEJ) Vol. 3, No. 2 .
[20] World Meteorological Organization, "Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1971 – 2000, 2006. Available from http://www.ncdc.noaa.gov.
[21] Affordable Solar, Affordable Solar Group, LLC, 2007, Available from http://www.affordable-solar.com/
[22] Reynolds, Michael. Earthship Volume 2: Systems and Components. New Mexico: Solar Survival Press, 1990.
[23] California Urban Water Conservation Council, "H2O Use: Water Saver Home, Available from", 2006. http://www.h2ouse.org
[24] Black & Veatch Enterprise Management Solutions Division, 2006, 50 Largest Cities: Water/Wastewater Rate Survey 2005, Available from http://www.wichita.gov.
[25] Peterson, Erik Nissen, and John Gould. Rainwater Catchment Systems for Domestic Supply: Design, Construction, and Implementation. London: ITDG Publishing, 2000.
[26] Austin, Anne. "It Ain't Easy Being Green", Flux Student Magazine, 2003. http://inlux.uoregon.edu/2003/green.html (2006-APR-10).
[27] Reed, Ryan. 2006,"Extreme Green: A Pair of Projects Point to Differing Paths to Sustainable Design", Builder News Magazine, 2004. http://www.buildernewsmag.com/viewnews.pl?id=120
[28] Reynolds, Michael. "Earthship Biotechture", Entire Website, 2005. http://www.earthship.org/ and http://www.earthshipbiotecture.com (2006-APR-10)
[29]Chrisensen, Bill. "A Sourcebook for Green and Sustainable Buildings, Passive Solar Guidelines", http://www.greenbuilder.com (2006-APR-08)
[30] Divyashree, C. P. 2012. Earthship – Scrap Materials Recycling in the Building Design.
[31] Earthship Karuna. 2007. Retrieved from http://www.earthshipkaruna.net/index.html
[32] Environment and Ecology. 2019. Retrieved from file: /E:/M.ARCH/2ND% SEM/RESEARCH % 20ETHODOLOGY/ REASEARCH%20METHODOLOGY/What%2 0is%20Earthship_.html
[33] Green Home Building. 2019. Retrieved from greenhomebuilding.com: file:///E:/M.ARCH/2ND%20SEM/RESEARCH%20METHODOLOGY/REASEARCH%20METHODOLOGY/Green% 20Home%20Building_%20Earthships.html.