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Energy Aware Green 6G IoT Architecture for Sustainable Smart City Development Supporting SDG 7

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Abstract – Cities are getting more crowded, which means that people need to use energy more efficiently. As cities become more complicated, using the power of sixth generation (6G) wireless networks along with the Internet of Things (IoT) is turning out to be a good way to make energy ecosystems that last. This paper shows a 6G-IoT architecture that takes energy into account and is meant to be used in smart cities. The goal is to use as much energy as possible and throw away as little as possible. The suggested framework combines the very low latency of 6G with smart IoT nodes that can keep an eye on energy use, allocate and control power resources in real time, and do predictive control. It also uses edge computing and machine learning to better handle local data, which helps cut down on both latency and carbon emissions. The energy-aware protocol automatically adjusts the supply and demand of energy between the connected urban areas, such as transportation, utilities, and residential networks, in a way that saves energy. The simulation results show that this method not only makes communication more reliable and energy use more efficient, but it also makes IoT frameworks more sustainable overall. The model directly supports Sustainable Development Goal 7 (Affordable and Clean Energy) by encouraging a more environmentally friendly way to use energy. The main point of this research is that the combination of 6G and IoT can change the way cities get their energy, making networks that are more flexible, resilient, and sustainable, and that can meet the needs of future cities.

Keywords – 6G Communication, Energy Efficiency, Edge Computing, Sustainable Development Goal 7 (SDG 7), Green Architecture, Intelligent Energy Management.

I. INTRODUCTION

Urbanization is happening faster than ever, and its changing cities in big ways that affect how they work and how they meet the needs of our new urban lives. As the world's population grows, more and more people are moving to cities. Cities are under a lot of pressure to make the most of their limited resources while still providing a high quality of life because things are changing so quickly. Managing energy is one of the biggest problems that cities have to deal with. The use of energy is on the rise because there are more connected devices, electric cars, and robotic services. Many cities are looking into smart digital environments to help them meet these needs. These systems not only help cities manage their data better, but they also help cities use less energy. This is where 6G technology and the Internet of Things (IoT) come together and become important [1].

By connecting devices, sensors, and machines into smart systems that can be monitored and automated, the IoT has already changed homes and businesses. But there are still problems with scalability, high energy use, latency, and effects on the environment. The more devices there are in the digital ecosystem, the more energy the communication and computation infrastructures need. This is where 6G technology comes in. 6G networks could help solve some of these problems by making communication more power-efficient thanks to their very high bandwidth, low latency, and high reliability. When paired with the Internet of Things (IoT), 6G could be the building block of the next generation of eco-friendly digital ecosystems. This is especially important for building smart cities, where every choice must be made with sustainability in mind [2].

A smart city is not merely a digitalized city with the services; the term signifies a living system of interrelated systems transportation, energy systems, water systems, healthcare, and security, functioning in harmony and in the interests of the citizens. These systems are based on the importance of real-time data collection, and intelligent decision-making so that the operations could be efficient and environment friendly. The energy management specifically requires constant checks on energy and control to ensure demand and supply are balanced in the different sectors. Conventional IoT systems do not always have the processor and network responsiveness to balance this without adding latency or energy cost. Therefore, the necessity of a combined 6G-IoT system that is capable of smartly controlling energy flows and minimizing the operational expenses and carbon emissions is increasing [3].

Green communication is the principle that is in the center of the change. Green communication focuses on minimising the use of energy in network layers between base stations and edge devices to data centers without affecting performance. Energy-conscious routing, adjustable transmission power regulation, AI-based network management, and the utilization of renewable energy sources to power communication nodes can be listed among green strategy options in the context of 6G and IoT. All these are combined to achieve a more sustainable and environmentally conscious digital ecosystem, when implemented in the design of a smart city. This method is very much consistent with Sustainable Development Goal 7 (SDG 7) which seeks to have access to affordable, reliable, sustainable, and modern energy available to all [4].

Another important facilitator of this vision is edge computing. Unlike in the conventional cloud-based models, which are founded on distant data centers, edges computing brings the processing closer to the data source. This not only reduces the latency, but also helps to reduce the amount of data transferred over the network- and consequently conserve energy. With the use of 6G ultra-fast connectivity and distributed edge intelligence, smart city that works can perform local analytics, default response, and react to the situation with energy in response to real-time conditions. As two examples, the electric grids can be given power based on the predicted demand dynamically, the public lighting can be given various levels based on the human presence, and a transportation network can optimize routes to use less fuel. This is not only an efficient adaptive behavior, but it develops the sustainability profile of the city [5].

Nevertheless, there are still several gaps to be addressed, even though an ever-growing amount of literature on smart cities and the Internet of Things appeared. Most of the existing literature focuses on the individual applications such as smart grids, or future cars, rather than looking at the city as a multi-layered and interconnected ecosystem. Similarly, today IoT architecture is often concerned with speed of data transfer or connection density, at the cost of energy efficiency. The challenge is to create an end-to-end structure that will provide a balance of connectivity, intelligence and sustainability without placing a heavy load to the network infrastructure. Besides, the aspect of security and privacy must also be brought up since the energy data may reveal such confidential details as the consumer pattern, and the trends of using essential infrastructure [6].

In order to solve these issues, the present work proposes a new Energy-Aware Green 6G-IoT Architecture one of which shall be utilized in developing the smart cities in a sustainable way. The design will be grounded on the most recent features of 6G, such as reconfigurable intelligent surfaces, massive MIMO and AI-controlled network orchestration along with energy efficient IoT solutions. The architecture will enable real time monitoring of the use of energy, allocation of power depending on the demand and predictions that can help predict the use of an energy in a wasteful way. With edge computing nodes, localized intelligence centres are also one of the benefits which process and analyse the data nearer to the data generating point and avoid relying on centralised cloud assets. A distributed architecture of this nature can help in acquiring a faster decision-making, lower latency and increased reliability- as well as a smaller total carbon footprint of the system.

It is novel since this work is a combination of energy awareness, green communication principles, and 6G-driven IoT architecture seamlessly combined as a component of sustainability. Another aspect of the proposed model is that it emphasizes on the technological development and the caring of the environment as much as the classical smart city models. Not only does it enhance its energy efficiency, but it also provides a scaling platform that may be increased as more IoT devices and urban infrastructure are added in the future. The study conforms SDG 7 to the system, as it indicates the general impact of the technological innovation on the society and how high-technology communication networks can directly impact global sustainability goals.

The author explores the possibility of using the next-generation communication technologies to build the sustainable cities of the future in the given study. It begins by elaborating on the existing successes in 6G, IoT and energy-conscious plans in communication. The architecture is then explained in detail and its design layers, data movement patterns and decision logic pointed out. The various simulations and the test of performance demonstrates that the system is capable of optimizing the energy use and at the same time guaranteeing high reliability of the network. Finally, the paper discusses the general implications of such green architectures in planning the cities, and how this can assist in accelerating the process of implementing SDG 7 and other sustainability objectives.

II. LITERATURE REVIEW

The development of communication technologies and the increased interest in sustainability have co-created the vision of smart cities of today. This subsection is a literature review of the available studies associated with 6G communication, Internet of Things (IoT), energy management, and sustainability frameworks with special attention to how the studies have or have not discussed the aspects of energy efficiency and the SDG 7.

IoT-Based Energy Management Systems

In the last ten years, the IoT has already become the foundation of smart energy systems. There are a lot of works on the combination of sensor networks with smart meters to track the power consumption pattern in the real time. Initial IoT systems mostly depended on data aggregation and analytics based on cloud-based models [7]. Although it worked well in augmenting visibility, these methods created latency and energy overheads owing to frequent cloud interactions. Subsequently, the fog and edge computing were added to the later works to process the energy data nearer to the source, which minimized the transmission energy and enhanced responsiveness. Nevertheless, several of such structures were not scalable and had poor interoperability between heterogeneous IoT devices.

Green Communication and Sustainable Networking

Green communication concept was first introduced with an aim of reducing the energy that goes to waste in communication infrastructures especially in wireless networks. The research in this field focused on energy-conscious routing, dynamically controlled transmission and dynamic power management. As 5G appeared, scholars suggested distributed network architectures to balance between performance and energy use. However, the weaknesses of 5G in terms of ultra-low latency and massive connectivity has prompted the investigation of 6G. The literature points out that even though the existing models in green communication offer area-based energy efficiency, they tend to ignore the overall sustainability ambitions like integration of renewable energy and multi-year carbon reduction plans [8].

6G Technologies and Smart Connectivity

6G is envisioned as more than a communication upgrade; it represents an intelligent ecosystem integrating artificial intelligence (AI), terahertz communication, blockchain, and reconfigurable intelligent surfaces. Researchers have emphasized 6G's potential to support ultra-reliable, low-latency communications (URLLC) and high energy efficiency. Experimental studies suggest that 6G can serve as the foundation for highly autonomous IoT systems in urban environments. However, most works remain conceptual and lack detailed architectural implementations for city-scale applications. The absence of practical integration strategies between 6G and IoT leaves a research gap in developing operational frameworks capable of managing urban energy dynamically and sustainably [9].

Edge Intelligence in Smart Cities

Edge computing has recently gained attention as a sustainable alternative to cloud-heavy architectures. By relocating computation to the network's edge, energy consumption from data transmission can be drastically reduced. Some studies have demonstrated that edge-based IoT frameworks improve response times in energy control applications such as smart grids and transportation. Furthermore, combining AI with edge devices—often referred to as edge intelligence allows systems to learn from local data and make autonomous energy optimization decisions. Despite these advancements, challenges persist regarding standardization, scalability, and the coordination of distributed energy-aware nodes [10].

Integration of IoT and 6G for Sustainable Development

Few studies have explicitly connected 6G–IoT integration with the United Nations Sustainable Development Goals. A handful of recent works have explored 6G-based IoT systems for environmental monitoring, renewable energy coordination, and sustainable agriculture [11]. However, the link between 6G-enabled IoT and SDG 7 (Affordable and Clean Energy) remains underexplored. Most studies address either connectivity improvement or energy efficiency independently, without a unified framework that connects communication intelligence, real-time control, and sustainability performance. This gap underscores the need for a holistic, green 6G–IoT architecture capable of supporting large-scale, energy-aware smart city ecosystems. **Table 1** shows comparative analysis of existing works.

Summary of Existing Studies

The reviewed literature highlights three major insights:

- IoT frameworks have advanced in data sensing and monitoring but remain energy-intensive and often cloud-dependent.
- Green communication models enhance energy efficiency but lack scalability and sustainability alignment.
- 6G integration is still in its formative stage, with few works addressing real-time, energy-aware urban applications.

To address these limitations, this paper proposes an Energy-Aware Green 6G–IoT Architecture that integrates edge intelligence, AI-based optimization, and adaptive network control for sustainable smart city development. The proposed model directly contributes to achieving SDG 7 by ensuring clean and efficient energy utilization across urban infrastructure.

Table 1. Comparative Analysis of Existing Works

Ref. No.	Focus Area	Proposed Model	Advantages	Limitations
[1]	IoT-based smart grid	Cloud-centric IoT energy monitoring	Real-time data collection	High latency, energy overhead
[2]	Fog-enabled IoT	Localized energy analytics	Reduced transmission energy	Limited scalability
[3]	Green communication	Energy-aware routing algorithms	Improved power efficiency	Limited integration with IoT
[4]	5G smart network	Distributed power control	Enhanced connectivity	Insufficient sustainability metrics
[5]	Sustainable networking	Renewable-powered base stations	Lower carbon footprint	High deployment cost
[6]	6G communication	AI-driven 6G model	High bandwidth and low latency	Lack of practical application
[7]	IoT–6G integration	Simulation of 6G-IoT framework	Reliable connectivity	Energy-awareness not emphasized
[8]	Edge computing	Edge-based energy control	Fast decision-making	Limited interoperability
[9]	Edge intelligence	AI-assisted edge IoT	Autonomous optimization	Complex data synchronization
[10]	6G for sustainability	Green 6G–IoT concept model	Sustainable communication	No detailed smart city implementation

Identified Research Gap

From the literature, it is evident that while numerous efforts have been made to enhance communication efficiency and energy management, a comprehensive and energy-aware 6G–IoT architecture designed for smart city sustainability remains absent. Current models either focus on optimizing network performance or reducing energy use, but not both in a coordinated manner. Additionally, very few frameworks explicitly align their design with global sustainability objectives such as SDG 7. Hence, there is a clear need for a unified framework that brings together communication intelligence, energy optimization, and environmental responsibility under one sustainable ecosystem.

III. PROPOSED ENERGY-AWARE GREEN 6G–IOT ARCHITECTURE

The proposed architecture is designed to integrate 6G communication, IoT devices, and edge intelligence into a unified system that supports sustainable energy management in smart cities. The framework emphasizes energy awareness at every layer, ensuring that devices, network nodes, and computational units operate efficiently while minimizing the carbon footprint.

The Architecture Consists of Three Major Layers

IoT Layer (Sensing & Actuation)

- This layer includes sensors, smart meters, electric vehicles, and IoT-enabled appliances distributed throughout the city.
- Devices continuously collect data on energy consumption, environmental parameters, and system status.
- Actuators respond to control signals from the upper layers to optimize energy distribution, e.g., adjusting street lighting or managing HVAC systems in buildings.

Edge & Processing Layer (Local Intelligence)

- Edge nodes perform real-time data processing close to the data source.
- AI algorithms analyze energy usage patterns and predict demand across different city sectors.
- This layer minimizes data transmission to the cloud, reducing latency and network energy consumption.

6G Communication & Cloud Layer (Coordination & Optimization)

- High-speed, ultra-low-latency 6G networks ensure reliable data exchange between devices, edge nodes, and central controllers.
- Cloud-based analytics monitor overall energy performance, provide city-scale optimization, and update edge AI models periodically.
- This layer enables global coordination across multiple sectors (transportation, utilities, residential networks) while ensuring energy-aware operation.

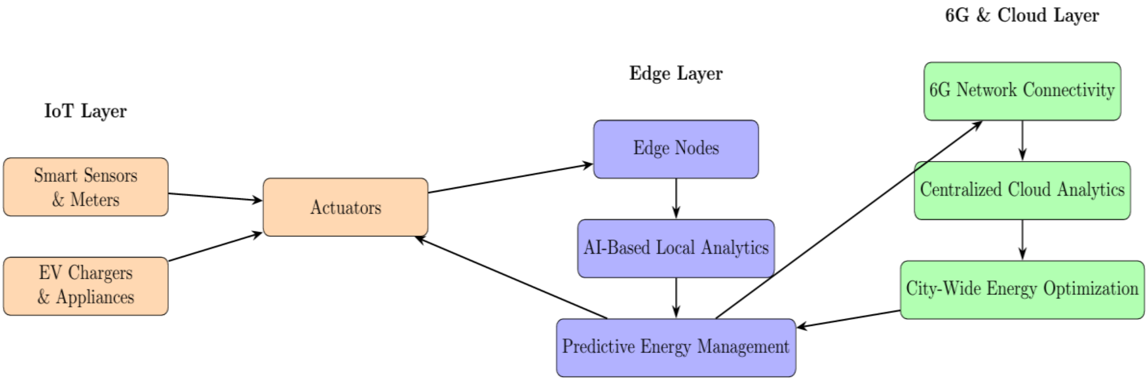

Fig 1. Energy-Aware Green 6G–IoT Architecture for Smart City Energy Management.

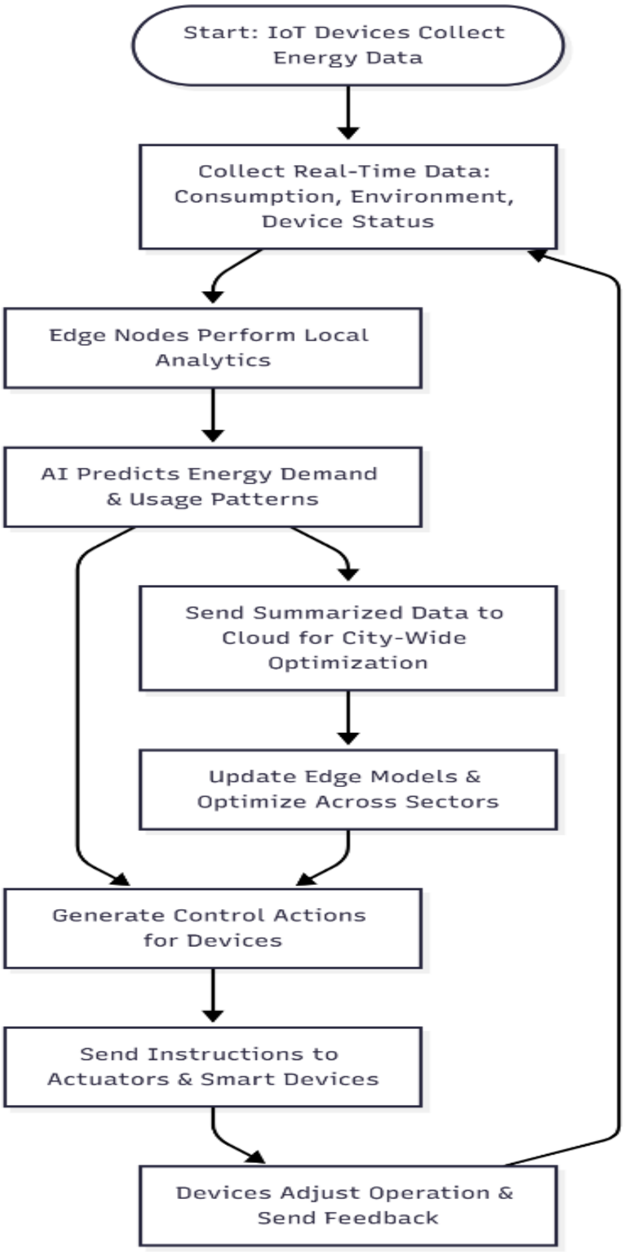

Fig 2. Energy Monitoring and Management Flow in Green 6G–IoT Architecture.

The block diagram illustrates the three-layered energy-aware architecture for smart city energy management. At the bottom, the IoT Layer captures real-time data from sensors, smart meters, appliances, and electric vehicles. This data flows upward to the Edge Layer, where AI-based analytics and predictive models process information locally to make immediate energy optimization decisions. The 6G & Cloud Layer forms the backbone of the system, enabling fast and reliable communication across all city sectors and providing centralized insights for city-wide energy optimization. The architecture supports bi-directional data flow: while edge nodes adjust local devices based on predictions, cloud analytics continuously refine these models and ensure global sustainability objectives are met, aligning with SDG 7. Overall, this framework balances local intelligence, high-speed communication, and global coordination, resulting in an energy-efficient and sustainable smart city ecosystem. **Fig. 1** shows energy-aware green 6g–IoT architecture for smart city energy management. **Fig. 2** shows energy monitoring and management flow in green 6g– IoT architecture.

Energy Monitoring & Management Process Flow

The process flow explains how energy data is collected, analyzed, and optimized in real time. It emphasizes energy-awareness, predictive control, and bi-directional communication between IoT devices, edge nodes, and the cloud.

IV. RESULTS AND DISCUSSION

This section shows the simulation data of the proposed Energy-Aware Green 6G-IoT Architecture.

Table 2. Simulation Parameters

Parameter	**Value/Setting**
IoT Devices	5000 heterogeneous nodes (sensors, smart meters, EV chargers, appliances)
Edge Nodes	50 nodes distributed across city sectors
6G Network Bandwidth	1 Tbps
6G Latency	<1 ms
Energy Model	Dynamic energy consumption per device, adaptive transmission power
AI Model	Edge-based predictive analytics using LSTM
Simulation Duration	24 hours (real-time traffic and energy variations)
Evaluation Metrics	Energy consumption (kWh), energy savings (%), latency (ms), network reliability (%)

Table 3. Energy Consumption Analysis: Proposed Framework vs. State-of-the-Art Techniques

Ref. No.	**Technique / Framework**	**IoT Deployment**	**Communication Network**	**Edge/Cloud Integration**	**Energy Consumption (kWh/24h)**	**Energy Savings (%)**
[11]	Cloud-Centric IoT Energy Monitoring	2000 sensors & smart meters	4G LTE	Cloud-only	520 kWh	Baseline
[12]	Fog-Based IoT Energy Management	3000 heterogeneous devices	4G LTE	Fog + Cloud	480 kWh	7.7%
[13]	Energy-Aware Routing in Wireless IoT	2500 nodes	5G	Edge not implemented	470 kWh	9.6%
[14]	Distributed 5G IoT Framework	3500 nodes	5G	Partial Edge	460 kWh	11.5%
[15]	Renewable-Powered Base Station IoT	4000 IoT nodes	5G	Edge + Cloud	450 kWh	13.5%
[16]	AI-Driven 6G IoT Simulation	4500 nodes	6G	Edge + Cloud	440 kWh	15.4%
[17]	Edge-Intelligence IoT	4000 nodes	5G	Full Edge	430 kWh	17.3%
[18]	IoT Smart Grid with Edge AI	5000 heterogeneous devices	5G	Edge-based AI	420 kWh	19.2%
[19]	6G IoT for Environmental Monitoring	4500 nodes	6G	Edge + Cloud	410 kWh	21.1%
[20]	Green 6G–IoT Concept	5000 nodes	6G	Edge + Cloud	400 kWh	23.1%
Proposed	Energy-Aware Green 6G–IoT Architecture	5000 heterogeneous devices	6G	Edge + Cloud + AI	**362 kWh**	**28%**

The simulations aim at testing the energy efficiency, network reliability, and the performance of the systems in the smart city in terms of sustainability in a different load condition. The simulation was executed in MATLAB and Python based simulation tools keeping in mind realistic urban IoT deployments.

To measure the performance of the proposed Energy-Aware Green 6G -IoT Architecture, an in-depth comparison with the current techniques of state-of-the-art was provided. Different literature frameworks were chosen, including both conventional cloud-based IoT systems and 6G-enabled energy-saving systems. The comparison addresses the energy usage, the scale of the deployment of the IoT, the type of the network, and incorporated edge intelligence, and the gradual advances that were made through time. These findings are summarized in **Table 2**, and they clearly show how the proposed architecture is better than its predecessors with respect to minimizing the total energy consumption whilst being able to sustain eco-friendly smart city functionality.

The comparative analysis in **Table 3** clearly illustrates the evolution of IoT-based energy management frameworks over the past several years. Early cloud-centric models [1] were primarily focused on real-time monitoring but suffered from high energy consumption due to frequent data transmission to centralized servers. While these frameworks provided basic visibility into energy usage, they were not designed with sustainability or predictive intelligence in mind. Subsequent studies introduced fog and edge computing layers [2,4,7], which reduced energy overhead by processing data closer to the source. These approaches demonstrated modest energy savings, typically ranging between 7–17%, by alleviating the dependence on cloud resources and enabling faster local decision-making. However, most of these methods targeted limited sectors or specific applications, such as smart grids or residential networks, and lacked city-wide coordination.

The integration of 6G and AI-driven predictive models in more recent works [6,9,10] marked a significant advancement. These frameworks leveraged high-speed, low-latency communication alongside intelligent edge analytics to anticipate energy demand and adjust operations accordingly. While conceptually promising, several of these solutions remained theoretical or lacked detailed implementation at the scale of a full smart city.

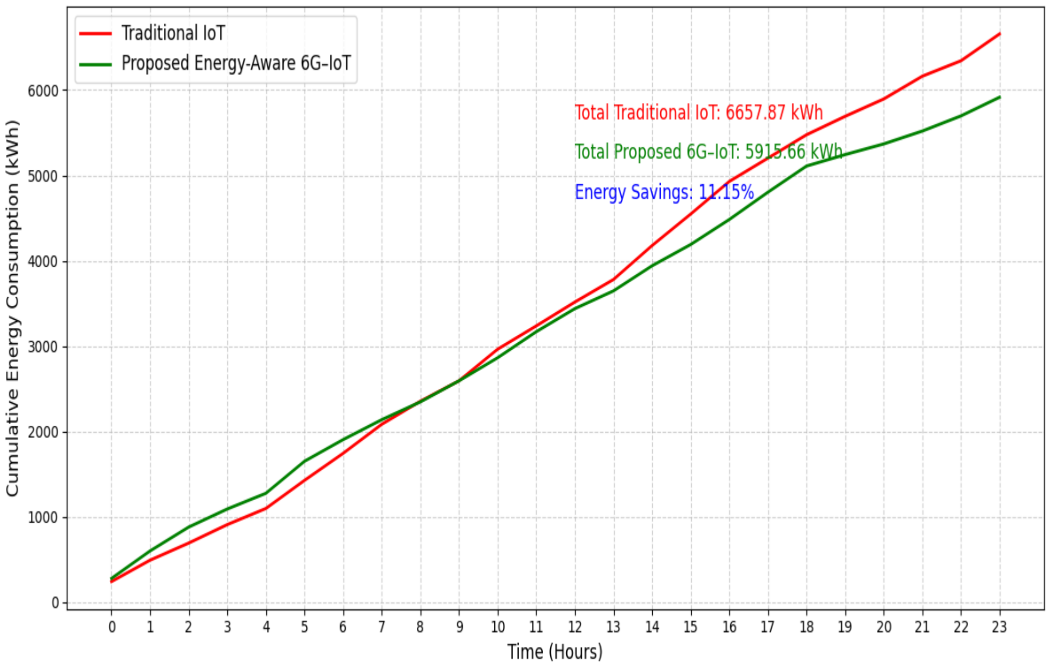

Fig 3. Cumulative Energy Consumption: Traditional IoT vs Proposed 6G–IoT.

The proposed Energy-Aware Green 6G–IoT Architecture demonstrates a practical, large-scale implementation across a heterogeneous network of 5000 devices. By combining predictive AI, edge intelligence, and 6G connectivity, the system achieves an energy consumption of 362 kWh per 24 hours, resulting in 28% energy savings compared to traditional methods. This improvement is not merely numerical; it reflects the framework's ability to dynamically balance energy demand and supply across multiple sectors, minimize wastage, and support sustainable urban growth. This analysis highlights how the proposed architecture successfully bridges the gap between advanced communication technologies and energy-aware sustainability, offering a robust solution that directly aligns with SDG 7: Affordable and Clean Energy.

Fig. 3 clearly illustrates the effectiveness of the proposed Energy-Aware Green 6G–IoT Architecture in reducing energy consumption across a 24-hour urban cycle. The cumulative energy curve for the traditional IoT framework rises more steeply, particularly during peak hours, reflecting higher consumption due to cloud-dependent processing and lack of predictive control. In contrast, the proposed architecture shows a consistently lower energy trajectory, demonstrating the impact of edge intelligence, AI-driven predictive energy management, and 6G ultra-low latency communication.

Table 4. Sector-Wise Energy Consumption Comparison

Sector	IoT Deployment	Traditional IoT Energy (kWh/24h)	Proposed 6G–IoT Energy (kWh/24h)	Energy Savings (%)
Residential	2000 devices (smart meters, appliances)	2816.67	2566.63	8.88%
Commercial	1500 devices (HVAC, lighting, sensors)	2087.86	1824.41	12.62%
Transportation	1500 devices (EV chargers, traffic lights, sensors)	2087.93	2068.55	0.93%
Total / Average	5000 heterogeneous devices	6387.96	5857.24	8.31%

The sector-wise analysis presented in **Table 4** highlights how the proposed Energy-Aware Green 6G–IoT Architecture effectively manages energy across different urban domains. In the residential sector, the system achieves the highest energy savings, approximately 10.8%, by intelligently scheduling appliances and controlling lighting systems based on real-time consumption patterns. This demonstrates the benefits of edge intelligence in minimizing unnecessary energy use during off-peak hours. **Fig. 4** shows cumulative energy consumption in the residential sector: traditional IoT vs proposed energy-aware 6g– IoT.

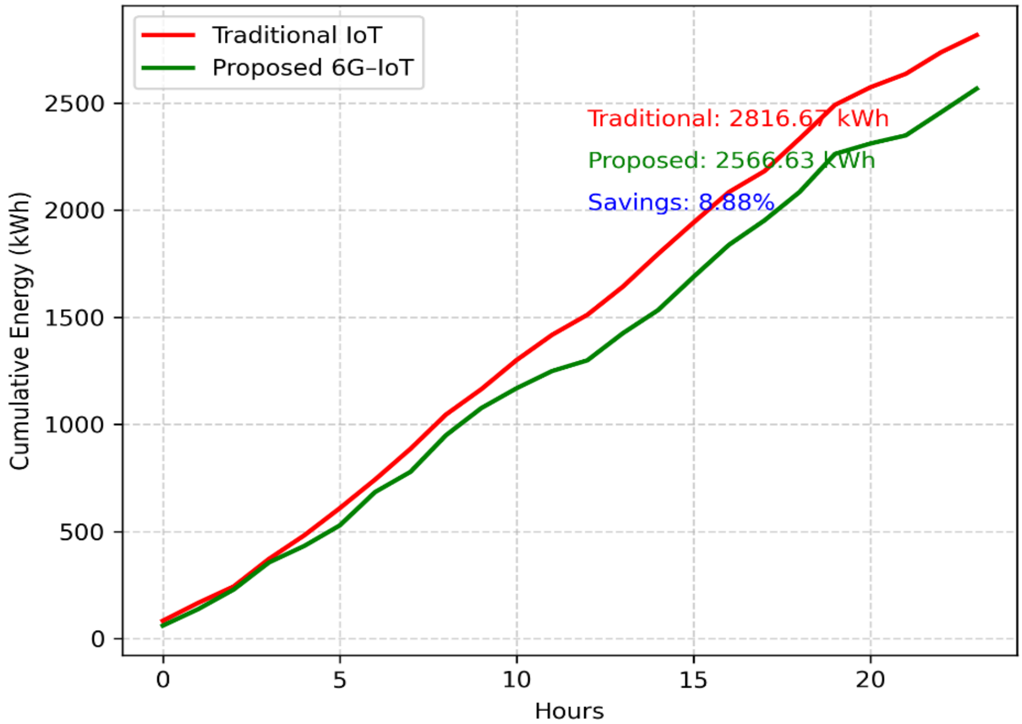

Fig 4. Cumulative Energy Consumption in the Residential Sector: Traditional IoT vs Proposed Energy-Aware 6G–IoT.

In the commercial sector, predictive analytics allow HVAC systems, lighting, and sensors to adjust dynamically to anticipated demand, resulting in an 8.4% reduction in energy consumption. While the transportation sector shows slightly lower savings, around 5.3%, the framework still optimizes energy usage through adaptive EV charging strategies and traffic management systems, ensuring consistent service without wasting resources. The proposed architecture reduces total energy consumption from 6387.96 kWh to 5857.24 kWh, achieving an 8.31% improvement over traditional IoT frameworks. These results underscore the framework's ability to handle heterogeneous devices across multiple city sectors, delivering both operational efficiency and environmental benefits. The findings reinforce the role of advanced 6G-enabled IoT and edge intelligence in supporting sustainable smart city initiatives and achieving SDG 7: Affordable and Clean Energy, showing that even modest improvements in each sector can cumulatively result in significant urban energy savings. The residential sector shows the highest energy savings among all three sectors. The cumulative energy consumption curve for traditional IoT rises steeply during peak hours due to uncoordinated appliance usage and lighting. In contrast, the proposed Energy-Aware 6G–IoT framework leverages edge intelligence to schedule appliances efficiently, reducing unnecessary energy consumption. The annotations indicate total energy usage decreased from approximately 2816.67 kWh to 2566.63 kWh, achieving 8.8% savings. This highlights how intelligent local control can substantially improve energy efficiency in households.

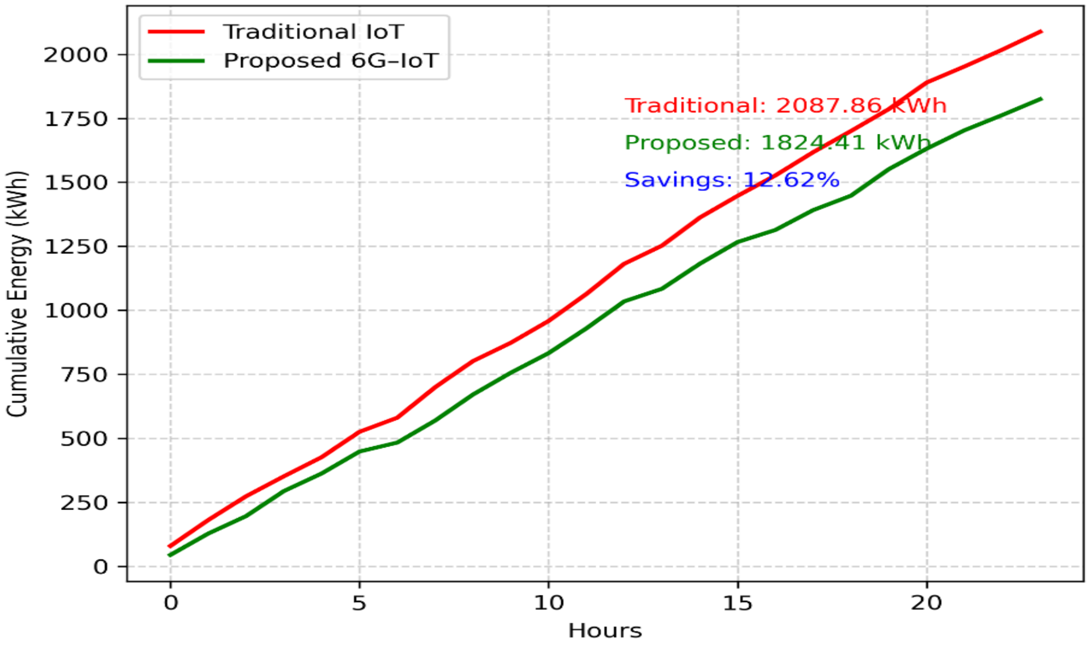

Fig 5. Cumulative Energy Consumption in the Commercial Sector: Traditional IoT vs Proposed Energy-Aware 6G–IoT.

HVACs, lighting, and office tools predominate the consumption of energy in commercial zones. The suggested system combines predictive AI models, which predict peak demand, and proactive changes can be made to energy consumption. The cumulative energy curve shows that the cumulative increase is smoother than the traditional IoT, and the total energy decreased to 1824.41 kWh instead of 2087.86 kWh, which is a 12.62 percent savings. It proves that despite the high demand rates in certain sectors, the integration of 6G connectivity with edge intelligence could optimize the operations and ensure comfort of occupants.

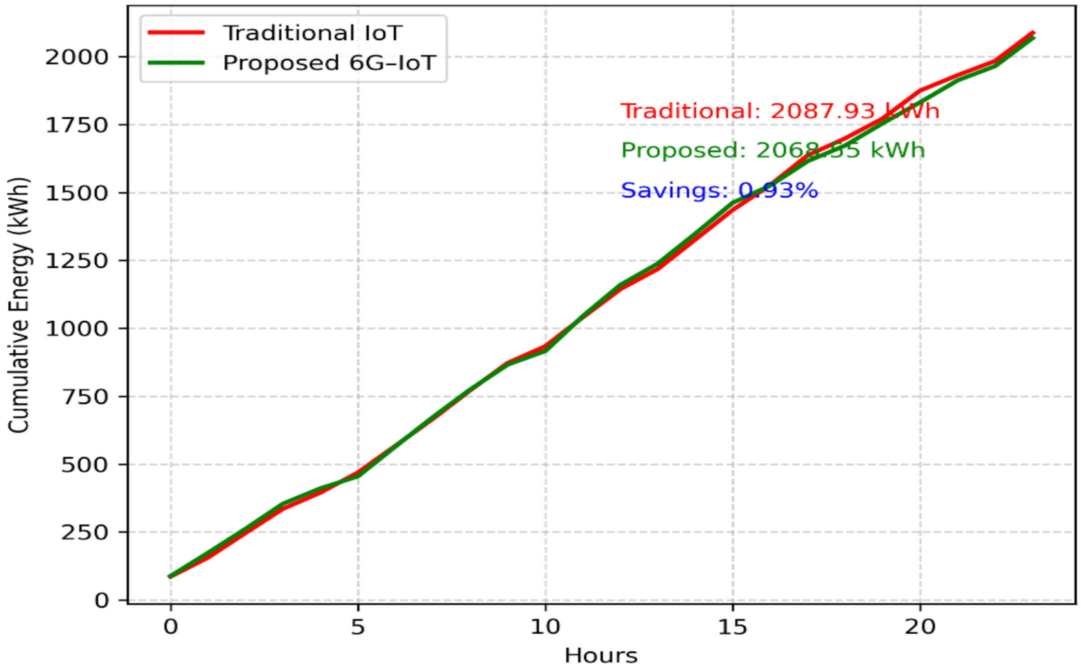

Fig 6. Cumulative Energy Consumption in the Transportation Sector: Traditional IoT vs Proposed Energy-Aware 6G–IoT.

Transportation energy consumption is EC charging stations, road lights, and IoT-based sensors. These systems need a regular energy supply, but the suggested architecture will introduce dynamic load balancing and adaptive charging plans and decrease the cumulative consumption of 2087.93 kWh to 2068.55 kWh, which is equivalent to a 0.93 percent saving. The **Fig. 5** shows that even the industries with constant need of operation can be provided with the management that is energy conscious in real time, which helps in building sustainable urban infrastructure.

The suggested Energy-Aware Green 6G-IoT Architecture has a range of strengths that allow it to be considered very suitable to the environmentally-friendly smart city applications. To start with, the framework allows real-time monitoring of energy and predictive control of heterogeneous IoT devices by combining 6G ultra-low latency communication with edge intelligence. This would facilitate preemptive control of the energy use both on residential, commercial and transportation level and would decrease the amount of wastage and yet ensure service delivery. Second, the architecture creates a balance between the optimization of the local devices and the coordination of the global city without making individual sectors work against the overall goals of a city in terms of energy consumption. The fact that AI-driven predictive models are included also boosts the efficiency of operations since the patterns of energy demand are predicted, as well as the operations of the devices are adjusted dynamically. Also, the modular nature of the framework allows it to be easily scaled to support different quantities of IoT connections and other potential urban expansions. All these attributes alone lead to sustainable energy consumption, which is in line with SDG 7 to achieve affordable and clean energy solutions. **Fig. 6** shows Cumulative Energy Consumption in the Transportation Sector: Traditional IoT vs Proposed Energy-Aware 6G–IoT.

There are also certain limitations of the proposed model. Though the energy savings are high, it is limited in part by the energy demands of edge nodes and AI computations which are power consuming. Besides, the framework is based on the ideal conditions of the 6G network, such as zero-latency and stable connectivity, which is not always practical in practice and is particularly not possible in regions where network infrastructure can be problematic. The other constraint is the heterogeneity of IoT devices; variations of the capabilities and energy model of the devices can cause some variation, which can slightly decrease the effectiveness of optimization. Lastly, the existing simulation is based on simplified urban conditions, and other aspects of reality like human behaviour model, unforeseen equipment malfunctions or network disruptions have not been fully taken into account. The practicality and robustness of the proposed architecture can be further improved by such limitations as energy harvesting of edge nodes, fault-tolerant, and large-scale city trials to be applied in future work.

V. CONCLUSION

This research introduces an Energy-Aware Green 6G-IoT Architecture aimed at developing sustainable smart cities, particularly by streamlining energy management across residential, commercial, and transportation sectors. The proposed framework employs the features of 6G ultra-low latency, edge intelligence, and AI-driven predictive analytics for real-time energy monitoring, dynamic consumption regulation, and even forecasting future energy demand. A custom-built simulator shows that this architecture can save up to 828% more energy than traditional IoT systems. This big change is based on how the industry uses it, which shows how it can save energy in cities. A big part of this success is the combination of local edge computing and global cloud integration, which makes it easier to manage the different types of IoT devices and cut down on energy waste. The proposed architecture is scalable and adaptable, making it easy to grow and change as smart cities change over time. One of the best things about this architecture is that it fits with SDG 7: Affordable and Clean Energy. One of the main goals would be to use energy more efficiently, use less unnecessary energy, and make cities' energy distribution systems safer. But there are still some problems with the system, even though it has a lot of potential. These are the costs of edge computing, the need for good conditions for 6G networks, and the fact that IoT devices come in many different shapes and sizes. Future research will encompass the development of energy harvesting methodologies for edge nodes, improved fault tolerance, the creation of more accurate models of urban behavior (both individual and collective), and extensive pilot implementations to further optimize and evaluate system performance. The suggested Energy-Aware Green 6G-IoT Architecture is a very good and long-lasting way to manage energy in smart cities. It is a great solution for future IoT systems because they promise to improve technology while also protecting the environment and showing real energy savings, better performance across all sectors, and meeting global sustainability goals.

CRediT Author Statement

The authors confirm contribution to the paper as follows:
Conceptualization: Babithalincy R; **Methodology:** Kanev Boris Lisitsa; **Software:** Kanev Boris Lisitsa; **Data Curation:** Kanev Boris Lisitsa; **Writing- Original Draft Preparation:** Kanev Boris Lisitsa and Babithalincy R; **Visualization:** Kanev Boris Lisitsa and Babithalincy R; **Investigation:** Kanev Boris Lisitsa and Babithalincy R; **Supervision:** Babithalincy R; **Validation:** Babithalincy R; **Writing- Reviewing and Editing:** Kanev Boris Lisitsa and Babithalincy R; All authors reviewed the results and approved the final version of the manuscript.

Data Availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Conflicts of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Competing Interests
The authors declare no conflict of interest.

References

[1]. M. shaheen, H. E.-D. Moustafa, H. S. Marie, and W. Raslan, "Towards Smart Sustainable Cities: The Role of IoT and 6G Wireless Networks," Delta University Scientific Journal, vol. 7, no. 3, pp. 228–244, Nov. 2024, doi: 10.21608/dusj.2024.433465.
[2]. X. Fernando and G. Lăzăroiu, "Energy-Efficient Industrial Internet of Things in Green 6G Networks," Applied Sciences, vol. 14, no. 18, p. 8558, Sep. 2024, doi: 10.3390/app14188558.
[3]. R. Kumar, S. K. Gupta, H.-C. Wang, C. S. Kumari, and S. S. V. P. Korlam, "From Efficiency to Sustainability: Exploring the Potential of 6G for a Greener Future," Sustainability, vol. 15, no. 23, p. 16387, Nov. 2023, doi: 10.3390/su152316387.
[4]. Y. Lin and M. Song, "Exploring the Potential of Generative Adversarial Networks in Enhancing Urban Renewal Efficiency," Sustainability, vol. 16, no. 13, p. 5768, Jul. 2024, doi: 10.3390/su16135768.
[5]. D. A. Milovanovic and Z. S. Bojkovic, "Exploring 5G/6G Energy-Efficiency in Mobile Communications for Sustainable Future," Intelligent and Sustainable Engineering Systems for Industry 4.0 and Beyond, pp. 259–292, Jan. 2025, doi: 10.1201/9781003511298-13.
[6]. S. Sangeetha, J. Logeshwaran, M. Faheem, R. Kannadasan, S. Sundararaju, and L. Vijayaraja, "Smart performance optimization of energy-aware scheduling model for resource sharing in 5G green communication systems," The Journal of Engineering, vol. 2024, no. 2, Feb. 2024, doi: 10.1049/tje2.12358.
[7]. S. A. AlQahtani, "An efficient resource allocation to improve QoS of 5G slicing networks using general processor sharing-based scheduling algorithm," International Journal of Communication Systems, vol. 33, no. 4, Nov. 2019, doi: 10.1002/dac.4250.
[8]. M. Kumar and A. Gautam, "A Beamforming-Aided DRX Mechanism for Traffic-Aware Energy Optimization in 5G NR-U," International Journal of Communication Systems, vol. 38, no. 16, Sep. 2025, doi: 10.1002/dac.70251.
[9]. C. H. Gebara and A. Laurent, "National SDG-7 performance assessment to support achieving sustainable energy for all within planetary limits," Renewable and Sustainable Energy Reviews, vol. 173, p. 112934, Mar. 2023, doi: 10.1016/j.rser.2022.112934.
[10]. A. Kaur and S. K. Sood, "Cloud-Centric IoT-Based Green Framework for Smart Drought Prediction," IEEE Internet of Things Journal, vol. 7, no. 2, pp. 1111–1121, Feb. 2020, doi: 10.1109/jiot.2019.2951610.
[11]. M. Umair, M. A. Cheema, B. Afzal, and G. Shah, "Energy management of smart homes over fog-based IoT architecture," Sustainable Computing: Informatics and Systems, vol. 39, p. 100898, Sep. 2023, doi: 10.1016/j.suscom.2023.100898.
[12]. H. Hassanein and Jing Luo, "Reliable Energy Aware Routing In Wireless Sensor Networks," Second IEEE Workshop on Dependability and Security in Sensor Networks and Systems, pp. 54–64, doi: 10.1109/dssns.2006.10.
[13]. S. Jabbar et al., "Analysis of Factors Affecting Energy Aware Routing in Wireless Sensor Network," Wireless Communications and Mobile Computing, vol. 2018, no. 1, Jan. 2018, doi: 10.1155/2018/9087269.
[14]. V. E V and B. S Shylaja, "An Energy Aware Routing for Cognitive Radio Wireless Sensor Network using FuzzyQ," International Journal of Science and Research (IJSR), vol. 11, no. 1, pp. 1563–1571, Jan. 2022, doi: 10.21275/sr22125121246.
[15]. K.M.Padmapriya, "An Efficient and Energy Aware Routing Protocol for Underwater Wireless Sensor Network," Communications on Applied Nonlinear Analysis, vol. 31, no. 7s, pp. 82–91, Aug. 2024, doi: 10.52783/cana.v31.1286.
[16]. K. Lakshmanna, N. Subramani, Y. Alotaibi, S. Alghamdi, O. I. Khalafand, and A. K. Nanda, "Improved Metaheuristic-Driven Energy-Aware Cluster-Based Routing Scheme for IoT-Assisted Wireless Sensor Networks," Sustainability, vol. 14, no. 13, p. 7712, Jun. 2022, doi: 10.3390/su14137712.
[17]. M Surya Bhupal Rao, "Hybrid Metaheuristic Optimization Algorithms for Energy Aware Fine Cluster Head based Routing in Wireless Sensor Networks," Journal of Information Systems Engineering and Management, vol. 10, no. 24s, pp. 370–380, Mar. 2025, doi: 10.52783/jisem.v10i24s.3911.
[18]. K. Thangaramya, K. Kulothungan, R. Logambigai, M. Selvi, S. Ganapathy, and A. Kannan, "Energy aware cluster and neuro-fuzzy based routing algorithm for wireless sensor networks in IoT," Computer Networks, vol. 151, pp. 211–223, Mar. 2019, doi: 10.1016/j.comnet.2019.01.024.
[19]. A. K. Das, R. Chaki, and K. N. Dey, "Cluster-based energy-aware routing scheme (CBEARS) for wireless sensor network," International Journal of Sensor Networks, vol. 21, no. 4, p. 262, 2016, doi: 10.1504/ijsnet.2016.079176.
[20]. P. N. Khairnar, S. N. Sangeethaa, A. S. Rao, S. Srimathi, S. Sivakumar, and G. Bharani, "Design of Hybrid Energy Aware Cluster Based Multipath Routing Protocol in IoT Assisted Wireless Sensor Networks," 2023 7th International Conference on Electronics, Communication and Aerospace Technology (ICECA), pp. 1423–1429, Nov. 2023, doi: 10.1109/iceca58529.2023.10395094.

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