IoT-Driven Sustainable Green Energy Systems in an Organization: Issues and Challenges

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Abstract: Sustainable energy harvesting from renewable sources such as solar, wind, or water power leads to a significant challenge in managing IoT applications. Utilizing renewable energy combined with optimized system energy has become a major concern across IoT-based large-scale systems for obtaining a reliable and energy-efficient eco-infrastructure system. A green technology-operated IoT (G-IoT) has been introduced as part of energy efficiency solutions for IoT-based systems to address the aforementioned issues. Many researchers have explored various solutions related to energy-efficient G-IoT approaches for eco-infrastructure systems in an organization such as a university campus. As there are various existing approaches to G-IoT, the question here is how to produce a reliable, real-time, and energy-efficient system to ensure sustainability for replicating a city like a university. This paper intends to explore existing works on G-IoT-based approaches in terms of energy efficiency issues and challenges from various authors' perspectives. The key goal of this study is to conduct a comprehensive overview to identify the parameters involved in developing a real-time and energy-efficient G-IoT system from existing works. Accordingly, an operational approach is introduced to review and analyze the work, factors, and techniques of G-IoT-related existing articles. From exploration and analysis, this study affords an in-depth description based on current trends, related parameter identifications, and capable approaches to bridge existing strategic gaps for future research. Thus, this study is expected to develop an IoT-powered sustainable green energy system replica for an organization.

Keywords: Energy Harvesting, G-IoT, Green Technology, Renewable, Sustainable

Citation: Ajra, H., Majid, M. A., Islam, M. S., Zabidi, T. A. B & Hammad, K. A. I. (2023). IoT-Driven Sustainable Green Energy Systems in an Organization: Issues and Challenges. In M. Shelley & O. T. Ozturk (Eds.), *Proceedings of ICRES 2023-- International Conference on Research in Education and Science* (pp. 1-14), Cappadocia, Turkiye. ISTES Organization.

Introduction

Nowadays, sustainable energy procurement has become very important due to the definition of new digital technologies or services day by day. Moreover, the growing population of today's world relies on a variety of technologies, such as the Internet of Things (IoT) and its applications, to meet their digital needs. Nevertheless, increasing global climate change can be accelerated by harnessing sustainable energy from renewable sources in digital technologies or services. The IoT [1] is a system and innovative technological paradigm of billions of interconnected objects through the internet around the world. In addition, IoT devices and applications play an essential role in developing some innovative applications in any country where various activities are involved, such as data collection, data sharing, data storage, data monitoring and testing, and data transfer without human intervention. Also, the real advancement of IoT has opened up opportunities for infrastructure development that is gaining worldwide acclaim. However, these infrastructures consume vast amounts of energy to accomplish their functions. With the increasing number of IoT devices like sensors, actuators, RFIDs, computers, and mobiles in IoT applications, the demand for energy in each sector is constantly increasing.

Thus, it is creating a shortage of energy sources and increasing energy expenditure, wasting energy in the form of heat, and the resulting crisis with uncertainty is deepening day by day. As a result, emissions of carbon dioxide (CO2) are rising day by day. Due to increasing energy demand, it will be very complicated to achieve high-quality services with greater energy efficiency. Also, uninterrupted renewable energy sources will be required when renewable energy sources are used as substitutes for non-renewable energy sources. Even energy demand and supply equilibrium, energy optimization [2], and cost analysis are important factors for attaining energy efficiency and achieving sustainability for any infrastructure. Thus, these are considered as main issues and challenges in any IoT-driven sustainable infrastructure for the green energy system.

However, in order to reduce energy costs and achieve sustainability, it is essential to build the structure of energy-efficient IoT, called green IoT (G-IoT). This configuration can certainly save costs and assist in keeping the balance of the environment as well as help in the longevity of human beings. For sustainable green structures [3], initially, renewable energy sources can be used as energy sources instead of fossil fuel or electric energy sources for any type of organization like university, company, campus, or industry. Consequently, green energy can be harvested from renewable sources for IoT-controlled energy systems, and optimization strategies can be applied to obtain energy efficiency [4] and sustainability of IoT-driven infrastructure. Thus, the objectives of G-IoT-based sustainable real-time infrastructure should be energy-efficient, green, and sustainable for any type of application of an organization. Researchers need to be concerned enough about what issues and challenges are considered for the green energy system to achieve the objectives of the proposed framework.

Section 2 broadly describes the related studies for concepts, approaches, components of IoT and G-IoT, sustainable structure, energy system, and application from different aspects. Section 3 represents the methodology of this study. Section 4 establishes the recent trends in the G-IoT methodology, including a comparative exploration of recent related research. Section 5 expresses details of the issues and challenges of G-IoT associated with reliable, sustainable infrastructure for energy-efficient systems. Section 6 discusses research gaps and prospective recommendations based on existing studies. Finally, section 7 concludes the last part of this study.

Related Studies of Sustainable Infrastructure

IoT network paradigm promises a broad scope for the researcher to optimize energy in various sectors. The research community has an attraction in working on G-IoT, which uses renewable energy sources and developed energy-efficient mechanisms to attain maximum energy efficiency, which leads to sustainability. Although, many research papers exist on IoT, G-IoT, technologies, and applications. Here, the basic concept of IoT and G-IoT is presented with a brief description so that readers get a brief concept at a glance. The structure of G-IoT towards sustainability, G-IoT technologies, and current technologies are shown in this section to get the idea of G-IoT sustainable infrastructure to develop a real-time model and which trends are currently used and why they are important.

Overview of IoT and G-IoT

IoT is a system of interdependent and interconnected devices, objects, machines, or applications that uses a unique identifier (UID) without human-to-computer or human-to-human interaction. In addition, it has various sensors, communication hardware, processors, and actuators by which it can sense and detect the environment or data and deliver functionality. Again, IoT [5] provides an opportunity to improve the overall efficiency of devices, machines, or applications so that lighting, office, building, health, manufacturing, education, transport, security, and energy can be smarter and safe more for daily living of human being. In addition, it reduces GHG and Co2 footprint, making the environment safer and more sustainable. Energy in IoT is the most critical factor since energy consumption in IoT is increasing in proportion to the number of devices like sensors, actuators, gateways, etc. The G-IoT is an energy-efficient IoT that makes the green ambient intelligence for reducing harmful gas emissions, providing the lowest energy consumption and operational cost, creating environmental policy, monitoring and preserving the environment, and supporting a sustainable policy of the potential smart world. Also, G-IoT is used to reduce carbon footprint as a technological advancement to initiate remarkable changes in the daily living of human beings.

Layer-based architecture of IoT

The term Internet of Things (IoT) connects billions of objects through a network and is a growing, promising technology that is considered to be a global infrastructure with tremendous potential for tackling a wide range of social, economic, and environmental challenges. It performs interaction between object-object or human-object through a network or cloud. As it connects billions of objects, the IoT also uses specific, flexible architectures that allow for a variety of important activities and interactions at different levels. Fig. 1 shows the basic IoT architecture, which contains cohesive protocol layers, supported applications, and intended functions.

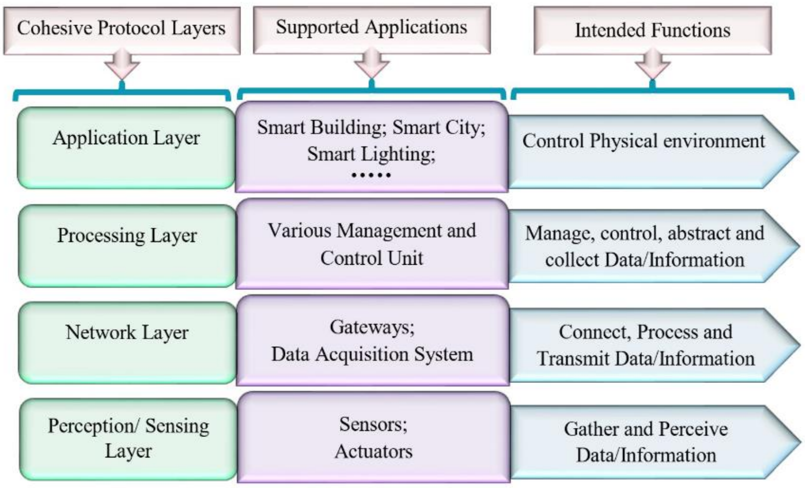

Fig.1: The basic architecture of IoT

At the perception/sensing layer, there are various physical devices such as sensors and actuators where data is collected and perceived. In the direction of the network level, there are various gateways and data acquisition systems where data is connected, processed, and transmitted. For the processing level, data management, control, data abstraction, and data collection take place. There are different types of applications, such as smart home, smart city, and others, towards the application layer with which the physical environment can be controlled. Due to power constraints, energy consumption in IoT devices is considered one of the most critical challenges in developing or managing a variety of applications on IoT systems.

G-IoT-driven sustainable structure

The G-IoT [6] reduces energy consumption and provides better energy efficiency by minimizing the GHG emission and carbon emission of existing IoT applications to achieve a smart, reliable, and sustainable environment. Furthermore, the reduced energy consumption of renewable resources and their continued energy efficiency increase the effectiveness of IoT applications. An overview of G-IoT for any organization is shown in Fig. 2, which introduces vital aspects such as smart lighting, vehicle, building, and office, as well as a smart green energy source. Smart green power or energy generated from renewable resources is a flexible and simple control system for more efficient utilization of multifaceted energy consumption management in IoT using smart technology, enhanced design, and conservation solutions. A G-IoT framework of any organization requires a basic solution for the deployment and design of the architectural blocks of smart lighting systems using interfaces to IoT-enabled sensors, bulbs, or adapters where lighting systems will operate automatically. A safe and smart green transportation system to build a beautiful green world is one of the important aspects of an organization or a country to create an energy-efficient, sustainable environment through the green services of IoT. Green smart building technology for a G-IoT-based organization refers to devices that are used to intelligently operate, monitor, data transfer, analyze and optimize user-centric ways of building environment by increasing green energy efficiency to achieve healthy, productive, and quality workplaces. Green management-enabled smart office system conducts IoT-enabled sensors and devices through the operations of sustainable renewable energy that remotely control and monitor all types of office equipment, techniques, and their security. G-IoT-based smart waste or E-waste management and planning technology presents a real-time remote monitoring and controlling system to collect and process various types of garbage, radioactive waste, daily household waste, and toxic industrial waste from a long-range area of any country using renewable energy. To maintain a green, healthy and clean ecosystem, researchers need to work more to make a G-IoT-based sustainable renewable energy system that will be cost-effective and efficient with low power consumption.

Fig. 2: G-IoT-driven sustainable infrastructure.

G-IoT technologies

The G-IoT is needed due to the increasing consciousness of global issues and disposing of the concerns of global issues. However, in G-IoT, various technologies can be used like green RFID, green WSN, data center, M2M, and cloud computing. The taxonomy of G-IoT technologies is shown in Fig. 3. Radio Frequency Identification (RFID) [7] is one of the most important technologies where the sensing mechanisms have been worked in the G-IoT network. It consists of active tags, passive tags, built-in batteries, various electronic devices, software, sensors, servers, access controllers, and antennas. The sensing technology can make a significant contribution to the identification of various activities in the IoT sector.

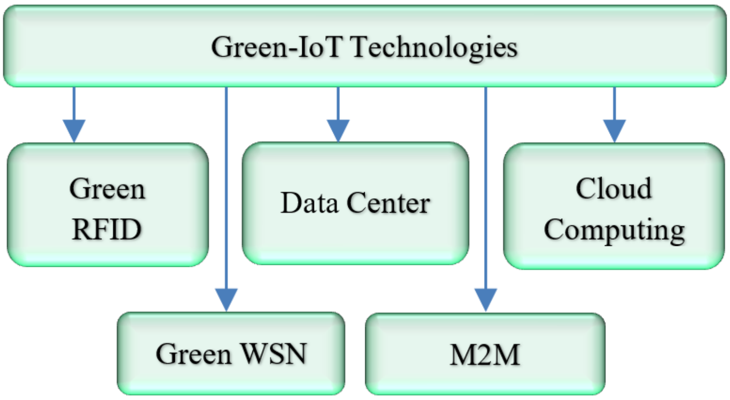

Fig. 3: Taxonomy of G- IoT Technology

However, it is included in the network world as a reliable, accurate, and efficient technology. Green WSN [8] is another important technology of G-IoT, which plays a significant role in reducing energy consumption through green energy saving and monitoring the environmental condition of IoT applications and devices through sensors. Also, green WSN has been achieved using energy conservation, green routing, and radio optimization. The uses of renewable energy sources and green data centers [9] are involved in various types of data storage, application storage, data processing, management, and data dissemination. Network infrastructure plays a vital role in the data center, providing a comprehensive idea of how energy consumption can be reduced, what performance can be obtained and how can be measured the scalability of the data center. Machine-to-Machine (M2M) is the concept to be an innovative technology to attain G-IoT that automatically reduces the energy consumption of the IoT system, enabling the IoT systems to become more efficient and even reducing the emission of various hazardous gases such as GHG and Co2. M2M [10] have transmission power, routing algorithms, and optimized power-saving protocols. Green Cloud Computing [11] is an innovative virtualization technology that is considered to be a significant and intelligent part of IoT. Because of its high-capacity storage, it is widely regarded as one of the essential services in the field of IoT, such as SaaS, PaaS, and IaaS. It provides services for energy consumption reduction, IoT sensor data analysis, unlimited computing, communication, and networking.

G-IoT-driven Energy System

G-IoT-driven power systems bring many benefits that contribute to energy efficiency through intelligent technology-based essential energy consumption and power consumption optimization [12]. The G-IoT Energy System is a battery-powered active system consisting of sensors and various devices that can contribute to maximum efficiency in energy management through maximum energy savings and minimum energy consumption. Existing energy systems have a variety of approaches to reduce energy consumption, increase energy savings, and achieve maximum energy efficiency. Among them, energy harvesting, energy saving, and energy optimization are the main approaches. For uninterrupted energy supply to IoT compatible systems, energy harvesting [13] is a mechanism that helps to generate more energy using green energy from the surrounding environment of the IoT network. Also, energy optimization is a great way to use energy when needed, which creates an environment to reduce energy costs and maximize energy efficiency to benefit any organization, climate, and human being. Again, energy-saving strategies are employed based on various protocols, developing algorithms, and different hardware solutions.

G-IoT-driven Existing Application towards Sustainability

G-IoT applications play an important role in making the real world greener and more sustainable, such as saving energy, reducing GHG and CO2 emissions, conserving pollution, and increasing energy efficiency. In addition, temperature changes can help reduce the risk of climate change in our lives. There are also other reasons for the widespread use of G-IoT, such as increasing reserve funds of energy, gaining ideas on how to conserve natural resources, enhancing social, economic, and environmental sustainability, and creating ways to conserve natural resources and enrich improved human well-being. There are various existing applications, among them are home automation, smart city, grid automation, smart healthcare, smart agriculture, transport automation, smart manufacturing, etc., in G-IoT, which concentrate on saving energy and increasing energy efficiency towards sustainability.

Home automation

G-IoT technology can be used to control a wide variety of lighting, fans, computers, televisions, heating systems, microwaves, air conditioners, ovens, and even the removal of waste from a computer or smartphone with remote sensors. As a result, energy consumption [14] can be controlled to operate different appliances in the house and successfully perform various tasks. For example, if home appliance devices are in hibernate, idle, or off mode, the power consumption can be turned off automatically using this technology. Also, the use of renewable energy can reduce the harmful emissions of greenhouse gases to the environment and the adverse effects of carbon footprint to achieve sustainability.

Smart city

Smart City [15] is an important application of G-IoT that provides a variety of services through the development of technological and intelligence standards in any of the most populous cities in the world to play a leading role in achieving economic, social and environmental sustainability. A smart city can involve smart lighting, building, metering, waste management, traffic execution, and smart water management. These applications help in the use of active energy through various sensors in a smart way, saving energy and increasing energy efficiency.

Grid automation

As our world's population grows, so does the demand for energy. Achieving energy efficiency can be impacted by a high-quality power supply, and reducing energy costs, leading to sustainability. The goal of Smart Grid is to provide the highest quality power at the lowest possible cost to meet the needs of a growing population. In that case, building meters that supply energy to every home, building, office, factory, company, and organization can be incorporated into the network where smart grid [16] operators can further enrich the services.

Smart healthcare

In today's world, healthcare is an important issue for human beings and is being improved day by day through technological advances with the help of the internet. Various necessary, complex, sophisticated, and modern devices and machines are used for tracking, diagnosing, and monitoring patients' diseases. In addition, these devices consist of various advanced sensors, actuators, and IoT physical devices to produce essential data in real-time in healthcare applications. In healthcare [17], performance is enhanced when medicines are integrated with advanced machines. However, sensors and actuators are used for analyzing data to present and explore the human body conditions so that patient's treatments can be possible in real-time and to take the necessary step when required. Energy-efficient IoT is applicable and valuable so that energy efficiency can be attained by reducing the amount of energy consumption required to operate these devices. Increased energy efficiency can be affected by higher levels of power supply and reduced energy consumption, leading to sustainable policy.

Smart farming and agriculture

The demand for grains and crops is increasing with the world’s growing population. As a result, the required energy consumption is much higher due to increased crop and grain productivity. Smart farming and agriculture [18] is a new technology and application consisting of various types of agricultural sensors, actuators, drones, networks, hardware, and software to increase crop productivity. This application provides maximum quality energy at the lowest possible cost for crop production and fertilizer management, crop quantity and quality monitoring, field monitoring, intrusion attack detection, real-time monitoring, and proper application of natural resources, which can help in achieving energy efficiency and sustainability. In addition, smart farming and agriculture play an important role in various tasks such as helping farmers reduce their physical workload, information exchange, managing information systems, analyzing; and storing data, and overcoming various challenges in crop production and management.

Transport automation

In today's world, smart transportation is a vital application for improving human life through technological advancement. These transports consume the highest amount of energy for improving transportation management. Automated transportation systems manage a variety of modern, complex, important, and sophisticated devices and software for the detection, operation, and monitoring of transport [19] that generates the necessary data in real-time smart transport applications using various sensors, physical devices, and actuators of IoT. Smart transport integrates all strategically challenging factors for data processing and collection. Thus, there is a need to increase energy efficiency, which can be achieved by reducing energy consumption. Increased energy efficiency can be affected by higher energy supply and lower energy consumption, which leads to sustainable policy.

Smart manufacturing

Smart manufacturing is a vital worldwide application where energy efficiency and sustainability are considered important issues. The integration of smart manufacturing [20] technology and IoT is used to provide new tools and facilities for real-time energy efficiency monitoring and analysis. In the webwork of G-IoT, smart manufacturing schemes towards sustainable principles can achieve maximum energy efficiency based on optimal energy management.

Methodology

This study presents the novelties of strategies, including sustainable architecture through various literature reviews in the context of G-IoT-based research, and can provide insights into the systematic improvement of energy consumption and the overall performance of green services. Furthermore, this study reflects a wide range of issues and challenges with gaps for future research perspectives, so that researchers can gain a broader understanding and scope for increasing energy efficiency and achieving green sustainability using renewable sources.

In the present study, critical and analytical research questions are being emerged from the relevant literature review for researchers to improve energy efficiency and achieve green sustainability. A sound research question for achieving sustainable green infrastructure could be what are the broad issues and challenges, recent trends, and research gaps related to G-IoT approaches from existing G-IoT-based research? Besides, based on the answers given, the following question can be also raised that the researchers need to be concerned enough about what problems and challenges are considered for the energy-efficient sustainable green system through the analytical search of the literature in this review study.

In this study, the significant information about this type of green IoT based industry has been extracted by reviewing the perception of various researchers, analysis of existing literature and relevant opinions of researchers. Latest trends in G-IoT systems, the related parameters under the defined algorithm, and their comparative exploration have been exposed in order to systematic methodology and future guidance.

Recent Trends In G-IoT Methodology

In view of rapidly growing applications in various sectors, smart IoT services are evolving the living standards of a growing population worldwide at various stages. At the same time, significant environmental and social changes are taking place at the global level. A green energy system can be a mainstream power system in these applications, which can meet the strong need for uninterrupted green power in urban and rural areas. The development of a green system against the current conventional power system is being seen as a need to change the overall quality of life of the people. Consequently, in this study, an attempt has been made to highlight the current trends in multi-purpose green energy systems involving hardware, software, sensor, power management, harvesting, energy management, and others. Current trends in green energy systems are decorated in Table 1 by selected factors such as standards of G-IoT, offered model, energy sources, and energy-efficient approaches from recent studies. Knowledge of these mentioned factors can support future researchers in making the best use of green energy consumption and achieving consistent feedback across the available allocation units of IoT applications. The operation of various G-IoT systems can be planned using energy-efficient approaches to ensure the minimum power consumption from renewable energy sources by studying the existing proposed model for optimal decision-making in a green system.

Table 1: Current trends of Green Energy System

Ref.	Standards of G-IoT	Offered Model	Energy Sources	Energy Efficient Approach
[21]	Power management	MODDA-based green energy management	Renewable energy	MODDA
[22]	Sensor	IoT-based WECS	Wind	FODPSO-based on FLC
[23]	Power management	IoT-based SGE	Local renewable sources	Deep reinforcement learning
[24]	Hardware	IoT-based HGES	Wind and solar	IoT based microcontroller
[25]	Software	GCDCs	Wind, power grid, and solar	Task Scheduling
[26]	Harvesting	LTE macrocell BS	Renewable energy	Monte-Carlo simulation
[27]	Power management	CCHP and WHR- based DCEA	Brown energy and power grid	CCHP and WHR
[28]	Harvesting	HEH communication system	Hybrid energy	GMM and FSMEC
[29]	Harvesting	Green cognitive sensor network model.	Wind and solar	Efficient algorithm with Bisection method
[30]	Energy management	Battery-aware green energy management	Solar and power grid	BAPA algorithm

MODDA = Multi-Objective Distributed Dispatching algorithm; WECS = Wind Energy Conversion System; FODPSO = Fractional Order Darwinian Particle Swarm Optimization; FLC = Fuzzy Logic Controller; SGE = Smart Green Energy; HGES = Hybrid Green Energy System; GCDCs = Green Cloud Data Centers; DCEA = Data Center Energy Architecture; CCHP = Combined Cooling, Heating and Power; WHR = Waste Heat Reuse; HEH = Hybrid Energy Harvesting; GMM = Gaussian mixture model; FSMEC = Finite-State Markov Energy

Channel; EMS = Energy Management System; BAPA = Battery Aging and Price-Aware (BAPA).

However, many researchers have offered different types of models based on green energy distribution, energy conversion, hybrid green energy, data center, green cognitive sensor network, battery-aware green energy management, and so on that are mentioned in this table. They have used wind, solar, hydroelectric, geothermal, hybrid energy, and even local renewable sources as green energy sources in their work models. Moreover, they have applied some specific energy-efficient approaches like multi-objective distributed dispatching, an efficient algorithm with bisection method, battery aging, price-aware, waste heat reuse, deep reinforcement learning, task scheduling, etc., to develop the G-IoT system.

Table 2: Focusing on the related parameters for G-IoT-driven sustainable infrastructure under the defined algorithm

Ref.	Algorithm	Measuring Parameter	Simulators	Domain	Sustainable Policy
[31]	SBO, Adam optimizer	Energy, delay, distance, throughput,	Shallow RVFL	IoT network	Economic
[32]	Fuzzy efficient energy algorithm	Power, speed, distance, temperature	MATLAB	Smart home	Environmental
[33]	Relaxation-based algorithm	Energy generation rate, fog nodes, QoS, energy consumption	Gurobi	Smart CPS	Economic and social
[34]	DPCOEM	Task arrival probability, deadline, distance, average energy harvest power.	MATLAB	IoT system	Environmental
[35]	Task Scheduling algorithm	CPU speed, power, delay, processing capacity	uTesla platform	IIoT system	Economic
[36]	Energy prediction algorithm	Energy harvesting profile, complete transmission, an average rate of drop bits	Numerical	IoT networks	Environmental, economic
[37]	IoT hub management algorithm	IoT-hub speed, energy, latency, network lifetime, packet overhead	Castalia	WSN assisted IoT	Environmental
[38]	JT-CoMP	Throughput, BW, Energy, Load Factor, PV module	MATLAB	Cellular Network	Environmental
[39]	Energy harvesting protocol	No. of Packets, Energy, Network Lifetime	OMNET++	IoT Network	Environmental
[40]	ABC	CUF, PR, PI, PR, line losses, and load consumption	MATLAB	Green Building	Economic, Environmental

SBO = Satin bowerbird optimizer; RVFL = Random vector functional link; CPS = Cyber–Physical System;

DPCOEM = Dynamic parallel computing offloading and energy management; JT-CoMP = Joint transmission coordinated multipoint; CUF=Capacity utilization factor; PR=Performance ratio; IIoT = Industrial IoT; PI=Performance index; PR=Proportion of the energy; ABC=Artificial Bee Colony

In addition, creating a more energy-efficient G-IoT framework requires a prominent or concise definition of sustainable policy, where a variety of existing algorithms can help to provide the most favorable decision and determine an optimal balance of dissimilar energy supply systems. Table 2 focuses on the measuring parameters specified to build a sustainable infrastructure powered by G-IoT under the recently defined algorithm, which can play an important role in balancing power transaction operations and potentially timely results from internal power generation sources. To build a reliable IoT-driven sustainable infrastructure for green industrial networks, researchers need to verify algorithms using measuring parameters through a simulation environment. This simulation environment will play a significant role in processing the performance and energy conservation challenges of the entire green industry network model, influencing the system towards sustainable policy. Besides, by looking at some recent existing studies for green IoT, IIOT, WSN, cyber-physical or cellular network systems, we have assembled the measuring parameters such as delay, distance, throughput, energy, power, speed, distance, temperature, CPU speed, energy generation rate, latency, task arrival probability, processing capacity, transmission, etc. which are disclosed in this table. The components mentioned here can play a key role in creating smart G-IoT infrastructure for current researchers.

Table 3: Comparative exploration for G-IoT of recent related research

Ref.	Energy enabled mode	Network Type	Key Contribution	Assessed Outcomes	Usefulness (+) Limitations (-)	Future Direction
[41]	EMS	WSN, RFID, MANET	Design EMS and fault tolerance scenario in IoT environment	Increased IoT network lifetime	(+) Control the energy consumption in IoT. (-) Questionable Energy source type	Not mention it
[42]	Edge-enabled green IoT	Edge computing network	Provide LDR scheme and its algorithm	Facilitate energy-efficient processing and QoS	(+) Offloading of intensive tasks to edge servers. (-) Capacity constraint in the edge server	Optimize workload in the edge server
[43]	EH-IoT	WSN	Suggest dynamic online EAA	Maximize network utility for quality-of-sensing of ESO	(+) Pursue zero-carbon IoT and network stability (-) Exclude energy harvesting capability measurement	Work on the heterogeneity of sensor nodes of EH-IoT
[44]	CR-based	Sensor	Formulate an	Significant	(+) Achieve efficient green	No indication on

	green IoT	network	efficient cross-layer optimized design	reduction in per-bit energy consumption	IoT and enhance network lifetime (-) Energy harvesting limitations in IoT	it
[45]	Q-EBIoT	WSN	Develop an energy optimization model with quantum computing	Provide better quality performance in efficient time.	(+) Prolong green network lifetime more (-) Energy capacity constraint in sensor	Explore other metaheuristic execution in Q-EBIoT
[46]	ECP	Bluetooth mobile network	Data transmission process in Bluetooth device using ECP	Estimate energy consumption in Bluetooth transactions	(+) Data transactions for smart cities with lower power (-) Design for only Bluetooth devices	Evaluate low battery design for Bluetooth transactions
[47]	GECKO	DSO network	Build decentralized and permissionless scheme for green energy certificate	Verify the integrity of green energy consumption certificates	(+) To market an affordable, diverse renewable energy. (-) Provide only prototypical implementation outline	Work on transmission loss in green energy protocol
[48]	Green Packer	Backbone network	Design fragmentation awareness enabled renewable GLB system	Diminish energy cost of data with effective result	(+) Distribution of geographical green data center (-) Workload placement constraints in the data center	Analyze optimal values of GreenPacker's parameters
[49]	MIoT	WSN	Provide sustainable GMTA	Reduce transmission energy consumption	(+) Change and serve the health community (-) Energy optimization constraint	Work on GMTA for healthcare applications
[35]	Deep-Green based IIoT	Ring	Provide dispersed computing scheme with task scheduling	Reduce communication overhead, a load of computing in IIoT network	(+) Joint optimization in computing and network resources. (-) Only focus on dispersed computing technology	Work on higher computational and container provision migration
[50]	AI-Edge computing scheme in	Edge computing network	Deliver intelligent edge computing with a scheduling	Offload AI tasks in high-end servers	(+) Edge computing for heterogeneous resources (-) Limited to offloading AI	Develop deep learning tasks, including large-

	driven IIoT	strategy	with an optimized algorithm	tasks with small-scale testbed	scale testbeds
[51]	GreenEdge WAN	Jointly formulate task offloading and green energy scheduling	Diminish system task execution cost	(+) Ever-increasing computation in multi-tier edge computing. (-) Optimal allocation and computation offloading constraint	Analyze the possibility of incorporating green energy prediction strategies

EMS = Energy Management Scheme; LDR = Local Data Reduction; EH-IoT: Energy harvesting IoT; WSN = Wireless Sensor Network; Q-EBIoT = Quantum inspired green for Energy Balancing in IoT; EAA = Energy Allocation Algorithm; ESO = Energy sustainability optimization; CR = Cognitive radio; ECP = Green energy consumption policy; GECKO = Green Energy Certificate on kWh Ownership; DSO = Distribution System Operators; GLB = Geographical load balancing; GMTA = Green Media Transmission Algorithm; MIoT = Medical internet of things; Deep = Dispersed Energy-Efficiency Computing Paradigm; IIoT = Industrial Internet of Things;

Also, in this study, the related recent explorations for G-IoT based on sustainable policy from the green energy systems perspective of each appraised research work are shown in Table 3. Referring to various traditional energy-enabled modes and their outcomes can further support the escalation of the research quality in this green-network area. This table provides a comparative exploration of existing green energy-enabled IoT schemes that have been emphasized under certain parameters such as network type, key contribution, assessed outcomes, utility, limitations, and future direction. Although these existing green energy-enabled IoT schemes may be well-suited in their activities of low- and medium-quality sustainable policy-related infrastructures, large IoT-based infrastructures lack facilitates for green energy-enabled high capacity and reliability, which are absolutely essential parts of achieving a quality green environment. So, the main purpose of this study is to realize the need and to inspire the development of a green energy-enabled IoT scheme across appropriate and much larger areas through the comparative exploration mentioned in this table.

In this manuscript, we have studied 57 published articles collected from 2018 to 2022. The articles analyzed have been mentioned in terms of Green Energy Analysis (GEA), IoT-driven Green Environment (IoT-dGE), Energy Efficient Method (EEM), and Sustainable Policy based System (SPS). Fig. 4 shows a typical histogram of the comparative study of recent G-IoT development for these collected published articles. This histogram analyzes the combination of defined content related to G-IoT development, years, and recent journals. Some interesting observations from the histogram outcomes indicate that the concept of G-IoT technology has become a hot topic of much interest in research in recent times.

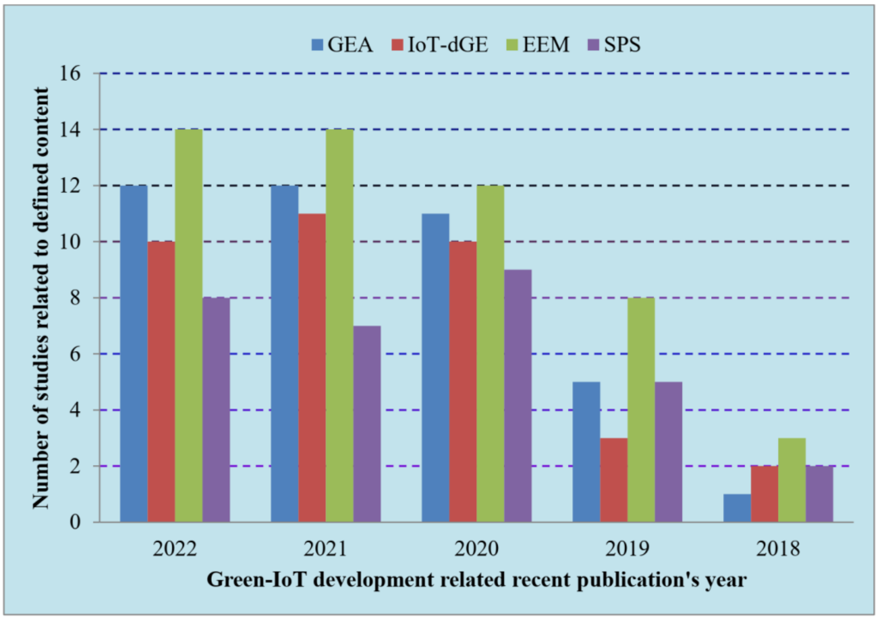

Fig. 4: Comparative study of recent green-IoT development

Issues and Challenges of G-IoT

The most important and fundamental condition of green technology is how to reduce greenhouse gas (GHG) emissions in IoT by reducing energy consumption, saving energy, and gaining energy efficiency so that an organization or a country can benefit socially, economically, and environmentally. G-IoT has many important energy efficiency issues and challenges for an organization. These issues and challenges have social, economic, and environmental implications for sustainability. Among the various issues and challenges, there are some technical issues and challenges; some issues have potentially increased the focus on green energy, some are prerequisites for G-IoT standardization, and some are security and privacy protection from system vulnerabilities. The issues and challenges of G-IoT based framework are shown in Fig. 5, which are outlined below:

Energy costs

The rising energy consumption costs in G-IoT can be considered a crucial issue and challenge. The IoT has developed a variety of applications like smart homes, intelligent buildings, smart agriculture, and smart healthcare to make our daily life simple, beautiful, smart, and smooth. These applications contain millions of devices for analysis, control, and sensing data that consume large amounts of energy resulting in high energy consumption and not being consistently stable. In that case, if renewable energy can always be used at a low cost, then it is possible to achieve maximum energy efficiency by using the maximum energy.

RE sources and quality

Maintaining environmental sustainability through renewable energy generation can be a promising concern for future generations. Due to increasing global warming using non-renewable energy, renewable energy resources are rising in today's world in the distribution of power within IoT systems. The energy harvesting distribution from renewable energy sources can be a major challenge in terms of quality, stability, and adjustment level for smart G-IoT systems. Ensuring maximum utilization, demand, and supply equality of renewable resources in the G-IoT scheme can be a key issue for a green city. Besides, renewable energy resources can be a significant matter to associate with industrial development that will positively influence environmental management towards dynamic and standard adoption.

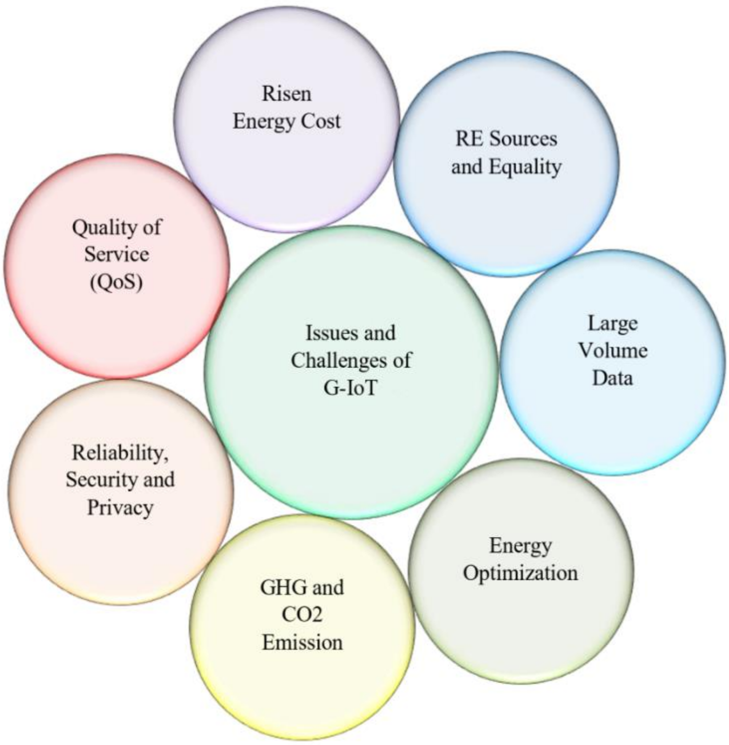

Fig. 5: Issues and challenges of G-IoT-based framework

Large volume of data

For accomplishing the operations such as transfer, process, and storage in IoT systems, a massive amount of data is generated that is collected by the huge number of sensors of objects and stored in the centralized node. IoT systems have unique features because these schemes have limited computing power to analyze since large amounts of data are generated. Besides, to design an energy-efficient G-IoT for any organization, the data-driven technique can use a massive amount of data that are transferred over the network using various processors. Thus, the large volume of data is the greatest challenge for managing a G-IoT system for predicting and detecting the functionalities to realize the sensor body and to analyze, store and process information intelligently and efficiently.

Energy optimization

For decades, energy has been an important element in various fields like building, city, manufacturing, agriculture, etc. Globally, energy is considered an expensive and valuable resource in IoT. The demand for fuel oil is increasing day by day to meet the demand of the people of the world. As a result, the effects of global warming and GHG emissions are increasing, which is having an adverse effect on climate change and human longevity. This is why it has become essential to store energy and achieve maximum energy efficiency in existing applications so that the required energy is consumed and further progress can be made towards achieving sustainability. Require energy can be utilized through the implementation of energy optimization, which can help maintain the optimal balance of energy use and development of energy efficiency structure, thus providing a sustainable environment by providing maximum benefits to people and the climate.

GHG and Co2 emission

The various devices and applications of IoT play an essential role in meeting the needs of people's daily life. IoT consumes much energy to handle a variety of applications, increasing emissions of atmospheric CO2 and harmful GHGs. Therefore, atmospheric CO2 and GHGs are considered important issues in achieving energy efficiency. If maximum energy efficiency can be achieved by reducing energy consumption by optimizing energy, then the environment can be moved towards sustainability.

Reliability, security, and privacy

IoT-based green energy systems use renewable energy to achieve energy efficiency and sustainability. The generation, optimization, and distribution of renewable energy are deeply involved in achieving energy efficiency and sustainability. Reliable management of the generation, optimization, or distribution of a large amount of renewable energy has become an important issue. Achieving efficiency and sustainability of energy structures involves environmentally friendly, comprehensive reliability management and renewable energy distribution, data availability, ease of data usage, and data accuracy. In the future, various tasks are directed towards ensuring the reliability of the power system to manage the context so that the storage capacity and efficiency of the system can be multiplied, but the sustainability of climate change can be ensured.

Besides, data privacy, security, and interoperability are vital issues and major concerns in energy systems of IoT so that aggregated data are used to minimize communication costs and keep the privacy that has not yet been addressed. The sensor nodes of networks are vulnerable due to different threads and attacks. As a result, security breaches have happened in the sensor. Data security is essential to impede unauthorized access and unwanted changes due to various attacks and threads. So, the IoT user is concerned about a green and sustainable system’s reliability, privacy, and security to achieve a reliable and secured system.

Quality of Service (QoS)

The focus of QoS helps to achieve the core goals of a system. Achieving improved and optimized QoS of green energy systems depends on some parameters such as availability, reliability, greenness, and sustainability. The availability of a system means the sources of the energy, data, and network coverage area are available for any system organization. Reliability provides reliable management of the generation, optimization, and distribution of a large amount of renewable energy data and services across IoT compatible devices and applications, network capabilities that are also the reliable backbone to G-IoT connectivity.

However, greening means achieving maximum energy efficiency from a system so that the minimum energy consumption, maximum energy saving, and optimization are attained. As a result, GHG and harmful gas emissions are reduced due to greenness. Besides, low battery charge and less system energy consumption can lead to sustainability. On the other hand, security and privacy are major concerns for getting QoS. To implement the QoS optimization strategy and get the best performance that is predictable and secure, we need to explore appropriate strategies that consider QoS as a significant challenge over G-IoT-based energy systems.

6.0 Research Gaps and Recommendations

In this study, as the focus is less on developing energy-efficient protocols for building reliable G-IoT structures, a detailed study is conducted to realize research gaps related to green energy systems based on IoT-driven sustainable infrastructure. In Table 3 of the previous section, this study presents further limitations or gaps left by the proposed strategies, perspectives, and solutions mentioned by existing researchers to gain insights into the developing green energy systems. In addition, a detailed analysis of the issues and challenges of G-IoT mentioned in the previous section presents the real-time variable impact of research gaps in understanding technological advances and sustainable environmental sustainability. Some of the ascertain gaps, including prospective recommendations based on existing studies, are reviewed.

- The optimized residential energy management system [14] has been designed and analyzed based on the multi-objective optimization mechanism. In this case, the long-term green sustainability can be enhanced by using renewable energy technology, which is an issue for the proper delivery of green IoT-based residential services.
- A novel green deployment framework in 6G communication has been designed using an optimization model by the general advantages of energy consumption [52]. Due to the prevalence of the demand for G-IoT in our world, the G-IoT system can face a big challenge in making it more energy-efficient for higher mobility in the connectivity of extensive coverage.
- An energy-efficient scheme for combining multicast beamforming and network caching has been formulated to enhance G-IoT performance based on transmission and caching protocols, including energy optimization [53]. Significantly, it may suffer for achieving the sustainability of energy structures concerning environmentally friendly, extensive reliability management and renewable energy distribution, and ease of data use.
- The optimized predictive model-based IoT task management module [54] has been introduced to evaluate the energy efficiency in terms of overall usage duration of receiving energy data from

different appliances in smart buildings. In spite of that, the management system mentioned in the Smart Residential Building application can be considered to utilize maximum energy efficiency by reducing the green data energy costs of the various device-based protection and machine learning-related technologies to move towards environmental sustainability.

- In addition, through appropriate simulations, the best energy-centric decision-making power management-based offloading query task processing system with performance [55] have been analyzed to balance resource management and its energy conservation using machine learning for G-IoT. The development of smart G-IoT systems can be an important issue that can be focused on integrating the positive functions in terms of quality, stability, and consistent level of renewable energy source management.
- An optimized energy efficient scheme based on the TPSS algorithm [56] has been used to analyze the extended battery life and energy cost, synthesizing the spreading factor, sensing interval, and power transmission along the distance among dynamic WSN nodes in IoT. In this case, the best plan can be implemented to achieve improved and optimized quality of services of this green power system by ensuring renewable energy sources and their green data availability in the network coverage area with sustainable policies.
- A cluster-based energy-balanced protocol called I-AREOR [57] has been mentioned for increasing network lifespan to balance power consumption by reducing the sensor node's use during data transactions in G-IoT-based smart city systems. However, reliability, security, and privacy management of large amounts of renewable energy distribution can be improved to achieve more optimized energy use efficiency and sustainability in such IoT-based green power systems.

This paper provides several recent empirical studies of evidence-based guidelines, gaps, and concerns for implementing and developing IoT-enabled sustainable infrastructure-based green energy systems. Researchers need to address these gaps and consider the policies involved in improving green-tech performance and sustainability in recovering economic, environmental, and social benefits based on G-IoT. Moreover, we will further work on this technology in the future to develop a secure and reliable G-IoT-based framework by eliminating energy optimization constraints and green power capacity limitations and ensuring the legitimacy of energy performance by focusing on affordable diversified renewable energy to achieve sustainable green infrastructure.

Conclusions

Sustainable green technology is currently a progressive issue in the global green industry, and its advances are usually on-going to be applied in G-IoT applications to more durable, as well as it needs the intervention of researchers to develop solutions to this issue to ensure reliable, sustainable development. Meanwhile, many specific functions of G-IoT operations and their technical algorithms are being improved due to the appearance of sophisticated green energy paradigms. This study presents a systematic overview of recent trends, growing difficulties, issues, and challenges, including the mostly agreed and consistently developed approaches, various infrastructures, operations, and applications related to the use and applicability of IoT-driven green energy systems. Inspired by previous research, this study's comparative exploration and empirical analysis can contribute to the development of sustainable green technologies and build a conceptual upgrading model to improve the decisions on the relationship between environmental, social, and economic performance. It affords a holistic concept and analytic idea of different types of G-IoT models, approaches, renewable sources, measuring parameters, and algorithms. Moreover, it mentions a synopsis of comparative exploration on contribution, assessed outcomes, utility, and limitations for different G-IoT-based network modes. In addition, the studies analyzed have been illustrated in terms of GEA, IoT-dGE, EEM, and SPS, which will generate a lot of interest in research on G-IoT technology in recent times. This study highlights current trends, research issues, and challenges of sustainable green applications from the perspective of renewable energy. This paper will allow further research directions for researchers to find faster and more effective solutions for developing IoT-driven sustainable scheme-based green energy systems.

Acknowledgements or Notes

This study has been funded by Green Technology Research Lab, Universiti Malaysia Pahang (UMP) under the Malaysia National Research Grant FRGS/1/2018/ICT04/UMP/02/4, and UMP Research Grant (RDU190167 and PGRS220338). This study is supported by Bangabandhu Sheikh Mujibur Rahman Science & Technology University, Bangladesh.

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