Energy Reports 8 (2022) 4822–4833

Contents lists available at ScienceDirect

Energy Reports

journal homepage: www.elsevier.com/locate/egyr

Design of low-energy buildings in densely populated urban areas based on IoT

Wenming Zhao [a,*], Jin Chen [b], Tao Hai [c,d], Muamer N. Mohammed [e], Zaher Mundher Yaseen [f], Xuelan Yang [g], Jasni Mohamad Zain [d], Ruihua Zhang [h], Qiang Xu [i,j]

[a] School of Art, Yangtze University, Jingzhou, 434000, Hubei, China
[b] School of Journalism and Communication, Northwest University, Xi'an, China
[c] School of Computer Sciences, Baoji University of Arts and Sciences, 721007, China
[d] Institute for Big Data Analytics and Artificial Intelligence (IBDAAI), Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
[e] Information Technology Department, Community College of Qatar (CCQ), Doha, Qatar
[f] New era and development in civil engineering research group, Scientific Research Center, Al-Ayen University, Thi-Qar, 64001, Iraq
[g] School of Computer Sciences, Universiti Sains Malaysia, 11800 Penang, Malaysia
[h] Faculty of Education, Language and Psychology Postgraduate Department, Segi University, Malaysia
[i] College of Physics and Optoelectronic Technology, Baoji University of Arts and Sciences, Baoji 721016, China
[j] Engineering Technology Research Center for Ultrafast Optics and Advanced Material of Baoji, Baoji 721016, China

ARTICLE INFO

Article history:
Received 29 December 2021
Received in revised form 1 March 2022
Accepted 17 March 2022
Available online 8 April 2022

Keywords:
Low-energy building
Urban area
Population
IoT
Traffic

ABSTRACT

As part of city planning and urban studies, it is customary to use the phrase urban density to describe people and other human activity and development throughout a certain area of land. Urban regions in affluent nations are not only more densely populated (DPUA), but they also have a greater population density per unit of land area than rural areas do as well. In densely populated urban areas, public transportation is more plentiful, reducing travel times making them more efficient. Greater affluent residents in metropolitan areas can also benefit from modern high-rise structures, which offer more breathing room. An energy-efficient design and features provide great living standards and comfort while using little energy and releasing minimal carbon dioxide in this sort of housing. In the absence of or rare usage of conventional active and passive heating and cooling systems, Smart sensors and other IoT devices make up the Internet of Things (IoT). IoT presents cities with new potential for using data from sensors in their infrastructure to improve traffic flow and reduce pollution. The more crowded and congested a city is, the more dissatisfied its residents are. There are numerous negatives to urban life, including high living costs, congestion, pollution, crime, and traffic, yet the benefits exceed the risks. Clean up the air by reducing the amount of energy used and using alternate modes of transportation. Provide services like garbage disposal and housing through private–public partnerships. Urban planning should include planting trees and the maintenance of municipal green areas. There are many advantages to living in densely populated places, such as better healthcare, better amenities, and faster emergency response times. The innovative DPUA-IoT approach proposed in this study is only one example of these advantages. Rapid population expansion is harmful to achieving economic and social progress and sustainably managing the natural resource base. However, there is still a large disparity between the interests of the commercial and public sectors when it comes to reducing fertility.

1. Concepts of low-energy building in densely populated urban areas

Low-energy construction reduces the primary energy demand by high insulation levels, efficient heating, and cooling systems, and incorporating renewable energy sources (Aram et al., 2020). The architects at regaled employed energy-efficient windows, heating, and lighting to create a net-zero structure (He et al., 2020). Rooftop photovoltaic panels and an energy-efficient heat pump will help the building reach its energy targets (Proque et al., 2020). Buildings that meet the criteria of zero-energy use energy efficiency and renewable generation to consume just the amount of energy that can be generated on-site during a specific period (Froemelt et al., 2020). All climatic zones have their own set of energy efficiency goals. Sustainable or green buildings are those that may enhance or maintain a variety of environmental

* Corresponding author.
E-mail address: zhaowm1982@163.com (W. Zhao).

https://doi.org/10.1016/j.egyr.2022.03.139

factors, including occupant comfort and well-being, while preserving or replenishing the natural resources and ecosystems that surround them throughout the building's lifespan because green construction considers all environmental implications, such as the usage of materials and water pollution (Barau et al., 2020; Bienvenido-Huertas et al., 2020).

In contrast, energy buildings consider the structure's energy use and potential to produce an equal amount, or more, of that energy (Kanemoto et al., 2020). General environmental concerns are crucial for personal norms at work, affecting several sorts of pro-environmental activity. People's attention to environmental issues is influenced by the context in which they find themselves. Promising and cost-effective means of promoting environmental stewardship in the workplace Grid operators can better control the intermittency of renewables in Renewable energy systems using Smart Grid technology.

Greater reliance on public transportation and shorter commutes are advantages of dense urban areas (Cai et al., 2017). Greater affluent city inhabitants can benefit from modern high-rise buildings, which allow more spread out (Feng et al., 2020). These are the world's densest urban areas. The number of people residing in a specific land area, generally a mile or kilometer, is the population density (Pigliautile and Pisello, 2020). Urban population means those who live in cities as defined by the government's statistics agencies (Jurasz et al., 2020). A densely populated area has at least people per square kilometer, and at least people live in a contiguous region of communes. According to this agreement, a densely populated region has a core population of at least people (Das et al., 2020). A city's surrounding territory is known as an urban area. Nonagricultural employment accounts for most of the work done by those in cities (Kamboj and Ali, 2021). There is a high concentration of human constructions in urban areas, including dwellings, commercial buildings, highways, bridges, and trains. Cities, towns, and suburbs are examples of urban areas (Gould et al., 2020). A rural area is characterized by wide-open spaces, few buildings, and a low population. Rural areas have a low population density (Hu and Li, 2020).

City dwellers comprise a large percentage of the population, and one of their residences and enterprises is placed within a short distance of each other (Rong et al., 2020). Most rural communities rely heavily on agriculture as their main source of income. An energy-efficient design and features allow this type of housing to provide great living standards while using minimum energy and producing minimal carbon dioxide emissions (Ghorbani et al., 2020). A traditional heating and air-conditioning system are either unused or used sparingly. Residential neighborhoods mostly populated by single-family houses or buildings with few units are sometimes referred to as low-density housing (Li and Wang, 2020). Urban regions with considerable units are often high-density locations (Mishra et al., 2020). This includes characteristics like a thermal envelope that is properly built and sealed, proper ventilation control, the proper size of the heating and cooling systems, and the use of energy-efficient doors and windows (Lampropoulos et al., 2020).

IoT devices such as sensors, lighting, and meters are used in earlier articles to gather and analyze data in smart cities (Girard and Nocca, 2020). After this, communities utilize the data to enhance infrastructure, public utilities, and other services. IoT enables smart city projects and efforts worldwide because of its widespread implementation (Wang et al., 2020). Because it is meant to support smart city concepts, the Internet of Things (IoT) may help cities and residents benefit from the latest communication technology. IoT, smart meters, and smart appliances allow electricity consumers to monitor and control how much electricity they use (Kotarela et al., 2020). Thanks to the IoT infrastructure, sensor data may be collected and analyzed in real-time. It comes to the IoT getting real-time warnings, a better ability to estimate energy demand, use trends, and new ways to save energy (Velraj and Haghighat, 2020). Using an IoT-based monitoring system, electric motor vibration/temperature issues may be detected before they become dangerous. Unexpected production shutdowns can be avoided with the use of condition monitoring. To be a smart city, a place must have established a technical infrastructure that allows it to gather, combine, and analyze real-time data better serve its citizens. IoT devices include smart sensors and other gadgets (Evola et al., 2020). IoT provides cities with new data-driven capabilities to control traffic and reduce pollution while keeping inhabitants safe and secure. Innovative management and remote monitoring of widely distributed operations are two of the primary uses of IoT for businesses. With the Internet of Things, cities can better manage traffic, cut pollution, and keep residents safe and secure. IoT infrastructure technologies aid in the efficient use of renewable energy systems. Customers may connect their solar panels, rainwater harvesters, and smart roofs using the Internet of Things to form a single system. Smart grid utilities can identify service problems more rapidly by using the Internet of Things (IoT) as a data collection tool.

The paper's key goals are:

- Even while energy-efficient architecture reduces carbon emissions, it has adverse consequences on human health, one of the most notable drawbacks.
- The features and initiatives of essential intelligent IoT in low-energy building installations are evaluated.
- Reduced energy expenditures can be attributed to IoT's regular data tracking, including how much power is being utilized by various organizations.
- It uses DPUA-IoT sensors to monitor the temperature of a room and complicated applications to regulate energy usage.
- As a result of the Smart Grid, grid operators are better prepared to deal with unpredictable output renewable energy systems.

The rest of the paper disused in Section 2 of the study is devoted to a literature review of current methods, Section 3 proposed method for DPUA-IoT to be discussed, Section 4 for experimental analysis, and Section 5 conclusion of the paper.

2. Related paper on the low-energy building in densely populated urban areas

Arghavani et al. (2020) introduced the low Thermal Comfort Levels (TCL) and air pollution in megacities that have been linked to rapid urbanization and changes in natural land-use/land-cover features across the world. Thermal comfort satisfaction may be improved and mitigated by developing urban green areas, reducing cooling energy consumption, and improving urban air quality. The current findings show that various environmental considerations must be considered when developing efficient urban green space projects. It may be inferred that the green roof technique with the least unfavorable nighttime impacts in Tehran's high-density megacity is more efficient than surface vegetation expansion.

Pinheiro and Luís (2020) introduced to combat the COVID-19 epidemic; the system required particular treatments, facilities, and equipment and the regulation of individual behavior and a time of communal confinement for the duration of this pandemic. Thus, this research aims to determine if COVID-19 can change the built environment (BE) and implement sustainable building or urban area solutions. The history of infectious pandemics has emphasized the BE's creation of novel approaches to combating the spread of infectious disease. Are challenged by the COVID-19 measures to reconsider the design of buildings and urban environments, which might lead to win–win results (minimalist design and other solutions). However, more investigation into the specifics of how this set of measurements was put together is required.

Lee and Shepley (2020) mentioned that the purpose of this research is to analyze how the government's sustainable energy plan offers low-income residents in public rental flats in metropolitan Seoul solar photovoltaic (PV) systems to generate their power. Examine if a government-sponsored solar photovoltaic system is an effective means of supplying electricity to those who lack it. Many sources of information were gathered, including government energy policy evaluations, surveys, and focus groups with renters, contractors, and government officials. A long-term study on larger samples, continuing education and feedback on energy consumption following installation, and the incorporation of intelligent technologies, such as smart grids, meters, and sensors, are all recommended.

Ivanova and Büchs (2020) discussed that per capita energy consumption and greenhouse gas (GHG) emissions are growing as family's worldwide shrink in size and share resources less widely. Household economies of scale have never been examined in this way before. Resource sharing efforts and policies can be better developed if compared across countries. According to research, one-person families had the highest carbon and energy use per capita. Social, political, and climatic factors may influence family economies of scale, argue. To aid in the fight against global warming, make policy proposals for promoting inter-and intra-household sharing.

Knickmeyer (2020) introduced cities as more densely populated, and global urban garbage increases simultaneously. Municipal solid waste management systems (MSWMS) benefit greatly from an awareness of the social aspects that impact household behavior. When disposing of trash in public places like parks, streets, and transport stations, consider including a recycling option along with the regular garbage collection. To maximize trash separation, use easy-to-handle, graduated-size bins. Maximize recovery by increasing the number of materials that can be accepted. It is possible to increase the quantity of intermittent renewable generation in the power system using smart grid approaches, such as boosting the capacity of grid-connected renewables like solar and wind power. Research on how to increase recycling habits in specific metropolitan locations, adapted to the local context, will be built on the findings of this study, which are meant to serve as a resource for practitioners.

Hoffman et al. (2020) introduced the result of human-caused climate change. Vulnerable groups, particularly those in metropolitan areas, are more likely to be affected by heatwaves, increasing severity, length, and frequency over the past several decades. This study has left key issues concerning how past housing decisions have affected contemporary exposure to climatic disparities, such as intra-urban heat. While these patterns may be partial because these locations have a higher percentage of impervious land cover than tree canopy, other variables may play. The findings of this study suggest that the disproportionate exposure to present heat events may be directly linked to the actions of the past.

Richards et al. (2020) discussed the increasing number of cities experiencing a phenomenon known as the urban heat island effect. Cities tend to be hotter than their surrounding rural regions. The extent to which urban vegetation cools the air depends on the type of plant present in the area. This research looked at the cooling effects of several vegetation types in a tropical city, including grass, shrub, managed trees, managed trees over a shrub, and secondary forest. However, not all vegetation is equally effective in reducing temperatures in hot, humid environments. Programs that educate and involve the general people can help dispel misconceptions about the secondary forest's cooling properties in densely populated areas.

Lin et al. (2020) introduced worldwide; rapid urbanization has become a major problem. In contrast to prior research, the spatial aspects of building heights have not been examined in depth. This data might have important ramifications for smart city design and administration. However, earlier studies did not thoroughly study the geographical elements determining building heights and their connections to urban growth. Overall, these findings might aid in the planning and administration of metropolitan areas. A major advantage of the suggested approach is that it may estimate future building heights and analyze the distribution of building heights in various places throughout the world.

Bao et al. (2020) explained that human activity significantly demands water supplies in metropolitan regions. Urban water demand can be properly simulated on a single-building level and scaled up to regional levels without any loss of accuracy. The technique incorporates building geometry, building physics, census, socioeconomic, and meteorological data to give a broad approach to analyzing water needs that overcome data privacy restrictions on aggregation and processing difficulties. Our approach may study the spatial distribution of building heights in other places if the appropriate spatial elements are obtained.

Novosel et al. (2020) discussed its cities rely on a reliable supply of heat. The obvious answer to this problem is district heating. Waste and renewable heat can be transported to where it is required with the help of power-to-heat technology, which makes it a potent motivator for the integration of renewables into the electrical grid. Because heat cannot be transported at great distances, spatial planning and GIS mapping have proved crucial in heat planning. This is often impossible because of the lack of readily available data. Based on the difference between the price and cost of heat and the projected cost of distribution infrastructure, a district heating evaluation is made based on the mapping results. When tested in Croatia, the approach revealed a large potential for district heating to be economically utilized.

Morakinyo et al. (2020) discussed that tree re-integration into the urban landscape is true climate mitigation and adaptation approach. However, many subtropical cities' landscapes are dominated by trees that reduce urban heat because of a lack of scientific foundation for tree selection. This study has proposed and evaluated a systematic framework for the right tree, a right site urban heat reduction. Experimental evidence shows this new strategy can increase human thermal comfort by a factor of up to two, which is superior to the other two. Finally, recommendations based on scientific data were provided to assist policymakers in developing urban green development plans.

Hwang et al. (2020) said just one weather station could be used to measure microscale city air cooling energy usage correctly. The study's purpose was to establish how big of an influence the urban heat island effect has on air conditioner power consumption and the risk of overheating. This study gathered data on microclimates from their metropolitan environments. Research on the effects of city microclimates on the likelihood of building overheating and the amount of energy consumed by air conditioning in the city relied on microclimate data from urban settings and building thermal and energy models. Microclimate data from urban settings and thermal and energy models for buildings were used to study the effects of city microclimates on building overheating and the amount of energy consumed by air cooling in the city. Reduced energy consumption in buildings is vital to accomplish the nation's energy and environmental goals. It accounts for around 76% of total electricity consumption and 40% of primary resource use and associated emissions of greenhouse gases (GHG). A modernized electrical grid that utilizes analog or digital information and communications technology is the key to maximizing the utilization of widespread renewable energy systems in a smart grid. Smart grid integration into renewable energy sources expands their potential and opens up new avenues of research because of the availability, applicability, and environmental friendliness of these sources.

Rehmani et al. (2018) Using RERs instead of fossil fuel-based generators can minimize greenhouse gas emissions and provide economic benefits. There is now a shift in the power grid toward a more intelligent system known as the "smart grid" (SG).

This article focuses on low-energy construction practices in heavily populated metropolitan regions. The DPUA-IoT virtual reality technique, which has been developed, is now being used to correct some of the issues found in the research. DPUA-IoT can be used to overcome these challenges. Rising urban density and energy consumption pose a challenge to planners and residents alike in many cities worldwide. Towns are a major source of development in global energy consumption, and their energy use, environmental implications, and need for transportation services put a lot of strain on our world. There are many aspects to consider when designing low-energy cities and buildings in densely populated places, such as the urban context, transportation planning, energy system design, and architectural and engineering features. Positive and negative consequences affect total energy consumption as communities become more densely populated. Population growth may be supported with little degradation of environmental quality if appropriate urban and building design features are used.

3. Low-energy building in densely populated urban areas based on IoT

Each node has unique properties to make a functional IoT system. Sensors: These are the gadgets that make up the front end of the IoT. Increased energy consumption due to device deployments, higher network energy costs for processing future IP traffic, and possible worldwide energy consumption are all possible consequences of this exponential expansion in gadgets. People's quality of life and the environment can be improved in a smart city, sustained for long. Using IoT and related technologies to implement a smart city improves urban services' quality, performance, and interactivity while reducing costs and optimizing resources. The above-stated real-time applications are conserving energy by incorporating the advantages of IoT, i.e., automation and remote monitoring and controlling lighting, lowering of lights based on detection of cars or people are one of the advanced functions to conserve more energy in street lighting.

Fig. 1, according to this, social impact assessment is the process by which planned actions are studied, monitored, and controlled for both positive and negative social repercussions resulting from such interventions. Quantitative analysis for stocks is finding the value or valuation of the stock using numbers. An urban area is a territory around a city. The selection of a location is the first stage in any initiative that succeeds. Most people in urban areas have nonagricultural employment. Urban regions are significantly developed, meaning human buildings are dense such as dwellings. The site selection procedure is the beginning of each successful project. The district, the neighborhood, and clearly, the location influences the design of any structure or idea. It shapes future growth. And it has the potential to motivate a reoriented vision of a city or neighborhood. It is described as an energy-efficient design and technological qualities that enable it to provide acceptable living standards and comfort while consuming minimum energy and emitting a minimal carbon footprint. Due to an energy-efficient design and features, great living standards can be achieved using little energy and

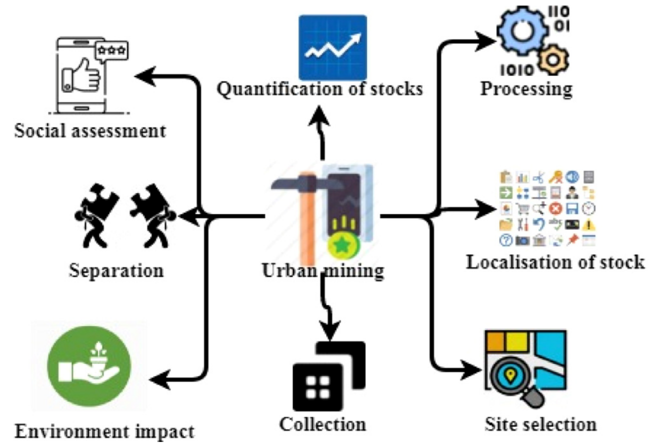

Fig. 1. Urban area mining process.

emitting minimal carbon dioxide emissions. Construction or renovating structures that use the most energy possible is the goal of energy-efficient building design. This includes reducing energy loss via the building envelope by installing better insulation. As a result of advances in smart grid technology, renewable energy sources such as solar, wind, and hydrogen can now be managed and distributed more efficiently. Smart grid technology, made possible by the Internet of Things, makes it possible to control these variable and frequently geographically scattered electricity-generating resources effectively. Traditional heating and cooling systems are either absent or used in a secondary capacity, ineffective. A facility's activities, commodities, or services can positively or negatively impact the environment, resulting in an environmental effect. Alternatively, it is the impact people's activities have on the world. Either directly through stated regulations or indirectly owing to market activities, the infrastructure and development of communities and suburbs have in certain circumstances perpetuated the segregation of social groupings with direct effects on the economy. It is possible to cut CO2 emissions by implementing smart grid technologies. Generation, transmission, distribution, and consumption go under the "electric grid". In a smart generation, renewable energy sources such as wind and solar electricity are used (wind, solar, or hydropower). It is essential that your company's carbon footprint is accurately calculated based on accurate consumption data. One should also record any other activities in the business that is determined to be energy or material intensive.

$$\mathrm{N} = \cot a\, [\![a]\!] \iiint a^{\,M/\prod \log_2 \delta M(a)} \tag{1}$$

Eq. (1) says that N is the urban mining, M for testing the batch life cycle, a for planning to monitor, cot is the trigonometric function of primarily the clean energy, δ is the mathematical function of stock. Urban mining is recovering raw minerals from waste items going to landfills. On a conceptual level, it looks at the garbage generated by cities and urban environs as a valuable resource, employing artificial stocks rather than geological ones to meet production demands. Cities have begun preparing for decentralized trash management and treatment within their borders to address the problem. Measures to reduce landfill loads include the 3Rs and the construction of "waste-to-compost" and biomethanation plants and alternative energy sources such as biogas. In a smart grid, electricity and data are exchanged in a two-way flow using digital communications technology to detect, react, and respond to changes in demand and other issues.

$$A = \max_{3} b \oiint (c) \oiint b * \sqrt{c}^{(b)} / \textstyle\sum_c (\log\, c) \tag{2}$$

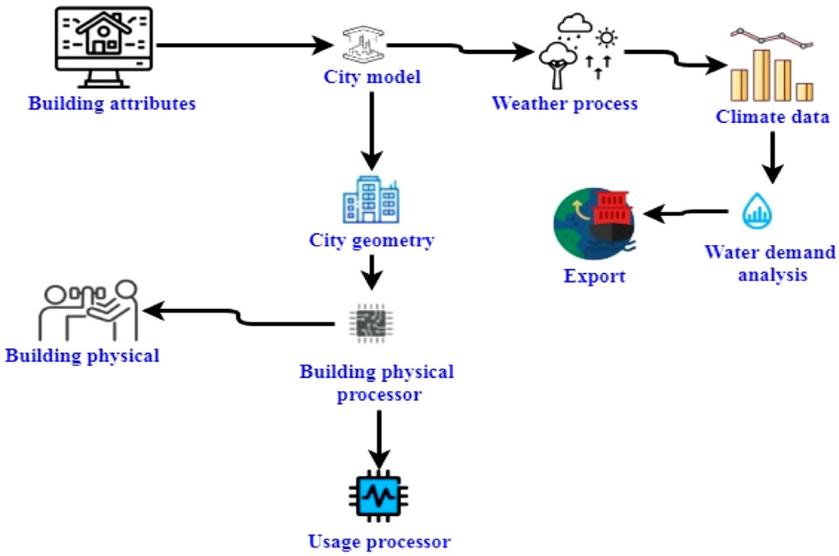

Fig. 2. Simulation and environment.

Eq. (2) says A for real-time monitoring, b for data monitoring, c for quantification, log for the logarithmic function of recent analysis, max for maximum localization value. Climate change, pollution, degradation of the ecosystem, and resource depletion are among the most pressing environmental issues of our day. The conservation movement aims to safeguard endangered animals, ecologically important natural areas, genetically modified foods, and the effects of climate change. Many species on the verge of extinction are being saved thanks to cutting-edge technology such as drones, remote-control automobiles, and visualization tools. Technology has given rise to many gadgetry concepts to protect, monitor, and preserve wild animal species.

$$B = \prod d\sqrt{e} * \iiint e\sqrt[1]{d}({}_3log\ d/ [\![e]\!]\, e/d) \tag{3}$$

Eq. (3) explained B for data sharing, d by computer laboratory for collection, e for separation, log for the logarithmic function of sorting analysis. When policies, plans, activities, and initiatives positively or negatively influence the community, it is necessary to conduct a social impact assessment. Social evaluation is a process in which objective and subjective information are utilized to identify high-priority issues or assets that influence the common good. These facts must be taken into consideration while doing any social assessment.

Fig. 2 says the urban design is about building links between people and places, mobility and urban shape, nature, and the built fabric. It is a three-dimensional digital depiction of urban areas that includes terrain surfaces, sites, buildings, plants, infrastructure, and landscape characteristics in three-dimensional scale and related goods, such as city furniture, associated with urban regions. Weather processes such as wind, clouds, and precipitation are all the consequences of the atmosphere responding to unequal heating of the earth by the sun. The urban climate is any combination of climatic conditions that prevails in a major metropolitan region and differs from its rural surroundings. An interconnected human and natural system, with complex human and natural system variables at various spatial and temporal scales, is reflected in urban water demand. The population growth of cities is linked to the city's socioeconomic, behavioral, and physical qualities. They provide for a new paradigm of city planning and understanding of the resilience and economics of urban environments. An urban system's resilience denotes its ability to remain stable in the face of shock or stress, saving people's lives and property. It entails both the ability to anticipate potential problems and the adaptability necessary to deal with unexpected events. For a city to be resilient, it needs a multi-faceted approach. There are other ways to refer to the actual processor on the computer's circuit board, including a CPU, socket, or package. A piece of electrical equipment that uses fewer units of electricity when utilized for long hours is known as a power-efficient electrical gadget. Urban regions are significantly developed, meaning dense human constructions such as residences, commercial buildings, highways, bridges, and trains.

$$C = f\sqrt{g} \pm \iiint g\,\|f\|\,\sqrt[3]{g} \int f * \cot g \tag{4}$$

Eq. (4) says C for excision making in building attributes, f for evolving methodologies for city model, g for the automated recording area, the cot is the trigonometric function for a processor in the model. Building facades and private gardens are both public and private places, and urban design theory considers this. They react and sustain particular development patterns, landscape, and culture in the townscape and landscape.

$$D = (\alpha + h)\,\sqrt[5]{i} \oiint h \sum i\, \|\|\alpha\| \sec h\| \tag{5}$$

Eq. (5) explained D for building, h for the census data, i for the production process, α is the mathematical function of the building processor, *sec* is the trigonometric function of the user processor. Combined, this uneven heating in horizontal and vertical orientations in the atmosphere is responsible for the observed weather. Heat islands are generated when vegetation is replaced by asphalt and concrete for roads, buildings, and other structures that are needed to support the growing population. These surfaces boost the air's temperature because they absorb heat instead of reflecting it to the source. Bitumen, the more common name for asphalt, is a substantial contributor to air pollution, especially in hot, sunny climates. Asphalt emissions from roads and rooftops may be a greater source of dangerous particle pollution than emissions from all gasoline and diesel-powered vehicles combined. Concreting new roads should be regarded as a more environmentally and economically friendly option because of this growing body of evidence. Prospective Uses Both asphalt and concrete may be made to emit less energy and cost less money.

$$E = j\left(\frac{1}{l}\right) \iiint \delta\, [\![j]\!] \oint l + \sum l\sqrt[2]{l} \tag{6}$$

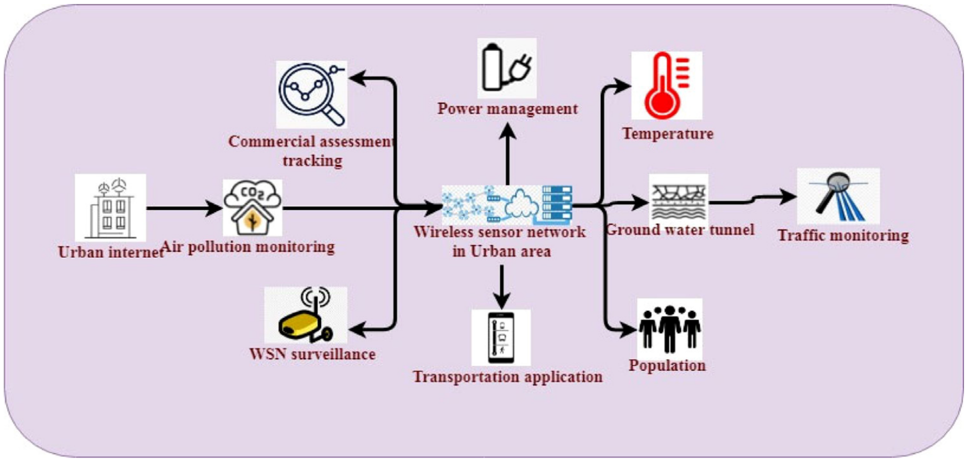

Fig. 3. Wireless sensor network in Urban area.

Eq. (6) denotes E for the total variety of weather processes, j for climate data, l for water demand analysis, δ is the mathematical function of the open-source in export. Communities must have a place to gather in these places. They evoke strong feelings in locals and tourists alike because of their political and cultural significance and status as historical and geographical monuments. Urban areas as human settlements with a high population density and built-environment infrastructure.

Fig. 3 says a region with a large population density, strong resources, many work opportunities, and a location that may be termed life-giving for human's luxuries. Referencing stations monitor air pollution, generate a long-term picture of air quality in a city, and indicate if it conforms with national air pollution guidelines. WSNs have the problem of meeting high-security standards while working with limited resources. Data confidentiality, anti-compromise, and resilience to traffic analysis are just a few of the security requirements for WSNs.WSN can be described as a tiny system of nodes that can sense, monitor, capture, process, and regulate conditions such as data/signals around an application, supporting interactions between people/computer systems and the local surroundings. Wireless sensor networks (WSN) are intrinsically resource-constrained: each node has limited processing speed, storage capacity, and bandwidth to operate with. The following are some of the WSN's most notable features: Battery-powered nodes are subject to power consumption constraints. Ability to deal with node failures Nodal heterogeneity and some degree of nodal mobility. It is the contractor's responsibility to determine whether or not accumulations in the contract area are commercially exploitable and whether or not commercial production is viable after considering all relevant technical, financial, and economic data, as well as any other relevant factors. An urban area island that surrounds a city. Those who reside in cities do most of their labor in nonagricultural jobs. Cities are densely populated with human-made structures, including homes, commercial buildings, highways, bridges, and railways. Urban areas include cities, towns, and the surrounding suburbs. Large swaths of urban areas consume large amounts of energy. In the past, city dwellings consumed far less energy than now. Temperatures in the city are higher than in the surrounding countryside, creating an urban heat island. A large number of cities, despite expenditures in road infrastructure, land use planning, and transportation development, experience congestion, traffic accidents, pollution of air, and noise. On the other hand, transportation is an integral part of urban planning and lifestyle. Transporting and distributing goods from ports to cities around the country is necessary.

$$F = \int_{-\infty}^{\infty} \tan \oiint \log_9 k\,|l|\,4\,k\sqrt[2]{l} \tag{7}$$

Eq. (7) explained F for urban internet interaction, l for the air pollution, k for commercial motivation, log for the logarithmic function of detection, *tan* for the trigonometric function of the placement of gas monitoring. Toxic gases such as Sulfur dioxide, nitrogen oxides, and carbon monoxide contribute to the formation of air pollution, which is a combination of natural and manmade substances in the atmosphere. Indoor burning of fossil fuels, wood, and other biomass-based fuels for cooking, heating, and lighting homes is the primary source of pollution in the home's atmosphere. Around 3.8 million people die prematurely each year because of indoor air pollution, with most of these deaths occurring in underdeveloped countries. Nature itself is responsible for the pollution that is created. Because of our actions, we create pollution labeled "manmade".

$$G = \cos n\,[o] \oiint n\sqrt[2]{\delta} \sum o \prod n \tag{8}$$

Eq. (8) denotes G for total monitoring of precipitation, o for some structural, n for management in authorization, δ is the mathematical function for performance in WSN, *cos* is the trigonometric function of purchase consummation.WSNs provide several sorts of applications for a pleasant and smart-economic life. Energy conservation, noise, air monitoring, and healthcare monitoring are WSN applications that positively impact the environment and health. Surveillance and monitoring in agriculture and habitat monitoring are among the most common uses for wireless sensor networks (WSN). Real-time system and control connection with the physical world has made environment monitoring a significant field in controlling and protecting systems. Wireless sensor networks (WSNs) offer a wide range of advantages, including real-time access to data, large area coverage, long-term monitoring, and system scalability, that can be used for creative and attractive solutions as well as pervasive environmental monitoring.

$$H = (p) \coprod q \exp \sigma^2 \prod [\![p]\!]\,q \iiint p\sqrt{q} \tag{9}$$

Eq. (9) explained that H for total number healthcare, p for data set in return products, q planning and scheduling of transportation, $\exp\sigma$Is the exponential function of the traffic monitoring. Businesses utilize business metrics to track, monitor, and evaluate the success or failure of their numerous business operations. Want a measure to be meaningful need to put it into context.

Fig. 4 says that if you ever wanted to run your virtual machine but do not want to deal with the hassle of maintaining the server, you may consider using a cloud server instead. For low latency

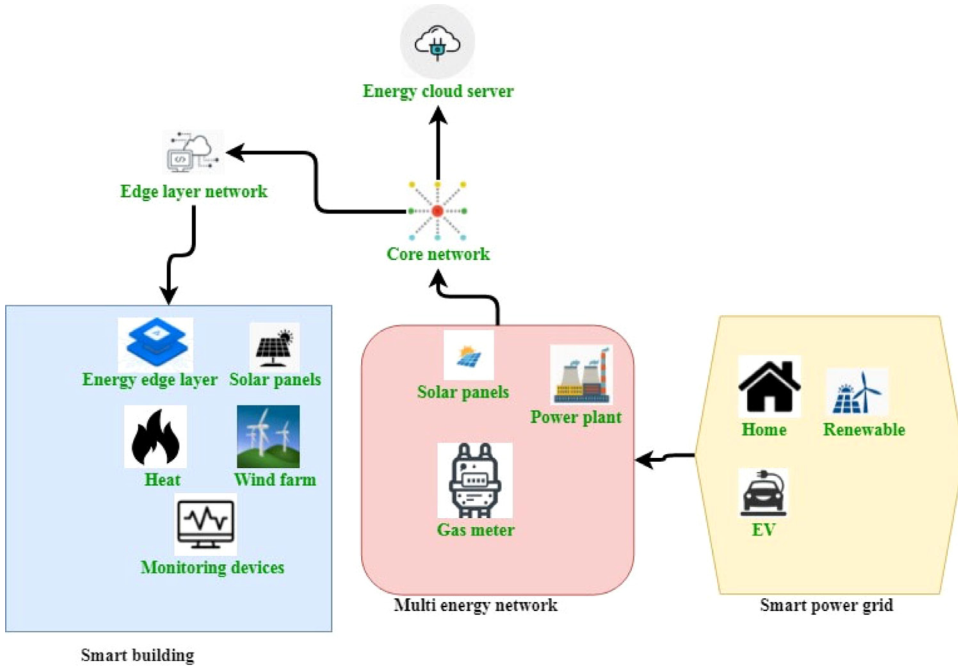

Fig. 4. IoT based energy management in the urban area.

and bandwidth savings, edge networking is a distributed computing model that closer processing and data storage. Telecommunications networks comprise a core network and an access network linking consumers. Edge networking is a distributed computing approach that brings together processing and data storage for reduced latency and bandwidth use. Networking at the edge is a distributed computing architecture that brings processing and data storage closer together to minimize latency and bandwidth. Locally, the edge layer connects devices and oversees data gathering from such devices. Solar panels are those gadgets that utilize the sun's rays to generate power or heat. On solar panels, these cells are organized in a grid arrangement.

And finally is the requirement for simple and ergonomic design in urban areas; huge wind turbines require sophisticated processes to align the rotor with the wind. Therefore, such systems cannot be incorporated into cityscapes. A city's ground cover is replaced by a high concentration of pavement, buildings, or another surface that absorbs and retains heat, creating an urban heat island effect. When a television or computer monitor displays a picture, a gadget that receives and displays signals is at work due to its closeness to the population centers, monitor computing equipment, computing machines, data processors, and electronic computers. High fault tolerance is the system crash on one server that does not affect other servers. Here, people can grow. More computers can be added as required in a distributed computing system. Flexibility in adding new services is a cinch due to its simplicity.

They tend to be placed among underserved populations and communities of color. Gas meters installed inside a home are often found in a kitchen or hallway, usually hidden in a cabinet or meter box. Find many gas meters in one location if live in a flat, such as a utility room. Homes in the city's center range from skyscraper flats to converted lofts in ancient warehouses and spaces above working companies to row homes and brownstones. Hydroelectricity is the primary source of renewable energy. All cutting-edge technology in electric cars, including high-capacity batteries and more, means that EVs are more expensive. Thus, the more expensive an automobile is, the more expensive it is.

$$I = \sin\frac{1}{\beta}\left(\log * \oint \beta \iiint J \log\left(\sum J - \frac{1}{\delta^2}\right) J\right) \tag{10}$$

Eq. (10) says J for finding energy, I for learning speed in the technology cloud server, β is the mathematical function for core network, log for the logarithmic function of edge layer, *sin* for the trigonometric assessment function, δ is the mathematical function of the environment. Imagine one that incorporates the best of all possible worlds to define a smart building: low-cost construction, effective use of available resources such as electricity, and a welcoming and handy interior.

$$\mathrm{U} = \sqrt{\iint \mathrm{T}*\frac{1}{2} - \sqrt[3]{(\mu + \mathrm{T}(\frac{(\alpha)}{2})2)}} \tag{11}$$

Eq. (11) says T to find the end-users in a generation for energy server, U for business model solar panels, μ is the mathematical function of time taken to deliver contents, α is the mathematical function of the wind farm identification. For example, a district city or region can benefit from multi-energy systems, which integrate several levels of energy sources, such as electricity and heat and cooling, and fuels and transportation at many levels.

$$R = \|\varphi\| \underset{2}{\sqrt{\varphi}} max\ V \div {}^{\beta}/_{\iiint \varphi} \prod \beta \int V \tag{12}$$

Eq. (12) says R for service-oriented in gas meter, V for several developments for the monitoring device, β is the mathematical function for multi-energy network, max for maximum value proof of concepts, φ is the mathematical function of heat implementation. In a smart grid, power and data are exchanged in a two-way flow using digital communications technology to detect, respond, and act to changes in demand and other faults. There are self-healing capabilities in smart grids and the ability for power consumers to participate.

Fig. 5 says the power generation, transmission, and distribution are all part of the power system's three primary components. For example, coal and diesel are used to generate electrical energy. There are limits to the quantity of electricity an electrical facility can conduct before it overheats or sags to the point that public safety is endangered. Conductors are objects or types of materials used in physics and electrical engineering that allow the flow of electric charge in more than one direction. One of

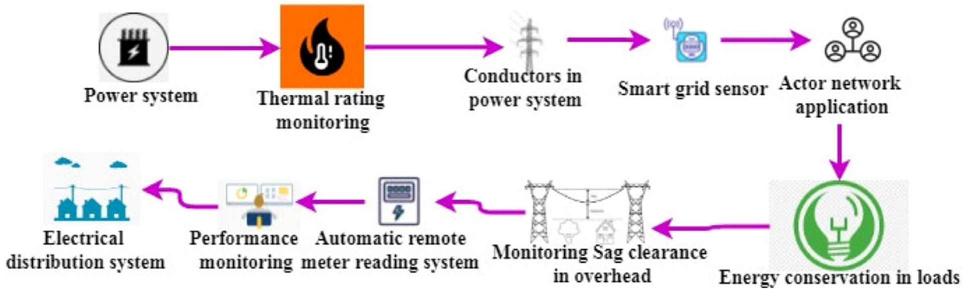

Fig. 5. Power system in WSN.

the most important components of a smart grid sensor network is a sensor node. Smart grid sensors monitor equipment like transformers and electrical cables remotely, allowing for more efficient resource allocation and demand-side management on an energy-smart grid. That technology, for example, might have agency and hence be an actor regardless of whether it is a human being or not is a unique thought. A person or organization tries to use less energy service to save energy. The most effective way to do this is to use less energy for consistent service, but it may be accomplished by cutting back on the overall quantity of service, for example, by driving less. May measure the amount of compression in millimeters or inches using the sag. Free sag is measured when the bike is motionless on the ground without any weight, as opposed to when the rider is sitting on the bike and measuring race sag. Using data from water meters or energy metering devices, gas, electricity may be collected and stored in a centralized database for use in invoicing, troubleshooting, and analysis automatically. Applications' cloud performance may be assessed using a set of methods and technologies known as performance monitoring. After the transmission system, the distribution system is responsible for providing electricity to the end customer. The HAN and WAN networks are two communication types used by smart grids. The smart meter's household appliances are connected via HAN. Zigbee, Wireless Ethernet, Wired Ethernet, and Bluetooth are a few technologies that can create a home area network.

$$K = \frac{O}{P} \iiint O \left\| P \right\| \sqrt{O} \sec K\left(O \right) \sum P \tag{13}$$

Eq. (13) says K create service thermal, O for rating monitoring, P for critical analysis, *sec* for the trigonometric function of the conductors in the power system. Automated meter reading (AMR), as the name implies, AMR meters link an energy provider and its corporate customers. Allows customers to analyze their energy use information and verifies that they are being billed accurately. Remote reading of an electric mechanical meter is impossible, and it is easy to figure out how much electricity a building uses simply by subtracting this month from last.

$$L = \sum (Q \log_z \alpha Q^{S}/_{\sin Q \iint Q}\alpha + S) \tag{14}$$

Eq. (14) says L for creation of smart grid, Q for a password for sensor, S for service actor-network application, sin for the trigonometric function of behavior and relationships among service energy conservation, α for the mathematical function of the management, log for the logarithmic function of loads. Measuring performance against predetermined benchmarks, often known as key performance indicators (KPIs), is the basis for performance monitoring. Benchmarking is the process of comparing a company's performance to that of other companies in its industry.

$$W = X^2 \left(Y + \sqrt[3]{Y^5} \right) {}^{Y}/_{\cot x}X \left\| Y \right\| \tag{15}$$

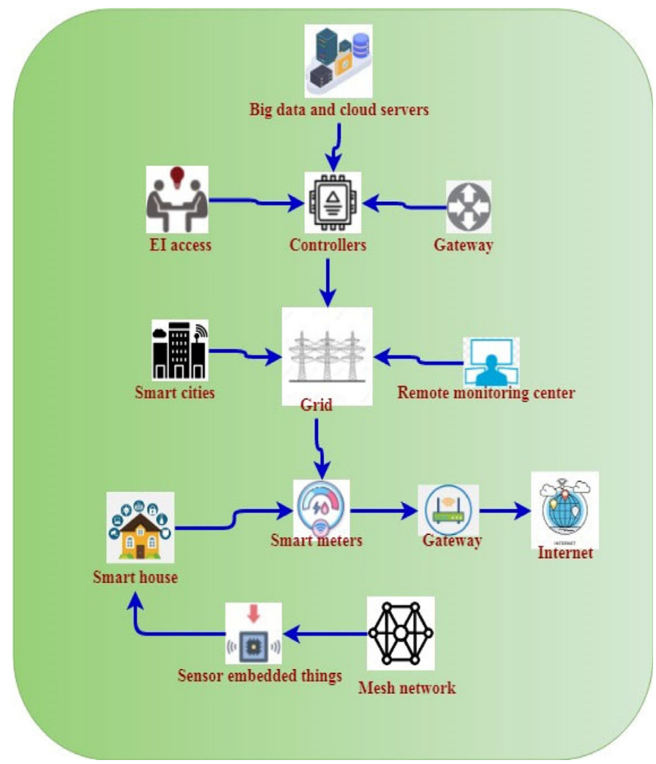

Fig. 6. Low energy building in an urban area based IoT.

Eq. (15) says W for data gathering in monitoring sag clearance, X for evolving methodologies in overhead conductors, Y for automated recording in remote meter reading system, *cot* is the trigonometric function of electrical distribution system After the transmission system, and the distribution system is responsible for providing electricity to the end customer. From the utility producing station to outlet or light fixture, the safe transportation and delivery of electrical energy is the responsibility of electrical distribution equipment. This category includes electrical bus ducts, circuit breakers, and power distribution centers.

Fig. 6 says ever want to run your virtual machine, but do not want to deal with the hassle of maintaining the server, may want to consider using a cloud server instead. Processing power, storage, and applications may all be provided via cloud servers in the same way that a regular physical server can. Urban gateway is an online platform for cities and urban practitioners worldwide to collaborate, share information, and take action on issues affecting their communities. Microcontrollers, extension cords, or standalone devices are all examples of controllers that connect with a more peripheral device. Unemployed employees can get short-term financial assistance through the employment insurance (EI)

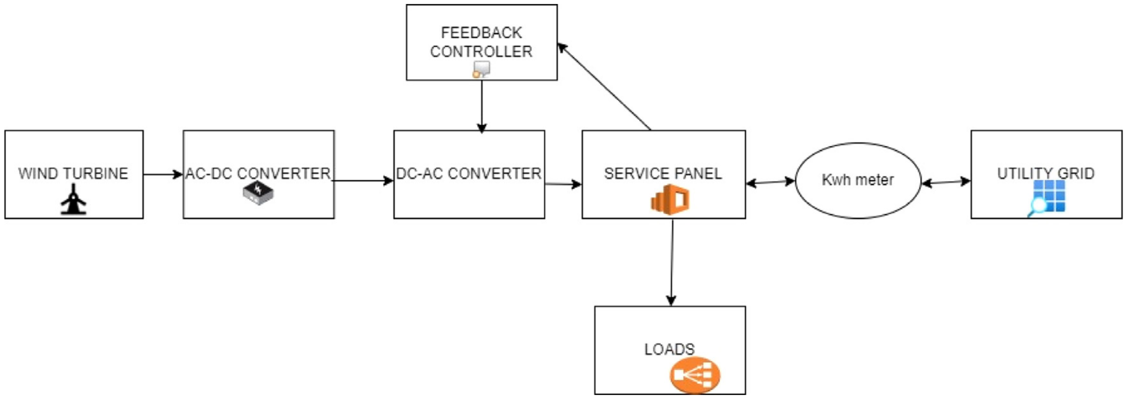

Fig. 7. Smart grid-connected Renewable energy systems.

programmer while they hunt for a job or improve their skills. Information and communication technology (ICT) is used in a smart city to promote operational efficiency, interact with the public, and improve government service and the welfare of its residents. There are several types of cities plans in urban planning, and one of the most common is the grid, grid street, or gridiron layout. Remote monitoring can refer to a wide range of practices. The ability to monitor a facility from afar provides peace of mind to security management by reducing the likelihood of break-ins and other criminal damage. In remote places, cellphone networks may not be stable enough for smart meters to reflect use accurately. If readings are not sent, and energy provider may be left scratching heads when it comes to billing. The smart house saves electricity. However, that is the beginning of the definition. It includes using home automation systems to handle the many functions of a household and integrating these systems with the city's smart networks. Put another way: the physical world is where embedded computers interact with their surroundings through sensors. Nodes or satellite modules are positioned throughout the home to offer full Wi-Fi coverage in a mesh, Wi-Fi, or Whole-Home Wi-Fi system.

$$Z = (\delta + \sin r\beta \log sr) \sum s \tag{16}$$

Eq. (16) explained Z for connectivity, r for the big data, s for feedback for the technology, β for the mathematical function of the cloud server, sin for the trigonometric function of monitoring, log for the logarithmic function of security in a controller, δ is the mathematical function of the gateway. On the other hand, big data relies on a distributed database instead of a central database. Several computers in a network work together to solve a problem. Aside from the fact that big data is much more scalable than traditional data, it provides greater performance and cost advantages.

$$t = \log\left(u - \iiint v \sqrt[3]{u}\,(\beta)\,\frac{1}{\partial^2}\right) * v \tag{17}$$

Eq. (17) denotes t for total profile EI access, u for software visualization, v for the smart city, log for the logarithmic function of data analysis, ∂ playing space for remote monitoring, β for planning destination, a for the grid. Several ancient civilizations used grid layouts to lay up their cities. Using columns and rows of sequentially ordered data, the grid system helps to align page components. This column-based layout allows us to consistently place text, pictures, and functionalities across the design (see Fig. 7).

Smaller distributed generation facilities are served by distribution networks, not the massive central power plants served by transmission systems. A converter's primary job is to correct the magnitude and phase of the PV system's output when receiving feedback from the utility grid. Additionally, wind turbine-connected grid systems benefit from mechanical and electrical frequency isolation in smart grid. Various technical concerns exist in grid-connected systems: Power Quality Concerns, Power and voltage changes, Storage and Protection issues, and Islanding. In Renewable energy systems, Grid-connected inverters for DG applications have a low risk of harmonic issues even at large penetration levels since they produce negligible harmonic currents. Voltage-source inverters, as opposed to current-source inverters, can offer the harmonic support required by the grid. Harmonic compensators can be found that are less expensive than voltage-source inverters, but they consume more energy.

$$w = [x] \iiint y \; log \; x \; + \frac{\|y\|}{(\varphi - 1)^2} \csc x \tag{18}$$

Eq. (18) says that w is responsible for the message in smart house, x for objects of smart meter, log for the logarithmic function of artificial intelligence, φ for distance surface approach, y for simulation, csc for the trigonometric function of planning analysis the internet. Large or complex facilities, such as manufacturing plants, power plants, network operations centers, airports, and even spacecraft, can be managed remotely using computer-aided design tools. Many different methods may be used to collect data and feed it into a system.

$$R_e = R\,(M) * (1 + (\gamma A\,(M) \ln \varepsilon)) \tag{19}$$

In Eq. (19), R_e represents smart grid sensor network, $R\,(M)$ represents types of materials used, $A\,(M)$ Efficient resource allocation.

4. Experimental analysis of low-energy buildings in densely populated urban areas

Sensor nodes translate real-world occurrences into data that may be analyzed, preserved, and utilized for various reasons in the future. Depending on the environment, each sensor node is tailored to its specific needs, such as a high-power transceiver for underwater sensors and a water-resistant outer shell for marine sensors. This ensures that the sensors can withstand saltwater, moisture, and other environmental factors. Using these sensor nodes, a central server can keep track of changes in the environment in real-time. To prevent catastrophic failures from occurring, sensor networks are essential. It is no longer a problem for large-scale distant installations because of the shrinking of electronic components, which has led to WSN deployment. The range of applications for WSNs has expanded as the technology's technical difficulties have been addressed. It is easy to establish wireless sensor networks since they are installed ad hoc. There

Table 1
Comparison of approaches.

Approaches	Weather station temperature %	Distance %	Transport %	Demand change %
TCL	0.48	0.21	45	48.33
BE	0.63	0.209	63	50.36
PV	0.68	0.15	76	52.99
GHG	0.74	0.086	82	67.45
DPUA	0.79	0.069	97	74.56

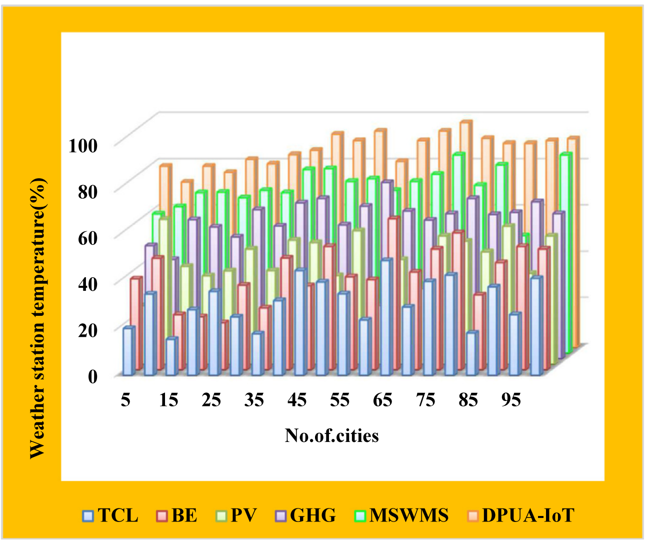

Fig. 8. Weather station.

are various ways in which wireless sensor networks can transmit information to a distant control center, including sensor nodes.

Table 1 shows the comparison of the existing technique with the proposed method. The proposed DPUA performs better than the existing approach, and DPUA-IoT is just one instance of these advantages. An ever-expanding human population threatens economic and social growth as well as environmentally sound resource management.

(i) Realization of Weather station

Fig. 8 says the weather station refers to a building with sensors and equipment for detecting atmospheric conditions to provide weather forecasts and research the environment. In contrast to automated measures, manual observations are carried out at least once daily. Personal weather stations, professional weather stations, home weather stations, weather forecasters, and forecasters are all examples of weather stations. Researchers can use weather stations to gather information on the weather and climate in an area by using sensors to monitor the atmosphere. Temperature, humidity, barometric pressure, wind speed and direction, and rainfall are all typically measured by most weather stations.

(ii) Increment of distance to the city center

Fig. 9 says successful city centers have grown mostly due to their capacity to attract new businesses. Since these new occupations, the city's downtown areas have become more desirable locations to reside, as more people visit stores, pubs, and restaurants. An urban core is the focal point of commerce, culture, history, politics, and geography, particularly in Western cities. If a city has a high density of residents and many land uses, it might be considered compact. Governments in outlying regions can adopt various actions, including increasing population density, to attain a more compact form.

(iii) Determination of Energy end user

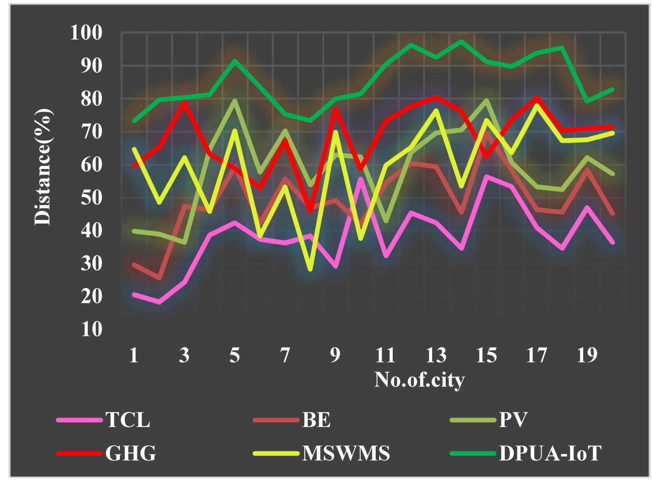

Fig. 9. Increased Distance to the city center.

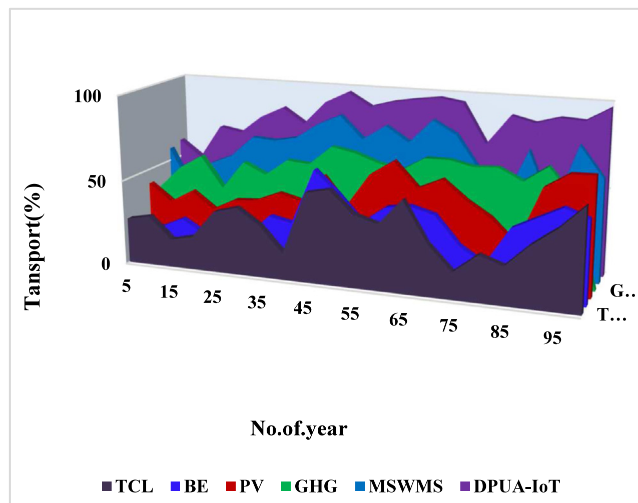

Fig. 10. Energy end user.

Fig. 10 talks about primary energy, referring to the energy extracted from natural resources and used directly by the consumer. Electricity, gasoline, and natural gas are all examples of end-use energy. A country's entire final consumption is sometimes referred to as the country's end-use energy profile. End-use technology is where it all begins for the electricity and gas business. The economy is powered by employing all energy sources, including electricity, natural gas, and oil, to perform productive labor. The adoption of new and improved end-use technologies is a possible solution.

(iv) Total demand without irrigation depending on temperature

Fig. 11 says that multiply the width by the yard's length in feet to figure out how much water is used. Even a brief period of high temperatures can harm crop development, particularly for crops like wheat. The growth of shoots is slowed by high air temperatures, which affects the formation of roots. High soil temperature is more important because roots are severely damaged, leading to a significant decrease in shoot growth. As the climate grows drier, irrigation is required. Due to differences in evapotranspiration and precipitation, more irrigation is required. Temperature rise and precipitation rates affect the amount of water needed for irrigation.

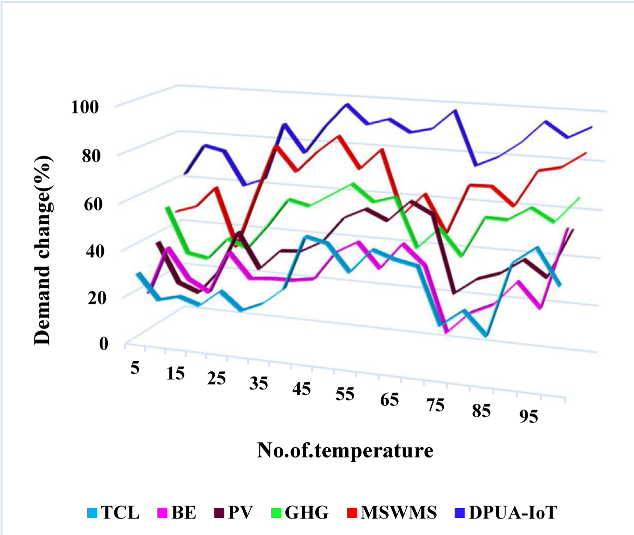

Fig. 11. Total Demand without irrigation depending on temperature.

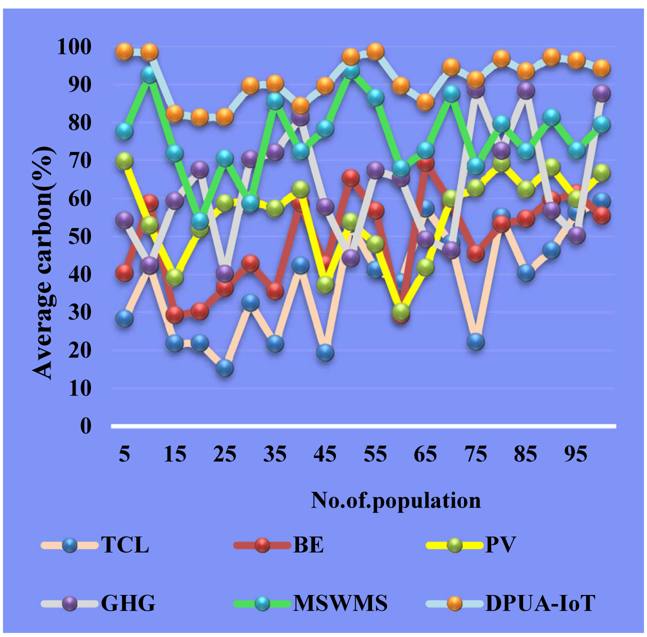

Fig. 12. Distribution of energy.

(v) Distribution of energy

Fig. 12 says coal and crude oil, and energy currencies for end-use such as gasoline or electricity are examples of human-created systems that carry energy. One or more principal energy sources are commonly used to meet a building's heating, air conditioning, lighting, and electrical demands. There are a number of ways to distribute energy, including steam, hydronic, air, and electrical. Distributor systems are characterized by the sequential flow of organized and integrated operations to permit and monitor the transfer of products and services from the source to the consumer. Control refers to the consumer's ownership of the goods or services.

(vi) Parameter calibration for the random tree

Fig. 13 says that each logistic regression model may be re-calibrated to produce a calibration data set for the random forest. A new estimate of the logistic regression model's intercept is used for re-calibration; all other coefficients remain the same.

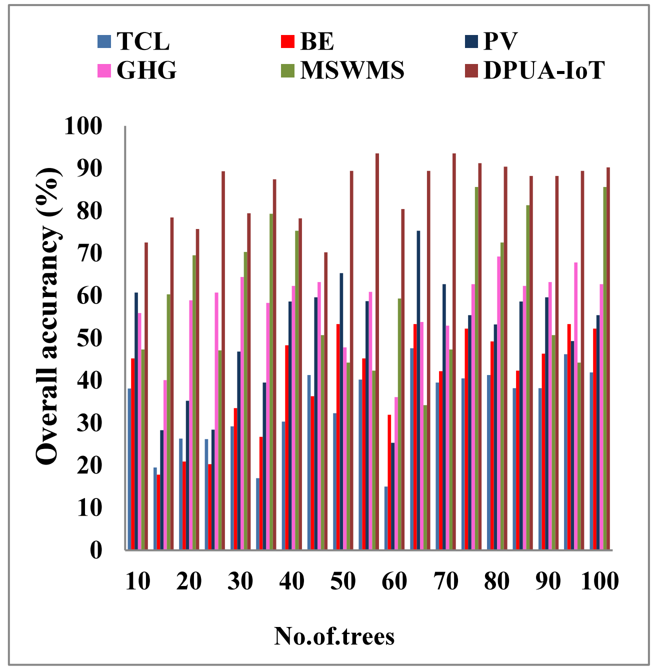

Fig. 13. Parameter calibrations for the random tree.

Calibration is the process of comparing an unknown value to a known value. In its purest form, calibration determines an instrument's accuracy. Once the predictions of a predictive model have been made, a rescaling technique known as calibration of prediction probabilities is used. It is common to use plat scaling and isotonic regression to calibrate probability.

5. Conclusion of the article

The deployment of wireless sensor networks in urban areas has been thoroughly studied and has attempted to classify each application situation exactly and include those examples that adequately match the scenario. Researchers have found that sensor networks have been integrated in such a creative and inventive way that it is nearly hard to tell the difference between wireless sensor networks, mesh networks, and other similar networks, even after conducting an exhaustive study. The Smart Grid allows grid operators to see further into the system and gives them greater flexibility in managing renewable energy systems intermittency. Researchers believe that shortly, all of the planet's diverse networks will unite to form one electronic skin. This research aims to separate and combine wireless sensor network applications to understand them better. WSN is an ever-expanding discipline, and this research might be broadened to incorporate more applications in metropolitan areas shortly. Smart city energy management is the focus of this essay. A software model of the suggested framework is used to introduce enabling edge computing technology. After that, a long-term strategy for managing cities' fluctuating and unpredictable energy sources and needs is proposed. It is compared to one without edge servers to determine how efficient an energy scheduling strategy is. It can see that the proposed methods can achieve lower energy costs while incurring fewer delays than conventional schemes.

CRediT authorship contribution statement

Wenming Zhao: Conception and design of study. **Jin Chen:** Conception and design of study. **Tao Hai:** Acquisition of data.

Muamer N. Mohammed: Acquisition of data. **Zaher Mundher Yaseen:** Analysis and/or interpretation of data. **Xuelan Yang:** Analysis and/or interpretation of data. **Jasni Mohamad Zain:** Analysis and/or interpretation of data. **Ruihua Zhang:** Analysis and/or interpretation of data. **Qiang Xu:** Analysis and/or interpretation of data.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

References

Aram, F., Solgi, E., Garcia, E.H., Mosavi, A., 2020. Urban heat resilience at the time of global warming: evaluating the impact of the urban parks on outdoor thermal comfort. Environ. Sci. Europe 32 (1), 1–15.

Arghavani, S., Malakooti, H., Bidokhti, A.A.A.A., 2020. Numerical assessment of the urban green space scenarios on urban heat island and thermal comfort level in Tehran Metropolis. J. Clean. Prod. 261, 121183.

Bao, K., Padsala, R., Thrän, D., Schröter, B., 2020. Urban water demand simulation in residential and non-residential buildings based on a CityGML data model. ISPRS Int. J. Geo-Inf. 9 (11), 642.

Barau, A.S., Abubakar, A.H., Ibrahim Kiyawa, A.H., 2020. Not there yet: mapping inhibitions to solar energy utilisation by households in african informal urban neighbourhoods. Sustainability 12 (3), 840.

Bienvenido-Huertas, D., Rubio-Bellido, C., Perez-Fargallo, A., Pulido-Arcas, J.A., 2020. Energy saving potential in current and future world-built environments based on the adaptive comfort approach. J. Clean. Prod. 249, 119306.

Cai, S., Wang, Y., Zhao, B., Wang, S., Chang, X., Hao, J., 2017. The impact of the air pollution prevention and control action plan on PM2. 5 concentrations in Jing-Jin-Ji region during 2012–2020. Sci. Total Environ. 580, 197–209.

Das, M., Das, A., Mandal, S., 2020. Outdoor thermal comfort in different settings of a tropical planning region: a study on Sriniketan-Santiniketan Planning Area (SSPA), Eastern India. Sustainable Cities Soc. 63, 102433.

Evola, G., Costanzo, V., Magrì, C., Margani, G., Marletta, L., Naboni, E., 2020. A novel comprehensive workflow for modelling outdoor thermal comfort and energy demand in urban canyons: Results and critical issues. Energy Build. 216, 109946.

Feng, H., Liyanage, D.R., Karunathilake, H., Sadiq, R., Hewage, K., 2020. BIM-based life cycle environmental performance assessment of single-family houses: Renovation and reconstruction strategies for aging building stock in British Columbia. J. Clean. Prod. 250, 119543.

Froemelt, A., Buffat, R., Hellweg, S., 2020. Machine learning based modeling of households: A regionalized bottom-up approach to investigate consumption-induced environmental impacts. J. Ind. Ecol. 24 (3), 639–652.

Ghorbani, S., Mohammadi, A., Teiri, H., Hajizadeh, Y., 2020. Spatio-temporal variations of asbestos fibres levels in ambient air of a densely populated and industrialized city of Iran. Int. J. Environ. Anal. Chem. 1–9.

Girard, L.F., Nocca, F., 2020. Climate change and health impacts in urban areas: Towards hybrid evaluation tools for new governance. Atmosphere 11 (12), 1344.

Gould, C.F., Schlesinger, S.B., Molina, E., Bejarano, M.L., Valarezo, A., Jack, D.W., 2020. Household fuel mixes in peri-urban and rural Ecuador: Explaining the context of LPG, patterns of continued firewood use, and the challenges of induction cooking. Energy Policy 136, 111053.

He, C., Zhou, L., Yao, Y., Ma, W., Kinney, P.L., 2020. Estimating spatial effects of anthropogenic heat emissions upon the urban thermal environment in an urban agglomeration area in East China. Sustainable Cities Soc. 57, 102046.

Hoffman, J.S., Shandas, V., Pendleton, N., 2020. The effects of historical housing policies on resident exposure to intra-urban heat: a study of 108 US urban areas. Climate 8 (1), 12.

Hu, L., Li, Q., 2020. Greenspace, bluespace, and their interactive influence on urban thermal environments. Environ. Res. Lett. 15 (3), 034041.

Hwang, R.L., Lin, T.P., Lin, F.Y., 2020. Evaluation and mapping of building overheating risk and air conditioning use due to the urban heat island effect. J. Build. Eng. 32, 101726.

Ivanova, D., Büchs, M., 2020. Household sharing for carbon and energy reductions: the case of EU countries. Energies 13 (8), 1909.

Jurasz, J.K., Dąbek, P.B., Campana, P.E., 2020. Can a city reach energy self-sufficiency by means of rooftop photovoltaics? Case study from Poland. J. Clean. Prod. 245, 118813.

Kamboj, S., Ali, S., 2021. Urban sprawl of Kota city: A case study of urban heat island linked with electric consumption. Mater. Today: Proc. 46, 5304–5314.

Kanemoto, K., Shigetomi, Y., Hoang, N.T., Okuoka, K., Moran, D., 2020. Spatial variation in household consumption-based carbon emission inventories for 1200 Japanese cities. Environ. Res. Lett. 15 (11), 114053.

Knickmeyer, D., 2020. Social factors influencing household waste separation: A literature review on good practices to improve the recycling performance of urban areas. J. Clean. Prod. 245, 118605.

Kotarela, F., Kyritsis, A., Papanikolaou, N., 2020. On the implementation of the nearly Zero Energy Building concept for jointly acting renewables self-consumers in Mediterranean climate conditions. Energies 13 (5), 1032.

Lampropoulos, I., Alskaif, T., Schram, W., Bontekoe, E., Coccato, S., Van Sark, W., 2020. Review of energy in the built environment. Smart Cities 3 (2), 248–288.

Lee, J., Shepley, M.M., 2020. Benefits of solar photovoltaic systems for low-income families in social housing of Korea: Renewable energy applications as solutions to energy poverty. J. Build. Eng. 28, 101016.

Li, P., Wang, Z.H., 2020. Modeling carbon dioxide exchange in a single-layer urban canopy model. Build. Environ. 184, 107243.

Lin, J., Wan, H., Cui, Y., 2020. Analyzing the spatial factors related to the distributions of building heights in urban areas: A comparative case study in Guangzhou and Shenzhen. Sustainable Cities Soc. 52, 101854.

Mishra, S.V., Gayen, A., Haque, S.M., 2020. COVID-19 and urban vulnerability in India. Habitat Int. 103, 102230.

Morakinyo, T.E., Ouyang, W., Lau, K.K.L., Ren, C., Ng, E., 2020. Right tree, right place (urban canyon): Tree species selection approach for optimum urban heat mitigation-development and evaluation. Sci. Total Environ. 719, 137461.

Novosel, T., Pukšec, T., Duić, N., Domac, J., 2020. Heat demand mapping and district heating assessment in data-pour areas. Renew. Sustain. Energy Rev. 131, 109987.

Pigliautile, I., Pisello, A.L., 2020. Environmental data clustering analysis through wearable sensing techniques: new bottom-up process aimed to identify intra-urban granular morphologies from pedestrian transects. Build. Environ. 171, 106641.

Pinheiro, M.D., Luís, N.C., 2020. COVID-19 could leverage a sustainable built environment. Sustainability 12 (14), 5863.

Proque, A.L., dos Santos, G.F., Junior, A.A.B., Larson, W.D., 2020. Effects of land use and transportation policies on the spatial distribution of urban energy consumption in Brazil. Energy Econ. 90, 104864.

Rehmani, M.H., Reisslein, M., Rachedi, A., Erol-Kantarci, M., Radenkovic, M., 2018. Integrating renewable energy resources into the smart grid: Recent developments in information and communication technologies. IEEE Trans. Ind. Inform. 14 (7), 2814–2825.

Richards, D.R., Fung, T.K., Belcher, R.N., Edwards, P.J., 2020. Differential air temperature cooling performance of urban vegetation types in the tropics. Urban For. Urban Green. 50, 126651.

Rong, P., Zhang, Y., Qin, Y., Liu, G., Liu, R., 2020. Spatial patterns and driving factors of urban residential embedded carbon emissions: An empirical study in Kaifeng, China. J. Environ. Manag. 271, 110895.

Velraj, R., Haghighat, F., 2020. The contribution of dry indoor built environment on the spread of Coronavirus: Data from various Indian states. Sustainable Cities Soc. 62, 102371.

Wang, C., Zhan, J., Xin, Z., 2020. Comparative analysis of urban ecological management models incorporating low-carbon transformation. Technol. Forecast. Soc. Change 159, 120190.