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# Analysis of 5G enabled smart energy management Systems in buildings.

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**ABSTRACT:**
Energy economy is one of the most important problems that scientists and the rest of society will have to solve in the coming years. Additionally, improved energy efficiency will support global sustainability. A whopping 40% of all energy used goes to buildings. Sustainability in the future generation of smart cities will be largely characterized by smart grids and smart buildings. The major objective is to minimize the negative effects of energy usage on the environment. This research looks at the major characteristics and contributions of information and communication technologies (ICTs) and methods for improving energy efficiency in smart buildings. The inquiry focuses mostly on electrical energy since it is the most often utilized energy. In this research, green energy sources and energy harvesting are also discussed since they boost energy efficiency by supplying extra clean energy. This investigation's key contribution is highlighting the most pertinent new and current ICT tools and methods that may be used to boost Smart Buildings' energy effectiveness.
**Keywords:** Smart buildings, energy, consumption, 5G network, communication

## I. INTRODUCTION:

Data transmission speeds are expected to increase from 1 Gbps to 20 Gbps with the introduction of 5G compared to 4G. Users will have much improved access to data and information as a result of this development.The military, first responders, and emergency services will greatly benefit from this breakthrough. Better battery options will be needed, however, since the usage of powerful signal boosters will result in a considerable reduction in the battery life of 5G-enabled devices. This speed boost has a number of severe downsides. One of a number of modifications made to the 5G radio was the usage of higher frequency bands. This helped to boost performance and cut down on latency. These higher frequency bands are only viable over minimum distances due to the speed with which things like buildings block them. To cover an identical area with 5G in cities, operators would need a lot more radios, they are good for industrial automation, and the technology is still inadequate for rural regions.

The fast growth of technology has greatly altered peoples' communication abilities. This will probably soon alter the look of numerous cities. Scientists believe that cities will soon face substantial changes as a consequence of shifting social norms and technology necessities, and as a result, urban planners and architects are under increasing pressure to accommodate these changes. Cities are expected to be home to between 66 and 70 percent of the world's population by 2050 [1]. Maintaining dependable, energy-efficient services without compromising the comfort and enjoyment of its users is a central topic of the abundant literature [2] on the impacts of urbanization on cities, communities, infrastructure, and the environment. This topic of research has been examined from a variety of perspectives by other academics [3], but it is still a popular one. The creation of an implementation strategy will need a variety of tools and skills. In the past, people were in charge of creating smart neighbourhoods, houses, and communities. This is mostly because to the current Internet's shortcomings and the inability to easily connect the many sensor networks found in urban areas, commercial structures, and transportation systems [4].The deployment of 5G wireless networks has started throughout the world [5]. Also, compared to the 10-100 Kbps offered by 2G GSM technology, 5G mobile communication's 1Gbps is a significant improvement [6]. In the past two years, the construction industry has made extensive use of 5G technology as academics and businesspeople have explored its possible applications. As evidence of the competitive advantage and bright future of 5G, certain businesses, such as IBM and Intel, have already built and marketed smart buildings [7]. Understanding the potential of 5G in intelligent buildings is crucial. Although there have been a few short studies on 5G-based smart buildings, to the best of our knowledge, no in-depth research has yet been undertaken on the use of 5G technology in building design [8]. Academics in the fields of civil, building, and architectural engineering may benefit from conducting an analytical review in light of the growing interest in this area. Understanding the technological needs of the construction business is crucial for those working in the 5G industry, which is customer-less and adopts a top-down strategy. The outcome is a boost in a structure's intelligence and a quicker development of 5G technology. The development of 5G technology may potentially enable communication between diverse devices. Once 5G wireless networks are available, individuals and companies throughout the world should be ready for substantial changes. The applications for smart cities are built on the Internet of Things (IoT), which generates enormous quantities of data [9].

Smart houses (SH), smart buildings (SB), smart grids (SG), and smart meters (SM) are some of the parts that make up a smart city (SC) [10]. The top five characteristics of SBs are:

- Automation: the ability to operate automated equipment and do automatic tasks.
- Multi-functionality: Permit several optimization processes within a single structure.
- Adaptability: the capacity to change depending on learning, prediction, and factors in order to meet the demands of users.
- Interactivity: Permit user interaction inside a building.
- Efficiency: the capacity to save time and money by achieving energy and other efficiency gains.

## II. MATERIALS AND METHODS

Increased attention has been paid to energy efficiency, smart grids, and smart houses in recent years. There will be a critical mass of people using 5G services by 2020, proving the urgent need to build 5G smart cities throughout the country. A collaborative intelligence smart edge system based on 5G and other technologies is crucial to the creation of smart cities. This is because the unique characteristics of these networks allow them to cater to the diverse demands of smart cities. To accomplish its goals, intelligent building must employ both proven techniques and cutting-edge technology. Intelligent buildings, which are designed with the help of modern communication and control technology, aim to give its occupants with a comfortable, secure, and convenient living space. Chinese academics define "smart buildings" as structures that use government-issued information technology and communication networks, efficiently monitor tenant data, and profit their owners. The environment, as well as the people who live there or work there, benefit from these buildings in terms of safety, productivity, and utility costs [11].

Information and communication technologies (ICTs) in general play a key role in helping to attain sustainability objectives via lower energy emissions [12]. 5G will be crucial in reducing energy usage and influencing new processes and applications, boosting energy efficiency [13], since there will be billions of devices connected to the cloud. With 5G, new features may be created to instantly identify environmental changes, which will help with disaster recovery efforts. 5G is expected to facilitate increased automation and digitalization across industries, including manufacturing, construction, transportation, and agriculture [14]. High energy efficiency is being achieved because to technological developments including smaller chipsets that reduce power consumption and device footprint [15]. The gear for the next 5G network is built with power-saving features and functionality in mind. By way of illustration, British Telcom (BT) estimated that by 2030, 5G may cut $CO_2$ emissions by 1.5 gigatons [16].

High goals for reducing carbon emissions are established by sustainability plans in the ICT industry. Such goals are difficult given that more linked and IoT-based gadgets will be used in the future. In order to meet increasing data use needs across diverse industries and deliver better energy efficiency via flexible operations, 5G will be vital in solving this problem. The "enabling effect" refers to the capacity of the existing network to improve energy efficiency in other sectors. The following are a few of the 5G network's enabling effects:

• Smart energy management across a variety of industries using a smart grid and metering system, IoT-based monitoring, and analytics powered by AI.
• Remote work, using cutting-edge technology like augmented reality and virtual reality, working from home, and reducing office space and travel.
• Minimal waste and proactive planning that results in just-in-time effectiveness across several processes.
• Reduced travel time due to intelligent movement management of people and products.
• Management of smart buildings using efficient real-time technologies.

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• Reduced food waste due to the farm sector's empowerment with predictive and sensor-based technologies.

The 5G network was created to accommodate an increasingly mobile and connected population [17]. It will also make it simpler for innovative company concepts to succeed. The main obstacle, however, is making it possible for 5G-based operations to be used in already-built structures since the design cannot be changed after it has been created. Thus, integrating an already-developed building into a smart city and undergoing change is quite difficult. As more people start using mobile broadband for a variety of purposes, the quantity of data that must be transferred and the volume of mobile broadband traffic will both skyrocket in the coming years. With the help of 5G, new, scalable services may be developed, and existing mobile broadband services can be expanded. As a result, 5G will be suitable for a broad variety of scenarios, from those needing a little quantity of data to those demanding a large number of data fast [18].In order to provide a high level of comfort and convenience for its tenants, smart buildings must make use of a wide range of interconnected devices, systems, controllers, and sensors.

## III. TECHNIQUES FOR ENERGY EFFICIENCY IMPROVEMENT

Smart cities seek to create an intelligent urban environment by integrating a wide range of urban infrastructures. In this case, smart buildings are crucial to smart cities and are essential to their viability. People in smart buildings may rest easy knowing that the Internet of Things and artificial intelligence are protecting them. Sensor data is used in IoT smart buildings to reduce energy usage and improve operational effectiveness. With the help of IoT devices, smart buildings may be able to regulate their energy use [19]. In order to establish the most effective means of conserving energy in smart buildings, the IoT gathers and analyses data on factors like humidity, temperature, and pressure. Lighting in smart buildings is monitored and controlled by Internet of Things sensors, which switch lights on and off as needed. The Internet of Things (IoT) has the potential to improve emergency response and management, leading to better results under these perilous conditions. Through the connection of sensors and the provision of real-time data to managers, rescuers, and those in danger, the Internet of Things has changed the way we think about safety systems. These sorts of applications might make structured smart systems more convenient and user-friendly. Diagrams for smart energy and smart buildings are shown in Figure 1 [20].

**LoRa communication module**

A relay module, sensors, an ESP32 microcontroller, and a RYLR896 LoRa module were all used in the recommended gadget. The ESP32 microcontroller type Node MCU ESP32 was used to test the gadget. The LoRa module, also known as the RYLR896 receiver, provides strong long-range frequency for establishing intercommunication and reliable disturbance security with little power consumption. The robotic system was therefore reinforced. An antenna and a CPU were integrated onto a printed circuit board. (PCB). With a 127 dB dynamic range RSSI and an integrated SimTech SX1276 motor, LoRa can run a variety of devices across distances of up to 12 km. The system uses the ESP32 microcontroller, a dependable and flexible module with a wealth of built-in functionality. This device was constructed utilizing a variety of electronic parts.

Using a cable connection, it acted as a gateway between different instruments and control buttons at the receiving end, and using a Wi-Fi connection, it did the same for the user program and the LoRa module at the sending end. To maintain track of the most current condition of the target setting or object, the system used a number of tools. The instruments were connected via the different I/O ports on the ESP32 module.

Predictive Circuits Ratings

Numerous beneficial methods exist to handle the available resources effectively [21]. Although using such predictive circuit models in practice avoids doing a thorough study, it often produces highly conservative findings with safety margins for the rating that are greater than anticipated to maximize the effectiveness of energy management. The flexibility that the network management operator has in achieving system constraint costs is a benefit, which supports the finding that the restrictions on power flows are relatively gentle.

To achieve the desired performance, it is necessary to overcome a number of significant obstacles, including the following:

• Better and more precise local weather prediction methodologies and approaches employing unique technology.

• The creation of algorithms based on machine learning and artificial intelligence that can handle data more effectively.

• Development of more accurate and affordable thermal modelling methods.

The majority of the time, the issue has already been technically resolved. Furthermore, because the suggested modifications do not call for new regulations, it is not a regulatory problem. However, it is a commercial issue, and the way things are done now makes it difficult to implement suggested changes, make the necessary investments, and train people to use new data. Regardless, the various areas will gradually be penetrated by these new methods, materials, and technology.

Automation Systems

Resource management in buildings must be automated and improved using intelligent building automation technologies. Managing the current number of devices and maintaining their connectivity are scalability concerns [22]. The total cost of an Internet of Things system is closely correlated with the time required to deploy every sensor. The BAS monitors each service's performance and notifies the building management of any potential problems [23].

Lighting Management System

Businesses have adopted IoT-based lighting control using a variety of strategies since it is important for effective building lighting management. Visible light communication (VLC) technologies will be introduced to help in the development of the Internet of Things (IoT) [24]. Infrared communication has been employed in a wide range of technological applications. Because LEDs produce visible light, it's a popular misconception that they don't emit visible light continuum (VLC) [25].

Big Data Handling System

When transmitting and integrating enormous amounts of data, many businesses encounter significant difficulties. To get the desired outcomes, extensive data databases and traditional databases collaborate. Big data has created substantial issues with the security and privacy of personal information, and extensive data interchange between consumers is seen as a severe threat [26]. Distributed energy systems with IoT integration provide higher energy efficiency and less waste. Environmental problems are therefore reduced [27]. Data sources in the smart building architecture that need to be efficiently stored and managed are shown in Figure 5.Determining the energy profile of a building allows for the development of a personalized resource management system, which is then able to make judgments and take actions that result in energy savings [28]. To prove the efficacy of their technique, the authors apply it to a reference structure (data contextualized over the course of a full year of monitoring). Understanding the building's context and energy usage is essential for selecting the most suitable approaches for producing a model of the reference building that predicts energy consumption in response to a particular set of inputs.

A significant portion of the total demand for energy is accounted for by the energy consumption of ICT hardware and networks. The information society revolves on many forms of networks, which are essential to current societal progress, the economy, and private use. In order to meet global sustainability and environmental objectives, society requires telecommunications networks and infrastructures with superior energetic properties and high energy efficiency [29].

Heating, Ventilation, and Air Conditioning (HVAC)

Sensors from the building automation system are used by intelligently designed heating and cooling systems to collect environmental data. Through the use of climate control and ventilation systems, building occupants may alter the humidity and temperature in different areas. The reliability of the facility may be improved by preventative maintenance, early detection of HVAC system faults, and less expensive tool failures [30].

Security Solutions

The proliferation called "smart buildings" has raised important difficulties that need to be resolved in order to comply with rules and make spaces far more cozy, effective, and safe. Two of these issues are security and picking an alarm verification service. Without access to modern tools, firms will be unable to create user-centric smart buildings. People must be secure within these facilities and be able to function normally even if a natural disaster or cyberattack shuts down the Internet.

Smart Weather Management

The temperature of a building is a crucial control factor. Modern buildings have the ability to regulate their temperatures, creating considerable opportunities for energy savings and comfort enhancement. A cold summer breeze is more likely to be felt than a cozy winter wind. The major purpose of the wind sensor is to monitor wind velocity in order to calculate ventilation airflow.

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For Smart Buildings to attain the maximum levels of energy efficiency, several technologies may be used. The improvement of overall building comfort and resource optimization are made possible through data gathering, processing, interchange, and decision-making (more precisely and consistently). It is necessary to ensure the integration of the various subsystems like sensors, actuators, and intelligent data processing systems). A specific collection of technologies (ICT) will be best suitable for each individual case, and the overall solution will be a mix of them, i.e., a heterogeneous communications system. Very basic electronics may be used to accomplish energy efficiency. For example, simple sensor devices may be used to record people's movements and occupancy levels, control the HVAC, ventilation, and lighting in real time, and more. The control unit, which has intelligence capabilities, analyses data, controls equipment and devices to increase ambient comfort and productivity of people using the facilities while also maximizing the level of energy consumption and lowering energy costs. In a similar vein, employing modern technology and a smartphone to operate a lift would result in an energy consumption decrease of roughly 3–10% of the building's total power usage and improved user comfort. Additional intelligence in the system is needed to get greater savings. A facility's temperature could be continuously monitored by the system, which could then act more accurately based on the sensor data by, for instance, taking into account hysteresis cycles and historical information records. These records would then be processed by the system using data analytics techniques, and decisions would then be based on high-performance artificial intelligence and machine learning algorithms [31].

The supporting (intelligent) system is often subject to limitations such as being low-cost, high-performance, secure, dependable, and accurate. The desired outcome is a smart, energy-efficient structure that ensures each occupant's comfort to the greatest extent feasible, and machine learning seems to be the right instrument for the job. The ability of the support technologies and approaches is constrained by the low cost limitation, which also has an impact on getting the optimal outcome.

## IV. REAL TIME APPLICATIONS:

Energy Digital Twin for Efficient Power Management

The Internet of Things (IoT) has generated it possible to develop a digital twin of a building's functioning that continually learns and updates itself utilizing data from building energy management systems (BEMS) and building information modelling (BIM). Energy model development and calibration is a labour- and time-intensive procedure. Through the development of an information sharing infrastructure, it will be possible to build physics-based models that accurately represent the main energy-consuming HVAC components. In order to maintain accuracy over time, the models would also be automatically calibrated regularly. This ongoing study's objectives are:

- Real-time evaluation of building system performance versus design criteria.
- Improving a building's performance and interior environmental quality via real-time operation optimization.
- Integration for automated fault identification and diagnosis using machine learning methods.
- Analysis of solar photovoltaic (PV) energy production for automatic rectification to increase output.

In this use scenario, the 5G network's function is to fulfil the demand for various IoT device support inside a constrained region. It will also help with cloud-based data processing, allowing for the collection of real-time data from a wide variety of Internet of Things devices. More real-time processing of data is assured with a low-latency 5G network.

**Facade Inspection System in Real Time Using Artificial Intelligence and Drones for Smart Maintenance Management**

The goal of this project is to develop a functional prototype of a drone-based façade inspection system capable of capturing high-definition digital stills and moving images in real time. The recordings will then be sent over 5G to a distant flaw detection system powered by AI for examination. The ability will change current manual inspection processes. Together, AI and drones will enhance the building inspection industry's workflow and operational efficiency by providing more extensive and comprehensive inspection results and ensuring the safety of personnel at heights.

Due to network difficulties, the existing method necessitates a facilities manager to examine data afterwards. The drones will transmit data to the cloud via a 5G network, where it will be analyzed. The findings will then be delivered in real-time to the facilities manager.

## V. PERFORMANCE ANALYSIS

Using studies that prioritize a device with various settings, mimic human pleasure, and apply cost-saving strategies, the efficacy of such an energy management software is assessed. the comparison of many contemporary models, including the long short-term memory (LSTM) network and the RNN based on RMSE, and MAE. These are contrasted with the LoRa_ BiGNN model, which uses a bidirectional gated recurrent neural network.

A measure for contrasting two continuous variables is the MAE. The hourly actual and predicted energy use figures obtained from the AI models are averaged to create the MAE utilized in this study. The formula for its composition is

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n} y - y'$$

Y' is the hourly anticipated net energy consumption and n is the sample size when y relates to hourly net energy consumption data.

The recommended approach bases assessment on the commonly used measure for prediction problems, the MAPE's inherent meaning in terms of relative error. The equation below describes the MAPE calculation. The RMSE is often used to quantify the discrepancy between actual values and values predicted by a prediction model. This is how it was calculated:

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y - y')^2}$$

Studies that prioritize a device with different settings, simulate human pleasure, and use cost-cutting techniques evaluate the effectiveness of such energy management software. Since most air cooling and heating systems are designed to operate within a limited temperature range or at a set temperature, they must be frequently switched on and off. The air conditioner, as an example, modifies its temperature in response to the customer's surroundings. As soon as the inside temperature reaches the desired level, the ac motor kicks on and begins to operate.

Additionally, the equipment is precisely handled so that it is consistently kept within the parameters of a user's cozy preferences. The data from the Moisture Temperature Controller and the Maximum Temperature in Degrees are utilized in this instance to compute the threshold value. The temperature is below 22 °C on average at 7:43:25 p.m. As a result, the microprocessor cut off the ventilation power.

Table 1 displays the results of an examination into the performance of the cooling load, while Tables 2 and 4 display the results of an analysis into the heating load. The heating load performance study is shown in Figures 3,5, and the cooling load performance analysis is depicted in Figures 4,6. The performance is examined according to RMSE, MAE, and day of the week metrics.

Table-1 Comparison of methods for heating load - RMSE

| Hours of the day | LSTM | RNN | LoRa_ GNN |
|---|---|---|---|
| 8:00 am to 12:00pm | 2.17 | 1.35 | 0.21 |
| 12:00 pm to 4:00pm | 2.23 | 1.58 | 0.18 |
| 4:00 pm to 8:00 pm | 2.29 | 1.62 | 0.19 |
| 8:pm to 12:00 am | 2.47 | 1.78 | 0.17 |
| 12:00 am to 4:00 am | 2.34 | 1.96 | 0.18 |
| 4:00 am to 8:00 am | 2.32 | 1.48 | 0.19 |

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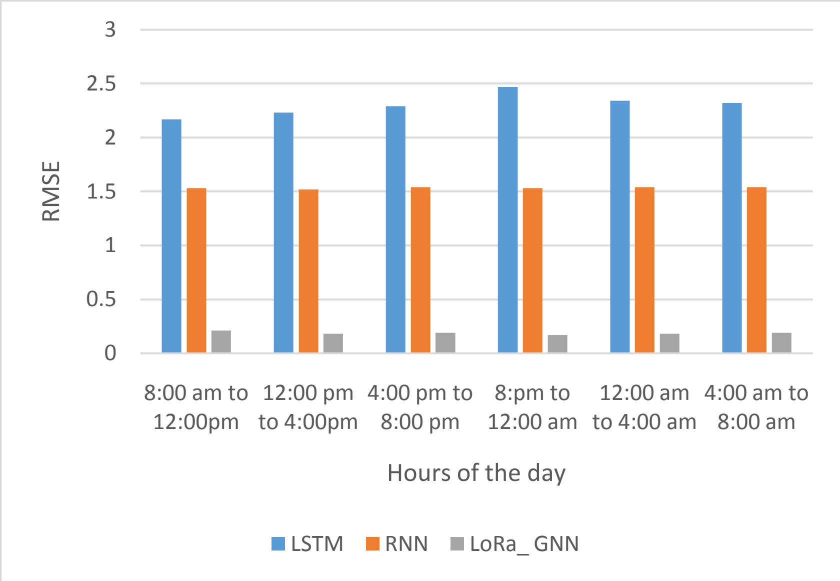


Figure-3 analysis of RMSE for heating load

Table-2 Comparison of methods for cooling load -RMSE

| Hours of the day | LSTM | RNN | LoRa_GNN |
|---|---|---|---|
| 8:00 am to 12:00pm | 1.42 | 1.78 | 0.12 |
| 12:00 pm to 4:00pm | 1.47 | 1.98 | 0.21 |
| 4:00 pm to 8:00 pm | 1.43 | 1.93 | 0.18 |
| 8:pm to 12:00 am | 1.45 | 1.87 | 0.29 |
| 12:00 am to 4:00 am | 1.46 | 1.91 | 0.30 |
| 4:00 am to 8:00 am | 1.38 | 1.87 | 0.21 |

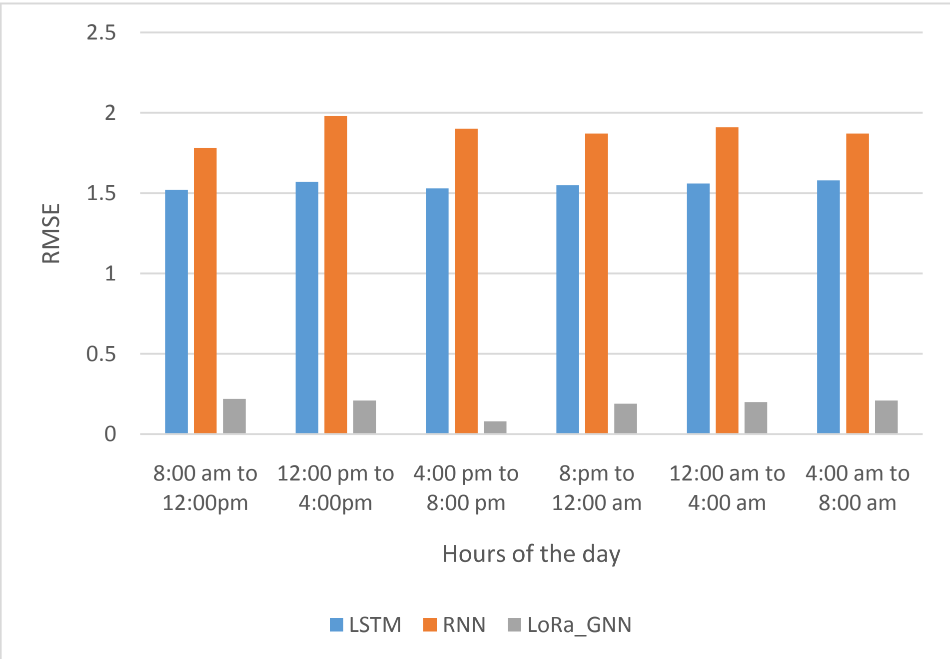


Figure-4 analysis of RMSE for cooling load

Table-3 Comparison of methods for heating load -MAE

| Hours of the day | LSTM | RNN | LoRa_ GNN |
|---|---|---|---|
| 8:00 am to 12:00pm | 1.31 | 1.68 | 0.11 |
| 12:00 pm to 4:00pm | 1.32 | 1.67 | 0.22 |
| 4:00 pm to 8:00 pm | 1.34 | 1.66 | 0.10 |
| 8:pm to 12:00 am | 1.33 | 1.65 | 0.21 |
| 12:00 am to 4:00 am | 1.33 | 1.64 | 0.12 |
| 4:00 am to 8:00 am | 1.34 | 1.65 | 0.20 |

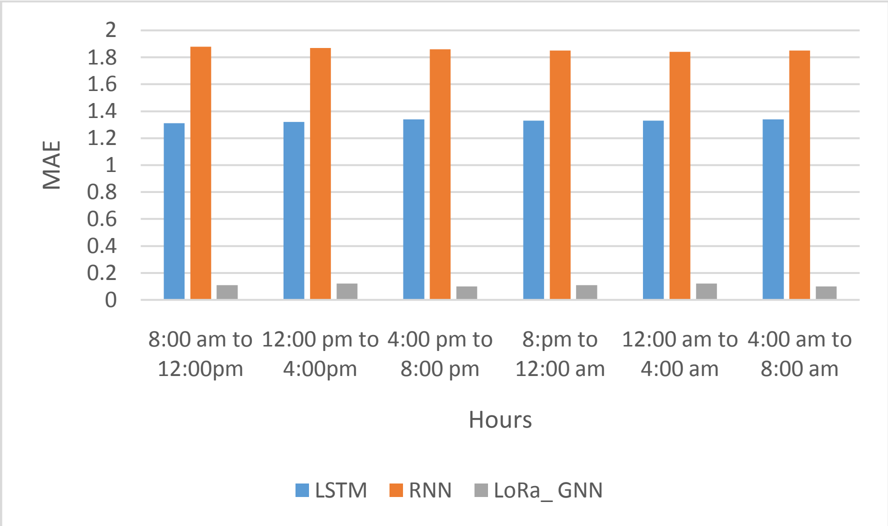

Figure-5 analysis of MAE for heating load

Table-4 Comparison of methods for cooling load -MAE

| Hours of the day | LSTM | rTPNN-FES | LoRa_ BiGNN |
|---|---|---|---|
| 8:00 am to 12:00pm | 2.68 | 1.88 | 0.22 |
| 12:00 pm to 4:00pm | 2.67 | 1.89 | 0.22 |
| 4:00 pm to 8:00 pm | 2.66 | 1.87 | 0.20 |
| 8:pm to 12:00 am | 2.65 | 1.88 | 0.11 |
| 12:00 am to 4:00 am | 2.67 | 1.89 | 0.12 |
| 4:00 am to 8:00 am | 2.68 | 1.87 | 0.10 |

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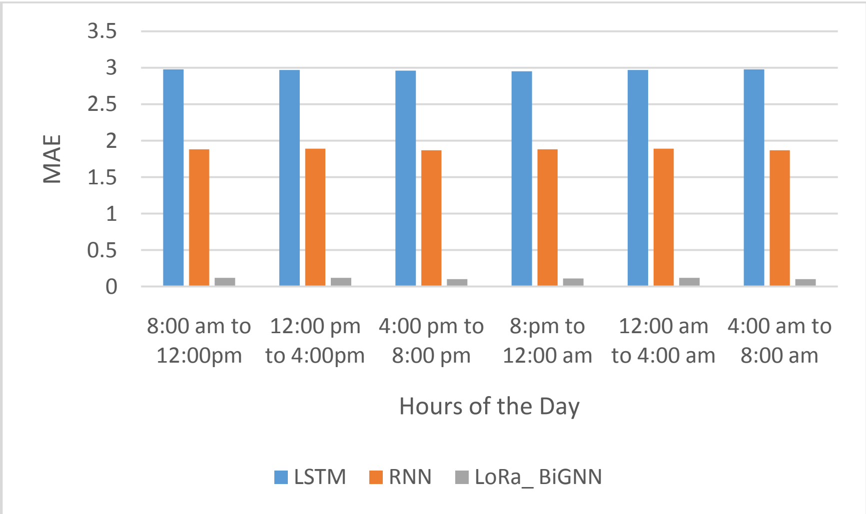
Figure-6 analysis of MAE for cooling load




From the above analysis, the existing method LSTM, RNN is compared with the proposed method of LoRa_GNN for the metrics of MAE, RMSE. This results reveals that all the metric error values are reduced to 0.11 of MAE, 0.21 of RMSE for heating load (kWh/m2) and the 0.11 for MAE, 0.18 of RMSE respectively. From this, the proposed method is very effective with LoRa communication module.

## VI. FUTURE WORK

The benefit of 5G technology, according to this section's recommendations for further research, might aid in the automation of smart building control. In the next years, it's anticipated that both 5G wireless technology and the Internet of Things will be widely used. At the level of actual application, metropolitan regions will see the first 5G installations. To create 5G cellular technology capable of handling massive data transmission rates, the millimeter wave spectrum must be used. However, millimeter wave solutions need the utilization of small cells. The goal of most implementers is to use no more than a handful of Internet of Things technologies. In this piece, we'll look at how 5G may be used for IoT applications in smart cities. However, the focus of this article is on the conditions under which smart cities operate. Fifth-generation technologies, due to their widespread use and advancement, have the potential to enhance the practicality of buildings, neighbourhoods, and whole cities. The domain-specific terminology and other use guidelines must be defined with the incorporation of AI and ML based techniques before 5G technology can be used in smart cities.Large cities have the potential to reap the benefits of state-of-the-art urban technology. As the concept of the creative city grows in popularity across the globe, there is a pressing need for more research on cost-effective approaches to urban design and development.Use of renewable energy sources is essential for limiting dependence on finite non-renewable energy supplies and ensuring the continued success of local enterprises. Another area of study that has room for growth in the future is the creation of a regulated and autonomous system based on 5G and AI for this purpose.

## VII. CONCLUSIONS:

In order to maximize energy savings, this article manages the factors that may be controlled in buildings and focuses on energy efficiency in smart buildings. In particular, research has been done on the factors optimize this improvement in these areas, leading to greater efficiency, lower energy costs, and less emissions of carbon dioxide into the atmosphere.

Information and communication technology are important in this situation. So far, energy savings have been achieved by simply turning on/off lights or controlling HVAC using smart devices. Researchers and technologists working on the design and development of smart buildings discovered that a plethora of data about the general condition of the constructions and each of their amenities is required for controlling energy and building resources which have an effect on energy consumption.

Because of the need of properly connecting all of the many installed components in a smart building (sensors, actuators, electromechanical parts, databases, information processing systems, etc.), connectivity is a crucial aspect of these structures. Wireless technologies are the most appropriate for this use because they provide more flexibility and less expensive implementation. Additionally, they provide a certain level of security.

The Internet of Things-related wireless technologies have been recognized as the most suited ones. This is so because they are widely used in so many widely used systems and devices, including smartphones, making it simple to integrate systems and devices.

IoT standards still cover a broad range of topics, however. This is because choosing the right technology for each application inside a Smart Building is dependent on factors such as range, power constraints, and data throughput needs.

This reality necessitates the compatibility of wireless protocols in the majority of situations, necessitating the need of an interoperable gateway. Furthermore, it could even be essential to employ cellular technology since Smart Buildings can collect data from their surroundings and other Smart Buildings (a phenomenon known as the "Cloud of Buildings").

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