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A SCOPING STUDY ON ENERGY MANAGEMENT SYSTEM IN THE CITY OF HYDERABAD

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ABSTRACT

India is one of the emerging economies attracting many industries for launching their business in its land. In the present scenario of global warming and in the light of environmental awareness, it is an alarming issue. An important point to be observed and highlighted is regarding waste disposal and radiation produced by various industries. Industries cannot be entirely held liable because they function as per the demand and requirements of customers. expectations. As socially and environmentally responsible citizens, we must Support our nation by making meaningful, feasible, implementable, and educated decisions that encourage sustainability and ethical practices. If we are not able to produce power, at least we should support saving power. The study titled "A scoping study on energy management systems in the city of Hyderabad" is an initiative to identify and gain an insight into the various issues and challenges we face due to power shortage The sensor system could prevent/save the unwanted usage of electricity, which could be utilized for another meaningful purpose. It is advisable for the huge societies and residential complexes in the highly urbanized localities of Hyderabad. This study is an attempt to provide an understanding regarding how various types of bulbs, their power consumptions, and cost-effective utilization of the technologies available in the market. This will lead not only to saving costs on electrical bill per month for the residential associations, which in turn brings down the monthly common area maintenance cost for the individual house, but also help the government avoid/reduce/minimize possible future power crisis. The findings of the study would help to acquire great knowledge. about the various problems with reference to maintenance bills and solve a few problems faced by owners of residential apartments— A win-win scenario for Both residents and associations should be welcomed by us.

Key words: *sensor system, common area lighting, residential complexes, residential associations, & electricity consumption.*

INTRODUCTION

Hyderabad, a busy/active city, is one of the metropolises in India. This is a city characterized by its rapid urbanization and growing population. We have witnessed many upcoming villas, bungalows, and multi-storied residential complexes and expecting many more such ventures to come up. In the view of with this sort of rapid urbanization, power, water, and basic needs would always be a challenge to the builders/residents of this lively city. Like many other metropolitan cities of India, Hyderabad also faces the challenge of managing its energy resources efficiently, especially in public utilities such as transport, residence, basic amenities, etc [4]. Common area lighting is one of the issues in an urban community of Hyderabad. Streetlights and other public utilities consume a significant amount of electricity, contributing to both high costs and environmental concerns. To address this issue, it is essential to explore innovative solutions that can reduce energy consumption while maintaining safety and functionality. One such solution is the implementation of sensors [14]. systems that activate streetlights only when there is human or animal presence within a certain range, such as 30-40 meters.

Table 1. Total energy consumption (20)

Energy statistics India 2025 Overview	
Released by	National Statistics office (NSO)
Ministry	Ministry of Statistics and Programme implementation
Energy Trends for	Financial Year 2023-24
Purpose	Shows energy production, consumption and import trends
Key Highlight	Strong energy recovery post-COVID
Total Primary Energy Supply (TPES)	903.158 kilo Tonnes of Oil Equivalent (K ToE)
Per Capita Energy Consumption	18,410 Mega Joules
Renewable energy Potential	21,09,655 Megawatt
Website	www.mospi.gov.in

Source: https://www.pw.live/upsc/exams/energy-statistics-india-2025

Table 1 here represents tabulated information on total energy consumption statistics of India in 2025, an overview(prediction) released by the National Statistics Office. Various details related to potential renewable energy; oil consumption is represented here for the financial year 2023-2024 [22].

In 2023, per capita energy consumption was 0.8 ToE, half the Asian average, with electricity use at 985 kWh per person. Total energy consumption averaged 8.9 million tons annually, growing at 6.5% per year since 2020, including 5% growth in 2023. From 2010 to 2023, the annual growth rate was 4.3%. Coal remained the dominant energy source, contributing 49%—up 9 points since 2010 and 4 since 2020 [40]. Oil and biomass followed at 22% and 20%, respectively. Natural gas provided 5%, while primary electricity sources (hydro, nuclear, solar, and wind) accounted for just 4% of the energy mix [20], [21], [23] [32].

The Problem of Energy Consumption in Public Utilities: Electricity consumption has grown at an impressive 6% per year since 2020, with the 2023 share being 6.5% to reach 1407 TWh. It also experienced a fast increase in the years 2010- 2019 by 7% per year and decreased by 8.5% in 2020.

Statistics for India Renewable Energy in Percentage of Electricity Production

Renewable in percentage of total electricity Made in IREDA, the Indian Renewable Energy Development Agency provides loans for the expansion of renewables [24], [31]. SECI, Solar Energy Corporation of India, which is a part of MNRE, oversees procedural aspects of the Jawaharlal Nehru National Solar Mission (JNNSM). The Solar Mission sought to achieve deployment of solar energy. systems in 100 GW over 2010-2022 (73 GW of 2023)32. The government further imposed the goal of 40 GW rooftop solar power within mid-2022 (at the end of 2023 only 10 GW was installed). In a bid to achieve the target by 2026, a new subsidy program aimed at landscaping roofs with solar was published in the month of April 2024.

Street lighting is crucial for urban safety and functionality. It ensures that Streets are illuminated during the night, preventing accidents and deterring crime. However, traditional common area lighting systems operate continuously from dusk till dawn, regardless of the actual need for lighting. This constant operation results in significant electricity consumption and unnecessary energy waste [29].

In Hyderabad, where the population and vehicle density are continuously rising, the demand for street lighting increases. According to estimates, street lighting can account for up to 30% of a city's total energy consumption14. This high demand leads to increased electricity bills and contributes to environmental degradation due to higher greenhouse gas emissions from power generation [30]. These cause a high load demand that in turn leads to high electricity tariffs and thus to pollution as well as degradation of the environment through production of higher levels of greenhouse gases resulting from power production.

Table 2. Energy statistics India 2025 highlights (31)

The Energy Statistics India 2025 emphasizes that during the fiscal year 2023-24, India has seen robust growth in energy supply and consumption, bouncing back from the pandemic-induced setbacks. The key highlights of Energy Statistics India 2025 are:	
Growth in Total Primary Energy Supply (TPES): Growth in Renewable Energy Capacity:	Installed capacity for renewable energy (including utility and non-utility) increased from 81,593 MW (2015) to 1,98,213 MW (2024), achieving a CAGR of 10.36%.
Electricity Generation from Renewables:	Reached 3,70,320 GWh, a 6.76% CAGR since 2014-15.
Increase in Per-Capita Energy Consumption:	India’s per-capita energy consumption increased from 14,682 Mega Joule/person in 2014-15 to 18,410 Mega Joule/person in 2023-24, with a CAGR of 2.55%.
Transmission and Distribution (T&D) Losses:	T&D losses declined from 23% in 2014-15 to 17% in 2023-24, reflecting improvements in energy efficiency.
Sector-Wise Growth:	The industry sector witnessed the highest energy consumption rise, from 2,42,418 KToE (2014-15) to 3,11,822 KToE (2023-24).

Source: Ministry of Statistics & Programme Implementation. (2025, March 27). Energy Statistics India 2025 [17]. Government of India.

Table 2 here represents the highlights of growth in primary energy supply from 2015 -2024, electricy generated from renewable sources, statistics of increased consumption of energy which is appoint of concer to be concentrated on and reflection of how the energy efficcency has improved fro m2014 to 2024 from 23% to 17% consumption.

Figure 1 shows state/union territory level data of per capita electricity consumption in India for the year 2018–19 in kilowatt-hours (kWh). It shows a staggering level of regional inequality with many states like Gujarat (2378kWh), Punjab (2046kWh) and Haryana (2082kWh) at the leading edge of consumption while other states like Bihar (311kWh), Assam (341kWh) and Uttar Pradesh (606kWh) lag woefully behind. Not only is the national average frustratingly low at 1181kWh, but the disparities in energy access between states reveals how lopsided development has been [37].

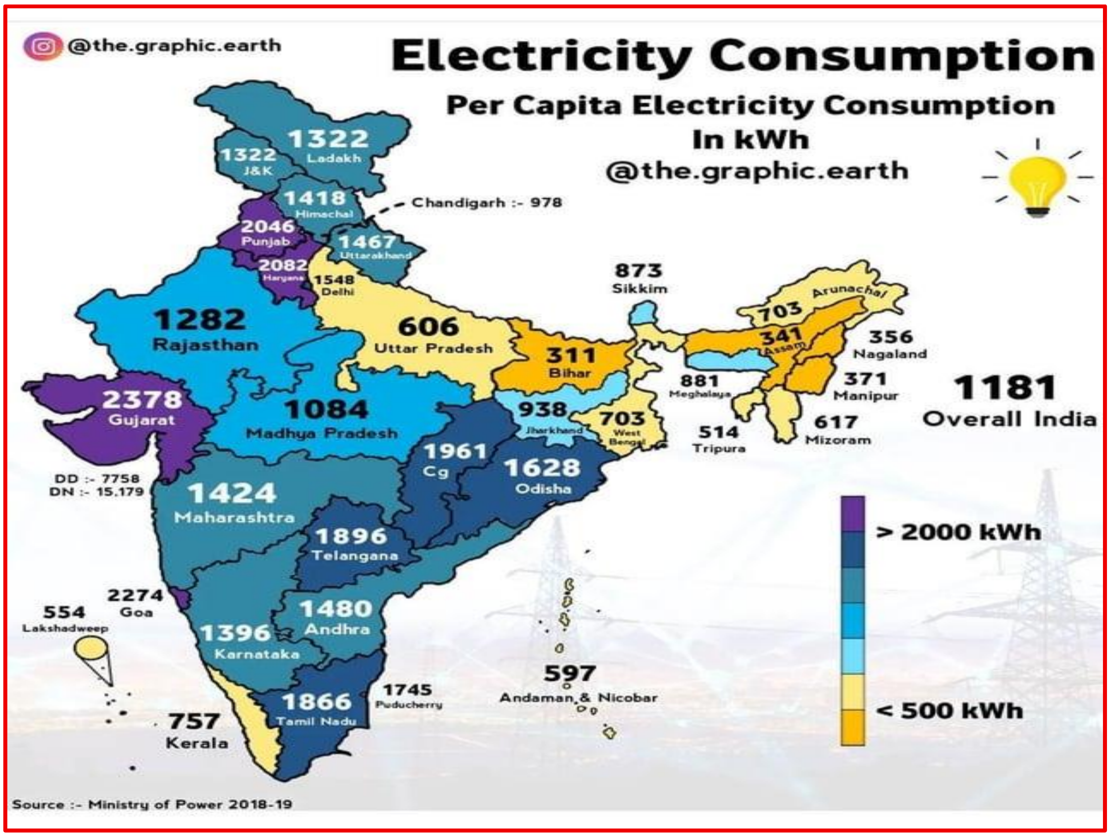

Figure 1. Electricity consumption: per capita electricity consumption in Kwh(11)

Source: Ministry of Power, Government of India. (2019). Per capita electricity consumption by Indian states [27] (2018–19)

Idea for Sensor-Based Street Lighting System

To reduce the problem of power shortage or interrupted power supply during the needy hours of energy wastage, sensor-based street lighting systems provide a good solution [5]. These systems utilize sensors in order to establish the existence of life, including human or animal life, within a certain degree of distance [15]. The glow and brightness sources are on only when there is movement. that is easily visible, thus minimizing unwarranted light, which can be reduced during periods of low worker productivity or overall organizational activity. Sensor system at residential units.

Need For the Study

There is a high need to understand how this issue can be addressed and what Else, tell me the alternative to reduce the power bills. A city like Hyderabad, which experiences rapid urbanization and an increasing population. We have witnessed a multitude of new residential projects, including villas, bungalows and multi-story structures, and anticipate many more to be developed in the future. The rapid urbanization potential would pose a constant water and basic needs challenge for the builder and residents of this dynamic city. Managing Energy efficiency in public utilities like transportation, homes, and basic facilities is a challenge that Hyderabad faces, similar to many other metropolitan cities in India. One of the problems in an urban community is Hyderabad is common area lighting.

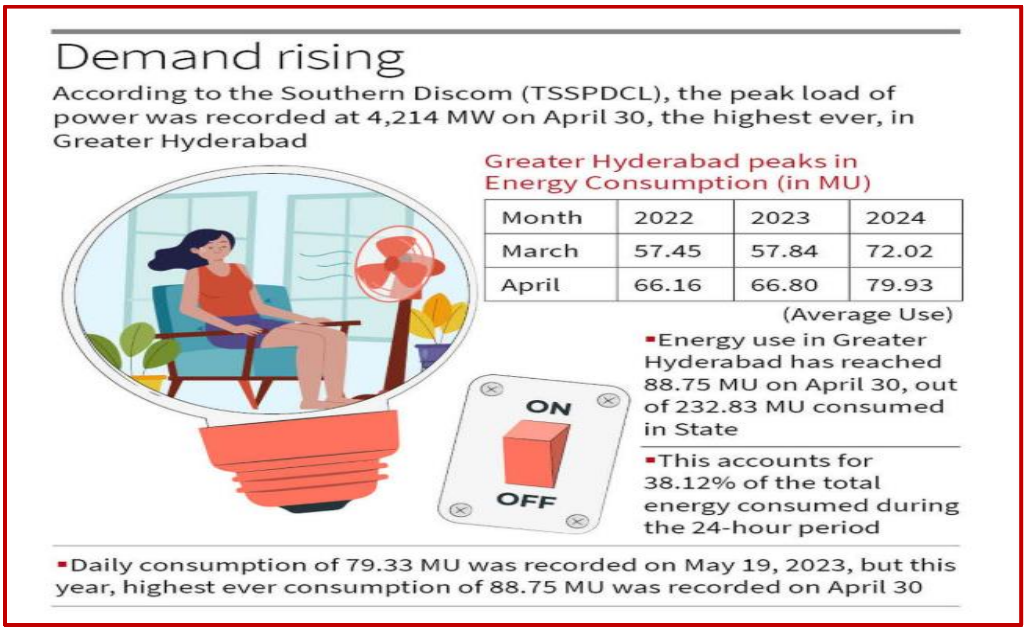

Figure 2. Representation of energy consumption (in MU) @ greater hyderabad (33)

Source: https://www.thehindu.com/news/national/telangana/energy-use-peaks-as-hyderabad-boils/ article68128857.ece.

The high electricity usage of public Utilities, including streetlights, are not only costly but also environmentally harmful. In order to tackle this issue, we must develop energy-efficient solutions that ensure safety and functionality. Sensor systems that activate streetlights when there is human or animal activity within a specific range of 30-40 meters are an alternative solution [25] (Figure 2).

With the increasing population and number of vehicles in Hyderabad, street lighting becomes increasingly important. Street lighting can be estimated to contribute up to 30% of a city's energy consumption. The high demand for electricity relectricityigher energy costs and environmental degradation [13]. resulting in increased greenhouse gas emissions. The demand for electricity is high, leading to high electricity tariffs and environmental degradation caused by pollution and greenhouse gas emissions. A solution to the problem of power shortage or interruptions in power supply during critical hours can be achieved. through the use of sensor-based street lighting systems [26]. The use of sensors in these systems enables the determination of life, such as human or animal life, within a certain distance [28]. The sources of illumination are activated only when there is visible movement, reducing unnecessary light that can be reduced during low worker productivity or organizational activity. The sensors feature a range of technologies that enable the selection of motion, including passive modes.

Types of Sensors That Can Be Used

Figure 3. Motion sensors

These sensors include several technologies to pick up the motions, such as passive. Infrared (PIR) sensors, ultrasonic sensors, and microwave sensors. PIR Sensors are commonly applied in the systems of street illumination. because of the ability to perceive heat, which is released by living creatures. First, ultrasonic sensors, which work by sending sound waves across the field and second, microwave sensors that use electromagnetic waves to pick up motion (Figure 3).

Source: [1] Real-Time Detection of Intruders Using an Acoustic Sensor and Internet-of-Things Computing. Sensors (15)

Figure 4. Light sensors

Sometimes referred to as automatic brightness sensors, these gadgets determine the degree of Rename/File/Source natural light. They can be used together with motion sensors in a way that the lights can only also tend to be activated during low light level circumstances (Figure 4).

Source: [18] Implementation of Passive Infrared Sensor in Street Lighting Automation System (3)

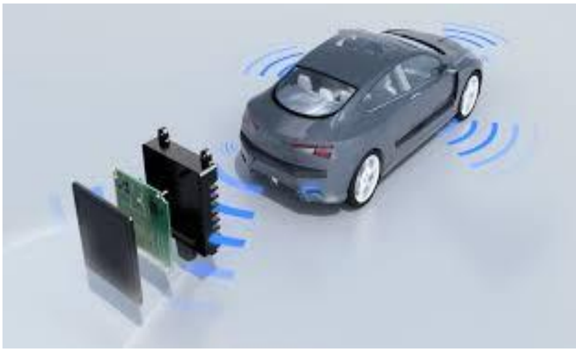

Figure 5. Radar sensors

Radar sensors help to perceive motion across large distances and even through an object in its path. They are efficient in the territories, including one with the changeable climate and can guarantee stable performance for street lighting systems (Figure 5).

Source: Rao & Naresh (2025). Ultrasonic sensor system for autonomous parking (25)

Pros of Using Sensor-Based Street Lighting

Sensor-based street lighting systems offer multiple advantages, starting with enhanced energy efficiency [12]. These systems intelligently adjust lighting based on real-time movement, dimming when no activity is detected, thereby reducing electricity consumption and operational costs significantly—by over 50% in some cases. This leads directly to cost savings, as reduced energy usage lowers electricity bills and extends the lifespan of lighting equipment, minimizing maintenance and replacement expenses [8]. Enhanced safety is another key benefit; motion sensors activate lights only when needed, ensuring well-lit pathways for pedestrians and vehicles, thereby reducing accident risks [3]. Lastly, the environmental benefits are substantial. By cutting energy use, sensor-based lighting systems help decrease greenhouse gas emissions from power generation, thus lowering the urban carbon footprint and contributing to environmental sustainability [9] [33]. These systems offer a smart, cost-effective, and eco-friendly approach to urban infrastructure management, aligning with modern goals of smart city development and climate resilience [28]. Cost-saving and energy saving if a sensor-based lighting system is used in multi-story complex and huge residential complex: a glimpse [10] (Table 3).

Table 3. Electricity consumption & expense comparison: present vs. LED vs. sensor-based system

Units per →	**Day**	**Week**	**Month**	**Quarterly**	**Half-Yearly**	**Yearly**
Present System Units	30.00	207.00	896.00	2,688.00	5,376.00	10,752.00
LED System Units (↓50%)	15.00	103.50	448.00	1,344.00	2,688.00	5,376.00
Sensor-Based System Units (↓30% over LED)	10.50	72.45	313.60	940.80	1,881.60	3,763.20
EB Rate / Unit (₹)	6	6	6	6	6	6
Present System Cost (₹)	180	1,242	5,376	16,128	32,256	64,512
LED System Cost (₹)	90	621	2,688	8,064	16,128	32,256
Sensor-Based System Cost (₹)	63	435	1,882	5,645	11,289	22,579
Savings vs Present (₹)	117	807	3,494	10,483	20,967	41,933

NOTE: Author's interpretation concerning Hyderabad city, restricted to selected residential complexes.

Source: [6]. Energy savings due to occupancy sensors and personal controls: A pilot field study.

CHALLENGES AND CONSIDERATIONS

Initially, sensor-based street lighting necessitates a significant investment. The expenses associated with acquiring motion sensors, connecting them to current lighting systems, and equipping the system with supporting components are included. Long-term energy and maintenance costs are offset by initial expenses [2].

Maintenance and reliability are crucial for these systems, which require regular monitoring and calibration to ensure the accuracy and responsiveness of sensors. Optimal performance can be achieved through the implementation of preventive maintenance schedules, which address potential faults and help avoid unexpected failures. It can be a technical challenge to retrofit existing lighting systems to accommodate sensors.

Careful planning, compatible technology, and efficient implementation are essential to prevent disruptions and ensure the system operates smoothly. Motion sensors may cause privacy concerns among the public. To ensure privacy, systems must be designed to detect presence without collecting and storing personal data.

Dual-technology sensors mix PIR and ultrasonic methods to improve accuracy and cut down on false alarms. These sensors work more by needing both technologies to confirm that a space is occupied at the same time. This setup works well in places where occupancy patterns or the environment changes a lot, which can cause errors with single-technology sensors [7].

The table below, from the work done by Garg & Bansal, shows energy savings. from using Smart Sensor compared to a regular sensor. It highlights how long rooms stayed empty during different times of the day and the energy saved as a result. The third and fourth columns refer to the Time Delay Interval (TDi), which does not change during the day for either sensor. This is different from another. where smart sensors use a TDI that changes based on the time of day. This method could also switch to a time-based TDi by tweaking model settings to fit various times. Research is ongoing to explore how these flexible TDI setups could work (Table 4).

Table 4. Energy savings from using smart sensor compared to a regular sensor (27)

Time	Duration (s)	TDi for smart sensor 2 (s)	TDi for ordinary sensor (s)	Energy saving by smart sensor 2 (kWh/day)	Energy saving by ordinary sensor (kWh/day)
0930	900	93	300	0.054	0.04
1054	480	93	300	0.026	0.012
1117	1020	93	300	0.062	0.048
1310	4080	93	300	0.266	0.252
1501	1140	93	300	0.07	0.056
1649	180	93	300	0.006	0
1723	1020	93	300	0.062	0.048
1830	300	93	300	0.014	0

Source: https://www.sciencedirect.com/science/article/pii/S0378778899000407 (27)

Camera-based sensors rely on visual input to identify if a space is occupied. These sensors can also gather detailed data like how many people are in a room or what they're doing. By adding artificial intelligence and machine learning, these systems gain the ability to study complex trends and make predictions to Adjust building systems [19]. But challenges such as privacy issues, data safety, and higher expenses can make these systems unsuitable in some places. Setting up a good energy management plan starts with tracking energy use from things like heat, electricity, water, and more [19]. It depends on measuring factors that do not change over time, like the materials used in the building, how it faces the sun, and where it is located. It also looks at changing factors like weather patterns, how many people are in the building, and the amounts of energy or water being used (Lavrinovica et al.) (12)

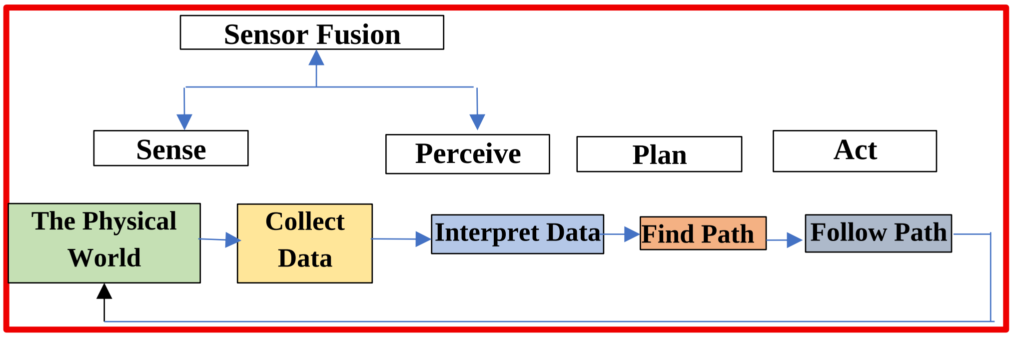

Figure 6. The sensor fusion framework

Source: https://www.mdpi.com/2076-3417/14/21/10057 (16) Case studies with successful implementation

Several cities have successfully implemented sensor-based street lighting systems. Barcelona, Spain, uses smart lights with sensors to adjust brightness based on traffic and pedestrian movement, improving energy efficiency and urban management. Los Angeles, USA, retrofitted streetlights with motion and light sensors, reducing energy use by around 63% [31]. Singapore, as part of its Smart Nation initiative, employs sensor-based lighting to enhance street visibility and optimize energy consumption, showcasing smart, sustainable urban infrastructure (Figure 6).

Plan to Implement in Hyderabad

An essential link between automated controls and physical spaces is usually established by occupancy sensing systems. They use a range of technologies, including passive infrared, ultrasonic, microwave, and AI-enabled vision. sensors to detect human presence or movements, even behaviours. By adjusting the electrical load in accordance with occupancy, these systems can decrease wasted energy and provide precise control over devices that consume a significant amount of power. In systems engineering, Intelligent Building incorporates occupancy sensing as a crucial element. Management Systems.

These systems gather information from sensors and use control algorithms or AI to make decisions, and activate equipment like relays or IoT devices to manage energy usage. All of these things are possible on their own. Lights in empty rooms can be turned off using a relay circuit by PIR sensors, which can detect heat patterns. More sophisticated arrangements combine sensor inputs by merging PIR sensors with ultrasonographic or artificial-intelligence camera sensors. e.g. The mixture boosts detection efficiency and minimizes false positives or negatives. Until a system detects no motion, it must wait for the time period indicated by its Time Delay Interval (TDi) to shut down. Engineers consider this parameter while designing. Users may not respond to the fixed TDI settings used by older systems. Utilizing machine learning-based TDI settings to analyze occupancy patterns over time.

Energy is conserved while maintaining user comfort through context-sensitive management [11]. Predictive maintenance and smart load forecasting are made possible through occupancy analytics, which is used in energy management. The advancement of sensor tuning for low-power circuits and instant data handling are directing strategies away from reacting to issues. These changes are bringing us closer to proactive energy systems that anticipate and adapt to use. With the growing need for smart cities and environmentally friendly buildings, engineering is playing an increasingly important role in energy management. Building efficiency numbers like Energy Use Intensity can be enhanced by controlling energy through occupancy, which also aligns with global green goals such as Net Zero Energy Buildings and LEED certification.

By integrating occupancy sensing frameworks into energy policies and management systems, a robust technical foundation can be established for the expansion of automated and sustainable energy setups. Sensor engineering Smart automation and energy analytics merge with traditional management ideas to create more advanced engineering solutions.

Occupancy sensors are used in energy-saving modern building automation systems to monitor and adjust lighting, HVAC, and other appliances while identifying when people are in the vicinity [16]. These sensors use different technology, each with its own advantages and limitations (Table 5).

Potential benefits of specific strategies can capture a lot of appeal for Hyderabad, for example, the installation of sensor-based street lighting system. It is observable that the city's population is constantly rising, and Energy requirements are also on the rise, such innovations. The implementation process would involve several key steps:

- Feasibility Study: Assess potential benefits, costs, and challenges of implementation. Review existing infrastructure, current energy usage, and area-specific energy needs in Hyderabad.

- Pilot Projects: Launch sensor-based lighting in selected sectors and equipment types. Evaluate system performance, cost-effectiveness, and user feedback to determine suitability.

- Public Engagement: Inform residents and stakeholders about the system's benefits. Address concerns related to privacy and operation through public outreach and feedback mechanisms.

- Scaling Up: Use pilot results to plan city-wide deployment. Develop a phased expansion strategy with resource allocation, budgeting, and implementation timelines.

- Monitoring and Evaluation: Conduct periodic reviews to track system effectiveness and identify areas for improvement. Ensure long-term sustainability and adaptability of the system through continuous evaluation.

Table 5. Suggestions for cost and power saving statistics

System	Initial Investment (₹)	Annual Savings (₹)	3-Year Savings (₹)	5-Year Savings (₹)	10-Year Savings (₹)
LED Lighting	30000	32256	96768	161280	322560
Sensor-Based LED	45000	41933	125799	209665	419330

Source: Author's Own Calculation. (2025). Comparative analysis of LED and sensor-based LED lighting systems: Investment and savings over time.

CONCLUSION

Smart sensor-based street lighting systems offer Hyderabad an effective way to reduce energy consumption and improve public utility efficiency. By using advanced internet-connected sensors, these systems adjust lighting based on street activity, leading to significant energy savings, cost reduction, and environmental benefits. Although challenges exist, such as initial investment and integration with urban infrastructure, the potential advantages for energy management are substantial. As Hyderabad grows into a global city, adopting sensor-based lighting can provide sustainable urban infrastructure, set a model for smart city planning, encourage public engagement, and attract further investments in advanced energy solutions for the future.

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