

# Smart Power Consumption Monitoring Using IoT: A Review of Design Approaches and Implementation Techniques

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**Abstract:** *The limitations of conventional energy meters—missing remote access, accurate billing, and real-time tracking—have been highlighted by the increasing need for efficient energy management. Smart energy meters based on IoT present a modern answer by enabling data storage, remote management, and continuous monitoring of power consumption, enhancing efficiency for both utility firms and consumers. To quantify electricity consumption in real time and transmit the information to a cloud platform for oversight and examination, this initiative proposes the creation and deployment of a smart energy meter equipped with Internet of Things (IoT) technology. The system includes an LCD display, current and voltage sensors, and a microprocessor (ESP8266/ESP32) for local monitoring. A mobile or web application can remotely access energy consumption data through Internet of Things technologies. To enhance energy management, additional features comprise analysis of past usage and notifications for atypical energy consumption.*

*The main objective of this project is to deliver a cost-effective, reliable, and intuitive platform that highlights the integration of cloud analytics, embedded systems, and Internet of Things connectivity. Potential applications for the technology might involve combining it with renewable energy sources, intelligent grid systems, and AI-driven energy management predictions.*

**Keywords:** IoT, Intelligent Energy Meter, Live Tracking, Embedded Systems, Energy Control

## I. INTRODUCTION

The explosive growth of the Internet of Things (IoT) has entirely reshaped how devices communicate, oversee, and control resources. Energy management ranks among the most crucial IoT applications since intelligent systems are essential for efficiently tracking, controlling, and enhancing energy usage. Energy loss, inaccurate billing, and insufficient realtime tracking are several problems that customers and utility companies face due to the increasing demand for electricity and its climbing expenses.

Traditional energy meters do not permit remote monitoring or real-time assessments; they only track total consumption and require manual readings. Users struggle to track their daily energy usage and identify abnormal patterns because of this. IoT-enabled smart energy meters offer an effective remedy by combining embedded technologies with wireless communication, facilitating ongoing monitoring, automated billing, and swift alerts.

To evaluate energy usage, the proposed system employs an ESP8266/ESP32 microprocessor combined with voltage and current sensors. The data is concurrently uploaded to a cloud service and displayed locally on an LCD, allowing customers to access it through a web app or mobile device. The system also enables notifications in the event of unusual usage, guaranteeing improved energy efficiency and savings.

Two key aspects of this project are remote access through IoT platforms and instantaneous energy tracking. The system is economical, easy to install, and scalable for larger applications. It can be utilized in workplaces, schools, and



organizations as well as in residences. In the future, the platform may be expanded to include artificial intelligence for forecasting energy management, intelligent grids, and renewable energy sources.

Along with tackling the limitations of conventional meters, this smart energy meter provides a modern, user-friendly approach to sustainable energy management by integrating embedded technology with the Internet of Things.

## II. LITERATURE SURVEY

Recent studies in the field of Internet of Things energy monitoring have highlighted the importance of remote access, energy efficiency, and real-time data gathering. Sharma and Lee [2] (2024) implemented a smart metering system utilizing multi-sensor fusion to track voltage and current parameters, enhancing precision in dynamic load situations. Chen [3] (2023) proposed an Internet of Things-driven energy management system utilizing ESP32 and cloud platforms that enables real-time monitoring and mobile app access.

Kumar et al. [4] (2023) developed a smart energy meter featuring Wi-Fi connectivity to facilitate remote monitoring of usage and to issue alerts for high power consumption. Focusing on cloud storage and user-friendly dashboards, Garcia and Martinez [5] (2023) examined how Raspberry Pi integrates with IoT for home energy analysis.

Singh and Agarwal [7] (2022) developed an affordable power monitoring system based on the Internet of Things using Arduino and sensors, demonstrating effective performance in small houses. Tanaka et al. [8] developed an IoT-enabled smart plug in 2022, allowing for remote control of loads and monitoring of energy use at the appliance level. To enable load balancing and data-informed decision-making, Fernandez [9] (2021) proposed an industrial energy management system utilizing cloud services and IoT.

Ibrahim et al. [10] (2021) focused on creating a meter equipped with GSM and Internet of Things capabilities for rural use, ensuring access in areas with limited connectivity. Nguyen [11] (2020) analyzed the performance of Bluetooth, Zigbee, and Wi-Fi as wireless communication protocols in Internet of Things energy systems and determined that Wi-Fi was the most reliable for continuous monitoring. Despite their restricted scalability, Okafor and Eze [12] (2020) explored DTMF- and GSM-based alternatives for IoT smart meters

**Table 1: Comparative Review of Smart Power Consumption Meter**

| Paper / Project       | System Architecture                      | Cost                   | Ease of Implementation               | Performance                            | User Experience              | Limitations                       |
|-----------------------|------------------------------------------|------------------------|--------------------------------------|----------------------------------------|------------------------------|-----------------------------------|
| Sharma and Lee [2]    | IoT Smart Meter with Multi-sensor Fusion | Moderate (~₹5,500)     | Moderate (Sensor calibration needed) | Accurate in dynamic load monitoring    | Reliable data feedback       | Requires complex sensor tuning    |
| Chen [3]              | ESP32 + Mobile App Integration           | Low-Moderate (~₹4,500) | Easy- Moderate (Appbased control)    | Real-time monitoring via app           | Convenient for households    | Limited to app connectivity       |
| Kumar et al. [4]      | Wi-Fi Enabled Smart Meter with Alerts    | High (₹10,000+)        | Complex (Advanced coding + cloud)    | Efficient, with overuse notification   | Useful for urban smart homes | High cost, power dependency       |
| Garcia & Martinez [5] | Raspberry Pi + IoT Dashboard             | High (₹9,000+)         | Moderate - Complex (Dashboard setup) | Detailed analytics and cloud storage   | Good visualization for users | More expensive hardware           |
| Tanaka et al. [8]     | IoT Smart Plug for Appliances            | Low (~₹2,500)          | Easy                                 | Appliance level control and monitoring | User-friendly, compact       | Works only for individual devices |



|            |                                     |                    |                               |                                           |                         |                                    |
|------------|-------------------------------------|--------------------|-------------------------------|-------------------------------------------|-------------------------|------------------------------------|
| Zhang [13] | Dual-Mode Smart Meter (Local + IoT) | Moderate (~₹5,000) | Moderate (Wi-Fi setup needed) | Flexible with both offline and online use | Reliable dualmode usage | Wi-Fi dependency, added complexity |
|------------|-------------------------------------|--------------------|-------------------------------|-------------------------------------------|-------------------------|------------------------------------|

### III. PROPOSED METHODOLOGY

The creation of the Smart Energy Meter includes combining hardware, communication components, and software to establish a precise and immediate energy tracking system. The primary goal of this project is to accurately measure electrical energy usage, show the readings locally, and send data wirelessly for analysis and remote monitoring. The system is built to be intuitive, effective, and adaptable for future improvements.

The NodeMCU microcontroller serves as the central processing unit at the core of the system. It gathers information from the PZEM-004T energy meter module, which assesses voltage, current, power, and total energy usage. The NodeMCU captures these readings through a serial interface, processes the information, and manages both the local display and the communication modules. The 16x2 or 20x4 LCD offers users immediate feedback on voltage, current, power, and total energy used, allowing for quick visualization of energy consumption.

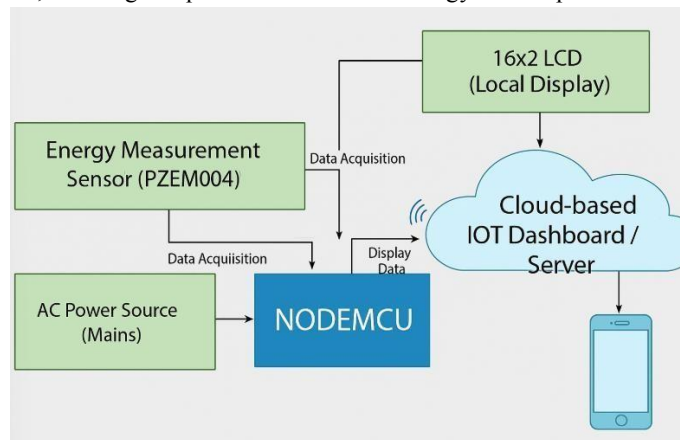


Fig:-IoT-Enabled Smart Power Consumption Meter

To improve usability and safety, the system may include a buzzer or LED lights that notify users when energy usage surpasses set thresholds or when an issue arises in the electrical supply. For wireless oversight, the NodeMCU utilizes its integrated WiFi feature to send energy information to a mobile app or cloud server. This enables users to track energy usage from a distance in real-time, get alerts, and view past consumption records.

The mobile app, created with tools such as MIT App Inventor or various Android IDEs, offers an easy-to-use interface for users to monitor energy metrics, view trends, and optionally manage connected devices remotely. The NodeMCU firmware, developed in Arduino C/C++ with the Arduino IDE, utilizes a systematic framework to manage routine functioning, notifications, and data communication effectively.

The system is flexible and extremely expandable. It can be enhanced to track several circuits or devices separately, combined with cloud-based interfaces for sophisticated analytics, or expanded with automated control functions for energy efficiency. The integration of NodeMCU, PZEM-004T, and LCD provides a compact, affordable, and flexible solution ideal for energy monitoring in residential, commercial, or industrial settings.

### IV. CONCLUSION

The Smart Energy Meter project utilizing IoT technology showcases how contemporary advancements enhance energy monitoring and management. Through the integration of IoT features, the system facilitates real-time monitoring of electricity usage, empowering users to make knowledgeable choices and minimize waste.



The meter offers precise measurements and immediate data access via an easy-to-use interface, ensuring its applicability for residential and commercial uses. The remote monitoring capability offers convenience, and automated notifications along with usage statistics aid in enhancing energy efficiency.

In conclusion, this initiative provides a cost-effective, feasible, and expandable approach to intelligent energy management. Its modular structure facilitates future improvements, including the incorporation of advanced analytics, predictive billing, or compatibility with renewable energy sources, rendering it extremely pertinent in today's energy-aware environment.

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