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A Review of AI Based Energy Consumptions Predictor

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Abstract— Building energy use prediction plays an important role in building energy management and conservation as it can help us to evaluate building energy efficiency, conduct building commissioning, and detect and diagnose building system faults. Building energy prediction can be broadly classified into engineering, Artificial Intelligence (AI) based, and hybrid approaches. While engineering and hybrid approaches use thermodynamic equations to estimate energy use, the AI-based approach uses historical data to predict future energy use under constraints. Owing to the ease of use and adaptability to seek optimal solutions in a rapid manner, the AI-based approach has gained popularity in recent years. For this reason and to discuss recent developments in the AI-based approaches for building energy use prediction, this paper conducts an in-depth review of single AI-based methods such as multiple linear regression, artificial neural networks, and support vector regression, and ensemble prediction method that, by combining multiple single AI-based prediction models improves the prediction accuracy manifold. This paper elaborates the principles, applications, advantages and limitations of these AI-based prediction methods and concludes with a discussion on the future directions of the research on AI-based methods for building energy use prediction.

Keywords—Artificial Intelligence, Machine Learning, Energy Consumption Prediction, Smart Grid, Time Series Forecasting, IoT, Renewable Energy, LSTM, Data Analytics, Energy Efficiency

I. Introduction

Energy consumption prediction has become an important requirement for modern homes, industries, and smart cities. As electricity usage continues to increase, it has become essential to understand how power is consumed and how future consumption can be predicted. Accurate forecasting helps reduce wastage, lower operational costs, manage peak load, and support sustainable energy planning. Traditional forecasting methods are often unable to handle the complex and changing nature of today's energy usage patterns, especially with the rise of renewable energy sources and digital devices.

Artificial Intelligence (AI) and Machine Learning (ML) have emerged as effective tools for improving the accuracy of energy forecasting. These techniques are capable of finding patterns in large datasets and learning from historical behavior. Models such as Linear Regression, Random Forest, and Long Short-Term Memory (LSTM) networks are widely used because they can consider factors like time, weather, seasonal changes, and user activity. LSTM, in particular, is very effective for time-series prediction and helps capture long-term usage trends.

With the increasing use of smart meters and IoT devices, real-time energy data has become more accessible. This allows AI-based systems to make more accurate predictions and provide insights into how energy is being consumed. The project "AI-Power Based Energy Consumption Predictor" uses multiple AI techniques to forecast future energy demand and includes a visual dashboard to help users make better decisions. Integrating contextual data and AI models can significantly improve energy efficiency and support smarter and more sustainable power usage. Overall, AI-driven energy prediction plays a key role in building intelligent and efficient energy systems.

II. Literature Review

Energy consumption prediction has been studied widely as modern energy systems have become more complex and data-driven. Early research used statistical models like Linear Regression and ARIMA, which performed well for simple and stable patterns but failed to capture nonlinear behavior and sudden fluctuations. Machine Learning methods such as Random Forest, SVR, and Gradient Boosting provided better accuracy by handling multiple features like weather, time, and appliance usage, though they still struggled with long-term dependencies. With the rise of IoT and smart meters, Deep Learning models—especially LSTM—became popular due to their ability to learn sequence patterns in time-series data. Hybrid models like CNN-LSTM achieved even higher accuracy by combining feature extraction and temporal forecasting. Overall, literature clearly shows that AI-based approaches outperform traditional methods and offer more reliable energy prediction.

III. Methodology

The methodology adopted for this review focuses on collecting, analyzing, and comparing existing research related to AI-based energy consumption prediction. To ensure accuracy and relevance, research papers were selected from trusted databases such as IEEE Xplore, ScienceDirect, Springer, and Google Scholar. The search keywords used included "energy consumption prediction," "machine learning energy forecasting," "LSTM energy prediction," and "smart grid AI models." Studies published between 2015 and 2024 were considered to capture both classical and modern approaches.

Each selected paper was examined based on the prediction techniques used, the type of dataset, the influence of contextual factors, and the reported accuracy. Machine Learning and Deep Learning methods such as Linear Regression, Random Forest, SVR, LSTM, and CNN-LSTM models were reviewed. The comparison focused on understanding the strengths, limitations, and application scenarios of each approach. Insights from multiple studies were then combined to identify common trends, performance gaps, and future research opportunities. This structured methodology ensures that the review provides a balanced and comprehensive understanding of current AI-based energy prediction techniques.

IV. Overview for AI Based Energy Consumptions Predictor

The AI-Based Energy Consumption Predictor is a smart system designed to forecast how much electricity will be used in the future by analyzing past usage patterns and other influencing factors. Modern homes, industries, and smart cities generate a large amount of energy-related data through meters, sensors, and IoT devices. This project uses Artificial Intelligence (AI) and Machine Learning (ML) techniques to study this data and predict energy demand more accurately than traditional methods.

The system considers multiple factors such as time of day, temperature, weather conditions, appliance usage, and user behavior to understand how consumption changes over time. Models like Linear Regression, Random Forest, and especially LSTM neural networks help recognize hidden patterns and trends in the data. These predictions assist users and energy providers in managing electricity more efficiently, reducing unnecessary wastage, and planning for peak load situations.

The project also includes a simple visualization dashboard where users can view both real-time consumption and future predictions. This makes it easier to monitor usage and make informed decisions. In the future, the system can be connected to IoT-based smart meters for real-time forecasting, automatic device control, and integration with renewable energy sources. Overall, this AI-powered solution supports smarter, more sustainable, and more efficient energy management.

V. Case Studies and Implementations

Several real-world studies and implementations demonstrate how AI-based energy prediction systems are being used across homes, industries, and smart cities to improve efficiency and reduce energy wastage. These applications show that AI models can work effectively with smart meters, IoT devices, and renewable energy sources to provide accurate and actionable forecasts.

Key Case Studies and Implementations:

- Smart Homes:
  LSTM-based models were applied to smart-meter data to predict hourly electricity usage. This helped users schedule appliances better and reduce unnecessary energy consumption.
- Industrial Load Forecasting:
  Random Forest and Gradient Boosting models were used in factories to forecast machine-level energy demand, allowing companies to plan operations and lower peak load costs.
- IoT-Enabled Energy Monitoring:
  Buildings with IoT sensors connected real-time energy data to cloud-based AI models. These systems automatically optimized lighting, HVAC, and other devices based on predicted demand.
- Smart Grid Management:
  Countries like Singapore and Germany implemented AI forecasting systems to balance renewable energy generation (solar, wind) with consumer demand, improving grid stability.
- University Campus Energy Systems:
  ML-based predictors were used in large campuses to forecast daily electricity needs, helping optimize generator usage and reduce operational expenses.
- Commercial Buildings:
  Hybrid CNN-LSTM models were tested in malls and office buildings to identify usage patterns and manage peak hours effectively.

VI. Enhancements and Innovations in AI Based Energy Consumptions Predictor

Several enhancements and innovative features have been incorporated into our AI-Based Energy Consumption Predictor to improve forecasting accuracy, user experience, and real-time energy management. These additions make the system more practical, intelligent, and adaptable to real-world usage patterns.

Key Enhancements and Innovations

1. Multi-Model Prediction Approach
   The system compares Linear Regression, Random Forest, and LSTM models to select the best-performing algorithm for different datasets, improving overall accuracy.
2. Context-Aware Forecasting
   Weather conditions, time of day, seasonal trends, and user activity patterns are integrated to provide more realistic and reliable predictions.
3. Real-Time Data Handling
   Support for live smart-meter or IoT inputs allows the model to update predictions dynamically based on current consumption behavior.
4. Interactive Visualization Dashboard
   A user-friendly dashboard displays real-time usage, future forecasts, and comparison graphs, helping users make informed decisions.
5. Scalable Architecture
   The system is designed to work for homes, industries, commercial buildings, and large campuses without major modifications.
6. Future Automation Capability
   The model can be extended to automatically turn

devices ON/OFF based on predicted demand, reducing wastage and improving efficiency.

7. Renewable Energy Integration
The system is capable of incorporating solar or wind generation data, making it suitable for smart and sustainable energy systems.

8. Edge Computing Compatibility
Future versions can run predictions directly on local devices for faster processing and reduced cloud dependency.

VII. Challenges and Limitations

AI-based energy consumption prediction offers strong advantages, but several challenges and limitations still affect the accuracy, reliability, and real-time use of such systems. These factors need to be addressed for building fully smart and automated energy solutions.

Key Challenges and Limitations

- Data Quality and Availability
Many buildings or households do not have continuous, clean, or labeled energy data, which reduces model accuracy.
- High Dependence on External Factors
Weather, occupancy, and appliance usage significantly impact consumption, and missing contextual data leads to weak predictions.
- Complexity of Deep Learning Models
Models like LSTM require large datasets and high computational power, which may not be suitable for small devices or low-budget systems.
- Real-Time Processing Issues
Live prediction from IoT sensors can face latency, network issues, or delays in data transmission.
- Generalization Problems
A model trained on one building's data may not perform well on another due to different usage behaviors.
- Renewable Energy Variability
Solar and wind generation are highly unstable, making it hard to align predictions with supply.
- Privacy and Security Concerns
Smart-meter data reveals user activity patterns, raising safety and privacy risks if not protected properly.

IX. Conclusion

AI-based energy consumption prediction plays a major role in improving how homes, industries, and cities manage electricity. The studies reviewed show that traditional forecasting methods are limited in handling modern, dynamic consumption patterns. Machine Learning and Deep Learning techniques, especially LSTM and hybrid models, provide more accurate and reliable predictions by understanding time-based patterns and contextual factors. With the rise of IoT devices and smart meters, real-time data has made AI forecasting even more practical and powerful.Our project, AI-Based Energy Consumption Predictor, contributes to this field by combining multiple AI models, contextual data, and a user-friendly dashboard to support smarter decision-making. Although challenges such as data quality, renewable variability, and real-time processing remain, AI-driven prediction systems hold great potential for building efficient, sustainable, and intelligent energy infrastructures.

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