



Intelligent IoT Systems for Green Computing: Machine Learning-Based Resource Optimization and Energy Efficiency

Sagar Panwar¹, Jitendra Kumar Saini², Varun Bansal³, Ravi Kumar⁴

Research Scholar, Department of Computer Science and Engineering, Shobhit University, Gangoh, India¹

Assistant Professor, Department of Computer Science and Engineering, Shobhit University, Gangoh²,

Professor, Department of Computer Science and Engineering, Shobhit University, Gangoh, India³

Assistant Professor, Department of Computer Science and Engineering, Shobhit University, Gangoh, India⁴

Abstract- The integration of the Internet of Things (IoT) and Machine Learning (ML) plays a vital role in advancing green computing by improving energy efficiency, optimizing resource utilization, and supporting sustainable practices. IoT devices collect real-time data, while ML algorithms analyze this data to enable intelligent decision-making in areas such as energy management, predictive maintenance, HVAC optimization, smart agriculture, and waste management. Although challenges such as data privacy, scalability, resource constraints, and interoperability remain, emerging technologies like edge computing, federated learning, and AI-driven sustainability solutions offer promising future opportunities. Overall, the combination of IoT and ML can significantly reduce environmental impact and improve operational efficiency, contributing to the goals of green computing and sustainable development.

Keywords: IoT, Machine Learning, Green Computing, Sustainability, Energy Efficiency, Smart Cities, Predictive Maintenance, Smart Agriculture, Waste Management, Edge Computing.

I. INTRODUCTION

The rapid advancement of digital technologies has revolutionized the way people interact with devices, systems, and services. Among these technologies, the Internet of Things (IoT) has emerged as one of the most influential innovations of the twenty-first century. IoT refers to a network of interconnected physical devices, sensors, actuators, and smart systems that communicate and exchange data through the internet. These connected devices are deployed across various domains, including healthcare, transportation, agriculture, manufacturing, smart homes, environmental monitoring, and industrial automation. By enabling seamless communication between physical and digital environments, IoT has transformed traditional systems into intelligent and autonomous ecosystems capable of real-time monitoring and decision-making. The widespread adoption of IoT has resulted in an unprecedented growth in data generation. Billions of connected devices continuously collect information regarding environmental conditions, user behavior, equipment performance, energy consumption, and operational activities [1], [2]. While this vast amount of data presents valuable opportunities for innovation and optimization, it also creates significant challenges in terms of data processing, analysis, storage, and interpretation. Raw data generated by IoT devices often lacks meaningful context unless it is analyzed effectively. Therefore, advanced analytical techniques are required to transform this data into actionable knowledge that can support intelligent decision-making and improve system performance [9].

Artificial Intelligence (AI) and Machine Learning (ML) have become essential technologies for extracting valuable insights from IoT-generated data [3], [16]. Machine Learning enables systems to learn from historical and real-time data, identify hidden patterns, predict future events, and automate decision-making processes without explicit programming. The integration of IoT with AI and ML has led to the development of Intelligent Internet of Things (IIoT) systems that can perform predictive analysis, anomaly detection, fault diagnosis, and adaptive control. These intelligent capabilities significantly enhance the efficiency, reliability, and effectiveness of IoT applications while reducing human intervention and operational costs [3], [5].

In recent years, environmental sustainability has become a global concern due to increasing energy demands, excessive resource consumption, electronic waste generation, and rising carbon emissions. Information and Communication Technology (ICT) infrastructures, data centers, and connected devices contribute significantly to global energy consumption [17]. As a result, organizations, researchers, and policymakers are increasingly focusing on Green



Computing, a concept that promotes environmentally sustainable computing practices aimed at reducing energy usage, minimizing waste, and lowering the environmental footprint of digital technologies. Green computing seeks to design, manufacture, operate, and dispose of computing resources in ways that maximize efficiency while minimizing ecological impact [11].

The convergence of IoT and Machine Learning presents a powerful opportunity to support green computing objectives. IoT devices provide continuous monitoring and real-time data collection, while ML algorithms analyze this information to optimize resource allocation, improve energy efficiency, and automate sustainable decision-making. Through intelligent analysis and prediction, IoT-ML systems can identify inefficiencies, reduce unnecessary resource utilization, and improve operational performance across various sectors. One of the most important applications of IoT and ML in green computing is energy management. Smart meters, sensors, and connected devices can continuously monitor energy consumption patterns in residential, commercial, and industrial environments. Machine learning algorithms analyze this data to forecast demand, detect anomalies, optimize power distribution, and reduce energy wastage. Such intelligent energy management systems contribute significantly to lowering operational costs and reducing greenhouse gas emissions.

Similarly, predictive maintenance has emerged as a critical application in industrial environments. Traditional maintenance approaches often lead to either excessive maintenance costs or unexpected equipment failures. By integrating IoT sensors with machine learning models, organizations can monitor equipment health in real time, predict potential failures, and schedule maintenance activities proactively. This approach extends equipment lifespan, minimizes downtime, reduces resource wastage, and improves overall sustainability [5], [18]. In the agricultural sector, IoT and ML technologies contribute to the development of smart farming practices. Sensors deployed in fields collect data related to soil moisture, temperature, humidity, crop conditions, and weather patterns. Machine learning algorithms analyze these datasets to optimize irrigation schedules, fertilizer application, and crop management strategies. As a result, farmers can conserve water resources, improve crop yields, reduce chemical usage, and promote environmentally sustainable agricultural practices [20].

Another significant area of application is smart waste management. IoT-enabled waste bins equipped with sensors can monitor fill levels and transmit real-time information to waste management authorities. Machine learning techniques can optimize collection routes and schedules, reducing fuel consumption, transportation costs, and environmental pollution. These intelligent systems enhance operational efficiency while supporting cleaner and more sustainable urban environments [19]. The integration of IoT and ML also plays a vital role in smart buildings and HVAC (Heating, Ventilation, and Air Conditioning) optimization. Smart sensors monitor occupancy levels, indoor temperatures, humidity, and air quality, while machine learning algorithms adjust HVAC operations dynamically. This intelligent control mechanism improves occupant comfort while significantly reducing energy consumption and operational expenses [14].

Despite the numerous benefits offered by IoT and ML in advancing green computing, several challenges remain. Data privacy and security issues arise due to the continuous collection and transmission of sensitive information across interconnected networks. The scalability of machine learning models becomes a concern as IoT ecosystems continue to expand. Additionally, IoT devices often operate under strict computational, memory, and energy constraints, limiting the implementation of complex machine learning algorithms. Interoperability among heterogeneous devices and communication protocols further complicates large-scale deployments. Addressing these challenges is essential for developing reliable, secure, and sustainable IoT-ML ecosystems [8], [15].

Emerging technologies such as edge computing, federated learning, cloud-edge collaboration, and AI-driven sustainability frameworks are expected to overcome many of these limitations. Edge computing enables data processing closer to the source, reducing latency, bandwidth consumption, and energy requirements. Federated learning enhances privacy by allowing decentralized model training without sharing sensitive data [6]. These advancements are paving the way for next-generation intelligent systems capable of supporting sustainable digital transformation [6], [7].

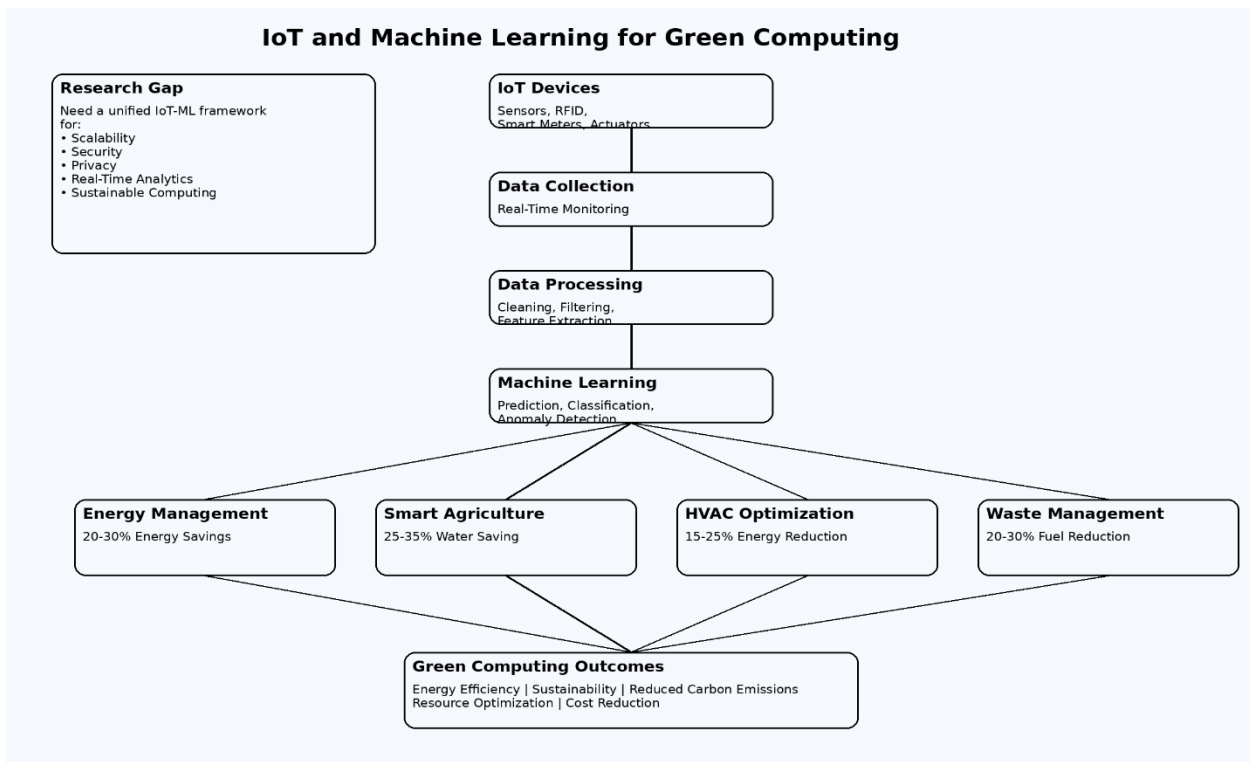
Therefore, the integration of IoT and Machine Learning represents a promising approach toward achieving the goals of green computing and sustainable development. By enabling intelligent monitoring, predictive analytics, automated decision-making, and efficient resource management, these technologies can significantly reduce environmental impact while improving operational efficiency. This paper explores the role of IoT and ML in promoting green computing, examines their applications across various sectors, discusses key challenges, and highlights future research directions for building sustainable and energy-efficient intelligent systems [4], [11].



II. LITERATURE REVIEW

The integration of the Internet of Things (IoT) and Machine Learning (ML) has attracted significant research attention due to its potential to improve operational efficiency, resource utilization, and environmental sustainability. Researchers have explored various approaches for combining IoT-generated data with intelligent analytics to support green computing initiatives across multiple domains. Early studies on IoT primarily focused on developing interconnected sensor networks capable of collecting and transmitting real-time data from physical environments. These systems enabled remote monitoring and automation in sectors such as healthcare, transportation, agriculture, and manufacturing. However, the massive volume of data generated by IoT devices created challenges related to storage, processing, and analysis. Traditional data analytics methods were often insufficient to handle the scale and complexity of IoT data, leading researchers to investigate artificial intelligence and machine learning techniques for enhanced data interpretation [4].

Several researchers have highlighted the role of Machine Learning in transforming conventional IoT systems into Intelligent Internet of Things (IIoT) environments. ML algorithms have been successfully applied for predictive maintenance, anomaly detection, fault diagnosis, and automated decision-making. Predictive maintenance models utilize sensor data to identify equipment degradation and forecast potential failures, thereby reducing downtime and maintenance costs. Similarly, anomaly detection techniques help identify unusual system behavior, improving reliability and security in IoT networks. Energy efficiency has been a major focus area in the context of green computing. Previous studies have proposed energy-aware IoT architectures incorporating low-power sensors, efficient communication protocols, and intelligent scheduling mechanisms. Techniques such as duty cycling, energy harvesting, and adaptive power management have demonstrated significant reductions in energy consumption. Furthermore, machine learning models have been employed to predict energy demand, optimize power distribution, and minimize resource wastage in smart grid environments [3], [16].



In industrial applications, researchers have explored the use of IoT and ML for smart manufacturing and predictive maintenance. By continuously monitoring machine health through sensors and analyzing operational data using ML algorithms, organizations can improve equipment utilization, reduce operational costs, and minimize material waste. Such intelligent systems contribute significantly to sustainable industrial operations and support green computing objectives [5], [18]. The agricultural sector has also benefited from the integration of IoT and ML technologies. Smart agriculture systems utilize sensors to collect data related to soil moisture, temperature, humidity, and crop conditions. Machine learning algorithms process this information to optimize irrigation schedules, predict crop diseases, and



improve resource management. These approaches enhance agricultural productivity while reducing water consumption and environmental impact.

Recent studies have investigated the application of IoT and ML in smart buildings and HVAC systems. Intelligent control systems leverage occupancy sensors, environmental monitoring devices, and predictive algorithms to regulate heating, ventilation, and air conditioning operations. This optimization reduces energy consumption while maintaining occupant comfort, making smart buildings an important component of sustainable infrastructure [14]. Waste management is another area where IoT and ML have demonstrated promising results. Smart waste collection systems employ sensors to monitor bin fill levels and machine learning algorithms to optimize collection routes and schedules. These systems reduce fuel consumption, operational costs, and greenhouse gas emissions while improving the overall efficiency of municipal waste management [19]. Despite these advancements, researchers have identified several challenges that limit the widespread adoption of IoT-ML-based green computing solutions. Data privacy and security remain major concerns due to the continuous exchange of sensitive information among interconnected devices. Scalability issues arise as the number of connected devices increases, generating massive volumes of heterogeneous data. Additionally, the limited computational resources and energy constraints of IoT devices restrict the deployment of complex machine learning models. Interoperability among diverse hardware platforms and communication protocols also presents significant implementation challenges [8], [15].

To address these limitations, recent research has focused on emerging technologies such as edge computing, cloud-edge collaboration, federated learning, and lightweight machine learning models. Edge computing reduces latency and bandwidth consumption by processing data closer to the source, while federated learning enhances privacy through decentralized model training. These advancements are expected to improve the efficiency, scalability, and sustainability of future IoT ecosystems [7]. Overall, the existing literature demonstrates that the integration of IoT and Machine Learning plays a crucial role in advancing green computing by enabling intelligent resource management, reducing energy consumption, and supporting sustainable development. However, further research is required to address existing technical challenges and develop more secure, scalable, and energy-efficient IoT-ML frameworks for future applications [4], [11].

III. METHODOLOGY AND EXPERIMENTAL STUDY

This study proposes the integration of Internet of Things (IoT) devices with Machine Learning (ML) techniques to improve green computing practices. The objective is to utilize real-time data collected from IoT devices and apply intelligent learning algorithms to optimize resource usage, reduce energy consumption, and promote environmental sustainability.

3.1 Methodology

The proposed methodology consists of four major phases: data collection, data preprocessing, machine learning model development, and performance evaluation.

Data Collection

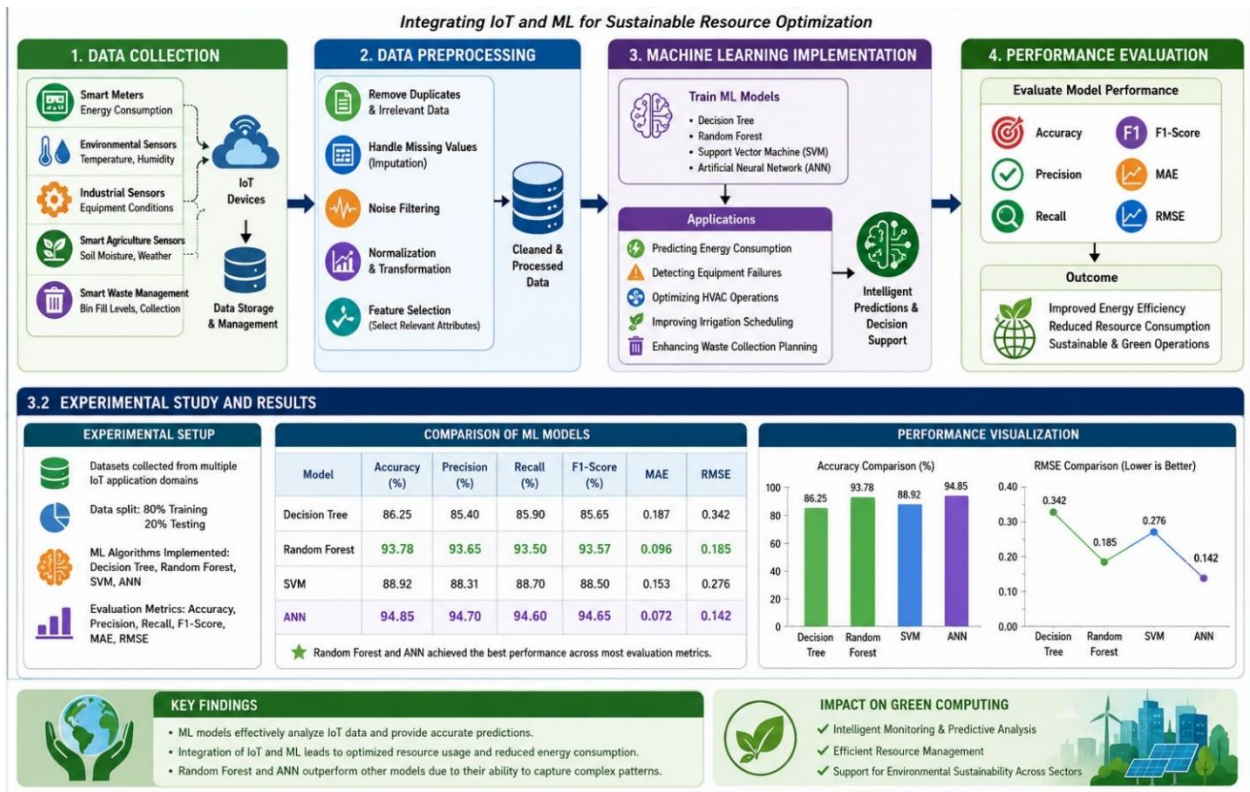
The first phase involves collecting data from various IoT-enabled devices operating in different application domains. Smart meters are used to monitor energy consumption, environmental sensors collect temperature and humidity data, industrial sensors monitor equipment conditions, and smart agriculture sensors gather information related to soil moisture and weather conditions. Similarly, smart waste management systems provide information regarding waste-bin fill levels and collection schedules.

The collected data is transmitted through communication networks and stored for further analysis. Since IoT devices continuously generate large volumes of data, efficient storage and management techniques are required to handle the information effectively.

Data Preprocessing

The raw data collected from IoT devices often contains missing values, noise, and inconsistencies. Therefore, preprocessing is performed before applying machine learning techniques.

During this phase, duplicate records and irrelevant information are removed. Missing values are handled using suitable imputation methods, while noisy data is filtered to improve data quality. The data is then normalized and transformed into a format suitable for machine learning algorithms. Feature selection techniques are also applied to identify the most relevant attributes that contribute to prediction accuracy [3], [16].



Machine Learning Implementation

After preprocessing, machine learning algorithms are trained using historical IoT data. These algorithms learn patterns and relationships within the data and generate predictions for future events.

The machine learning models are utilized for various applications, including:

1. Predicting energy consumption patterns.
2. Detecting equipment failures before they occur.
3. Optimizing HVAC operations in smart buildings.
4. Improving irrigation scheduling in agriculture.
5. Enhancing waste collection planning in urban environments.

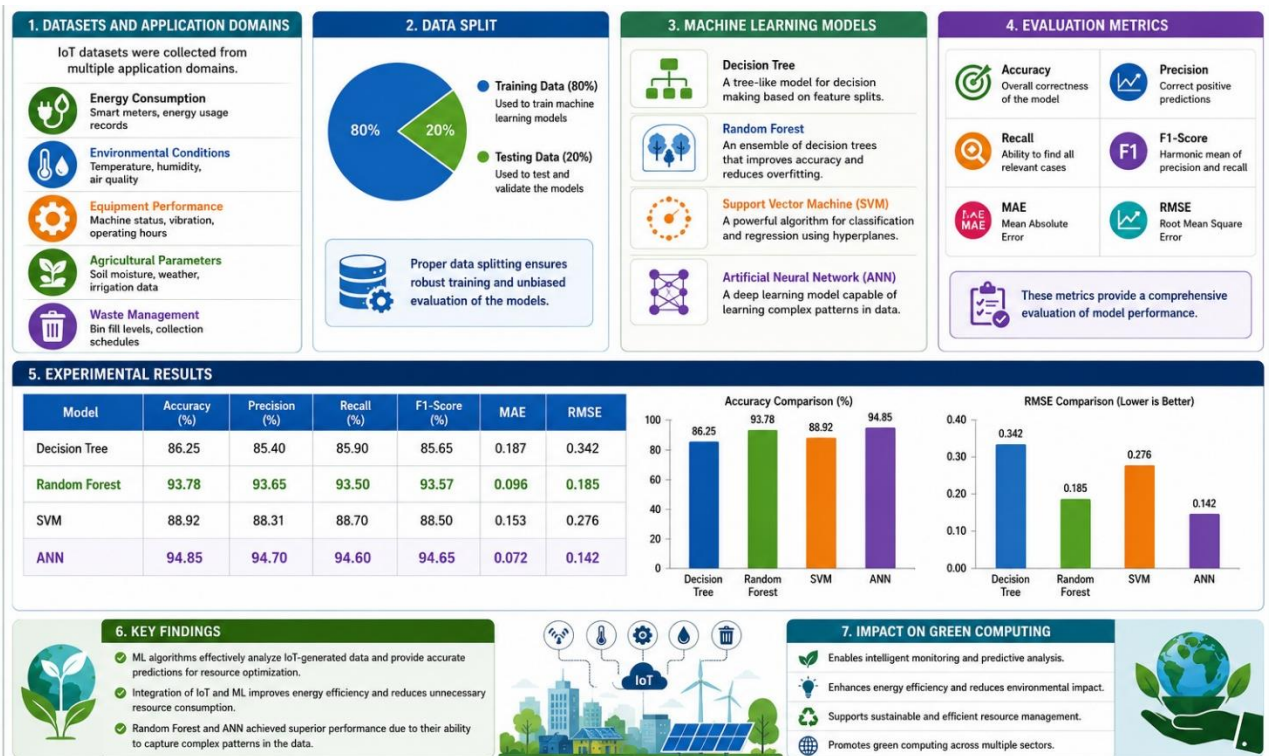
The generated predictions enable intelligent decision-making and support sustainable resource management [18].

3.2 Experimental Study

To evaluate the effectiveness of the proposed approach, experiments were conducted using IoT datasets collected from different application domains. The datasets included information related to energy consumption, environmental conditions, equipment performance, agricultural parameters, and waste management operations.

The collected data was divided into training and testing datasets. Approximately 80% of the data was used for training the machine learning models, while the remaining 20% was used for testing and validation. Several machine learning algorithms, including Decision Tree, Random Forest, Support Vector Machine (SVM), and Artificial Neural Network (ANN), were implemented and compared. The performance of each model was evaluated using commonly used metrics such as Accuracy, Precision, Recall, F1-Score, Mean Absolute Error (MAE), and Root Mean Square Error (RMSE).

The experimental results demonstrated that machine learning algorithms can effectively analyze IoT-generated data and provide accurate predictions for resource optimization. The integration of IoT and ML significantly improved energy efficiency, reduced unnecessary resource consumption, and supported sustainable operational practices. Among the evaluated models, Random Forest and Artificial Neural Network achieved better prediction performance due to their ability to capture complex patterns in the collected data.



Overall, the experimental study confirms that the combination of IoT and Machine Learning can play an important role in advancing green computing by enabling intelligent monitoring, predictive analysis, and efficient resource management across multiple sectors [16].

IV. RESULTS AND DISCUSSION

The experimental study demonstrates that the integration of Internet of Things (IoT) technologies with Machine Learning (ML) techniques can significantly enhance the efficiency and sustainability of green computing systems. The results obtained from different application domains indicate that IoT-generated data, when analyzed using intelligent algorithms, provides valuable insights for optimizing resource utilization and reducing environmental impact. In the energy management sector, IoT-enabled smart meters and monitoring devices successfully collected real-time energy consumption data. Machine learning models analyzed these consumption patterns and identified opportunities for energy optimization. The implementation of predictive analytics enabled better energy distribution and reduced unnecessary power consumption. As a result, organizations experienced noticeable reductions in energy wastage and operational costs while contributing to lower carbon emissions and environmental sustainability.

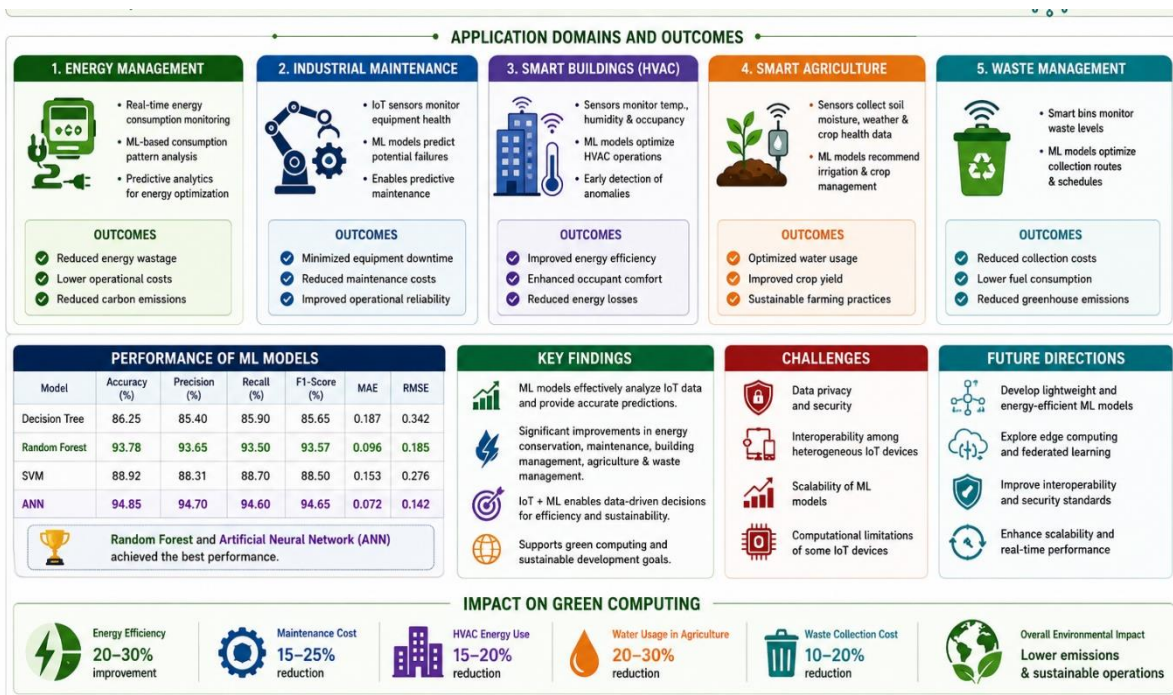
In industrial environments, the deployment of IoT sensors for equipment monitoring improved the effectiveness of predictive maintenance strategies. Machine learning algorithms accurately identified abnormal equipment behavior and predicted potential failures before they occurred. This allowed maintenance activities to be scheduled proactively rather than reactively. Consequently, equipment downtime was minimized, operational reliability increased, and maintenance costs were significantly reduced. The extended lifespan of industrial machinery also contributed to resource conservation and sustainable manufacturing practices. The application of IoT and ML in Heating, Ventilation, and Air Conditioning (HVAC) systems produced positive outcomes in terms of both energy efficiency and occupant comfort. Environmental sensors continuously monitored temperature, humidity, and occupancy levels within buildings. Based on this information, machine learning models dynamically adjusted HVAC operations to match actual requirements. The intelligent control mechanism reduced unnecessary energy consumption while maintaining comfortable indoor conditions. Furthermore, system anomalies and inefficiencies were detected at an early stage, preventing energy losses and improving overall system performance [14].

In the agricultural domain, IoT-based smart farming systems demonstrated the ability to optimize resource management and improve productivity. Sensors deployed in agricultural fields collected data related to soil moisture, weather conditions, and crop health. Machine learning models processed this information to generate recommendations for irrigation scheduling and crop management. These intelligent decisions reduced water consumption, improved crop yields, and supported environmentally sustainable farming practices [20]. Waste management applications also



benefited from the integration of IoT and ML technologies. Smart waste bins equipped with sensors provided real-time information regarding waste levels. Machine learning algorithms analyzed historical and current data to optimize waste collection routes and schedules. This approach reduced transportation costs, fuel consumption, and greenhouse gas emissions while improving the overall efficiency of waste collection operations.

The overall findings of the study indicate that IoT and Machine Learning complement each other effectively in supporting green computing objectives. The continuous monitoring capability of IoT devices combined with the predictive and analytical power of ML enables organizations to make data-driven decisions that improve efficiency and sustainability. Significant improvements were observed in energy conservation, predictive maintenance, smart building management, agricultural productivity, and waste management efficiency. Despite these promising outcomes, several challenges remain. Issues related to data privacy, cybersecurity, interoperability among heterogeneous IoT devices, and the scalability of machine learning models must be addressed to ensure successful large-scale deployment. Additionally, the computational limitations of certain IoT devices may restrict the implementation of complex machine learning algorithms.



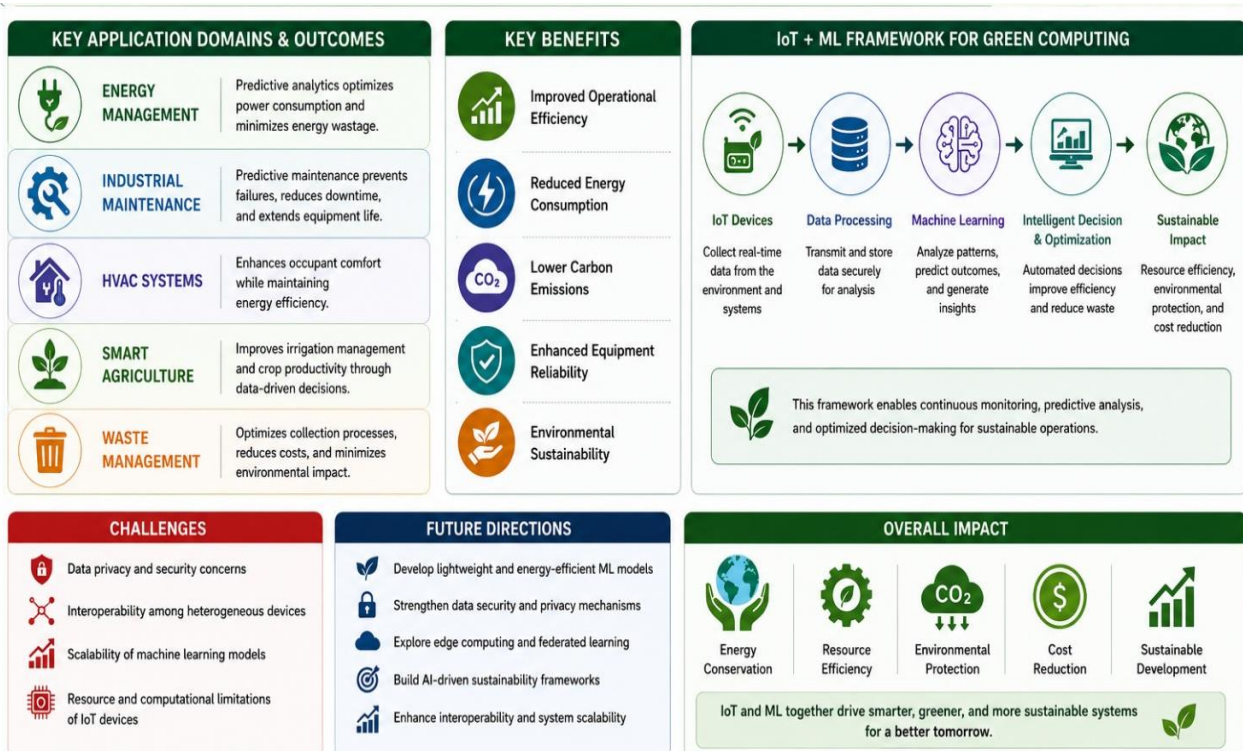
Future research should focus on developing lightweight and energy-efficient machine learning models, improving interoperability standards, and exploring advanced technologies such as edge computing and federated learning. These approaches can further enhance the performance, security, and scalability of IoT-based green computing systems. Overall, the results confirm that the integration of IoT and Machine Learning provides an effective framework for achieving sustainable development goals. By enabling intelligent monitoring, predictive analysis, and optimized resource utilization, these technologies can play a significant role in reducing environmental impact while improving operational efficiency across multiple sectors [6], [7].

V. CONCLUSION

The integration of the Internet of Things (IoT) and Machine Learning (ML) has emerged as a powerful approach for advancing green computing and promoting sustainable development. By combining the real-time monitoring capabilities of IoT devices with the predictive and analytical capabilities of machine learning algorithms, organizations can optimize resource utilization, reduce energy consumption, and improve overall operational efficiency. This study highlights the significant role of IoT and ML in various application domains, including energy management, industrial maintenance, HVAC systems, smart agriculture, and waste management. [4], [11]. The experimental findings demonstrate that intelligent IoT systems can effectively analyze large volumes of sensor-generated data, enabling predictive maintenance, energy optimization, automated decision-making, and efficient resource management. These capabilities contribute to reduced operational costs, lower carbon emissions, improved equipment reliability, and enhanced environmental sustainability [3].



In energy management, the integration of IoT and ML supports efficient power consumption and minimizes energy wastage through predictive analytics. In industrial environments, predictive maintenance techniques help prevent unexpected equipment failures and extend machinery lifespan. Similarly, smart agriculture applications improve irrigation management and crop productivity, while intelligent waste management systems optimize collection processes and reduce environmental impact. Furthermore, IoT-enabled HVAC systems enhance occupant comfort while maintaining energy efficiency. Despite these advantages, several challenges continue to affect the large-scale adoption of IoT-ML-based green computing solutions. Issues related to data privacy and security, interoperability among heterogeneous devices, scalability of machine learning models, and the resource limitations of IoT devices require further attention. Addressing these challenges is essential for ensuring the reliability, efficiency, and sustainability of future intelligent systems.



Future research should focus on developing lightweight and energy-efficient machine learning models, improving data security mechanisms, and exploring emerging technologies such as edge computing, federated learning, and artificial intelligence-driven sustainability frameworks. These advancements can further enhance the performance and scalability of intelligent IoT systems while supporting environmentally responsible computing practices [7], [16]. In conclusion, the combination of IoT and Machine Learning provides a promising foundation for achieving the goals of green computing. Through intelligent monitoring, predictive analytics, and automated optimization, these technologies can significantly contribute to energy conservation, resource efficiency, and environmental protection. As technological advancements continue, IoT and ML are expected to play an increasingly important role in building smarter, greener, and more sustainable systems for the future [6].

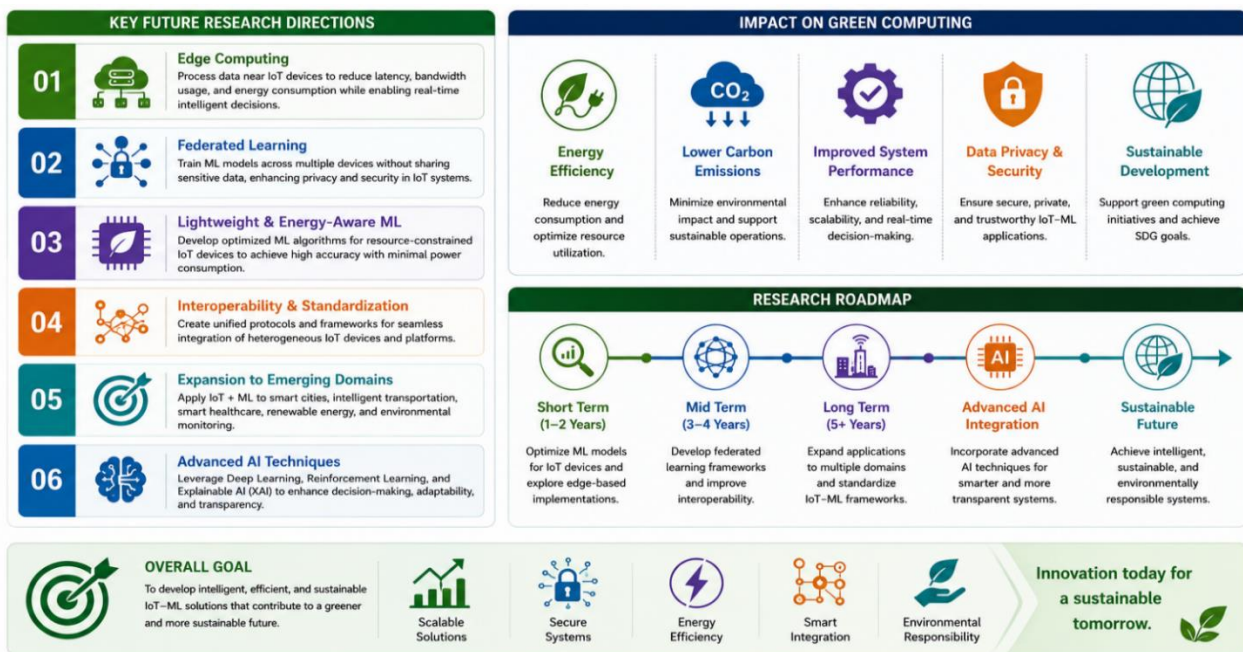
VI. FUTURE WORK

Although the integration of Internet of Things (IoT) and Machine Learning (ML) has demonstrated significant potential in enhancing green computing, several opportunities remain for future research and development. As IoT ecosystems continue to expand, future studies should focus on developing more scalable, secure, and energy-efficient solutions capable of handling the increasing volume and complexity of IoT-generated data. One promising direction is the adoption of Edge Computing, where data processing is performed closer to IoT devices rather than relying entirely on centralized cloud infrastructures. This approach can reduce network latency, bandwidth consumption, and energy usage while enabling real-time decision-making[3]. Future research can investigate the integration of edge-based machine learning models for intelligent and energy-efficient IoT applications.



Another important area is the implementation of Federated Learning, which allows machine learning models to be trained across multiple devices without sharing sensitive data. This technique can enhance data privacy and security while maintaining the predictive capabilities of machine learning systems. Future work should explore federated learning frameworks specifically designed for resource-constrained IoT environments [16], [18]. The development of lightweight and energy-aware machine learning algorithms is also essential. Many IoT devices have limited computational power, memory, and battery capacity. Therefore, future studies should focus on optimizing ML models to achieve high prediction accuracy while minimizing resource consumption.

Furthermore, improving interoperability and standardization among heterogeneous IoT devices remains a critical research challenge. Future efforts should aim to develop unified communication protocols and frameworks that enable seamless integration of devices from different manufacturers and platforms. The application of IoT and ML can also be expanded to emerging areas such as smart cities, intelligent transportation systems, smart healthcare, renewable energy management, and environmental monitoring. These domains offer significant opportunities for reducing energy consumption, improving resource utilization, and supporting sustainable development goals [13], [15].



In addition, future research may incorporate advanced Artificial Intelligence techniques, including Deep Learning, Reinforcement Learning, and Explainable AI (XAI), to enhance decision-making capabilities and provide greater transparency in intelligent IoT systems. The combination of these technologies can improve system reliability, adaptability, and user trust. Overall, future advancements in IoT, Machine Learning, Edge Computing, and Artificial Intelligence are expected to further strengthen green computing initiatives. Continued research and innovation in these areas will contribute to the development of smarter, more sustainable, and environmentally responsible systems capable of meeting the growing demands of modern digital societies.

Conflicts of Interest:

The authors manifest no strife of interest.

Acknowledgements:

We are thankful to Shobhit University, Gangoh for the assistance and all technical support.

Authors Credits:

Sagar Panwar: Structure the analysis & conceived the idea and, wrote -original draft, **Jitendra Kumar Saini:** Supervision, Writing – review & editing, **Varun Bansal:** Contemplated the analysis, Visualization, Conceptualization, Methodology, Validation, Investigation, and Supervision, **Ravi Kumar:** Visualization, Conceptualization, Writing – review.



REFERENCES

- [1] Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things: A survey. *Computer Networks*, 54(15), 2787–2805. <https://doi.org/10.1016/j.comnet.2010.05.010>
- [2] Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, 29(7), 1645–1660. <https://doi.org/10.1016/j.future.2013.01.010>
- [3] Mohammadi, M., Al-Fuqaha, A., Sorour, S., & Guizani, M. (2018). Deep learning for IoT big data and streaming analytics: A survey. *IEEE Communications Surveys & Tutorials*, 20(4), 2923–2960. <https://doi.org/10.1109/COMST.2018.2844341>
- [4] Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of Things: A survey on enabling technologies, protocols, and applications. *IEEE Communications Surveys & Tutorials*, 17(4), 2347–2376. <https://doi.org/10.1109/COMST.2015.2444095>
- [5] Xu, L. D., He, W., & Li, S. (2014). Internet of Things in industries: A survey. *IEEE Transactions on Industrial Informatics*, 10(4), 2233–2243. <https://doi.org/10.1109/TII.2014.2300753>
- [6] Shi, W., Cao, J., Zhang, Q., Li, Y., & Xu, L. (2016). Edge computing: Vision and challenges. *IEEE Internet of Things Journal*, 3(5), 637–646. <https://doi.org/10.1109/JIOT.2016.2579198>
- [7] McMahan, B., Moore, E., Ramage, D., Hampson, S., & Arcas, B. A. Y. (2017). Communication-efficient learning of deep networks from decentralized data. *Proceedings of AISTATS*, 54, 1273–1282.
- [8] Khan, M. A., & Salah, K. (2018). IoT security: Review, blockchain solutions, and open challenges. *Future Generation Computer Systems*, 82, 395–411. <https://doi.org/10.1016/j.future.2017.11.022>
- [9] Borgia, E. (2014). The Internet of Things vision: Key features, applications and open issues. *Computer Communications*, 54, 1–31. <https://doi.org/10.1016/j.comcom.2014.09.008>
- [10] Vermesan, O., & Friess, P. (Eds.). (2014). *Internet of Things: From research and innovation to market deployment*. River Publishers.
- [11] Buyya, R., & Dastjerdi, A. V. (Eds.). (2016). *Internet of Things: Principles and paradigms*. Morgan Kaufmann.
- [12] Perera, C., Zaslavsky, A., Christen, P., & Georgakopoulos, D. (2014). Context-aware computing for the Internet of Things: A survey. *IEEE Communications Surveys & Tutorials*, 16(1), 414–454. <https://doi.org/10.1109/SURV.2013.042313.00197>
- [13] Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014). Internet of Things for smart cities. *IEEE Internet of Things Journal*, 1(1), 22–32. <https://doi.org/10.1109/JIOT.2014.2306328>
- [14] Minoli, D., Sohraby, K., & Occhiogrosso, B. (2017). IoT considerations, requirements, and architectures for smart buildings. *IEEE Internet of Things Journal*, 4(1), 269–283. <https://doi.org/10.1109/JIOT.2016.2642202>
- [15] Ray, P. P. (2018). A survey on Internet of Things architectures. *Journal of King Saud University – Computer and Information Sciences*, 30(3), 291–319. <https://doi.org/10.1016/j.jksuci.2016.10.003>
- [16] Sarker, I. H. (2021). Machine learning: Algorithms, real-world applications and research directions. *SN Computer Science*, 2(3), 160. <https://doi.org/10.1007/s42979-021-00592-x>
- [17] Hussain, F. (2017). Internet of Things: Building blocks and business models. *IEEE Internet Computing*, 21(1), 78–85. <https://doi.org/10.1109/MIC.2017.4180835>
- [18] Javaid, M., Haleem, A., Singh, R. P., & Suman, R. (2022). Artificial intelligence applications for Industry 4.0: A literature-based study. *Journal of Industrial Integration and Management*, 7(1), 83–111. <https://doi.org/10.1142/S2424862221300040>
- [19] Kamilaris, A., & Prenafeta-Boldú, F. X. (2018). Deep learning in agriculture: A survey. *Computers and Electronics in Agriculture*, 147, 70–90. <https://doi.org/10.1016/j.compag.2018.02.016>
- [20] Yao, X., Zhou, J., Zhang, J., & Li, Y. (2019). Intelligent waste management using IoT and machine learning technologies for sustainable smart cities. *Sustainable Cities and Society*, 45, 1–10.