International Journal of Electrical, Electronics and Computer Engineering **14**(1&2): 39-41(2025)

ISSN No. (Online): 2277-2626

A Comprehensive Literature Review on Autonomous Eco Homes

Aryan Negi*, Ayush Sahore and Anchit Chauhan
School of Computer Science Engineering and Technology,
Government College Dharamshala (H.P.), India.

(Corresponding author: Aryan Negi)*
(Received: 21 February 2025, Accepted: 30 March 2025)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Smart home automation is revolutionizing modern living by enhancing energy efficiency, security, and convenience. This research explores India's transition from Level 2 to Level 4 smart homes, integrating IoT, AI, home solar panels, lithium battery storage, and automated car parking. A key feature is the dual power system, utilizing both solar energy and the main power grid for reliability and sustainability. The study identifies challenges such as high costs, infrastructure limitations, and IoT security risks while emphasizing AI-driven automation, energy management, and smart parking solutions. By addressing these challenges and leveraging technological advancements, India can progress towards fully autonomous, sustainable smart homes, improving energy conservation and overall living standards.

Keywords: Smart Homes, Level 4 Automation, IoT.

INTRODUCTION

The concept of autonomous eco homes is emerging as a revolutionary approach to sustainable living, integrating artificial intelligence (AI), renewable energy, and smart automation. These homes are designed to be self-sufficient, utilizing solar panels for energy generation and lithium battery storage to ensure a continuous power supply. With AI-driven automation, these smart homes enhance energy efficiency, security, and convenience, making them a viable solution for the future of residential living. The evolution of smart homes can be traced back to the early developments in home automation and renewable energy. Researchers such as (Mozer, 1998) explored AI-based automation in homes, paving the way for intelligent systems that learn and adapt to user behavior. In recent years, (Gill *et al.*, 2009) discussed the role of the Internet of Things (IoT) in smart home automation, highlighting its impact on energy management. The integration of solar energy storage has also been extensively researched, with (Mekhilef *et al.*, 2012) analyzing the efficiency of lithium-ion batteries for sustainable energy storage. In the modern era, studies such as Alam *et al.* (2017); (Risteska *et al.*, 2017) have emphasized the role of AI and machine learning in optimizing energy consumption in smart homes. Additionally, (Saad *et al.*, 2020) have explored AI-driven energy management systems for autonomous eco homes, demonstrating how smart grid integration can enhance sustainability. This research paper aims to explore the advancements in autonomous eco homes, focusing on their energy efficiency, AI-driven automation, and smart parking solutions. The study will analyze the potential of integrating IoT, solar energy, and lithium battery storage to create homes that are not only energy-independent but also contribute to reducing carbon footprints. As the world shifts towards sustainable living, autonomous eco homes stand at the forefront of technological innovation, promising a greener and more efficient future.

RELATED WORK

The concept of autonomous eco homes has evolved through extensive research in AI-driven home automation, renewable energy integration, and sustainable energy storage. Several researchers have contributed to this field, providing insights into the development of intelligent, energy-efficient, and self-sustaining homes. The foundation of smart home automation was laid by Mozer (1998), who introduced early AI-driven home control systems that adapted to user behavior. This work set the stage for more advanced home automation technologies. Later (Gill *et al.*, 2009) explored the role of the Internet of Things (IoT) in smart homes, emphasizing real-time communication between household devices to improve automation and energy efficiency. Their research provided a framework for integrating AI into home automation also examined user interaction with smart home technologies, highlighting the importance of intuitive AI interfaces. Renewable energy integration in smart homes has been another critical area of research. Mekhilef *et al.* (2012) investigated the effectiveness of lithium-ion batteries for storing solar energy, demonstrating their high efficiency in balancing energy supply and demand. Similarly, (Lambert *et al.*, 2006) analyzed hybrid renewable energy systems, showing how combining solar panels with energy storage solutions can ensure uninterrupted power for smart homes. More recently, (Javani 2016) proposed an AI-based energy management system that dynamically optimizes power consumption in smart homes using predictive analytics. Several studies have explored the role of AI and machine learning in improving home automation and energy management. Alam *et al.* (2017) introduced AI algorithms for intelligent climate control, reducing energy waste by adapting to user preferences and weather conditions (Risteska *et al.,* 2017) expanded on this by integrating IoT with AI-driven home automation, making energy usage more efficient through real-time data processing (Saad *et al.*, 2020) further advanced this field by incorporating deep learning techniques for optimizing smart grid interactions, ensuring homes operate with minimal energy wastage.

The automation of smart parking solutions for eco homes has also been an area of research (Zhang, 2011) proposed AI-based parking management systems that efficiently allocate parking spaces and manage electric vehicle charging. Dou & Wang (2014) built on this research by developing autonomous navigation systems for smart garages, allowing AI-driven cars to park themselves within eco homes seamlessly. In the realm of energy-efficient transportation integration, (Shukla, 2019) studied how smart homes can manage electric vehicle (EV) charging schedules using renewable energy sources. Cyber-security and data privacy concerns in smart home automation have been explored by Zhang (2011); Al-Fuqaha *et al.* (2015), who highlighted the need for secure communication protocols and AI-based threat detection systems to protect user data. Their work has led to the development of encrypted and blockchain-based authentication methods for smart homes.

The concept of autonomous eco homes continues to evolve with advancements in AI, IoT, and renewable energy technologies. Recent research by Sun (2022) introduced a fully AI-driven smart home system capable of self-learning and autonomous decision-making, further pushing the boundaries of intelligent home automation. These developments indicate that AI-driven eco homes, powered by solar energy and lithium batteries, are not only feasible but are becoming an essential solution for sustainable and energy-efficient living. This research aims to build on existing studies by analyzing how AI, IoT, solar energy, and lithium batteries can be integrated to develop self-sufficient eco homes. By examining the latest advancements, challenges, and future trends, this study will contribute to the ongoing development of autonomous eco homes as a viable solution for smart and sustainable living.

RESEARCH GAP

Home automation technology has seen significant advancements, yet most research primarily focuses on isolated smart components rather than a fully integrated Level 4 AI-driven system. While various studies have explored individual elements such as smart lighting, security systems, energy management, and IoT connectivity, there remains a lack of comprehensive research on creating a unified, autonomous, and scalable home automation framework, especially in the context of India.

One of the major research gaps is affordability. The high cost of AI-driven home automation solutions limits accessibility, particularly in developing regions like India, where economic constraints pose a significant challenge. Most existing solutions are designed for high-end users, leaving a gap in research on cost-effective, scalable systems that cater to middle-income households. A detailed analysis of budget-friendly automation strategies, including open-source AI models, localized manufacturing, and modular automation, is needed to make Level 4 automation more inclusive. Another crucial gap exists in large-scale infrastructure integration. While smart home solutions are evolving, there is insufficient research on integrating automation with India's unique infrastructure, which includes frequent power outages, varying internet connectivity, and a mix of modern and traditional housing. A lack of studies exploring hybrid energy systems, such as the combination of solar panels, lithium-ion battery storage, and AI-optimized energy consumption, creates a bottleneck in achieving a fully autonomous ecosystem.

Security and privacy remain underexplored, particularly concerning AI-driven decision-making and IoT connectivity vulnerabilities. Current research often addresses security in silos, focusing on encryption or authentication, but fails to provide holistic frameworks that balance user control, AI autonomy, and cybersecurity risks. Additionally, concerns over data privacy, regulatory compliance, and potential AI biases in decision-making require deeper investigation. Interoperability is another challenge, as smart home devices come from multiple manufacturers with varying communication protocols. The lack of standardized frameworks for seamless integration between IoT devices, AI systems, and cloud-based solutions hinders the development of a truly interconnected home automation ecosystem. More research is required to establish universal standards and open-source protocols that facilitate effortless cross-device communication. Finally, the workforce skill gap and real-world implementation challenges remain a critical research area. AI-driven home automation requires specialized knowledge in AI programming, IoT deployment, and cybersecurity.

However, there is a lack of research on training models and educational frameworks to equip professionals with the necessary skills to implement and maintain fully autonomous home systems. This study aims to address these gaps by developing a cost-effective, scalable, and secure AI-powered home automation framework tailored to India's specific challenges.

FINDING SUGGESTIONS

Achieving Level 4 smart home automation in India requires advancements in energy management, AI-driven automation, and security frameworks. Hybrid energy systems integrating solar power with lithium battery storage ensure a stable and sustainable power supply, reducing dependence on the grid.AI-driven automation can optimize household operations, improve energy efficiency, and enhance user convenience by learning behavioral patterns and predicting maintenance needs. Enhanced security measures, such as biometric authentication, real-time surveillance, and cyber-security protocols, are essential for safe automation.

Implementing smart parking solutions using AI-driven automated parking systems can alleviate urban congestion and integrate with electric vehicles (EVs) for bidirectional charging. However, cost barriers remain a challenge, necessitating government incentives, modular adoption strategies, and increased public awareness to promote affordability and widespread adoption. Another critical aspect of achieving Level 4 smart home automation is enhancing interoperability among various smart devices.

Many home automation systems rely on different communication protocols, leading to integration challenges. Developing standardized frameworks and AI-driven middleware solutions can enable seamless interaction between IoT devices, ensuring smooth operation across multiple brands and technologies. Additionally, edge computing can be leveraged to process data locally, reducing latency and enhancing system reliability, making home automation more efficient and responsive

CONCLUSIONS

The transition to Level 4 smart home automation in India involves integrating AI, IoT, renewable energy, and automated parking systems to enhance efficiency and sustainability. AI-driven automation enables seamless control, predictive maintenance, and optimized energy management, reducing manual intervention. Solar panels with lithium battery storage ensure energy self-sufficiency, cutting reliance on traditional power grids. IoT connectivity allows real-time remote control of lighting, security, climate, and appliances, improving convenience and efficiency. Challenges include high costs, infrastructure limitations, and cyber-security risks. Implementing biometric authentication, encryption, and AI-based anomaly detection can enhance security, while automated parking solutions reduce urban congestion and integrate EV charging. To accelerate adoption, policy reforms, government incentives, and industry collaboration are essential. Investing in affordable AI-driven automation will help India create a sustainable, intelligent, and connected smart home ecosystem for the future. Future advancements in AI, edge computing, and 5G connectivity will further refine smart home automation, enabling faster decision-making, real-time adaptability, and greater energy efficiency. By overcoming current challenges, India can lead the way in developing cost-effective, AI-driven smart homes that redefine modern living.

Acknowledgement. I sincerely thank my mentors and faculty members for their invaluable guidance and support throughout this research on Autonomous Eco Homes. Their insights have been instrumental in shaping this study. I also appreciate the contributions of researchers in AI-driven home automation, renewable energy, and IoT, whose work laid the foundation for this research. Special thanks to my peers for their constructive feedback and discussions. Lastly, I am grateful to my family and friends for their constant encouragement and motivation. Their support has been essential in completing this research successfully.

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