

THE USAGE OF SMART THERMOSTATS IN SMART HOME

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Purpose: The purpose of this publication is to present the usage of smart lighting in smart thermostats.

Design/methodology/approach: Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.

Findings: Smart thermostats stand as a transformative innovation in home automation, reshaping the management of heating and cooling systems in smart homes. This integration introduces a host of advantages that go beyond conventional thermostat functionalities. The ability to remotely control and monitor temperature settings via dedicated mobile applications provides users with unparalleled flexibility and convenience. The seamless integration with popular smart home platforms like Amazon Alexa, Google Assistant, or Apple HomeKit fosters a cohesive and automated living environment by harmonizing with other smart devices. Beyond temperature control, smart thermostats exhibit a dedication to energy efficiency through learning algorithms that optimize settings over time, potentially reducing energy bills. Features such as weather integration, occupancy sensors, and voice control further enhance efficiency and convenience. With a pivotal role in environmental sustainability, these devices promote energy conservation, offer insights into consumption patterns, and support compatibility with renewable energy sources. While acknowledging substantial advantages, potential challenges such as connectivity issues and privacy concerns should be addressed through measures like stable internet connections and prioritizing security features. Smart thermostats embody the fusion of technology, convenience, and sustainability in modern homes, with ongoing evolution poised to further shape intelligent and comfortable living spaces.

Originality/Value: Detailed analysis of all subjects related to the problems connected with the usage of smart thermostats in smart home.

Keywords: Smart City, energy efficiency, smart home, smart house, digitalization, smart thermostats.

Category of the paper: literature review.

1. Introduction

Smart thermostats play a pivotal role in the seamless integration of heating and cooling systems within a smart home environment. As a central component of the modern connected home, these intelligent devices leverage advanced technologies to enhance both comfort and efficiency.

One of the primary advantages of incorporating smart thermostats into a smart home ecosystem is the ability to remotely control and monitor temperature settings. Through dedicated mobile applications, users can effortlessly adjust their home's climate from anywhere, providing unprecedented flexibility and convenience. Whether at work, on vacation, or within the confines of their own home, occupants can easily manage heating and cooling preferences at the touch of a button (Bsarir-Ozel et al., 2023).

The synergy between smart thermostats and other smart home devices further contributes to a cohesive living experience. Integration with popular smart home platforms like Amazon Alexa, Google Assistant, or Apple HomeKit allows for seamless communication between devices. Users can create intricate automation scenarios where the thermostat collaborates with lighting, security systems, and other connected devices, promoting a harmonized and efficient home environment (Huda et al., 2024).

The purpose of this publication is to present the usage of smart thermostats in smart home.

2. Smart thermostats in smart home

Smart thermostats are innovative devices that have revolutionized the way we control and manage the temperature in our homes. Unlike traditional thermostats, smart thermostats leverage advanced technology to provide users with enhanced convenience, energy efficiency, and customization options (Hussain et al., 2023).

One of the key features of smart thermostats is their connectivity to the Internet of Things (IoT). This connectivity allows users to remotely control and monitor their home's heating and cooling systems through dedicated mobile applications (Olabode et al., 2023). Whether you are at work, on vacation, or simply lounging in another room, the ability to adjust your thermostat settings from your smartphone provides an unprecedented level of flexibility and control (Chaudhari et al., 2023).

Energy efficiency is a significant advantage offered by smart thermostats. Many models come equipped with learning algorithms that analyze your patterns and preferences over time. By understanding your daily routines, these thermostats can automatically adjust the temperature to optimize energy usage, leading to potential cost savings on your energy bills.

Additionally, some smart thermostats integrate weather forecasts and occupancy sensors to make real-time adjustments, further improving efficiency. The integration of voice control technology has added another layer of convenience to smart thermostats. Users can now interact with their thermostats using voice commands, making adjustments hands-free. This feature is particularly beneficial in situations where manual control may be inconvenient or when users have limited mobility.

Compatibility with smart home ecosystems is a notable aspect of smart thermostats. They often integrate seamlessly with popular smart home platforms such as Amazon Alexa, Google Assistant, and Apple HomeKit (Afroz et al., 2024). This interoperability enables users to create comprehensive smart home systems where thermostats can interact with other connected devices, such as smart lighting, security systems, and more, fostering a cohesive and automated living environment (Valencia-Arias et al., 2023).

Smart thermostats also contribute to environmental sustainability by promoting energy conservation. The ability to monitor energy usage, set efficient schedules, and receive insights into consumption patterns empowers users to make informed decisions that reduce their carbon footprint (Dhaou, 2023). In terms of design, smart thermostats typically feature sleek and modern aesthetics, blending seamlessly with contemporary home decor. Touchscreen interfaces, intuitive controls, and user-friendly mobile applications contribute to an overall positive user experience (Raff et al., 2024).

Smart thermostats also demonstrate a keen understanding of user behavior and preferences through learning algorithms (Chen et al., 2023). By analyzing patterns over time, these devices optimize temperature settings automatically, adapting to the occupants' routines. This not only enhances comfort but also contributes to energy efficiency, potentially leading to cost savings on energy bills (Alsaedi et al., 2023).

Incorporating geofencing technology, smart thermostats take personalization to the next level. They can detect the proximity of users to their homes and adjust temperature settings accordingly, ensuring a comfortable environment upon arrival while minimizing unnecessary energy consumption during absences. Moreover, the integration of voice control technology adds an extra layer of convenience. Occupants can interact with their smart thermostats using voice commands, offering hands-free control and simplifying the user experience (Gajdzik et al., 2023; Jonek-Kowalska, Wolniak, 2021, 2022).

The usage of smart thermostats in a smart home transcends mere temperature control. It embodies a holistic approach to modern living, where connectivity, automation, and energy efficiency converge to create an intelligent and comfortable living space (Tong et al., 2023). As technology continues to evolve, the role of smart thermostats in smart homes is likely to expand, offering even more sophisticated features and contributing to the ongoing transformation of our living spaces (Wu et al., 2023).

Table 1 contains descriptions of key features of smart thermostats usage.

Table 1.
Key features of smart thermostats usage

Key Features of Smart Thermostats	Description
Remote Connectivity	Enables users to control and monitor thermostat settings remotely via dedicated mobile applications, providing flexibility and convenience.
Learning Algorithms	Analyzes user patterns and preferences to automatically adjust temperature settings over time, optimizing energy usage and potentially reducing energy bills.
Weather Integration	Utilizes weather forecasts to make real-time adjustments, ensuring efficient heating and cooling based on external conditions.
Occupancy Sensors	Incorporates sensors to detect occupancy and adjust temperature settings accordingly, preventing energy wastage in unoccupied spaces.
Voice Control Integration	Allows users to interact with the thermostat using voice commands, enhancing convenience, especially in situations where manual control is impractical.
Smart Home Ecosystem Compatibility	Integrates seamlessly with popular smart home platforms (e.g., Alexa, Google Assistant, HomeKit) to create a cohesive and interconnected smart home environment.
Energy Monitoring and Insights	Provides detailed energy usage data and insights, empowering users to make informed decisions to reduce their carbon footprint and promote environmental sustainability.
Modern Aesthetics and Intuitive Controls	Features sleek and modern designs with touchscreen interfaces and user-friendly controls, enhancing the overall user experience and blending with contemporary home decor.
Geofencing Technology	Utilizes location-based technology to adjust temperature settings based on the user's proximity to home, optimizing comfort and energy efficiency.
Scheduling and Programming	Allows users to create custom heating and cooling schedules, ensuring that the thermostat operates according to individual preferences and daily routines.
Smart Alerts and Notifications	Sends alerts and notifications to users for events such as extreme temperature changes, system malfunctions, or reminders for maintenance tasks, enhancing system monitoring.
Compatibility with HVAC Systems	Supports integration with a wide range of heating, ventilation, and air conditioning (HVAC) systems, ensuring compatibility with various home setups.
Multi-Zone Control	Enables independent temperature control in different zones or rooms of the house, providing personalized comfort levels for each living space.
Adaptive Recovery	Learns and predicts the time needed to reach a set temperature, ensuring the home is comfortable at the scheduled times without unnecessary energy consumption.
Data Security and Privacy Features	Implements robust security measures to protect user data and privacy, addressing concerns related to the connectivity and smart features of the thermostat.
Integration with Renewable Energy Sources	Supports integration with renewable energy sources, allowing users to optimize energy consumption and contribute to a more sustainable and eco-friendly home.
Smart Thermostat Firmware Updates	Offers regular firmware updates to enhance functionality, improve performance, and address potential security vulnerabilities, ensuring a continuously evolving system.
Usage Reports and Analytics	Provides detailed reports and analytics on energy usage, temperature patterns, and system performance, empowering users with insights for better energy management.

Source: (Gøthesen et al., 2023; Alsaedi et al., 2023; Chaudhari et al., 2023; Huda et al., 2024; Husain et al., 2023; Rhode et al., 2023; Basarir-Ozel et al., 2023; Tong et al., 2023; Chen et al., 2023; Douha et al., 2023; Sobhani et al., 2023).

3. The advantages and problems of using smart thermostats

Smart thermostats offer a multitude of advantages when integrated into a smart home environment, transforming the way we control and interact with our heating and cooling systems. One of the key benefits is the ability to exercise precise control remotely. Through dedicated mobile applications, users can effortlessly adjust temperature settings from anywhere, ensuring optimal comfort upon arrival and efficient energy usage. The integration of learning algorithms sets smart thermostats apart by adapting to user behavior over time. This not only optimizes energy efficiency by automatically adjusting temperature settings based on daily routines but also contributes to potential cost savings on energy bills (Sobhani et al., 2023).

Compatibility with popular smart home platforms such as Alexa, Google Assistant, or HomeKit allows for seamless integration and coordination with other connected devices. This paves the way for automation scenarios where the thermostat collaborates with lighting, security systems, and more, creating a cohesive and synchronized smart home environment. Geofencing technology takes personalization to the next level. By leveraging location-based services, smart thermostats can detect when users are approaching home and adjust temperatures accordingly. This feature not only enhances comfort but also minimizes energy wastage during periods of absence (Ramanujam et al., 2024).

Voice control adds an extra layer of convenience to smart thermostat usage. Users can interact with their devices using voice commands, providing hands-free control and simplifying the overall user experience. The learning algorithms employed by smart thermostats contribute to a personalized living experience. By analyzing user patterns, these devices automatically tailor temperature settings to individual preferences, ensuring a comfortable environment without the need for constant manual adjustments (Douha et al., 2023).

Smart thermostats also offer data-driven insights through detailed reports and analytics on energy usage, temperature patterns, and system performance. This information empowers users to make informed decisions about energy management, further optimizing efficiency and sustainability. The compatibility of smart thermostats with renewable energy sources, such as geothermal systems, aligns with sustainability goals. This integration allows users to contribute to environmental conservation efforts while optimizing their energy consumption (Afroz et al., 2024).

Regular firmware updates ensure that smart thermostats stay current with the latest technological advancements. These updates not only enhance functionality and performance but also address security concerns, providing users with a reliable and evolving smart home solution. In essence, the advantages of using smart thermostats extend beyond temperature control, offering a holistic and intelligent approach to home comfort, efficiency, and sustainability (Douha et al., 2023).

Table 2 highlighting the advantages of using smart thermostats in smart home.

Table 2.
Advantages of using smart thermostats

Advantage	Description
Remote Control	Users can adjust heating and cooling settings from anywhere via dedicated mobile applications, offering convenience and flexibility.
Energy Efficiency	Learning algorithms optimize temperature based on user behavior, promoting energy efficiency and potentially reducing energy bills.
Integration with Smart Home Platforms	Seamless compatibility with popular platforms like Alexa, Google Assistant, or HomeKit enables cohesive automation within the smart home ecosystem.
Geofencing Technology	Utilizes location-based technology to adjust temperature settings based on user proximity, enhancing comfort upon arrival and reducing energy waste during absences.
Voice Control	Integration with voice assistants allows for hands-free control, adding an extra layer of convenience to the user experience.
Automation and Coordination	Collaborates with other smart devices to create automated scenarios, where the thermostat interacts with lighting, security, and more, for a synchronized smart home environment.
Learning Algorithms for Personalization	Learns user patterns over time to automatically tailor temperature settings, providing a personalized and comfortable living experience.
Data-driven Insights	Provides detailed reports and analytics on energy usage, temperature patterns, and system performance, empowering users with information for better energy management.
Geothermal and Renewable Energy Integration	Supports integration with renewable energy sources, contributing to sustainability efforts and allowing users to optimize energy consumption.
Firmware Updates for Continuous Improvement	Regular firmware updates enhance functionality, improve performance, and address security concerns, ensuring the thermostat evolves with advancing technology.

Source: (Gøthesen et al., 2023; Alsaedi et al., 2023; Chaudhari et al., 2023; Huda et al., 2024; Husain et al., 2023; Rhode et al., 2023; Basarir-Ozel et al., 2023; Tong et al., 2023; Chen et al., 2023; Douha et al., 2023; Sobhani et al., 2023).

Table 3 highlighting some of the common problems and challenges associated with the problems of using smart thermostats in smart homes.

Table 3.
Problems of using smart thermostats

Problem	Description	Methods of Overcoming
Connectivity Issues	Smart thermostats heavily rely on internet connectivity. If there are network disruptions or Wi-Fi issues, users may experience difficulties in remotely controlling the thermostat.	<ul style="list-style-type: none"> • Ensure a stable and reliable internet connection. • Place the Wi-Fi router in a central location for better coverage. • Consider using a mesh Wi-Fi network for improved coverage.
Compatibility Challenges	Some smart thermostats may not be compatible with certain HVAC systems or smart home platforms, leading to integration challenges.	<ul style="list-style-type: none"> • Prioritize research to choose a thermostat compatible with your HVAC system. • Check for compatibility with your existing smart home ecosystem before purchasing. • Utilize compatibility check tools provided by manufacturers.

Cont. table 3.

Privacy and Security Concerns	The connectivity of smart thermostats raises privacy and security issues, as these devices collect data on users' habits and routines. Unauthorized access could compromise sensitive information.	<ul style="list-style-type: none"> • Choose thermostats from reputable manufacturers with a focus on security. • Regularly update firmware to patch security vulnerabilities. • Implement strong passwords and enable two-factor authentication where available.
Learning Algorithm Limitations	While learning algorithms enhance efficiency, they may not always accurately predict user preferences or routines. This can lead to suboptimal temperature adjustments.	<ul style="list-style-type: none"> • Regularly review and adjust thermostat settings manually to fine-tune preferences. • Provide feedback to the thermostat system when it makes adjustments that do not align with preferences. • Consider thermostats with user-friendly interfaces for easier manual adjustments.
Initial Cost and Installation	The upfront cost of smart thermostats can be higher compared to traditional thermostats, and installation may require professional assistance, incurring additional expenses.	<ul style="list-style-type: none"> • Look for rebates or discounts offered by utility companies to offset the initial cost. • Explore DIY-friendly models for simpler installation, if applicable. • Consider the long-term energy savings that may offset the initial investment.
Power Outage Impact	During power outages, smart thermostats may lose functionality or require reprogramming once power is restored. This can disrupt temperature control settings.	<ul style="list-style-type: none"> • Invest in smart thermostats with built-in battery backup capabilities. • Consider auxiliary power solutions, like uninterruptible power supplies (UPS), for critical smart home components. • Have a manual thermostat as a backup for temporary use during power outages.
Sensor Accuracy and Placement	Inaccurate temperature readings may occur if sensors are poorly placed or if the thermostat is installed in a location that doesn't reflect the actual temperature of the living spaces.	<ul style="list-style-type: none"> • Ensure proper thermostat placement in a central location away from direct sunlight or drafts. • Calibrate sensors regularly according to manufacturer guidelines. • Use additional temperature sensors in different zones for more accurate readings.
Software Bugs and Glitches	Like any technology, smart thermostats may experience software bugs or glitches that can impact their performance and responsiveness.	<ul style="list-style-type: none"> • Keep firmware and software up to date with the latest releases. • Report bugs to the manufacturer for prompt resolution in future updates. • Follow troubleshooting guides provided by the manufacturer.
Complexity for Technologically Inexperienced Users	Users unfamiliar with technology may find the setup, configuration, and operation of smart thermostats challenging, leading to underutilization of features.	<ul style="list-style-type: none"> • Choose thermostats with user-friendly interfaces and clear setup instructions. • Seek assistance from customer support or professional installation services if needed. • Utilize online tutorials and resources to familiarize yourself with the device.
Dependence on External Services	Smart thermostats often depend on external cloud services. If these services experience downtime or discontinuation, it can impact the thermostat's functionality.	<ul style="list-style-type: none"> • Research the reliability and reputation of the manufacturer's cloud services. • Choose thermostats that offer local control options or have fallback mechanisms in case of cloud service disruptions. • Be aware of potential service limitations and have alternative heating or cooling methods available.

Cont. table 3.

Limited Compatibility with Older HVAC Systems	Some older HVAC systems may not be compatible with the advanced features of smart thermostats, limiting their effectiveness.	<ul style="list-style-type: none"> • Prioritize compatibility checks before purchasing a smart thermostat. • Consider upgrading the HVAC system if compatibility issues persist. • Consult with HVAC professionals for advice on integrating smart thermostats with older systems.
Overreliance on Automation	Overreliance on automated settings may lead to discomfort if the thermostat fails to accurately predict user preferences or if there are unexpected changes in daily routines.	<ul style="list-style-type: none"> • Regularly review and adjust thermostat settings manually to ensure comfort. • Have alternative heating or cooling methods available for unexpected scenarios. • Use automation as a complement rather than a sole means of temperature control.

Source: (Gøthesen et al., 2023; Alsaedi et al., 2023; Chaudhari et al., 2023; Huda et al., 2024; Husain et al., 2023; Rhode et al., 2023; Basarir-Ozel et al., 2023; Tong et al., 2023; Chen et al., 2023; Douha et al., 2023; Sobhani et al., 2023).

4. Conclusion

Smart thermostats represent a groundbreaking advancement in the realm of home automation, revolutionizing the way we manage and control heating and cooling systems within smart homes. Their integration into the modern connected home brings forth a myriad of advantages that transcend traditional thermostat functionalities. The ability to remotely control and monitor temperature settings through dedicated mobile applications stands out as a primary advantage, offering users unprecedented flexibility and convenience. The synergy with other smart home devices, facilitated by seamless integration with popular platforms like Amazon Alexa, Google Assistant, or Apple HomeKit, contributes to the creation of a cohesive and automated living environment.

Smart thermostats not only excel in temperature control but also showcase a commitment to energy efficiency. Learning algorithms analyze user patterns and preferences, automatically optimizing temperature settings over time to reduce energy consumption and potentially lower energy bills. The incorporation of weather integration, occupancy sensors, and voice control further enhances efficiency and convenience. These devices play a pivotal role in environmental sustainability by promoting energy conservation and offering insights into consumption patterns. Additionally, the compatibility with renewable energy sources aligns with efforts to create eco-friendly living spaces.

While the advantages are substantial, it is essential to acknowledge and address potential challenges associated with smart thermostat usage. Connectivity issues, compatibility challenges, and privacy concerns may arise, requiring users to implement measures such as ensuring stable internet connections, thorough compatibility checks, and prioritizing security features. The learning algorithm's limitations and overreliance on automation are challenges that users can mitigate by providing manual adjustments and maintaining alternative heating or

cooling methods. The initial cost and installation complexities can be addressed by exploring available discounts, opting for DIY-friendly models, and considering long-term energy savings.

Smart thermostats exemplify the fusion of technology, convenience, and sustainability in the modern home. As they continue to evolve, addressing challenges and enhancing user experiences, their role in shaping intelligent and comfortable living spaces is poised to expand further.

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