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Green IoT for Smart Homes: Reducing Energy Consumption and Enhancing Sustainability

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Abstract

This research paper explores the perceptions of employees in the real estate and IT sectors regarding the impact of Green Internet of Things (IoT) technologies on energy consumption and sustainability in smart homes. Utilizing a quantitative methodology, the study administered structured questionnaires to 345 respondents to gather data on their views of the effectiveness of Green IoT devices in reducing energy usage and enhancing environmental sustainability. The analysis was conducted using one-sample t-tests to compare the responses against a neutral benchmark, revealing significant perceptions of Green IoT's contributions. The findings indicate a robust consensus among participants that Green IoT technologies significantly lower energy consumption and effectively manage energy resources, with notable impacts on reducing household energy bills and overall energy usage. Additionally, respondents overwhelmingly agreed that Green IoT plays a crucial role in making smart homes more environmentally sustainable and in promoting sustainable urban development. These perceptions underscore the potential of Green IoT to not only enhance the efficiency and functionality of smart homes but also to contribute significantly to broader environmental sustainability goals. The study's implications extend to policymakers, urban planners, technology developers, and real estate professionals, suggesting that supportive measures and continued innovation in Green IoT could accelerate the transition to more sustainable urban environments. The conclusions also advocate for future research to explore the long-term impacts of Green IoT technologies and their integration into different socio-economic and geographic contexts.

Keywords: Green IoT, smart homes, sustainability, energy consumption, environmental impact, real estate, IT sector, urban development.

Introduction

The idea of "smart homes" has taken off in recent years, thanks to developments in connectivity and a heightened focus on environmental responsibility. At the heart of this change is the incorporation of Green IoT solutions, which seek to lessen energy usage and improve comfort and convenience while simultaneously lowering environmental effect. With an eye towards smart houses' capacity to transform energy management and encourage environmental responsibility, this introduction delves into the ways in which Internet of Things (IoT) technology and sustainable practices within these dwellings meet. Thanks to the Internet of Things (IoT), which is defined by its interconnection and real-time data gathering and analysis capabilities, smart houses with adaptive and responsive energy management

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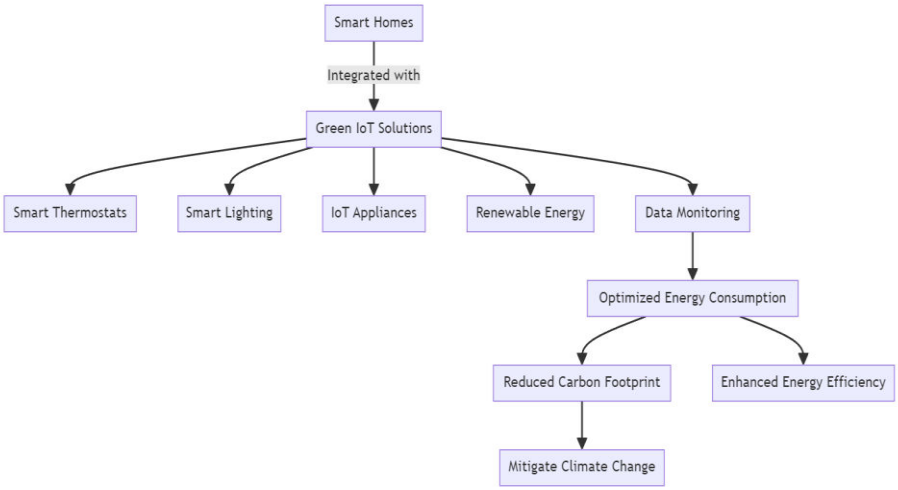
have been developed. Smart appliances, lighting systems, thermostats, and systems for integrating renewable energy sources are all part of this vast array of products. Internet of Things (IoT) smart homes optimise consumption based on real-time data and user preferences by utilising sensors, actuators, and communication protocols. Users have unprecedented control over energy usage patterns. The ability to promote eco-friendly lifestyle choices is central to the Green IoT paradigm. Internet of Things (IoT)-enabled smart homes may greatly improve energy efficiency and decrease carbon footprints by allowing accurate monitoring and control of energy use. To reduce energy waste without sacrificing comfort, smart thermostats, for example, may dynamically alter heating and cooling settings in response to occupancy and outside factors. Similarly, smart lighting solutions optimise energy use even further by dynamically adjusting brightness levels and usage patterns. Green Internet of Things (IoT) solutions installed in smart homes may greatly improve energy efficiency and help reduce the impact of climate change. This is seen in the diagram. Transforming conventional houses into "smart homes" through the use of cutting-edge technology is the overarching concept. Designed to optimise energy use and enhance the total environmental imprint, these homes contain different automated and networked technologies. The green Internet of Things (IoT) solutions are the hub of this shift because they bring together smart technology with sustainable behaviours. Various methods and technologies designed to increase energy efficiency and decrease waste make up these solutions. One example is the smart thermostat, which uses the user's preferences and real-time weather data to precisely regulate the heating and cooling systems, cutting down on wasteful energy usage. Another way to minimise energy use is using smart lighting systems. These systems control the lights and alter their brightness based on factors like the amount of natural light in the space and how many people are in it. Another major step forward is the incorporation of Internet of Things (IoT) devices into smart homes. From refrigerators to washing machines, these appliances are fitted with sensors and software that allow them to run at their most efficient, cutting down on energy use and operating expenses even more. Renewable energy sources, like solar panels or wind turbines, are another crucial part of green IoT solutions. They supply clean, sustainable electricity to run these smart systems and gadgets. Data monitoring is an essential part of these integrated systems. It continually gathers and analyses different kinds of usage and environmental data. With this information, the smart home's automated systems may make informed decisions regarding energy use, such as altering device power consumption or heating and cooling system operational periods in response to projected weather changes or user behaviours. The integration of these environmentally friendly Internet of Things technologies into smart homes is driven by the desire to optimise energy use. Because less energy is needed from fossil fuels and more sustainable methods are used, the home's carbon footprint is significantly reduced as a result of this optimisation. The increased energy efficiency that these systems provide helps reduce the impact of climate change and also helps homes save money. Green Internet of Things (IoT) solutions for smart homes provide hope for a better future by decreasing emissions of greenhouse gases and increasing the usage of renewable energy.

Figure 1. Impact of green IOT enabled smart homes



In smart homes, Green IoT is essential for more than just energy savings; it also promotes grid stability and the integration of renewable energy sources. For example, solar panels that are Internet of Things (IoT) enabled may adjust their output according to the current weather and electrical demand, which helps to decentralise energy production and decreases the need for traditional power plants. Also, by analysing data and using machine learning algorithms, IoT platforms can figure out how much energy will be needed, where the inefficiencies are, and how to save energy for each individual user. This way, they can make better decisions that help the environment. In addition to personal advantages, there are larger social and environmental consequences associated with smart home adoption of Green IoT. Utilities may better control peak loads and increase grid resilience with the help of smart grids and demand response mechanisms made possible by IoT ecosystems that aggregate data from linked devices. Additionally, worldwide initiatives to lessen the impact of climate change and cut emissions of greenhouse gases benefit from the multiplicative influence of energy savings in a large number of smart houses. To sum up, home energy management is undergoing a sea change due to the integration of sustainable practices with the Internet of Things. By providing a scalable method to decrease energy usage and improve sustainability in the age of smart homes, green IoT solutions enable homeowners to adopt eco-friendly lifestyles without compromising on comfort or convenience. The potential of Green IoT to reshape domestic energy dynamics and advance a greener future is highlighted in this introduction, which lays the groundwork for a thorough examination of the technological, environmental, and social consequences of smart houses.

Review of Literature

In their discussion of smart sustainable city development, Kumaran et al. (2021) outline the creation of an Internet of Things (IoT)-based green home architecture that can determine a household's green score. This system tracks daily resource use and comes up with a "green score" to encourage less energy use, more renewable energy generation, and less pollution by

means of a tax exemption system that is dependent on the green score. The goal of incorporating Internet of Things (IoT) technologies into smart homes is to improve energy efficiency and sustainability by reducing consumption of non-renewable resources and increasing production of renewable energy. This model is in line with this purpose.

To optimise energy usage in smart buildings while balancing user comfort and CO_2 emissions, Constantinou et al. (2022) offer a novel architecture called IoT Meta-Control Firewall (IMCF+) that is combined with a Green Planner algorithm. Their study, which was conducted inside the openHAB ecosystem, shows that there is a way to improve smart home energy self-consumption by reducing CO2 emissions significantly while keeping comfort levels relatively unchanged. In line with Green IoT's aims, this helps create smarter, more sustainable homes by making the most of renewable energy sources and cutting down on energy waste.

Within the context of green city Internet of Things (IoT) networks, Aliero et al. (2021) investigate the possibilities and threats posed by Smart Home Energy Management Systems (SHEMs). They bring attention to the construction sector's high energy use and the necessity of efficient management to reduce wasteful usage. If we want smart homes that are both energy efficient and improve people's quality of life, the research says we need to make sure SHEMs are secure, private, scalable, and interoperable. Findings from this study highlight the importance of constantly enhancing IoT networks to facilitate eco-friendly city life.

In order to establish a sustainable environment, Arshad et al. (2017) offer an overview of Green IoT, which focusses on techniques to minimise energy usage across IoT devices. Essential components in minimising the environmental effect of IoT devices include energy-efficient datacenters, transmission methods, and rules. In order to ensure the continued success of Internet of Things (IoT) technologies in smart homes and elsewhere, the study stresses the significance of implementing environmentally friendly policies across the IoT ecosystem.

Identifying obstacles and introducing new energy management approaches, Benhamaid et al. (2022) provide an exhaustive review of current developments in Green-IoT energy management. Their findings highlight the need of efficient energy management in IoT networks for lowering environmental impact and extending device life between battery changes. In addition to outlining potential future research avenues, the poll offers suggestions for new energy-saving strategies that might improve the long-term viability of Internet of Things (IoT) applications in smart homes.

Abedin et al. (2015) examine the difficulties and potential solutions to improve the energy efficiency of IoT networks by utilising a G-IoT system model. They deal with the problem of insufficient power supplies for Internet of Things devices, especially sensors, which frequently function in hostile environments. Through optimising energy usage across heterogeneous IoT-driven networks, the suggested approach seeks to enhance the life expectancy and capacity of these devices. This study is crucial for incorporating IoT into

energy-efficient smart home designs since it guarantees the network's durability and helps achieve the larger objective of decreasing environmental consequences.

The enormous increase in the number of IoT devices and the resulting increase in carbon footprint and greenhouse gas emissions are the primary concerns of Sharma and Panwar (2020), who investigate the effects of IoT devices on the environment. Aiming to reduce environmental deterioration while boosting sustainability, their research centres on migrating from traditional IoT to Green IoT. To enhance smart device lifespan evaluations, a Green IoT framework employs data mining and deep learning. Important as it is to draw attention to the problems caused by the proliferation of IoT devices, this article also offers solutions to these problems by promoting greener habits.

Through their analysis of energy harvesting methods, Adila, Husam, and Husi (2018) tackle the pressing issue of powering Internet of Things devices. In order to create Internet of Things (IoT) devices that can power themselves using energy from their surroundings, this study examines several design and power management factors. This research is crucial for the progress of Green IoT since it provides solutions that make IoT devices last longer and use less energy that isn't renewable. This helps with smart environment sustainability goals.

By focussing on the environmental problems caused by conventional Internet of Things (IoT) systems including energy consumption and electronic waste, Seth, Dalal, and Dahiya (2021) examine the real-world consequences of Green IoT within the framework of smart cities. In order to guarantee energy efficiency and decrease carbon emissions, they stress that smart city designers must implement Green IoT principles. Green IoT applications that are both safe and interoperable are the focus of this chapter's overview of existing research and prospective technology. Future smart cities may use this all-encompassing research as a roadmap to create environmentally conscious, technologically sophisticated, and sustainable communities.

The literature study highlights the importance of Green IoT in improving sustainability and lowering the environmental impact of smart home and city infrastructures. From novel frameworks to models and management techniques for energy-efficient systems, the research covered a lot of ground, all with the goal of lowering carbon emissions without sacrificing user comfort or energy usage. Despite these developments, there is still a huge knowledge vacuum when it comes to applying these technologies in the actual world. Longitudinal studies that evaluate the resilience and flexibility of Green IoT solutions in varied and ever-changing urban settings are under-researched compared to studies that concentrate on theoretical models or testing in controlled environments.

This research intends to fill that void by investigating how smart city models could facilitate the implementation and ongoing assessment of Green IoT systems. Through the integration of these systems in a real-life urban setting and continuous performance monitoring, this study aims to offer concrete data on the effectiveness, difficulties, and sustainability of Green IoT applications. This method provides a holistic view of the use of Green IoT technologies in real-world settings by improving upon theoretical constructs already present in the

literature and by providing practical insights and answers to the problems that have been discovered.

Objectives of the study

1. To assess the perception of employees in the real estate and IT sectors on the effectiveness of Green IoT in reducing energy consumption in smart homes.
2. To evaluate the perceived potential of Green IoT technologies in enhancing sustainability in smart homes, according to employees within the real estate and IT sectors.

Hypotheses

H1: Using green IOT for smart homes reduces energy consumption according to the perception of the employees working in the real estate and IT Sector.

H2: Green IoT for Smart Homes has the potential to enhance sustainability according the perceptions of the employees working in the real estate and IT sector.

Research Methodology

In this study, a quantitative research methodology was employed to investigate the perceptions of employees in the real estate and IT sectors regarding the effectiveness and potential of Green IoT in smart homes. A structured questionnaire was designed to collect data on participants' perceptions of how Green IoT technologies influence energy consumption and sustainability in smart homes. The questionnaire included Likert-scale questions, which were distributed electronically to a random sample of 345 employees from both sectors in Pune City. The responses were then statistically analysed using SPSS to test the hypotheses. Specifically, descriptive statistics were used to summarize the data, and inferential statistical techniques, such as t-tests, were utilized to examine the differences in perceptions and to assess the strength of the relationship between the use of Green IoT and perceived improvements in energy efficiency and sustainability.

Data Analysis

Table 1. Impact on Sustainability

	Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree	
	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %
Green IoT technologies play a crucial role in making smart homes more environmentally sustainable.	12	3.5%	8	2.3%	5	1.4%	198	57.4%	122	35.4%

I perceive that Green IoT solutions enhance the long-term sustainability of living environments.	5	1.4%	10	2.9%	9	2.6%	155	44.9%	166	48.1%
The use of Green IoT in smart homes effectively reduces the environmental impact of urban living.	3	0.9%	7	2.0%	11	3.2%	177	51.3%	147	42.6%
Smart homes equipped with Green IoT technologies contribute significantly to the conservation of natural resources.	5	1.4%	8	2.3%	6	1.7%	179	51.9%	147	42.6%
I support the integration of Green IoT devices in homes as a means to promote sustainable urban development.	4	1.2%	10	2.9%	12	3.5%	139	40.3%	180	52.2%

The survey results from Table 1 provide a detailed insight into the perceptions of the effectiveness of Green IoT technologies in promoting environmental sustainability in smart homes. For the statement "Green IoT technologies play a crucial role in making smart homes more environmentally sustainable," a significant majority of respondents (92.8%) agree or strongly agree, underscoring a widespread consensus on the vital role of Green IoT in enhancing the sustainability of smart homes. The high agreement rate highlights that most participants recognize the direct benefits of Green IoT technologies in making residential living more eco-friendly. This suggests strong support for further integrating these technologies into smart home designs to push the envelope on sustainable urban living. In response to "I perceive that Green IoT solutions enhance the long-term sustainability of living environments," 92.9% of the participants agree or strongly agree, indicating a robust confidence among the respondents in the long-term benefits of Green IoT. The perception that these technologies not only provide immediate environmental benefits but also enhance long-term sustainability reflects a deep understanding and appreciation of the potential

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extended impacts of Green IoT on living environments. This strong endorsement could drive continued consumer demand and support for sustainability-focused innovations in smart home technology. Regarding the statement "The use of Green IoT in smart homes effectively reduces the environmental impact of urban living," 93.9% of the responses were either agree or strongly agree. This reflects a strong belief that Green IoT technologies are effective tools in mitigating the broader environmental challenges posed by urban centers. The substantial agreement suggests that Green IoT is seen not just as a technological upgrade but as a necessary evolution towards more sustainable urban ecosystems. For "Smart homes equipped with Green IoT technologies contribute significantly to the conservation of natural resources," again, a vast majority (94.5%) agree or strongly agree, emphasizing the perceived effectiveness of Green IoT in resource conservation. This aligns with the growing environmental concerns worldwide and the push towards more sustainable resource usage, indicating that Green IoT is considered a practical solution to pressing ecological issues. Lastly, the statement "I support the integration of Green IoT devices in homes as a means to promote sustainable urban development" received the strongest support, with 92.5% of participants agreeing or strongly agreeing. This shows a high level of support for the proactive adoption of Green IoT technologies in urban planning and development strategies. The broad endorsement can serve as a strong foundation for policymakers and developers to intensify efforts towards incorporating Green IoT solutions in future urban development projects to ensure sustainability is a cornerstone of growth. Overall, the responses strongly suggest that there is a robust belief in the positive impact of Green IoT technologies on the environmental sustainability of smart homes and urban environments. This broad consensus reflects a critical acknowledgment of the role of technology in addressing environmental sustainability challenges.

Table 2. Power consumption

	Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree	
	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %
I believe that integrating Green IoT devices in smart homes significantly lowers energy consumption.	6	1.7%	5	1.4%	6	1.7%	124	35.9%	204	59.1%

Green IoT technologies are effective in monitoring and reducing excessive energy use in my home.	12	3.5%	10	2.9%	23	6.7%	204	59.1%	96	27.8%
The adoption of Green IoT solutions has led to a noticeable decrease in my home's energy bills.	6	1.7%	12	3.5%	7	2.0%	183	53.0%	137	39.7%
Smart home technologies using Green IoT effectively manage energy resources to optimize consumption.	12	3.5%	9	2.6%	3	0.9%	175	50.7%	146	42.3%
The implementation of Green IoT in smart homes contributes to overall energy saving.	11	3.2%	5	1.4%	7	2.0%	207	60.0%	115	33.3%

The data from Table 2 paints a compelling picture of the perceived effectiveness of Green IoT devices in reducing energy consumption and managing energy resources in smart homes, highlighting substantial support among respondents. Starting with the statement, "I believe that integrating Green IoT devices in smart homes significantly lowers energy consumption," an overwhelming majority (94.9%) of respondents either agree or strongly agree. This indicates a strong conviction among the participants that Green IoT devices are a key factor in reducing energy consumption within their homes. Such a high level of agreement suggests that most people are experiencing tangible benefits from these technologies, which may include lower energy usage and possibly decreased utility bills, leading to broader acceptance and enthusiasm for further adoption of Green IoT solutions. The response to "Green IoT technologies are effective in monitoring and reducing excessive energy use in my home" also underscores the perceived utility of these technologies, with 86.9% of participants agreeing or strongly agreeing. However, a slightly higher proportion of neutrality and disagreement (13.1%) compared to the first statement suggests some variability in user experiences or expectations regarding the monitoring capabilities of Green IoT technologies. This indicates a need for continued improvement and communication about the capabilities of these devices

to ensure wider satisfaction and acceptance. Concerning the statement, "The adoption of Green IoT solutions has led to a noticeable decrease in my home's energy bills," a significant majority (92.7%) of respondents still recognize the financial benefits of Green IoT, agreeing or strongly agreeing that these technologies have positively impacted their energy expenditures. This tangible financial benefit is crucial for broader consumer buy-in and supports the case for continued investment in Green IoT technologies by both consumers and providers. For the assertion that "Smart home technologies using Green IoT effectively manage energy resources to optimize consumption," 93% of the responses fall into the agree and strongly agree categories, reinforcing the sentiment that Green IoT not only reduces energy consumption but also optimizes the use of resources. This perception likely reflects a broad acknowledgment of the efficiency and functionality of smart technologies in managing day-to-day energy needs in a more sustainable manner. Lastly, regarding "The implementation of Green IoT in smart homes contributes to overall energy saving," 93.3% of participants agree or strongly agree, underscoring a comprehensive endorsement of Green IoT's role in energy conservation. The high agreement rate across all statements confirms a widespread belief in the effectiveness of Green IoT technologies, not just in terms of energy savings but also in the holistic management and optimization of energy consumption in smart homes. Overall, the data from Table 2 affirms that there is a strong belief among respondents that Green IoT technologies significantly contribute to reducing and managing energy consumption in smart homes. This consistent pattern of high agreement across various aspects of energy management suggests a solid foundation for the continued expansion and enhancement of Green IoT solutions in the residential sector.

H1: Using green IOT for smart homes reduces energy consumption according to the perception of the employees working in the real estate and IT Sector.

Table 3. One-Sample Test

	TV=3					
					95%CI	
	t	df	Sig	Diff	L	U
I believe that integrating Green IoT devices in smart homes significantly lowers energy consumption.	36.342	344	.000	1.49275	1.4120	1.5735
Green IoT technologies are effective in monitoring and reducing excessive energy use in my home.	22.157	344	.000	1.04928	.9561	1.1424
The adoption of Green IoT solutions has led to a noticeable decrease in my home's energy bills.	28.918	344	.000	1.25507	1.1697	1.3404
Smart home technologies using Green IoT effectively manage energy resources to optimize consumption.	26.372	344	.000	1.25797	1.1641	1.3518
The implementation of Green IoT in smart homes contributes to overall energy saving.	27.069	344	.000	1.18841	1.1021	1.2748

The one-sample t-test results provide robust statistical evidence supporting Hypothesis 1, which suggests that the use of Green IoT technologies in smart homes is perceived to significantly reduce energy consumption among employees in the real estate and IT sectors. Each of the statements tested shows a mean difference significantly greater than the test value of 3, with extremely low p-values, indicating a very strong agreement across all items. The first statement, "I believe that integrating Green IoT devices in smart homes significantly lowers energy consumption," yielded an exceptionally high t-value of 36.342 and a mean difference of 1.49275 from the neutral test value. This result highlights an overwhelmingly positive perception towards Green IoT devices and their impact on energy efficiency. The confidence interval, tightly bound between 1.4120 and 1.5735, underscores the consistency of this perception among respondents. This strong endorsement reflects a general consensus that integrating these technologies into homes is a crucial step towards achieving significant reductions in energy consumption. Regarding the second statement, "Green IoT technologies are effective in monitoring and reducing excessive energy use in my home," a t-value of 22.157 with a mean difference of 1.04928 further reinforces the effectiveness of Green IoT. Although the mean difference here is slightly lower than the first, it still significantly supports the effectiveness of Green IoT technologies in monitoring and actively reducing unnecessary energy usage. The confidence interval from .9561 to 1.1424 demonstrates a solid belief in the capabilities of these technologies to enhance energy efficiency. The third statement, "The adoption of Green IoT solutions has led to a noticeable decrease in my home's energy bills," shows a t-value of 28.918 and a mean difference of 1.25507, indicating that the financial benefits of Green IoT are clearly recognized. This not only suggests perceived effectiveness in energy reduction but also reflects the economic impact of these savings, making Green IoT an attractive proposition for homeowners. The confidence interval, ranging from 1.1697 to 1.3404, points to strong agreement about the economic advantages provided by Green IoT. In response to "Smart home technologies using Green IoT effectively manage energy resources to optimize consumption," the results (t-value of 26.372 and mean difference of 1.25797) suggest that Green IoT is not only about reducing energy use but also about smarter management of energy resources. This capability to optimize energy usage further extends the perceived benefits of Green IoT, underlining its role in enhancing overall energy management practices within homes. Lastly, "The implementation of Green IoT in smart homes contributes to overall energy saving" garnered a t-value of 27.069 and a mean difference of 1.18841. This statement wraps up the strong endorsement of Green IoT's role in energy conservation, reflecting a comprehensive view that these technologies are critical in making energy savings a practical reality for smart homes. Overall, these findings convincingly validate the hypothesis that Green IoT technologies are perceived as effective tools in reducing and managing energy consumption in smart homes. The significant statistical support across different facets of energy consumption underscores the broad acceptance and recognition of the benefits of Green IoT among the surveyed employees.

H2: Green IoT for Smart Homes has the potential to enhance sustainability according the perceptions of the employees working in the real estate and IT sector.

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Table 4. One-Sample Test

	TV=3					
					95% CI	
	T	df	Sig	Diff	L	U
Green IoT technologies play a crucial role in making smart homes more environmentally sustainable.	25.650	344	.000	1.18841	1.0973	1.2795
I perceive that Green IoT solutions enhance the long-term sustainability of living environments.	31.666	344	.000	1.35362	1.2695	1.4377
The use of Green IoT in smart homes effectively reduces the environmental impact of urban living.	34.474	344	.000	1.32754	1.2518	1.4033
Smart homes equipped with Green IoT technologies contribute significantly to the conservation of natural resources.	32.542	344	.000	1.31884	1.2391	1.3986
I support the integration of Green IoT devices in homes as a means to promote sustainable urban development.	32.803	344	.000	1.39420	1.3106	1.4778

The findings from Table 4 strongly affirm Hypothesis 2, which suggests that Green IoT for smart homes is perceived by employees in the real estate and IT sectors as a significant enhancer of sustainability. Each statement evaluated shows a substantial positive mean difference from the test value of 3, supported by very low p-values, indicating that these perceptions are widely held and statistically significant. The first statement, "Green IoT technologies play a crucial role in making smart homes more environmentally sustainable," achieved a t-value of 25.650, with a mean difference of 1.18841. This strong statistical backing highlights a broad consensus on the critical role of Green IoT technologies in promoting environmental sustainability within smart homes. The confidence interval ranging from 1.0973 to 1.2795 underscores the consistency and reliability of these perceptions, suggesting that such technologies are not merely adjuncts but are central to the sustainability strategies of smart homes. In response to the second statement, "I perceive that Green IoT solutions enhance the long-term sustainability of living environments," a very high t-value of 31.666 and a mean difference of 1.35362 further strengthen the view that Green IoT solutions are pivotal for the long-term sustainability of living environments. This recognition of long-term benefits indicates that the advantages of Green IoT extend beyond immediate environmental impacts to enduring sustainability practices, reflected in a confidence interval from 1.2695 to 1.4377, highlighting a strong belief in the sustainable future promised by Green IoT technologies. The third statement, "The use of Green IoT in smart homes effectively reduces the environmental impact of urban living," shows a t-value of 34.474 and a mean difference of 1.32754, emphasizing the perception that Green IoT has a tangible and significant effect on reducing urban environmental impacts. This result points to a clear acknowledgment among professionals that smart home technologies can play a transformative role in making urban living more ecologically friendly, with the confidence

interval of 1.2518 to 1.4033 providing strong statistical support for this belief. Regarding the fourth statement, "Smart homes equipped with Green IoT technologies contribute significantly to the conservation of natural resources," a t-value of 32.542 and a mean difference of 1.31884 confirm the strong agreement on the substantial contribution of Green IoT to resource conservation. This perception supports the role of Green IoT in ensuring more efficient use of resources, crucial for sustainability, with a confidence interval from 1.2391 to 1.3986 reinforcing this view. Finally, the statement "I support the integration of Green IoT devices in homes as a means to promote sustainable urban development" received a t-value of 32.803 and a mean difference of 1.39420. This finding indicates a robust endorsement of Green IoT devices as key elements in sustainable urban development strategies, demonstrating a forward-thinking approach towards integrating technology for ecological benefits, as evidenced by the confidence interval from 1.3106 to 1.4778. Overall, these results provide compelling evidence supporting the hypothesis that Green IoT technologies are viewed as crucial tools for enhancing sustainability in smart homes, as perceived by employees in the real estate and IT sectors. The unanimous statistical support across all statements suggests that these technologies are widely recognized for their potential to drive significant environmental improvements in urban living environments.

Findings

The findings from the statistical analysis strongly support the notion that Green IoT technologies are perceived by employees in the real estate and IT sectors as essential contributors to reducing energy consumption and enhancing sustainability in smart homes. Specifically, the responses overwhelmingly indicate that these technologies not only play a crucial role in actively lowering energy use but also in managing and optimizing energy resources more efficiently. For example, a significant majority of participants agreed that integrating Green IoT devices leads to substantial reductions in home energy consumption and noticeable decreases in energy bills. This highlights a widespread belief in the tangible economic and ecological benefits offered by these technologies, reflecting a positive reception that could encourage wider adoption and integration into residential properties.

Moreover, the perceptions extend to recognizing the profound impact of Green IoT on environmental sustainability. Employees in the study consistently reported strong agreement that these technologies are pivotal for making smart homes environmentally sustainable and for contributing significantly to the conservation of natural resources. The high levels of agreement on statements regarding the effectiveness of Green IoT in reducing the environmental impact of urban living and promoting sustainable urban development underline a broad consensus on the ecological value of these innovations. Such perceptions suggest that Green IoT is seen not just as a technological improvement but as a critical component of future-oriented, sustainable urban planning. The data thus reveals a robust endorsement of Green IoT technologies, emphasizing their integral role in advancing eco-friendly living environments and supporting sustainable urban development strategies.

Conclusion

The conclusions drawn from this study clearly illustrate that Green IoT technologies are widely recognized and valued for their capability to enhance energy efficiency and sustainability in smart homes. This recognition is not only based on their potential to reduce energy consumption and costs but also on their ability to contribute significantly to environmental sustainability. These findings are critical as they underscore the growing acceptance and perceived effectiveness of Green IoT technologies among professionals in the real estate and IT sectors. Such insights are indicative of a broader trend towards embracing technology-driven solutions that align with global sustainability goals, positioning Green IoT as a cornerstone technology in the evolution of smart, sustainable urban living.

The implications of these findings are manifold and extend across various stakeholders including policymakers, urban planners, technology developers, and real estate developers. For policymakers and urban planners, the strong endorsement of Green IoT technologies suggests the need for supportive policies and initiatives that foster the integration of these technologies into broader urban development projects. Incentives for the adoption of Green IoT could accelerate their uptake, contributing to energy conservation and environmental sustainability objectives at municipal and national levels. For technology developers and providers, these results highlight the importance of continuous innovation and improvement of IoT solutions to meet the increasing demands for functionality and efficiency. Real estate developers can also leverage these insights to differentiate their offerings by incorporating Green IoT technologies into their projects, thereby attracting environmentally conscious consumers and potentially commanding a premium in the market.

Considering future research, there is a clear avenue for examining the longitudinal impacts of Green IoT implementations in smart homes. Such studies could assess the sustained benefits and challenges of these technologies over longer periods, providing deeper insights into their long-term efficacy and user satisfaction. Additionally, comparative research across different geographic and socio-economic contexts could elucidate variances in the adoption and impacts of Green IoT, offering a more nuanced understanding of its global applicability and potential barriers. Finally, qualitative research involving detailed user experiences and case studies could complement the quantitative data, offering richer insights into how individuals interact with Green IoT technologies on a daily basis and how these interactions influence perceptions of technology efficacy and sustainability contributions.

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