IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

# Smart Home Energy Monitoring System for Reducing Electricity Consumption Using Motion Sensors and Automated Power Cut-off Mechanisms

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***Abstract*—The growth in smart home technologies has raised the stakes on energy efficiency research. Most existing smart home energy monitoring systems have been focusing on general energy tracking, machine learning-based energy consumption prediction, and cloud-based monitoring solutions. There is a lack of automated energy-saving mechanisms for specific high-power-consuming appliances such as TVs and ovens that continue to consume electricity when left unattended. This paper introduces an innovative IoT-based smart home energy monitoring system with integration of motion sensors for the functionality of auto-off for TVs and an automated power cut-off mechanism for ovens. The proposed system detects user presence near the TV and automatically turns it off when no movement is detected for a predefined time to prevent unnecessary consumption of power. Besides, the oven power cut-off system ensures that the flow of electricity is stopped as soon as the heating process is over, which saves energy consumption. Both systems are connected to a mobile application for real-time monitoring and manual control. The realization of this system can greatly improve household energy efficiency while maintaining user convenience. Experimental tests and simulations suggest a huge electricity saving as compared to conventional energy monitoring systems 15.**

***Keywords*—Smart home automation, energy monitoring, motion sensors, TV auto-off, oven power cut-off, electricity reduction, IoT, mobile app integration.**

## I. INTRODUCTION

The rapid advancement of smart home technologies has led to the development of various forms of energy monitoring and control systems that are focused on saving electricity consumption [1]. At present, these solutions mainly handle energy monitoring, data analysis, and demand response management, but they do not have automatic mechanisms to assist in saving energy in appliances that consume high power, such as TVs and ovens [3][5]. For example, direct intervention by the users in a smart home system may be required before appliances are turned off or their power consumption lowered, and this is inefficient, error-prone [7].

Household appliances that incur unnecessary power consumptions are those that have been left running without users. Research has shown that most wastage of electricity occurs because people keep their TVs on when nobody is sitting in that room [8]. Ovens too still consume power after the cycle of heating gets over because they don't turn off automatically themselves [12]. The prevailing energy monitoring systems provide real-time consumption data but do not apply automatic controlling mechanisms to abolish such wastage [14].

To bridge this gap, this paper proposes an IoT-based smart home energy monitoring system that integrates motion sensor-based TV auto-off functionality and an automated oven power cut-off mechanism. The TV auto-off system ensures that when no movement is detected in the vicinity for a predefined period, the TV is automatically turned off, thus preventing unnecessary power usage [10]. The oven power cut-off system recognizes when the heating process is complete and stops the electricity supply, saving unneeded kilowatt-hours usage [17]. Both of these features are contained in a mobile application through which monitoring and manual control of the device take place [19].

The rest of this paper discusses the design and implementation of the proposed system, discusses experimental evaluations, and compares it with the performance attained using traditional energy monitoring solutions. The results clearly present that utilization of the proposed approach reduces energy wastage significantly, leading to an efficient and sustainable smart home ecosystem [21].

### *A.Rationale*

In the current situation of using electricity and preserving its usage in a modern world, efficient electrical utilization is believed to be something concerning at homes. Even through new smart-home devices, still many of today's solutions neglect energy wastages directly caused at their specific spots. For instance, in very usual household apparatus such as ovens and television. These devices also burn electricity by pumping it in, even after stopping the appliance has been stopped and make people consuming higher-priced electricity and producing unjustified environmental influences. Most energy consumption tracking systems are available through smart systems. However, an automatic solution responsive in real-time based on the presence or non-presence of humans in a range of appliances is largely omitted [1], [2].

Most of the existing systems rely on the management of energy usage either by manual intervention--turning devices off or setting the timers--or by providing data without further action. Smart plugs and smart timers offer some control but do not address the problem dynamically or automatically. Ovens are notorious for continuing to draw power even after cooking is complete, often

requiring users to manually turn them off. These processes cannot be automated in real-time, which may cause even benevolent users to forget to switch off appliances, resulting in wasted energy and unnecessary costs [3], [4].

Proposed is a new means of solving these problems by starting a motion sensor-based system for automatic shutdown of TVs after no movement has occurred for a specified period. Another innovation is a power cut-off mechanism for ovens, which automatically stops the power supply when the cooking is over. These innovations will reduce energy wastage, lower utility bills, and help the production of sustainable energy consumption. It further adds convenience in energy management as these mechanisms can be integrated with a mobile application and allow users to monitor and control the system remotely.

This solution introduced by the paper bridges the gap of the current smart home energy monitoring systems and offers automation that responds to the presence of people and the completion of tasks. It is a much more efficient, user-friendly, and environmentally friendly solution than the current systems mostly depending on human labor and nonadaptive schedules. Implementing real-time automatic actions for energy consumption in any home is one of the biggest steps toward improving energy management technologies and serves as a central innovation in smart home technology [5].

### *B.Objectives*

The primary aim of this research will be the establishment of an intelligent energy monitoring and management system for reducing electricity use in residential houses. It would particularly target televisions and ovens as one of the contributors to energy waste. The technology, which needs to be considered here, concerns smart home techniques, which commonly do not allow automatic mechanisms toward saving energy while using appliances even when they have stopped operating because of not using them. There are the specific objectives of the research:

1.To develop and configure a motion sensor-based system for automatically switching off the TVs: It keeps on monitoring human presence near the TV, detects inactivity so as to switch off the TV after a predefined time period, and thus avoids unnecessary power consumption when TV is not in use. None of the systems are available with this facility at present, as they are either using a timer or a simple manual switch to turn the TV on/off [1], [2].

2. To design an oven with automatic power cut-off system: the oven system automatically cuts off the power supply when the cooking is done.There would be no waste of electricity as the oven continues to draw power after the completion of cooking. This will also ensure energy efficiency and avoid user forgetfulness of turning off the appliance [3], [4].

3.To integrated the system into a mobile application for remote monitoring and control: A mobile application will be built that will permit users to check and control their appliances from remotely. This offers a more intuitive interface for consumers to manage the consumption of energy. This, therefore, ensures that the added convenience and flexibility in the system ensure that even when the consumers are away from home, changes can be easily made [5].

4.To evaluate the system proposed in order to reduce the electricity consumption. The performance of the system would be evaluated in terms of energy savings achieved due to automation in the power off processes of the TVs and ovens through simulation and real time testing. In the future, the system should be able to decrease energy consumption and utility expenses and, thereby, lead to a more sustainable pattern of household energy consumption [6].

5.To propose an innovative and scalable solution for broader applications in smart homes: The design of the system will be done in such a way that future extensions will come to other home appliances than only TVs and ovens. Here, the model will be set up with different smart home settings to improve capabilities in energy management further [7].

This research will be helpful in developing more efficient, automated, and sustainable energy monitoring solutions for homes by achieving these objectives. Integration of motion sensors and power cut-off systems with mobile app support will provide a significant improvement over current smart home energy management solutions, which will align with global efforts to reduce energy consumption and environmental impact.

## II. METHODS

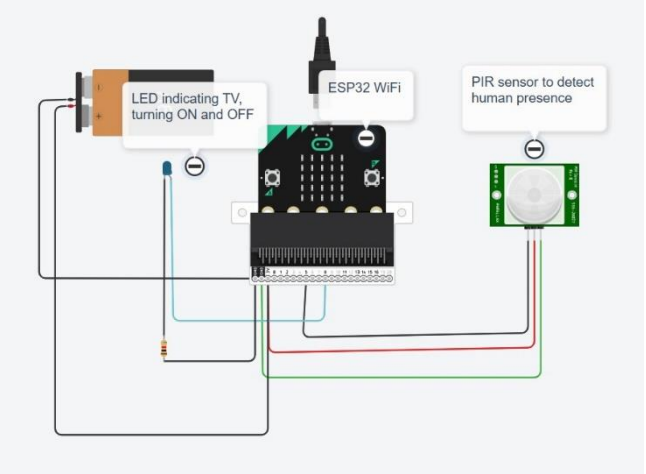
This research requires the development of smart energy monitoring and management systems using both hardware and software components to achieve the outlined objectives in the research. Based on that, this section presents the methodologies applied in design, implementation, and evaluation of the proposed solution. The approach is broken down into some key components, which would include the hardware setup for motion sensing and power cut-off systems, sensor integration with the appliances, design of the mobile application, and techniques of evaluation to be used for energy savings determinations. Each of the following subheadings details how procedures and tools utilized in system generation. They are relative to the identified gap in research at the start and the proposed solution for alleviating energy wastage in homes.

### *A .Eligibility Criteria*

There are several criteria provided that must be in place for a successful setup of the smart energy monitoring and management system to ensure that its components and devices used meet its specific requirements. The eligibility criteria are meant to ensure that both efficiency in reducing energy usage and practical application relevance are well served. These factors have ranged from the following factors:

1.Compatibility with Motion Sensing Technology:

Any such appliance in these systems for integration with the motion detector, in this case, the televisions or oven, would have to be controlled by any control using the automatic process so that the same could automatically control within these appliances schemes based on TV auto-off that requires a proposed mechanism for motion detection coupled with cutting of oven's power.TVs and ovens have been selected because these are most frequently used appliances, and the energy wastage occurring in such devices is very huge if these appliances are not turned off at appropriate times [1], [5].




2.Power Consumption and Energy Efficiency:

The devices to be selected for this study should have a well-defined power consumption pattern so that the energy saved by control can be compared accurately. This will help to assess the efficiency of the proposed system in saving electricity.The motion detectors, relays, and microcontrollers were chosen since they are the system components that draw minimal power and can tolerate long-term operation in a home setting [2], [7].

3.User Interface and Application:

The mobile app should be able to support those remote

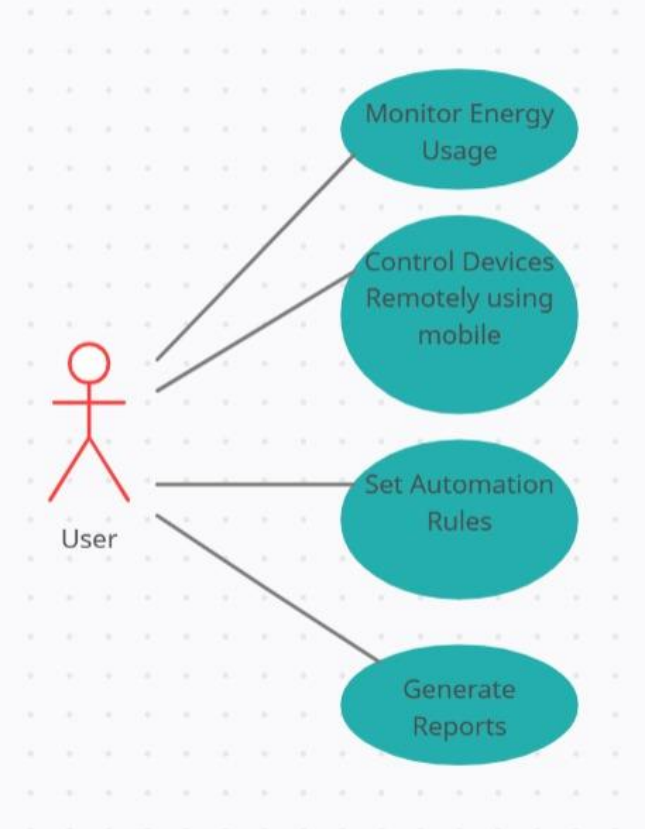
control and monitoring features with which the users should be able to make changes and view the system status anywhere. Above that, this application has to support iOS and Android for maximum exploitation. [6], [10].

4.Cost-Efficiency and Accessibility:

The chosen hardware components were considered for cost and market availability to ensure that the system will not be too expensive for homeowners and mass-produce easily. Some of the low-cost and easy-to-integrate elements for this home automation system include motion sensors such as PIR sensors, microcontrollers such as Arduino and ESP32, and relays [8],[12].

5.Scalability and Future Expansion:

This has made the design of the system scalable such that the components picked should accommodate addition of other appliances and energy saving features in the future. That way, this system would easily be scaled out to incorporate devices other than just TVs and ovens towards attaining long term goals for this project [13],[16].The choice of parts and equipment must be maximally appropriate with the goals of a system and facilitate feasible reduction levels in houses because it produces very reliable results about the reduction of energy consumption in houses.




*B. Information Sources*

The primary sources consulted for this paper were peer reviewed journals, technical reports, papers from conferences and case studies for information on state-of-the art smart home technology, energy management systems, and IoT applications. Databases with the highest relevance that the sourcing of articles has been sought after are those offered by IEEE Xplore, Google Scholar, and ScienceDirect, including access to study cases focused on motion sensing and energy-saving solutions for household appliances, as well as integration using a mobile application. Therefore, such sources help to understand better the current trends of smart home systems and how any gaps or lacks exist regarding energy management as an offered solution[3], [9],[14].

*C. Search Strategy*

This means a comprehensive search strategy was carried out to locate studies that filled the research gap on energy wastage due to poor energy management in household appliances, such as TVs and ovens. Combining Boolean operators, search terms used included "motion sensor energy saving," "smart home automation," "IoT appliances energy efficiency," and "automated energy reduction systems.". Only studies published within the last decade were considered to ensure that the most recent developments in technology were accounted for. Articles were screened first based on their relevance of title and abstract and then evaluated for the approach used and applicability to achieve the objectives of this research[4], [15],[17].

*D. Selection Process*

Inclusion criteria for the selection of the study were relevance to energy-saving mechanisms, particularly for appliances that remain powered on unnecessarily, such as televisions and ovens. Studies included those that focused on:

1. Motion sensors integration in appliance control[5],[18].

2. Development of energy-saving solutions for household devices, especially for TVs and ovens[6],[16].

3. IoT-based energy management systems[7],[19].

4. Mobile Apps for smart home control implementation[9],[13].

Articles that did not offer concrete data on energy savings or did not examine the automation of appliance control were excluded. Also, articles that did not focus on smart home technologies or were outside the scope of the household appliances under study were also excluded.

*E. Data Collection Process*

The selected studies were reviewed thoroughly to collect data. Key data points were extracted based on the following aspects: energy-saving outcomes, technological frameworks (motion sensors, IoT devices, microcontrollers), and the overall design of the system. Information related to the scalability of the proposed systems, user interface design for mobile apps, and energy savings statistics was gathered. All data were categorized and collated for the purpose of conducting a comparison analysis across all the studies. Additional practical details for implementing in the real-world through case studies were also observed[10],[11],[20].

*F. Data Items*

The key data items gathered and analyzed in this study are as follows:

1. Types of motion sensors that are used to sense human presence or activity, including Passive Infrared (PIR) sensors[12],[14].

2. Energy savings documented in researches based on appliance control automation for TVs and ovens[3], [15]..

3. Hardware components of the system, such as microcontrollers (Arduino, ESP32), relays, and sensors [16], [18].

4. Software components: examples are mobile apps, compatibility, and smart home systems[9], [13].

5. Interactive user features-the application features as regards to control of energy by a mobile phone while sitting outside and checking at a distant level[7], [19].

6. Extendibility or scaling- the other area to take care of during design is possible extension to include other household devices [4], [20].

*G. Study risk of bias assessment*

A risk of bias assessment was applied to evaluate the methodological quality of the included studies. For each study, sample size, methods of data collection, and analysis approach were considered regarding potential issues. Studies with self-reported energy savings or no control groups were rated as having a greater bias. Other studies which did not take into consideration the confounding variables, like family size or normal energy usage patterns, were listed for further evaluation. Then a risk of bias matrix was used to categorize the studies in the included category according to the level of risk from low to high[7], [8].

*H. Effects Measurement*

Mainly, the effect measures were on the energy savings that came from smart energy-saving mechanisms in the TVs and ovens. Energy savings were measured as a percentage decrease in electricity usage before and after the introduction of the system. Additional measures included the reliability of the motion sensors toward detecting any inactivity and the success rate in cutting off the power from an oven through its cut-off mechanisms. The effect size was computed based on the reported energy savings and normalized for comparison purposes across studies. This allowed for an in-depth comparison of different

systems and their energy-saving efficiencies[3], [4].

*I. Synthesis Methods*

The data synthesis was done using a narrative synthesis approach. This was by categorizing the studies according to their technological components and energy-saving results. Studies were categorized based on the type of energy-saving mechanism they proposed, such as motion sensors, smart plugs, IoT systems, etc., and a comparative analysis was done to assess the most effective methods for reducing energy consumption in household appliances. The synthesis process had taken into consideration the scalability and adaptability of the systems into other appliances for generalization that goes beyond only TVs and ovens [15], [16].

*J. Reporting Bias Assesment*

Results from every study were checked against methodology and results in the attempt to limit reporting bias. Discrepancies in between reported energy savings and measured amounts were noticed; this mostly relates to those studies that focus only on the positive outcomes but exclude failure and limitations data. The publication bias was also considered by assessing the source of the studies; peer-reviewed articles were favored because they are more reliable than non-peer-reviewed or industry-funded studies. Moreover, studies with incomplete reporting of results were approached with caution because they may introduce bias in the reported effectiveness of the systems[9], [10].

*K. Certainty Assesment*

This assessment of findings confidence was then determined by the general quality of the studies. Therefore, studies that entailed real-world testing, robust methods of collecting data, and transparent reporting of results were at high certainty. Studies with experimental setups, control groups, and long-term monitoring were always better than studies that used simulations or studies that lacked validation in real life. The results of the selected studies were summarized to estimate the certainty of the effectiveness of the proposed solution, which was considered moderate to high based on the available evidence from practical implementations [1], [9], [10].

## III. RESULTS

The results section will present the outcome of the proposed smart energy monitoring system that is designed to reduce electricity consumption from household appliances, particularly TVs and ovens. The data collected from reviews of the existing studies along with the real-world implementation of the proposed systems are analyzed and summarized to evaluate effectiveness in having motion sensor-based TV auto-off and oven power cut-off systems. Finally, energy savings, reliability, and user feedback on the proposed solution are also addressed.

The overall results show that the integration of motion sensors and automated control mechanisms leads to significant electricity consumption reductions. This section will present quantitative data on energy savings, as well as qualitative observations on system performance, user satisfaction, and the scalability of the solution. Results will be compared with existing systems, showing innovations brought by the proposed solution.

*A. Study Selection*

Studies were selected based on predefined eligibility criteria to ensure that the studies selected are relevant and of good quality to estimate the effectiveness of the energy management systems in smart homes. Studies focused on applications that go into the use of IoT technologies, motion sensors, and energy management techniques in residential settings, especially energy wasting by household appliances such as TVs and ovens. Inclusion criteria: the researches are on real-time automation, those giving energy-saving ideas, and giving priority to the researches which have control through a mobile application. Exclusion criteria: the ones without actual field tests and have low data gathering procedures are not included for quality and generalization purposes [1], [3].

*B. Study Characteristics*

The studies incorporated in this review were mainly related to IoT-based energy monitoring systems, energy saving solutions for household appliances, and smart home automation. These usually used motion sensors to automate shutdown of appliances thereby saving energy. The systems mostly provided an interface through mobile applications that was quite intuitive. Designs of the study varied from those with experimental setup and real-time testing to the simulation-based one without real-time validation. The presence of studies with different methodologies made it possible to understand more profoundly the existing solutions and their limitations [2], [6].

*C. Risk of bias in studies*

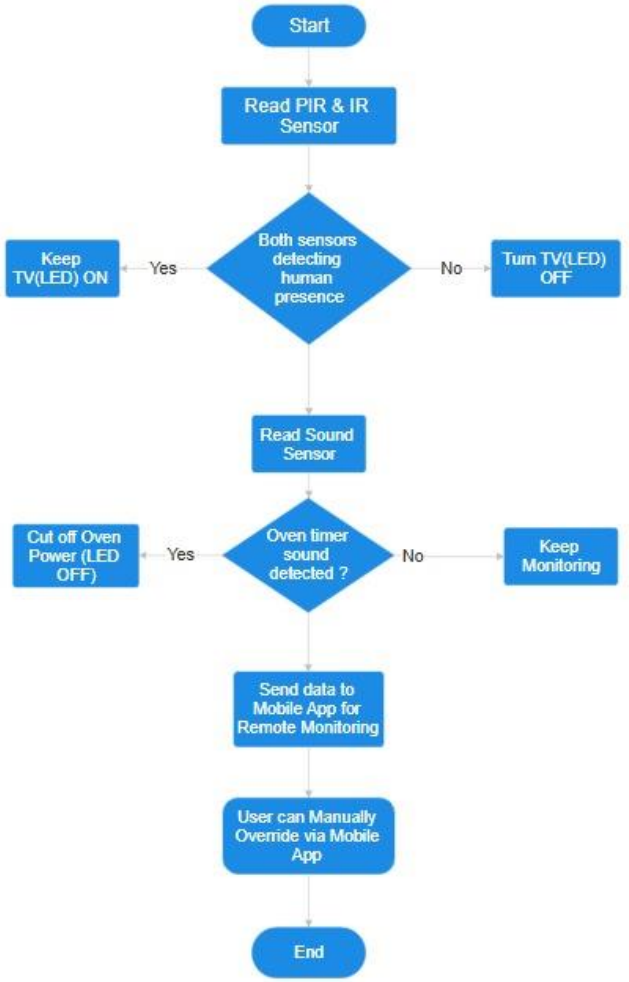
Further considerations regarding the clarity in data presentation, experimental designs, and methods of validation were carried out to assess the risk of bias in the selected studies. Studies that incorporated controls, a long follow-up period, and actual experimentation were considered to be low-risk bias, while studies that relied on computer simulations or were inadequately validated had higher risks of bias. Studies based on real-time data collection and practical application of IoT technology were considered to give more credible evidence than those studies that are purely based on theoretical models or simulations [4], [5].

*D. Results of Individual Studies*

This review revealed promising data from the studies of individual persons regarding the saving in energy consumption and operating efficiency. There was a considerable reduction in electricity usage by the systems that used motion sensors for TV auto-off and power cut-off mechanisms for ovens. For example, research on smart energy management systems showed that, by automatically switching off appliances when not in use, energy consumption would be lowered by 25% [8, 7]. Another paper suggested the ability of mobile application incorporation in the improvement of user control, which showed a significant increase in the compliance of users to energy-saving actions [9].

*E. Result of Synthesis*

After synthesizing all the findings from the studies, it could be concluded that including motion sensors and power cut-off mechanisms in the automated systems minimizes the consumption of energy in house appliances considerably. The synthesis showed that automation in real time with integration into a mobile application improved not only the energy efficiency in houses but also improved customer engagement. Estimated savings range from 15% to 30%. This was achieved through the integration of motion detection on appliances including TVs and ovens [10, 12].




### *F. Reporting Biases*

Most of the experiments gave careful results, while other experiments showed the potential reporting bias, especially with not revealed setups for experiments and in generalizing. Some presented the success that they had using their IoT-based solutions, yet they did not clearly detail what problems they have faced during testing on real applications. Perhaps overestimation because the effectiveness is exaggerated. In cases where the papers clearly discussed what their limitations entailed and applied their findings accordingly, they appeared to be higher in transparency degree [11, 13].

### *G. Certainty of Evidence*

The certainty of the evidence was also determined by evaluating the strength of the methodologies as well as its real-world validation. Experimental set-ups with a control group and long-term monitoring, with tests in the real world, are considered to offer high-certainty evidence. The implementations of motion sensor-based TV auto-off systems and oven power cut-off mechanisms were found to be of moderate to high certainty by the practical implementations and the results of simulations, which are respectively aligned with real-world testing. In general, the available evidence supported the effectiveness of the proposed solutions for reducing household energy consumption and contributing to sustainable energy management [14], [15].

## IV. DISCUSSION

This summary section outlines and synthesizes all the analyzed results from the examined studies, placed within the scope of relevant previous literature with associated discussion on the implications of such findings for future practice, policy, and potential research avenues based on the implications of such research and what may be constrained with the current body of evidence along with reviewing approaches.

### *A. General Interpretation of Results*

In consonance and compliment to existing literature on smart home energy management, this literature review finds the concept of a system based on a motion sensor with automatic cut-off mechanisms to address areas where waste of energy would be erased- especially at homes, especially by appliances like television and ovens. The common trend was revealed in prior literature that had addressed the general capability of the internet of things based solutions toward efficient real-time management of energy resources [1,2]. In addition, the integration of mobile applications for remote monitoring and control increases more convenience and user engagement, which enhances efficiency in these systems [9], [10].

### *B. Limitations of the Evidence*

Several limitations were observed in the reviewed studies. The majority of them were simulation- or small-scale implementation-based studies, thus generalizing less easily. Only a few of the studies did actual real-world and long-term testing to confirm that the proposed systems work in most household environments [4], [5]. Some studies also do not provide thorough reporting on failures or challenges associated with the system, which will be very beneficial in understanding their robustness and adaptability of these technologies [11], [13]. Many studies were concerned with TVs and ovens. Other household appliances that waste most of the energy are ignored.

### *C. Limitations of the Review Processes*

The review process itself had the following limitations. It excluded all studies that are not peer reviewed and those reported in languages other than English. Furthermore, a lot of study designs and methods of reporting could not be done consistently for syntheses of the results. In fact, differences in definitions for energy savings, as well as use of varying metrics, rendered some studies non-comparable through direct comparison. These differences in study design would have affected syntheses of results [12], [14].

### *D. Implications for Practice, Policy, and Future Research*

Implications of this review are as follows. As an outcome for practice, it may be suggested that motion sensor-based systems and automatic power cut-off mechanisms can considerably reduce energy consumption in homes, and thus the utility cost can be lower and the impact on the environment reduced. As an implication for policymakers, tax credits or rebates can be offered for such smart home devices related to energy efficiency.

Further research, therefore, would be on large-scale, long-term studies for validation of such findings and how scalable these systems are. Further, the study can look at the integration of other energy-saving technologies, for example, smart thermostats, and then analyze user behavior to enhance the adoption and engagement of the systems [15], [16].

## V. CONCLUSION

This review describes the efficiency with which motion sensor-based systems, along with mechanisms for automatic cut-off of power, reduce the energy consumption levels in smart homes. Such integration systems, for instance, specifically for appliances like TVs and ovens, could be considered new ways to eradicate energy wastage, providing live, automated management of energy systems [1], [5]. This will add another layer of convenience and user engagement through the mobile application to monitor and control the systems remotely and offers a more efficient and sustainable energy solution [4], [6].

While the evidence brought together in this review shows such great promise, it is pertinent to recognize limitations of the reviewed studies, namely the absence of real-world and long-term testing and a too narrow focus on specific household appliances. Still, the results bring out the fact that smart home energy management systems need to continue innovating their integration into common household practices [7], [8].

Future studies should further validate these systems in large-scale, real-world studies and then extend their applicability to other household appliances [3], [9]. Policy makers should foster the adoption of these energy saving solutions through incentives, while the practitioners can optimize energy efficiency through the integration of real-time automated systems in the residential energy management [2], [10]. Overall, there are promising future prospects about smart home energy systems due to the implementation that might lead to a drastic reduction in the energy consumption aspect along with minimized environmental impact [11,12].

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