A Hybrid Renewable Energy System for Smart Homes

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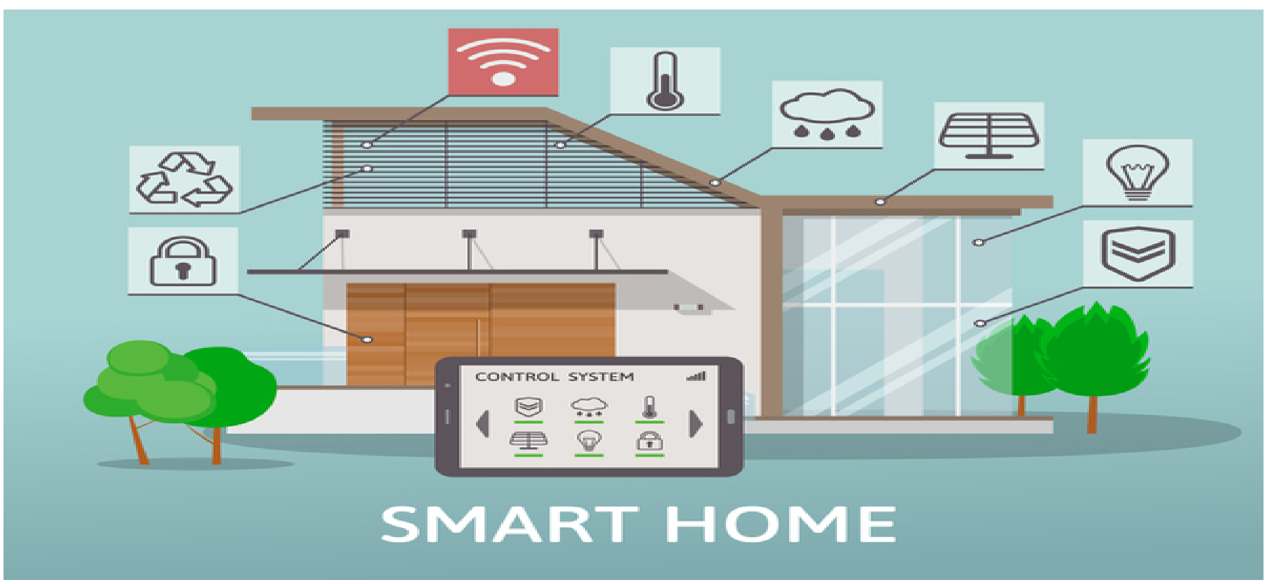
1 Introduction

Renewable energies play a vital role in the world. Hybrid energy systems are interconnected with different forms of energy i.e. photovoltaic, wind, microturbine generator, fuel cells. For environmental, economic and social benefits, hybrid systems being a better option. Optimal sizing, energy management, operating and control strategies and integration of different renewable energy sources are important to construct hybrid systems. There are different types of controllers which are feasible such as microcontroller, hysteresis controller, proportional integral controller etc. Smart home refers to the use of technological systems, automated processes, and connected, remote-controlled devices in apartments and homes. The primary purpose of the functions is to enhance the quality of life and comfort in the residence. As a result of connected, remote-controllable devices, additional objectives include increased security and more efficient energy consumption.

On the other hand, Renewable energy is energy generated from naturally replenished sources such as the sun and wind. Renewable energy may be used to generate power, heat and cool buildings, and move people.

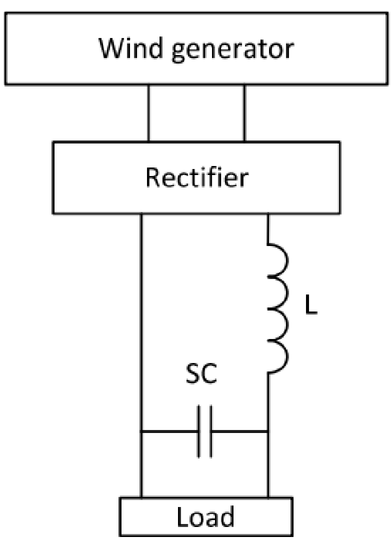


Reference: https://en.vcenter.ir/technical/smart-home-definition/

For powering a smart house, a hybrid power system comprising a wind turbine and a supercapacitor. Utilizing a supercapacitor as a means of energy storage is the core concept.

Reference:
https://www.smithsonianmag.com/science-nature/us-could-switch-mostly-renewable-energy-no-batteries-needed-180957925/

A wind generator (WG) essentially comprises an electric generator, a gear, and a wind turbine. The basic system can be connected to the generator directly or via a frequency converter device. When running without a frequency converter, the rotor speed is changeable, however when operating directly linked to the basic, the speed is set by the mains frequency. With the aid of renewable energy, one may implement a system for managing the energy usage in the home. Its primary goal is to lower excessive power expenses associated with peak usage.



Reference: https://ieeexplore.ieee.org/abstract/document/9240573

Smart home energy management systems allow for successful penetration of distributed renewable energy sources. It improves the effectiveness, efficiency and dependability of the distribution grid. These systems rely on reliable forecasting, optimization, control, and scheduling algorithms that are capable of managing the erratic nature of demand and renewable generation.

2 Background History

Using early versions of wind turbines as early as the 9th century in Persia, the idea of renewable energy sources has been around for centuries. Renewable energy sources, as a potential replacement for fossil fuels, did not begin to get widespread attention until the 20th century.

In the 1970s, Denmark created the first commercial wind turbine, and in the 1980s, solar panels began to be accessible to more people. Renewable energy sources did not, however, truly start to take off until the turn of the twenty-first century, when worries about climate change and the depletion of fossil fuel supplies grew more urgent. Since the early 20th century, the concept of smart homes, or houses endowed with advanced automation and technology, has existed. Leland W. Sprinkle created the first smart home in the 1920s, when he constructed a house with a series of knobs and switches for controlling the lights, thermostat, and other features.

When automation and remote control technology became more widely available in the 1950s and 1960s, the concept of smart homes gained popularity. In the 1960s, the first home automation systems with a central control console for managing various domestic functions were developed. During the 1970s and 1980s, smart homes began incorporating computer technology, and early prototypes of the modern smart home emerged. These early smart homes were typically controlled by a single computer and could perform tasks such as turning on and off lamps, regulating the temperature, and controlling home security systems. During the 1990s and early 2000s, the concept of the "smart home" continued to evolve with the introduction of more sophisticated automation technology and the growing prevalence of the internet. With the ability to control various household functions via mobile devices and even to integrate with other smart devices such as voice assistants and smart appliances, smart homes have become more sophisticated. Homeowners now have access to a vast array of automation and technology for their smart homes, which are becoming increasingly common. The emphasis of smart homes has shifted from basic automation to more sophisticated features such as energy efficiency, home security, and health monitoring. As technology continues to advance, it is likely that the concept of the smart home will continue to evolve, allowing for more sophisticated automation and integration.

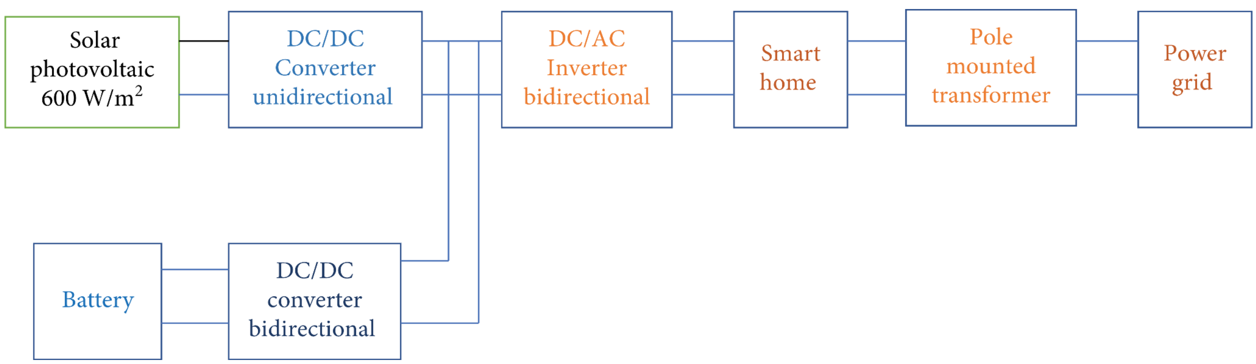
Technology advancements at the same time, notably in the area of energy storage, started to make it feasible to incorporate renewable energy sources into smart homes and other structures more successfully. In order to provide dependable and effective electricity to smart homes and other structures, hybrid renewable energy systems, which mix various renewable energy sources, such as solar and wind power, together with energy storage, have grown in popularity in recent years.

As the world works to cut carbon emissions and make the transition to a more sustainable energy future, hybrid renewable energy systems are being used more and more often. Hybrid renewable energy systems are projected to expand much farther in the coming years as technology advances and becomes more effective.

Reference:
https://www.cannyelectrics.com.au/smart-home-vs-connected-home-vs-home-automation/

3 Summary of previous research

The energy sector is seeing increased demand, and smart grid provides new solutions to satisfy that need. The residential sector accounts for one-third of total energy use. An emerging market is energy management systems (EMS) for intelligent houses of the future. Without human interaction, smart homes can ascertain, control, and optimize their apparatus. In order to be successful, smart houses must manage energy generation and storage. Households exhibit both controllable and uncontrollable loads. Only controllable loads, as opposed to uncontrollable loads, can be subject to demand regulation over time. In contrast to lighting loads, washing machines can be scheduled. The SHEMS system relies on loads that can be scheduled and adjusted for use in demand response. The total load of a house is made up of unpredictable factors.



Reference: https://www.hindawi.com/journals/ijp/2022/9607545/fig1/

3.1 Goals of SHEMS

The goal of Smart Home Energy Management System (SHEMS) architectures is to reduce energy costs without sacrificing comfort by monitoring and controlling a home's energy consumption, demand, and supply. The framework should automatically make decisions.
With predicting, SHEMS may truly shine. Things like renewable energy source (RES) load forecasting, appliance scheduling, trading, energy storage, and so on.

Electricity is essential to our daily existence. The need has increased significantly. Energy efficiency is the key to meeting our energy needs, not more power plants. Smartly managing home loads is a breeze for the right SHEMS. The effectiveness of SHEMS is affected by a number of factors. SHEMS research gaps are analyzed, reviewed, and highlighted in this paper. Locale, tenant pattern, environment, tariff, etc. should all be taken into account as SHEMS make their adjustments. By attempting to reduce either energy use or UC, SHEMS introduces a multiobjective optimization challenge.

Smart houses keep tabs on their residents and provide proactive support. Helping the disabled and elderly maintain their independence while relieving the burden on family caregivers and healthcare providers is a recent proposal. Due to the widespread availability of low-cost sensors, radios, and embedded processors, modern smart homes have many networked sensors that collectively process and draw conclusions from data on the home's state and residents' activities and behaviors.

3.2 Usage of different sensors in smart home

A smart home is one equipped with sensors to keep tabs on the outside world and devices/actuators to make life easier for its inhabitants. The original goals of the smart home concept were efficiency, safety, and comfort. The proliferation of cheap, low-power sensors, radio frequency chips, and embedded processors has allowed for the development of "smart homes," which are residences equipped with a network of sensors to keep an eye on the well-being of its inhabitants.

In modern "smart" homes, a network of sensors and processors is used to produce rich multi-modal data. Residents' basic and instrumental daily living chores, such as bathing, dressing, cooking, and medication administration, are identified and tracked using sensory data. Direct environmental sensing is achieved through the use of video cameras, RFID, and a plethora of DIY binary sensors. However, there are practical and complexity implications associated with this sensing, as it may expose genuine behaviors and situations.

Smart homes frequently make use of binary sensors, which report their findings with a simple "1" or "0" when they detect an object or motion. Binary sensors including motion, pressure, and contact switches are commonly utilized in automated dwellings. Inhabitants and positions can be tracked using motion and pressure sensors installed throughout the dwelling.

3.3 Applications of the sensors in different sectors

The entrance door, as well as cabinet and appliance doors in a smart home, are equipped with contact switches that record the inhabitants' precise interactions with the home's many components. Video cameras and other high-content sensors yield a wealth of information useful to humans and machines alike. However, data storage and retrieval are sometimes more challenging.

Temperature, light, humidity, barometric pressure, and other sensors can be used to infer activities and trigger automatic maintenance in smart houses. Data is transmitted from readers to tags via radio waves in RFID systems. Tags' unique identity and stored information are retrieved by RFID readers.

3.4 Feasibility of the user and its performance

The vast majority of studies focusing on smart home sensor technology demonstrate the potential or feasibility of these solutions. The technical performance of these sensors in laboratories or small communities is also the focus of early assessments. Stakeholder needs, such as those of end users, carers, and clinical experts, should inform the design and implementation of smart home sensing technology now that technical advancements make sophisticated home-based monitoring solutions possible. Evidence on the viability, utility, effectiveness, and cost-benefits of smart home sensing technologies is lacking.

Most studies using technology in the home either kept tabs on what people were up to or looked for deviations in their habits. The capacity to comprehend delays, omitted procedures, and correctable vs irreparable errors in routine activities is limited.

Other technological challenges include data analysis in real-time, uncertainty management for sensors, and long-term dependability, robustness, and maintenance. Until these technical issues are rectified, sensor technology cannot be deployed in domestic settings.

End user approval of sensor technology and its impacts is crucial to the technology's widespread adoption. When it comes to using sensor technology in the home, privacy is the main concern. The number of disabled and elderly persons who wish to age in place is on the rise, and smart home technology may help family caregivers and healthcare providers manage this trend. This study of smart home sensor technology demonstrates that most research only demonstrates the viability of technical solutions in lab settings. Users, loved ones, caregivers, and medical professionals all have demands that must be considered while developing sensor technologies for smart homes. Smart home sensor technology may help in condition detection by recognizing changes in habit that are associated with functional or cognitive decline, however this has not been shown. Until technological, therapeutic, and ethical challenges are answered, sensor technology cannot be implemented into homes or clinics.

The development of smart grids and smart homes has led to the automation of many mundane household tasks. Many different gadgets and programs are available for smart homes to employ. The introduction of the smart home and the smart grid has made it possible for users' appliances to connect with one another, allowing for greater levels of automation, monitoring, and remote control. The systems' advantages and disadvantages are detailed in the technical descriptions.

Smart home technology is encouraged by European regulations like EN 15232 and the Energy Performance of Building Directive 2010/31/EU, which are in line with Directive 2009/72/EC and the Energy Road Map 2050.

3.5 Effectiveness of the technologies for the advancements in the future

In the future, thanks to advancements in artificial intelligence, processing power, communication capabilities, monitoring, and control, homes may be able to participate in an interactive energy management system through the Internet of Things. They make life easier, especially at home.
A more seamless human-home appliance interface will lead to greater ease of use, healthcare, security, and cost savings. Hence, the rise of the "smart home."
Technology in smart homes gives people more independence and convenience. A smart house is an integrated system of electronic and mechanical components that can exchange data with one another and with the homeowner to create a dynamic, responsive environment. Through means such as ambient intelligence, remote home control, and home automation systems, it can automate tasks for or provide assistance to people. These examples show that the goal of smart homes is to improve the quality of life for their owners.

This can be accomplished in **two ways**:

(i) By determining which human tasks are most important and automating them in the home, and
(ii) By implementing remote home control to improve amenities like convenience, safety, efficiency, economy, and environmental impact.

Digital signals are transmitted across twisted-pair power lines or fiber optics in a smart house via a communication protocol, linking residents and their electronic devices. A smart home's primary communication device is typically used to remotely operate various appliances.

These five characteristics define smart homes.

(i) Automation: the support for automated devices and the execution of automated tasks

(ii) Multi-functionality: the execution of multiple tasks and the generation of multiple results

(iii) Adaptability: the capacity to learn and anticipate user needs

(iv) Interactivity: the capacity to permit user interaction

(v) Efficiency: the execution of tasks in a time- and money-saving manner.

Due to increased home electricity consumption as well as environmental and regulatory constraints, there has never been a greater need to enhance electrical grid efficiency. Energy efficiency is crucial in both smart homes and smart grids. Smart technologies track and manage household energy consumption through two-way communication with electrical equipment.

Saving primary energy and lowering one's carbon footprint both depend on how well insulated and sealed a building is. With the proliferation of sensors, active automation tools, and two-way connectivity, the world's 100-year-old power infrastructure is struggling to keep up. Smart grids are encouraged most by this last factor. Individuals are producing and consuming energy on their own premises, even if they are not the exclusive or ultimate users. Bidirectional energy transmission is essential for exporting surpluses to the grid. Instead of simply transmitting energy in one direction, a smart grid can anticipate, monitor, and control energy flows in both directions. Smart grids use energy management technologies to disperse user-generated power locally at daily rate.

If implemented, the HEMS will expand the range of devices that consumers may use to access their energy accounts, regulate their thermostats and other household appliances, learn about ways to reduce their energy consumption, set up a profile for demand-response programs, and check their bills.

Through their interconnections with other components, Smart house Micro-Computers (SHMC) control and automate the smart house infrastructure. They are microcontrollers that have additional parts to help with coding and combining. Connecting a CPU board to different shields is made possible by their standard connectors. They use a variety of detachable connectors to process data from a wide array of sensors and drive lights and other actuators to generate dynamic programs.

3.6 Home Automation Systems

In home automation (HA), a smart user interface observes and learns user habits in order to better predict and aid their actions. Comfort and energy savings can be enhanced by HA's remote communication with humans. HA facilitates the management of connected dwellings. Common HA platforms include the Raspberry Pi, Banana Pi, Libelium WaspMote, and British Gas. More efficiency and less waste: Iris and KNX smart meters

For this reason, energy management systems are required to (i) plan production levels to economically benefit from exchanging energy with the grid, and (ii) interact with the external network to manage energy flows using intelligent commands and a supervision system that can interact with both loads and generations to balance demand and supply.

Optimal operation scheduling for economically dispatching electricity to meet load demand could be made possible with the integration of forecasting models that can anticipate hourly power generation based on weather forecasting inputs. Approximately 28% of daily spending might be avoided, according to one study.

3.7 Difficulties, Rewards, and Inspiration for Users

In recent years, load level has gained prominence as a result of end-users' increasing participation in power grid energy management and as a result of the realization that unpredictable human variables can impact the effectiveness of DR systems and residential energy management. Planning ahead strategically for goods that can be relocated.

Despite the many advantages of active energy management, there are still barriers that could hinder the widespread adoption of smart home technologies among homeowners. The largest challenge in bringing the benefits of the smart grid to fruition is the need for utilities and energy management solution providers to update their technological infrastructures to accommodate new bidirectional and dynamic loads.

More research into algorithms and human behavior is needed to improve the efficiency and adaptability of energy management plans. It has also been looked at and shown to be a significant potential driver for the deployment of energy management solutions in households, the ability to communicate household energy usage in a systematic viewpoint, i.e., seeing the residence as part of a smart grid. Direct feedback from users yields better results. Users' needs, preferences, and level of knowledge should inform how data is presented to them.

Another study details a wind generator and supercapacitor-based hybrid power system for intelligent homes. Power can be stored in a supercapacitor.

WGs are equipped with wind turbines, transmissions, and power generators. The generator can be linked to the central system either directly or via a frequency conversion mechanism. With a frequency converter, the rotor speed can be adjusted, but when connected directly to the fundamental, it cannot.

When wind speeds are high, the wind generator can produce energy at a rate greater than its rated output. Wind power generation can be kept to a minimum to guarantee no-load operation. Reduce the effect of the wind by adjusting the blade pitch.

In this experiment, 10 kW loads are powered by wind generators. In times of limited power, supercapacitors provide a source of energy. Energy redundancy can also be stored using supercapacitors. The proposed solution can provide a variety of smart home services such as lighting, climate control, and more.

It has been suggested that smart houses implement an energy management system that makes use of solar power and battery storage to lessen their reliance on the utility grid and cut costs. The proposed system coordinates the delivery of energy from batteries, utility power, and solar panels to the smart house. When the load is low, the power grid can take in surplus energy from the planned system, and when it's high, it can send electricity to the load. Users can make money by selling their surplus electricity thanks to this technology. The approach's effectiveness in energy management between sources was demonstrated by a comprehensive simulation of the system.

The environmental friendliness and adequacy of renewable energy resources (RER) make them appealing. Renewable energy is the best alternative to depleting conventional energy sources. Sustainable energy sources are at the heart of home energy management (HEM) systems. In most cases, this setup results in lower electricity costs and better peak load management. Efforts to develop a smart grid that integrates renewable energy sources will also reduce reliance on traditional power plants.

Recent studies have focused on topics like photovoltaic energy cost minimization as an optimization challenge based on the unexpected output from renewable energy resources, and home energy management coupled with storage devices.

We have discussed the potential of demand response (DR) systems in residential energy management, including its usage in prioritizing load rescheduling based on projected renewable energy (RE) output, battery dependence, and other factors. Home energy management with photovoltaics is discussed. Integration of energy storage and photovoltaics with the HEM has been considered in the literature, but there are still certain obstacles to overcome. For instance, if the solar panels aren't producing enough power, the battery can step in, and renewable sources of energy can alleviate pressure during times of peak demand.

In order to provide surplus power to the grid and to absorb electricity in case of deficit, the paper recommends merging storage devices and photovoltaics with the HEM. As a result, a state of perfect equilibrium guarantees the robustness and efficacy of the system.

Modern "smart" houses are equipped with solar panels and batteries. A 5 kW photovoltaic system is indicated in the current voltage lookup table. Maximum Power Point Tracking regulates the array's operating point to maximize energy harvesting under varying environmental conditions.Energy is stored in a lithium-ion battery with a voltage of 200 V and an amp-hour capacity of 40 Ah. Battery details are listed in Table 1. When the solar panel's output is insufficient, a bidirectional converter takes over and powers both the battery and the load.

In order to control both the base and peak load, an article suggests including renewable energy resources into the supply mix. Loads consume the energy generated by solar panels and battery storage devices.

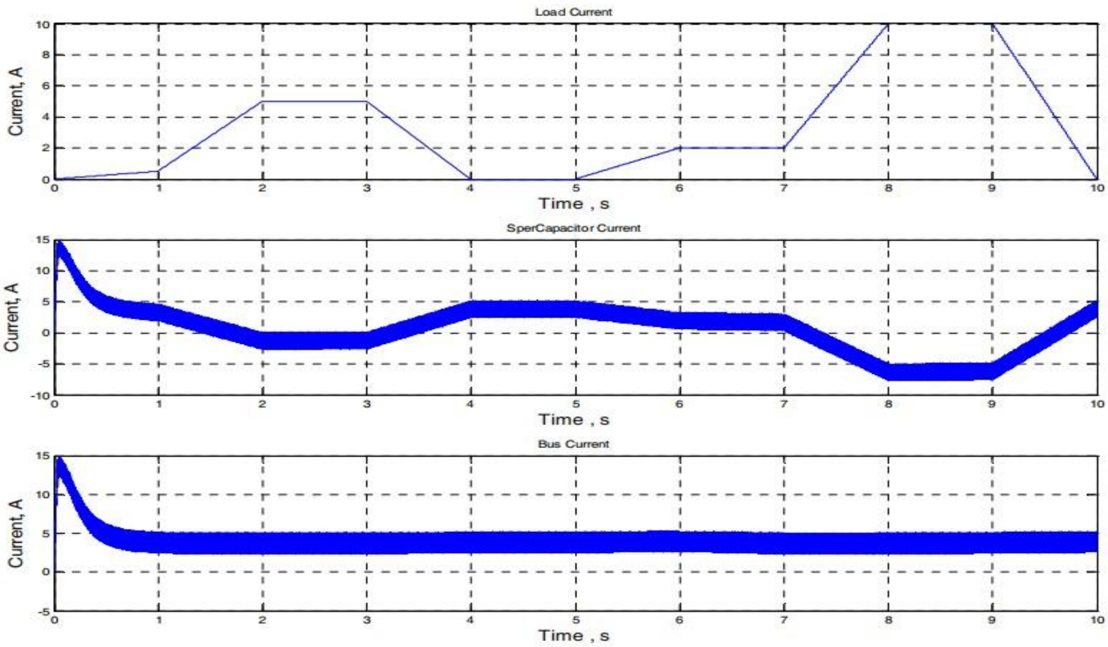


Fig.4. Load current, current of the supercapacitor and bus current

MATLAB shows the results of alternative energy management strategies. According to the data presented, users are less reliant on the grid and are now able to contribute revenue by selling their excess electricity to the grid. Through future research, HEM may be able to manage residential loads with time-of-use pricing, as demonstrated by the simulation.

4 Critical Evaluation

Research in Hybrid Renewable Energy Systems (HRES) for smart homes has increased in recent years as interest in sustainable energy solutions has grown further in 21 st century. While there have been many valuable contributions to this field of research, there are also limitations and areas for improvement.As per studies from various papers based on HRES some inconsistency in data was found out. One critical evaluation of HRES research is that many studies are focused on technical aspects of the systems rather than on the social, economic, and environmental implications of their implementation. While technical considerations are important, it is also essential to understand how HRES can be integrated into people's lives and how they can contribute to reducing carbon emissions and promoting sustainable energy.
Some of the most significant limitations include:

4.1 Lack of standardization

The lack of standardization in research of Hybrid Renewable Energy Systems (HRES) for smart homes is a significant challenge for the field. Standardization is critical for ensuring that research results are reliable, reproducible, and comparable.

Metrics and performance indicators: There is no standard set of metrics or performance indicators in popular literature used to evaluate the performance of HRES in smart homes. This makes it difficult to compare the results of different studies or assess the effectiveness of different systems.

Simulation and modeling tools: There are numerous simulation and modeling tools available for HRES research, but there is no standard tool or methodology for modeling HRES performance in smart homes.As the requirements for smart homes entities varies from family to family, this lack of standardization can lead to inconsistent results and makes it difficult to compare the results of different studies.

Terminology and definitions: There is no standard set of terminology and definitions used in HRES research.This leads to confusion and misunderstandings, particularly when different research groups use different terms to describe the same concepts.

4.2 Limited data availability

Limited data availability is a significant limitation in research on Hybrid Renewable Energy Systems (HRES) for smart homes.Studies show that reliable and comprehensive data is essential for developing accurate models and predicting HRES behavior in real-world settings.However, obtaining such data is very challenging.

Limited availability of real-world data: There is a lack of available data on the performance of HRES in real-world settings. This is because HRES technology is relatively new, and not many households have installed such systems. This makes it difficult to test the technology and gather reliable data on its performance.

Difficulty in obtaining data from existing installations: Even in cases where HRES systems are installed in households, obtaining data on their performance can be challenging due to privacy concerns or technical issues with data collection.

To overcome these limitations, researchers can collaborate with industry partners to obtain access to data, establish standardized data collection methods, and make efforts to increase data availability by promoting the adoption of HRES technology in households. Governments and funding agencies can also play a role in incentivizing the collection and sharing of HRES data through policies and grants. Overall, addressing the limitation of limited data availability will be critical for advancing HRES research and promoting their widespread adoption in smart homes.

4.3 High cost

The cost of implementing HRES in smart homes is still relatively high, which limits their widespread adoption and makes it difficult to conduct large-scale studies.The existing models which have not been yet implemented because of high installation cost of HRES.
Equipment costs: The cost of HRES equipment, such as solar panels, wind turbines, and energy storage systems, is potentially high. This makes it difficult to implement the available systems.As a result it is difficult to get real data for further study.

4.4 Integration challenges

Integrating HRES with existing home energy systems is indeed very complex and challenging.Integrating renewable energy sources, such as solar and wind, into the existing energy infrastructure is sometimes not feasible and results in unwanted interruption on living conditions.

Intermittency: Solar and wind energy are intermittent, meaning that their output can vary significantly depending on weather conditions. This can make it challenging to predict and manage energy production, which can impact system stability and reliability.

Grid connection: Connecting HRES systems to the grid can be challenging due to compatibility issues between the different components. This can impact system performance and reliability.
Energy storage: Energy storage systems, such as batteries, are necessary for storing excess energy generated by HRES systems. However, current storage technologies can be expensive and have limited capacity, which can limit the effectiveness of HRES systems.
Technical expertise: HRES systems require specialized technical expertise for installation, maintenance, and repair. A shortage of skilled workers in the renewable energy industry can make it challenging to maintain and operate HRES systems effectively.

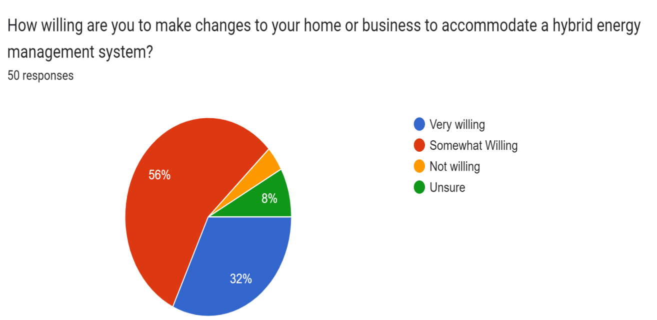
4.5 Limited research on consumer behavior

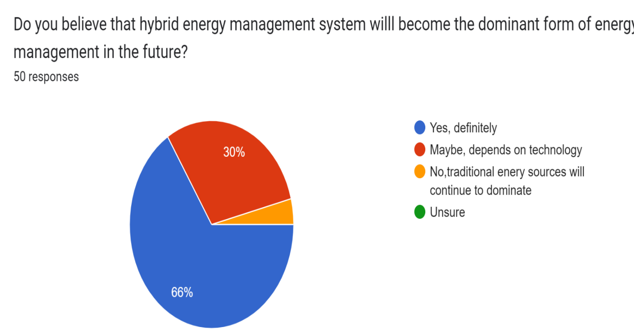
There is limited research on consumer behavior and preferences regarding HRES adoption, which makes it difficult to design systems that meet their needs and preferences.Understanding consumer behavior is critical for promoting the adoption of HRES technology in households and designing effective HRES systems that meet the needs and preferences of consumers. Some of the main factors contributing to the limited research on consumer behavior in HRES include:

Lack of data: There is a lack of available data on consumer behavior in relation to HRES technology. This makes it challenging to develop accurate models of consumer behavior and predict the adoption and use of HRES systems in households.

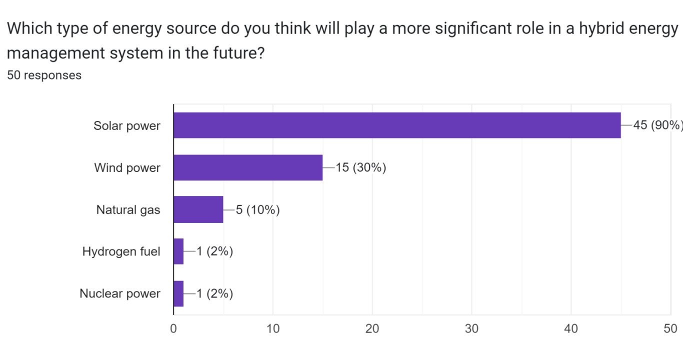
Limited sample size: The number of households that have adopted HRES technology is still relatively small, making it difficult to conduct large-scale studies on consumer behavior.
Complexity of consumer behavior: Consumer behavior is influenced by a range of factors, including attitudes, values, social norms, and financial considerations. This complexity makes it challenging to develop accurate models of consumer behavior and predict the adoption and use of HRES systems in households.

5 Survey Review:

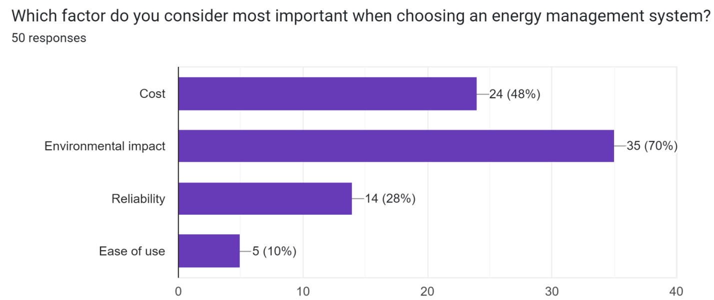




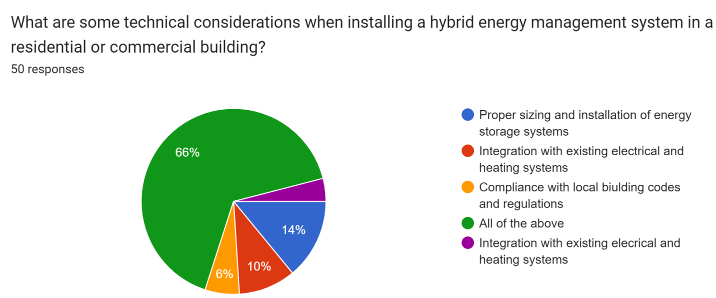
According to the conducted survey it is seen that the
majority of the people (almost 70%) believes that the hybrid energy management system will become the dominant form of energy in the future and almost ⅔ of the people are potentially willing to shift into a hybrid management system.



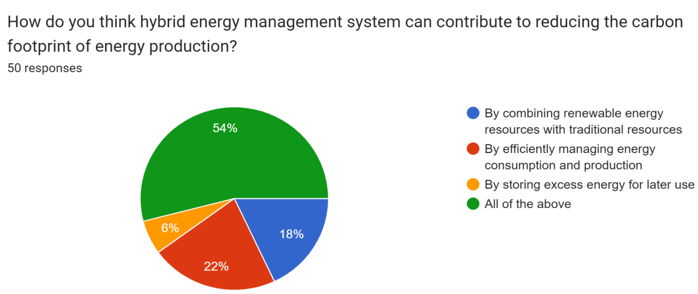
Most people think that solar power will play a more significant role (90%) in wind power (30%) , natural gas, hydrogen fuel and nuclear power.



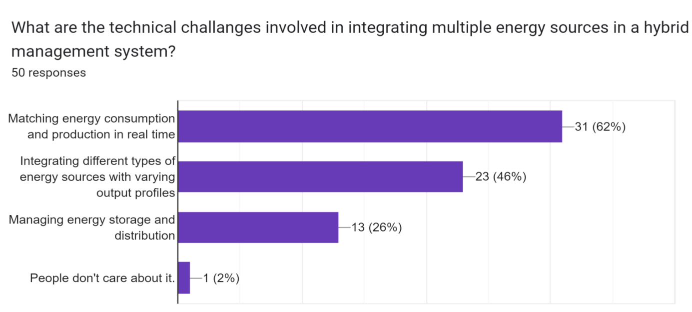
We found that more than 50% of the responders consider environmental impact and cost as the most important factor when choosing an energy management system. After that a few highlighted factors are reliability and ease of use.



Hence an HEMS system is a new technology, there are few technical considerations when installing a HEMS in residential or commercial buildings. Proper sizing and installation of energy storage systems, integration with existing electrical systems are some common issues.

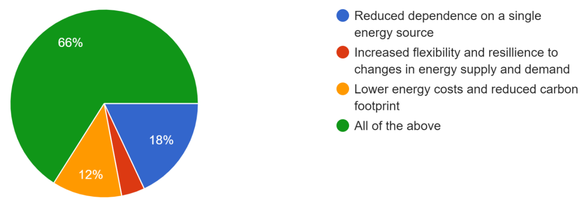


HEMS can definitely contribute the most to reduce the carbon footprint of energy production. Combining renewable energies with traditional resources and efficiently managing energy consumption and production will play a vital role here.



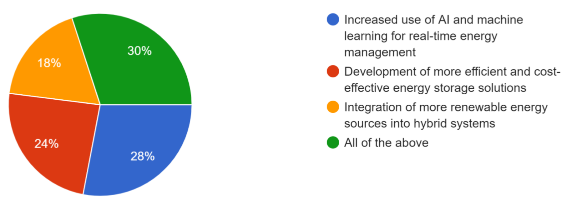
Integrating multiple sources in a hybrid energy management system might face some technical challenges. Majority thinks that matching energy consumption and production in real time.

What are some potential advantages of a hybrid energy management system over a traditional energy management system?
50 responses



Implementing HEMS will have a very positive impact according to the survey. Reducing dependence on a single energy source, lowering energy costs and reduction of carbon footprint are some of the potential advancements.

How do you see the future development of hybrid energy management systems involving in the next 5-10 years?
50 responses



People expect to increase use of AI and ML for real time energy management, Integration of more renewable energy sources into hybrid systems, etc.

6 Future Research Possibilities:

Hybrid Renewable Energy Resources integrated with smart homes have enormous possibilities in the future. As per the survey conducted on 50 students of ISLAMIC UNIVERSITY OF TECHNOLOGY the result shows prominent numbers of students are indeed familiar with Smart Homes Management System (SHMS) terminology. This opens up the possibility of implementing Smart homes in the real world. Increasing numbers of Smart homes can provide a huge data collection source for the researcher. This solves the problem of lacking real data present in popular literature.

Further Study shows that, people are aware of the initial huge cost for implementing a smart home. Still they think that SHMS with smart homes will dominate Energy Management in future.

6.1 Possibilities of Solar Energy:

As most of the people thinks that Solar Energy will play the most significant role in SHMS, it argues that we need to implement as efficient a solar power system as possible.This opens the need for research in solar technology.Some potential areas of research in solar technology include:

Improving solar cell efficiency: Solar cells are the building blocks of solar panels, and improving their efficiency is essential for making solar energy more cost-effective and widespread. Researchers can explore different materials, designs, and manufacturing processes to improve solar cell efficiency.

Enhancing solar panel performance: Researchers can explore new materials and designs for solar panels to improve their performance in different weather conditions, increase durability, and reduce maintenance requirements.

Developing new solar energy storage solutions: Energy storage is essential for storing excess energy generated by solar panels during peak hours for later use. Researchers can explore new energy storage technologies, such as batteries and supercapacitors, to improve energy storage capacity and efficiency.

Another important part of the survey is that the people are now really cautious about environmental impact of any technology more than ever.So, Researchers need to ensure the minimal impact on the environment in SHMS regard.

6.2 Harmful Environmental Effect of Metals used in Electronics:

Modern Ecologists argue that rare metals used in electronics and chip production are harmful for the environment.When these products end their life period they are dumped and piled up in an open environment.Researchers need to find a rapid and effective solution to this problem.

6.3 Carbon Footprints:

As the survey indicates HEMS can reduce carbon footprints greatly.This is an opportunity to design a model based on experimental data that could be the relation between HEMS and carbon footprints. If possible then formulate a completely isolated SHMS with no external energy consumption with carbon footprints generation.

6.4 Technical Challenges in integrating hybrid energy resources:

As per survey, matching energy consumption and production in real time is the main challenge in integrating the resources together.But by increasing the efficiency of solar and wind technology and implementing super battery concept solves this problem completely.So,Researchers need to find a way to maximize the possibility of ensuring these futuristic devices as soon as possible.

7 Conclusion

Hybrid renewable energy systems are a viable option for efficiently fueling smart dwellings. By combining solar, wind, and battery storage, homeowners can assure a steady supply of sustainable energy for daily use. Such a system can not only reduce the ecological footprint but also result in substantial long-term cost reductions.

However, installing a hybrid renewable energy system in a smart home requires meticulous planning, installation, and maintenance. Before investing in such a system, homeowners should consider their energy requirements, available resources, and local regulations.

Hybrid energy management systems are a promising future option, despite their current limits and service unreliability. Overall, a hybrid renewable energy system is an excellent way to transition to a sustainable and environmentally-friendly lifestyle while appreciating the advantages of modern technology.

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9 Appendix

9.1 Abbreviations:

SHMS - Smart Home Management Systems
EMS - Energy Management Systems
SHEMS - Smart Home Energy Management System
UC - User Consumptions
RFID - Radio Frequency Identification
HEMS - Hybrid Energy Management System
HRES - Hybrid Renewable Energy Systems
HA - Home automation
DR - Demand response

9.2 SurveyResults:

https://docs.google.com/spreadsheets/d/11VOx9AvFA82k_LvAg1nOWeFEFPkjqc3B5VGF55F93QM/edit?usp=sharing

10 Member Contribution:

1. NIFAT MOUDDIT NIZHUM (ID: 200011119):

Critical Evaluation of previously available literature in Hybrid Energy Management System,Study of standardization of HEMS,Available data summarization of HEMS,Definition of SHMS and HEMS,Cost sorting study of HEMS,Integration challenges of HEMS with SHMS,Study on consumer behavior towards researchers,Study of Future Research Possibilities in HEMS and SHMS, Study of Possibilities of solar technology.

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Introduction of Hybrid Energy Management System, Background History of Renewable energy Systems for smart homes, Table of Contents, goals of SHMS, applications of sensors in different sectors, feasibility of the user and its performance, effectiveness of the technologies for the advancements in the future, Home Automation Systems and it's difficulties, rewards, and inspiration for users, Conclusion, Appendix

3. IFTEKHAR AHMED (ID: 200011153):

Summary of previous research, goals of SHMS, Applications of sensors in different sectors, Home Automation Systems and it's difficulties, rewards, and inspiration for users, Study on consumer behavior towards researchers, Study of Future Research Possibilities in HEMS and SHMS Survey Form Management, Survey Report Review, References