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Smart Home Energy Management Systems: A Systematic Review of Architecture, Communication, and Algorithmic Trends

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Abstract. This systematic review synthesizes 93 articles on smart home energy management systems guided by the preferred reporting item for systematic reviews and meta-analysis (PRISMA) framework. Analysis of the sample along with architecture components, communication mechanisms, services provided, and algorithms implemented reveals the proliferation of home automation technologies lacking holistic integration. Setup complexity persists alongside suboptimal efficiency. Structuring research around resident experience rather than technical novelty may forward solutions. Though artificial intelligence holds promise in predictive optimization, deterministic rule-based controls often demonstrate sufficiency. Collaborative initiatives reconciling technical possibilities with user needs can best propel the field.

Keywords: Smart home, energy management, PRISMA, literature review

1. Introduction

Recently, smart homes have been equipped with various renewable energy sources that can produce electrical energy. Microgrids may also supply electricity to homes, buildings, or other energy grids when self-produced renewable energy is available (Hassan et al., 2020; Wei et al., 2023). The aim is to optimize the cost of energy use with the concept of energy management in scheduling various household appliances to test on a smart home model and consider energy consumption and generation in real time (Shirazi & Jadid, 2017). Smart home on artificial intelligence in optimizing energy management on control algorithms and adaptive predictive models that have been carried out from previous literature, smart home with hybrid smart grid supply chain management system with revolutionary architecture (Marzband et al., 2017), approach with internet of things (IoT) with algorithm management (Siswipraptini et al., 2021). As well as smart home energy management systems in minimizing power consumption in smart homes. This can be achieved by controlling and monitoring home electrical appliances via a microcontroller (Chouaib et al., 2019). Smart homes with artificial intelligence will refer to data-based energy management, which can adaptively follow future needs by implementing new technologies to improve energy management knowledge based on the availability of big data (Badar & Anvari-Moghaddam, 2022; Siregar et al., 2022). Energy management is growing exponentially, generating big data that has become a primary key in modern smart homes to assist residents in decision-making (Leitao et al., 2020).

This study aims to systematically review some literature on smart homes and present a comprehensive study on different types of smart home automation systems regarding architecture systems, functions, services, and algorithms. Smart, as well as analyzing machine learning applications in controlling and unifying household appliances, managing renewable and hybrid energy sources, predicting yields, assessing sample quality and classification, and predicting the results obtained based on the knowledge used (Koltsaklis et al., 2022; Lee & Choi, 2019; Lissa et al., 2021).

Table 1 explains the novelty of this study is to address a comprehensive review of energy management of smart homes regarding architecture system, services, functions, and algorithms.

Table 1: Comparison other existing literature surveys.

Reference	Research content	Our paper
(Badar & Anvari-Moghaddam, 2022)	demand response strategies used and the various equipment's considered along with renewable energy generation and plug in electric vehicles (EV) employed in smart home.	in this paper, various emerging technologies for smart home energy management are reviewed and assessed. Based on the literature from 2016 to 2022, architecture systems, functions services, and algorithms do not cover the survey smart home models.
(Shareef et al., 2018)	considering various DR programs, smart technologies, and load scheduling controllers. The application of artificial intelligence for load scheduling controllers, such as artificial neural network, fuzzy logic, and adaptive neural fuzzy inference system	Deep learning algorithm such as LSTM, RNN and FNN have been discussed in our paper.
(Zhaoyu He, Weimin Guo,	the AI-based thermal energy	various sensors integrated by

2022)	storage (TES) performance modelling to control smart building.	Internet of Things around the smart home system to detect the mobility of the smart home residents have been discussed in our paper.

To answer this comprehensive review, we established three research question: how is the architecture system of energy management of smart home? what are the services and functions of energy management of smart home? and what the algorithms are used in smart home to optimize energy management.

2. Related Works

A systematic review approach was carried out to obtain architecture systems used to reveal the goal, with low costs in energy management in smart homes, utilizing the internet of things (IoT) (Chinnathambi et al., 2022; Qiu et al., 2020; Siswipraptini et al., 2021), artificial intelligence (Lu, Zhang, et al., 2020; Zhaoyu He, Weimin Guo, 2022) on machine learning techniques (Jin et al., 2017; Koltsaklis et al., 2022) to help turn big data into knowledge, and improvements by leveraging action control systems and automation, all relevant for energy management especially those that will be applied to smart home(Alfaverh et al., 2020; Lu, Lü, et al., 2020).

Recently, researchers have great attention to smart homes research, especially from some points of view such as the energy efficiency (Leitao et al., 2020), electrical energy load prediction (Zhao & Keerthisinghe, 2020), and resident comfort index (Shah et al., 2020). The goals of smart home system are to identify the needs and preferences of residents by coordinating home appliance operations. Smart homes provide a better quality of life by enhancing remote monitoring, control of electricity load, cost efficiency, and safety. As seen on Figure 1, wired and wireless sensor and actuator networks are deployed on smart homes, being collected sensor data and contextual information stored in a central platform. As seen on Figure 1, wireless sensors connected with home appliances are implemented in smart homes and sensor data as information retrieval are stored in a central point. Distributed power generation from renewable energy sources has also been improved. Renewable energy sources such as hydro, solar, and wind are the fastest growing consumed source in the United States through 2050 (Administration, 2022).

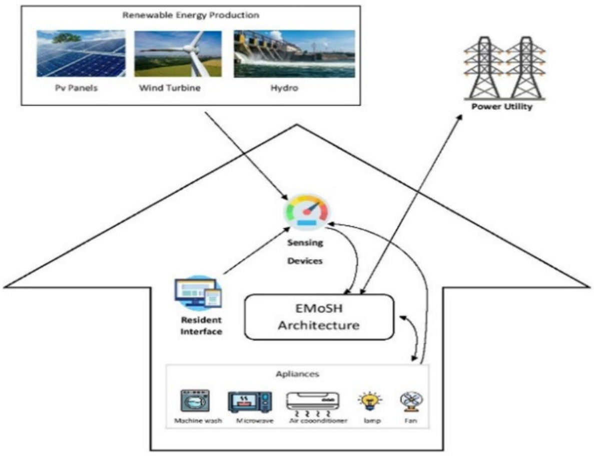

Fig 1: Energy Management for Smart Home (EMoSH) Architecture

Smart home system concepts mostly implement an IoT perspective. Figure 2 describes layers for IoT architecture implemented in smart homes.

A. The first layer known as the physical devices layer, its task is collecting data and sends it to the upper layer. This layer is where energy transactions take place. The physical devices layer includes common home appliances such as fan, TV, lamps, microwave, oven, etc.
B. The second layer known as the perception layer responsible for data acquisition from inputs (e.g., camera, sensor, mic) are deployed to gather information. Other than that, some outputs (e.g., actuator, image, notification, graphic) are presented to present information such monitoring daily electricity consumption.
C. The third layer known as the communication network layer, enables communication and integration among different devices. The technology adopted for energy consumption monitoring depends on the location of the server at which data is sent. The key of the smart home system is generally implemented using wired, wireless, or the combination of both. The wireless media offers more flexibility and scalability, especially in terms of installation of sensors around the house. Thus, short-range wireless communication is preferred where the most popular standards are IEEE 802.11(Wi-Fi), ZigBee (a low-power wireless technology), 6LowPan, and LoRa.
D. The fourth layer called the middleware layer connects IoT devices and software applications. Since computational requirements for this layer are very high, most referenced solutions sit at the domains of cloud computing or web server base. Therefore, this layer acts as an architecture abstraction between the user interface and all deployed devices. Functional requirements, including data management, data storage, big data analysis, real-time data analysis, and deep data analysis with AI should be considered.
E. The top architecture is known as the application layer. It provides specific services offered to residents. This layer provides a variety of energy management applications for smart home solutions that could be performed.

The novelty of this study is to address a comprehensive review of energy management of smart homes regarding architecture system, services, functions, and algorithms.

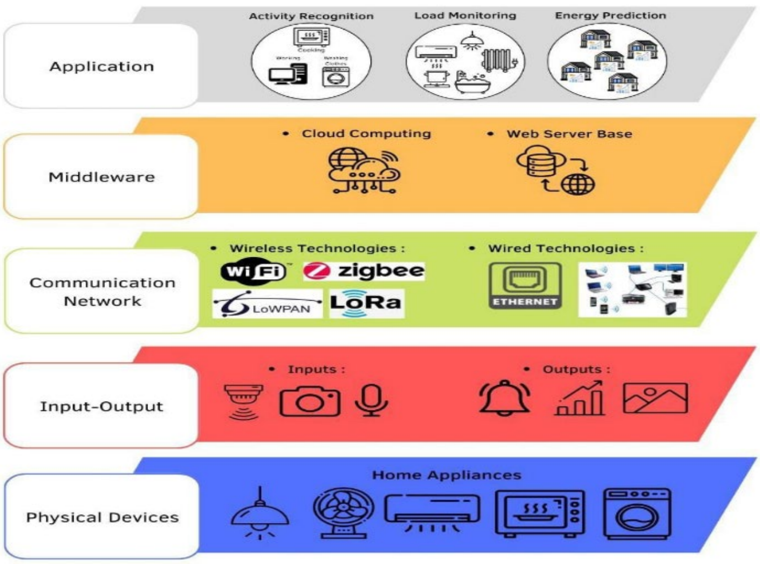

Fig 2: IoT architecture for Smart Home Model

3. Research Methodology

Please The systematic literature review (SLR) manages research information sources according to specific topics. This study uses SLR to determine the feasibility and analysis of energy management technology in smart homes. Studies that are searched for with the term "smart home" are then inserted with the word "energy management", which will appear in the title, abstract and keywords of an article with one approach with "smart algorithms", "machine learning", "deep learning", "IoT" and "energy source" applied to smart home systems. This paper adopts a preferred reporting item for systematic reviews and meta-analysis (PRISMA) as a research methodology. PRISMA is a procedure to prove the validity of an article for a literature review (Page et al., 2021). Stages for guiding a checklist item for this method as follows:

A. The title identifies and confirms literature as a predetermined topic.
B. Abstract is a structured explanation consisting of background, methods, results, and discussion.
C. Introduction is providing the objective or question for the review of the existing knowledge.
D. Method is conducting a literature search process, specifying inclusion and exclusion criteria from articles, determining the number of articles obtained during the searching process, and judging how many articles will be used in the systematic review.
E. Result is presenting for main outcomes such as a diagram describing a summary of the selection articles.
F. Discussion is providing a brief summary of the limitations evidence and interpretation of the important implications.
G. Conclusion summarizes findings from systematic reviews brief, concise, and clear.
F. Four stages of the PRISMA procedure are depicted in Figure 3.

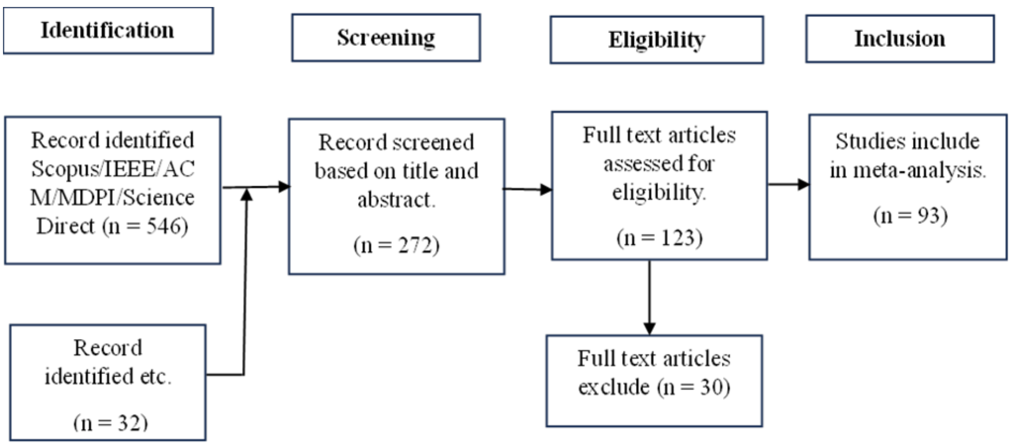

Fig 3: Literature review of energy management of smart homes

3.1. Literature Review

The literature review in perspective identifies, evaluates, and interprets the scope and results of related and relevant research, as shown in Table 2.

Table 2: Systematic observation of energy management of smart homes.

Research Question (RQ)	1. How is the architecture system of energy management of smart home?
	2. What are the services and functions of energy management of smart home?
	3. What are the algorithms used in smart home

	to optimize energy management.
Selection literature	1. Journals, review papers, conference papers
	2. Range publication years 2016 -2022. 3. Scopus indexed articles by including title, year, database, abstract, and quartiles.
	4. The literature focuses on the development of smart home energy management based on artificial intelligence algorithms.
	5. Only English articles are included in the criteria.
Literature databases	Scopus, IEEE, ACM, Multidisciplinary Digital Publishing Institute (MDPI), Science Direct.
Search keyword	((“smart home” OR “smart house”) AND (“photovoltaics” OR “pv”) AND (“power” OR “electricity”) AND (“energy management”) AND (“renewable energy”) AND (“iot smart home” OR “artificial intelligence smart home”) AND (“algorithm smart home”))

Figure 3 explains the systematic literature that have been mentioned and referred in Table 2. Further explanations of each stage as follows:

1. Identification: This process aims to reveal the relevant sources for the collection of recent papers related to energy management of smart home based on Artificial Intelligence. The papers were collected from three databases such as ACM (https://www.acm.org/), Science Direct (www.sciencedirect.com), and still others using IEEE Xplore (https://ieeexplore.ieee.org). The amount of data from searches in those databases is 546. The amount of data from other sources (recommendations from experts/manual searches/reports/news) is 32.
2. Screening: The total of articles selected based on the title and abstract was 272. The exclusions of search results based on title and abstract are: “Smart Home”, “Energy Management”, “Artificial Intelligence”, “Photovoltaics and Power”, and “published outside 2016–2022”.
3. Eligibility: 30 articles were excluded because they didn’t meet the systematic observation based on Table 2.
4. Inclusion: 93 articles were included in the meta-analysis review as inclusion process.

3.2. Characteristics of Included Studies

The results obtained from the four stages of the systematic process of literature were obtained as many as 93 articles. The identification process through the searching process and synthesizing of the linkage of the articles obtained are shown in Figure 4 and Figure 5. The results of keyword synthesis are based on the number of years of publication and the quartile cluster of indexations on Scopus.

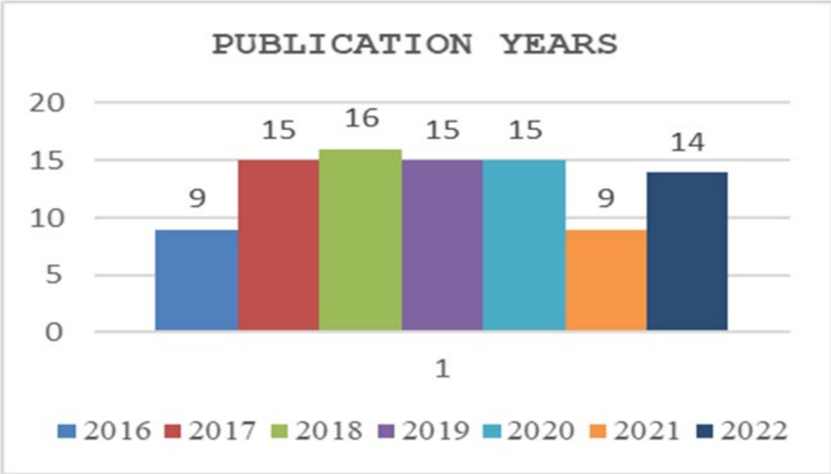

Fig 4: Distribution literature of 2016 – 2022 of energy management of smart home

As depicted in Figure 4, the trends in energy management of smart homes become interesting for researchers in the last 5 years. We identified that energy management is an interesting and important topic to consider since the crisis of energy hit the world.

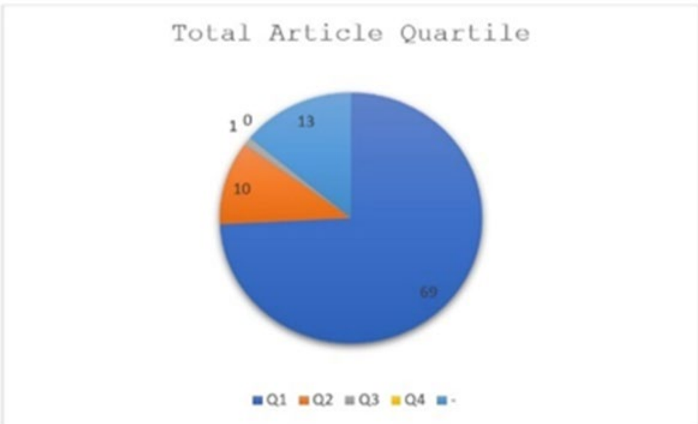

Fig 5: Distribution of article's quartiles of energy management of smart home

The distribution of scientific articles indexed by reputable database (Scopus) is depicted in Figure 5.

4. Result and Discussion

This section answers the research question as stated in table 2 and explain a comprehensive systematic review of smart homes.

4.1. Architecture system of energy management of smart home (RQ1)

A smart home system comprises of a combination of architecture system which can be classified into three main groups: component, communication type, communication protocol, and energy source as depicted in Table 3.

Table 3: Architecture System of Energy Management of Smart Home

Reference	Component	Communication Type	Communication Protocol	Energy Source
(Alam et al., 2019; Molla et al., 2018; Oprea et al., 2019; Saba et al., 2018; Spencer & Alfandi, 2016)	Humidity sensor, temperature sensor, light sensor	Hybrid	Wi-Fi	Wind, Photovoltaic
(Celik et al., 2017; Iram et al., 2017; Javaid et al., 2017; Kasmi et al., 2016)	Air quality sensor, noise level sensor, humidity sensor, actuators	Wireless	Middleware, Cloud server	Grid
(Kazmi et al., 2017; Shareef et al., 2018; Yassine et al., 2019)	Sensor, metering system, devices, home appliances	Hybrid	Cloud server	
(Chouaib et al., 2019)	Sensor, actuator, web server, micro controller	Wireless	Wi-Fi, Zigbee	
(Rehmani, 2016; Shah et al., 2020)	Sensor, actuator	Wireless	Wi-Fi	Photovoltaic
(Hui et al., 2017; Yang & Wei, 2021)	Sensor, mobile application,	Hybrid	Wi-Fi, cloud server	Energy storage
(Samuel, 2016; Xu et al., 2019; Yi et al., 2016)	Home appliances, sensor, web server	Hybrid	ZigBee	Energy storage

The component contains a collection of various sensors and other devices that act as the input of the system. As automation and intelligent systems are incorporated in the system, data about the conditions of the home and its surroundings are needed for the system to produce certain outputs or actions. The data is collected by various sensors installed around the smart home system, for example light sensors, temperature sensors, air humidity sensors, air quality sensors to detect the mobility of the smart home residents. More recently proposed smart home systems are integrating more types of sensors into its design. Data collected by the input devices is passed to the processing part. Generally, it includes microprocessors or microcontrollers, database for storing generated sensory data, cloud services, and a server. In addition to storing the database, the server is responsible for receiving commands from the application, processing data according to the commands given (by users or the owners of the smart home system) and generating commands that will be passed to the actuator. The output of this system can be an action, for example, opening and closing a garage door or turning on/off the lights, or in the form of a notification via mobile applications.

Wi-Fi enables communication between home appliances equipped with electronic devices. It will be effective at the nearest access point. Wi-Fi is used to perform wireless local network linking between master and slave and enable smart homeowners to interact and control the slave part of the system. This protocol is widely used in smart home systems to transmit data from sensors to the processing part or to connect smart devices to the internet. Zigbee technology is known for its security support. It includes the provision of 128-bit AES encryption, two preconfigured-enabled security keys, a trust center support, message integrity warranty, confidentiality, and authentication. Besides providing reliable and secure data transfer, it also offers several features. i.e., cost effectivity, multiple network topology support, low latency, higher data rate, longer battery life, and higher number of nodes per network. Due to the advantages offered by Zigbee, such as low cost, low power consumption, high efficiency, high security, and strong networking ability, this technology has been used to support many smart home system models.

There are several alternative sources of energy that can be used in smart homes. Some of the systems employ the hybrid power system, that is the combination between power generator module and storage system. The smart home uses a combination of fuel cells and Li-ION batteries. The amount of Hydrogen is predicted to adjust to the amount of the electrical energy to be produced.

Photovoltaic (PV) systems become a popular electricity generation of smart homes; however, their electricity production depends heavily on the solar irradiation. In addition to PV, some smart home systems also utilize wind power. The energy they produce fluctuates depending on weather conditions and has not been able to meet the total power demand. This gave rise to an interest in combining several energy sources to provide more energy.

4.2. Service and function of energy management of smart home (RQ2)

Smart home residents may consist of the elderly, children, and adults in general. For their convenience (Son & Park, 2022), the services and functions offered in the smart home concept become a challenge to be considered. Besides, they are interesting things to study for some researchers.

Tabel 4: Service and function of energy management of smart home

Reference	Service	Function
(Bhati et al., 2017; Chammas et al., 2019; Chouaib et al., 2019; Gholami & Javidan, 2018; Gupta & Chhabra, 2016; Hussain et al., 2018; Majeed et al., 2020; Pirbhulal et al., 2016; Sicari et al., 2018)	Comfort, convenience, security, safety	Optimize energy consumption, cost efficiency, energy conservation, predict energy consumption
(Hu et al., 2020; M. Li et al., 2018; Y. Li et al., 2020; Nilsson et al., 2018; Wilson et al., 2017)	enhance the interactivity of home life	Management and energy utilization
(Akbari-Dibavar et al., 2020; Domb, 2016; E. Park et al., 2017; Rahman et al., 2017; Rajagopal et al., 2019)	control the electricity load	Optimize energy consumption, cost efficiency, manage home appliances

Table 4 explains, the smart home models should provide several services that can be generalized as provide more comfort and convenience for the residents. One example of the convenience is the ability to connect to the real-time meter of electricity, water, and gas. Smart home should promote security and safety for its residents, enhance the interactivity of home life and optimize the resident's lifestyle, and support the energy management service that enables make a better decision about their electricity consumption. It includes the ability to control the electricity load for more efficient use of energy and manage several additional power sources. Besides, the research presents the optimization of the size of PV panels and storage media (batteries) in a home energy management system using a web-based application developed on a household scale. It recommends the optimal size of PV panels and storage media (batteries) to provide optimum power consumption from the grid. Users can manage configurations and energy constraints, such as house load profiles to get the best results. Researchers have studied the impact of installing rooftop Photovoltaic (PV) on the operational costs of using electrical energy in smart homes.

4.3. Algorithms in energy management of smart home (RQ3)

This section discusses mostly implementing algorithms to manage and predict energy consumption. Other than that, improving energy efficiency, and residents' comfort, managing energy, monitoring household consumption, and coordinating home appliance operations are important.

Table 5: Variant of algorithms in energy management of smart homes.

Reference	Algorithm	Dataset	Task
(Desot, T., Raimondo, S., Mishakova, A., Portet, F., Vacher, 2018; J. Park et al., 2018; Zhao & Keerthisinghe, 2020)	LSTM-RNN	Smart Grid Smart City (SGSC) - Australia, French smart home dataset	predicting PV generation, voice command
(Franco et al., 2021; Hsu et al., 2019; Kim et al., 2020; Surantha & Wicaksono, 2018; Talal Alshammari, Nasser Alshammari, Mohamed Sedky, 2018)	FFNN, LSTM, and SVM	UK Dale	Activity Daily Living (ADL) classification
(Duman et al., 2021; Gonçalves et al., 2019; Leonori et al., 2020; Meena et al., 2019; Oprea et al., 2019; Soetedjo et al., 2018; Yassine et al., 2017)	Fuzzy logic rule-based, Genetic Algorithm	TARBIL-U.K, Domestic Appliance Level Electricity	To optimize demand, respond of AC and maintenance of thermal comfort, to measure and analyses energy usage
(Ashenov et al., 2021; Collotta & Pau, 2017; Moon et al., 2014; Oyeleke et al., 2018; Shareef et al., 2018; Wang et al., 2018)	ANN, reinforcement learning-based	REFIT Electrical Load Measurements, TMY2 Seoul Korea	To schedule home appliances and optimize profit from renewable energy, to measure the thermal performance.

Various algorithms such as long short-term memory network (LSTM), recurrent neural networks (RNN), support vector machine (SVM), fuzzy logic rule-based, feed-forward neural network (FFNN), and artificial neural network (ANN) have been implemented in smart home research as depicted in table 5. Long short-term memory network (LSTM) and recurrent neural networks (RNN) as methods of deep learning (DL) proved to be the best in predicting PV generation to predict the electrical energy load in residential homes. The PV generation forecast of the LSTM-RNN is significantly better than any other approach, and the electrical load forecast is also better. The total annual electricity cost of households can be reduced by about 39 % by using a PV battery system controlled. The limitation of this paper that the dataset only consists of the aggregated load profiles it was unable to show the complete benefits of using LSTM-RNN for electrical load prediction. The gap is the computational time of SS-ADP only increases linearly when we incorporate additional DER while DP results in an exponential increase. The computational time for Household B is higher than the Household A because Household B as a larger PV system and a higher electrical load profile so the number of states required is also higher (Zhao & Keerthisinghe, 2020). Research by (Franco et al., 2021) using three ML classifier models to be integrated with the application recognition system, namely FFNN, LSTM, and SVM. The purpose of tool recognition is to set a label for each sensor which allows the application of different home applications such as the Activity Daily Living (ADL) classification. The gap of this paper is an intrusive load monitoring (ILM) approach for load monitoring and activity recognition based on IoT architecture in smart homes implemented by those three models. The LSTM model architecture proposed in this study has the length of the feature vector as ten and the number of target classes as five. The accuracy obtained in the UK Dale dataset is equal to 0.9. The limitation of this paper is the system does not work in real-time, so the design and complete IoT platform cannot be implemented in a laboratory environment yet.

The fuzzy mamdani algorithm was proposed to set a point temperature for response time based on electricity prices and solar radiation. The gap of this study is to combine a smart thermostat with a home energy management system (HEMS). The fuzzy logic-based smart thermostat adjusts an initialized set-point in response to changing conditions (electricity prices, solar radiation, and occupant presence). It defines different setpoints for each time interval. Home appliance is included in day-ahead optimization with other electrical loads at home and it is ensured that a stored solar energy is optimally distributed among all household appliances and peak power limits are met. The limitation of this study is an analysis just based on a daily cost reduction may be misleading since the savings due to cost reduction may not return the investment for distributed generation and energy storage units (Duman et al., 2021).

Pre-trained ANN was used to predict prices in real-time and stored in the cloud to provide information for the next prices. The controller will schedule home appliances based on regression model (Ashenov et al., 2021). Recently, ANN has been widely used to optimize efficiency/energy saving in home or building design, for example, to optimize heating operating systems in a home or building (Moon et al., 2014). The gap of this study is a novel approach for using reinforcement learning for scheduling the loads. A power tariff dataset was fed to the ANN of the system to predict day-ahead prices and create a scheduling environment. ANN can also be integrated with ensemble models to predict cooling dynamics in a building (Wang et al., 2018).

Dataset is used to train and test the models proposed in each study. For energy management in smart homes, several datasets are available from various countries, for example, PV output data and electrical load profile provided by Ausgrid, Australia which was taken online in 2020. One feature is used to predict PV output and load by applying the nonlinear auto-regressive model. Training data is used for two years while testing data is used for one year. The electrical load measurement dataset in Watts at REFIT is the electricity consumption for 20 households in the London area, the United Kingdom in 2016.

4.4. Discussion

The smart home has great potential to meet energy supply-demand by strengthening the digital home system to support precision in energy management with technology and artificial intelligence. The prospects of energy management in smart homes involve the use of explainable artificial intelligence for load monitoring and daily activity recognition based on IoT architecture, predicting day-ahead power prices, optimizing electrical loads at home, and ensuring that stored solar energy is optimally distributed among all household appliances and peak power limits are met. IoT integration in smart homes is focused on optimization and automation technologies that seamlessly integrate knowledge, products, and services to achieve high productivity, quality, and profit. Not much research has been conducted and put forward regarding systematically reviewing some literature on smart homes and presenting a comprehensive study on different types of smart home systems regarding architecture systems, functions, services, and algorithms. The main findings of several studies are presented in Table 3-5.

Various technological problems and architectural problems have been addressed through the development of smart home systems, but most of these systems are in the model concepts. Its main focus lies in energy management, predicting day-ahead power prices, and home appliance control. Some of these studies have also explained the implementation of IoT in smart home systems such as cloud servers and web server bases. In addition, most research focuses on addressing specific problems. Artificial intelligence approaches and digital technologies in smart home systems make energy management more efficient and easier to use. Based on the findings summarized in the previous section, machine learning algorithms and IoT smart technologies can be used to increase the overall efficiency of a smart home system. However, in other existing literature reviews, the analysis of the smart home energy management concept is partial and not complete enough. Our paper presents a comprehensive study of different types of smart home systems.

5. Conclusion

The contribution of this study will be carried out around smart home systems to support energy management. Smart home energy management with IoT approaches has been carried out in several previous studies. The limitation of this review is that it uses only the prioritized online repositories for literature searches (Scopus, IEEE, AVM, MDPI, and Science Direct). On the other hand, additional keywords and synonyms can be revealed in future research. PRISMA framework implemented in 93 articles from 2016 to 2022 discussing architecture systems, services, functions, and algorithms for smart home systems analyzed in this study. The pattern in the energy management of the smart home has become interesting for researchers in the last 5 years as depicted in Figures 4 and 5. 93 articles were chosen to discuss the energy management of smart homes. The research questions posed are regarding architecture systems implemented in smart homes, services and functions of energy management, and the algorithms used in smart homes to optimize energy management.

The distribution of utilization of the IoT has been completed and discovered as depicted in the architecture system regarding component, communication type, and protocol. The services and functions provided by smart homes including comfort, security, and cost-efficiency become an important thing to be considered. The algorithms implemented in the energy management of smart homes around machine learning and deep learning, such as LTSM, RNN, SVM, etc.

In reviewing the state of research on smart home energy management, clear gaps emerge between narrow technical explorations and integrated platforms reliable, useful and usable for residents. Progress rests not simply on leveraging emerging capabilities around AI, renewables and distributed computing but aligning control solutions with lifestyle needs. Insights reside as much in reproductive validation studies as novel demonstrations. With consumer expectations rising amidst energy and climate challenges, transdisciplinary collaboration anchoring innovations around human factors provides the most viable path forward. Fundamental technical advances should target convenience and practicality as much as strictly optimal efficiency or accuracy.

The added value of this study has various advantages compared to other literature surveys; a comprehensive and complete view of energy management in smart home systems has been analyzed clearly, the implementation of IoT concepts has been depicted according to architecture system. The results of studies from previous research on IoT applications in smart homes have been developed to manage various services for energy management. Most of the systems are still classified as prototypes and conceptual models. As the results shown from 93 articles reviewed, the use of artificial intelligence algorithms from machine learning and deep learning as well as technologies such as big data and analytics, cyber-physical systems, and digital twins have not been significant and explored in smart homes. This is because the costs required to develop intelligent smart homes are still expensive, including implementation, operational, and maintenance costs. This research reveals that there are new research opportunities to investigate and study big data analytics and digital twins as future research.

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