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Study on Energy Saving in Smart Homes: A Brief Overview

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Abstract. The issue of energy efficiency is facing a serious global challenge, and we must optimize energy consumption for the survival and development of mankind. In the paper, various schemes for energy saving in smart homes are categorized and explained. The effect of each energy saving scheme is compared, categorized, and summarized. Energy-saving solutions for smart home systems, home energy management systems, and various other solutions that can effectively realize energy saving are described and compared. Solutions that combine various algorithms with smart homes to achieve energy saving are also discussed. This paper provides a critical overview of various energy saving schemes. The problems of the various schemes are discussed. It is important to consider not only the energy consumption but also the comfort of the users and their safety. The introduction also confirms the importance of education about energy usage for the users. The overview provides some useful suggestions for the research and development of optimized energy management systems applicable to homes, buildings, etc. Readers could use this article to get an idea of the solutions and ways of energy management in smart homes. It is hoped that energy and power saving can be better carried out in the future to protect the environment and reduce carbon emissions.

Keywords: Energy Saving, Smart Home, Home Energy Management System.

1. Introduction

As technology continues to evolve and a new era is ushered in for all kinds of electrical products, the ensuing issue of energy efficiency has become one of the many issues that we must focus on. Energy efficiency is facing serious global challenges, such as the common economic crisis, atmospheric pollution, climate impacts, and energy issues [1]. In order to protect the health and ecosystems of all human beings as well as plants and animals, we must reduce greenhouse gas emissions and optimize energy consumption [2]. And for the above mentioned problems, some relief can be achieved by choosing appropriate energy efficient alternatives. As more and more energy is being consumed, it has compelled governments and relevant organizational sectors around the globe to promote energy efficient behaviors as a way to alleviate the energy crisis [3]. One of the sectors that has received a lot of attention is the residential sector, which is gradually becoming recognized as a high energy consuming sector. This has led to the gradual emergence of smart homes in the public eye. The smart home market has grown greatly, especially in the areas of energy efficiency systems, entertainment and living, lighting systems, monitoring, and detection. And it continues to evolve and improve. With the advancement of energy conversion, information technology, and communication technology, home energy management systems (HEMS) have become the top pillar of energy management [4].

Smart home is a business model that focuses on the development of services, application models, and home networks that allow buildings to bring better benefits to their users [5]. It allows us to focus on energy efficiency along with better user satisfaction for home comfort [6]. The emergence of Internet of Things (IoT) devices, appliances, and applications in the field of energy has greatly improved the sustainability of cities and homes and has brought great convenience to the residents. It is not a bad idea to link IoT with energy saving [7]. IoT refers to connecting all devices to the Internet in a particular way. HEMS and Building Energy Management Systems (BEMS) use smart devices with IoT technology to improve the living and working environments. IoT data includes HEMS data, which refers to data sensed by sensors in a sensor network [8].

In the 21st century, there is an increasing number of devices related to IoT [9], which has led to the emergence of energy management devices and home automation solutions [10]. Some of the challenges in smart home solutions are protocols, communication technologies, effective use of sensor data, and automation, of which automation technology is a key part, and automation technology plays a vital role in exchanging data between the central control unit and each end node [11]. Data transmission and reception should be as timely as possible without delay. Various solutions are available in the field of smart home automation, but each of them has its own advantages and disadvantages. Hybrid solutions in smart home automation systems are now more widely used with the support of IoT devices. Energy management systems can utilize these hybrid solutions for effective energy management [12].

Smart homes contain a wide variety of sensors such as access control, temperature, humidity, light, etc., which are often associated with home automation systems [13]. People are also more concerned about price prediction in the context of time-sharing tariffs. More users are willing to use smart homes for prediction purposes [14]. The smart home system can be controlled by the data received from sensors. Energy management is a key issue in smart home. The most important function of the smart home is to manage energy with more consideration to the comfort of the user, and ideally, it can automatically adjust the power resources according to the user's needs [15]. In addition, we should pay more attention to the user's safety, the smart home system has to predict the existence of the surrounding dangerous situations and reasonable treatment of these situations, to provide greater benefits for the user. Various smart home systems have been developed and marketed, which are mainly controlled through message services, android applications, Internet, and wireless communications.

Home automation mainly refers to the control of household appliances through a number of technologies and it is a passive way of saving energy. Home automation brings better control to the end user in many ways, such as access control, monitoring, lighting, environment, energy management, and more. Home automation provides users with access control mainly through the installation of surveillance cameras in the home. Most of the operational control of home automation technology is achieved through sensor data [11].

Smart grid is the intelligence of the power grid built on an integrated, high-speed two-way communication network [16]. It allows access to different forms of power generation and is dedicated to the efficient operation of the electricity market. The aim of achieving a safe, environmentally friendly, economical, safe, reliable, and efficient grid is achieved through the application of advanced control methods, device technologies, measurement technologies, sensing technologies and decision support system technologies in the smart grid [17]. The smart grid is able to process the grid models of different energy sources in a decentralized and efficient way. It is well capable of recognizing the truest state of the network, which is a grid that connects the points of consumption with the points of generation, and its purpose is to deliver electricity. The smart grid has seen the emergence of new and some developing technologies in power generation, transmission, and distribution [18]. Overall, the smart grid can be viewed as a network that provides quality of service, security, reliability, and efficiency, and can manage electrical devices in a number of areas. Requirements for smart grid applications when applied to smart home scenarios include consumer energy efficiency and demand response [19].

In order to avoid energy waste, existing electricity should be used more efficiently [20]. Using smart home and other methods to save energy has become the focus. The remainder of this paper is organized as follows: Section 2 discusses the smart home energy-saving system architecture and reviews the concepts, uses, and applications of smart meters and smart socket devices. Section 3 discusses various smart home energy-saving solutions, including smart home systems, HEMS, and some other energy-saving systems. The design and application of energy-saving systems by various scholars are reviewed. Section 4 discusses some smart homes that are combined with algorithms to achieve energy savings. Section 5 summarizes the entire article and provides suggestions for future directions.

2. Smart Home Energy-Saving System Architecture

2.1. IoT and Energy Saving

Smart home refers to a number of sensors, appliances and devices that are equipped with interconnections in the home [21]. These devices can be controlled remotely and also communicate with each other. Along with the development of services, application models, and home networks, smart home buildings can bring better benefits for the users. It allows users to better detect their own electricity consumption and adjust their living habits to achieve the purpose of saving electricity [22]. Currently, smart home energy management system (SHEMS) is widely used [23]. The concept of smart home is shown in Figure 1.

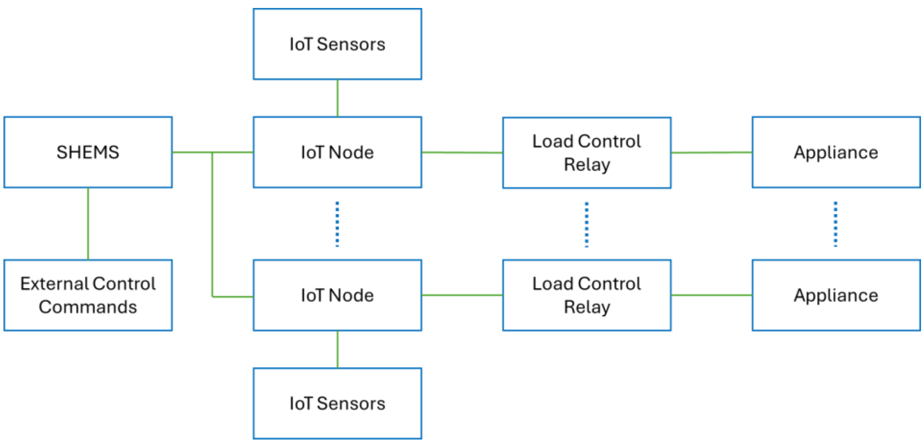

Figure 1. Concept of smart home.

Without affecting user comfort and in ensuring safety, for the current smart home devices, many communication devices can be used to collect home energy consumption data [24]. The brief architecture of the smart home energy saving system is shown in Figure 2.

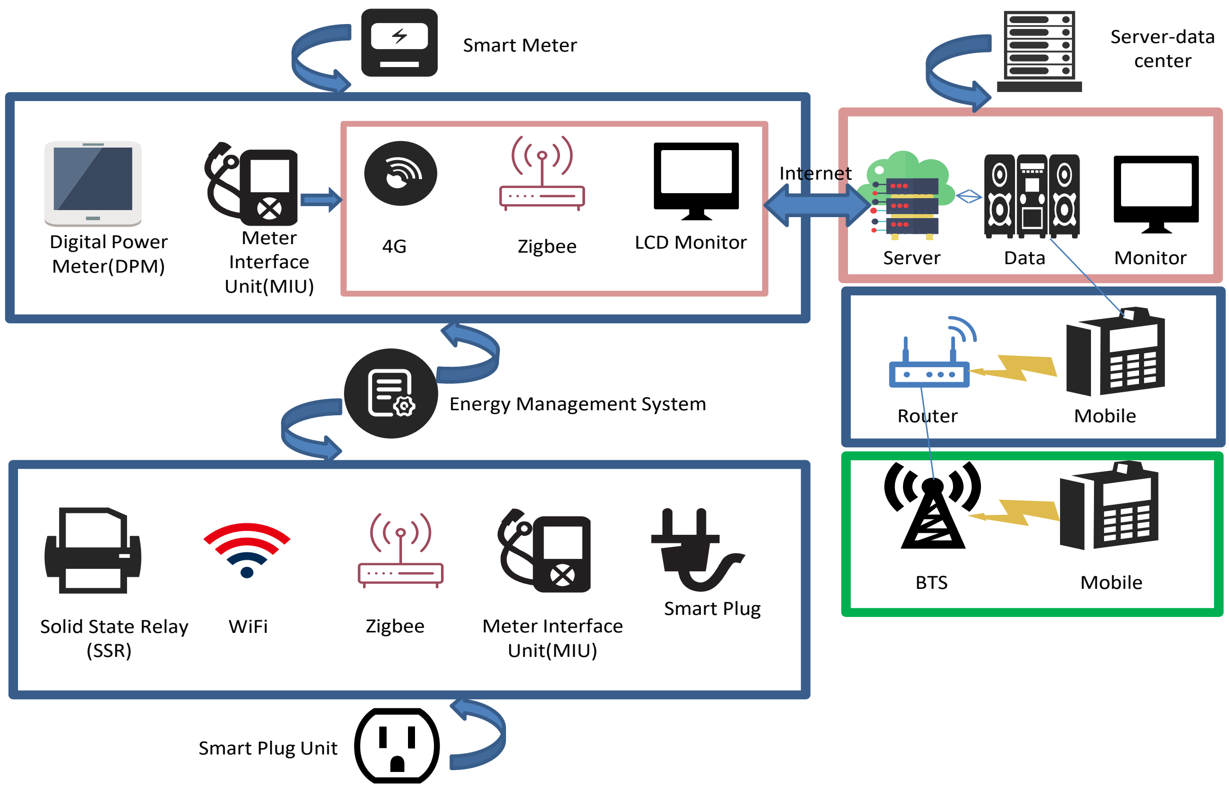

Figure 2. Concept of smart home energy saving system.

The architecture of the smart home energy saving system is divided into four units: smart meter, smart plug, server-data center, and energy management system. Users can observe the real-time power consumption through Digital Power Meter (DPM) and can also see the abnormal conditions at a glance. Various power information can be transmitted to mobile devices via Wi-Fi modules. Each device is monitored individually using a Smart Plug Unit (SPU), which provides a clear understanding of the operation of the device and easy access to information. The raw system voltage and current signals from the smart meter are sampled using a digital power meter. The power consumption is then calculated, and the accumulated power information is transmitted to the Meter Interface Unit (MIU). The load power data collected using the smart plug can be displayed on the LCD monitor. The data also can be transmitted to the MIU via the ZigBee module. A client-server architecture can be used to transfer the information to the server-data center. The smart plug can be accessed by users on the LAN via Wi-Fi and router.

The following subsections focus on the unfolding description of the above mentioned units as well as the wireless communication technology. The concepts and uses of the two devices, smart meters, and smart sockets, as well as their applications are reviewed.

2.1.1. *Smart Meter*

A smart meter unit consists of DPM and MIU for data sampling and calculation. Data transmission to the server-data center can be done via Internet. Smart meters are smart terminals of smart grids. They not only have the metering and billing functions of traditional meters, but also have many intelligent functions such as user-side control, two-way data communication, anti-theft, and two-way multi-rate metering. They can adapt well to metering and billing functions of different electricity price mechanisms such as real-time electricity prices and time-of-use electricity prices [25]. They can be programmed remotely for settings and software upgrades. Smart meters also have the functions of remote power on and off, prepayment, and detection.

The main advantage of a smart meter is that it is a good way to collect data about the consumption of the user, which can be accessed more easily through mobile apps and some websites. This makes it easier for consumers to understand their consumption patterns and the power consumption of individual appliances more quickly, so that they can take some action to reduce their power consumption based on this data. For example, they can reduce the usage time of certain appliances that are not essential. Another advantage of smart meters is dynamic electricity consumption based on tariffs [22]. It can guide the user to shift the usage time of appliances that do not affect the comfort level from the peak to the low peak of electricity consumption.

Eduardo Viciana et al. in [17] detail the openZmeter (oZm), a low-cost but highly accurate and relatively reliable, small, open-source electric energy meter. The oZm device in the work serves as a key part of the smart metering infrastructure. It can realize cloud data collection and monitoring of electrical characteristics, and it is single-phase open hardware with bidirectional functionality. The oZm as a smart meter has various functions, which not only meets the minimum requirements of a smart meter, but also receives some information detected in the electrical device, detects anomalies through the detection of this information, and implements some preventive measures. The oZm hardware framework is shown in Figure 3. The first module (green) is the signal acquisition stage; the second module (orange) consists of management elements and power supply; the third module (black) is a microcontroller; and the fourth module (yellow) is a controller. The oZm has an important feature that it can go on to measure some power quality (PQ) events. The oZm ensures the energy consumption and power quality measurement.

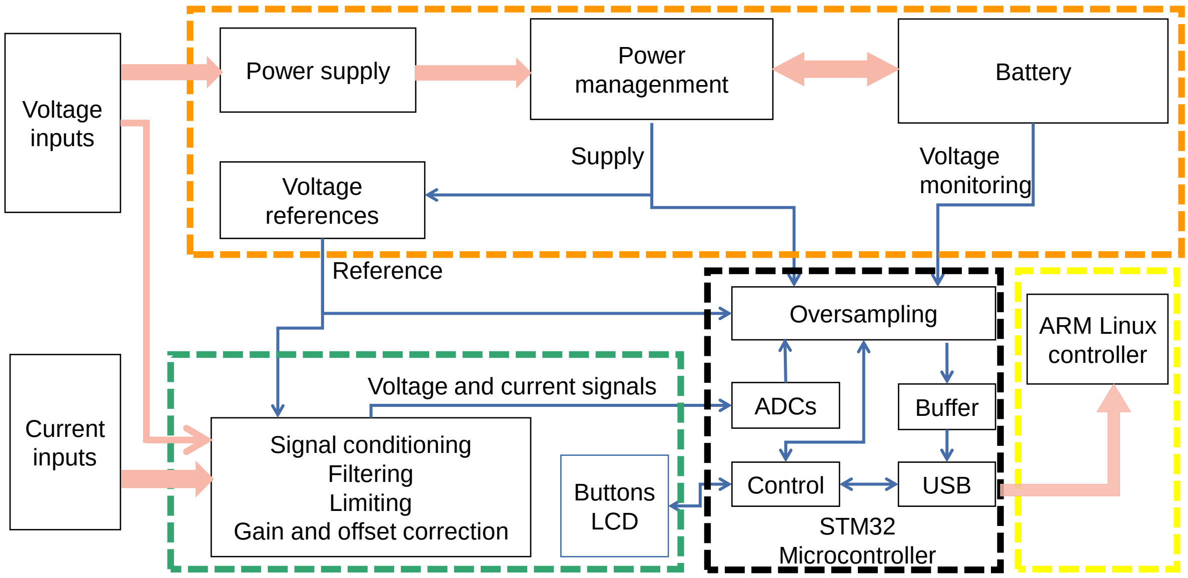

Figure 3. Hardware architecture of oZm.

Abhishek Bhati et al. in a case study in [22] evaluated some energy consumers who have smart meters. Their results showed that the information provided by smart meters is not sufficient in terms of data and many times consumers are not able to fully understand the information provided and sometimes they are not able to take appropriate action based on the information provided. This suggests that the relevant energy suppliers should provide details on the analysis of energy consumption data, and at the same time, consumers should be adequately educated and informed about the energy consumption of their appliances. In the future smart meters should detect behavioral patterns and also act proactively. The study in the literature shows that the maturity of smart meters is still in the early stages of development.

Xingxing Zhang et al. in [26] used smart meters and in-home displays (IHDs) with the goal of helping residential users to control energy consumption and satisfy the environment and provide security. The IHDs can be provided to home users as a part of smart metering. In this study, the smart meter automatically collects electricity consumption data from individual home electrical boxes and then transmits this data to the IHDs and GPRS terminals and finally transmits securely to a database. The IHDs automatically record the frequency of user checks. The study has shown that households using IHDs consume significantly less electricity and shift power consumption from peak to low peak hours through the IHD's TOU feature.

2.1.2. Smart Plug

A smart plug unit performs power management via Solid State Relay (SSR) to remotely control the switching of the power supply. Parameters and information are transmitted to the smartphone via the Wi-Fi module and transmitted to the MIU via the ZigBee module. Smart plugs are plugs that can save electricity. Some high-end energy-saving plugs can not only save electricity, but also protect electrical appliances. Smart plugs can usually be used to collect the on/off status and power consumption information of household appliances, such as refrigerators, air conditioners, dishwashers, televisions, microwave ovens and other appliances. When the future smart grid manages and controls individual household appliances, smart plugs will become the core equipment. Smart plugs have the following main functions: energy-saving function, detection of power on and off of standby appliances; tripping protection will be generated when the power is lower than the set power, and timed tripping function; providing plugs with protection functions; measuring and displaying current, voltage, frequency, power, accumulated energy and other power consumption information; providing metering plugs with communication interfaces such as RS485, wireless, and USB.

Jooseok Oh et al. [7] found that when as many appliances as possible are connected to smart plugs and their power usage is frequently monitored, the energy consumption reduction rate will be better improved. At the same time, when smart plugs are used for heating and cooling appliances and related equipment such as audio, the energy consumption reduction rate can also be increased. Real-time power consumption monitoring strategies can be used to reduce users' unnecessary power expenditures and power consumption. The number of smart plugs and switches installed has a great impact on reducing energy usage. Users who use smart plugs and switches can cut off the standby power supply inside and outside the house and can also cut off the power supply during use, which can help users achieve better power saving effects. The study aims to reduce household electricity consumption by letting users use IoT-based smart plugs and switches, as well as voluntary education. The importance of education to people is demonstrated from the perspective of energy conservation and some related policies. However, there are some practical limitations to the study: consumers want to recover their initial investment costs, which will take many years to achieve, and existing homes are not willing to purchase related equipment, which will reduce efficiency. However, the study is meaningful. It has produced relevant results through long-term monitoring and provides direction for energy conservation in various aspects.

2.1.3. Server-Data Center

As the most important and core part of cloud services, server-data center is used to store various application data. It transmits, calculates, and processes information on the Internet. In the local area network, users can access the smart plug through Wi-Fi and routers. In the wide area network, network address translation (NAT) technology is used to convert IP addresses. Server-data center collects data, checks transmission information, and provides guarantees for data security.

2.1.4. Energy Management System

The energy management system consists of two parts: hardware and software. It allows users to monitor the generation and use of energy. It can be used to collect and process not only energy consumption information, but also many types of information. The energy management system processes the information by receiving data from the smart meter unit and the smart plug unit. It takes appropriate measures, and then sends the data to the server-data center to further process the data and manage the information.

2.2. Wireless Communication

With the continuous development of science and technology, there are many wireless communication technologies to choose from. Among the many wireless communication technologies, no one wireless communication technology is omnipotent because of various environmental factors. Under different conditions in different environments, there are different functional requirements that cannot be met by a single wireless communication technology. In this study, some of the commonly used wireless communication technologies are summarized.

Zigbee is a technology based on IEEE 802.15.4, which is characterized by low power consumption and low data rate. Zigbee is mainly used in application scenarios with short distance, small amount of data and low power consumption at the same time. The more commonly used is the mesh topology. Zigbee is most commonly used in wireless control and monitoring application scenarios in smart homes. Wi-Fi is the trademark name of all IEEE 802.11 standard wireless local area networks (WLANs). Its common operating frequency bands are 2.4 GHz and 5 GHz. But Wi-Fi also uses other frequency bands. The latest Wi-Fi technology can be used for longer distances, higher throughput, and wider coverage. Bluetooth is divided into Bluetooth Classic and Bluetooth LE. Bluetooth LE is most commonly used in indoor navigation, smart lighting systems, medical and fitness equipment, real-time positioning systems and other applications. Besides, 4G/5G telecommunication networks can also be used for the IoT-based energy management systems, but they are not license-free communications to use. ZigBee, WiFi, and Bluetooth are license-free. The 4G/5G communication is commonly used on mobile devices for data and information transmission in mobile applications of smart home energy management. In addition, power line communication (PLC) has the characteristics of high-speed transmission, wide transmission range, energy saving and safety. This technology uses power lines as communication carriers. Data is transmitted through wires and finally the signal is sent to the terminal device. The transmission rate of information is greatly improved. At present, it is mainly used in home Internet access and intelligent network control of home appliances. Table 1 shows the summary of the communication technologies.

Table 1. Communication technologies for smart home energy management.

	ZigBee	WiFi	Bluetooth	PLC
Frequency Band	868/915 MHz, 2.4 GHz	2.4/5.0 GHz	2.4 GHz	1.6-39 MHz
Transmission Rate	20/40/250 Kbps	10-300 Mbps	720 Kbps	4.5-45 Mbps
Transmission Range	30-50 m	50-100m	1-100m	1-2 Km
Power Consumption	Low	High	High	Low
Cost	Low	High	Medium	Low

3. Smart Home Energy Saving

The emergence of smart homes has gradually reduced building energy consumption. After years of development, energy saving has become an important part of the progress of smart home systems. Various energy-saving solutions have also become a hot topic for public research. Energy saving is the focus of the development of the smart home industry. Most of the current smart home energy-saving solutions use various systems to adjust temperature, brightness, etc. in different modes, so that the equipment can be automatically turned on when the user needs it and can be automatically turned off when it is not needed. These functions can have a good effect on saving energy consumption. Energy consumption in the home is mainly divided into the following three aspects: one is lighting, the second is heating or cooling, and the third is standby energy consumption. Smart homes save electricity while ensuring user comfort. The following subsections will describe specific energy-saving solutions in detail.

3.1. Smart Home Energy Saving Systems

Smart home systems combine energy saving with residents' comfort and have developed rapidly in recent years. Energy consumption can be better reduced. Many scholars have also studied smart home systems and published related papers. For example, Ming-Tang Chen and Che-Min Lin used an effective method of Support Vector Machines (SVM) in [27, 28] to actively identify the characteristics of electrical loads in different working states. And achieved through the Smart Home Energy Saving System (SHESS). SVM classifies operating status through power information features. This SHESS implements control of standby power consumption and reduces unnecessary power consumption. The feasibility of the system was verified through experiments. Bingjie Yuan et al. proposed a comprehensive energy efficiency smart home system in [29], which uses ZigBee's data compression, routing node rotation mechanism and scheduled sleep to achieve energy saving. This paper realizes energy saving based on fuzzy neural network and proposes a learning and design program for home control. It used WI-FI and ZigBee hybrid network to implement home intelligent network structure and introduce sensors and fuzzy control systems.

The energy saving of the smart home control system mentioned by Sérgio Henrique Andrade et al. in [19] is achieved using fuzzy technology. This article introduces a new architecture, Smart Consumption Management Architecture (SmartCoM). Use fuzzy logic to inform residents of increased energy consumption and use strategies to optimize energy consumption, configured in SmartCoM. SmartCoM is the most widely used interoperability solution in the smart home field. SmartCoM finds end-to-end solutions for smart homes. It is suitable for managing and monitoring contexts. SmartCoM allows you to observe consumption patterns among connected local customers. The system uses computational intelligence to generate metrics that reduce power waste. Bilal Mubdir et al. [30] designed a smart home energy-saving management system, which is based on Hidden Markov Model (HMM) and detects resident activities, identifies energy consumption and relies on remote actuators and motion sensors to control home appliances. Use WiFi technology for data transmission and monitoring of home appliances and sensors. External communications use GSM technology. In this article, residents' activities are divided into three states: Sleep, Away and Active. When the room is unoccupied (5-10 minutes), the lights in the room will be turned off. This is mainly achieved by home smart gateways (HSG) individually controlling rooms through motion sensors. The SHEMS proposed in this study adds an adaptive method, resulting in energy savings of 18 percent. Users can monitor their home situation very well through text messages. In the future, the SHEMS will target detecting home safety issues when residents are away. Salloom Al-Juboori et al. [31] introduced a Smart Residential House Saving Energy System. Achieve energy cost reductions and provide services to housing security. The system provides information to users by recording and monitoring residents' consumption behavior. Warnings are sent to users when high temperature faults are detected, which not only saves power but also provides safety. The system has a consumption prediction function that will notify residents to raise alerts when high consumption is predicted. It also has the function of a scheduling tool, which shifts the use time of non-essential equipment to periods of low power consumption. Cost reduction is achieved through a series of operations. Using this strategy for refrigerators and kettles can reduce costs by 12.7 percent. Strategies for washing machines and dishwashers can reduce costs by 22.4 percent. For TVs and PCs, the strategy can reduce costs by 44.4 percent. Using the suggested strategy, the total cost can be reduced by 22.75%. Overall, the practical value in reducing costs is considerable. Gembong Edhi Setyawan et al. [32] created a centralized smart home system that can be manually controlled remotely through the Internet through a smartphone. People can use the system to monitor the condition of their appliances, and the system can automatically shut off appliances when not in use. This system can automatically check whether there is anyone in the house and can also perform operations based on user customization. Residents can control the switches of electrical appliances through their smartphones. The system can also measure the power consumption of any appliance and monitor power usage. In the future, the system is expected to achieve cloud storage and monitoring on the web or mobile devices. Prithvi Pal Singh et al. [11] discussed the importance of smart home and automation, while emphasizing energy saving. The entire power network is covered in detail. Integrate IoT-based signal processing with smart homes. A list of the methods used in smart home systems proposed by various literatures is shown in Table 2.

Table 2. Energy-saving solutions for smart home systems.

Year	Literature	Feature
2019	Prithvi Pal Singh et al. [11]	IoT-based smart home
2017	Sergio Henrique Andrade et al. [19]	A decision-making fuzzy technique used in SmartCom
2018	Ming-Tang Chen et al. [27]	Support Vector Machines (SVM)
2017	Bingjie Yuan et al. [29]	Basedon ZigBee and Fuzzy Neural Network
2016	Bilal Mubdir et al. [30]	Hidden Markov Model (HMM)
2019	Salloom Al-Juboori et al. [31]	Rules-based housing energy systems
2016	Gembong Edhi Setyawan et al. [32]	Centralized Smart Home

3.2. Home Energy Management Systems

In addition to smart home systems that can save energy and improve comfort, there are many other energy-saving systems that can also achieve this effect. HEMS is a technology platform consisting of hardware and software. It allows users to monitor the generation and use of energy and can choose to manually control or automatically control energy use in the home [33]. HEMS can be used not only to collect energy consumption information, but also to collect many types of information. Its role has expanded to include indoor comfort, medical care, home security and more. Isaac Machorro-Cano et al. [3] proposed HEMS-IoT, which uses big data analysis technology to collect and analyze information. Leverage machine learning to provide solutions. Big data technology and machine learning technology are used to help HEMS-IoT analyze energy efficiency and identify user behavior. HEMS-IoT provides energy-saving suggestions, real-time monitoring of sensors and demotic devices, and helps users and devices communicate. The HEMS-IoT proposed in this study can be used for home energy saving, safety and comfort. Kanae Matsui [8] proposed the use of data collection through HEMS. The data collected was used to create a short-term indoor comfort index called predicted mean vote (PMV). The system can reduce power consumption while maintaining indoor comfort based on each user's PMV. The two most important functions of this system are: (1) Displaying appropriate information in this database to users on the web page; (2) Calculate the PMV through the data collected by the network sensors, and then determine the residents' indoor comfort preferences based on the calculated PMV. Create more useful data through different types of sensory data. Research results show that households using this system reduce power consumption by approximately 2.7%, increase indoor comfort perception by approximately 16.4%, and the actual PMV value increases by 42.3%. Marco Pritoni et al. [34] proposed a framework that can identify and classify HEMS use cases. When no one is in the house, the thermostat will automatically adjust the temperature to reduce redundant services. These use cases can support smart home product design and better implement HEMS. There are following six HEM Strategies in this framework. The framework classifies opportunities to shift or reduce energy consumption, which are then applied to specific strategies for HEM products, and it specifies the systems or products needed to interact with users. A list of the HEMS energy-saving solutions proposed by the above literatures is shown in Table 3.

(1) Reduce superfluous service.
(2) Reduce useful service.
(3) Take advantage of free service.
(4) Shift useful service to a different time.
(5) Take advantage of storage.
(6) Reduce wasted energy in the conversion process.

Table 3. HEMS Energy Saving Methods.

Year	Literature	Feature
2020	Isaac Machorro-Cano et al. [3]	Big data and machine learning-based
2018	Kanae Matsui et al. [8]	Collection of data, creation predicted mean vote (PMV)
2020	Macro Pritoni et al. [34]	A framework for identifying use cases for HEMS

3.3. Other Energy-saving Systems

In addition to the above systems, the systems studied by the following researchers have also made great contributions to energy saving. For example, Alessandra De Paola et al. [35] achieved energy saving through a fog-based intelligent building hybrid system. Monitoring equipment is used to collect information so that the environment can respond well to the various needs of users and achieve energy saving. Fuzzy controllers provide reactive intelligence. Combining cloud and fog computing greatly improves the computing power of edge devices. The results show that the system can achieve the goal of energy saving without reducing user satisfaction. In the future, the dynamics between different buildings will also be studied to better achieve energy saving. The results show that energy consumption can be saved by up to 35% within a range of 10% decrease in user satisfaction, which is a considerable benefit. Y Nurfaidah et al. [36] designed a system using photovoltaic grid-connected power generation. Photovoltaic renewable energy is used to achieve the goal of saving electricity. Power data loggers are used to record energy use. HOMER, an analysis tool, is used to design renewable energy systems. Installing photovoltaic renewable energy can reduce PLN electricity. Hisham Alghamdi et al. [37] designed an energy-saving system using polymer dispersed liquid crystal (PDLC) glass. The workflow of the system is shown in Figure 4. The system achieves energy saving while using a lower cost. The system can also control harmful solar rays. The power saved in the smart room is nearly 39% compared to the ordinary room. Rabea Cheggou et al. [15] designed a smart security system using Raspberry Pi and sensors. A page was developed to allow users to better observe the use of home appliances. The functions of home automation are divided into residential, security and autonomous. The system consists of hardware and software parts and is a good remote home monitoring system.

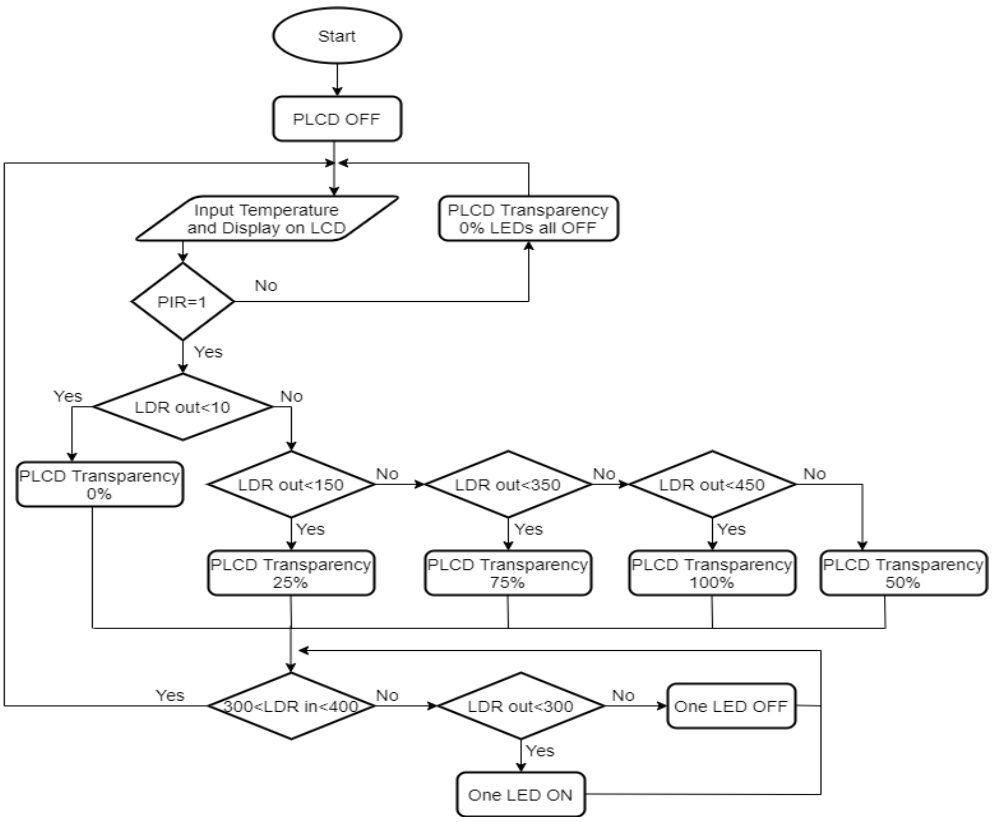

Figure 4. The workflow proposed in literature [37].

Nesarani Abraham et al. [38] proposed an automatic control system for electrical appliances. It uses home automation to make adjustments to achieve the purpose of saving electricity. A power reduction module is described. The module is used to switch appliances based on whether the user is in the house. When the user leaves the house, all smart appliances such as fans and lights will be turned off to achieve power saving. In this article, for users, especially those with limited mobility, not only is the moderation improved, but automatic monitoring is also achieved. Studies have shown that the total energy consumption is reduced by 20% with smart system control compared to without smart system control, and the cost is also reduced. M. Anto Bennet et al. [39] proposed a remote monitoring system based on WAP. Android devices are used to control applications on the GPRS network. When monitoring is required, the Android module is connected to home appliances. This system makes it easy to control home devices, making them both safe and energy-saving. Daniele Spoladore et al. [40] proposed a semantic framework called ComfOnt. ComfOnt provides services to users by using equipment, indoor comfort indicators and energy consumption. As a semantic knowledge base, ComfOnt aims to represent certain characteristics of the smart home ecosystem. The functions of this research system are specially designed for elderly users with limited mobility and defects, such as low light sensitivity, short-term memory, damage to related memory functions, cognitive impairment and other defects. However, the user group of this system is not limited to the above users, that is, all kinds of users, including normal users and users with disabilities, can use it. In this research design, the application will give corresponding warnings to different users when using electrical appliances. Gayatri Samrutwar et al. [41] proposed a context-aware and rule-based activity recognition system that makes energy saving possible while taking into account residential comfort. In future development, information can be provided for home energy saving without changing the state of home appliances, thus making a better contribution to energy conservation. The contributions to the research on energy-saving systems are as follows. Table 4 shows the list of the solutions described in this section and Table 5 shows several result data.

(1) Energy Prone Context System.
(2) Energy-Responsive Aggregate Context Systems.
(3) Fuzzy Controller system in Smart Home.
(4) Coordinated Illumination.

Table 4. List of the solutions describe in section 3.3.

Year	Literature	Feature
2017	Rabea Cheggou et al. [15]	Multiple sensors and Raspberry Pi
2020	Alessandra De Paola et al. [35]	Fog computing paradigm
2019	Y Nurfaidah et al. [36]	Helioscope and homer applications
2019	Hisham Alghamdi et al. [37]	Polymer dispersed liquid crystal (PDLC) glass
2018	Nesarani Abraham et al. [38]	Electrical automatic control system and power reduction module
2017	M. Anto Bennet et al. [39]	Based on the WAP framework
2019	Daniele Spoladore et al. [40]	A semantic framework is called ComfOnt
2019	Gayatri Samrutwar et al. [41]	Context-aware application and rule-based approach

Table 5. Result data of several solutions.

Year	Literature	Feature
2018	Kanae Matsui et al. [8]	Electricity consumption decreased by about 2.70 percent
2016	Bilal Mubdir et al. [30]	Energy savings of up to 18 percent
2019	Salloom AI-Juboori et al. [31]	Total cost reduction 22.75 percent
2020	Alessandra De Paola et al. [35]	Reducing energy consumption by more than 35 percent
2019	Hisham Alghamdi et al. [37]	Electricity savings 39 percent
2018	Nesarani Abraham et al. [38]	Total energy consumption reduced by 20 percent

4. Algorithm Research for Smart Homes

In the research process of smart home systems, multiple algorithms are usually integrated to achieve the goal of more automated home life. At present, there are also many literatures that mention the research on various algorithms. Azzaya Galbazar et al. [42] studied buildings based on ant colony algorithms. The parameters in the ant colony algorithm are temperature, light and other environments. These parameters are input into the algorithm for optimization. The purpose is to achieve better comfort and energy saving effects. The ant colony algorithm system is compared with the genetic algorithm system in terms of temperature power consumption, lighting power consumption, air quality power consumption, comfort index and total power consumption. The results show that the system based on the ant colony algorithm has better performance in all aspects. The ant colony algorithm flow chart is shown in Figure 5.

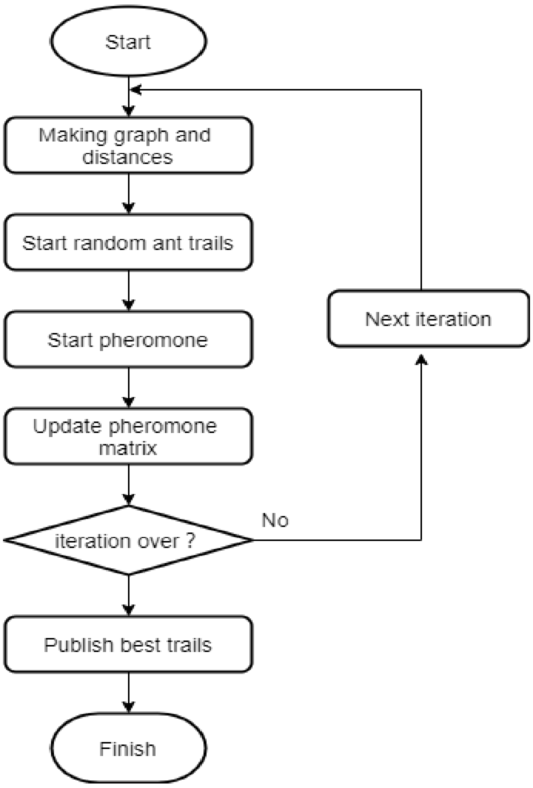

Figure 5. Ant colony algorithm.

Henrique F. Lacerda et al. [43] used multi-objective technology to provide energy-saving solutions for household electricity consumption. This contributed to residential energy consumption management. They used the non-dominated sorting genetic algorithm (NSGA-II) to recommend better solutions. NSGA-II is widely used as a multi-objective version of the genetic algorithm. However, this technology is meaningless when applied to refrigerators, because refrigerators are usually not turned off and are working 24 hours a day. In [20], they also mentioned a Binary Multi Objective Particle Swarm Optimization technology, which was applied to smart homes. Through appropriate data preprocessing and using this technology as a device environment recommendation system, the energy-saving effect was achieved well. In the future, clustering algorithms can be used for improvement to better filter out some recommendations that are not very useful to users. Krishna Prakash N et al. [44] used fuzzy logic algorithm for load management system and battery management system and designed a SHEMS that integrates battery management and load management. It reduced the user's daily energy consumption by more than 35%. Emilio Orsi et al. [45] used a greedy algorithm to implement smart home energy planning. The results showed that after optimization, the water heater opening time can be reduced by 38.9%, and one air conditioner and two water heaters can be optimized without reducing the quality of service. Ghulam Hafeez et al. [46] proposed a wind-driven bacterial foraging algorithm (WBFA). The simulation results showed that WBFA has a good effect in reducing electricity costs and can also reduce the peak-to-average value. Safdar Ali and Do-Hyeun Kim [47] used a genetic algorithm for energy saving and prediction, which greatly improved user comfort and reduced energy consumption. The list of system software in some articles mentioned above is shown in Table 6, and the list of performance evaluation methods is shown in Table 7.

Table 6. List of system software used in some studies.

Literature	Evaluation
Isaac Machorro-Cano et al. [1]	Weka 3.8, Java, Apache Mahout, RuleML
Kanae Matsui et al. [3]	Linux
Rabea Cheggou et al. [5]	Raspberry Pi 2, Apache web, Linux
Eduardo Viciana et al. [6]	Linux, STM32, oZm
Che-Min Lin et al. [12]	TMS320-F28335, TMS320-F449, ADE7953, Android SDK, Eclipse SDK
Bilal Mubdir et al. [14]	Visual Basic
Salloom Al-Juboori et al. [15]	Lab-View
Alessandra De Paola et al. [19]	Tabu Search, AMI module
Y Nurfaidah et al. [20]	SDM120-Modbus, Arduino RS485
Hisham Alghamdi et al. [21]	Arduino
Nesarani Abraham et al. [22]	ACS712, Arduino Nano
M.Anto Bennet et al. [23]	Embedded system
Daniele Spoladore et al. [24]	Java
Azzaya Galbazar et al. [26]	Matlab/Simulink, C#

Table 7. List of performance evaluation methods in some studies.

Literature	Feature
Jooseok Oh et al. [2]	Empirical study based on 15-month monitoring
Kanae Matsui et al. [3]	Three families conducted a 12-day winter test
Rabea Cheggou et al. [5]	Prototype implementation and test
Feitosa, A. R. S.et al. [8]	Model experiment
Abhishek Bhati et al. [9]	Questionnaire survey
Xingxing Zhang et al. [10]	Establishment of statistical analysis model
Ming-Tang Chen et al. [11]	Established a virtual living room prototype system
Che-Min Lin et al. [12]	Build system prototype
Bilal Mubdir et al. [14]	Case study of a three-bedroom house
Salloom Al-Juboori et al. [15]	Modeling and simulation
Alessandra De Paola et al. [19]	Experiments on actual sensor trajectories
Hisham Alghamdi et al. [21]	Simulation, reduction model (100:1)
Nesarani Abraham et al. [22]	Electric appliance for 72h experiment
Azzaya Galbazar et al. [26]	Matlab/Simulink simulation
Henrique F. Lacerda et al. [27]	Select five appliances for testing
Krishna Prakash N et al. [28]	Simulink simulation

5. Conclusion

Energy efficiency is facing severe global challenges. For the survival and development of mankind, we must optimize energy consumption. This article classifies and explains various smart home energy-saving solutions. There are energy-saving solutions for smart home systems, energy-saving solutions for HEMS, and other solutions that can effectively achieve energy saving. It also discusses solutions that combine various algorithms with smart homes to achieve energy-saving goals. Without the active cooperation of customers, a series of energy-saving operations cannot achieve the desired results. For users, it is necessary to carry out appropriate energy-saving education. Users must understand the importance of energy saving from the bottom of their hearts and want to save energy themselves, so that various energy-saving solutions are meaningful. Many smart home energy-saving systems also take into account people with limited mobility, and some systems are also tailored for them. In terms of energy saving, we should not only consider the problem of energy consumption, but also pay attention to the comfort of users and their safety. After all, society cannot regress to a period without electrical appliances. These appliances are designed to improve people's quality of life. Using all energy-saving solutions that do not focus on comfort and safety is empty talk. This article critically reviews various energy-saving solutions, and the problems existing in various solutions are worth in-depth discussion. This article provides some useful suggestions for the research and development of optimized energy management systems for homes and buildings and conducts a survey on the field of smart home energy saving in recent years, so that readers can understand the solutions and methods of using smart homes for energy management in recent years through this article.

In future research, we should find more optimized solutions to various energy-saving solutions, such as cost, safety, comfort, user groups, and scope of application. We should pay more attention to optimizing the user experience and try to achieve the desired energy-saving effect without knowing it. When ensuring the safety of users and the energy-saving solutions that do not affect the comfort of users, we should pay more attention to protecting the privacy of users, ensuring that the user's data is safe, and preventing the rights and interests of users from being damaged due to data leakage. Many of the designed applications mentioned in the article can only be used in the Android system, which will put higher requirements on the system for future application development, so that the designed applications have higher system compatibility and meet the needs of customers with different systems.

(1) Use machine learning and big data technology to collect, analyze and manage data.

(2) Hope that the smart home system can calculate the time when the user returns home in advance, and automatically take some actions based on this to increase the user's comfort, such as playing music in advance, turning on the air conditioner or heating in advance, etc.

(3) Combine various types of sensory data to create data that is more beneficial to us. Implement cloud storage on the server.

(4) Use multiple microprocessors to control standby power.

(5) Hybrid realization of visual smart home. The developed application will consider compatibility with different systems.

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