Journal of Operation and Automation in Power Engineering

vol. XX, no. XX, Dec. 2022, Pages: XXXX (Proofed)

http://joape.uma.ac.ir

A Novel Energy Management System to Optimize the Energy Consumption in a Smart Building

A. Abdukarimov[1], S.A. AbdulAmeer[2], M. Zaidi[3], R. Khalid[4], J.K. Abbas[5], A.H.O. Al-Mansor[6], Kh. Fawwaz[7]

[1] *Associate Professor of the Department of "Automation and Robotics", JSC Almaty Technological University, Republic of Kazakhstan.*
[2] *Ahl Al Bayt University, Kerbala, Iraq.*
[3] *Al-Manara College For Medical Sciences (maysan), Iraq.*
[4] *Medical technical college; Al-Farahidi University, Baghdad , Iraq.*
[5] *AL-Nisour University College, Baghdad, Iraq.*
[6] *Department of Optical Techniques, Al-Zahrawi University College, Karbala, Iraq.*
[7] *Kazan state power engineering university, Kazan, Russia.*

Abstract— *Over the last few decades, the majority of industrialized and developed countries have placed a strong emphasis on reducing the amount of wasted energy. In this study, electrical energy consumption is optimized by monitoring power consumption caused by residents' activities at various times of the day and storing this data in a database. An optimization algorithm was used in this study to smarten up the management of energy consumption in the building based on inhabitants' activities. The Genetic Algorithm (GA) was used to optimize the energy consumption in a smart building compared to a traditional building. Furthermore, the algorithm will enable the creation of a smart building that requires no human intervention by presenting a model based on the energy efficiency management system for the automatic operation of household equipment based on the presence of the resident scenario. The main benefit of implementing smart grid technology in the studied building was the ability to manage and monitor the energy supply and demand process. The results showed that the proposed management system in the smart building consumes less energy and power than conventional buildings. The smart building reduces energy consumption for outlets, lighting, cooling, and heating by* 38%, 28%, 34%, *and* 33%, *respectively.*

Keywords—Energy Managment, Smart Building, Energy consumption, Optimization.

1. Introduction

Over the last several decades, minimizing energy waste has been one of the primary concerns in the majority of industrialized and developed countries [1, 2]. With the advent of the energy crisis in the initial years of the 1970s, when the demand for energy resources expanded dramatically. Obviously, this emphasis is on decreasing energy consumption, with a focus on energy efficiency [3].

Despite global attempts to reduce carbon emissions by optimizing energy usage and growing clean and renewable energy sources, the International Energy Agency's 2012 statistics indicate that fossil fuels continue to dominate the global energy consumption sector [4, 5]. In 2012, the building sector consumed the most fossil fuel [6]. Increasing the energy efficiency in the building industry is a realistic and sustainable way to reduce greenhouse gas emissions and energy expenditure [7]. China is the leading producer of carbon dioxide ($CO2$) with $10.081 billion$ megatons. Iraq's carbon dioxide emissions at approximately $121.83 million$ tons (https://www.iea.org/countries/iraq).

Among the repercussions of these changes are the use of energy sources and fossil fuels, the increase in pollutant emissions, and the occurrence of negative environmental effects [8]. Studies indicate that up to 40 percent of the world's total energy production is utilized in the building sector (e.g. [9]), with 80 percent of that amount attributable to services such as air conditioning, lighting, and equipment [10]. The building sector accounts for 39% of England, 37% of the European Union, 37% of the United States, and 31% of Japan's total energy consumption. Among them, air conditioning accounts for the highest percentage of energy consumption in buildings, particularly in buildings [11, 12]. In the European Union and the United States, the building sector consumes more energy than the transportation and industry combined [13]. The growth rate of energy consumption in Iraq is five times the global average [14]. In the past decade, numerous international organizations have allocated huge sums of money to limit the use of nonrenewable resources and optimize energy usage in various industries, particularly construction, in an effort to create sustainable surroundings [15].

Smart building management systems employ cutting-edge technology to generate optimal conditions and energy usage in buildings [16]. These systems optimize energy consumption and increase the efficiency and productivity of the building systems and facilities [17]. In addition, different parts of the building are controlled to create suitable environmental conditions by providing simultaneous services. Meanwhile, to minimize energy consumption, smart building management systems provide comfort and well-being [18, 19]. A smart building management system refers to the hardware and software placed in the building for the integrated monitoring and control of key and vital components [20]. The purpose of this system is to monitor the building's different components and issue continuous commands to them such that their performances interact with each other under optimal

Received: 27 Jun. 2023
Revised: 2 Aug. 2023
Accepted: 27 Aug. 2023
*Corresponding author:
E-mail: stelastelageorgieva31@gmail.com (S.A. AbdulAmeer)
DOI: 10.22098/joape.2023.13225.2001
Research Paper

conditions, thereby reducing wasteful energy consumption and allocating energy resources only to spaces in use [21].

Energy consumption management improves the thermal comfort of occupants and decreases environmental pollution caused by greenhouse gas emissions, in addition to its economic benefits [22]. In building construction, the primary contributors to greenhouse gas emissions are construction materials and waste, fuel utilized by construction equipment, and electricity utilized by construction machinery [23]. Using a building energy simulation, Reginald [24] assessed the level of carbon dioxide emissions and energy consumption of a university administration building equipped with a smart building management system and compared these figures to the allowable levels. One of his objectives was to use the data received from smart building management reading to conduct a thorough analysis of the building's energy performance. Oti et al. [25] individually calculated the quantity of electricity consumption, energy cost, and carbon dioxide emission level for various sections of heating, cooling, hot water, and lighting using Revit plugins, and analyzed the presence of the two factors and their estimations. They established a smart building management system and compared the consumption of each segment in these two instances. Namvar and Salehi [26] introduced an innovative conceptual framework that focuses on cost and emission considerations to optimize energy-gas utilization within a smart home. This framework specifically addresses the context of residential energy hubs, with the aim of striking a balance between financial savings and environmental preservation. Salehi et al. [27], propose a multi objective model that incorporates fuzziness to account for the uncertainty arising from renewable energy generation and customer consumption. Juyal and Kakran [28] examine the case of a solitary consumer who possesses a home energy management system ($HEMS$) encompassing thermostatic and non-thermostatic appliances with characteristics dependent on energy consumption, as well as photovoltaic panels, an electric vehicle, and a battery energy storage system. The impact of different demand response (DR) strategies was analyzed and discussed.

In this study, we optimized electrical energy usage by keeping track of power consumption caused by inhabitants' activities at various times of the day and storing this data in a database. In this study, an optimization algorithm was used to intelligently manage the energy consumption of a building based on scenarios of occupant presence or absence. A genetic Algorithm (GA) was utilized to improve the energy efficiency of the smart building in comparison with the conventional building type.

2. MATERIALS AND MEHODS

Considering that most of the electrical energy is consumed in the presence scenario, that is, when residents spend most of their time at home, in this research, the electrical power consumed in the presence scenario is investigated. The activities of residents were collected and recorded in the initial stage of the smart home management system to understand the behavior of residents and build their behavioral patterns in response to energy consumption and the quantity of electrical power utilized during the day and night. Using smart meters placed on the power distribution lines in various areas of the building, the type of device used, duration of use, and quantity of power consumed were measured and recorded. The data collected by the smart meters separates the consumed electric power into two categories: constant and variable.

Constant power consumption statistics pertain to electrical equipment that consume a constant amount of electrical energy during the day and night. Certain home appliances such as refrigerators and fire alarm systems must always be linked to electricity. Data on variable electrical power consumption contain information on the consumption of domestic electrical systems that consume electrical power according to the behavior of residents, such as lighting and entertainment systems and cooking, cooling, and heating systems. Environmental factors, such as brightness, temperature, and oxygen, also affect the amount of variable power consumption. Consequently, the overall power consumption in an autonomous smart home is computed as the sum of the variable power consumption (variable and constant). After modeling the features of consumption loads and the distribution of electrical supply lines to various portions of the building, the final information on consumption is obtained by placing smart power meters on these lines.

Variable data collection was performed according to the type of home electrical system used. Household electrical systems are divided into sockets and lighting, cooling, and heating systems. The system of outlets is recorded only according to the residents' actions in using electrical equipment and their power consumption during the day and night.

After collecting, evaluating, and formatting data based on various approaches, data mining algorithms are stored in the database system as two sets of frequent and periodic data in a generic and comprehensive form of the electrical power required by each system at different times of the day. This amount of registered electric power is available to the home's smart grid system, which monitors and controls the amount of energy needed at different times, and provides it based on the amount of renewable energy produced at home.

2.1. Genetic algorithm

The genetic approach is a parallel, multilateral search guided by the idea of evolution, which seeks the most comprehensive solution to a problem by imitating the biological processes of survival of the fittest. MATLAB was used to develop the optimization algorithm. In the natural system, competent organisms have a greater chance of survival and reproduction, and after multiple generations, they attain an even greater level of competence. Combining genetic operators, including selection, crossover, and mutation, is a natural process of selection. Each of these operators is simulated in the mathematical model of the genetic approach; Fig. 1 depicts the genetic algorithm flowchart [29, 30].

Three operators make up a simple algorithm: selection, crossover, and mutation. In actuality, the selection operator is the selection of members from the existing population to generate a new population. The term chromosome refers to a numerical value or values that represent a potential solution to the problem that the genetic algorithm is attempting to solve. Each candidate solution is encoded as an array of parameter values, comparable to other optimization algorithms. Whenever a problem has N dimensions, each chromosome is typically encoded as an array of N elements (Equation (1)):

$$\text{chrosome} = [p_1, p_2, ..., p_N] \tag{1}$$

where, each p_i is a particular value of the i^{th} parameter. The main criterion in this selection is the fitness value of each member; any member with a higher fitness has a higher probability of being selected. In this method, the selection probability is calculated as follows for each member (Equation (2)):

$$P_i = \frac{f_i}{\sum_{j=1}^{popsize} f_j} \tag{2}$$

where f_i is the fitness value for member i. The production of the new generation is done under the operation of two operators. Fitness function is used as a measure for the selection of chromosomes Cross-over with the probability of p_c and Mutation with the probability of p_m. In general, if the population size is chosen to be small, the algorithm does not have enough samples to perform the calculations, and the likelihood that it will be taken at a relative optimal value increases significantly. In contrast, as the number of people in a population increases, the volume of calculations during a generation rises and the rate of convergence

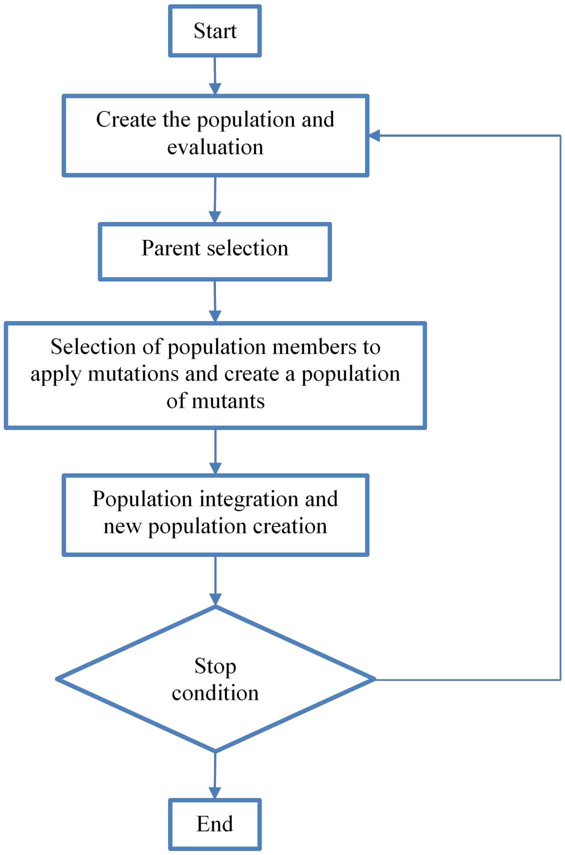

Fig. 1. GA flowchart.

slows. Since the selection is based on the laws of probability, there is no assurance that the new generation's answer will be superior, as the best member of the previous generation may be eliminated. This may result in evasion of the question and a diversion from the topic at hand.A system of different designs is acceptable, with some designs being superior to others. The criterion for comparing these designs should be a scalar function whose numerical value can be calculated by specifying the design variables. The term for such a criterion for a design problem is objective function. The objective of this study is to minimize the smart building's energy consumption based on the parameters involved (Equation (3)):

$$f = \min\mathrm{imize}\left[\mathrm{power}\left(\mathrm{outlet}, \mathrm{lightening}, \mathrm{cooling}, \mathrm{andheating}\right)\right] \tag{3}$$

3. RESULTS AND DISCUSSION

This study examines and interprets the recorded consumption patterns of residents' actions when utilizing various electrical systems within the building. Upon gathering the data and classifying it according to the temporal and power consumption attributes of each system within the context of a smart home scenario for building automation, this information was inputted into the home management system. Subsequently, a comparison was made between this data and that of a conventional house with identical specifications, in order to assess the level of energy optimization achieved. Hence, by utilizing the data repository pertaining to household appliances, an analysis has been conducted to determine their respective energy consumption levels.

Table 1. Constant power consumed in automatic smart building during a day.

Device and systems	Consumption power (Wh)
Fire alarm and extinguishing system	2152
Telecommunication system	3012
Refrigerator and Freezer	10215

Table 2. Comparison of the power consumption of the outlet system and night in a smart building during a day.

Application type	Consumption time (min)	Consumption power (Wh)
Coffee maker	30	2087.07
dishwasher	100	3359.59
Entertainment system	500	5116.83
Gas stove and hood	120	1301.44
laundry	60	206.12
Kitchen outlet	130	1514.14
Bedroom outlet	530	1570.15

3.1. Electrical systems with constant daily power consumption

These devices must be in standby mode throughout the day and night; therefore, they have a constant power consumption. Table 1 shows the different features of these systems in the smart buildings.

3.2. Electrical systems with variable power consumption in the smart home

Table 2 classifies the amount of electric power consumed together with the time and length of use in the scenario of presence based on data collected from the residents' activities in the use of outlet systems. This data demonstrates that inhabitants utilize electrical energy after a test period of using the outlet system and after repetitions and consolidation of the data at the recorded periods.

The findings make it abundantly clear that, with the sole exception of lighting, the kitchen is responsible for the majority of the total energy consumption. The appliances in the kitchen are responsible for more than half of the total energy consumption, while the energy consumption of the other appliances is significantly lower. This demonstrates that a significant portion of the efforts that should be directed toward improving and smartening homes should be focused on the kitchens of those homes. In accordance with these requirements, standards for the selection of lighting equipment, and directions for the admission of natural light in lieu of the lighting system, the final form of the building lighting system data was collected in the form of Fig. 2 for this study.

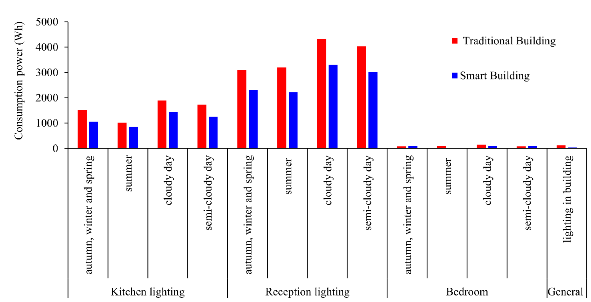

Fig. 2. Comparison of one day and night lighting system in normal and smart automatic home.

In contrast to the spring and summer months, the fall and winter months bring with them a significant increase in the amount of energy that is required to keep the lights on inside the home. The months of fall and winter, in particular, have a greater number of days that are cloudy or partly cloudy compared to the months of spring and summer. The lighting in the kitchen area must be increased, and the amount of electricity it uses makes up the bulk of the total.

Table 3. Optimization results of consumption power in different sector of the building.

sector		Consumption power (kWh)	
		Traditional Building	Smart Building
Outlet		11587	7128
lightening	autumn, winter and spring	1702	1232
	summer	1567	1047
	cloudy day	2187	1611
	semi-cloudy day	2102	1572
Cooling		4952	3282
Heating		6839	4533

3.3. Cooling and heating system data in the presence scenario

The optimal temperature for the home environment was determined using the available [31]. The electrical energy usage measurement in this section is dependent on the amount of time the device is on. This approach relies solely on the presence or absence of individuals in residences. In the presence scenario, the residents are at home. However, not all family members may be in the same section of the building at the same time; they may be in other parts of the building or visit the area of the house at other times. Hence, based on the behavior of residents at different times, if family members are present in any portion of the building, the system will deliver the best temperature for those who reside there. This method has two significant benefits: the system no longer needs to start at high power to provide the ideal ambient temperature, and the level of comfort and satisfaction of the residents increases. Fig. 3 shows the results of the cooling and heating system power consumption for different months during a specified day.

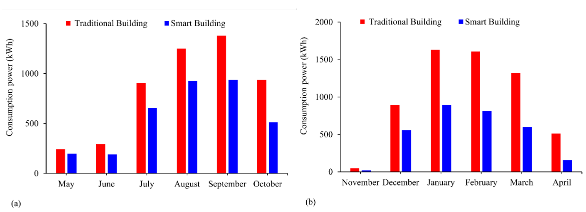

Fig. 3. Cumulative results of the a) cooling, b) heating system consumption power in different months during a specified day.

3.4. Optimization Results

Table 3 shows the optimization results by GA during a year for smart and traditional building. As can been seen in the Table 3, the proposed management system in the smart building reduce the energy and power consumption in the smart building against traditional one. The outlet, lightening, cooling, and heating power consumption reduce 38%, 28%, 34%, and 33% in the smart building respectively. Although the lighting industry saves less energy as a percentage than other sectors, the greatest impact of consumption optimization can be seen in the lighting industry in terms of sheer volume.

4. CONCLUSIONS

This study resulted in the implementation of metrics related to actual energy usage in smart homes, based on residents' energy consumption behavior. By capturing this information and incorporating its final algorithm into the building's intelligent management system, an automatic house was created that automatically supplied electrical energy to its residents. Unlike previous research, all electric power supply lines in the building were controlled and monitored during the test to collect and record the amount of electric power consumed, the time of use, and the duration of use of the equipment in accordance with the established standards. The survey was integrated into a smart home management system as an implementation template. As a result, all factors were considered to ensure that, in addition to optimizing energy consumption, the level of comfort of the residents did not decrease, and the final system with high reliability predicted the residents' behavior at various times and activated the necessary electrical system based on their preferences and habits. By comparing the automatic intelligent building to a conventional building with identical features, the amount of electrical energy optimized in all electrical components of the building (outlets, lighting, cooling, heating, etc.) was observed. Residents were not forced to collect data on energy consumption and equipment use during the development of the autonomous smart home project, and they were engaged in their normal at-home activities. In this study, a smart network connected to the home management system was created to monitor and control the energy supply and demand, to use as much as possible the production of renewable resources that have been designed and implemented in the building to meet the demand, and the excess energy from the production of resources to meet the demand. Renewable energy sources or trade deficits with the national grid. Energy and power consumption in smart buildings were found to be reduced by 38% for outlets, 28% for lights, and 34% and 33% for cooling and heating, respectively, when compared to traditional buildings using the same management system.

REFERENCES

[1] W. Mao, Z. Zhao, Z. Chang, G. Min, and W. Gao, "Energy-Efficient Industrial Internet of Things: Overview and Open Issues," IEEE Trans. Ind. Inf., vol. 17, no. 11, pp. 7225–7237, Nov. 2021, doi: 10.1109/TII.2021.3067026.

[2] A. Molajou, A. Afshar, M. Khosravi, E. Soleimanian, M. Vahabzadeh, and H. A. Variani, "A new paradigm of water, food, and energy nexus,"Environ. Sci. Pollut. Res., 2021, doi: 10.1007/s11356-021-13034-1.

[3] T. Wu, S. T. Ng, and J. Chen, "Deciphering the CO2 emissions and emission intensity of cement sector in China through decomposition analysis," J. Cleaner Prod., vol. 352, p. 131627, Jun. 2022, doi: 10.1016/j.jclepro.2022.131627.

[4] S. Berdysheva and S. Ikonnikova, "The Energy Transition and Shifts in Fossil Fuel Use: The Study of International Energy Trade and Energy Security Dynamics," Energies, vol. 14, no. 17, p. 5396, Aug. 2021, doi: 10.3390/en14175396.

[5] T. Kober, H.-W. Schiffer, M. Densing, and E. Panos, "Global energy perspectives to 2060 – WEC's World Energy Scenarios 2019," Energy Strategy Rev., vol. 31, p. 100523, Sep. 2020, doi: 10.1016/j.esr.2020.100523.

[6] X. Yang, S. Zhang, and W. Xu, "Impact of zero energy buildings on medium-to-long term building energy consumption in China," Energy Policy, vol. 129, pp. 574–586, Jun. 2019, doi: 10.1016/j.enpol.2019.02.025.

[7] A. S. Alamoush, F. Ballini, and A. I. Ölçer, "Ports' technical and operational measures to reduce greenhouse gas emission and improve energy efficiency: A review," Mar. Pollut. Bull., vol. 160, p. 111508, Nov. 2020, doi: 10.1016/j.marpolbul.2020.111508.

[8] M. H. Sial, N. Arshed, M. A. Amjad, and Y. A. Khan, "Nexus between fossil fuel consumption and infant mortality rate: a non-linear analysis," Environ. Sci. Pollut. Res., vol. 29, no. 38, pp. 58378–58387, Aug. 2022, doi: 10.1007/s11356-022-19975-5.

[9] L. Belussi et al., "A review of performance of zero energy buildings and energy efficiency solutions," J. Build. Eng., vol. 25, p. 100772, Sep. 2019, doi: 10.1016/j.jobe.2019.100772.

[10] A. Shajahan, C. H. Culp, and B. Williamson, "Effects of indoor environmental parameters related to building heating,

ventilation, and air conditioning systems on patients' medical outcomes: A review of scientific research on hospital buildings," Indoor Air vol. 29, no. 2, pp. 161–176, Mar. 2019, doi: 10.1111/ina.12531.

[11] L. Zhou and F. Haghighat, "Optimization of ventilation system design and operation in office environment, Part I: Methodology," Build. Environ., vol. 44, no. 4, pp. 651–656, Apr. 2009, doi: 10.1016/j.buildenv.2008.05.009.

[12] A. L. S. Chan, T. T. Chow, K. F. Fong, and Z. Lin, "Investigation on energy performance of double skin façade in Hong Kong," Energy Build., vol. 41, no. 11, pp. 1135–1142, Nov. 2009, doi: 10.1016/j.enbuild.2009.05.012.

[13] M. K. Nematchoua, A. Marie-Reine Nishimwe, and S. Reiter, "Towards nearly zero-energy residential neighbourhoods in the European Union: A case study," Renewable Sustainable Energy Rev., vol. 135, p. 110198, Jan. 2021, doi: 10.1016/j.rser.2020.110198.

[14] H. I. Naji, M. Mahmood, and H. E. Mohammad, "Using BIM to propose building alternatives towards lower consumption of electric power in Iraq," Asian J. Civ. Eng., vol. 20, no. 5, pp. 669–679, Jul. 2019, doi: 10.1007/s42107-019-00134-0.

[15] V. Hartkopf and V. Loftness, "Global relevance of total building performance," Autom. Constr., vol. 8, no. 4, pp. 377–393, Apr. 1999, doi: 10.1016/S0926-5805(98)00085-5.

[16] T. Mazhar et al., "The Role of ML, AI and 5G Technology in Smart Energy and Smart Building Management," Electron., vol. 11, no. 23, p. 3960, Nov. 2022, doi: 10.3390/electronics11233960.

[17] S. A. Sharif and A. Hammad, "Simulation-Based Multi-Objective Optimization of institutional building renovation considering energy consumption, Life-Cycle Cost and Life-Cycle Assessment," J. Build. Eng., vol. 21, pp. 429–445, Jan. 2019, doi: 10.1016/j.jobe.2018.11.006.

[18] M. Khalil, M. Esseghir, and L. Merghem-Boulahia, "Federated Learning for Energy-Efficient Thermal Comfort Control Service in Smart Buildings," IEEE Global Commun. Conf. (GLOBECOM), Dec. 2021, pp. 01–06. doi: 10.1109/GLOBECOM46510.2021.9685286.

[19] S. Bicer and F. H. Halicioglu, "Rethinking the influence of the Intelligent Building Systems on productivity, health, and well-being for enhancing the quality of life during mandatory working from home: Lessons learned from the COVID-19 pandemic," IOP Conf. Ser.: Earth Environ. Sci., vol. 1101, no. 3, p. 032001, Nov. 2022, doi: 10.1088/1755-1315/1101/3/032001.

[20] J. Al Dakheel, C. Del Pero, N. Aste, and F. Leonforte, "Smart buildings features and key performance indicators: A review," Sustainable Cities Soc., vol. 61, p. 102328, Oct. 2020, doi: 10.1016/j.scs.2020.102328.

[21] M. O. Oyewole, F. M. Araloyin, and P. T. Oyewole, "Residents' Awareness and Aspiration for Smart Building Features: The Case of Okota, Lagos, Nigeria," Niger. J. Environ. Sci. Technol., vol. 3, no. 1, pp. 30–40, Mar. 2019, doi: 10.36263/nijest.2019.01.0098.

[22] W. W. Che et al., "Energy consumption, indoor thermal comfort and air quality in a commercial office with retrofitted heat, ventilation and air conditioning (HVAC) system," Energy Build., vol. 201, pp. 202–215, Oct. 2019, doi: 10.1016/j.enbuild.2019.06.029.

[23] T. K. L. Nguyen et al., "Environmental impacts and greenhouse gas emissions assessment for energy recovery and material recycle of the wastewater treatment plant," Sci. Total Environ., vol. 784, p. 147135, Aug. 2021, doi: 10.1016/j.scitotenv.2021.147135.

[24] A. I. Reginald, "Integrating BIM with BMS in Energy Performance Assessment," Int. J. 3-D Inf. Model., vol. 4, no. 1, pp. 19–44, Jan. 2015, doi: 10.4018/IJ3DIM.2015010102.

[25] A. H. Oti, E. Kurul, F. Cheung, and J. H. M. Tah, "A framework for the utilization of Building Management System data in building information models for building design and operation," Autom. Constr., vol. 72, pp. 195–210, Dec. 2016, doi: 10.1016/j.autcon.2016.08.043.

[26] A. Namvar and J. Salehi, "Adaptive Residential Energy Hubs Scheduling Considering Renewable Sources," J. Oper. Autom. Power Eng., 2022, doi: 10.22098/joape.2023.11083.1826.

[27] J. Salehi, F. S. Gazijahani, and A. Safari, "Stochastic Simultaneous Planning of Interruptible Loads, Renewable Generations and Capacitors in Distribution Network," J. Oper. Autom. Power Eng., 2022, doi: 10.22098/joape.2022.7826.1553.

[28] V. D. Juyal and S. Kakran, "Optimized Cost of Energy by a Home Energy Management System Employing Dynamic Power Import Limit Strategy: A Case study Approach," J. Oper. Autom. Power Eng., vol. 11, no. 4, pp. 285–294, 2023, doi: 10.22098/joape.2022.10254.1728.

[29] Y. Wang and C. Wei, "Design optimization of office building envelope based on quantum genetic algorithm for energy conservation," J. Build. Eng., vol. 35, p. 102048, Mar. 2021, doi: 10.1016/j.jobe.2020.102048.

[30] H. Wei et al., "Unified Multi-Objective Genetic Algorithm for Energy Efficient Job Shop Scheduling," IEEE Access, vol. 9, pp. 54542–54557, 2021, doi: 10.1109/ACCESS.2021.3070981.

[31] R. Z. Homod, A. Almusaed, A. Almssad, M. K. Jaafar, M. Goodarzi, and K. S. M. Sahari, "Effect of different building envelope materials on thermal comfort and air-conditioning energy savings: A case study in Basra city, Iraq," J. Energy Storage, vol. 34, p. 101975, Feb. 2021, doi: 10.1016/j.est.2020.101975.