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DIGITAL TWIN ENERGY MANAGEMENT SYSTEM WITH ARTIFICIAL INTELLIGENCE INTERNET OF THING TO SMART CAMPUS

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ABSTRACT

The purpose of this research study is to develop a twin energy management system with intellectual technology to connect all things to a smart campus and to evaluate the suitability of a twin energy management system with intellectual technology to connect all things to a smart campus. The research is divided into two phases: Phase 1 is the development of a twin energy management system with intelligent technology that connects all things to be able to meet the needs of energy management within the smart campus. Theories from documents and research related to physical energy management. It then synthesizes and links the relationships of all the important physical elements to design the architecture. Phase 2 is the development of a twin energy management system with intelligent technology that connects all things to the world, which consists of 4 main working system components, Part 1 is Physical part Synthesizing various areas within the smart campus that must be equipped with smart sensors to process data and control smart devices in that area to have an environment suitable for learning in a smart campus. Part 2 is Energy Management, which is an important process of managing data received from sensors to process various data, Cloud Gateway, Streaming Data, Data Lake, Control Applications, Data Analytics, User Engy Business logic, and Part 3 is Intelligence Technology, consisting of Machine leaning Decision marking and Models algorithm that analyzes and forecasts energy management intelligently. Part 4 is the Digital Twin part that uses the dashboard to display in a digital form that is like a physical aspect of communicating with the user. The results show that twin digital energy management systems that design and develop the system can be used to manage energy in smart campuses at the greatest scale.

Keywords: *Digital Twin, Energy Management System, Smart Campus*

1. INTRODUCTION

In the digital age where technological changes and advancements are the driving force of the economy, society, and industry. In terms of energy development and management, there is no difference. In a world where energy is an important resource for livelihood and economic development. Energy consumption in buildings has become a major factor with a significant impact on the environment.[1] Economy and Society Effective management of energy in buildings can help reduce negative impacts and increase energy efficiency. The problem of energy consumption in buildings has a large impact that is evident from climate change and energy resources. Improper use of energy in buildings also affects the performance of equipment and systems, such as heating systems.[2] This can cause equipment to deteriorate faster and reduce the comfort of residents or users. This affects long-term productivity and productivity. The cost and efficiency of operations and inefficient energy consumption in buildings lead to higher operating costs. In particular, electricity and heating costs are a high financial burden and cause unnecessary increases in operating costs of businesses and organizations.[3] Using technology to increase energy management efficiency can effectively help reduce these costs. The uneconomical use of energy resources in buildings leads to inefficient and wasteful use of energy resources.[4] This has led to a rapid decline in natural energy resources. This is one of the factors that cause energy prices to rise and the risk of future energy shortages. Good energy management can help reduce the use of these resources and promote long-term sustainability. Climate change, most of the energy consumption in buildings still relies on fossil fuels such as coal.[5] This is a major cause of greenhouse gas emissions, such as carbon dioxide (CO2), resulting in climate change that has global impacts such as global warming.[6] The need to reduce greenhouse gas emissions makes energy efficiency in buildings critical.

Improper energy management can cause uncomfortable indoor environments such as inappropriate temperatures, inadequate lighting, or noise from various systems, which affects the satisfaction and quality of life of building users. One of the most sought-after and highly impactful technologies is Digital Twin, a technology that creates accurate digital models of real systems in the virtual world, working with Cognitive Technology, which helps to intelligently analyze and optimize the system.[7] Digital Twin in Power Management is the digital modeling of a device. systems or processes that consume various energy using data collected from sensors and devices in the actual system. This model allows us to analyze and understand energy consumption behavior in depth. The integration of Cognitive Technology with Digital Twin allows the model to improve itself based on the data received in a time close to reality.[8] Artificial intelligence and machine learning technologies enable systems to learn from historical data, analyze trends, and optimize their operations to the ever-changing environment and energy demand, such as improving HVAC (Heating, Ventilation, and Air Conditioning) systems in large buildings or optimizing energy efficiency in industrial facilities.[9] Digital twins provide energy managers with granular visibility into energy consumption habits in real-time. This makes it possible to forecast future energy consumption more accurately, leading to more efficient planning and management. Emergency response is provided by simulating a virtual environment.[10] Digital Twin helps to identify and analyze potential problems such as power leakage or equipment damage. Cognitive Technology enables Digital Twin to continuously improve processes. By learning from new information and adapting to situations. Energy management is therefore more flexible and efficient. Costs and environmental impact are reduced by using Digital Twin, which makes it possible to monitor energy consumption and find ways to reduce energy consumption.[11] And when Digital Twin and Cognitive Technology are applied in the industrial sector, the use of Digital Twin can help in managing and controlling the production process effectively.[12] It can simulate production and analyze energy consumption in factories to find ways to improve energy consumption.[13] And in smart campuses, Digital Twin can be used to control indoor energy systems, such as heating systems. Ventilation, and air conditioning (HVAC) make it possible to optimize energy consumption.[14]

The increase in energy consumption in large-scale educational campuses has created challenges in energy management efficiency. Although several studies have explored the use of IoT in monitoring energy consumption [15], there is a lack of integration of artificial intelligence for analytics and optimization. In addition, the application of Digital Twin in campus contexts is limited [16], which points to the need for further research in this area. Therefore, this research focuses on the development of a digital twin energy management system that integrates AI and IoT for smart campuses to increase energy efficiency. This is to fill the gap in current literature. Reduce excess energy consumption and increase user comfort in the renewable energy sector.[17] Although there is a lot of research on energy management systems, only a few studies have integrated artificial intelligence. It is integrated into the Internet of Things (IoT) under the framework of Digital Twin, especially for smart campuses. Most of the existing approaches focus on managing energy through static models or using real-time data to a limited extent without taking full advantage of the predictive potential of AI. For example, the research of [P., Reshma et al., 2024][18] focuses primarily on the IoT aspect. However, there is a lack of comprehensive and predictive approach that AI can offer. There is also a huge gap in how Digital Twin technology is used for simulating dynamic energy consumption behavior in smart infrastructure. This research fills the gap in energy management by offering a Digital Twin energy management system that fully integrates AI and IoT, which enables energy management in smart campuses in real-time and can accurately predict energy consumption. This system differs from previous models that only focus on static tuning or monitoring via IoT. By offering a comprehensive solution that can adapt to real-time data and predict energy consumption patterns to increase efficiency. The result is a smarter and more adaptable energy management system. which can be applied to large-scale smart infrastructure. Addressing limitations found in current research. The combination of Digital Twin and Cognitive Technology not only helps to optimize energy management, but is also an important step forward in sustainable innovation in the energy industry. Respond effectively to the challenges of changes in the environment and increasing demands in the future.

2. LITERATURE REVIEW

The author presents the essence of "Digital twin Energy Management with Cognitive Technology System", which occurs from the analysis and synthesis of relevant documents and research as follows.

2.1 Areas to be managed in a smart campus

The space to be managed in a smart campus is very important. The installation of smart sensor devices for energy management can be divided into issues such as efficient energy management. Smart sensors help to collect data on the energy consumption of buildings, such as electricity consumption. Energy consumption for heating and cooling These data can be used to optimize energy efficiency.[19] Reduce waste and save costs in real-time control and monitoring of energy consumption, where smart sensors can track and report on energy consumption in real time. This makes it possible to identify problems immediately and take quick action to fix them. [20] It is analyzed and forecasted by collecting data from smart sensors, allowing it to analyze energy consumption trends and forecast future energy demand. This accurate forecast helps in planning energy consumption and campus infrastructure expansion appropriately. System performance has been improved. The data from the sensors can be used to improve energy control systems such as HVAC (Heating, Ventilation, and Air Conditioning), lighting, and hot water systems in buildings, making these systems more efficient and reducing energy consumption. The use of smart sensors in energy management promotes sustainable management in smart campuses, such as reducing greenhouse gas emissions. The smart sensors improve the comfort and safety of campus residents. The environment can be adjusted to suit the needs of users, such as lighting adjustment, temperature control, and building access management, with elements in campus energy management, which the researcher synthesized as shown in the table.

Table 1: Composite table of elements in energy management.

Elements in energy management	Zheng, Zhuang, et al, (2024) [21]	Mishra, Priyanka, and Ghanshyam Singh, (2020) [22]	Schmeck, Hartmut, and Veit Hagenmeyer., (2022) [23]	Zahraoui, Younes, et al, (2021) [24]	Rathor, Sumit K., and Dipti Saxena, (2022) [25]	Mahapatra, Bandana, and Anand Nayyar, (2022) [26]	Dai, Haifeng, et al., (2022) [27]	Mariano-Hernández, Deyslen, et al, (2021) [28]
Electricity				✓	✓	✓	✓	✓
Water	✓		✓	✓	✓	✓		
CO2	✓	✓	✓	✓	✓	✓	✓	✓
Humidity	✓	✓	✓	✓	✓	✓	✓	✓
Sound	✓	✓	✓				✓	✓
PM2.5	✓	✓	✓					
Flicker	✓	✓	✓	✓	✓	✓	✓	✓
Smoke		✓	✓	✓	✓			
Light	✓	✓	✓			✓	✓	✓
Position		✓	✓	✓		✓	✓	✓

2.2 Artificial Intelligence Internet of Thing

Artificial Intelligence (AIoT) technology is an integration of artificial intelligence. The AIoT framework involves a layered architecture where IoT devices collect data, which is then processed and analyzed by AI algorithms to generate actionable insights.[29] This integration consists of several components, collecting data from sensors and devices. IoT collects large amounts of data from the physical environment and delivers it.[30] The collected data is sent to a centralized computing platform or at the edge. Data processing with AI algorithms , including machine learning techniques and deep learning.[31] Process data to identify patterns and make forecasts. It relies on key technologies such as edge computing to reduce latency and bandwidth usage.[32] Data processing is being moved from centralized cloud servers to edge devices closer to the data source, and the 5G network in the high-speed connectivity that 5G networks provide supports the real-time data transmission required for AIoT applications.[33] The aggregation of a large number of devices increases the attack surface, making it necessary to implement robust security measures, including encryption and secure communication protocols. It has interoperability with a wide range of devices and platforms involved. Ensuring interoperability between IoT devices and various AI systems has the ability to scale as the number of connected devices increases.[34] Infrastructure must be scaled accordingly. This requires the ability to efficiently handle and process data to handle the large volumes of data generated. AIoT is important in the development of smart cities, which enables efficient urban infrastructure management.[35] Applications include traffic management. In the healthcare field, AIoT enables remote patient monitoring. IoT devices such as wearable sensors have collected health data, which AI algorithms analyze to provide insights into a patient's health status. and in industrial automation. AIoT optimizes automation in the industry by enabling predictive maintenance.[36] Supply chain optimization and operational efficiency improvement Sensors embedded in the machine collect performance data. The AI model analyzes to predict failures and optimize maintenance schedules.[37] In other words, the integration of AI and IoT into AIoT presents a wealth of opportunities for innovation in many sectors. However, addressing challenges such as data privacy is a great way to solve problems. Interoperability, and scalability are essential to make the most of AIoT.

2.3 Digital Twin

Digital twin is a technology used to create digital models of physical systems. It will be applied in a variety of industries such as manufacturing, With the Digital Twin framework, digital modeling of physical systems is collected. IoT in collecting data from the actual system that sends the data to the processing platform.[38] The data is used to create a digital model that can represent the behavior of the actual system. Key edge computing technologies are used to reduce latency and increase data processing efficiency.[39] Data is analyzed using machine learning algorithms and deep learning to analyze and predict system behavior. The technical components of the Digital Twin include sensors and IoT devices that are used to collect data from the actual system, such as temperature, pressure, humidity, and motion data. The collected data is then sent to a real-time processing platform. The Processing and Analytics Platform processes data with AI and machine learning algorithms to analyze and predict system behavior.[40] Computing platform based on Edge Computing to increase efficiency and reduce latency. The use of 3D and AR/VR visualization technologies allows users to visualize digital models and the operation of data visualization systems in easy-to-understand formats such as graphs and dashboards based on communication and connectivity, the use of 5G networks and highly secure communication protocols for data transmission.[41] Digital twins are used to optimize production by simulating and testing the manufacturing process before it is actually used in medicine. In infrastructure management, digital twins are used to manage and maintain infrastructure such as buildings, bridges, and electrical networks, which can be said to be a technology with high potential for application in many industries.

2.4 Smart Campus

A smart campus is the use of technologies such as the Internet of Things (IoT), artificial intelligence (AI), and big data analytics to improve and optimize resource management and operations in a smart campus. IoT to collect data on energy consumption Water, student and staff movements, as well as environmental information.[42] The data collected from the sensors is sent to a computing platform that uses AI and Big Data Analytics technology to analyze and create models that can forecast trends and improve university operations. The use of 5G networks and secure communication protocols to ensure fast and secure data transmission between devices and integration and interoperability by integrating technologies to work together smoothly and efficiently requires accepted standards and protocols.[43] It can be applied to energy management, where sensors are used to monitor energy consumption and improve energy management systems to be more efficient.[44] It can help reduce energy consumption and costs, or improve teaching and learning by using technology to support teaching and learning, such as using applications that help track student progress and improve teaching methods, or using data from sensors to manage resources such as water and building space more efficiently.[45] Addressing challenges such as data security and technology integration will enable the full utilization of Smart Campus.

3. RESEARCH AND DISCUSSION

Based on the study of internet of things, the Digital twin Energy Management with Cognitive Technology System, the author summarizes and presents examples of articles and research on interesting educational developments towards smart campus

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management. The architecture system is as follows.

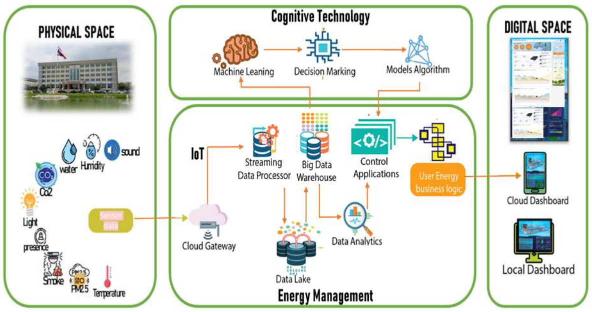

Figure 1: Digital twin Energy Management with Cognitive Technology Architecture System

Smart universities have a system to monitor various physical values of the university, classrooms, classrooms, etc. Laboratories, learning workspaces, library spaces, meeting rooms, counseling centers. Pedestrian walkways, offices, Research centers, meeting rooms, stadiums, cafeterias, With sensors that detect and measure things such as electricity, water, temperature, humidity, noise, dust, PM2.5, vibration, etc. The principle of operation of the sensor converts a form of energy into an electrical signal. It is a device used to detect or measure the value of various environments or states, usually converting the measured signal into a signal that can be used for further use, such as electrical signals, analog signals, or digital signals.[46] Direct Measurement: Some sensors work by directly detecting and measuring the values of the environment, such as temperature, humidity, pressure, and so on, using mechanical principles. Devices used in this category may be electronic sensors or sensors that use electrical principles, such as charge source sensors. Temperature Sensor Humidity sensors, etc. Transduction: Some sensors work by converting a signal from a measured state or value into an electrical signal.[47] This can be easily used for processing, such as motion sensors that are used to convert motion into electrical signals, light sensors, etc. Light sensor used to measure the intensity of light and convert it into electrical signals, etc. Wave-based sensing: Some sensors use different types of waves, such as sound waves.[48] Radiation waves or microwaves to measure and detect things in the environment, such as ultrasonic sensors that use sound waves to measure distance. Infrared sensors use infrared waves to detect motion, etc., and when the sensor has measured the value, it will be sent to the Cloud Gateway IoT (Internet of Things) which serves to connect sensor devices.[49] IoT is installed in various places with the foundation of the cloud infrastructure used to store and process data, as well as connect and integrate data, acting as an intermediary to receive data from various IoT devices and send that data to the cloud for further storage and processing. Control and management can control and manage IoT devices remotely through the cloud, where the transmitted data is stored securely and can be processed for further analysis or action, such as generating reports, monitoring anomalies, or managing devices.[50] After that, the data is sent to the streaming data processor, which is another important part of the IoT system and is closely related to the Cloud Gateway IoT because it is a tool or service used to process real-time data (live data processing) or data that is continuously transmitted (streaming data) from IoT devices to the cloud.[51] Anomaly detection or actionable insights at the same time that the data is submitted. By collaborating between the Streaming data processor and Cloud Gateway IoT by notifying and managing after the Streaming data processor has successfully processed the data. It can send the results or data that has been processed to the IoT Cloud Gateway to alert users or administrators, or it may continue to take actions according to predefined settings,[52] such as IoT device commands or notifications through applications. Streaming data processors can send processed data to a data lake for long-term storage, which can be used for further analysis and processing. The primary function of a data lake is to preserve large and varied data formats, without limitation on the format or structure of the data, and to store data that has not been pre-formatted or processed. The data lake provides the ability to analyze the data that is collected. It can analyze data in a very large format and size to obtain important information and relevant knowledge. The data can be used to generate meaningful reports and visualizations so that users can make effective decisions or analyses by using the right data repository for future use. Data lakes send data to a Big Data Warehouse into two concepts with different uses and capabilities, but can work together to create a more efficient data storage and utilization system. Therefore, the collaboration of data lake and big data warehouse will look like this: data aggregation, where data lakes can serve to store low-quality data and come from different sources.[53] To have a comprehensive and large amount of information. At the same time, Big Data Warehouse is often used for high-quality and structured storage, which is often organized and prepared before being imported into the system. The integration of data lakes and big data warehouses provides data coverage of both high-quality and low-quality data.[54] Data lake management can store data in an unstructured format or data file in the form of raw data, while Big Data Warehouse is often used for storing more structured and complete data. Data is often stored and prepared to be suitable for import. Therefore, data management in data lakes and big data warehouses has different characteristics and capabilities. The data stored in the data lake can be used in an organized or disorganized manner. It can be used to analyze data or search for data on demand. While the data stored in Big Data Warehouses is usually more structured and high-quality,[55] and is often used for high-quality analysis and summarization. Big Data Warehouses are usually responsible for storing data in a structured, high-quality format, and often the data is managed and prepared to be suitable for import. Data Analytics usually uses the data provided to perform analysis. Predictions and predictions Based on the data collected in the Big Data Warehouse and through the analysis of Data Analytics, the data obtained can be used to predict and predict trends or events. Data Analytics is a process that uses technology to analyze data to draw valuable conclusions or knowledge. It focuses on extracting meaningful and substantive data from large and diverse data sets. The data analytics process is an important process in analyzing data for decision-making to make machine learning.[56] Machine learning is a process in which computer systems can learn and improve operations without the need for explicit programming like direct instructions. The model is created using training data so that the system can predict the outcome of data that has never been seen before with accuracy. The main processes of machine learning work include Data Preparation to ensure that the data can be used for model training appropriately, including data cleaning,[57] data transformation, and data division into training sets and test sets for model testing and evaluation. Model Selection Selecting a model that is appropriate for the problem being encountered, such as classification, prediction, or clustering, based on the nature of the data and the purpose of the analysis, as well as model training. Model training often uses parameter tuning techniques to improve model performance. After that, model evaluation is the use of test datasets to evaluate the performance of the model by measuring the predicted results against the actual results, such as accuracy. Precision, recall, or deployment and refinement when the model is approved as having satisfactory performance. The model will be deployed in a real environment.[58] Follow up on the implementation to further improve the model. There are many methods and techniques at each stage of the machine learning process that can be used, which depend on the nature of the data. The objectives and needs of the program developer or data analyst in each case. Decision making is an important process in the daily life and work of individuals and organizations. There are many ways of making decisions, but they can be summarized The first step is important, where you need to collect information that is relevant and important to the decision, such as information related to the problem or situation to be solved. After that, analysis and evaluation are carried out when sufficient data is available. The information must be analyzed and evaluated to better understand the problem or situation and find an appropriate solution by clearly setting the desired goals or outcomes. To help make decisions in the right direction. After receiving the data and setting the target, All possible options must be considered and the suitability of each option must be analyzed.[59] Once the possible options are known and the feasibility assessment of each path is completed, the company will be able to provide a safe and secure solution. must make a decision to choose the most correct path according to the set goals. After the decision is made, it must be carried out according to the set plan and the results must be monitored.[60] To improve or modify further actions as appropriate. At each stage of decision making, tools or techniques may be used, such as the use of decision theory models. Decision-making models to help analyze and make decisions in situations such as the use of holistic decision-making techniques. Rational Decision Making or the use of a decision-making process linked to problem solving.[61] Choosing the right technique or tool will help make decisions more efficiently and minimize the risk of decision-making, which will be passed on to the model algorithm in the role of machine learning or data analysis. Support Vector Machines (SVMs) are used for classifying data by finding the best line of segmentation in the separation area between groups, or Decision Trees are used for building decision tree structures. For data analysis and classification, and send it to the software application used to control the device. These applications can run on the IoT device itself, on a remote server, or on the user's smartphone or tablet, such as lighting control, can turn on, turn off, dim, or change the color of LED lights , or control the temperature, can set the thermostat temperature, or turn on, off, air conditioning, as well as humidity control or lighting on/off exposure. It facilitates users to control IoT devices remotely without being close to the device.[61] Easy to

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understand, fast Displays important information of the business and organization, allowing users to analyze the data. Make decisions and follow up effectively. The main components of a dashboard are data, which is pulled from sources such as file databases or web APIs to visualize. Data is presented in a graphical format, such as charts, graphs, tables, or numbers, or interactions.[62] A dashboard is a tool used to display data or status information in a graphical or tabular format so that users can get a quick overview of the data. Dashboards are typically designed to be customized to meet the needs of each user. Important information may be displayed using graphs or charts such as line charts, bar charts, or maps.

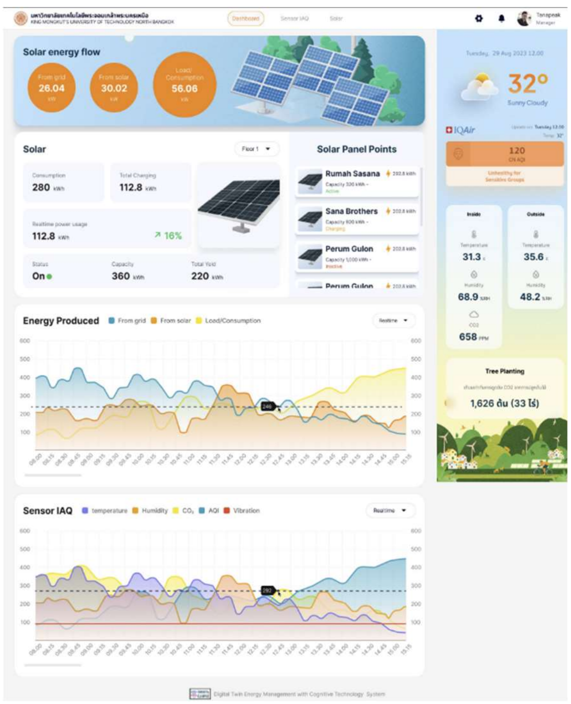

Figure 2: Dashboard displaying twin power overview

From the architecture, it has been used to develop a twin energy management system. The dashboard page consists of Solar energy flow, electricity imported from central electricity. The cost of generating electricity from solar cells, including the cost of energy consumed in the building in the upper part, is followed by the cost of producing solar cells in each set. The sum of the charging that produces electricity, including the status of the solar cells that are operating and each set. It is displayed in the form of letters and line graphs to show the comparison of electricity imported from the Provincial Electricity Authority and the generation of electricity from solar energy through solar cells. When the mouse or touch skin is placed at the graph position, it will appear as a number of energy. The upper right part contains the date display. Real-time time, including displaying the temperature values detected by the temperature sensor.

Figure 3: Twin Power Display Dashboard On the 3rd floor of the building.

From Figure3 Twin Power Display Dashboard The data is displayed on a simulation of each room in the building, which consists of: Temperature, humidity In the form of a number, which will appear while touching the screen of the room where you want to view that information, and show the details of the value captured by the sensor in the Sensor AQI This consists of temperature, humidity, Carbon dioxide and sensor operating status Attainability of air quality in the selected room for viewing data In addition, the lower part will display air quality data. Carbon dioxide, humidity, dust PM1.0 PM2.5 and room temperature in line and bar graph formats to see real-time comparisons. The calculation of CO2 absorption from tree planting can be done in a variety of ways, depending on the type of tree and the environment in which the tree grows. We can use a preliminary formula to estimate the CO2 absorption of trees, with the following steps and formulas:

1. Assessment of the amount of carbon stored by trees (C)

$$C = \text{biomass} \times \text{carbon fraction}$$

Where biomass is the biomass of the tree (dry weight). Carbon fraction is the proportion of carbon in biomass (usually around 0.5 or 50%).

2. Calculation of the amount of CO_2 absorbed (CO_2) Knowing the amount of carbon that trees have accumulated, It can be converted to the amount of CO_2 absorbed by the tree using the formula $CO_2 = C \times (44/12)$. Where 44 is the molecular mass of CO_2. 12 is the atomic mass of carbon. And shows the value of solar power generation in each zone. It includes capacity, power produced, and recorded date and time, which can be viewed on each page. Evaluation of the Suitability of Twin Energy Management Systems with Intelligent Technology to Connect All Things to a Smart Campus. The evaluation of the suitability of the twin energy management system with intellectual technology to connect all things to a smart campus by 20 experts in energy and information technology is as follows

Table 1: Suitability of Twin Energy Management System with Intellectual Technology Connecting Everything to Smart Campus.

Assessment List	Evaluation Results		
	(χ)	S.D	Results
1. Analysis and Requirements			
1.1 The need to reduce energy costs	4.82	0.31	Very good
1.2 The need to improve energy consumption	4.76	0.45	Very good
1.3 Reducing greenhouse gas emissions	4.71	0.77	Very good
1.4 Increasing Energy Security	4.72	0.36	Very good
1.5 Energy Consumption Reduction Goals	4.80	0.32	Very good
1.6 Monitoring and analyzing energy consumption	4.79	0.39	Very good
1.7 Forecasting energy needs	4.61	0.68	Very good
2. Architecture and Technology			
2.1 System Structure	4.62	0.43	Very good
2.2 Easily Adaptable System Design	4.43	0.57	Good
2.3 Integration with other systems	4.45	0.53	Good
2.4 Connecting to IoT Sensors	4.81	0.33	Very good
2.5 Integration with ERP System	4.31	0.62	Good
2.6 Using AI and Machine Learning	4.56	0.51	Very good
3. Data and Data Management			
3.1 Real-time data	4.82	0.36	Very good
3.2 Power History Information	4.76	0.32	Very good
3.3 Forecast and Analysis Data	4.69	0.61	Very good
3.4 Using Relational Databases	4.45	0.73	Good
3.5 Using NoSQL Databases	4.44	0.61	Good
3.6 Data Storage in Data Lakes	4.32	0.62	Good
3.7 Descriptive Analysis	4.25	0.68	Good
3.8 Predictive Analytics	4.31	0.71	Good
3.9 Prescriptive Analysis	4.34	0.74	Good
4. Safety and protection			
4.1 Data encryption	4.44	0.35	Good
4.2 Data Access Rights Management	4.72	0.42	Very good
4.3 Cyber Attack Prevention Measures	4.48	0.47	Good
4.4 Making a backup system	4.71	0.31	Very good
5. Adaptability and scalability			
5.1 Supporting Technological Changes	4.71	0.47	Very good
5.2 Flexibility to add new features	4.52	0.33	Very good
5.3 Sensor Multiplier Support	4.79	0.38	Very good
5.4 System Expansion as Additional Users Become	4.65	0.41	Very good
5.5 Supporting Technological Changes	4.41	0.41	Good
5.6 Flexibility to add new features	4.36	0.35	Good
6. Maintenance and Support			
6.1 Software Management and Updates	4.61	0.43	Very good
6.2 Proactive Monitoring and Maintenance	4.52	0.52	Very good
6.3 Technical Support	4.66	0.42	Very good
6.4 User Training and Support	4.60	0.48	Very good
6.5 Software Management and Updates	4.51	0.42	Very good
6.6 Proactive System Monitoring and Maintenance	4.44	0.41	Good
6.7 Technical Support	4.61	0.51	Very good
7. Value Assessment			
7.1 System Development and Installation Costs	4.42	0.33	Good
7.2 Cost of Purchasing IoT Devices	4.39	0.41	Good
7.3 System Maintenance Costs	4.44	0.32	Good
7.4 System Upgrade Costs	4.31	0.59	Good
7.5 Long-term reduction in energy costs	4.86	0.46	Very good
7.6 Improving Energy Efficiency	4.78	0.32	Very good
Overall average score in all aspects	4.57	0.47	Very good

From Table 1, it was found that the results of the evaluation of the suitability of the twin energy management system with intellectual technology to connect all things to the smart campus in each item were the most appropriate. Long-term reduction in energy costs The average value is the most ($\bar{x}$= 4.86 S.D. = 0.46), followed by analytics and demand, with the need to reduce average energy costs ($\bar{x}$= 4.82 S.D. = 0.31) and architecture and technology. In the real-time data section. They have an average value ($\bar{x}$=

4.81 S.D. = 0.33), respectively. The overall average of the evaluation results of the twin energy management system with intelligent technology to connect all things to a smart campus is the most appropriate ($\overline{x}$= 4.57 S.D. = 0.48).

4. DISCLUSION

From Table 1. Twin energy management system with intellectual technology to connect all things to develop electrical energy management in educational institutions and smart campuses. Electricity management is the development of a system that is consistent with international energy management using the concept of digital twins. In developing a digital model that simulates the energy system of the campus in terms of energy production, storage, and consumption, data collection from IoT devices and sensors installed on campus such as electrical appliances, lighting systems, air conditioning systems, etc.[63] It is integrated with artificial AI technology, which uses AI technology to analyze data. AI to create energy forecasting models Machine learning is used to continuously improve and optimize energy consumption and the Internet of Things (IoT). IoT across the campus to collect real-time energy consumption data and connect systems through the Internet network to enable efficient communication and collaboration. To meet campus energy needs in real-time. The digital twin is a digital model of the campus energy management system, which can accurately simulate and predict the impact of various energy uses. Artificial intelligence technology is used to analyze the data received from sensors and devices. IoT installed throughout the building to enable the system to make decisions and improve energy efficiency. The use of digital twins in combination with AI and IoT can significantly increase energy efficiency on campus. Reduce energy loss and increase campus sustainability. It also helps in the inspection and maintenance of various equipment on campus, allowing for quick identification and resolution of problems, as well as the creation of an environmentally friendly learning and work environment. Reduce energy costs in the long term and improve the quality of life of campus users. In addition to energy, the system also monitors and displays the temperature and humidity values that affect the electricity consumption [64] of the air conditioner in the smart campus building by predicting the suitability of the weather conditions displayed on the digital dashboard so that the air conditioner works properly and efficiently. The system can reduce energy consumption for lighting by up to 30% compared to traditional systems, and the maintenance and monitoring system can monitor the operating status of various equipment and alert when problems or malfunctions are found. In terms of sustainability, reducing energy consumption results in reduced greenhouse gas emissions and supports environmental sustainability. In addition, safety from earthquakes. The system will have vibration sensors that detect vibration and display the results to a digital dashboard. The system can detect vibrations caused by earthquakes and alert executives and personnel through a digital dashboard, so that emergency procedures can be taken in a timely manner. In terms of air quality, PM2.5 sensors are installed throughout the campus to monitor air quality and PM2.5 [65] values are displayed on a digital dashboard so that users can know the air quality information and take appropriate steps. This allows users to know air quality information and make appropriate decisions about activities on campus, with alerts when PM2.5 levels exceed safe levels, enabling timely prevention and remediation actions. It also shows the carbon dioxide absorption value as a colorless and odorless gas. The system displays the number of trees planted to absorb carbon dioxide. This allows users to know the positive impact caused by reduced energy consumption and tree planting, which is calculated and displayed as the number of trees that need to be planted to compensate for energy consumption on campus. This shows the efforts to reduce the amount of carbon dioxide.[66] The results of this study are significant both theoretically and practically. Theoretically, the integration of AI and IoT within the Digital Twin system has helped strengthen a new understanding of real-time energy management with predictive predictions, which is more accurate compared to traditional approaches based on fixed models. In practice, DTEMS systems can significantly improve energy efficiency in smart campuses. As a result, it will reduce costs and use energy sustainably. The system can also be deployed in large infrastructures such as smart cities and industrial facilities. The findings also have significant implications for energy policy, suggesting that technological solutions such as the Digital Twin play an important role in achieving future energy efficiency goals.

5. CONCLUSIONS

Analytical systems to help you successfully implement AI and IoT under the framework of Digital Twin, enabling smart campus management still need to take into account the main considerations, namely the use of this system, including many others and the energy demand that emphasizes the need for further system customization regarding AI and IoT technologies, still need both hardware and hardware at that point. For the control at a large scale, the system should be able to expand the scope of use to other areas such as smart cities and industrial industries. In terms of the energy resources of the control system... The direction and direction of this research system helps improve the understanding of the current literature, especially the use of Digital Twin in conjunction with AI and IoT. The characteristics of energy that do not need to be deeply understood before. Using Digital Twin Energy Management System Digital Twin, combined with intellectual technology and Internet of Things (IoT), is a modern approach with high potential to develop smart campuses to be efficient and sustainable. Both in terms of energy consumption, security, and creating a good environment for learning and working. By applying Digital Twin in an electrical power management system, it can accurately simulate and predict the impact of energy use. It allows for continuous management and improvement of energy consumption. The integration with AI helps to analyze data from sensors and IoT devices installed throughout the campus, enabling the system to make decisions and improve energy efficiency. The digital twin power management system also results in efficient control of the operation of the lighting and air conditioning system. Motion and lighting sensors are installed to automatically turn the electricity on and off. Reduce energy consumption In addition to energy management, The system also supports monitoring and displaying temperature, humidity, PM2.5 and earthquake vibration values through a digital dashboard. Installing vibration and air quality sensors improves the safety and quality of life of campus users. In addition, the display of carbon dioxide absorption values helps to illustrate efforts to reduce CO2 emissions through tree planting. Using Digital Twin, AI, and IoT Technologies in Smart Campus Energy Management Systems It not only increases energy efficiency. This research has made an important contribution to the integration of artificial intelligence technology. The choice of these technologies is based on the capabilities of big data management and real-time processing of AI, which is suitable for complex energy management in large campuses. Factors affecting the research, such as the environment of the smart campus, real-time energy management requirements, and the need to improve energy efficiency, were carefully considered to obtain a model that can quickly respond to changes in the environment and various factors. The results are not only effective in smart campus applications. But it can also be extended to other infrastructures such as smart cities. It also helps in equipment maintenance. Reduce energy costs in the long term and support environmental sustainability. This makes the campus a pleasant place to live and promotes sustainable learning and work. The integration of these technologies can bring benefits to both the environment, the environment, and the environment. Economy and Society As a result, smart campuses become a model of efficient and sustainable energy management in the future. Twin energy management system with intellectual technology to connect all things to develop electrical energy management in educational institutions and can be applied to various organizations or agencies effectively. This research has succeeded in integrating artificial intelligence. Under the framework of Digital Twin for Energy Management in Smart Campus, it answers the key questions set out in the introduction on how to improve real-time energy management efficiency. The introduction of this approach reduces limitations found in previous research, such as the lack of integration of new technologies in energy management. This research also presents clear guidelines for improving energy management systems to be more resilient and adaptable. Not only can it improve the energy consumption in smart campuses, but it can also be applied to other infrastructures such as smart cities and large-scale industrial facilities, opening the way for future research.

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