International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 05 May 2025, pp: 332-337 www.ijaem.net ISSN: 2395-5252

Overview Study of Smart Energy Management Solutions for Universities Aimed At Saving and Reducing Costs

Trần Văn Điền(1), Thạch Ngọc Phúc(2)

Date of Submission: 05-05-2025 Date of Acceptance: 15-05-2025

ABSTRACT:
In the context of rising energy costs and the growing demand for sustainable development, the implementation of Smart Energy Management Solutions in universities is considered a strategic direction to enhance energy efficiency and optimize operational costs. This reality emphasizes the urgent need to research, evaluate, and select effective energy management solutions that aim to conserve energy, reduce greenhouse gas emissions, and contribute to environmental protection.

This study focuses on surveying and analyzing energy consumption systems within universities - such as lighting, air conditioning, office equipment, laboratories, and dormitories - and proposes the application of smart electricity management solutions in higher education institutions. The emphasis is placed on modern technologies, including sensor-based monitoring systems, the Internet of Things (IoT), Artificial Intelligence (AI), and renewable energy solutions. Integrating these technologies enables real-time monitoring, analysis, and control of energy consumption systems, while also optimizing the operation of electrical devices, thereby reducing unnecessary electricity use and improving overall operational efficiency.

By analyzing both domestic and international documents and real-world models, the study draws lessons and proposes a suitable energy management model tailored to the conditions of Vietnamese universities. The results show that smart solutions can help save 20–45% of annual electricity costs and support the digital transformation of education toward a greener, more efficient, and sustainable future.

Keywords: Smart energy management, energy saving, Internet of Things (IoT), renewable energy, power monitoring systems, energy consumption optimization.

I. PROBLEM STATEMENT

In recent years, the demand for energy consumption in educational institutions, especially universities, has tended to increase sharply due to the expansion of training scale, modernization of facilities and application of technology in teaching and research. In addition, fluctuations in energy prices and international commitments on greenhouse gas emissions are posing urgent requirements in the development and implementation of strategies for efficient, economical and environmentally friendly energy use.

The National University of Singapore (NUS) is a model in the region with its "Smart Campus" strategy. The university has implemented an intelligent sensor network to monitor temperature, humidity, light, and space usage. The central air conditioning system is integrated with AI to automatically adjust the temperature based on the number of people in each area, helping to save about 30-40% of the energy consumed for cooling, which is a significant factor in the total energy costs in tropical regions.

The University of California, Irvine (USA) implements an integrated energy management model based on Big Data, combining solar power, storage batteries, and real-time control systems. The university also deploys a system to predict electricity consumption based on seasons and academic activities, enhancing the efficiency of operational planning and resource allocation.

The Ho Chi Minh City University of Technology –National University Ho Chi Minh City - Vietnam is one of the pioneers in implementing energy-saving solutions. The university has applied an IoT-based power monitoring system in several academic buildings and laboratories. Sensors measuring voltage, current, and power consumption are installed in areas with significant energy use. Data is transmitted to a central system for analysis, allowing management to quickly detect unusual consumption patterns. Results recorded a reduction in electricity consumption by 15–20% after a few months of pilot implementation. Hanoi University of Industry has also installed a rooftop solar power system with a capacity of over 100 kW, serving part of the electricity needs for the administrative block and lecture halls. This system not only helps reduce electricity costs but is also used as a practical teaching model for students specializing in engineering and energy.

Therefore, the application of IoT and AI in energy monitoring and control is an inevitable trend for optimizing operations. Renewable energy, such as solar power, not only provides economic benefits but also enhances sustainability and practical education for students. Real-time data is a core factor that enhances the ability to analyze, forecast, and make appropriate adjustments. However, in general, in Vietnam, these models are still in the pilot stage, with limited scope and not yet integrated into a comprehensive system, but they initially yield noticeable effectiveness.

II. THEORETICAL BASIS

2.1 Current Situation of Energy Consumption at the University

The significant difference between Vietnamese universities and international ones lies in the level of automation, technology application, and long-term strategic energy orientation. While international institutions focus on data-driven energy management, comprehensive optimization, and integration with digital transformation, domestic universities are still primarily at the manual control level, lacking system integration [1]. Improving the current energy consumption situation at Vietnamese universities requires substantial investment in both technical infrastructure and mindset change, gradually moving towards creating smart, green, and sustainable educational institutions.

2.1.1 The current situation at universities in Vietnam

Most universities in Vietnam are currently employing traditional energy management methods, lacking automated monitoring systems and mechanisms for analyzing electricity consumption data. This results in energy waste, especially in continuously used areas such as lecture halls, laboratories, libraries, and dormitories. According to reports from the Ministry of Industry and Trade and local survey results, the average electricity consumption at higher education institutions ranges from 500,000 to 1,500,000 kWh/year, depending on the size and modernization level of their equipment.

In these institutions:

- Lighting accounts for approximately 25–30% of total consumption.
- Air conditioning and cooling equipment represent 35–45%.
- Office equipment, computer rooms, and laboratories account for about 20–30%.

Many institutions are still using inefficient electrical equipment (with high age and low efficiency) and lack automated control measures such as light sensors and scheduled on/off systems. This leads to unnecessary energy consumption outside of business hours or during breaks. On the other hand, the awareness of staff and students about energy saving remains limited, and a culture of using electricity responsibly has not yet been established. Additionally, there are no clear policies or specific incentives from the universities to optimize electricity consumption.

2.1.2 The situation at international universities

In developed countries such as the United States, Germany, Singapore, or South Korea, most universities have already implemented energy-efficient strategies aligned with sustainability goals. Universities like Stanford University (USA), ETH Zurich (Switzerland), and the National University of Singapore (NUS) have established integrated smart energy management systems:

- Electricity consumption is monitored in real-time through sensors connected to IoT and AI platforms.
- Integration of renewable energy sources such as solar or wind power, combined with energy storage to balance the load.
- Centralized air conditioning systems are controlled based on data from occupancy and temperature sensors, saving up to 30–40% of energy used for cooling.
- Training programs and internal communications aim to raise awareness and change the behavior of end-users regarding energy usage.

TT	university	country	usable area (m²)	average annual electricity consumption (kWh)	electricity consumption (kWh/m²/year)
1	Hanoi University of Science and Technology	Viet Nam	~120.000	~5.200.000	~43.3
2	Vietnam National University, Ho Chi Minh City	Viet Nam	~250.000	~9.800.000	~39.2
3	ĐH Ton Đuc Thang	Việt Nam	~90.000	~4.100.000	~45.5
4	National University of Singapore (NUS)	Singapore	~600.000	~30.000.000	~50.0
5	University of California, Berkeley	America	~1.000.000	~42.000.000	~42.0
6	Kyoto University	Japan	~500.000	~20.500.000	~41.0
7	Chulalongkorn University	Thaiand	~300.000	~14.000.000	~46.7

Table 1: Current Status of Energy Consumption at Some Domestic and International Universities

2.2 Existing Issues in Energy Management

Energy management is a key factor in improving resource use efficiency, reducing operational costs, and lowering greenhouse gas emissions. However, many facilities are still facing significant issues as follows: [2] [4]

2.2.1Real-time Monitoring and Data System

Most units do not haveenergy management system (EMS), leading to the inability to proactively and accurately monitor and control energy consumption

2.2.2 Long-term Energy Management Strategies and Policies

Many organizations have not developed comprehensive energy plans or integrated efficient energy use objectives into their development strategies. This results in management practices that are reactive rather than sustainable. Users (staff, students, employees) often lack awareness about energy conservation, such as leaving electrical equipment running after hours or not turning off air conditioning when leaving a room, leading to widespread waste.

2.2.3 Lack of Regular Energy Audits

Failing to assess the current state of energy usage results in large, wasteful, or abnormal consumption points not being detected and addressed promptly, causing resource and cost wastage.

2.2.4 Energy-intensive Infrastructure and Equipment

Most lighting, air conditioning, ventilation systems, or industrial equipment still use old, low-efficiency technology that does not meet modern energy-saving standards. Investments in technology lack synchronized energy-saving solutions and, if implemented, are often fragmented, lacking connectivity and integration into a comprehensive system. The application of technologies such as IoT, artificial intelligence (AI), or renewable energy is still sporadic and experimental.

There are limitations in applying renewable energy, despite the significant potential for solar energy exploitation in Vietnam. Most universities have not integrated renewable energy systems into their operations. The main reasons include a lack of initial investment capital, the absence of specific support policies, and the lack of a management model suitable for existing infrastructure.

2.2.5 Lack of Dedicated Personnel and Management Capacity

Many units do not have dedicated energy personnel, or the team is not well-trained, resulting in limited capacity to monitor, evaluate, and optimize system operations.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 05 May 2025, pp: 332-337 www.ijaem.net ISSN: 2395-5252

III. APPLICATION OF SMART TECHNOLOGY IN ENERGY MANAGEMENT

To accompany digital transformation and sustainable development, the application of smart technology in energy management is not only an inevitable trend but also an effective solution to optimize energy consumption, reduce operational costs, and minimize environmental impact. These technologies allow for real-time monitoring, analysis, and control of energy systems, thereby enhancing operational efficiency and decision-making.

3.1 Smart Energy Management System (SEMS)

SEMS is a platform that integrates sensor technologies, software, and data analytics to monitor the entire energy usage process in real time. The system can detect anomalies, issue warnings, and propose solutions to optimize consumption.

3.2 Internet of Things (IoT)

IoT sensors are used to collect data from electrical consuming devices (lights, air conditioners, computers, etc.). Through network connectivity, the data is sent to a central hub for analysis, supporting the control of devices based on environmental conditions or usage history.

3.3 Artificial Intelligence (AI) and Machine Learning

AI has the ability to learn from historical energy consumption data and operational conditions to forecast energy demand and automatically adjust loads. This helps to avoid peak consumption and increase the efficiency of electricity use.

3.4 Automated Control and Optimization Platforms

Technologies such as SCADA, BMS (Building Management System), and PLC (Programmable Logic Controller) allow for the automatic control of electrical systems – lighting – HVAC under optimal settings, reducing manual intervention and enhancing control accuracy.

3.5 Integration of Renewable Energy

The combination of solar panels (PV), storage batteries, and smart controllers maximizes the use of clean energy sources and appropriately regulates loads, reducing dependency on the traditional power grid.

3.6 Big Data Analytics

Energy data is analyzed to identify consumption trends, anomalies, and device performance. This supports decision-making in maintenance, equipment upgrades, or the development of more effective energy-saving policies.

IV. SMART ENERGY MANAGEMENT SOLUTIONS

With rising energy costs and the need for a shift to sustainable development models, the implementation of Smart Energy Management Solutions (SEMS) in universities and public organizations is an inevitable trend. Smart energy management solutions not only help save electricity costs but also represent a significant advance in the digital transformation of the education sector, aiming towards a "green, smart, sustainable university" model. The systematic, coordinated, and practical integration of technology is a key factor in ensuring effectiveness and feasibility in implementation.

4.1 Smart Energy Monitoring System (SEMS)

- Real-time monitoring of energy consumption in each area and for each device.
- Utilizes smart sensors, electronic meters, and IoT platforms.
- Detects anomalies, warns of excessive consumption, and provides intuitive dashboards.
- Assists managers in accurately understanding electricity usage and taking timely intervention measures.

4.2 Automation & Control Systems

- Remote control via IoT, programmable logic controllers (PLC), and building management systems (BMS).
- Controls lighting, air conditioning, and ventilation based on motion, temperature, and time sensors.
- Reduces energy waste from operating devices outside working hours or when not in use.

4.3 AI-based Load Optimization

- Uses AI, machine learning, and analysis of past electricity consumption data.
- Forecasts energy demand, schedules device usage, and suggests cutting loads during peak hours.
- Prevents overload, reduces peak-hour electricity costs, and optimizes the load profile.

4.4 Integration of Renewable Energy and Smart Storage

- Installation of solar power systems combined with energy storage batteries and smart inverters.

- Supplies power to priority loads, performs logical charging/discharging based on timeframes, and alleviates grid load.
- Reduces dependency on grid power, lowers CO_2 emissions, and ensures a proactive power supply.

4.5 Implementation of Regular Energy Audits and Performance Assessments

- Conduct annual or periodic energy audits.
- Analyze device performance, identify wastage points, and develop energy-saving reports.
- Enhances operational efficiency and provides a scientific basis for improvement investments.

4.6 Raising Awareness and Changing User Behavior

- Implement internal communication programs, guide efficient device usage, organize energy-saving initiative competitions.
- Develop online portals and apps for individual/department/faculty energy tracking.
- Increase participation from staff, faculty, and students in the energy-saving process.

V. EVALUATION OF EFFECTIVENESS

- Schools implementing smart monitoring systems combined with IoT and automated controls have saved between 20-45% on annual electricity costs. Reducing peak-hour consumption and optimizing loads contribute to lowering electricity bills.
- The payback period for smart energy projects (e.g., solar energy systems combined with storage and IoT) typically ranges from 3 to 6 years, depending on the scale and technology deployed.
- Smart control systems help equipment operate at optimal capacity, reducing overload and extending the equipment's lifespan.
- Real-time monitoring and analysis of electricity consumption data help identify abnormal consumption points, thereby limiting losses and waste.
- AI algorithms and machine learning models help predict energy demand and coordinate load appropriately based on academic schedules, operational hours, and weather conditions.
- Reduction in greenhouse gas emissions: Efficient electricity use and the integration of renewable energy sources like solar power significantly reduce CO_2 emissions, contributing to low-carbon or carbon-neutral goals.
- Well-controlled environments in terms of temperature, lighting, and humidity enhance the quality of teaching and learning, creating a "Green School" model.
- Increased transparency and proactivity: SEMS provide transparent data on electricity usage for management to allocate budgets more accurately.
- Enhanced community responsibility: Through technology applications, individuals or units can monitor their energy consumption, fostering awareness and more rational usage behavior.
- Easy scalability: IoT-based solutions and open platforms allow for phased deployment expansion (by building, faculty, center, etc.).
- Integration into the Smart Campus model: Deploying SEMS is a critical foundation for forming smart campus models, integrating lighting, security, air conditioning, teaching, and infrastructure management on a single platform.

VI. CONCLUSION

- The implementation of smart energy management solutions in universities is a necessary step to meet the demands of cost savings, enhance operational efficiency, and aim for sustainable development. Technologies such as IoT, AI, sensors, and renewable energy have demonstrated their effectiveness in monitoring, optimizing, and controlling energy consumption. Although there are still some challenges related to finance, human resources, and infrastructure, these solutions are entirely feasible and should be prioritized with a reasonable roadmap and coordinated efforts during the development of smart, green, and digital universities.
- In the future, expanding the application of smart energy management models should not be limited to universities. It can also be extended to other educational institutions such as secondary schools, vocational schools, and student dormitories.

REFERENCES

[1]. Hoàng, T. Q., & Nguyễn, V. M. (2021), Nalysis of electricity consumption on the campus of a Vietnamese university, Journal of Science & Technology, Danang University of Science & Technology.
[2]. JICA & Ministry of Construction of Vietnam (2019), Survey of Current Status and Proposals for Energy Savings in Public Buildings.
[3]. University of Queensland. (2020). Energy Management in Campus Facilities.
[4]. Trần, H. L., & Phạm, V. H. (2020),Energy Consumption in Practice Workshops at

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 05 May 2025, pp: 332-337 www.ijaem.net ISSN: 2395-5252

Technical Schools. Journal of Engineering Science & Applications.

[5]. IEEE Smart Campus Initiative. (2018). Energy Monitoring in Higher Education Facilities..

[6]. International Energy Agency (IEA) (2022),Energy Efficiency 2022. https://www.iea.org/reports/energy-efficiency-2022.

[7]. U.S. Department of Energy. (2019),Guide to Energy Efficiency Opportunities in K–12 Schools. https://www.energy.gov/.

[8]. Nguyen, T. H., & Le, T. N. (2021), Application of the Internet of Things in Monitoring Electricity Consumption at Educational Institutions, Journal of Science & Technology, Danang University of Science & Technology19(2), 45–52.

[9]. Trần, M. H. (2020). Study on the Deployment of Solar Energy Systems at a University, Vietnam Energy Journal, 56(3), 34–39.

[10]. Farhangi, H. (2010). The path of the smart grid. IEEE Power and Energy Magazine, 8(1), 18–28. https://doi.org/10.1109/MPE.2009.934876.