ISSN: 2834-4928

Case Study

Journal of Electrical Electronics Engineering

Enhancing the Potential of Smart Building for Hospital Pulau Pinang: A Case Study in Malaysia

Mohd Faisal Bin Baharuddin[1]*, Lim Chin Haw[2], Ahmad Fazlizan[3]

Solar Energy Research Institute (SERI), University Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

***Corresponding Author:**
Mohd Faisal Bin Baharuddin, Solar Energy Research Institute (SERI), University Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

Submitted: 01 Mar 2023; **Accepted:** 27 Mar 2023; **Published:** 14 Apr 2023

Citation: Baharuddin, M. F. B., Haw, L. C., Fazlizan, A. (2023). Enhancing the Potential of Smart Building for Hospital Pulau Pinang: A Case Study in Malaysia. *J Electrical Electron Eng, 2*(2), 79-86.

Abstract

Hospital Pulau Pinang and the concession company are bound in the concession agreement to achieve energy savings of 10% within five years and other sustainability targets such as 3-star Energy Management Gold Standard and Green Building Certification. The requirements are beneficial for the hospital itself to establish the Smart Building Program to improve its energy efficiency concurrent with the green policy of the Ministry of Health Malaysia and Sustainable Development Goals by the United Nations.

This paper reviews the background of Hospital Pulau Pinang energy data, energy consumption trending, energy-saving trending, and energy conservation measures taken for the hospital from 2015 to December 2021.The yearly energy consumption baseline taken in 2016 was 27,496,731.00 kWh. It reduced significantly to 21,356,063 kWh in 2021 due to energy conservation measures. As a result, Hospital Pulau Pinang has achieved energy-saving about 16% at approximately RM7.3 million reduction in operational expenditure. The main objective of this case study is to provide further potential energy savings by studying the energy reduction by implementing solar photovoltaics using the simulation method. The simulation method can predict that Hospital Pulau Pinang can achieve another 5,130,000 kWh energy savings annually. This type of simulation has never been done before at a public hospital, and it will give further enhancing strategies to the Smart Building Program itself.

Furthermore, the potential of smart building can be maximized to the next level by simulation, which helps the hospital energy committee make the potential decision on the energy-saving investment.

Keywords: Digital Twin, Energy Saving, Simulation, Solar Energy, Smart Building

Introduction

Background

To achieve established smart building for Hospital Pulau Pinang, the Energy Management Program (E.M.P.) and Sustainability Program (S.P.) are essential and concurrently with requirements in the Concession Agreement (C.A.). Today the entire world has realized the importance of being sustainable, smart building and energy-efficient building, and the hospital must also change eventually. Research into the intelligent design of buildings began in the early 1980s [1]. Through the Ministry of Health (M.O.H.), Hospital Pulau Pinang is bound to the Concession Agreement. The contract signed from 2015 until 2025 aims to achieve 10% energy saving for all hospitals in Malaysia and a few other key performance indicators that are subject to terms & conditions [2].

In 2002, at the World Summit on Sustainable Development in Johannesburg, health was highlighted as an essential prerequisite for the future. In summary, healthcare buildings should be sustainable, healthy, technology-aware, responsive to the needs of the occupants and the building, and flexible and adaptable to cope with change. This leads to a building that has a combination of environmental, social and economic values [3].

Hospital is using a lot of energy to operate the hospital to meet its healthcare standard. Among other buildings, the hospital is one of the largest energy consumers, while energy savings and cost reductions are among the biggest challenges considered by planners, engineers and stakeholders. Hospital has the highest building energy index (B.E.I.) compared to other building types due to its non-stop 24/7 operations, especially in the pandemic season of Covid-19 [4].

Smart Building Program of Hospital

In line with the national vision to create more green buildings within government building, this concession agreement also included with the Sustainability Program including Energy Management Program (E.M.P).

The program from 2015 until 2021 has started with data collection and energy countermeasure. This paper gives a better understanding of how to maximise the solar photovoltaic potential tailored suit with the Hospital Pulau Pinang building. It can be achieved through building energy simulation, using I.E.S. iCD and VE where the software can generate a digital twin of the hospital. It can simulate the potential energy saving, carbon emission, P.V. electricity yield and P.V. radiation from the interactive dashboard. Identifying the potential and calculating the output of renewable energy in an urban setting is essential for designing future urban areas and retrofitting existing structures. To achieve this goal, accurate modelling is essential [5].

Methodology

Case Study Background

Hospital Pulau Pinang is the biggest hospital in the northern region and second-largest hospital in Malaysia which offer clinical services, training & research centre. It is located at latitude 5.42 N and longitude 100.31 E of Peninsular Malaysia. This multiple-building hospital is categorized as a state hospital that first started its operation in 1812 and is managed by the Ministry of Health (M.O.H.) Malaysia. This hospital has a building gross floor area of 119,383.77   with a total air-conditioning area about 37% at 44,799.17 with total energy consumption at 27,496,731.00 kWh from 2016 baseline. Most of the buildings are designed with natural and mechanical ventilation with windows.

Hospital Pulau Pinang is a specialist state hospital that acts as a medical referral center for the northern region of Peninsular Malaysia with multiple disciplines of medical departments with 15 secondary specialist, 34 tertiary specialist, and 16 clinical support services. Its facilities include 1,163 beds, 4749 staff and 24 hours operation. Total electricity consumption for year 2020 is 22,412,620.00 at RM9,600,974.30. Hospital Pulau Pinang is classified as a High Energy Consumption Hospital. The trend of energy consumption in Malaysia is on the rise. with hospitals topping the list of energy consumers with an average of 2,533 GWh per year [6].

Three methods were involved: Data collection from various documents such as Monthly Energy Report, Detailed Energy Audit (D.E.A), etc. Secondly is the empirical evidence approach by on-site measurement using the Energy Monitoring System as per shown in Figure 1. Furthermore, to enhance the potential saving for the hospital, building energy simulation is used by implementing of the I.E.S. Intelligent Community Lifecycle, which contains iCD & VE software.

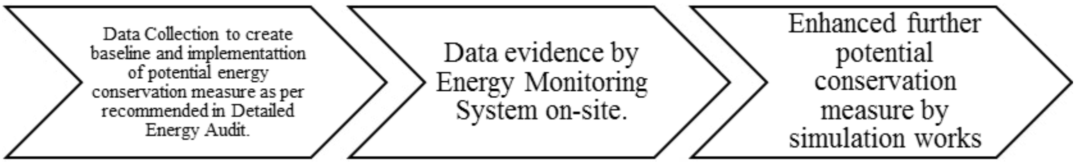


Figure 1: Methodology of Enhancing the Potential Smart Building for Hospital

Based on the review, the benefit of this paper has become relevant due to the impact of the energy performance contracting and energy management on the sustainable and smart building solution. Green building has become one of the most widely discussed topics among academia, government agencies, civil society and the construction industry. Many countries have introduced their own green rating systems for the benefit of the population, and this progress is seen as a global goal for the greening of the earth [7].

Building Energy Index (B.E.I.)

In normal condition to determine the performance of the E.M.P. activities at each building or facility, the Gross Floor Area (G.F.A.) is being used as a factor for the calculation of the Building Energy Index (B.E.I.), and it is measured in the unit of kWh/m2/year. The B.E.I. can be used as an indicator to compare the building energy consumption against the floor area. By the end of every interval, the hospital's management will know the hospital's energy performance based on the B.E.I. as the indicator. From the figure 2 below, Hospital Pulau Pinang has shown a significant decrease in B.E.I. This trend can prove the implementation of energy-saving measures. The Hospital B.E.I. is usually higher than a typical office building. The new trend of designing and building healthcare facility using green technologies, sustainable resources and systems to reduce energy usage and carbon emissions is enabling higher building performance.

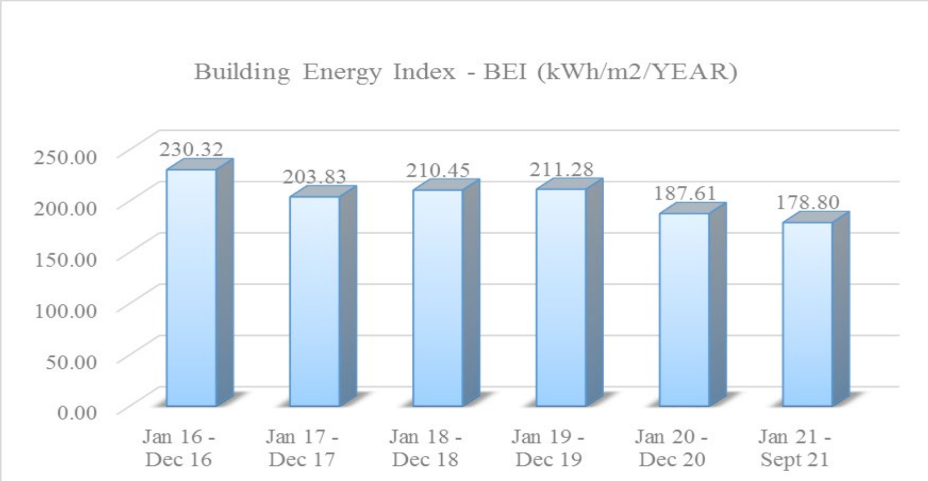


Figure 2: Building Energy Index for Hospital Pulau Pinang from 2016 to 2021. (Monthly Energy Report,2021)

Therefore, the heath sector could respond by reducing energy usage, enhance indoor air quality and creating an acceptable healing environment [8]. Electricity consumption in commercial buildings requires special attention, as electricity is the main source of energy in these types of buildings. With rising fuel prices, consumers are now more careful with electricity [9].

Energy Monitoring System for Smart Building

Smart buildings historically and technologically refer to the integration of four unique systems: Building Automation Systems (B.A.S.), Telecommunications Systems, Office Automation Systems and Computer Building Management Systems. The highly anticipated B.A.S. have become the "heart and soul" of the smart building concept. The integration of energy supply and user needs has become an important concept in energy efficiency policy, often referred to as demand-side management. (D.S.M) [10]. In the Sustainability Program, the monitoring system is limited to the energy or kWh as per shown in Figure 3. The energy monitoring system installation was first started in 2015.

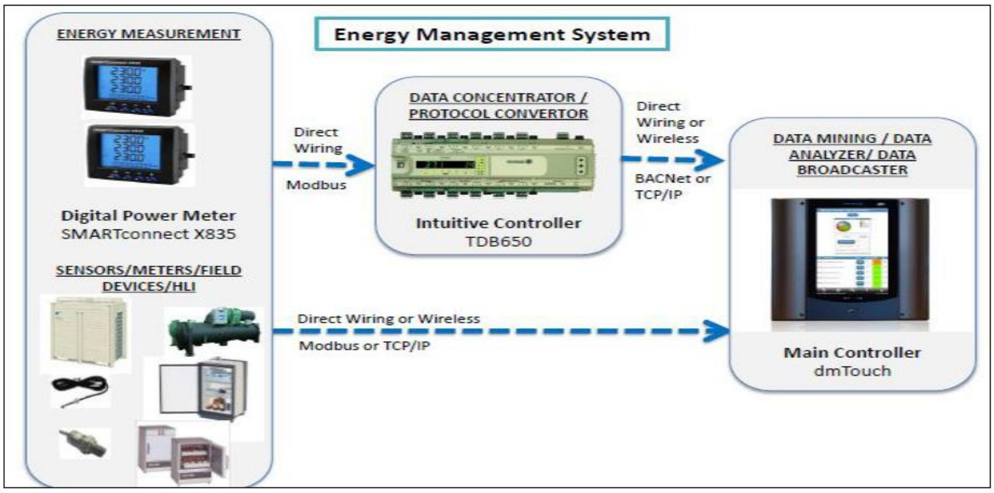


Figure 3: Type of Monitoring System for Energy at Hospital. (Monthly Energy Report,2021)

An Energy Management System (E.M.S.) is a set of software tools used to monitor, control, and analyses a building's energy consumption. Any building should be considered an installation of EMS for building with air-conditioned space ≥ 4000 m2 (Malaysia Standard on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings, 2014). This make Hospital Pulau Pinang included as the air-conditioned space inside the building is 37.0%. The Energy Management System consists of several components: the main controller, intuitive controller, and set of energy measurement meters, as shown in the following figure. Monitoring, analysis and optimization of building energy use is central to retrofitting and energy efficient operation of buildings, as it enables identification and correction of inefficient energy use. In general, E.M.S. has three main functions: Control of equipment, monitoring of equipment and integration of equipment subsystems. The main purpose of control equipment is to save energy through (preferably real-time) optimized system controls. At Pulau Pinang Hospital, 178 digital power meters were installed. The data from the digital power meter (D.P.M.) is transmitted to the intuitive control system. The intuitive control then transmits the data to the main control for further E.A.C. analysis for each D.P.M. Researchers around the globe are developing on energy models and controls to create strategies to reduce the energy consumption of buildings [11].

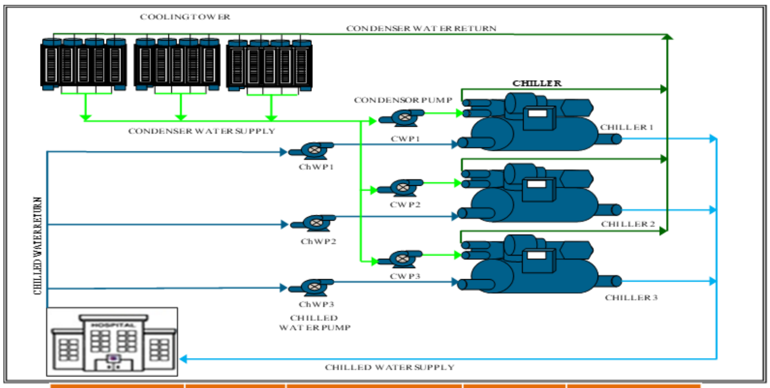
Energy Conservation Measure. (E.C.M.)

Hospital Pulau Pinang has benefited a lot from the program of Sustainability Program since a large amount of money has been invested wisely which helps energy saving such as air-conditioning and lighting retrofitting.

Figure 4: Oil-Free Compressor for Chiller System during Retrofit Program by Energy Performance Contracting with zero initial capital cost

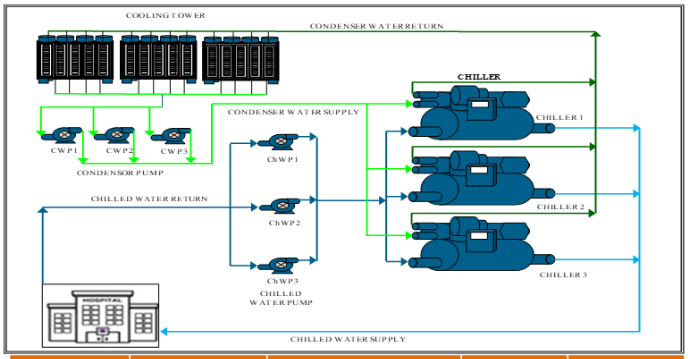
More than RM2.8 million has been invested in the Energy Management Program. Figures 4 and 5 show a few examples of the activities that have been done to make sure energy saving is achieved.

ACC Centralized Cooling System



Description	Brand	Type	Cooling Capacity	Operation Mode
Chiller 1	SMARDT	Magnetic Bearing	250 RT	2 Running 1 Standby
Chiller 2	York	Screw Chiller	250 RT	
Chiller 3	SMARDT	Magnetic Bearing	250 RT	

BLOK B Centralized Cooling System



Description	Brand	Type	Cooling Capacity	Operation Mode
Chiller 1	SMARDT	Magnetic Bearing	500 RT	2 Running 1 Standby
Chiller 2	Dunham Bush	Screw Chiller	350 RT	
Chiller 3	Dunham Bush	Screw Chiller	350 RT	

Figure 5: Chiller retrofit program through E.P.C

The Energy Service Company (E.S.C.O.), are responsible for designing, supplying, installing, and maintaining the E.P.C. project for Hospital Pulau Pinang. The E.P.C. Contract Period starts from 1st October 2019 until 31st March 2025. For the record, the Physical installation period started 1st October 2019 to 31st March 2020. It was followed by a Performance Period from 1st April 2020 to 31st March 2025 with an expected guaranteed saving of 5,664,691 kWh/year or RM 2.3 million. This smart and practical option can greatly contribute to energy savings and environmental benefits. According to a report by researchers, a smart building equipped with a monitoring and control system can lead to energy savings of around 20%, which is an essential step towards smart building automation and energy management [12].

Digital Twin Technology

Conventionally, digital twins have been used to enhance the performance of a single asset, such as a car, but more recently digital twins are also being applied to systems with multiple assets, facilities or an entire organization [13]. A lot of energy is wasted in buildings because of a lack of energy management or because existing building automation systems (B.A.S.) are not maintained and operated properly. These scenarios of technological waste occur because we are not able to manage and control buildings efficiently. More than 90% of buildings are either small (< 5,000 sf) or medium sized (between 5,000 sf and 50,000 sf); these buildings do not currently use B.A.S.s to manage, monitor and control their building systems from a central location [14]. In recent decades, detailed individual building energy models (B.E.M.) regional and country-wide building stock models and have established themselves as methods of analysis for the groups of architects, engineers, builders or energy policy stakeholders [15]. Hospital Pulau Pinang does have an energy monitoring system, but it is only limited to data presentation with no analysis or simulation can be generated from the system. It will be significant if the energy data can be analyzed, simulated, and presenting the data in the interactive platform.

Today, modelling and simulation are preliminary stages of system development, e.g. to manage the project or to validate system properties. Meanwhile, simulation-type of technologies are used in early phases to enhance operations and forecast errors. Thanks to this kind of innovation, simulation merges the real and virtual worlds in all stages of the life cycle. For this case study, building modelling through digital twin technology uses software such as I.E.S. Intelligent Community Lifecycle (I.C.L.) software can generate data and provide information to enhance energy performance analysis. The I.C.L. consists of Intelligent Community Information Model (iCIM), Intelligent Portfolio Information Model (iPIM), Intelligent Community Design (iCD), Intelligent Control and Analysis (iSCAN) and Intelligent Virtual Network (iVN). Researchers around the world are developing on energy modelling and control to manage strategies to reduce the energy consumption of buildings [16,17].

Hospital Pulau Pinang building-related information can be collected and visualized as the digital twin of the hospital to the energy management committee with an interactive platform. Building energy modelling and management is an interdisciplinary field of study that encompasses concepts and studies in electrical and electronic engineering, mechanical engineering, civil engineering and architecture. Miniaturization and price reduction enable the integration of information, communication and sensor technologies into virtually for most of the product. Products are enabled to sense their condition and the state of their environment. Equipped with the ability to analyses and communicate this data, it enables the creation of digital twins. The digital twin is a comprehensive digital image of a single product that will play an essential role in a fully digitized product lifecycle.

Smart Building Energy Simulation

Hospitals in Malaysia have been exposed to the idea of Industrial Revolution 4.0 to operate the buildings with sustainable approaches. Align with the government's intention to reduce greenhouse gas emissions, converting the existing hospitals into smart hospitals will contribute largely as the buildings that operate in hot and humid climates are currently using enormous amounts of energy consumptions to maintain the thermal comfort level reduce infection control rate. Nowadays, while public healthcare's in Malaysia have already used to an energy management programmed, all they need is a platform to monitor and simulate. The B.I.M. energy consumption analysis can compare different design and concept, maximize the output of the different materials and calculate the most suitable and energy-efficient concepts for the maintenance of the building structure. A new phase of energy monitoring is to leverage the digital twin technology, which will bring a new phase of the internet of things (IoT) to the energy management program itself Building energy simulation programmed perform heat balance calculations based on the physical parameters of the building, such as design, materials, building orientation, mechanical systems operating in the building, and dynamic inputs such as occupancy, lighting, weather, sunpath etc. This type of simulation becoming an ideal step to forecast the condition of a building in the early stage of building design. Architects and engineers able to enhance the energy management of the building based on the calculated forecasting element already in the design phase.

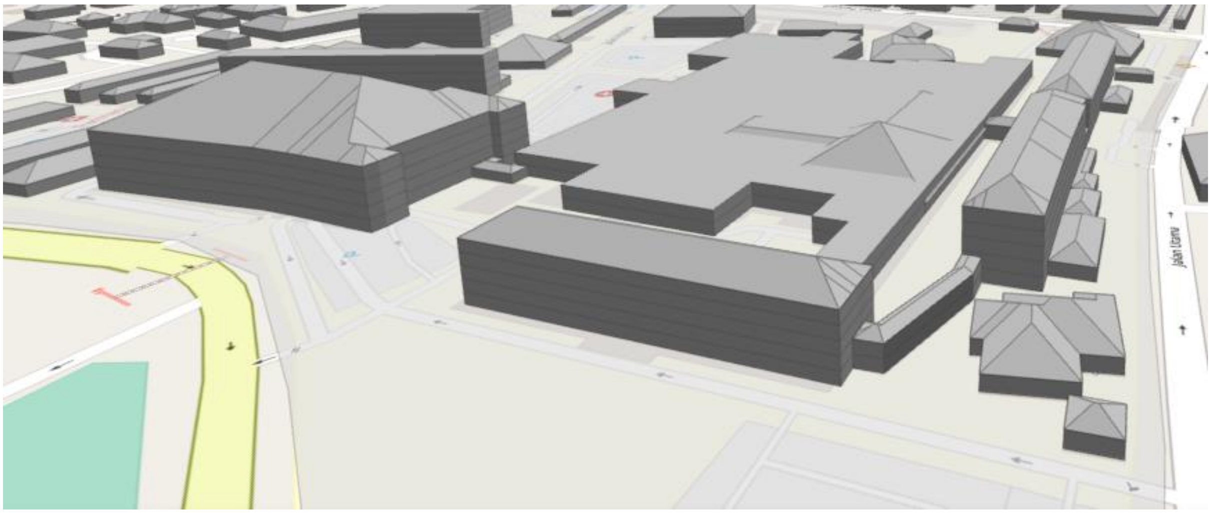


Figure 6: Digital Twin of Hospital Pulau Pinang

Energy efficient Building Digital Twins (B.D.T.s) are researched using Building Information Model (B.I.M.) to further study the main elements of Digital Twins (DTs). (Weixi Wang, 2022). By using the I.E.S. Intelligent Community Lifecycle software to create the three-dimensional digital twin of the hospital, the energy simulation can be produced and thus the Building Energy Index (B.E.I.), Cooling, Energy Consumption, Lighting energy consumption in kWh/m2/year and Annual Carbon Emission of the hospital in tCO2 for Hospital Pulau Pinang are generated in an interactive platform that can be accessed from web browser as per shown in Figure 6. In addition to active measures, many other energy-saving potentials can be tapped through passive strategies. The simulation method is used to establish an energy baseline as a basis for forecasting energy reductions potential for passive strategies that cannot be measured by an energy audit. The mixture of these steps is important to enhance the potential for energy savings through active and passive methods, which nowadays never been implemented in any public healthcare in Malaysia.

All information was generated by I.C.L. software and the digital twin for hospitals was modelled according to AutoCAD & google maps. Some information was taken with the help of a drone view. The results of energy simulation by software can be shown in table 1.

Table 1: The Attributes Summary of the Hospital Pulau Pinang by simulation

Hospital / Indicator	**AVERAGE ENERGY USER INTENSITY (E.U.I.) kWh/m2/yr**	**AVERAGE CO0LING ENERGY (kWh/m2/yr)**	**AVERAGE LIGHTING ENERGY (kWh/m2/yr)**	**Annual CO2 emission (tCO2)**
Hospital Pulau Pinang	249.66	62.51	27.05	28081

Further enhancement of the energy conservation measure is taking place with the implementation and integration of the renewable energy system in the hospital buildings. By simulation of I.E.S. iCD software, it can generate the best position of solar photovoltaic (P.V.) based on sun path, analyse the solar photovoltaic (P.V.) radiation, site solar photovoltaic (P.V.) electricity yield and furthermore simulate the potential total solar photovoltaic (P.V.) contribution. The capacity of the solar photovoltaic (P.V.) system will be sized according to the roof surface area of the Hospital Pulau Pinang as can be shown in Figure 7 below.

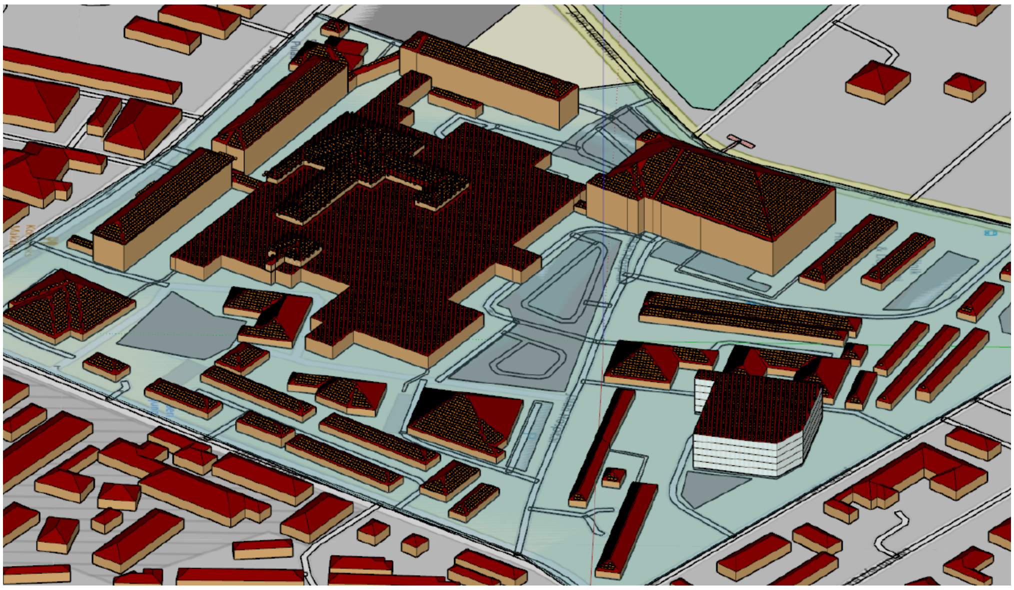


Figure 7: The Solar P.V. positions are generated by the iCD solar assessment simulation

Results and Discussion

The energy report showed significant energy saving for the hospitals. The energy management system and utility bills show that the energy consumption from 2017 to 2021 is decreasing, and total energy saving can be summarized in the table below. Approximately RM 7.3 million has been saved from 2017, and it can be concluded that the program was successful and has achieved its target as per Table 2.

Table 2: Total saving since 2017 until 2021. (Monthly Energy Report,2021)

Year	Total saving in ringgit (RM) equivalent
2017	RM1,475,023.25
2018	RM827,700.25
2019	RM285,189.10
2020	RM1,844,557.40
2021	RM2,876,843.50
Overall	RM 7,311,892.10

A Smart Hospital model can be utilized by Energy Management Committee (E.M.C) for a particular hospital or even at the Ministry level in Putrajaya, and it can also be extended throughout the other hospital in Malaysia. For the result of the simulation works, implementing the solar photovoltaic (P.V.) at the best possible location as recommended in the software. It can be further improving energy saving by contributing about 5,130,000 kWh more to the existing saving that the hospital has achieved. In terms of carbon emission reduction, if the hospital implements the solar P.V. as per simulation, approximately about 3,801 tCO^2e can be offset from the total carbon emission. All the results from the simulation can be analyzed and visualized to the hospital management levels in an interactive dashboard.

Conclusion

After all, achieving the energy-saving for at large hospital is not an easy task and it has been shown that large hospitals such as the Hospital Pulau Pinang needed almost five years to achieve such energy savings. The right policy and top management trust in the energy committee to fulfil the program are critical factors. Driven by the high standard in concession agreement requirement, a journey for the smart building is in the proper structure, and steady investment is needed to see this program continuously improve in the next phase, renewable energy, particularly solar energy. For more than a 5-year energy management program, this hospital needs few more investments in retrofitting the HVAC. They can look for solar P.V. to improve energy saving in the future as recommended by the simulation to further enhance the potential for smart building.

The ability to assess, monitor, analyses and manage these public hospitals energy consumption throughout Malaysia is a sustainable approach to make the idea of Smart Hospital. Implementation of digital twin technology by I.E.S. software can help the committee decide on the suitable investment for energy-saving measures and monitor the energy data from the fingertips.

The enormous amount of energy-saving from large hospitals, which have never undergone any energy management program, will significantly succeed with the right and structured policy and management. Hopefully, the figure and exposure from this review can inspire any type of building to achieve the same goals as Hospital Pulau Pinang.

Acknowledgements

Thanks to all the person that involve in this review and case

study that eventually will help the hospital in Malaysia to maximize their potential to become a smart building.

References

1. Wong, J. K., Li, H., & Wang, S. W. (2005). Intelligent building research: a review. Automation in construction, 14(1), 143-159.
2. Ministry of Health Malaysia (M.O.H.) (2015). "Concession Agreement in respect of provision of Hospital Support Services at Contract Hospital". Ministry of Health Malaysia, Putrajaya.
3. Sahamir, S. R., & Zakaria, R. (2014). Green assessment criteria for public hospital building development in Malaysia. Procedia Environmental Sciences, 20, 106-115.
4. Moghimi, S., Azizpour, F., Mat, S., Lim, C. H., Salleh, E., & Sopian, K. (2014). Building energy index and end-use energy analysis in large-scale hospitals—case study in Malaysia. Energy efficiency, 7, 243-256.
5. Allegrini, J., Orehounig, K., Mavromatidis, G., Ruesch, F., Dorer, V., & Evins, R. (2015). A review of modelling approaches and tools for the simulation of district-scale energy systems. Renewable and Sustainable Energy Reviews, 52, 1391-1404.
6. Sung C.T.B. (2016). "Electricity demand, economic growth, and sustainable energy resources in Malaysia". Extraordinary mind discusses ideas, pp. 1-8.
7. Ahmad, A. S., Hassan, M. Y., Abdullah, H., Rahman, H. A., Majid, M. S., & Bandi, M. (2012, December). Energy efficiency measurements in a Malaysian public university. In 2012 IEEE International Conference on Power and Energy (PECon) (pp. 582-587). IEEE.
8. Figueiredo, J., & Martins, J. (2010). Energy production system management–renewable energy power supply integration with building automation system. Energy Conversion and Management, 51(6), 1120-1126.
9. Harish, V. S. K. V., & Kumar, A. (2015). A review on modeling and simulation of building energy systems. Renewable and sustainable energy reviews, 56, 1272-1292.
10. O'Donnell, J., Keane, M., & Bazjanac, V. (2008). Specification of an information delivery tool to support optimal holistic environmental and energy management in buildings (No. LBNL-918E). Lawrence Berkeley National Lab. (LBNL), Berkeley, CA (United States).
11. Jafari, M. A., Zaidan, E., Ghofrani, A., Mahani, K., & Farzan, F. (2020). Improving building energy footprint and asset performance using digital twin technology. IFAC-PapersOnLine, 53(3), 386-391.
12. Katipamula, S., Underhill, R. M., Goddard, J. K., Taasevigen, D. J., Piette, M. A., Granderson, J., ... & Kuruganti, T. (2012). Small-and medium-sized commercial building monitoring and controls needs: A scoping study (No. PNNL-22169). Pacific Northwest National Lab. (PNNL), Richland, WA (United States).
13. Reinhart, C. F., & Davila, C. C. (2016). Urban building energy modeling–A review of a nascent field. Building and Environment, 97, 196-202.
14. Boschert, S., & Rosen, R. (2016). Digital twin—the simulation aspect. Mechatronic futures: Challenges and solutions for mechatronic systems and their designers, 59-74.
15. Haag, S., & Anderl, R. (2018). Digital twin–Proof of concept. Manufacturing letters, 15, 64-66.
16. Wang, W., Guo, H., Li, X., Tang, S., Xia, J., & Lv, Z. (2022). Deep learning for assessment of environmental satisfaction using BIM big data in energy efficient building digital twins. Sustainable Energy Technologies and Assessments, 50, 101897.
17. Abd Rahman, N. M., Lim, C. H., & Fazlizan, A. (2021). Optimizing the energy saving potential of public hospital through a systematic approach for green building certification in Malaysia. Journal of Building Engineering, 43, 103088.