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The Implementation of Solar Roof Panel Responding to Sustainable Society: A case study of Tropical Medicine Hospital, Bangkok, Thailand

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Abstract

Climate change is a critical issue worldwide due to the increasing of Carbon Dioxide emission and its consequence. Carbon Dioxide is classified as one of Green House Gas emissions that linked to Climate Change. The Green and Clean hospital approach is one strategy for Climate Change mitigation and adaptation measures. This study attempts to determine the greenhouse gas emissions (CO2) from solar power generated on the rooftop building as well as the feasibility of generating 187,778 kW of electricity from solar energy at the Tropical Medicine Hospital, Bangkok. According to the study's findings, 321,906.34 GWh/year of electricity might be produced annually, which would result in a monthly reduction of roughly 164,204.43 tCO2e/year in greenhouse gas emissions. The production of electricity and used in the hospital can support Thailand to be sustainable for energy usage and respond to the concept of clean and green hospital issued by Ministry of Public Health, Thailand.

Keywords: *Greenhouse Gas Emissions (CO2), Solar Energy Production, Clean and Green Hospital, CO2 reduction*

Introduction

Climate change is a critical issue worldwide due to the increasing of Carbon Dioxide emission and its consequence. Carbon Dioxide is classified as one of Green House Gas emissions that linked to Climate Change. Thailand has designed to be a neutral and zero emission country in 2050 and 2065, respectively. Hospital operation is not the main emission source of greenhouse gas (GHG) however, energy is necessary. The energy sources in Thailand comprise of various sources such as hydrology, fossil fuels, biogas and others. Almost of the mentioned sources above are classified as the sources of GHG emission that stimulate the climate change problem. Thailand government has launched the program of alternative environmentally friendly energy such as solar radiation and wind that is cleaner (Wattana 2020). In case of hospital, Ministry of Public Health Thailand has launched a program of green and clean hospital. This program is

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responding to cope the climate change in terms of mitigation and adaptation as well (Department of Health 2016; Wattana 2020).

In addition, this approach will be benefit for sustainable society according to the SDG (Sustainable Development Goal) target 7: Affordable and Clean Energy. The CO_2 reduction from solar roof installations and their economic viability have been critical considerations in the widespread adoption of this technology. Several studies have explored the financial and environmental implications of grid-tiled rooftop solar photovoltaic (PV) systems employing net metering. One such study analyzed financial factors such as Net Present Value, Return on Investment, Internal Rate of Return, Payback Period, Life Cycle Cost, Annualized Life Cycle Cost, and Cost per unit of electricity generated through the installed photovoltaic system to assess the economic feasibility of a 10 kWp system under both the CAPEX model for residential sectors and the RESCO model for commercial sectors (Kalke, Kokkonda, and Kulkarni 2018). The findings suggest that the per-unit cost of electricity generated through the grid-tied rooftop solar photovoltaic system is cheaper than the current electricity rate charged by the utility. Moreover, customers in both residential and commercial sectors do not have to pay any electricity bills as the generation exceeds their needs, with the excess energy being fed back into the grid.

A comparative analysis between traditional and emerging solar cell technologies was conducted to evaluate the project's viability, both with and without the sale of surplus energy to the grid (Pinho Correia Valério Bernardo et al. 2023). The results indicated that the project was not economically viable for any of the technologies considered without the sale of excess energy. However, when the sale of surplus energy was factored in, the project became economically viable with traditional technologies, achieving a payback period of less than 10 years.

Many researchers suggest that they build upon the findings of previous studies, which have explored the economic viability and environmental benefits of solar roofs (Klamka, Wolf, and Ehrlich 2020; Ma et al. 2017; Soleja et al. 2018) These studies have consistently highlighted the significant reduction in carbon emissions that can be achieved through the adoption of solar photovoltaic systems, both in commercial and residential settings. Furthermore, research has shown that the key advantage of solar roofs lies in their ability to reduce the heat flux through the roof, leading to substantial savings in annual energy use, particularly during the summer cooling season.

The assessment of economic feasibility and CO_2 reduction from installing solar roofs is a complex matter that balances financial factors with environmental benefits. The incorporation of solar energy systems, particularly photovoltaic (PV) technology, was vital in promoting Sustainable Development Goals (SDGs) (Saiz et al. 2006). Specifically, it supports SDG 7, which seeks to provide affordable, reliable, sustainable, and modern energy for everyone.

In this study, the assessment of reducing greenhouse gas emissions and the economic viability of solar roofs is a multifaceted process that must consider various factors, including technological advancements, financial feasibility, environmental benefits, and social impact the assessment of reducing greenhouse gas emissions and the economic viability of solar farms is a multifaceted process that must consider various factors, including technological advancements, financial feasibility, environmental benefits, and social impacts. The CO_2 reduction potential of solar roofs is also well-established, with studies highlighting the environmental benefits of this technology.

Material and Method

Hospitals data

Figure 1. Illustration of a located of this study as XXXX Bangkok, Thailand. The solar energy was installed in four buildings on the rooftop. The solar radiation data are supported by the Thailand Pollution Control Department (PCD).

Fig 1. The location of monitoring stations in Bangkok (QGIS 3.22 Biatowieza) (QGIS Development Team 2023)

Solar Resource at the Selected Locations

In eq.1 can quantifying the environmental impact of electrical energy consumption in terms of greenhouse gas emissions, specifically carbon dioxide equivalents (CO_{2e}). The activity data in kWh represents the total energy consumed and measured in kilowatt-hours (kWh). However, this is a standard unit of measurement for energy usage, and it is usually found on electricity bills. Making it accessible data for both households and businesses.

CO_2 Emission produce ($kgCO_2e$) = Activity data kWh X gk CO_2e ……………………… (eq.1)

To determine the monthly money saved from electricity production, we utilize a straightforward formula (eq.2). The electricity production from sola panel in each month was regularly monitored in the unit of the total kilowatt-hours (kWh) of electricity. The Rate per kWh is the cost of electricity per kWh if we buy from the Metropolitan Electricity Authority (MEA). This study we fixed it at 5 Baht per kWh. This approach allows us to calculate the money saved over the monthly period.

Reduced cost per Month = Energy production per Month × Rate per kwh ………………. (eq.2)

Where the rate per kwh of 5 Baht was used for this study

The calculation of their contributions to CO_2 emission reductions, we follow eq.3. The electricity generation from solar energy has been identified as low carbon dioxide emission. In this study. The coefficients of emission factors were obtained from the Thailand National Communication

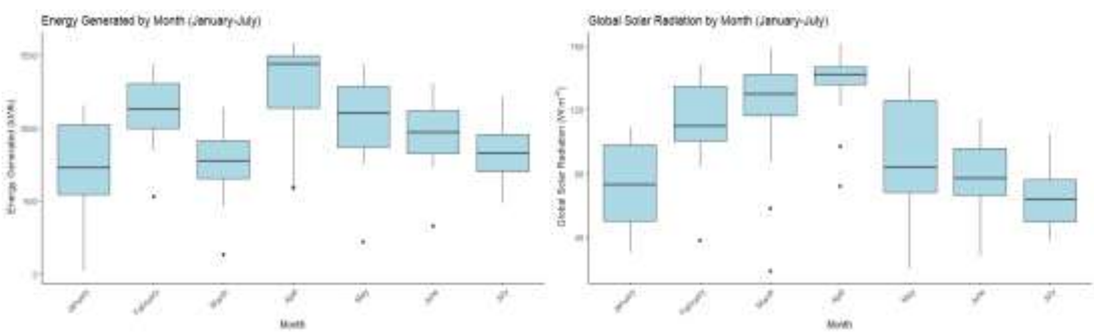
Report (NC). The energy production in each month is typically measured in kilowatt-hours (kWh) that was obtained from the direct measurement as hourly basis. Carbon Dioxide reduction can be calculated.

CO_2 Emission Reduced per Month = Energy use per Month × CO_2 Reduction Factor……… (3)

Results and Discussion

Relationship of Energy generation and Solar Radiation

As can be seen from Figure 2, the Solar Radiation and Energy generation were taken highest on April. The power produced from PV modules is highly affected by solar radiation. As solar radiation has the relationship as 0.53 with Solar radiation, the power produced will also increase, as shown in Figure 3. The level of solar radiation is affected by the position of the sun (Irwan et al. 2016) The environment's temperature, amount of sunshine, and meteorological circumstances all have an impact on the voltage, current, and electrical power that solar cells generate (Masthura and Abdullah 2024).



(a) **(b)**

Fig 2. Boxplot for daily energy generated and (b) solar radiation.

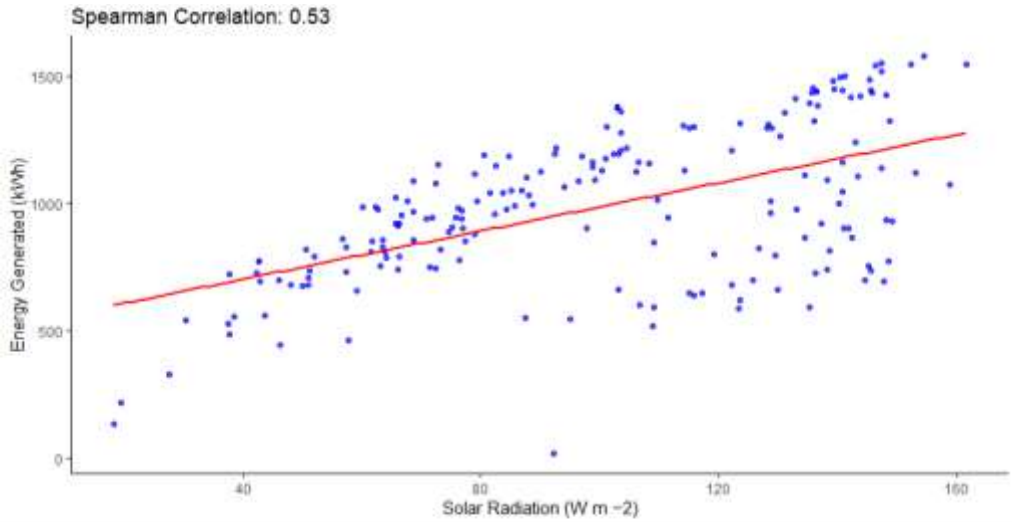


Fig 3. Relationship between Solar Radiation and Energy generation from Solar roof.

The History of Electricity Consumption

The electricity consumptions during 2022 to 2023 are obtained from the MEA bills. There is a noticeable increase in total electricity consumption (about 5.64%). The consumption in 2024 (up to July) is slightly lower compared to 2023 but higher than in 2022 for the same months. The monthly variations were related to the hospital activities such as the number of customers and research activities since some floors of this building have been used for laboratories and research supporting the XXX missions. The highest monthly consumption for 2022 was in March (306,180 kWh), and the lowest was in February (262,440 kWh). In 2023, the maximum consumption (326,579 kWh) was seen in March, with the lowest in February (273,203 kWh). In 2024, the pattern of consumption is similar to the previous years, the maximum consumption was detected in March (302,990 kWh), and minimum consumption was found in February (272,970 kWh), based on the data available up to July.

The electricity consumption in the first seven months of 2024 has generally been lower compared to the same period in 2023 but is like or slightly higher than in 2022. However, we found the maximum consumption in March for three years patterns. There is an overall upward trend in electricity consumption from 2022 to 2023, indicating a potential increase in hospital activities or others such as research activities. The results of electricity consumption during 2022-2024 are presented in Table 1. Concerning the carbon dioxide emissions, they were illustrated in Figure 4.

Table 1 The energy of electricity uses from hospital building

Month	**Electrical energy unit (kWh.)**		
	2022	**2023**	**2024**
January	281,989	281,070	290,790
February	262,440	273,203	272,970

March	306,180	326,579	302,990
April	290,790	321,158	289,598
May	304,560	339,884	300,289
June	302,130	319,041	300,289
July	303,750	319,588	290,599
August	314,280	321,410	-
September	300,510	304,414	-
October	285,930	310,722	-
November	289,170	309,234	-
December	291,600	306,281	-
Total	3,533,329	3,732,584	2,047,525
Average	294,444	311,049	292,504

Fig 4. The CO_2 Emission from electric consumption for hospital building during 2022-2024

The data presented in Table 2 was estimated for energy production from solar panels and CO_2 reductions over a series of months. The last column presents the money saved each month from this production. The monthly breakdown of energy production (kWh) had total energy generated by the solar panels each month, the value ranged from a low of 9,785.90 kWh in January to a high of 37,717.10 kWh in April. The main influencing factors of energy production are related to the temperature, moisture contents and sun radiation, the surface dirty of solar panel might be another factor that might reduce the efficiency of production. However, this solar panel is new and just operated, the longer usage without cleaning might reduce efficiency. The money saved was estimated from energy production by the solar panel system. The money saved peaks at 188,585.50 Baht (5,388 US$) in April. Moreover, CO_2 reduction represented the estimated CO_2 emissions reduced by using a coefficient of 0.5101 tCO_2/MWh (ONEP 2023) The reductions range from 4,991.79 kg in January to 19,239.49 kg in April.

The cumulative energy generated over the six months is 187,778.70 kWh and total saved cost amounts to 938,893.50 Baht with the total CO_2 emissions reduction of 87,917.99 kg.

Table 2. Estimation of Carbon dioxide reduction and the saved cost of electricity by using the solar roof panel

Month	**Energy (kWh)**	**CO_2 reduced. (EF=0.5101) (kg)**	**Cost saved (Baht)**	**US dollar (1 US$=35 Baht)**
1: January	9,785.90	4,991.79	48,929.50	1,397.99

2: February	32,171.80	16,410.84	160,859.00	4,595.97
3: March	24,048.60	12,267.19	120,243.00	3,435.51
4: April	37,717.10	19,239.49	188,585.50	5,388.16
5: May	32,943.00	16,804.22	164,715.00	4,706.14
6: June	25,127.50	12,817.54	125,637.50	3,589.64
7: July	25,984.80	13,254.85	129,924.00	3,712.11
Total	187,778.70	95,785.91	938,893.50	26,825.53
Average	26,825.53	13,683.70	134,127.64	3,832.22

Conclusion

The significant factor influencing the reduction of carbon emissions in the Tropical Medicine hospital is the implementation of thorough inspections. Higher education institutions can help lower carbon emissions by conducting these inspections. Furthermore, this approach will further aid in minimizing carbon emissions. However, the installation of solar roofs offers a strong argument for both cost effectiveness and CO_2 reduction. CO_2 emissions at Tropical Medicine hospital have decreased from 6,815.61 kg CO_2 to 4,441.20 kg CO_2 compared to the previous year. This reduction may be attributed to changes in the duration of appliance usage and the number of appliances utilized. Additionally, the hospital has adopted low carbon technology, including the installation of solar panels on the sides and rooftop of the building. The installation and operating the rooftop solar panel is challenging for the urban area, since we can use the benefits of roof. However, the study of building strength is a key factor for installation and must be incorporated prior to the installation. The electricity generation by this approach is the alternative energy source that is identified as environmentally friendly concept.

Conflict of interest

The authors declare they have no competing interests.

Data availability

Data used and analyzed in the manuscript will be made available upon request to the corresponding author.

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