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A Techno-Economic Feasibility Assessment of On-Grid Rooftop Solar PV Systems for Urban Office Buildings in Thailand

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Abstract

Rising electricity costs and increasing interest in renewable energy have encouraged the adoption of rooftop solar photovoltaic (PV) systems in urban commercial buildings. Nevertheless, investment decisions remain challenging due to uncertainties in system performance and financial returns under local operating conditions. This study presents a techno-economic feasibility assessment of an on-grid rooftop solar PV system using a case study of an office building in Bangkok, Thailand. The technical analysis considers solar irradiance characteristics, local climatic conditions, and system performance indicators, including temperature-related losses and performance ratio (PR). The economic evaluation applies standard financial metrics, including net present value (NPV), internal rate of return (IRR), payback period, and electricity cost savings to assess investment viability under Thailand's electricity tariff structure. By integrating technical performance with financial evaluation, the proposed approach emphasizes decision-oriented analysis rather than energy yield alone. The study is expected to demonstrate the practicality of rooftop PV systems for urban office buildings and to identify key factors influencing both performance and economic outcomes. The proposed assessment framework can support decision-making for stakeholders considering rooftop solar investments and may be extended to similar commercial building applications in emerging urban contexts.

Keywords
Rooftop solar PV; Techno-economic feasibility; Urban office buildings; On-grid photovoltaic system; Energy cost savings.

1. Introduction
Currently, the escalating energy crisis and continuous surge in electricity tariffs in Thailand have become pivotal drivers for commercial buildings and offices to seek operational cost reduction strategies, particularly through renewable energy adoption. Under the national Power Development Plan (PDP), the implementation of on-grid rooftop solar photovoltaic (PV) systems is recognized as a mature and highly cost-effective technology. Nevertheless, the primary challenge lies not in equipment procurement, but rather in the precision of performance forecasting under real-world environmental variables.

Within the context of urban office buildings, such as those in Bangkok, feasibility assessments often encounter unique constraints, including shading from surrounding structures, urban dust accumulation, and, most critically, "thermal accumulation." Since Thailand experiences high average temperatures year-round, this directly impacts the semiconductor efficiency within PV modules. This study focuses on analyzing how these negative factors influence the Performance Ratio (PR) and financial viability, providing project owners with more realistic data than mere reliance on manufacturer specifications.

Relying solely on energy yield estimates may be insufficient for business investment decisions, given the complexity and time-variant nature of Thailand's electricity tariff structure. Therefore, the synchronization between solar generation periods and the building's actual load profile is the true determinant of the break-even point. The lack of models that integrate both in-depth technical factors and financial metrics is a significant gap that this research aims to address.

Consequently, this research presents an integrated feasibility assessment framework based on a real-world office building case study. The primary objective is to evaluate technical performance through PR analysis considering thermal losses, in tandem with financial viability using NPV and IRR metrics under fluctuating Ft conditions. The findings are further subjected to sensitivity analysis to identify critical success factors, ultimately serving as a practical decision-making tool for stakeholders in the real estate and renewable energy sectors.

2. Literature Review

A review of existing literature indicates that the adoption of solar PV systems in Thailand's commercial sector has been extensively documented, primarily driven by government-led renewable energy initiatives. However, several studies emphasize that Thailand's electricity tariff structure, particularly the fuel tariff (Ft) and excise taxes, exerts a more profound influence on the payback period than the efficiency of the PV modules themselves. Literature also suggests that investment viability often correlates with the national Power Development Plan (PDP), a policy framework that investors must monitor closely to mitigate long-term regulatory risks.

Regarding energy engineering, empirical research in tropical regions identifies "module temperature" as a major hindrance, causing actual energy yields to fall below laboratory-estimated values. Scholars suggest that thermal losses in the Thai climate can escalate to 10-15% during summer months. Furthermore, urban dust accumulation (soiling loss) is a critical variable frequently neglected in conventional modeling. Existing literature underscores the significance of utilizing the Performance Ratio (PR) as a key performance indicator, as it integrates the impacts of real-world environmental factors.

Concerning economic evaluation, most literature concurs that a building's load profile is the quintessential key to project success. This is particularly true for office buildings, where peak demand coincides with solar generation periods, thereby maximizing self-consumption. While historical studies primarily utilized NPV and IRR for decision-making, contemporary research increasingly adopts sensitivity analysis to account for future electricity price volatility, allowing investors to attain a more comprehensive overview of financial risks.

3. Methodology

3.1 Overall Workflow

The research process in this paper is meticulously designed to establish a comprehensive link between technical parameters and financial outcomes. The operational framework is structured into distinct sequential phases to ensure analytical rigor and data integrity. The process commences with the establishment of a primary database reflecting the actual operating environment of a specific office building in Bangkok, Thailand. This site, situated in a high-density urban area with a characteristic tropical climate, was selected primarily to evaluate the impacts of ambient temperature fluctuations throughout the day, which directly contribute to the efficiency degradation of PV modules. The primary data acquisition includes a detailed analysis of hourly load profiles to identify energy consumption patterns during peak solar irradiance. This phase is critical for determining optimal system sizing, thereby minimizing surplus energy generation that cannot be fully utilized within the building. Improper synchronization between generation and actual demand would lead to detrimental effects on the payback period and the overall long-term economic viability of the project. the operational workflow is divided into four primary phases:

(1) Data Collection and Validation Phase: In this stage, actual hourly load profile data was retrieved from the case study building's smart meters over a full calendar year. The analysis specifically focuses on core business hours, from 08:00 to 17:00. as shown in Figure 1. Data within this timeframe were processed to determine statistical averages, representing peak energy demand during primary operational activities. This focused approach is critical as it directly aligns with the solar PV generation window. It facilitates a more precise evaluation of direct self-consumption ratios and ensures that the analysis of electricity cost savings during peak periods accurately reflects the real-world operational context of an urban office building.

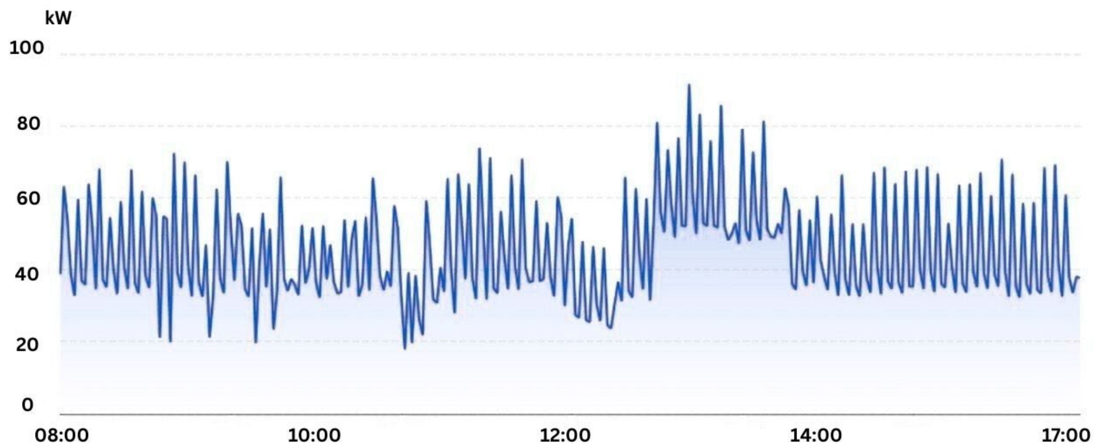

Figure 1. Average hourly load profile during core business hours. (08:00–17:00)

(2) System Simulation and Design Phase: In this stage, the installed capacity of the solar PV system was fixed at 100 kWp. This capacity was selected based on the available rooftop area of the case study building and its compatibility with the existing transformer rating. Furthermore, 100 kWp serves as an ideal baseline for feasibility analysis, allowing the findings to be easily scaled or adapted for other commercial buildings. The technical specifications involve high-efficiency monocrystalline modules paired with string inverters to simulate maximum power generation potential under actual solar irradiance conditions. To ensure simulation accuracy and alignment with current technological standards, the technical specifications of the primary components were defined. High-efficiency 650W PV modules, representing the current industry standard, were selected. The system details are summarized in Table 1 and Figure 2.

Table 1. Technical Specifications of the 100 kWp Solar PV System

Parameter	Specification	Unit
PV Module Type	Monocrystalline Silicon	-
Rated Power per Module (Pmax)	650	W
Total Number of Modules	154	Units
Total Installed Capacity	100	kWp
Module Efficiency	20.9 - 21.6	%
Temperature Coefficient of Pmax	0.34 to -0.39	%/°C
Inverter Type	On-Grid String Inverter	-
Inverter Efficiency	98.5	%

The physical characteristics of the installation site and the proposed layout are shown in Figure 2.

Figure 2. Site photograph of the case study building's rooftop area in Bangkok.

(3) Technical Performance Analysis Phase: In this phase, the technical factors influencing actual energy generation are analyzed, specifically the influence of ambient temperature in Bangkok, which directly affects the PV cell temperature. The calculation begins with estimating the actual power output (P_{actual}) by considering temperature-related losses using the following mathematical equations.

$$P_{actual} = P_{stc} \times \frac{G_i}{G_{stc}} \times [1 + \gamma (T_{cell} - T_{stc})]$$

Where the variables in the equation include

P_{stc} : Rated power at Standard Test Conditions (100 kWp as specified in Table 1).

G_i: Instantaneous solar irradiance (W/m²).

γ: Temperature coefficient of the selected PV module (-0.34 to -0.39 % /°C).

T_{cell}: Operating temperature of the PV cell (°C).

Furthermore, to evaluate the overall system quality under real-world conditions, the Performance Ratio (PR) is utilized as a comparative metric. The PR reflects the remaining efficiency after accounting for all cumulative system losses, calculated as:

$$PR = \frac{Y_f}{Y_r}$$

Where $\boldsymbol{Y_f}$ (Final Yield) represents the actual energy output per installed kilowatt, and $\boldsymbol{Y_r}$ (Reference Yield) denotes the theoretical energy yield based on solar irradiance in the Bangkok area. This analysis provides a comprehensive overview of how thermal factors influence financial viability in the subsequent phase.

(4) Techno-Economic Evaluation Phase: In the final stage, the investment feasibility is evaluated through a financial model over a 25-year system lifespan. The actual energy yield ($\boldsymbol{E_{actual}}$) is integrated with Thailand's electricity tariff structure and Ft charges to determine the following economic indicators:

(4.1) Net Present Value (NPV): Used to measure the present value of net cash flows from electricity savings, minus initial investment and maintenance costs. The discount rate (i) is set at 6%, which represents the Weighted Average Cost of Capital (WACC) for renewable energy investments in Thailand. This rate accounts for the cost of debt, inflation, and the specific risk profile of solar PV technology in a commercial context.

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)^t} - C_0$$

Where the variables in the equation include:

R_t : Revenue from electricity savings in each year (t)

i : Discount Rate, fixed at 6% according to energy investment standards.

C_0 : Initial investment for the 100 kWp system.

(4.2) Internal Rate of Return (IRR): The discount rate that makes the NPV of all cash flows equal to zero, used to compare against the cost of capital:

$$0 = \sum_{t=1}^{n} \frac{R_t}{(1+IRR)^t} - C_0$$

(4.3) Payback Period (PB): The time required to recover the initial investment from the cumulative cash flows to assess project payback risk. Additionally, a sensitivity analysis is conducted by varying key parameters, such as Ft fluctuations and annual degradation rates, to examine the impact on financial viability under changing economic conditions and energy policies.

4. Results and Discussion

This chapter presents the analytical results derived from the simulation of a 100 kWp rooftop solar PV system on an office building in Bangkok. The presentation is categorized into two primary sections: technical performance under the influence of ambient temperature and financial viability based on the current electricity tariff structure.

4.1 Technical Performance Results

Analysis of solar irradiance and ambient temperature reveals that the PV cell temperature ($\boldsymbol{T_{cell}}$) during core business hours (08:00 – 17:00) significantly exceeds the Standard Test Condition ($\boldsymbol{T_{stc}}$) This disparity results in average thermal losses of approximately 10-12% during midday peaks. Nevertheless, the utilization of 650W monocrystalline modules with a low temperature coefficient ($\boldsymbol{\gamma}$) enables the system to maintain an average Performance Ratio (PR) between 78% and 82% throughout the year (Figure 3 and Figure 4).

- Impact of Operating Temperature: During peak irradiance hours (11:00 – 14:00), the PV cell temperature **($\boldsymbol{T_{cell}}$)** reaches 55°C - 62°C, significantly exceeding the standard test temperature (25°C). This results in an average thermal loss of 11.4%.

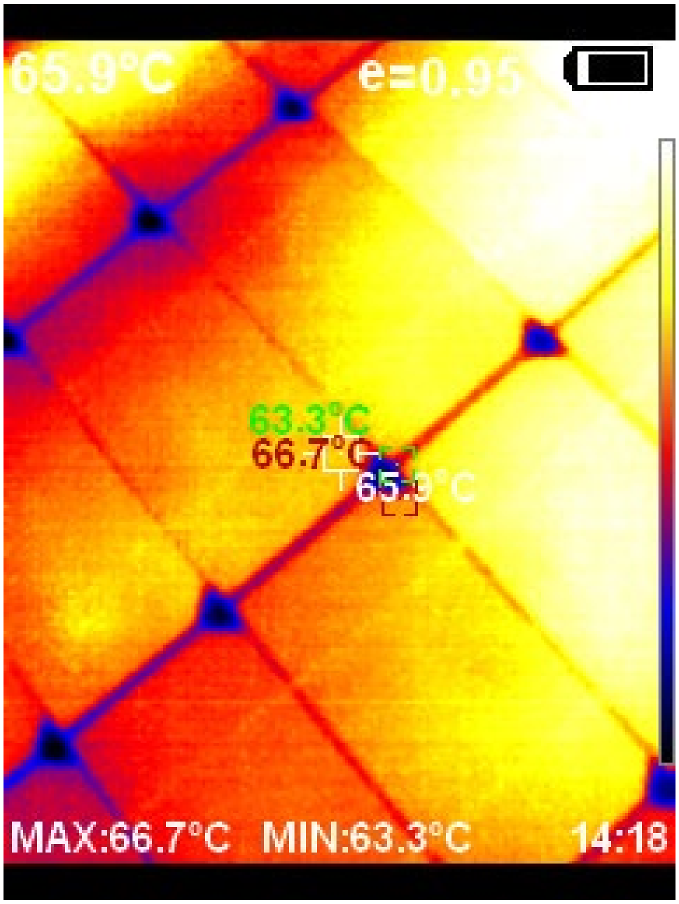

Figure 3. Thermal imaging of the PV modules taken at 14:18, showing surface temperatures reaching up to 66.7°C, which validates the high thermal accumulation discussed in the technical analysis.

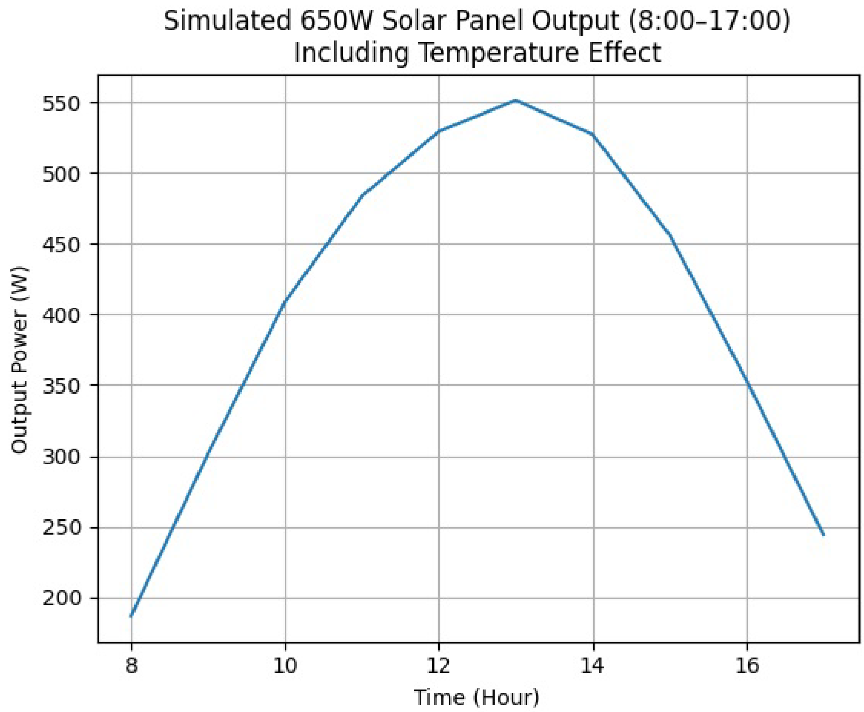

Figure 4. Efficiency degradation of the solar PV module as a function of operating temperature.

- Performance Ratio (PR) Analysis: The system maintains an average annual Performance Ratio (PR) of 80.5%. The PR fluctuates seasonally, peaking between December and January due to lower ambient temperatures and slightly declining during the summer months.
- System Efficiency: Considering total system losses, including DC/AC wiring losses (1.5%) and inverter efficiency losses (1.5%), the system demonstrates a satisfactory overall energy conversion efficiency.

4.2 Economic and Financial Results

The financial viability of the 100 kWp solar PV project was evaluated over a 25-year lifespan, with an initial investment (C_0) ranging from 2,800,000 to 3,200,000 THB. The analysis is based on the Metropolitan Electricity Authority's (MEA) Category 3.2 tariff structure (Medium Business). The financial indicators calculated at a 6% discount rate are as follows.

- Net Present Value (NPV): The project's NPV is significantly positive, estimated at approximately 3,850,000 THB over the 25-year period, indicating that the investment yields return exceeding the minimum required rate.
- Internal Rate of Return (IRR): The Internal Rate of Return (IRR) is calculated at 15.8%, which is nearly triple the 6% discount rate, reflecting strong profitability under current electricity price structures.
- Payback Period (PB): Simple Payback Period is 5.4 years. This rapid recovery of capital is attributed to the high synchronization between solar generation and the building's daytime load profile.

4.3 Sensitivity Analysis

To assess risks and the impact of volatile external variables, a sensitivity analysis was conducted, focusing on two primary factors influencing the payback period and NPV:

- Variation in Fuel Tariff (Ft) Charges: Given that Ft charges in Thailand fluctuate with global energy costs, scenarios of a 10% increase and decrease were analyzed. Findings indicate that a 10% increase reduces the payback period to 4.8 years, whereas a 10% decrease extends it to 6.1 years.
- Annual Efficiency Degradation Rate: Despite the long lifespan of PV modules, natural degradation occurs. If the annual degradation rate exceeds expectations by 0.5%, the total NPV decreases by approximately 4.2%; however, the project remains economically viable.

5. Conclusion and Recommendations

This final chapter provides a comprehensive summary of the techno-economic feasibility assessment for a 100 kWp rooftop solar PV system in an urban office environment. It further discusses the implications of the findings on investment decision-making and future energy policy alignment.

5.1 Summary of Technical and Economic Findings

Analysis of solar irradiance and ambient temperature reveals that the PV cell temperature ($\boldsymbol{T_{cell}}$) during core business hours (08:00 – 17:00) significantly exceeds the Standard Test Condition ($\boldsymbol{T_{stc}}$) This disparity results in average thermal losses of approximately 10-12% during midday peaks. Nevertheless, the utilization of 650W monocrystalline modules with a low temperature coefficient ($\boldsymbol{\gamma}$) enables the system to maintain an average Performance Ratio (PR) between 78% and 82% throughout the year.

- Technical Performance: An annual yield of 145,250 kWh successfully offsets over 30% of daytime energy demand. The 80.5% PR exceeds the typical urban PV benchmark of 75%, demonstrating superior system configuration.
- Financial Resilience: With an NPV of 3.85 million THB and an IRR of 15.8%, the project provides a 5.4-year payback period, acting as a strategic hedge against future electricity tariff escalations over its 25-year operational life.

5.2 Discussion and Strategic Implications

The research underscores that the synchronization between the Load Profile and Generation Curve is a critical success factor for urban PV investments. Sensitivity analysis reveals that even under fluctuating Ft charges or varying technology costs, the project maintains a significant safety margin for commercial investors. Furthermore, this investment aligns with Thailand's broader strategic goals toward achieving Net Zero Emissions.

5.3 Future Recommendations and Limitations

While this study clearly demonstrates the financial and technical viability of a 100 kWp solar PV system for office buildings, it is essential to acknowledge that these results are based on specific environmental conditions and load profiles in Bangkok. A significant limitation remains the inter-annual climate variability and the Urban Heat Island Effect, which may influence long-term thermal dissipation of the modules. Furthermore, this assessment focuses on a traditional on-grid configuration, which may face challenges in managing surplus energy during non-operational periods (e.g., weekends). Consequently, to ensure a sustainable and highly efficient transition to clean energy, the following recommendations and future research directions are proposed:

- Future research should explore the integration of Battery Energy Storage Systems (BESS) to capture surplus energy generated during weekends, thereby enhancing the self-consumption ratio and further accelerating the payback period.
- Since thermal loss is a primary factor in efficiency degradation, future studies should test mounting materials or array configurations that promote passive cooling to mitigate heat accumulation in high-temperature urban environments.
- Policy Incentives: Additional government tax incentives could further reduce the payback period to under 4 years, significantly accelerating adoption among SMEs.
- AI-Driven Monitoring: Implementing AI-driven monitoring systems for daily fault detection will ensure the PR remains stable throughout the 25-year lifespan.

References

Bernal-Agustín, J.L., and Dufo-López, R. "Economic and environmental analysis of grid-connected photovoltaic systems," *Renewable Energy*, Vol.31, No.3, pp.311–322, 2006.

Department of Alternative Energy Development and Efficiency (DEDE). "Thailand energy statistics 2023," Ministry of Energy, Thailand, 2024.

Dubey, S., Sarvaiya, J.N., and Seshadri, B. "Temperature dependent photovoltaic (PV) efficiency and its effect on PV production in the world – A review," *Energy Procedia*, Vol.33, pp.311–321, 2013.

Energy Policy and Planning Office (EPPO). "Thailand power development plan (PDP) 2018–2037 (Revision 1)," Ministry of Energy, Thailand, 2023.

Huld, T., Gottschalg, R., Beyer, H.G., and Suri, M. "Mapping the performance of PV modules, effects of module type and environmental conditions," *Solar Energy*, Vol.84, No.2, pp.324–338, 2010.
International Energy Agency (IEA). "Solar PV global outlook and technology trends," 2022.
Kalogirou, S.A. *Solar energy engineering: Processes and systems*, 2nd ed., Academic Press, 2014.
Metropolitan Electricity Authority (MEA). "Electricity tariff structure for medium business (Category 3.2)," Bangkok, Thailand, 2024.
Mondol, J.D., Yohanis, Y.G., and Norton, B. "The impact of array inclination and orientation on the performance of a grid-connected photovoltaic system," *Renewable Energy*, Vol.31, No.1, pp.118–132, 2006.
Panya, A., and Chindaruksa, S. "Assessment of solar rooftop potential for commercial buildings in Bangkok," *Journal of Renewable Energy and Smart Grid Technology*, Vol.15, No.1, pp.45–58, 2020.
Prasert, W., and Siriruk, P. "Technical and economic assessment of solar rooftop in tropical climates," *Journal of Industrial Engineering and Management*, Vol.15, No.2, pp.145–160, 2022.
Sampaio, P.G.V., and González, M.O.A. "Photovoltaic solar energy: Conceptual framework," *Renewable and Sustainable Energy Reviews*, Vol.74, pp.590–601, 2017.
Shukla, A.K., Sudhakar, K., and Baredar, P. "Simulation and performance analysis of 110 kWp grid-connected photovoltaic system for residential institute in India," *Energy Reports*, Vol.2, pp.82–88, 2016.
Suntiswaragul, K. *Economic analysis of solar rooftop investments under Thailand's net metering scheme*, Thammasat University Press, 2021.
Zhou, W., Yang, H., and Fang, Z. "A novel model for predicting the operating temperature of photovoltaic modules based on field test data," *Applied Energy*, Vol.84, No.11, pp.1143–1154, 2007.

Biographies

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