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Solar Photovoltaic Potential and Environmental Performance in Tropical Urban Thailand: A Secondary-Data Assessment of Pak Kret, Nonthaburi

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ABSTRACT

Solar photovoltaic (PV) systems are increasingly important for sustainable energy development in tropical countries, where high solar availability is accompanied by environmental conditions that may influence system performance. This study assessed solar PV potential and key environmental constraints in Pak Kret, Nonthaburi, Thailand, using publicly available secondary data and a narrative synthesis of relevant scientific literature. Annual solar-resource indicators obtained from the Global Solar Atlas were evaluated together with environmental factors including solar irradiance, temperature, relative humidity, dust and soiling, wind, shading, and panel tilt. The study area showed a Global Horizontal Irradiation (GHI) of 1,800.6 kWh/m²/year and a Global Tilted Irradiation (GTI) of 1,851.1 kWh/m²/year. Estimated photovoltaic power output (PVO_{UT}) was 1,452.6 kWh/kWp/year, corresponding to approximately 3.98 kWh/kWp/day and an approximate capacity factor of 16.6%. The optimal annual panel tilt was 15°, at which GTI was approximately 2.8% higher than horizontal irradiation. Evidence from the literature indicates that high module temperature, humidity, dust accumulation, and shading may reduce PV performance, whereas wind can improve thermal dissipation. Overall, Pak Kret has favorable potential for rooftop PV deployment; however, system design should account for local thermal and environmental constraints. Because the analysis is based on modeled secondary data rather than field measurements, the findings should be interpreted as a preliminary location-specific assessment and validated through future on-site monitoring.

INTRODUCTION

Solar photovoltaic (PV) systems are widely used as a clean and scalable alternative to fossil-fuel-based electricity generation. Their energy yield depends primarily on incident solar radiation, but module technology, operating temperature, mounting configuration, and local weather also influence actual performance (De Soto *et al.*, 2006; Huld *et al.*, 2010; Huld *et al.*, 2012). Thailand has favorable conditions for solar-energy development because of its tropical location and substantial year-round solar irradiation, as documented in national solar-resource mapping and energy reports (Department of Alternative Energy Development and Efficiency [DEDE], 2017, 2023, 2024a; Silpakorn University & DEDE, 2018).

Environmental effects are especially important under tropical urban conditions. Higher module temperature generally reduces voltage and electrical efficiency, while wind can enhance convective cooling (Faiman, 2008; Köhl *et al.*, 2011; Skoplaki & Palyvos, 2009a, 2009b; Schwingshackl *et al.*, 2013; Dubey *et al.*, 2013). Dust and soiling reduce optical transmission and can cause meaningful energy losses, with the magnitude depending on local deposition, rainfall, cleaning frequency, and installation geometry (Mani & Pillai, 2010; Mekhilef *et al.*, 2012; Adinoyi & Said, 2013; Appels *et al.*, 2013; Sarver *et al.*, 2013; Sayyah *et al.*, 2014). In urban settings, partial shading from buildings and surrounding objects can further decrease PV output and complicate maximum-

power-point operation (Batzelis *et al.*, 2015).

Panel inclination is another important design variable because it changes the solar radiation received by the module surface. Numerous studies have shown that location-specific tilt optimization can increase annual irradiation compared with a horizontal surface (Yakup & Malik, 2001; Kacira *et al.*, 2004; Günerhan & Hepbasli, 2007; Calabrò, 2009; Mehleri *et al.*, 2010; Benghanem, 2011; Jacobson & Jadhav, 2018). Thai work has likewise examined PV configuration and installation performance under local conditions (Yotooratai, 2023; DEDE, 2024b). The present study focuses on Pak Kret, Nonthaburi, and uses secondary solar-resource data to quantify local PV potential while integrating evidence on environmental constraints. The objectives were to: (1) assess annual solar-resource indicators and expected PV yield; (2) quantify the irradiation advantage associated with optimal panel tilt; and (3) identify practical environmental considerations relevant to rooftop PV planning in tropical urban Thailand.

MATERIALS AND METHODS

Study Design

This study used a secondary-data analytical design combined with a narrative synthesis of published evidence. No new field measurements were collected. The analysis was designed as a location-specific preliminary assessment rather than an experimental performance study.

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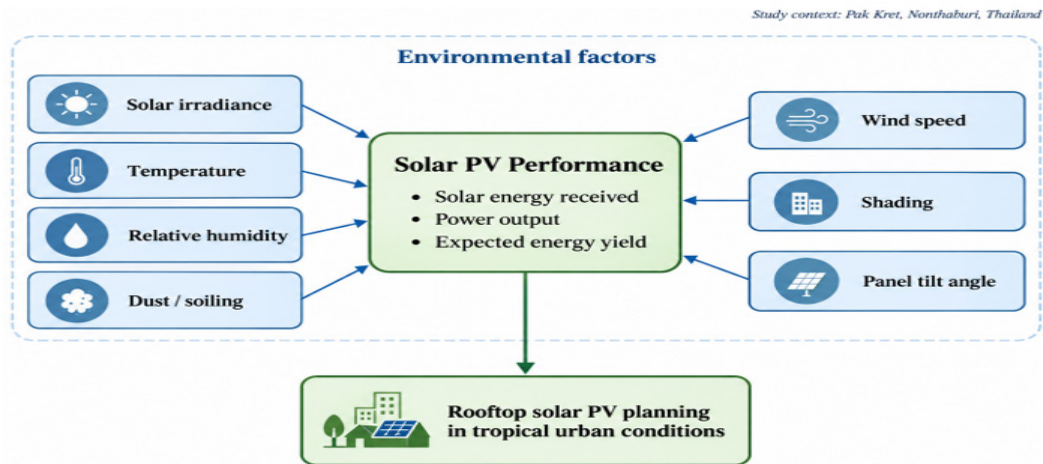


Figure 1: Conceptual framework of environmental factors affecting solar PV performance under tropical urban conditions.

Study Area and Data Sources

The study area was Pak Kret, Nonthaburi, Thailand. Annual solar-resource indicators were obtained from the Global Solar Atlas, a World Bank/ESMAP-supported resource developed with Solargis for solar-resource and photovoltaic assessment (Energy Sector Management Assistance Program [ESMAP], 2019). The variables extracted from the original project dataset were specific PV power output (PVO_{UT}), direct normal irradiation (DNI), global horizontal irradiation (GHI), diffuse horizontal irradiation (DIF), global tilted irradiation (GTI) at optimal tilt, optimal tilt angle, mean ambient temperature, and elevation. National context was

supported by DEDE solar-resource mapping and Thai energy publications (DEDE, 2017, 2023, 2024a; Silpakorn University & DEDE, 2018).

Environmental Variables

The environmental factors considered in the evidence synthesis were solar irradiance, module and ambient temperature, relative humidity, wind speed, dust/soiling, cloud conditions, shading, and panel inclination. These variables were selected because they are repeatedly identified as determinants of PV output in established performance and environmental studies (Skoplaki & Palyvos, 2009a, 2009b; Mekhilef *et al.*, 2012; Batzelis *et al.*, 2015).

Data Analysis

Solar-resource indicators were summarized descriptively. Daily specific yield was calculated as annual PVO_{UT} divided by 365. The relative irradiation gain from optimal tilt was calculated as $[(GTI - GHI)/GHI] \times 100$. An approximate annual capacity factor was calculated as $[PVO_{UT}/8,760] \times 100$. Because the available dataset consisted of annual summary indicators rather than repeated observations, inferential correlation or regression analyses were not performed. Literature findings were used only to interpret plausible environmental influences and were not treated as locally measured effect sizes.

RESULTS AND DISCUSSION

Solar Resource and Photovoltaic Potential

The secondary dataset indicated favorable solar-resource conditions in Pak Kret. Annual GHI was 1,800.6 kWh/m²/year, while GTI at the optimal tilt was 1,851.1 kWh/m²/year. Specific PV power output was 1,452.6 kWh/kWp/year, equivalent to approximately 3.98 kWh/kWp/day. DNI and DIF were 1,189.9 and 933.3 kWh/m²/year, respectively. Mean ambient temperature was 27.8°C and the reported elevation was 8 m.



Figure 2: Solar-energy potential of Thailand with the approximate location of Pak Kret, Nonthaburi. Source map adapted from DEDE solar-resource mapping; Pak Kret locator added by the authors.

Table 1: Solar-resource and photovoltaic indicators for Pak Kret, Nonthaburi

Indicator	Value	Unit
PVOUT	1,452.6	kWh/kWp/year
Daily specific yield	3.98	kWh/kWp/day
DNI	1,189.9	kWh/m ² /year
GHI	1,800.6	kWh/m ² /year
DIF	933.3	kWh/m ² /year
GTI at optimal tilt	1,851.1	kWh/m ² /year
Optimal tilt angle	15	degrees
Mean ambient temperature	27.8	°C
Elevation	8	m
GTI gain over GHI	2.80	%
Approximate capacity factor	16.58	%

Note. GTI gain and capacity factor are derived from the reported annual secondary-data indicators.

Effect of Optimal Panel Tilt

GTI at the optimal 15° inclination exceeded GHI by 50.5 kWh/m²/year. This corresponds to an irradiation increase of approximately 2.8% relative to a horizontal surface. This value represents a modeled irradiation advantage rather than a directly measured increase in electrical energy generation.

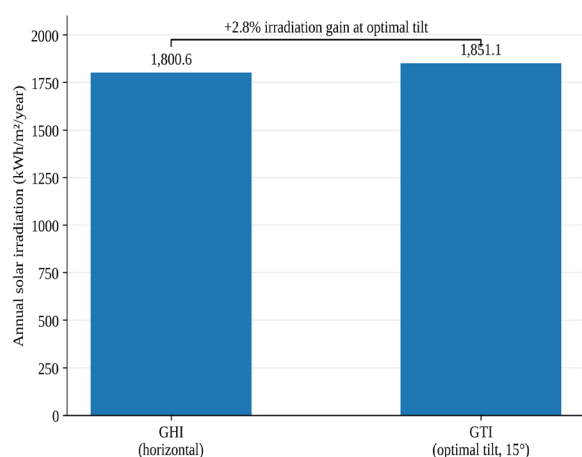


Figure 3: Comparison of annual GHI and GTI in Pak Kret, Nonthaburi. GTI at the optimal 15° tilt is approximately 2.8% higher than horizontal GHI.

Expected PV Energy Yield and Environmental Context

The reported PVOUT corresponds to an approximate annual capacity factor of 16.6%. The mean ambient temperature of 27.8°C is above the 25°C cell temperature used in standard test conditions, and actual daytime module temperatures can be substantially higher than ambient temperature. The literature therefore suggests that thermal management, shading control, and soiling maintenance are relevant considerations when translating modeled solar potential into real rooftop-system performance (Faiman, 2008; Skoplaki & Palyvos, 2009a, 2009b; Mani & Pillai, 2010; Mekhilef *et al.*, 2012; Batzelis *et al.*, 2015).

Discussion

The analysis indicates that Pak Kret has favorable conditions for rooftop PV deployment. The annual GHI and estimated PVOUT are consistent with the broader solar-resource potential documented for Thailand and with satellite-based approaches used internationally to estimate PV performance (DEDE, 2017, 2023; ESMAP, 2019; Huld *et al.*, 2010, 2012). These results support the use of secondary solar-resource databases for preliminary site screening when direct monitoring data are not yet available.

The 15° optimal tilt produced a modeled irradiation gain of approximately 2.8% relative to a horizontal surface. Although modest, such a gain can accumulate over the operating life of a PV system and can be achieved through installation design rather than increased nominal capacity. The result is directionally consistent with prior studies showing that optimum tilt depends on latitude, season, and local irradiance distribution (Yakup & Malik, 2001; Kacira *et al.*, 2004; Günerhan & Hepbasli, 2007; Calabrò, 2009; Mehleri *et al.*, 2010; Benghanem, 2011; Jacobson & Jadhav, 2018).

High solar availability does not eliminate environmental losses. Elevated module temperature can reduce voltage and power, while wind can partially offset thermal effects through convective cooling (Faiman, 2008; Köhl *et al.*, 2011; Dubey *et al.*, 2013; Schwingshackl *et al.*, 2013). Similarly, accumulated dust and surface contamination can reduce optical transmission and energy yield, particularly where cleaning intervals are long or deposition is substantial (Mani & Pillai, 2010; Adinoyi & Said, 2013; Appels *et al.*, 2013; Sarver *et al.*, 2013; Sayyah *et al.*, 2014). Humidity may interact with soiling and atmospheric transmission, while urban shading can produce non-uniform irradiance and nonlinear electrical losses (Mekhilef *et al.*, 2012; Batzelis *et al.*, 2015).

For practical planning in Pak Kret, solar-resource potential should therefore be interpreted together with roof orientation, shading, ventilation, maintenance access, and local installation constraints. Thai technical guidance and

local PV studies provide useful complementary context for system design, but direct field validation remains necessary before site-specific financial or engineering decisions are made (DEDE, 2024b; Yotooratai, 2023).

CONCLUSION

This study assessed the solar photovoltaic potential of Pak Kret, Nonthaburi, Thailand, using secondary solar-resource data and supporting literature. The area showed favorable conditions for rooftop PV development, with a Global Horizontal Irradiation (GHI) of 1,800.6 kWh/m²/year, Global Tilted Irradiation (GTI) of 1,851.1 kWh/m²/year, and estimated PV output of 1,452.6 kWh/kWp/year, equivalent to approximately 3.98 kWh/kWp/day. An optimal panel tilt of about 15° increased annual solar irradiation by approximately 2.8% compared with a horizontal surface.

Environmental factors, particularly temperature, dust and soiling, humidity, wind, and shading, should also be considered because they may influence actual system performance. Appropriate panel inclination, ventilation, shading control, and regular maintenance can support more efficient rooftop PV operation under tropical urban conditions.

Overall, Pak Kret has good potential for rooftop solar PV deployment. However, the findings are based on secondary data and should be confirmed through future field measurements of irradiance, module temperature, and actual electricity generation.

Limitations

The analysis relied on annual secondary-data indicators rather than direct field measurements. Annual averages do not capture short-term or seasonal variability in cloud cover, rainfall, temperature, humidity, wind, soiling, or shading. The 2.8% tilt advantage was derived from modeled GHI and GTI and should not be interpreted as an experimentally measured energy-yield improvement. In addition, module technology, inverter efficiency, roof geometry, electrical losses, maintenance practices, and local obstruction patterns were not directly evaluated. Future studies should compare modeled values with time-resolved measurements of irradiance, module temperature, and actual AC energy generation.

Data Availability

The study uses publicly available secondary solar-resource information from the Global Solar Atlas and Thai government energy-resource publications. No new participant-level or proprietary dataset was generated.

Ethics Statement

Not applicable. The study involved no human participants, animals, or identifiable personal data.

REFERENCES

Adinoyi, M. J., & Said, S. A. M. (2013). Effect of dust accumulation on the power outputs of solar

- photovoltaic modules. *Renewable Energy*, 60, 633-636. <https://doi.org/10.1016/j.renene.2013.06.014>
- Appels, R., Lefevre, B., Herteleer, B., Goverde, H., Beerten, A., Paesen, R., De Medts, K., Driesen, J., & Poortmans, J. (2013). Effect of soiling on photovoltaic modules. *Solar Energy*, 96, 283-291. <https://doi.org/10.1016/j.solener.2013.07.017>
- Batzelis, E. I., Georgilakis, P. S., & Papathanassiou, S. A. (2015). Energy models for photovoltaic systems under partial shading conditions: A comprehensive review. *IET Renewable Power Generation*, 9(4), 340-349. <https://doi.org/10.1049/iet-rpg.2014.0207>
- Benghanem, M. (2011). Optimization of tilt angle for solar panel: Case study for Madinah, Saudi Arabia. *Applied Energy*, 88(4), 1427-1433. <https://doi.org/10.1016/j.apenergy.2010.10.001>
- Calabrò, E. (2009). Determining optimum tilt angles of photovoltaic panels at typical north-tropical latitudes. *Journal of Renewable and Sustainable Energy*, 1(3), 033104. <https://doi.org/10.1063/1.3148272>
- De Soto, W., Klein, S. A., & Beckman, W. A. (2006). Improvement and validation of a model for photovoltaic array performance. *Solar Energy*, 80(1), 78-88. <https://doi.org/10.1016/j.solener.2005.06.010>
- Department of Alternative Energy Development and Efficiency. (2017). *Project for improving Thailand's solar energy potential map using satellite imagery* [Thai-language report]. Ministry of Energy, Thailand. https://data.go.th/dataset/item_087dadb0-4ad2-4acf-890f-fbc6c2d2e730
- Department of Alternative Energy Development and Efficiency. (2023). *Solar energy potential map of Thailand from satellite data (2020)*. Ministry of Energy, Thailand. <https://gis.dede.go.th/gallery-map-view.aspx?p=93>
- Department of Alternative Energy Development and Efficiency. (2024a). *Thailand energy statistics 2023* [Thai-language report]. Ministry of Energy, Thailand.
- Department of Alternative Energy Development and Efficiency. (2024b). *Solar electricity generation: Technology transfer and dissemination of solar-energy utilization* [Thai-language technical guide]. Ministry of Energy, Thailand.
- Dubey, S., Sarvaiya, J. N., & Seshadri, B. (2013). Temperature dependent photovoltaic (PV) efficiency and its effect on PV production in the world-A review. *Energy Procedia*, 33, 311-321. <https://doi.org/10.1016/j.egypro.2013.05.072>
- Energy Sector Management Assistance Program. (2019). *Global Solar Atlas 2.0 technical report*. World Bank. <https://documents1.worldbank.org/curated/en/529431592893043403/pdf/Global-Solar-Atlas-2-0-Technical-Report.pdf>
- Ekvitayavetchanukul, P., & Ekvitayavetchanukul, P. (2025). Artificial intelligence-driven design thinking: Enhancing learning efficiency in pre-medical education. *Educación XXI*, 28(1), 728-747. <https://doi.org/10.5944/vol28n1a51>
- Faiman, D. (2008). Assessing the outdoor operating

- temperature of photovoltaic modules. *Progress in Photovoltaics: Research and Applications*, 16(4), 307-315. <https://doi.org/10.1002/pip.813>
- Günerhan, H., & Hepbasli, A. (2007). Determination of the optimum tilt angle of solar collectors for building applications. *Building and Environment*, 42(2), 779-783. <https://doi.org/10.1016/j.buildenv.2005.09.012>
- Huld, T., Gottschalg, R., Beyer, H. G., & Topić, M. (2010). Mapping the performance of PV modules, effects of module type and data averaging. *Solar Energy*, 84(2), 324-338. <https://doi.org/10.1016/j.solener.2009.12.002>
- Huld, T., Müller, R., & Gambardella, A. (2012). A new solar radiation database for estimating PV performance in Europe and Africa. *Solar Energy*, 86(6), 1803-1815. <https://doi.org/10.1016/j.solener.2012.03.006>
- Jacobson, M. Z., & Jadhav, V. (2018). World estimates of PV optimal tilt angles and ratios of sunlight incident upon tilted and tracked PV panels relative to horizontal panels. *Solar Energy*, 169, 55-66. <https://doi.org/10.1016/j.solener.2018.04.030>
- Kacira, M., Simsek, M., Babur, Y., & Demirkol, S. (2004). Determining optimum tilt angles and orientations of photovoltaic panels in Sanliurfa, Turkey. *Renewable Energy*, 29(8), 1265-1275. <https://doi.org/10.1016/j.renene.2003.12.014>
- Kiatsoongsong, P., & Ekvitayavetchanukul, P. (2025). Associations Between Daily PM2.5 Exposure and Respiratory Symptoms in Thai Adolescents: Evidence from Nonthaburi Province. *American Journal of Environment and Climate*, 4(3), 59-68. <https://doi.org/10.54536/ajec.v4i3.5093>
- Kitsana Intadet, Phongphon Dupong, Ronnkrit Kumsook, Punnika Anuchartbutara, Pongkit Ekvitayavetchanukul. Effect of Airflow Velocity on Cooling Rate of Heated Water: A Comparative Experimental Study Between 3-Blade and 5-Blade Electric Fans. *European Journal of Applied Science, Engineering and Technology*, 2026, 4(3), pp.86-94. [https://doi.org/10.59324/ejaset.2026.4\(3\).09](https://doi.org/10.59324/ejaset.2026.4(3).09)
- Köhl, M., Heck, M., Wiesmeier, S., & Wirth, J. (2011). Modeling of the nominal operating cell temperature based on outdoor weathering. *Solar Energy Materials and Solar Cells*, 95(7), 1638-1646. <https://doi.org/10.1016/j.solmat.2011.01.020>
- Mani, M., & Pillai, R. (2010). Impact of dust on solar photovoltaic (PV) performance: Research status, challenges and recommendations. *Renewable and Sustainable Energy Reviews*, 14(9), 3124-3131. <https://doi.org/10.1016/j.rser.2010.07.065>
- Mekhilef, S., Saidur, R., & Kamalisarvestani, M. (2012). Effect of dust, humidity and air velocity on efficiency of photovoltaic cells. *Renewable and Sustainable Energy Reviews*, 16(5), 2920-2925. <https://doi.org/10.1016/j.rser.2012.02.012>
- Mehleri, E. D., Zervas, P. L., Sarimveis, H., Palyvos, J. A., & Markatos, N. C. (2010). Determination of the optimal tilt angle and orientation for solar photovoltaic arrays. *Renewable Energy*, 35(11), 2468-2475. <https://doi.org/10.1016/j.renene.2010.03.006>
- Rujopakan, P., Jundaboot, S., & Ekvitayavetchanukul, P. (2024). Impact of Room Colors and Construction Materials on Temperature Distribution in Tropical Climate: An Experimental Study in Nonthaburi, Thailand. *International Journal of Social Science and Human Research*. <https://doi.org/10.47191/ijsshr/v7-i12-38>
- Saraswat, M., Singh, J., Dandotiya, M., Ekvitayavetchanukul, P., Rana, M., & Singh, B. (2026). Deep learning approaches for optimizing renewable energy generation and consumption forecasting in smart grids. In S. Das, M. Paprzycki, A. Ghosh, & M. Bianchini (Eds.), *Advanced computing and intelligent technologies: ICACIT 2024* (Lecture Notes in Networks and Systems, Vol. 1359). Springer. https://doi.org/10.1007/978-981-96-4933-4_21
- Sarver, T., Al-Qaraghuli, A., & Kazmerski, L. L. (2013). A comprehensive review of the impact of dust on the use of solar energy: History, investigations, results, literature, and mitigation approaches. *Renewable and Sustainable Energy Reviews*, 22, 698-733. <https://doi.org/10.1016/j.rser.2012.12.065>
- Sayyah, A., Horenstein, M. N., & Mazumder, M. K. (2014). Energy yield loss caused by dust deposition on photovoltaic panels. *Solar Energy*, 107, 576-604. <https://doi.org/10.1016/j.solener.2014.05.030>
- Schwingshackl, C., Petitta, M., Wagner, J. E., Belluardo, G., Moser, D., Castelli, M., Zebisch, M., & Tetzlaff, A. (2013). Wind effect on PV module temperature: Analysis of different techniques for an accurate estimation. *Energy Procedia*, 40, 77-86. <https://doi.org/10.1016/j.egypro.2013.08.010>
- Silpakorn University, & Department of Alternative Energy Development and Efficiency. (2018). *Improvement of Thailand's solar-energy potential assessment using satellite data* [Final research report, Thai language]. Ministry of Energy, Thailand.
- Singh, B., Ekvitayavetchanuku, P., Shah, B., Sirohi, N., & Pundhir, P. (2024). IoT-based shoe for enhanced mobility and safety of visually impaired individuals. EAI Endorsed Trans. *Internet Things*, 10, 1-19.
- Singh, J., Thakur, H. K., Dandotiya, M., Ekvitayavetchanukul, P., Rana, M., & Singh, B. (2026). Deep learning-based solar tracking system for maximizing solar power generation efficiency. In S. Das, M. Paprzycki, A. Ghosh, & M. Bianchini (Eds.), *Advanced computing and intelligent technologies: ICACIT 2024* (Lecture Notes in Networks and Systems, Vol. 1359). Springer. https://doi.org/10.1007/978-981-96-4933-4_28
- Skoplaki, E., & Palyvos, J. A. (2009a). On the temperature dependence of photovoltaic module electrical performance: A review of efficiency/power correlations. *Solar Energy*, 83(5), 614-624. <https://doi.org/10.1016/j.solener.2008.10.008>
- Skoplaki, E., & Palyvos, J. A. (2009b). Operating

- temperature of photovoltaic modules: A survey of pertinent correlations. *Renewable Energy*, 34(1), 23-29. <https://doi.org/10.1016/j.renene.2008.04.009>
- Srivastava, A., Singh, J., Dandotiya, M., Ekvitayavetchanukul, P., Rana, M., & Singh, B. (2026). Integrating UAV imagery and deep learning models for automated crop health monitoring and analysis. In J. C. Bansal, S. Borah, S. Hussain, & S. Salhi (Eds.), *Computing and machine learning: CML 2025* (Lecture Notes in Networks and Systems, Vol. 1613). Springer. https://doi.org/10.1007/978-981-95-2875-2_31
- Teepun, K., Polpetch, N., Srikaue, T., & Ekvitayavetchanukul, P. (2026). Behavioral and Clinical Correlates of Frequent Self-Reported Sleep Bruxism Among Thai Participants: A Cross-Sectional Study. *American Journal of Physical Education and Health Science*, 4(2), 56-66. <https://doi.org/10.54536/ajpehs.v4i2.8230>
- Yakup, M. A. B. H. M., & Malik, A. Q. (2001). Optimum tilt angle and orientation for solar collector in Brunei Darussalam. *Renewable Energy*, 24(2), 223-234. [https://doi.org/10.1016/S0960-1481\(00\)00168-3](https://doi.org/10.1016/S0960-1481(00)00168-3)
- Yotooratai, G. (2023). *Study on the efficiency of a vertical solar photovoltaic power generation system* [Master's thesis, Thammasat University]. https://ethesisarchive.library.tu.ac.th/thesis/2023/TU_2023_6509031552_18994_28911.pdf