Data-Driven Monitoring, Forecasting, Fault Detection and Performance Optimisation of Solar PV Systems in Tropical ASEAN Environments

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Tenaga Suria Brunei, 1.2 MWp solar PV system
Officially launched 26th May 2011

Background and Targets: Tropical Environments PV Operation

Background:

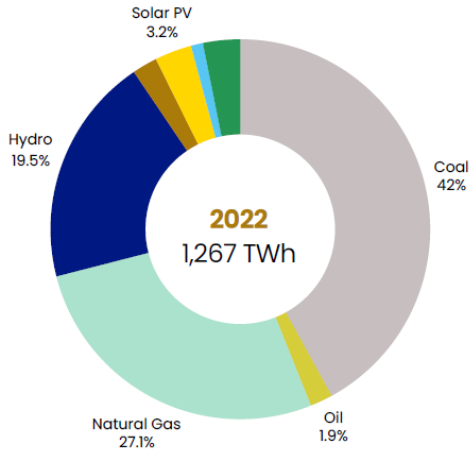
- The deployment of solar photovoltaic (PV) system has expanded across ASEAN.
- ASEAN member states are committed in transitioning towards cleaner, more sustainable and climate-resilient energy system.

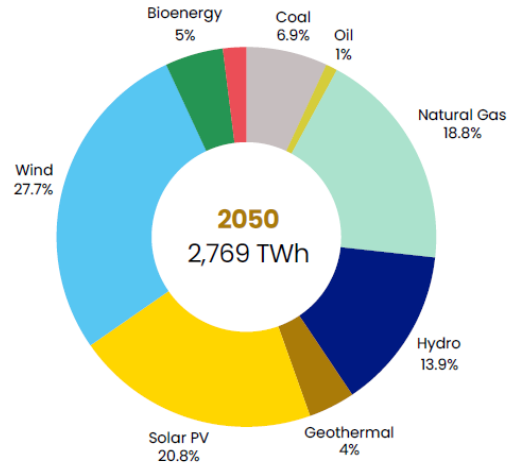
Issue – Intermittent Solar Energy Generation:

- Clouds appearance, rainfall over the solar PV system
- Shading due to trees and buildings
- High temperature and humidity that lowers conversion efficiency
- Local or transboundary haze particles
- Accumulation of dust and dirt (soiling) on solar panels

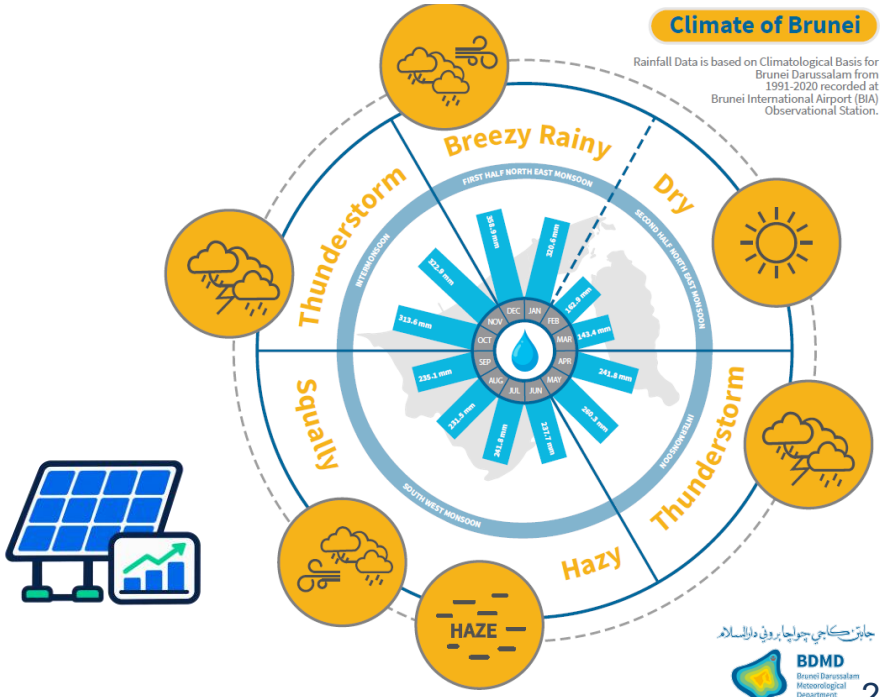
Need for Reliable Site Data:

- Solar plant operators need forecasts and early warnings to distinguish between environmental effects and potential faults.
- Aim is to have better real-time monitoring, forecasting and maintenance decisions for tropical solar PV systems





(Source: ACE projection in AEO8's ATS)



Brunei Darussalam Meteorological Department, 2024 ©

Background and Targets: UTB and Project Scope

Existing UTB Solar PV System

Capacity of 120 kWp



- Grid-connected solar PV system
- 236x580Wp PV panels, 4x30kW string inverter
- 10° tilt angle, Ground mounted and Rooftop

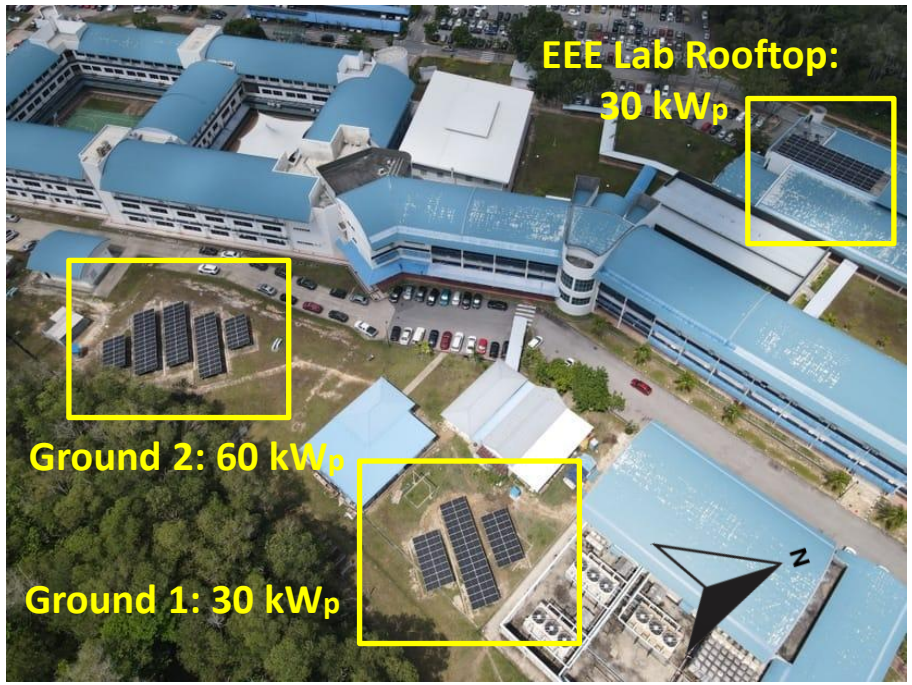
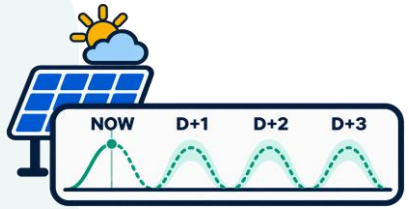


Figure 1: Existing UTB solar PV system installation

Project Objectives/Targets:

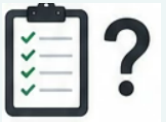
- Monitor solar PV energy generation and system performance (with existing system)



- Forecast PV energy generation



- Identify early signs of degradation performance





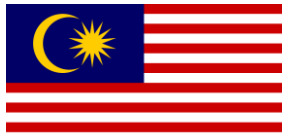
- Detect potential system faults
- Support maintenance and interventions for overall system improvement.





Participating sites: Brunei Darussalam, Malaysia and Lao PDR





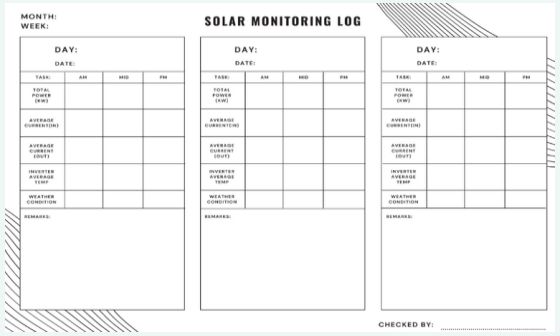


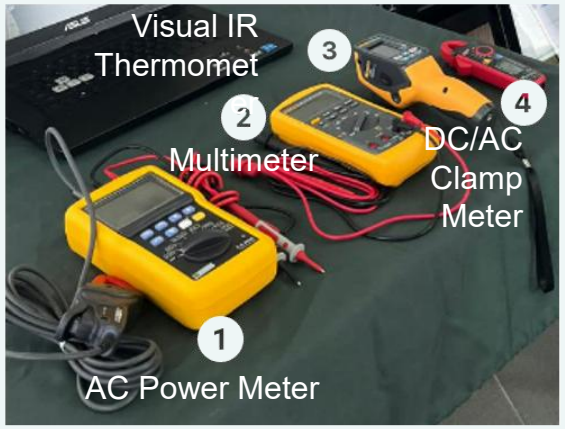
Current Operation and Maintenance Activities

Operation Activities

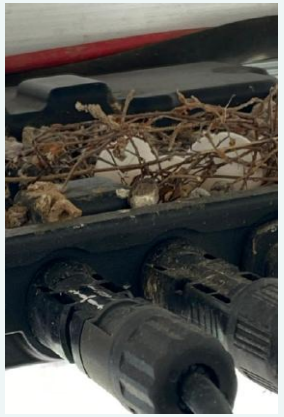






Maintenance Activities







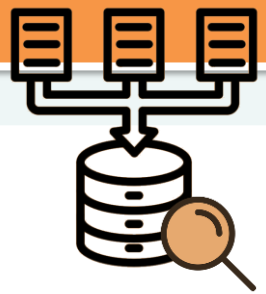

Proposed Method: Scientific and Technological

The project proposes integrating an AI-based system into UTB's solar PV plant to monitor and potentially optimise its performance, with the aim of maximising energy generation.

Integrating IoT and AI Framework

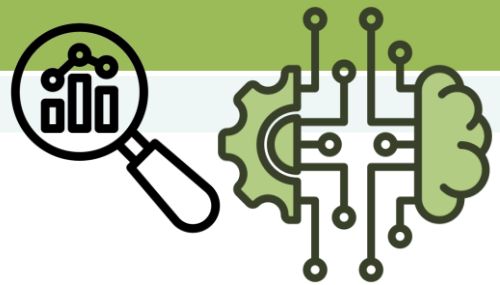
Collect operational and environmental data

- IoT-enabled sensors and smart metering to capture PV generation, system performance, local and site environmental data.
- Require environmental data such as solar irradiance, ambient temperature, module temperature humidity, wind speed/direction.
- Electrical data/Inverter data such as DC Power, AC Power, Voltage and Current, Hourly/Daily energy yield.
- Data capture and Preprocessing



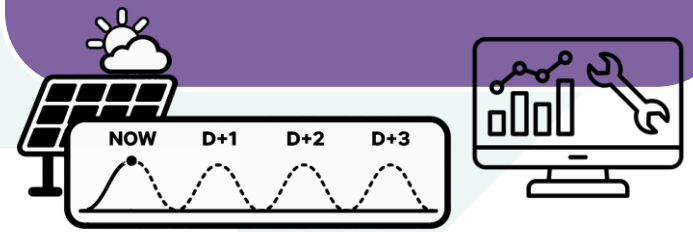
Analyse data using AI/ML

- Develop models to forecast generation and identify abnormal performance.
- E.g. Random Forest, Gradient Boosting, XGBoost, LSTM. For example, feeding the data can predict short-term (hourly and daily) power output
- Model training
- Develop diagnostic classifier
- String level data/Inverter data can be used to detect PV panels defects, loose connection, thermal anomaly



Support operational and maintenance decisions

- Present forecasts and alerts so technical teams can investigate and plan interventions.
- Evaluate algorithms using RMSE, MAE or R^2
- Derived KPIs metrics such as Performance Ratio, reduce unscheduled downtime.
- Support predictive and preventive maintenance.



Sensor Deployment and Dashboard Integration

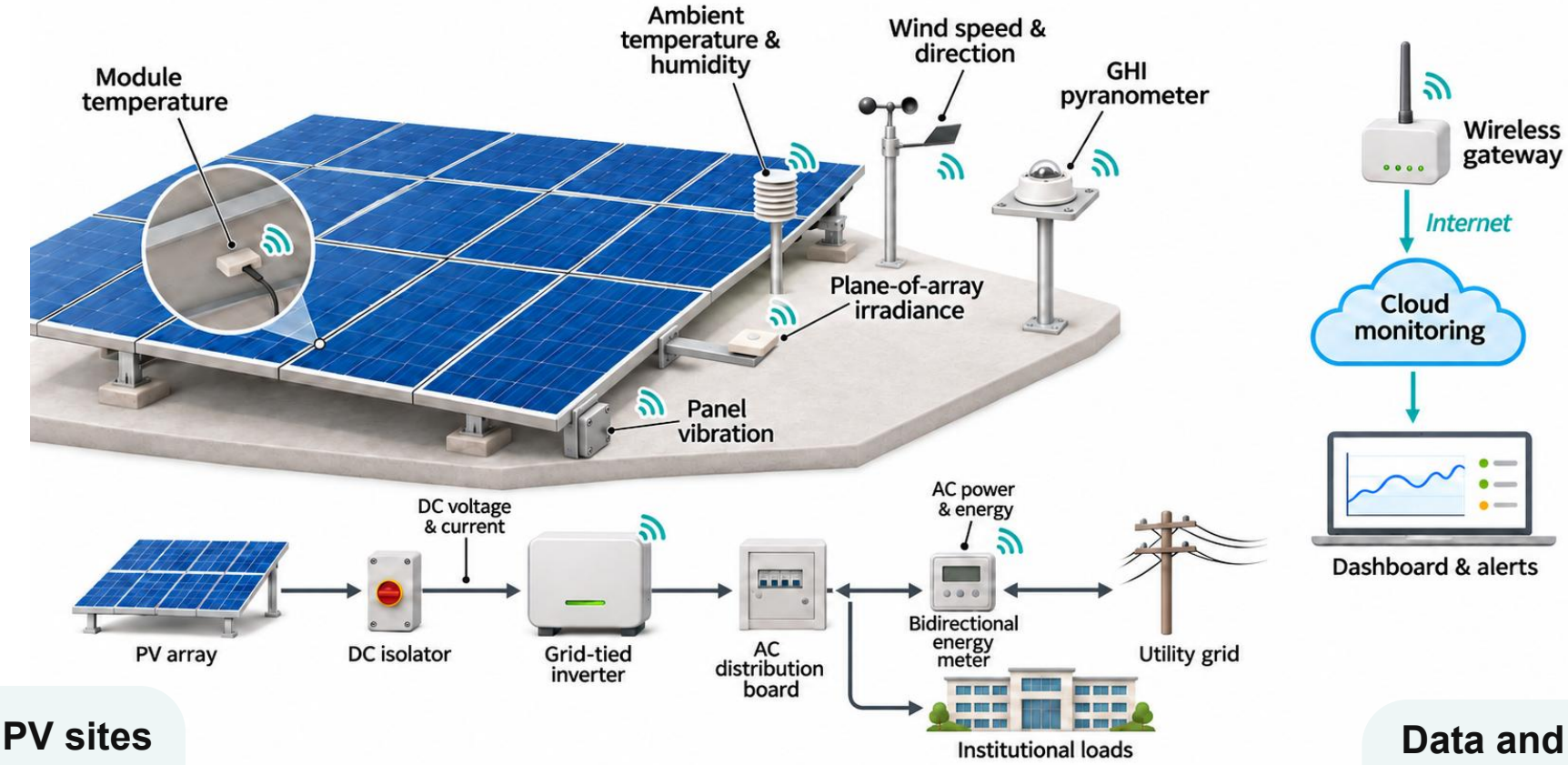


Figure 2: Proposed sensor arrangement

At participating PV sites

Install IoT-enabled sensors and collect operational and environmental measurements using Cloud monitoring.

Data and decision support

Process the data, run prediction models and present site-specific results and alerts.

Proposed Method: Experiments and Field Testing

To further strengthen this initiative and extend its application beyond Brunei, UTB will be collaborating with local utility and ASEAN partner organisation from Malaysia and Lao PDR.





- **Field validation across three countries**
- **Confirm data access, sampling interval and event labels with partners**



Collect Field Data

Comparable PV, environmental and system-configuration data. Common timestamp and quality checks.



Test

Forecasts vs measured generation, against baseline. Alerts reviewed against site records.



Cross-country studies

Compare sites and PV configurations. Report where models work and where they need adaptation.

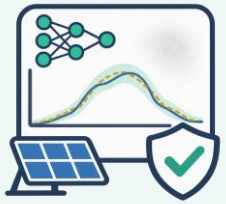
Impact and Outcome: Scientific and Technological

Expected benefits: Field validation and evidence to guide technical investigation and solar PV management



Tropical PV behaviour

Share generation and performance findings. Changes to conditions measured at each site in chronological periods.



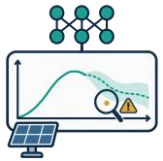
Model reliability

Establish how forecasting and detection models behave across participating solar PV system installations.



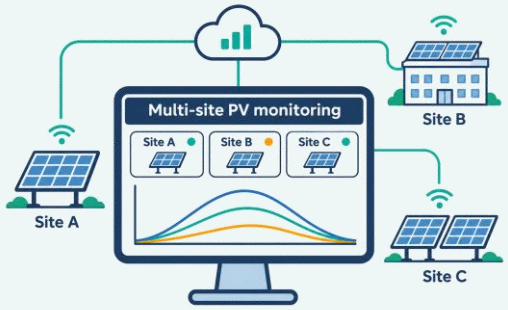
Maintenance decisions

Prioritise technical investigation Inform maintenance decision and planning.

PLANNED DELIVERABLE	PROPOSED EVIDENCE
 Integrated monitoring framework	Traceable PV and environmental data with quality flags
 Forecasting and detection models	Forecast errors against a baseline Alert review against site records
 Validation across countries	Site-level comparisons, limitations and adaptation needs

Impact and Outcome: Societal and Collaborative

Visible campus energy



Local displays PV generation, building demand and carbon estimates to support research, teaching and learning.

Public and campus awareness on solar energy use and local system performance.

Regional research collaboration



Brunei Darussalam, Malaysia and Lao PDR jointly develop and validate AI/ML models, compare local experience and share protocols.

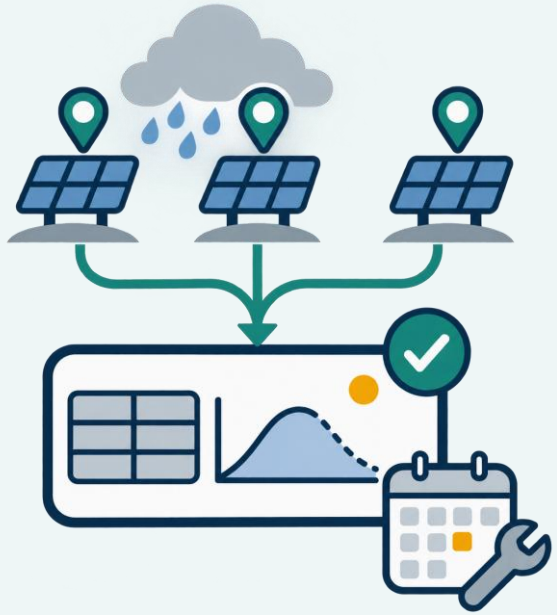
Compare experiences across the participating PV configurations and tropical environments.

Strengthen working relationships for further solar PV research and future joint collaborations and research activities.



Figure 3. Proposed UTB Lobby Display
[for Illustrative only, not project measurements]

Conclusion



- Tropical solar PV systems requires regional field evidence.
- Three solar PV sites across three countries.
- Share common site data.
- One validation framework.
- Energy forecasting and alerts.
- Informed decisions backed by field measured data.
- Evidence to prioritise investigation and maintenance planning.

Aligned with Brunei Wawasan 2035, support SDGs and APAEC.







Discussion and Feedback

