

TENAGA SURIA BRUNEI

1.2 MW SOLAR PHOTOVOLTAIC POWER PLANT BRUNEI DARUSSALAM



**Submitted to Board of Judges on ASEAN Renewable Energy Project
Competition
ASEAN Energy Awards 2016**

**By
Department of Electrical Services (DES) in collaboration with Energy
and Industry Department at the Prime Minister's Office (EIDPMO)
and Brunei National Energy Research Institute (BNERI)**



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Category:

On-Grid

Off-Grid

Title of Activity / Project / Theme:

TENAGA SURIA BRUNEI – 1.2 MW SOLAR PV POWER PLANT, BRUNEI DARUSSALAM

Applicant General Information

Name of Company	Department of Electrical Services, Prime Minister's Office (DES)
	Brunei National Energy Research Institute (BNERI)
Primary Contact Person(s)	Haji Yusri bin Haji Md Ali
	Muhammad Nabih Fakhri bin Matussin
Position	Power Station Superintendent Engineer
	Researcher, Renewable and Alternative Energy Department
Business Address	DES Headquarter, Jalan Muhibbah, Mukim Berakas, BB3510, Brunei-Muara District, Brunei
	BNERI, Science and Technology Building, Faculty of Science, Universiti Brunei Darussalam, Jalan Tungku Link, Mukim Gadong, BE1410, Brunei-Muara District, Brunei
Project Site Address	Tenaga Suria Brunei, Jalan Lorong Tengah, Mukim Seria, KB1173, Belait District, Brunei
Office Phone	+6733236950 ext. 236 / +6732461336 ext. 111
Mobile Phone	+6738974575 / +6737215082
Email	yusri.ali@des.gov.bn / nabih.matussin@bneri.org.bn

Project Abstract:

Tenaga Suria Brunei is an on-grid 1.2 MW solar PV power plant in Seria, Belait District, developed through a collaboration between Brunei Government and Mitsubishi Corporation from Japan. The project, which was fully funded by the Mitsubishi Corporation with a capital expenditure of BND26 million, was in evaluation and analysis phase under the ownership of Mitsubishi for two years with the objective to identify the performance characteristics of six different types of PV panels and therefore identify the best performing PV panel under Brunei meteorological conditions. After evaluation period, the Government took over the ownership, looking after the daily normal operation.

This plant is an excellent example of an on-grid solar electrification in Brunei. Data from 2011 to 2014 have shown that the application of Tenaga Suria Brunei has cumulatively saved about 87,678 mmBtu of the domestic natural gas consumption, as well as avoided about 5.302 million kg of CO₂ over the same period. In terms of monetary savings, the plant has contributed to cumulative savings of about USD1.388 million, equivalent to BND1.744 million.

This project is one of the initiatives by Brunei Darussalam to develop and promoting renewable energy, in line with the country's target of generating about 10% of the total power generation mix from renewable energy.



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CERTIFICATION AND ENDORSEMENT

The TENAGA SURIA BRUNEI – 1.2 MW SOLAR PV POWER PLANT hereby agreed to allow the ASEAN Board of Judges and other experts that may be designated by ACE to visit the RE project site and verify the authenticity of the data. However, two weeks advance notice is required to allow for necessary arrangements.

We also hereby agree that ACE can publish the whole submission in ACE publications and website, without any prior consent of the owner of the RE project. If the submission will be published in other publications, the consent of the concerned RE project owner would be required.

We, the undersigned certified that the information given is true and accurate and prepared with the consent of the party/ies involved.

Applicant	Top Manager/Owner
 Muhammad Nabih Fakhri bin Matussin Researcher, Renewable and Alternative Energy Department Brunei National Energy Research Institute Office Phone: +6732461336 ext. 111 Mobile Phone: +6737215082 Email: nabih.matussin@bneri.org.bn	 Haji Yusri bin Haji Md Ali Power Station Superintendent Engineer, Lumut Power Station, Department of Electrical Services Prime Minister's Office Mobile Phone: +6738974575 Email: yusri.ali@des.gov.bn
RE-SSN Focal Point	
 Abdul Matiin bin Haji Muhd Kasim Renewable Energy Unit, Sustainable Energy Division, Energy and Industry Department, Prime Minister's Office Office Phone: +6732384488 ext. 1442 Mobile Phone: +6737177014 Email: matiin.kasim@jpm.gov.bn	

For further inquiries, please contact:

ASEAN Centre for Energy
6th Floor, Jl. HR Rasuna Said, Blok X-2
Kav. 07-08 Kuningan, Jakarta 12950, Indonesia
Tel.: (6221 – 527-9332) Fax: (6221 – 527-9350)
E-mail: aseanenergy@gmail.com



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ORIGINALITY

Background Introduction

Tenaga Suria Brunei is an on-grid 1.2 MW solar PV power plant which is located in the town of Seria, Belait District of Brunei Darussalam. It is a joint project of the Government of Brunei Darussalam and Mitsubishi Corporation of Japan.

Officially inaugurated in 26th May 2011 by His Majesty the Sultan and Yang Di-Pertuan of Brunei Darussalam, the plant was in evaluation and analysis phase for two years with the objective to identify the performance characteristics of six different types of PV panels and therefore identify the best performing PV panel under Brunei meteorological conditions. After the evaluation period, the Government took over plant ownership, looking after the daily plant operation and maintenance. Other main objectives of the project include: i) to develop capacity building, including technical expertise; ii) to increase public awareness on renewable and alternative energy; iii) to help the Government in formulating renewable energy policies through data gathering; and iv) to demonstrate Brunei Darussalam’s commitment towards developing and promoting renewable and alternative energy.

Design

Tenaga Suria Brunei system comprises six different types of PV panels, each rated at 200 kW: Monocrystalline Silicon (Type 1), Polycrystalline Silicon (Type 2), Microcrystalline-Silicon Tandem-Type (Type 3), Amorphous Silicon (Type 4), Copper-Indium-Selenium (CIS) (Type 5), and Heterojunction Intrinsic Thin-layer (HIT) (Type 6). These panels are connected to three 420 kVA-rated power conditioning systems which convert DC power to AC power. The converted AC power goes into the existing 11 kV grid through 500 kVA isolating transformer, LV switchgear, 1500 kVA main transformer and 12 kV switchgear. A monitoring system was equipped to monitor real-time data.

Application

This system is an excellent example of an on-grid solar electrification in Brunei. Data from 2011 to 2014 have shown that the application of Tenaga Suria Brunei has cumulatively saved about 87,678 mmBtu of the domestic natural gas consumption, as well as avoided about 5.302 million kg of CO₂ over the same period. In terms of monetary savings, the plant has contributed to cumulative savings of about USD1.388 million, equivalent to BND1.744 million.

Approach

A signing ceremony of the Memorandum of Understanding (MOU) between Brunei Government and Mitsubishi Corporation was reached, with Mitsubishi to provide complete funding for the project. The approach to the project is illustrated in a Gantt chart below:

Task	2008	2009	2010	2011	2012	2013
Detailed Design	■					
Procurement and Manufacturing		■				
Installation and Commissioning		■				
Operation and Maintenance, Data Collection, Performance Evaluation and Analysis, Training of O&M Personnel, Public Awareness			■			



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ENVIRONMENTAL AND ECONOMIC CONSIDERATION

Cumulative Amount of Carbon Dioxide (CO₂) Avoided

The installation of Tenaga Suria Brunei has cumulatively (2011 – 2014) avoided **5.302 million kg of CO₂**, based on Brunei’s grid emission factor of 820 kg of CO₂ per MWh of electricity produced.

Example Calculation:

In January 2011, the electricity generated from the plant was 122.1 MWh, therefore the amount of CO₂ avoided was calculated as follow:

$$\text{Amount of CO}_2 \text{ Avoided} = 122.1 \text{ MWh} \times 820 \frac{\text{kgCO}_2}{\text{MWh}} = 100.2 \text{ kgCO}_2 = 0.100 \text{ million kgCO}_2$$

Table 1: Amount of CO₂ Avoided from 2011 to 2014

Month	Amount of CO ₂ avoided / million kg			
	2011	2012	2013	2014
January	0.100	0.118	0.112	0.0864
February	0.107	0.125	0.113	0.114
March	0.119	0.120	0.138	0.140
April	0.110	0.114	0.118	0.129
May	0.109	0.123	0.119	0.100
June	0.0961	0.113	0.104	0.103
July	0.108	0.118	0.110	0.0917
August	0.115	0.125	0.112	0.110
September	0.111	0.114	0.109	0.108
October	0.123	0.093	0.118	0.0248
November	0.119	0.125	0.117	0.0999
December	0.108	0.0740	0.111	0.107
Total	1.331	1.366	1.387	1.217

Number of Trees

The abovementioned 5.302 million kg of CO₂ could have been absorbed by a total of **243,546 trees in Brunei over the past four years**, based on an estimated CO₂ absorption of 21.77 kg per tree. This corresponds to CO₂ absorption by about **60,887 trees per year**.

$$\text{Cumulative Number of Trees} = \frac{5,302,000 \text{ kgCO}_2}{21.77 \text{ kgCO}_2} = 243,546 \text{ trees}$$

$$\text{Annual Number of Trees} = \frac{243,546}{4} = 60,887 \text{ trees}$$

Natural Gas Savings

Cumulatively from 2011 to 2014 the solar PV plant has saved approximately **87,678 mmBtu** of natural gas that could have been used in power stations in Brunei, corresponding to an average **annual value of 21,919 mmBtu**. This translates to a cumulative monetary saving of about **USD1.388 million**



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(BND1.744 million), which is calculated based on the Asian gas prices (Japan import prices) from 2011 to 2014.

Table 2: Economic Benefits from Tenaga Suria Brunei

Parameter	Year			
	2011	2012	2013	2014
Annual natural gas savings / mmBtu per year	22,014	22,598	22,938	20,126
Monthly average Asian gas price (Japan import prices) / USD	14.65	16.55	15.95	16.03
Annual monetary natural gas savings / USD	323,826	375,278	366,033	323,566



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SOCIAL CONSIDERATION

Participation from Communities and Resident

Since its establishment, Tenaga Suria Brunei has been receiving a number of visitors from various agencies, particularly the NGOs, schools and individuals. These visitors have enhanced their understanding on the overall operation of the solar PV system through the design, construction and implementation. This also helps visitors to better understand the importance of conserving the environment through renewable energy usage.

Benefits

To Community

- Increased awareness on renewable energy, especially amongst students who wish to learn more about solar energy and other renewable energy resources.
- Opportunity for the public, especially the clean energy enthusiasts to understand more on the detailed operation of renewable energy power plants.

To Country

- Support to renewable energy development which is clean and environment friendly energy.
- Reduce country's dependence on fossil fuels for electricity generation.
- More opportunities for the country to tap in renewable energy sources in other areas.
- Can be used for research study purposes, through data gathering, etc.
- Help the government in formulating renewable energy policies.



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TECHNICAL AND MARKET CONSIDERATION

Installation Capacity

The solar PV power plant has a nominal capacity of 1.2 MW, generating about 1616 MWh of electricity per annum on average.

Technical Components

Solar PV Panel

9234 panels have been installed which consists of the following:

Type No.	Type of Panel	Module Efficiency (%)	Number of Array
Type 1	Monocrystalline Silicon	14.1	62
Type 2	Polycrystalline Silicon	13.4	61
Type 3	Tandem	8.2	128 + 1 string
Type 4	Amorphous Silicon	6.3	100
Type 5	CIS	8.9	125
Type 6	HIT	16	98

Support Frames

The solar PV arrays are supported by steel support frames which sits on top of concrete bases. The frames allow interchanging of mounting angles (5 and 15 degrees) of the PV panels without special mechanisms, enabling the panels to be mounted on the frames in the vicinity of their centre of gravity. Currently the panels are inclined at 5 degrees instead of 15 degrees for maximum power output.

Power Conditioning System (PCS)

The model name of each of the PCS unit is HIVERTER-NP201i, manufactured by Hitachi Japan. Each unit is rated at 400 kW, 400 V_{dc} and 415 V_{ac}, with a maximum efficiency of 98.7%.

Battery System

The battery bank comprises 86 identical Nickel-Cadmium (Ni-Cd) battery cells manufactured by GAZ, each rated at 1.15 V at a discharge rate of 5 hours. The purpose of the battery system is to supply backup DC power in case of any loss of low-voltage supply.

Technical Performance

The 1.2 MW Tenaga Suria Brunei produces around 1616 MWh of electricity into the national grid per year, taking into account its capacity factor of around 15-16%. Normally as with other solar PV plants the electricity production decreases annually due to decrease in the cumulative efficiency of the PV panels (about 1% decrease). This is mitigated by replacing older panels with new ones, which help optimise the electricity production.

Funder

Japan's Mitsubishi Corporation fully funded the entire solar PV power plant for the Brunei government.

Market Size (Potential within 5 Years)

Tenaga Suria Brunei is the maiden on-grid solar PV plant in Brunei. Data collected since its establishment has shown that the country has the potential to harness significant amount of electricity from solar energy. Brunei is targeting to produce 10% of its total power generation mix from renewable energy by 2035. Although currently the country does not have policies related to renewable energy, the



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decreasing trend in cost of solar PV modules and balance of systems would be the main thrust for the country to develop more utility-scale or residential-scale solar PV plants within 5 years.

Materials and Equipment Listing

Order	Materials	Manufacturer
1	Monocrystalline Silicon PV Module	SHARP, Japan
2	Polycrystalline Silicon PV Module	Mitsubishi Electric, Japan
3	Tandem PV Module	Mitsubishi Heavy Industries, Japan
4	Amorphous Silicon PV Module	Mitsubishi Heavy Industries, Japan
5	CIS PV Module	Solar Frontier, Japan
6	HIT PV Module	SANYO, Japan
7	Power Conditioning System	Hitachi, Japan
8	Battery Bank	GAZ (Geräte-und Akkumulatorenwerk Zwickau) GmbH, Germany
9	Station Transformer	Japan
10	Main Transformer	Japan
11	Isolation Transformer	Japan
12	Self-standing Display	Japan
13	Terminal Box	Japan
14	Low-Voltage Switchgear	Japan
15	Low-Voltage DC Panel	Japan

Amount of Fossil Energy Avoided

The generation from Tenaga Suria Brunei has cumulatively avoided about 87,678 mmBtu of natural gas which could have been utilised in single-cycle natural gas power stations.

Project Lifespan

The lifespan of the system is about 25 years.

Investment Indicator

The entire construction of Tenaga Suria Brunei incurred a capital investment of BND26 million which consists of:

Component	Cost
Engineering, Procurement and Construction (EPC)	BND 18 million
Solar PV modules of 6 kinds of panel	BND 6 million
Consultancy, including Design and Surveillance	BND 2 million

Electricity Production

The monthly electricity production from 2011 to 2014 is shown in the table below:

Month	Monthly Electricity Production / MWh per month			
	2011	2012	2013	2014
January	122.1	144.2	137.4	105.4
February	131.1	153.3	138.7	139.5



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March	145.9	146.4	169.0	170.9
April	134.9	139.1	144.2	157.6
May	133.8	150.2	145.5	122.9
June	117.3	138.1	127.0	126.3
July	131.9	144.7	135.3	111.9
August	141.4	153.3	137.7	134.9
September	135.8	139.4	132.9	131.8
October	150.9	114.2	144.3	30.2
November	145.6	153.3	143.8	121.9
December	132.5	90.4	135.6	130.7

Year	Annual Electricity Production / MWh per year
2011	1,623.2
2012	1,666.6
2013	1,691.1
2014	1,484.0
Average	1,616.2



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OPERATING AND MAINTENANCE SCHEME

Operational hours (day/month/year)

The solar PV system operates throughout the year without any human intervention, as the system is made to operate automatically.

Maintenance scheme

Mitsubishi Corporation provided the technical expertise to DES personnel on operating and maintaining TSB plant, through on-the-job training and capacity building classes.

Local service content

Based on the technical expertise provided by Mitsubishi Corporation to DES, local staff have developed their expertise on the maintenance. With that, there is a huge opportunity for these staff to develop further their expertise on other solar PV systems in Brunei in the future, while transferring their knowledge to younger generations in the future.



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REPLICABILITY

Relevance, Impact, Efficiency

The establishment of Tenaga Suria Brunei provides significant potentials for the development of on-grid solar PV power plants in other sites in Brunei with minimal modifications to the existing system. Despite limited number of lands in Brunei due to government policies on forest conservation, there are a number of flat-land areas that could be utilised for further solar PV deployments. One potential could be the installation of a utility-scale solar PV plant on a flat area near Kampong Tanjong Maya in Tutong District, where the area is situated next to a 66kV substation. Other potential could be the hybridisation of solar PV plant with the existing diesel power station in Temburong District. Having seen the significant energy-saving effect from Tenaga Suria Brunei, increase in on-grid solar PV deployments would substantially reduce the nation's fossil fuel demands for electricity generation.

Cost Effectiveness

Generally, a utility-scale solar PV power plant just like Tenaga Suria Brunei is more cost-effective than a residential-scale solar PV due to better economies of scale and greater electricity output, resulting from optimised orientation of the panels and tracking. This results in a higher capacity factor in utility-scale systems than for residential-scale systems.

Project Sustainability

- The abundance of solar radiation in Seria.
- The solar PV system is reliable, well-tested and requires only low maintenance.
- The system is significantly quiet and does not produce pollutants.
- The solar PV system's lifespan is quite long, about 25 years.



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FIGURES, TABLES AND PHOTOS



Figure 1: Construction Work



Figure 2: Completion of Tenaga Suria Brunei



Figure 3: His Majesty Sultan Haji Hassanal Bolkiah Mu'izzaddin Waddaulah, the Sultan and Yang Di-Pertuan of Brunei Darussalam at the Inauguration of Tenaga Suria Brunei



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Table 3: Amount of CO2 Avoided from 2011 to 2014

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Table 4: Economic Benefits from Tenaga Suria Brunei

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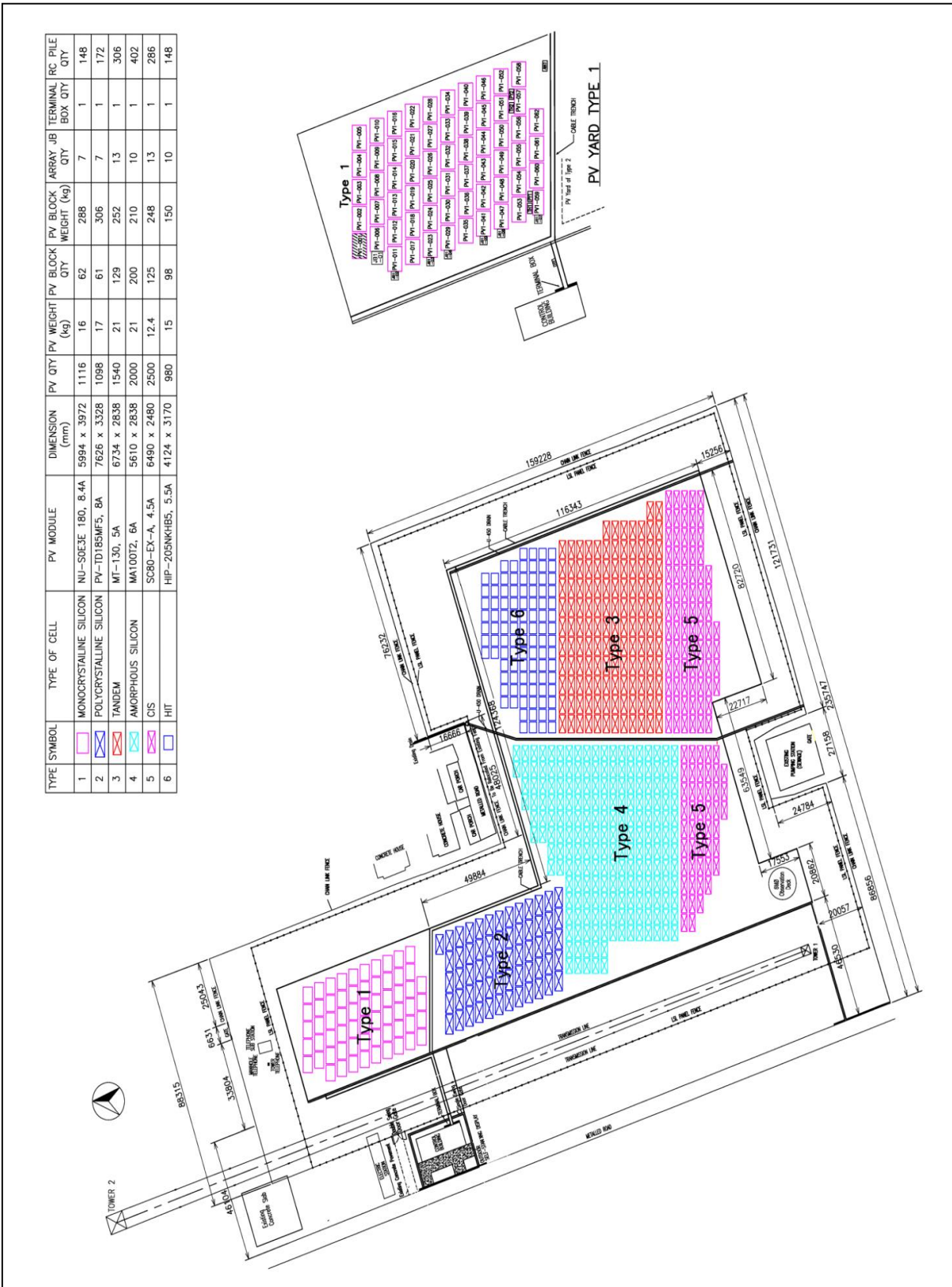


Figure 4: Site Layout of Tenaga Suria Brunei

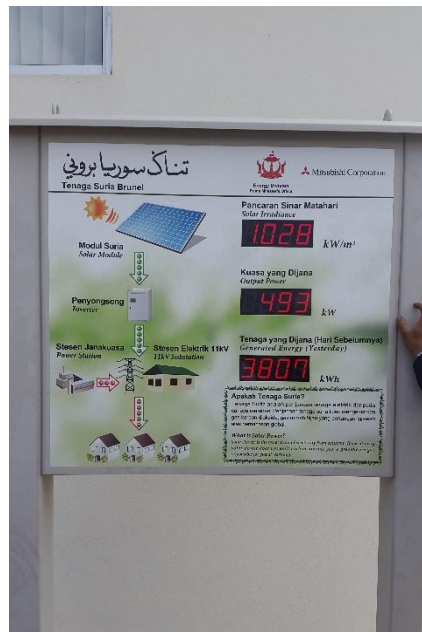


Figure 5: Outdoor Self-Standing Display, showing the instantaneous solar irradiance and output power as well as electricity generated in the previous day.



Figure 6: Mounting Structure Supporting PV Panels

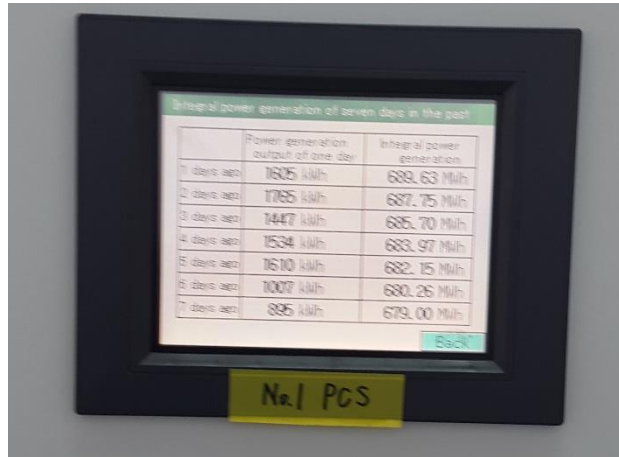


Figure 7: Left - Power Conditioning Systems (PCSs); Right - A PCS displaying the AC power output over one week period



Figure 8: Nickel-Cadmium Battery Bank System