NET ENERGY METERING SCHEME WITH AND WITHOUT BATTERY STORAGE ANALYSIS

YENG KOK PING

A project report submitted in partial fulfillment of the requirements for the award of Master of Engineering (Electrical)

Lee Kong Chian Faculty of Engineering and Science
Universiti Tunku Abdul Rahman

May 2021

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

Signature : 

Name : Yeng Kok Ping

ID No. : 2000230

Date : 16/12/2021

APPROVAL FOR SUBMISSION

I certify that this project report entitled **"NET ENERGY METERING SCHEME WITH AND WITHOUT BATTERY STORAGE ANALYSIS"** was prepared by **YENG KOK PING** has met the required standard for submission in partial fulfillment of the requirements for the award of Master of Engineering at Universiti Tunku Abdul Rahman.

Approved by,

Signature : L.I.M. B. H.

Supervisor : DR. LIM BOON HAN

Date : 16 Dec 2021

Signature : ____________________

Co-Supervisor : ____________________

Date : ____________________

ACKNOWLEDGEMENTS

I would like to thank everyone who had contributed to the successful completion of this project. I would like to express my gratitude to my research supervisor, Dr. Lim Boon Han for his invaluable advice, guidance, and his enormous patience throughout the development of the research.

Special thanks to my friend, Mr. Goh Siang Ching for supporting the valuable data, advice, and information for the success of this research.

ABSTRACT

The Net Energy Metering (NEM) scheme is introduced throughout Malaysia promoting consumers' interest in photovoltaic (PV) installation. PV generated kWh will be exported to the utility grid and credited to their monthly bill which will be "net" of the amount of electricity imported from the grid. Consumers are also able to explore further with the combination of battery storage allowing consumers to utilize the excess generated electricity. Most of the analysis in solar PV concentrates on residential consumers, in this analysis, the main focus will be a larger development with real-time load studies in the feasibility of NEM without and with battery storage installation based on the government's latest implementation of NEM 3.0 "Net Offset Virtual Aggregations (NOVA) Programme". In general, installing battery storage can utilize the excess generated electricity to store into the battery storage and use it at their will, reducing their reliance on utility grid supply. Most of the commercial buildings are charged by Tenaga Nasional Berhad (TNB) with monthly maximum demand (MD) charges, the battery storage will provide a solution to consumers in reducing the MD and thus, the monthly electricity bills. The analysis is based on a shopping mall commercial building, applied meter charges under Tariff C1. A compiled data of the monthly electricity bills is collected and analyzed in terms of the consumption, and the MD. The shopping mall has a wide footprint at the rooftop which is currently used as open space parking and M&E plant room. The proposed solar PV shall be installed elevated with steel structures support. It is expected that upon installation the development will be able to reduce their current monthly MD consumption and lower down the electricity bill. In conclusion, the consumer able to enjoy profit and saving with solar PV installation, however, with installation of battery storage system, the cost and return of investment is too long and only applicable with proper scheduling to the consumer's load profile. As battery lifespan decreases depending on the usage, replacement is required every few years. If the battery storage installation is without proper scheduling, the consumer will not be benefited from the installation and require to pay hefty cost throughout the years. Nevertheless, the consumer with solar PV under NEM NOVA able to enjoy the benefits even after 10 years of the scheme changes to SELCO.

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LIST OF SYMBOLS / ABBREVIATIONS

kWp	peak power of PV, in kilowatts peak
kW	measure of power in electric appliances consume, in kilowatts
kWh	measure of power in electric appliances consume usage in an hour, in kilowatts hour
A	unit of measure of electric current flow, in ampere
Ah	unit of measure of electric current flow in an hour, in ampere-hour
W	unit of measure of electric appliances consumer, in Watts

ACEM	Association of Consulting Engineers Malaysia
BAS	Building Automation System
BEI	Building Energy Index
CA	Capital Allowance (Tax)
COE	Cost of Energy
DESCO	Dhaka Electric Supply Company Limited
DOD	Depth of Discharge (For Battery)
FiT	Feed-in Tariff
GBI	Green Building Index
GFA	Gross Floor Area
ITA	Incentive Tax Allowance
LCOE	Levelized Cost of Energy
MD	Maximum Demand
MS	Malaysian Standard
NEM	Net Energy Metering
NEMAS	NEM Assessment Study
NLA	Net Lettable Area
NOVA	Net Offset Virtual Aggregation
PAM	Pertubuhan Akitek Malaysia
PR	Performance Ratio of Solar PV
PV	Photovoltaic
PVGIS	Photovoltaic Geographical Information System
RES	Renewable Energy Source

ROI	Return of Investment
SEDA	Sustainable Energy Development Authority
SELCO	Self Consumption Photovoltaic
SMP	System Marginal Price
SOP	Standard Operating Procedure
SREP	Small Renewable Energy Power
STC	Standard Test Conditions
TMY	Typical Meteorological Year
TNB	Tenaga Nasional Berhad
UTC	Universal Time Coordinated
WHO	World Health Organization

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

Sustainable Energy Development

Sustainable energy is being promoted all over the world. The world is taking this issue seriously due to the constant human activities such as greenhouse gas emissions, air pollution, natural resources depletion, deforestation, and global warming. Considering the rapid deterioration of the world's environment, global organizations started to take the necessary preventive measure to avert further harm to the world. In Malaysia, the Sustainable Energy Development Authority (SEDA) was established under the Sustainable Energy Development Authority Act 2011 [Act 726]. Its objective is to administer and manage the implementation of the Renewable Energy Standards and Act.

Energy policy in Malaysia began in 1979, with the National Energy Policy, followed by Four Fuel Diversification Policy in 1981. The policy evolved into Five Fuel Diversification Policy and Small Renewable Energy Power (SREP) in 2001. However, the policy has not been successful and has been kept aside for the next eight years. The next policy introduced as the National Green Technology Policy was in 2009, the same year, Malaysia introduced the Green Building Index (GBI) developed by Pertubuhan Akitek Malaysia (PAM) and the Association of Consulting Engineers Malaysia (ACEM) to guide Malaysia's industry towards the environment – friendly. With the introduction of GBI's, the National Green Technology Policy is further refined and introduced as the Renewable Energy Act 2011. Since 2011 SEDA has been implementing the Act to this date.

Policy, Tariff, and Scheme for PV

Part of the government's policy to make it more attractive to consumers is the Feed-in Tariff (FiT) which has been successfully implemented in Germany. The government is aware that the same policy can be implemented in Malaysia under electrical utility providers such as Tenaga Nasional Berhad (TNB). Although the FiT has been successful in attracting a larger number of consumers to invest in renewable energy, the concept of FiT is not able to be sustained in the long term. This is because the FiT requires a pool of money collected from all consumers who pay their bills monthly and then subsidize into the tariff. When the pool of money was exhausted, the subsidy could no longer be sustained and eventually collapsed. Therefore, the Ministry introduced a new policy similar to FiT but much more sustainable in terms of long-term investment, called the Net Metering Scheme (Net Energy Metering, NEM). This scheme allows consumers who have installed PV systems to export excess solar PV-generated energy back to the grid. The meter then records the amount of energy generated and credit it to the consumers. This means that every 1 kWh exported to the grid is used to deduct 1 kWh consumed from the grid instead of the consumer paying for the energy used (SEDA).

As the NEM scheme announced by the government ended in December 2020, the Energy Commission of Malaysia (Suruhanjaya Tenaga Malaysia) then introduces NEM 3.0 in April 2021 by publishing the "Guidelines for Solar Photovoltaic Installation under Net Offset Virtual Aggregations (NOVA) Programme for Peninsular Malaysia" also known as the NEM 3.0 (NEM NOVA). This programme is mainly targeted at the non-domestic consumers (known as NOVA Consumer), which includes commercial, industrial, mining, and agriculture. Surplus energy generated and not consumed by the NOVA Consumer at their development or buildings may be exported to the designated premise by way of the Distribution Licensee's distribution system or the utility grid.

Under the NEM NOVA, two different categories have been set, first, Category A (Offset Only), any excess energy generated in a month that is not consumed by the consumers may be exported back to the Distribution Licensee. The credits are similar to NEM 2.0, where the consumers can be used to offset their billing for the next billing period, but if the offset is not exercised in the next billing period, the credits are automatically forfeited. Note that the unit price of the energy exported shall be based on Average System Margin Price (SMP) instead of gazette tariff.

Next, the Category B (Offset + Virtual Aggregation), any excess energy generated in a month that is not consumed by the NOVA Consumers may be exported to a maximum of three Designated Premise. The Designated Premise shall fulfill the following given condition:

- A premise having an account with the Distribution Licensee that is under the name of the NOVA Consumer: or
- A premise used or operated by a wholly-owned subsidiary company of the NOVA Consumer.

Similar to Category A NOVA Consumer, the value of energy exported is subsequently credited to the respective Designated Premise's account with the Distribution Licensee, and the credits are then used to offset the bill payment. Aggregation of the credits of the Designated Premises' accounts will be based on their preset priority.

Energy Commission Malaysia has set a total quota capacity of 300MW available for NOVA Consumers application and the application date is made available from 1st April 2021 and will end on 31st December 2023 or quota capacity fulfilled.

Tabulation below shows the Medium Voltage Tariff C1 & C2 rates which is the common tariff application for commercial consumers:

Table 1: *Part of TNB Electricity Tariff Schedule (Effective from 1st January 2014 to date)*

Tariff Category	Unit	Existing Rates (1 June 2011)	New Rates (1 January 2014)
3. Tariff C1 - Medium Voltage General Commercial Tariff			
For each kilowatt of maximum demand per month	RM/kW	25.90	30.30
For all kWh	sen/kWh	31.20	36.50
The Minimum Monthly Charge is	*RM*	*600.00*	*600.00*
4. Tariff C2 - Medium Voltage Peak/Off-Peak Commercial Tariff			
For each kilowatt of maximum demand per month during the peak period	RM/kW	38.60	45.10
For all kWh during the peak period	sen/kWh	31.20	36.50
For all kWh during the off-peak period	sen/kWh	19.20	22.40
The Minimum Monthly Charge is	*RM*	*600.00*	*600.00*

From the tabulation above, we can see that TNB charges consumers a different rate depending on their kWh consumption per month. The tariffs for commercial consumers where Maximum Demand (MD) is charged in each month billing in addition to the electricity consumption. Irrespective of the consumption in the building, TNB charges the consumers every month the MD in RM/kW with a minimum monthly charge of RM 600.00. Note that the credits accumulated by the NOVA Consumers are not allowed to offset the minimum monthly charges.

1.2 Importance of the Study

Many studies and analyses of NEM with battery storage focus on the residential category where the impact on the electricity bills is small and electricity consumption is very stable because these consumers follow the same norm and behavior every day. The same analysis is then applied as if the other categories of consumers were the same.

However, this study will provide realistic data based on a commercial consumer where the installation of PV under NEM is proposed in conjunction with a battery storage system to harvest the full potential of solar PV and reduce electric bills and dependance on utility supply. The study will provide a handful of data for other commercial categories.

1.3 Problem Statement

Battery storage with PV system is often not considered by the consumer. Apart from the higher capital cost, this is another device that falls under the wear and tear category and requires service, maintenance, and replacement. With the improvement in battery technologies, many types of batteries are being developed for solar PV system installation. This includes the increase of the efficiency, lifespan, and lowers the cost of batteries offered by competing manufacturers. In addition, the consumers are also required to modify the distribution boards to accommodate for the battery storage, and additional service and maintenance are required. Battery storage is also been viewed as a wear and tear item that reduces efficiency over the time of use. For this reason, many consumers choose not to install battery storage. Finally, for commercial consumers, installing battery storage typically requires additional rooms to house the batteries. In most of the buildings, these rooms are lacking because the spaces in commercial buildings are fully utilized to increase the Net Lettable Area (NLA). The analysis and study will give commercial categories a reliable comparative data for consumers' who have installed PV under the NEM NOVA scheme to install or not to install battery storage system.

It is anticipated that this study will be able to justify the benefits of installing solar PV systems in conjunction with NEM NOVA for the commercial category consumers and SELCO scheme after 10 years.

1.4 Aims and Objectives

The purpose of this research is to study and analyze the electricity data of a commercial category consumer and propose a proper Solar PV installation to the building. The design the further developed with a battery storage system. The research and analysis shall be able to reflect on the benefits of installing solar PV without battery storage compared to those with battery storage.

- To study the feasibility of installation with solar PV under the NEM NOVA scheme for a commercial category consumer, shopping mall.
- To study the cost effective in the solar PV system utilization for the consumer under the NEM NOVA scheme and SELCO scheme implementation after 10 years.

1.5 Scope and Limitation of the Study

Due to COVID-19 and government MCO implementation, extracted data may not be up to date, and data is mainly furnished by the administration via email correspondence and without an on-site visitation due to the management's SOP throughout the MCO. The NEM or NOVA NEM scheme applies to all types of categories with different tariff and electricity consumption behaviors. However, this study is limited to one commercial consumer of a shopping mall complex rather than analyzing multiple categories. Unlike, the electricity consumption behavior of residential which is much consistent and stable compared to commercial, the comparison and data analysis of the electricity consumption will be quite challenging. The economic evaluation in the software simulation will not be included however, the overall cost per Watt of the entire system installation will be used as the basic comparative studies for this analysis.

1.6 Contribution of the Study

Since the study and analysis use actual data from a commercial consumer, the same categories of the consumer can revisit their development (with or without solar PV installation) to consider incorporating a battery storage system into their renewable energy development project for their maximum benefits.

1.7 Expected Outcome

The data obtained from the outcomes will provide details on the electricity billings throughout the period. By analyzing the electricity bills, the amount payable to the utility can be summarized and compared to the period with battery storage and without battery storage. This will provide strong reference to the consumers that battery installation can further reduce the electricity bill, in comparison with the additional investment, service, and maintenance cost. Savings from the electricity bill will be able to provide a faster return of investment (ROI) to the consumer. The consumer may also enjoy the benefits of the SELCO scheme implementation after 10 years of installation of the PV. The compiled data will provide better outcome analysis than the theoretical projection at the beginning.

CHAPTER 2

LITERATURE REVIEW

2.1 Analysis of Net Energy Metering Scheme with and Without Battery Storage

SEDA and utility providers aimed to reduce consumers' peak demand, which is a crucial consideration in their operation point of view. This is because the higher the peak demand consumption, the higher the utilities' operating costs, such as providing standby generators, higher rating transformers, transmission cables, and the infrastructures to distribute the electricity to meet such demand. Although the utility providers did charge consumers for peak demand consumption, the utility providers would like to focus more on educating consumers on electricity savings and reducing electricity consumption.

This is where the installation of PV takes place. The net metering scheme is indeed good, and it is expected that it will encourage more consumers to install PV systems. However, this will raise another problem for the environment, which is electricity wastage. When consumers understood the scheme allowed them to generate electricity and credit to their monthly bills, this means that they are entitled to spend their credit via the usage of electricity. Second, psychologically consumers are concerned that these credits may expire or not be used if they accumulate over an extended period of time while their solar PV system continues to feed the electricity into the grid. As a result, heating and air conditioning services are used incessantly over time without concern for the amount of electricity used and the monthly cost. It is important to educate consumers about the use of electricity, even if it is under the net metering scheme.

Consumers may further improve the electricity generated more effectively by installing battery storage into the system. This provides the advantages of storing the excess generated electricity storage and can be used when required and reducing the reliance on utility providers' grid supply.

2.2 Net Energy Metering Scheme without Battery Storage

Consumers installing PV in their building can enjoy lower electricity bills through the NEM NOVA. The amount of generated electricity from the PV will be then exported to the utility grid and recorded via kWh meter, the consumers will then be credited at the end of the monthly bill.

Configuration of NEM scheme connected to the grid without battery storage is shown in Figure 1 below:

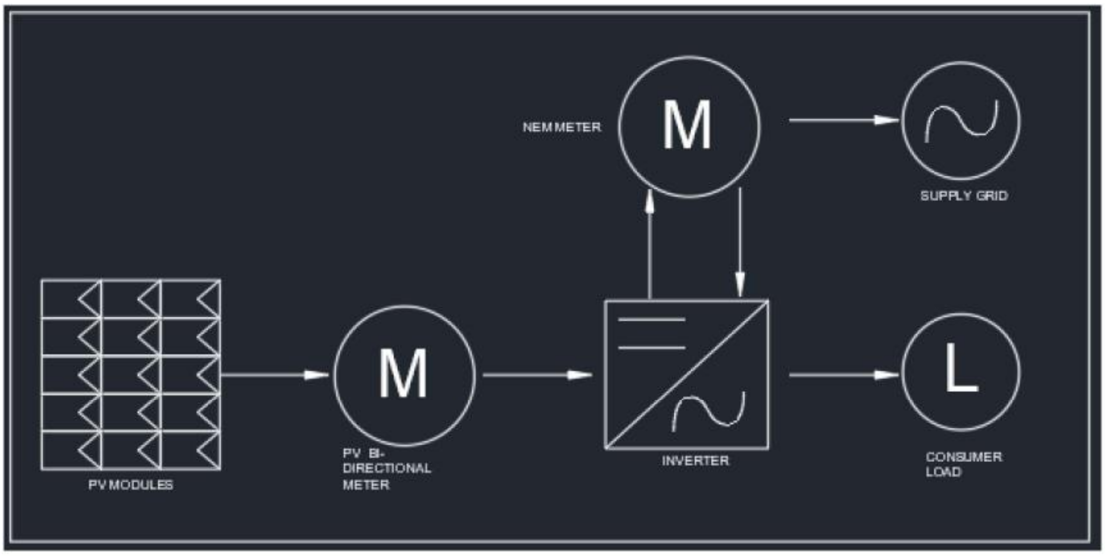

Figure 1: Typical Net Energy Metering Scheme Distribution Diagram Connected to Grid

The diagram shows that the electricity generated from the PV will be exported back to the grid via a NEM meter which records import and export electricity within a typical household. The billing will then show the total of imports and export of the month and consumers will be billed according to the total imported "net" with exported electricity. However, a maximum export is capped at each household which will not allow consumers to continue to accumulate the credits upon reaching the maximum capped credits. The PV will continue to generate electricity to export to the grid at this point which will be beneficial to the utility's providers. Albeit consumers do not lose "actual money", the credits are supposedly considered as "virtual money" to the consumer at this point.

2.3 Net Energy Metering Scheme with Battery Storage

The NEM scheme allows consumers to enjoy lower electricity bills monthly with the PV exporting generated electricity back to the utility grid, providing credits in terms of kWh reflected in the monthly bills. The installation of the PV system can reduce utility operating costs, equipment costs, and wirings cost for distribution with lower MD consumption, reducing standby units, the output of equipment such as generator sets, and cables' capacity. These ideal theories are only applicable when consumers install PV systems to take a larger percentage of an area. Thus, there is a maximum capacity one household can export to the grids which can be credited to the monthly bill. Battery storage will then become a handful in such a situation, where the PV continues to generate electricity exporting to the utility grid, no credits will be counted at maximum capacity. Consumers can store the excess electricity in the battery and then use it.

With the advancement of batteries technology such as Lithium-ion or Lead-acid batteries, consumers can utilize this technology to store excessive generated electricity from the PV before supplying it back to the grid. This allows consumers to use the electricity later, some industrial consumers may take the advantage of this to schedule their operations. TNB charges industrial consumers at different rates and with MD peak charges, with the battery storage installations, consumers can reduce the MD peak consumption via the battery supply.

Batteries can act as a backup supply to the consumers, PV electricity generation is not generating electricity 24 hours all day, it is only during the daytime and which subject to the conditions, such as cloudy days, solar irradiance, and other factors of the PV itself. Hence, introducing batteries into the PV network will improve the reliability of the electricity network. Consumers can then use the electricity at their convenience from the battery storage. Not mentioning that the failure from grid supply which causes inconvenience to the consumers, battery storage gives stronger security feels to the network as self-sustainable.

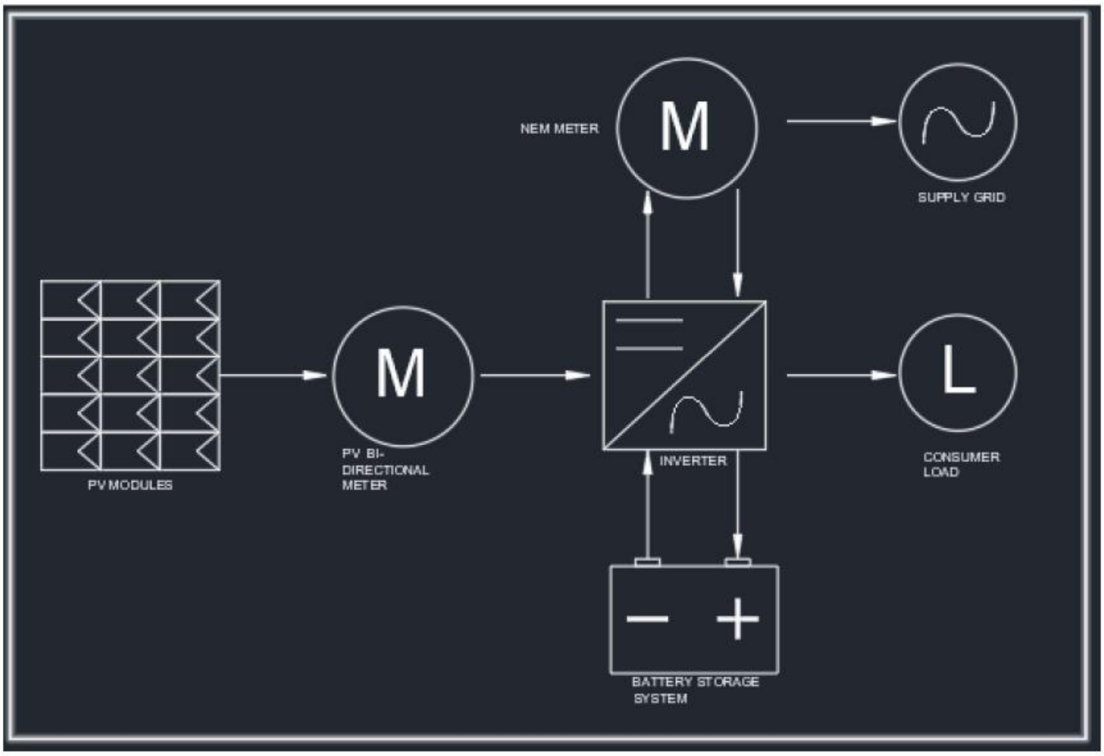

Figure 2: Typical Diagram of PV Network Connected to Grid with Battery Storage

In summary, the NEM scheme is indeed mutually beneficial, both parties whether from the consumers' or utility providers' point of view. The installation of PV by consumers will reduce the utility's provider generation and provide clean energy to the environment bringing self-sustainable energy at consumers' end instead of relying on the utility's provider grid supply. Consumers can sustain the building's electricity consumption partly or fully depending on the initial kWp investment. In case of power failure from the grid, the consumer can still maintain electricity via the PV.

In addition to the PV investment, if the consumers decided to increase the electricity supply reliability, the battery storage system will provide a solution to consumers. In this configuration, consumers will be enjoying PV-generated energy during the day and store excess energy into the battery while supplying it back to the utility's grid. During the night, consumers can utilize the energy stored within the battery to continue powering the household electricity needs. Like industrial and commercial consumers, the storage of energy in battery banks will allow them to avoid high MD charges and operate during the off-peak hour which is a bonus effort in lowering tariff charges. This will indirectly reduce the operating cost of those categories of consumers maximizing their profits when they installed PV with battery storage under the NEM scheme.

Further analysis between NEM scheme with and without battery storage in terms of capital investment, operation, and maintenance cost, and return of investment shall be done to provide sufficient evidence in the theoretical projection on NEM scheme with battery storage benefitting the consumers compared to those NEM scheme consumers without battery storage.

2.4 PV Rooftop with Net-Metering Scheme

Chawin & Surachai (2017) studies conducted in their journal on the installation of battery storage in PV systems with net metering scheme have shown the suitable capacity and the targeted operation schedule. The application of the Battery Energy Storage System (BESS) is one of the main criteria in this journal. A residential household with Time of Use (TOU) has been studied to propose a battery capacity and operation schedule that minimizes the electricity cost as much as possible and with the lowest investment cost and operation and maintenance cost of the BESS.

The analysis focused on residential consumers whose electricity consumption pattern is relatively stable and no high and low load fluctuation throughout the period unlike other category consumers such as a commercial building. Based on the studies, the NMS reduces the electricity charges than SCS. This is due to reverse power flow during such configuration. The SCS shows that the savings reduces slightly when the size of the PV installation increased. NMS wise, shows a higher reduction in electricity charges saving with a constant rate. The simulation of the PV rooftop suggested a 1kW size, residential load with Li-ion Battery. The BESS schedule charges in the daytime, estimated from 6.00 a.m. – 1.00 p.m. then the BES started discharging in the late evening typically at 6.00 p.m. – 8.00 p.m.

Chawin & Surachai (2017), state that an installation of BESS for PV rooftop with NMS is not necessarily beneficial and gives consumers better savings. It is only achievable if an appropriate battery capacity based on the schedule is applied in the household. This way the consumers will be able to minimize the electricity bills as much as possible with the lowest investment and maintenance cost of the BESS.

The analysis and studies are solely for residential consumers located in Thailand, although the scheme and application of the system are very similar to a commercial consumer category, the outcome of the data will be very different due to the higher load of solar PV installation and bigger battery capacity for the development. The tariff charges are also different between Thailand and Malaysia.

2.5 Impact of policy incentives on the promotion of integrated PV and battery storage systems: a techno-economic assessment

The PV and BES systems are evaluated based on a techno-economic model. Although PV systems are encouraged by the government through a variety of policies, such as net metering, net billing, and feed-in tariff, the BES system remains an open issue when being introduced to integrate with the PV system.

According to Angelos et al. (2020), the profitability of integrated PV and BES systems significantly depends on the BES system cost. This is due to the high capital cost investment on the battery storage system. For residential consumers, the consumption, and PV capacity installed is smaller compared to commercial consumers, hence the overall cost study and economic viability in the integration becomes small.

With the right policy and the forecast of future battery price, the PV-BES system shows a positive sign with reduction of the system cost of installation and thus increasing the benefits to the consumers. Consumers can generate electricity during the daytime and store them in the BES, during the peak hour of tariff charges, the consumer then utilizes the BES electricity supply instead of the grid.

In Malaysia, the government policy has not yet to introduce PV with BES integration, mainly focusing on PV installation with FiT, NEM, and the current NOVA NEM. As mentioned in the analysis, the policy and incentives play a crucial role in the economic viability in the integration of the PV-BES system. Not to mention that the tariff rate in Malaysia is different from European and so do the solar irradiation output. The outcome may be much more beneficial compared to the European countries' analysis.

2.6 Analysis of Grid Integrated PV System as Home RES with Net Metering Scheme

In a study by Saqib et al. (2019), a typical residential household is used as a reference for analysis. The household with an average area of 149 square meters in Dhaka city is considered for designing the solar PV system. The average daily load is given by 11.27 kWh/day and the annual peak load of 1.21kW. With the enforcement of government policy and technological improvement of PV, the numbers of installation in Dhaka city are increasing and the cost of installation is decreasing with more competitors and products for PV. PV installation is usually for self consumption when there is no power supply and infrastructure in a particular area, as secondary power source or backup supply to the consumers. The analysis focuses on a typical residential house of Dhaka city, where grid supply is available, and consumers can install a solar PV system connected to the grid. The integrated PV system has been simulated, analysed, and presented.

Using HOMER Pro, the simulation of a proposed integrated PV system was completed. The components of the PV system consist of PV modules, battery storage system, and inverter. The simulation then continues with multiple capacities of PV system, the optimum size suitable for the residential household is selected. 11.5 kW PV modules are integrated with the supply grid. With the economic analysis from HOMER Pro assistance, the total investment shows that the cost of the designed system is $ 13,825.84, the payback period is as early as 2 years where first year of total sell back is $ 12,194.15 which is about 88 percent return. The COE is further optimized when the solar PV system installed without the battery storage system. Saqib et al. (2019) mentioned that the renewable fraction of the system is approximate 85%. The integrated PV system with battery storage improves the power supply and serves as a backup source for emergencies.

The tariff reported in the analysis is comparatively higher than Malaysian TNB's tariff, without multiple consumers groups based per unit consumption. The solar irradiation values based on the Dhaka city will be lower than of Malaysia's location. Economic analysis shows that 11.5 kW PV costs $13,825.84, which is equivalent to $0.832/W. Assuming a stable electrical consumption pattern, the study shows a promising return rate in less than 2 years. Since the electricity consumption profile of residential consumers is very different from that of commercial customers.

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

In this approach, we will be analyzing data in terms of electricity consumption via monthly bills, and it is expected to round up to one (1) year analysis. As electricity consumers can be categorized into multiple categories such as residential, agriculture, industrial, commercial, and others as specified in the utility provider's tariff rates. We will narrow down the analysis to a commercial building, a shopping mall. The studies will then be conducted based on the analysis of monthly bills. Commercial building is one of the biggest electricity-consuming categories in the world, and the same goes for Malaysia. We can observe from Table 1 that the tariff rate is charging the particular consumer in two different rates, one for all the kWh consumption, and other charges based on the MD consumption in kW. Figure 3 shows the project flow chart of the whole study and analysis, starting with basic information collection, data compilation, data analysis from the respective consumer. Then a preliminary design is calculated and a proposal for a detailed design is made, a software simulation using PVsyst before the results and analysis are compiled. The flow continues with the writing of report and the conclusion.

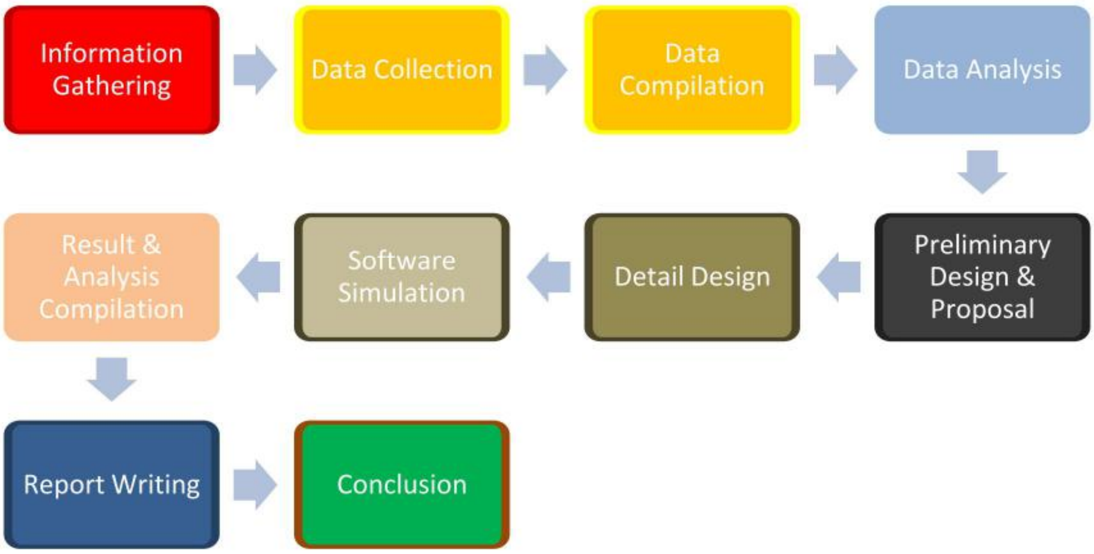

Figure 3: Project Flow Chart

The first step is to approach the mall's management to request their electricity bill. Each shopping mall shall be equipped with Building Automation System (BAS) under the compliance of MS1525. Hence, all the electricity billings are recorded via BAS into management's data collection. Since the analysis will be based on a year-round analysis, the electricity bills can be any recent years that the management can provide. To provide reliable data analysis, the expected years of the analysis will be based on July 2018 up to June 2019 a full year (12 months) of detailed consumption used. Hence, Table 2 shows the electricity consumption from July 2018 up to July 2019 with segregation between two incoming namely "Consumer 1" and "Consumer 2", based on the information, the reason behind two separate incoming is to provide higher reliability of electricity supply to the building and also to provide balance electrical distribution from two different sides. Figure 4 and 5 then shows compiled electricity consumption, maximum demand between two incomers, and occupancy rates in graphs.

In the year 2020, World Health Organization (WHO) declared COVID-19 as a pandemic, Malaysia, as well did not relief from the virus transmission and declared several lockdowns such as Movement Control Order (MCO), 2.0, 3.0, and Full Movement Control Order during the year 2021. To provide better results of the analysis, a higher occupancy rate in the building is required as this will provide much comprehensive data and outcomes. Targeted occupancy rates for the buildings aimed to be at least 80% and above. Table 3 shows the occupancy and vacancy rates in the building between July 2018 up to July 2019. With approximated gross floor area (GFA), a simple BEI value is generated and shown in the tabulation.

Table 2: Electricity Consumption of Consumer 1 and Consumer 2

Month	Consumer 1		Consumer 2		Total	
	Consumption (kWh)	MD (kW)	Consumption (kWh)	MD (kW)	Consumption (kWh)	MD (kW)
Jul-18	1,293,047	3,380	1,032,723	2,534	2,325,770	5,914
Aug-18	1,320,250	3,400	1,052,741	2,837	2,372,991	6,237
Sep-18	1,215,035	3,132	1,056,038	3,084	2,271,073	6,216
Oct-18	1,151,228	3,124	1,178,400	3,336	2,329,628	6,460
Nov-18	1,164,400	2,890	1,089,695	2,680	2,254,095	5,570
Dec-18	1,236,237	2,903	1,088,048	2,655	2,324,285	5,558
Jan-19	1,190,861	2,864	1,077,744	2,529	2,268,605	5,393
Feb-19	1,011,456	2,903	1,016,750	3,178	2,028,206	6,081
Mar-19	1,021,112	3,158	1,239,267	3,360	2,260,379	6,518
Apr-19	708,524	1,695	1,415,713	3,353	2,124,237	5,048
May-19	1,021,112	3,158	1,239,267	3,360	2,260,379	6,518
Jun-19	1,218,036	3,159	1,002,882	2,412	2,220,918	5,571
Jul-19	1,294,215	3,348	925,071	2,389	2,219,286	5,737

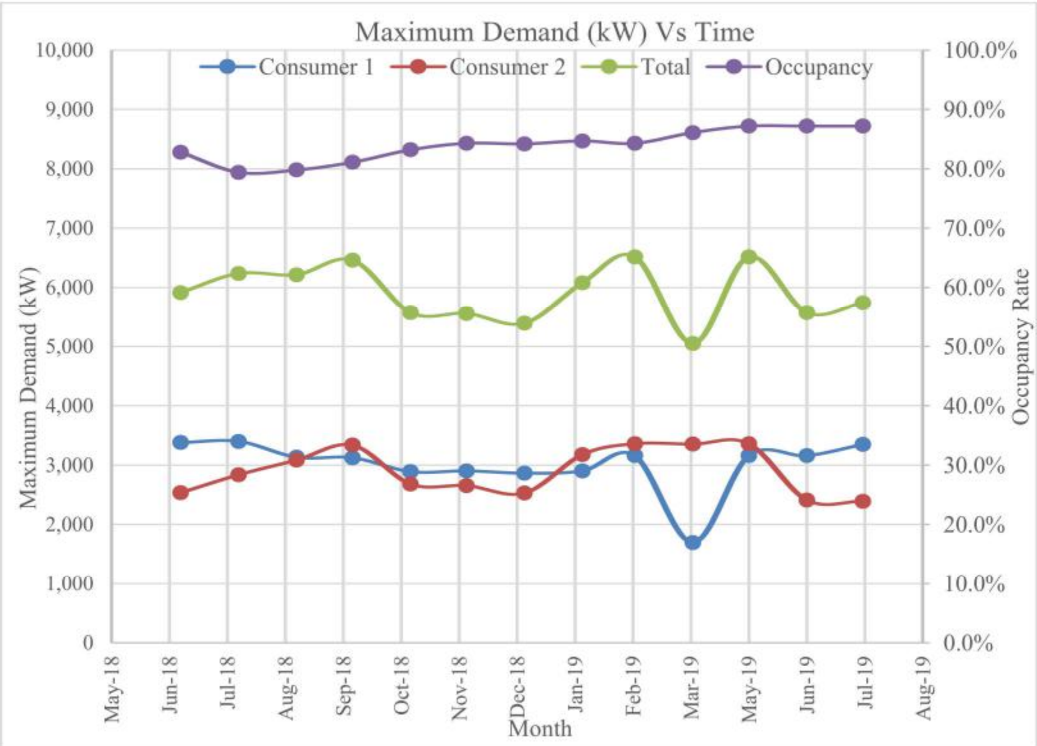

Figure 4: Maximum Demand (kW) and Occupancy Rate (%)

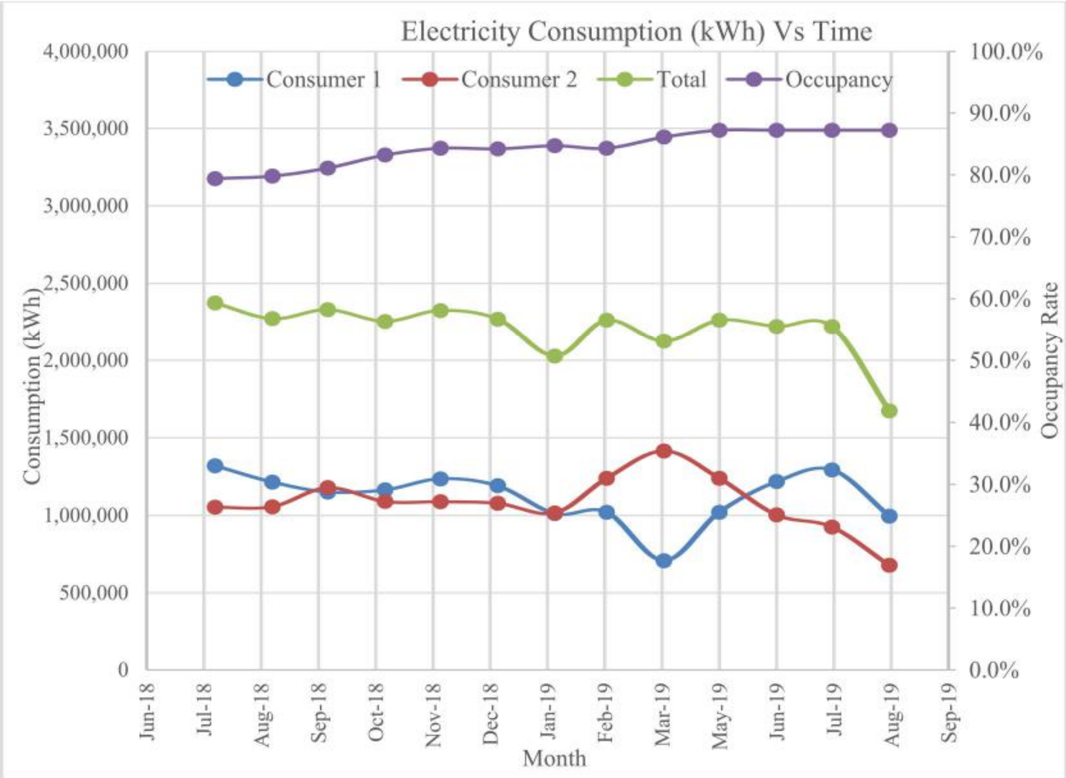

Figure 5: Electricity Consumption of Consumer 1 and Consumer 2 (kWh) and Occupancy Rate (%)

Table 3: Gross Floor Area (GFA), Occupancy Rate and Simple BEI (kWh/sqm.year)

Month	GFA (Sqm)	Occupancy	Floor Vacancy Rate	Simple BEI_2 (kWh/sqm.year)
Jul-18	87,706	82.8%	17.2%	360
Aug-18	87,706	79.4%	20.6%	377
Sep-18	87,706	79.8%	20.2%	360
Oct-18	87,706	81.1%	18.9%	365
Nov-18	87,706	83.2%	16.8%	348
Dec-18	87,706	84.3%	15.7%	356
Jan-19	87,706	84.2%	15.8%	347
Feb-19	87,706	84.7%	15.3%	309
Mar-19	87,706	84.3%	15.7%	346
Apr-19	87,706	86.1%	13.9%	321
May-19	87,706	87.2%	12.8%	338
Jun-19	87,706	87.2%	12.8%	332

The next course of action would be a proposal of solar PV installed based on the roof size of the building. The area of roof measurement will be measured by Google Maps for approximation as shown in Figure 6. This will then provide us with the total generated kW from solar PV installation and give us the projection of kW import and export from the consumers. Based on the earlier data recorded and analyzed, the battery storage can be sized according to the projected kW surplus generated from the PV and consumption.

Based on the information conveyed, the building's electrical distribution system for the development is supplied by both left-wing and right-wing plant rooms.

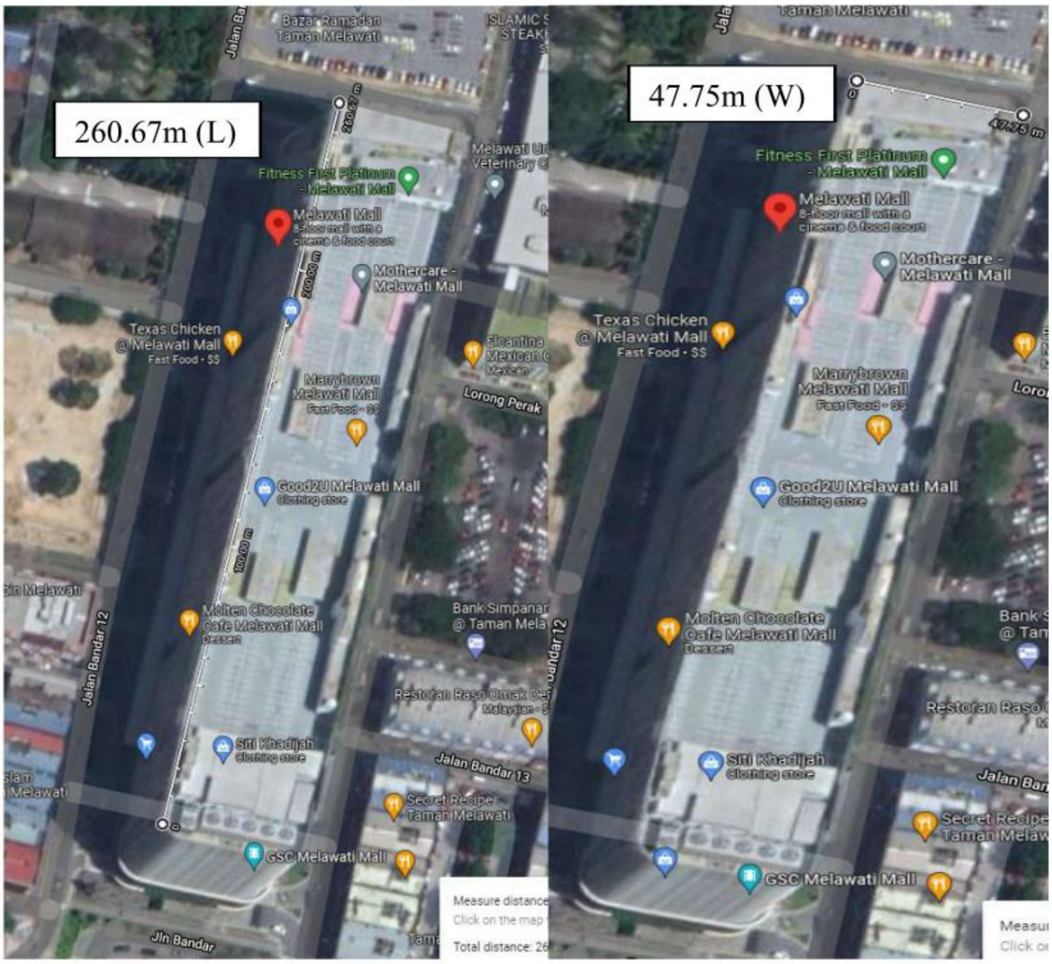

Figure 6: Google Maps Rooftop Size Approximation *(Longitude & Latitude 3°12'37.9"N 101°44'55.6"E)*

The roof floor plan is currently shown as an open-spaced car park with an approximate 260.67 m (L) X 47.75 m (W) footprint. The same size approximated will be used in the solar PV generation area. The shopping mall consists of a 7 stories shopping mall with 2 basement car parks and 5 stories of elevated car parks. Located in Kuala Lumpur, Selangor, the shopping mall complex area has approximately 180,000m^2 of GFA build-up.

Total available area 260.67 m X 47.75m = 12447m^{2,} estimating that roof area consists of M&E plantrooms say 20 %, 10% not useable space for solar PV installation. Hence, net total area available for overall development, 12447m^2 X 0.7 = 8713 m^2 (*For optimum design purposes, the size of the roof shall be proposed 190 m X 46m = 8740 m^2.)*

3.2 Requirement/ Specification/ Standards

Material selection for the Photovoltaic Module and Inverter to be as close as to PVsyst simulation's material possible.

Specification

Solar PV Modules

Jinko Cheetah 72M 380W (JKM380M-72)

Table 4: Extracted Specification of Jinko Cheetah 72M 380W (JKM380M-72)

Parameters	**Value**	**Unit**
Maximum Power (P_{max})	380	Wp
Maximum Power Voltage (V_{mp})	40.5	V
Maximum Power Current (I_{mp})	9.39	A
Open-circuit Voltage (V_{oc})	48.9	V
Short-circuit Current (I_{SC})	9.75	A
Cell Temperature	25	°C
Operating Temperature	-40 ~ + 85	°C
Temperature Coefficients of P_{max}	-0.37	%/°C
Temperature Coefficients of V_{oc}	-0.29	%/°C
Temperature Coefficients of I_{SC}	0.048	%/°C

From Jinko Solar (Solar PV Modules, Jinko Cheetah 72M 380W) (https://www.jinkosolar.com/en/)

Inverter

Huawei Smart String Inverter 60kW (SUN2000-60KTL-HV-D1-001)

Table 5: Extracted Specification of Huawei Smart String Inverter 60kW (SUN2000-60KTL-HV-D1-001)

Parameters	Value	Unit
Maximum Current per MPPT	22	A
Maximum Short Circuit Current per MPPT	30	A
MPPT Operating Voltage Range	600 ~ 1,450	V
Number of Inputs	8	
Number of MPP Trackers	4	
Rated AC Active Power	60,000	W
Operating Temperature Range	25 ~ 60	°C

From Solar Huawei (Huawei Smart String Inverter) (https://solar.huawei.com/eu/Products/FusionSolar)

Standards

The design area allowed is 8740 m^2 (190 m (L) X 46m (W)). Based on NOVA guidelines, the capacity limit shall not exceed more than 1,000kW subject to the following conditions, the Figure 7 shows part of “Guidelines for Solar Photovoltaic Installation Under NOVA Programme For Peninsular Malaysia” extracted from SEDA (2021):

9.2. A NOVA Consumer under Category A shall not install more than 1,000kW for net offset and subject to the following conditions:

(a) The maximum capacity of the inverter output of the solar PV Installation shall not be more than 75% of Maximum Demand of the NOVA Consumer under the NOVA Contract.

(b) The Maximum Demand of the NOVA Consumer is based on:

(i) the average of the recorded Maximum Demand of the past twelve (12) months; or

(ii) the declared Maximum Demand for NOVA Consumers with less than twelve (12) months record.

(c) For low voltage Consumers, the maximum capacity limit is 60% of fuse rating (for direct meter) or 60% of current transformer (CT) rating.

GUIDELINES FOR SOLAR PHOTOVOLTAIC INSTALLATION UNDER
NOVA PROGRAMME FOR PENINSULAR MALAYSIA
REGISTRATION NO.:GP/ST/NO.28/2020

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Figure 7: Part of "Guidelines For Solar Photovoltaic Installation Under NOVA Programme For Peninsular Malaysia". From SEDA Malaysia (2021) (http://www.seda.gov.my/reportal/nem/)

Since the consumer is applying NOVA under Category A, the design of the solar PV shall limit less than 1,000kW. The building's current MD are ranging from 5 – 6 MW monthly, highest at 6,518 kW March and May 2019 and lowest recorded at 5,098kW April 2019.

Based on Table 2, the average of twelve (12) months MD would be:

$$\text{Allowed Capacity} = \text{MD Average (12 months)} * 75\% = <1{,}000\text{kW}$$

$$6{,}402\text{kW} * 75\% = 4{,}801\text{ kW} > 1{,}000\text{ kW}$$

Hence, the design shall limit to 1,000kW instead of 4,801kW.

$$\text{Allowed Capacity/ Panel Wattage} = \text{Total Modules Required}$$

$$1{,}000\text{kW}/0.38\text{kW} = 2{,}631\text{ (rounded down for even number)} = 2{,}630$$

Tabulation below summarizes the design information required:

Description	Details
Area Allocated	(190m X 46m) or 8,740m^2
Area Allocated Per Wing	(95m X 46m) or 4,370m^2
Maximum Capacity Allowed	1,000kW
Total Modules Expected	2,630 (round down) or 1,315 per Wing

3.2.1 Preliminary Manual Calculation of Design

The minimum voltage of the module according to the site temperature can be estimated as:

$$V_{mp\_70°C} = V_{mp\_STC} * [\ 1 + \beta\ (T_2 - T_1)] \qquad (1)$$

Where $V_{mp\_70°C}$ = minimum module voltage expected according to site temperature (V)

V_{mp_STC} = rated module maximum power voltage (V)

β = module temperature coefficient of V_{mp} (% / °C)

T_1 = temperature in standard condition (25°C)

T_2 = highest ambient temperature for site installation (°C)

Since the design location for the PV system is at rooftop elevated, the highest temperature on site will be set to 70° C, hence,

$$\text{At } 70°\text{ C, } V_{mp\_70°C} = 40.5 * [1 - \left(\frac{0.29}{100}\right) * (70 - 25)] = 35.21\text{V}$$

Minimum solar panel per string can be obtained by the following equation:

$$Minimum\ number\ of\ solar\ panel\ per\ string\ = \frac{Vmin}{\text{V'mp}} \qquad (2)$$

Where V_{min} = minimum operating voltage range of inverter's MPPT

$$\frac{Vmin}{\text{Vmp\_70°C}} = \frac{600}{35.21} = 17.04\ (round\ up) = 18 \text{ strings}$$

For the maximum voltage of the module according to the site temperature (at worst case scenario) shall be 20°C,

$$\text{Voc\_20°C} = \text{Voc} * [1 + \beta\,(\text{T2} - \text{T1})] \tag{3}$$

Where $V_{oc\_20°C}$ = open-circuit voltage of the module (V)

V_{oc} = module rated open voltage (V)

β = module temperature coefficient of V_{mp} (% / °C)

T_1 = temperature in standard condition (25°C)

T_2 = highest ambient temperature for site installation (°C)

Hence,

$$V_{oc\_20°C} = 48.9 * [1 - \left(\frac{0.29}{100}\right) * (20 - 25)] = 49.61\text{V}$$

The maximum number of solar panels per string can be obtained by the following equation:

$$Maximum\ number\ of\ solar\ panels\ per\ string = \frac{Vmax}{\text{Voc\_20°C}} \tag{4}$$

Where V_{max} = maximum operating voltage range of inverter's MPPT

$$\frac{Vmax}{\text{Voc\_20°C}} = \frac{1450}{49.61} = 29.22 \text{ (round down) 29 strings}$$

The optimum number of panels per string is 18 – 29 numbers

Short circuit current, $I_{sc\_70°\,C}$ of the module shall be defined as follow:

For Maximum Operating Current of Solar Panel at 70° C:

$$Isc\_70^\circ C = Isc\_STC\,[1 + \alpha\,(T2 - T1)] \quad (5)$$

Where $I_{sc\_70^\circ C}$ = short-circuit current of the module (Amp)

I_{sc_STC} = maximum power current of the module (Amp)

α = temperature coefficient of I_{sc} (% / °C)

T_1 = temperature in standard condition (25°C)

T_2 = highest ambient temperature for site installation (°C)

Hence,

$$I_{sc} = 9.39 * [1 - \left(\frac{0.48}{100}\right) * (70 - 25)] = 9.59A$$

The maximum current per MPPT for the inverter is 22A,

If MPPT with 3 Strings:

Operating Current 9.59 * 3 = 28.77A – Higher than the capacity designed which is 22A, hence, 3 strings per MPPT shall not be connected.

If MPPT with 2 Strings:

Operating Current 9.59 * 2 = 19.18A – Lower than the capacity designed of 22A, hence 2 strings per MPPT are acceptable.

The maximum short circuit current per MPPT for the inverter is 30A:

Max. Short Circuit Current = 1.25 * 9.59 * 2 = 24.75A – Since the amperes rating is much smaller than the designed capacity, hence it is acceptable for 2 strings with 25% additional buffer to consider the highest solar irradiance peak exceeding 1000W.

Since the target PV installation location is based on the rooftop, the arrangement of the solar PV is designed to suit as many parking spaces as it could below with allowance of circulation for the traffic. This way the management will not lose all the car park spaces as for the mall as the car park spaces considered part of their revenue. Figure 8 shows the arrangement to maximize the spaces is best at 28 modules connected in series, with each MPPT connected to 2 strings.

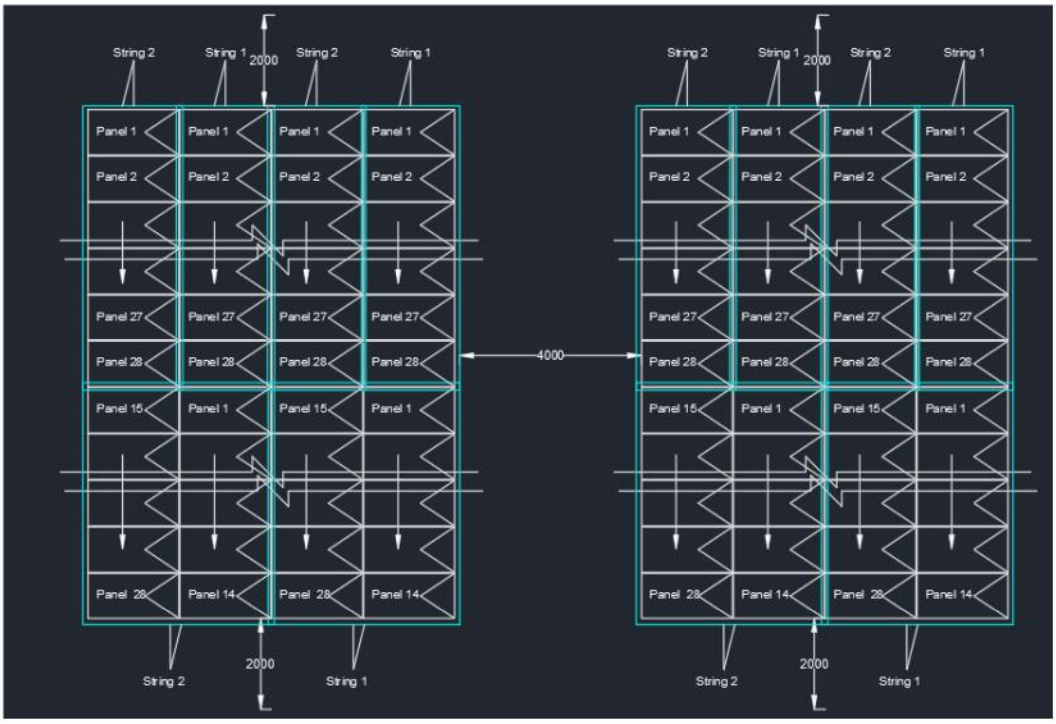


Figure 8: Part of General Arrangement of Solar PV and Spacing

Figure 8 shows the part of the general arrangement for the solar PV where panel arrangement in landscape (4 numbers) and portrait (42 numbers). The panel will be grouped into six (6) strings in total and spaced four (4) meters apart from each group which allows cars to pass through between each group. Appendix E shows the full arrangement of the solar PV in the roof layout.

On right-wing, a total of 6 inverters is required. Since each inverter comes with 4 MPPT with a total of 24 MPPT and based on the calculation 1 inverter is limited to 2 MPPT with 28 strings each due to the operating current and maximum short circuit allowance. Hence, the MPPT shall be allocated with 24 MPPT with 2 strings each.

However, on the left wing, a total number of 6 inverters is required with 21 MPPT will be connected to 2 strings and 3 MPPT with 1 string. This ensures that all MPPTs are utilized with a minimum of 1 string.

Tabulation below summarizes the final design details:

Description	Left Wing	Right Wing	Overall
Total Module Used	1,260	1,344	2,604
Numbers of Modules Per String		28	
Numbers of Strings	45 Strings	48 Strings	93 Strings
Total MPPT Used	21 MPPT – 2 Strings, 3 MPPT – 1String	24 MPPT – 2 Strings	45 MPPT -2 Strings, 3 MPPT – 1 String
Numbers of MPPT		12 * 4 = 48	
Numbers of Inverter	6	6	12
Total Capacity	1,260 * 0.38kW = 478.8kW	1,312 * 0.38kW = 510.7kW	990kW

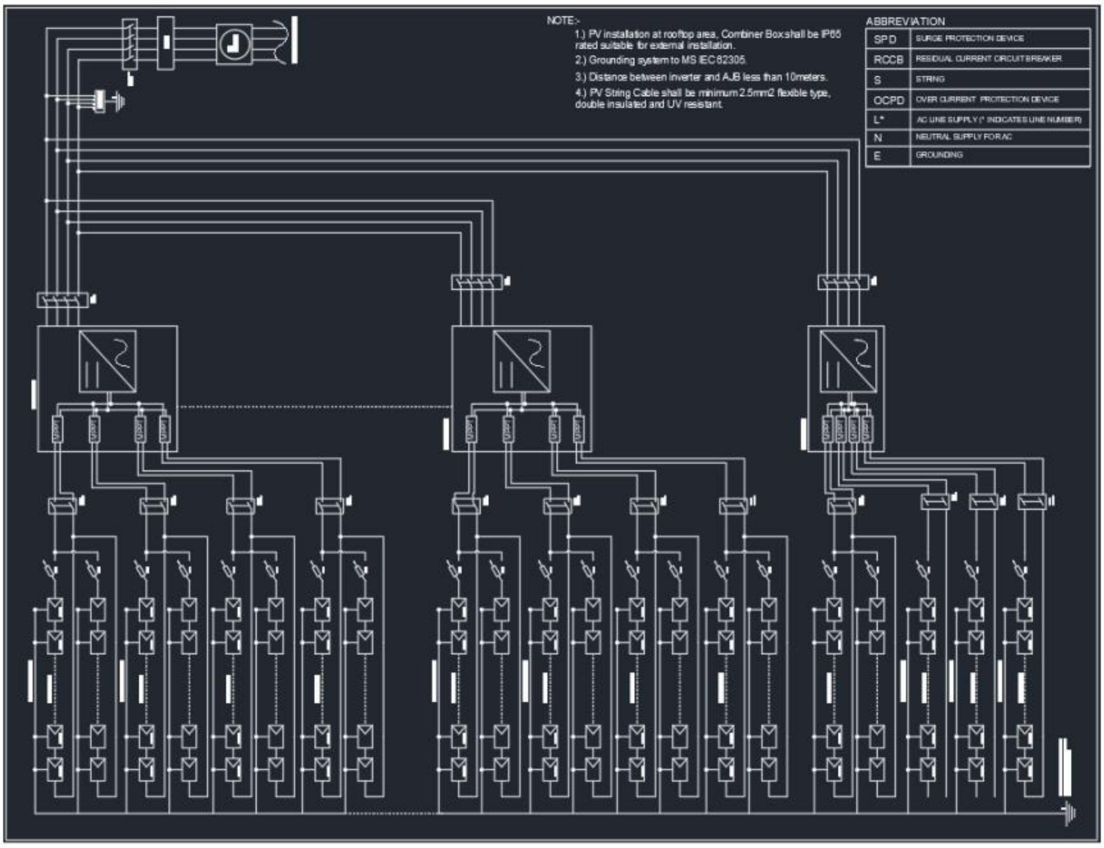


Figure 9: Single Line Diagram of PV System

A single line diagram of the PV system based on the design earlier shown in Figure 9. The details with the actual size are shown in Appendix E.

The performance ratio (PR) is then calculated with the following criteria:

$$PR = f_{low\text{-}irr} * f_{dirt} * f_{temp} * f_{mm} * f_{inv} * f_{dc\_cable} * f_{ac\_cable} \quad (6)$$

Where derating factors are given as below:

$f_{low\text{-}irr}$	= factor of low or non-usable irradiance
f_{dirt}	= factor of dust or dirt accumulated on modules
f_{temp}	= factor of temperature change in the modules
f_{mm}	= factor caused by the interconnection of the modules
f_{inv}	= factor of inverter's average efficiency
f_{dc_cable}	= factor of power drop in DC cables
f_{ac_cable}	= factor of power drop in AC cables

Temperature, f_{temp} based on the site temperature and module temperature;

$$1 - \gamma * (Tcell\_avg - TSTC) \quad (7)$$

Where γ	= temperature coefficients of P_{max}
T_{cell_avg}	= average cell temperature of the module
T_{STC}	= temperature of the modules in STC

$$\left[1 - \left(\frac{0.37}{100}\right) * (55 - 25)\right] = 0.89$$

Assumption below are made for the following factors:

$f_{low\text{-}irr}$	0.98
f_{dirt}	0.97
f_{temp}	0.89
f_{mm}	0.96
f_{dc_cable}	0.98
f_{ac_cable}	0.98

$$PR = 0.98 * 0.97 * 0.89 * 0.96 * 0.98 * 0.98 = 0.78$$

$$\text{Annual Electricity Yield} = \text{Insolation} * \text{PR} * \text{Capacity} \qquad (8)$$

Insolation data extracted from PVsyst simulation shows that the location has 1630kWh/m^2.

Hence, Annual Electricity Yield = 1630kWh/m^2 * 0.78 * 990kW = 1,258,686 kWh

3.2.2 PVsyst Software Simulation

PVsyst will be used as the software reference in the simulation.

Site: Kampong Kelang Gates Baharu (Malaysia)

Data source: Meteonorm 8.0 (1991-2009)

	Global horizontal irradiation	Horizontal diffuse irradiation	Temperature	Wind Velocity	Linke turbidity	Relative humidity
	kWh/m²/mth	kWh/m²/mth	°C	m/s	[-]	%
January	133.3	73.5	27.2	1.60	3.838	79.3
February	131.3	76.9	27.8	1.60	4.284	76.9
March	153.7	83.1	28.2	1.60	4.395	77.8
April	142.8	82.9	27.8	1.60	4.185	82.4
May	145.0	77.9	28.6	1.69	3.972	79.1
June	133.3	78.9	28.1	1.70	4.536	79.4
July	134.7	79.5	28.1	1.79	4.352	77.8
August	136.8	84.4	28.1	1.80	4.697	77.7
September	133.5	72.4	27.3	1.71	4.847	81.0
October	140.4	82.9	27.6	1.70	5.078	80.4
November	123.9	72.1	26.7	1.50	3.967	85.5
December	120.9	77.3	27.2	1.49	3.702	82.4
Year	**1629.6**	**941.7**	**27.7**	**1.6**	**4.321**	**80.0**

Global horizontal irradiation year-to-year variability 6.8%

Figure 10: Global Horizontal Irradiation (extracted from PVsyst)

Figure 10 shows the global horizontal irradiation based on PVsyst database, it shows that each month the kWh/m^2 /mth ranges from 120 – 150 kWh/m^2 /mth. The yearly global horizontal irradiation is 1,629.6 kWh/m^2 / year.

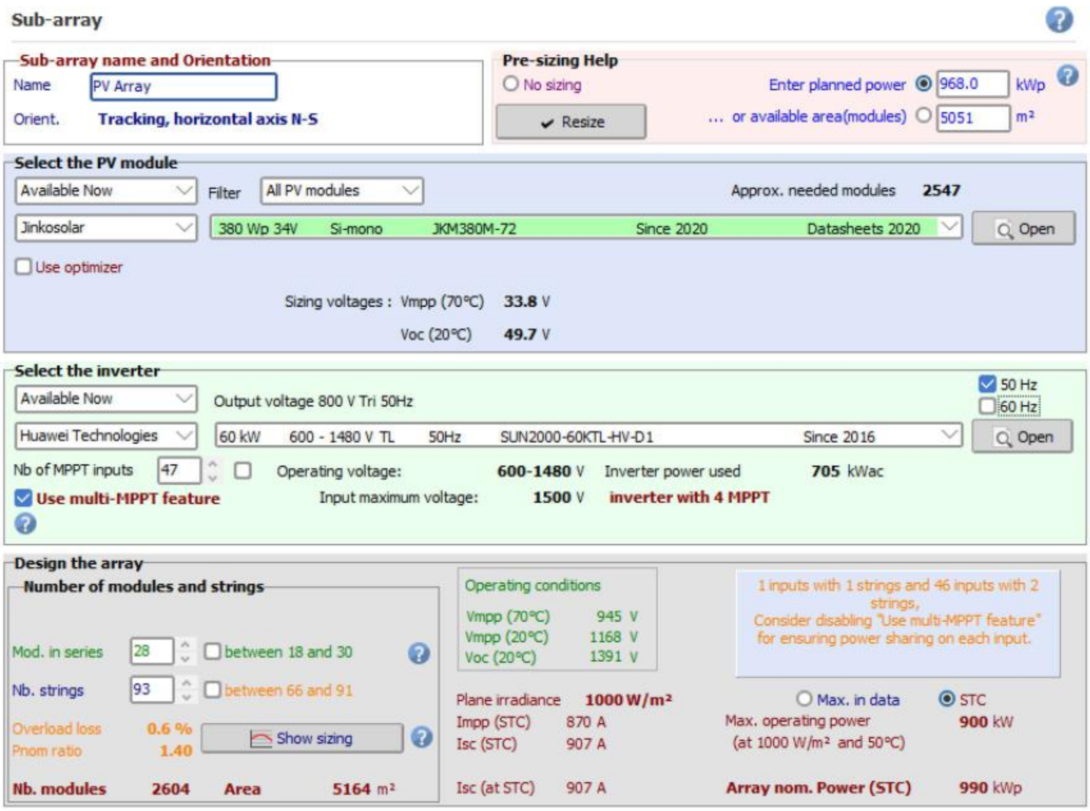


Figure 11: System Overview of PVsyst

Figure 11 shows the PVsyst data input for the simulation and the parameters are based on earlier pre-calculated values.

3.2.3 With Battery Storage Installation

Although the same location used for the battery installation analysis. The load profile of the development is not available, however, a typical shopping mall load profile shall be used in this part of the analysis. Although the load consumption overall is approximately 1.3MW which is 20% of the 6 MW MD development in our earlier design. However, note that the load profile is very much similar to the earlier development which also includes Cinema tenant that operates with the same operating hours. Hence, in the NEM NOVA with battery storage analysis, the solar PV capacity shall be designed according to the new capacity according to the load profile shown in Figure 13. The MD of the shopping mall is 1.3 MW, with the allowed maximum design of PV capacity of 975kW. Hence, the new annual electricity yield shall be recalculated accordingly:

Annual Electricity Yield = 1630kWh/m^2 * 0.78 * 975kW = 1,240 kWh

Data of Solar Irradiance is extracted from PVGIS 5. The latitude and longitude of the site as per Figure 6 are provided in PVG Tools. Typical Meteorological Year (TMY) can be obtained and the period year of selection to be closest possible to the current year. The tabulation below shows the data extracted on 1st August 2014.

Table 6: TMY of Site on 1st August 2014

Time (UTC+8)	T2m	RH	G(h)	Gb(n)	Gd(h)	IR(h)	WS10m	WD10m	SP
00:00	26.13	92.23	0	0	0	427	0.9	172	100271
01:00	25.69	93.25	0	0	0	424.2	0.88	174	100268
02:00	25.43	93.72	0	0	0	423.07	0.99	171	100238
03:00	25.17	94.18	0	0	0	421.93	1.1	168	100208
04:00	24.91	94.65	0	0	0	420.8	1.21	164	100178
05:00	25.15	94.87	0	0	0	420.85	1.24	166	100205
06:00	25.38	95.08	0	0	0	420.9	1.26	167	100231
07:00	25.62	95.3	0	0	0	420.95	1.28	168	100258
08:00	27.59	86.07	33	0	33	427.01	1.19	218	100301
09:00	27.96	86.51	176	81.1	147	427.36	1.22	223	100324
10:00	28.33	86.95	448	398.03	219	427.71	1.24	227	100347
11:00	28.69	87.39	644	505.91	262	428.06	1.27	230	100291
12:00	29.06	87.83	737	440.91	347	428.41	1.3	234	100235
13:00	29.43	88.26	642	186.4	464	428.76	1.33	238	100178
14:00	29.79	88.7	684	233	460	429.11	1.36	240	100135
15:00	30.16	89.14	412	28.78	386	429.46	1.39	242	100092
16:00	29.27	90.96	567	266.14	358	435.4	1.74	243	100049
17:00	28.9	91.96	537	577.51	182	435.42	1.56	200	100066
18:00	28.54	92.96	274	265.23	167	435.43	1.38	158	100082
19:00	28.17	93.96	56	24.12	52	435.45	1.2	115	100099
20:00	27.78	92.71	0	0	0	434.5	1.11	132	100159
21:00	27.39	91.45	0	0	0	433.55	1.03	150	100218
22:00	27	90.2	0	0	0	432.6	0.94	168	100278
23:00	26.56	91.22	0	0	0	429.8	0.92	170	100274

Terminology of Table 6

T2m	*2-m air temperature (°C)*
RH	*Relative Humidity (%)*
G(h)	*Global Irradiance on the Horizontal Plane (W/m^2)*
Gb(h)	*Beam/Direct Irradiance on a Plane Always Normal To Sunrays (W/m^2)*
Gd(h)	*Diffuse Irradiance on the Horizontal Plane (W/m^2)*
IR(h)	*Surface Infared (Thermal) Irradiance on a Horizontal Plane (W/m^2)*
WS10m	*10-m Total Wind Speed (m/s)*
WD10m	*10-m Wind Direction (0 = N, 90 = E) (°)*
SP	*Surface (Air) Pressure (Pa)*

The main data required for the battery sizing will be focusing on value G(h), where the global irradiance on the horizontal plane is used to determine the daily sunlight and the time of PV output.

For better accuracy and output, a full month of August 2014 G(h) value will be averaged from the time between 08:00 – 19:00, where the data shows PV generating electricity to the consumers. Figure 12 shows the average global irradiation in August 2014 from the time of 08:00 – 19:00:

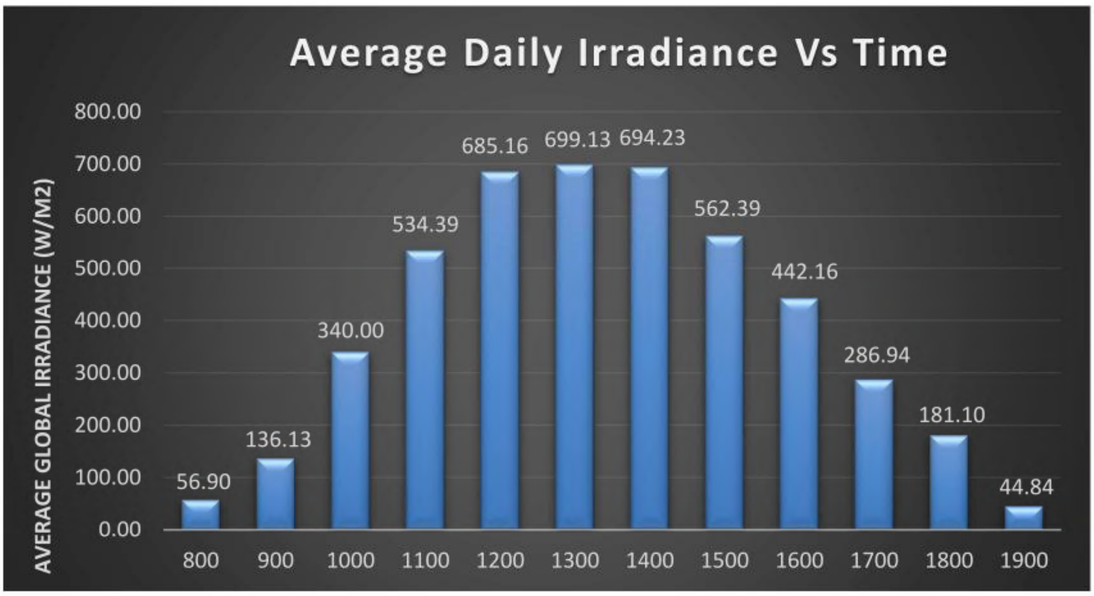


Figure 12: Average Daily Irradiance in August 2014 Between 08:00 – 19:00

It shows that the highest irradiance of the day is between 12:00 to 14:00 where the value exceeds 600 W/m^2. The PV is expected to generate electricity up to 4,600 W/m^2 a day.

A typical shopping mall's load profile will then be used as the term of reference for scheduling of battery charge and discharge. The projected MD for the shopping mall is 1.3 MW. Based on the PVGIS's solar irradiance profile and the load profile, we can design the battery sizes suitable for the development.

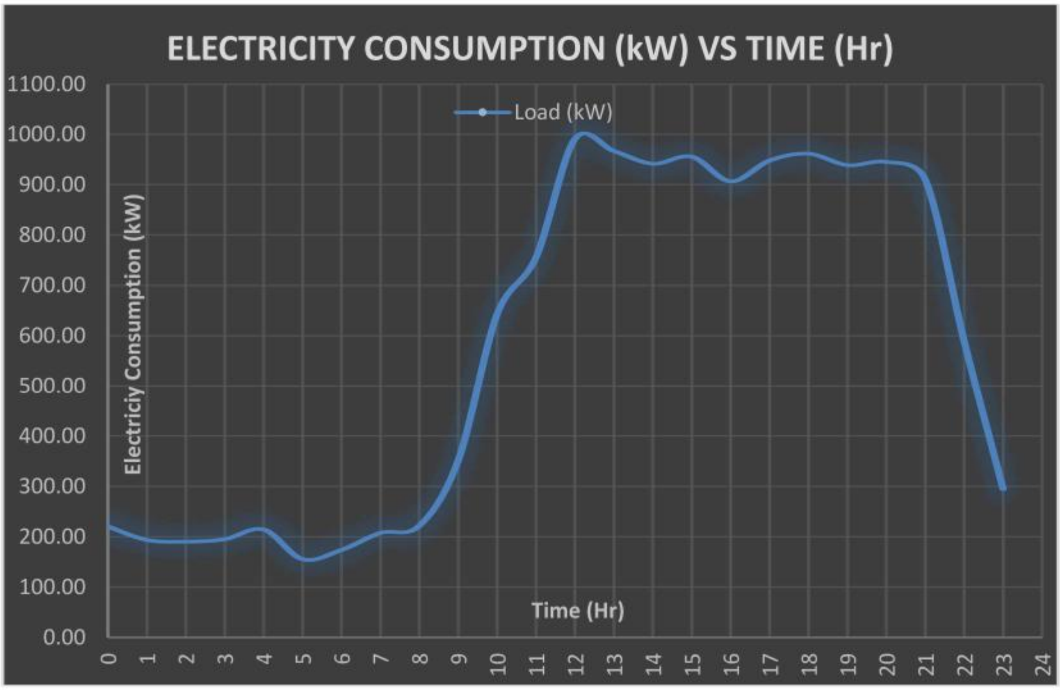


Figure 13: Typical Shopping Mall Load Profile

Based on Figure 13, we can see the load consumption for the building is low from the early hours 00:00 up to 09:00, this is understandable where the shopping mall will be running with minimum load to the building and most of the shopping complex operating hours starts from 10:00 to 03:00 with the Cinema operating at the end hours. The peak load of the consumption will be at midnight and gradually decreases for the next hour but maintaining at a very close load consumption throughout the day up to 21:00. Since most of the retail closing theirs shops at 22:00, the load can be seen drops fifty percent by the time 22:00.

A preliminary design of the battery storage system will be done according to the information above. Since the battery storage energy system affected the purpose, usage, and schedule, the design will be done in multiple scenarios.

Scenario 1

The battery storage system of this scenario is calculated with the design assuming the battery capacity at 2,500 kWh.

$$P = V * Ah \tag{9}$$

Where P is the battery design capacity at 2,500 kWh and V of the voltage system to be 24V.

$$2500k = 24V * Ah$$

$$Ah = \frac{2500k}{24} = 104{,}167\ Ah$$

With 12 series connection of 2V and 3000Ah each battery, the overall batteries required for 104,167Ah shall be:

$$\frac{104{,}167}{3000} = 34.72$$

Rounding the numbers to 35 parallel connections and 12 series. The summary of the design is shown in Table 7.

Table 7: Summary of Battery Storage Design (Scenario 1)

Description	**Overall**
Total Battery Used	417
Series Connection	12 Numbers
Parallel Connection	35 Numbers
Battery Capacity	104,167 Ah
Total Capacity	2,500 kWh
Battery Charging Hours	10Hr
Battery Type	Lead Acid
Battery Voltage	24V
Battery DOD	50%
Battery Efficiency	85%

The battery storage will be charged during the night, where the load of the development is low. From Figure 13, the 10 hours battery charging period fall in-between time 23:00 – 08:00, with each hour shall charge up to 250kW. The charged battery storage will then discharge to the load during the high peak in order to create "peak-shaving" at the highest load.

Scenario 2

In this scenario, the battery storage system will be designed based on the PV generation output. In Table 6 and Figure 12, the daily output from the PV can be derived. Table 10 shows the expected output based on 975kW capacity PV at each respective time between 08:00 – 19:00.

Table 8: PV Generation Output Between Time 08:00 – 19:00

Time (UTC+8)	Solar Irradiation (W/m^2)	PV Output (kW)
08:00	56.9	43.27
09:00	136.13	103.53
10:00	340	258.57
11:00	534.39	406.40
12:00	685.16	521.06
13:00	699.13	531.69
14:00	694.23	527.96
15:00	562.39	427.70
16:00	442.16	336.26
17:00	286.94	218.22
18:00	181.1	137.73
19:00	44.84	34.10
Total PV Generation in one (1) day		3,546.49 kW

With the total PV generation output in one day estimated, the battery shall be designed to the closest battery storage capacity possible. Using equation (9), where P is the battery design capacity at 7,000 kWh and V of the voltage system to be 24V. The capacity of the battery in Ah is shown below:

$$7000k = 24V * Ah$$

$$Ah = \frac{7000k}{24} = 291{,}667\ Ah$$

With 12 series connection of 2V and 3000Ah each battery, the overall batteries required for 291,667 Ah shall be:

$$\frac{291{,}667}{3000} = 97.22$$

Rounding the numbers to 97 parallel connection and 12 series. The summary of the design is shown in Table 11.

Table 9: Summary of Battery Storage Design (Scenario 2)

Description	**Overall**
Total Battery Used	1,164
Series Connection	12 Numbers
Parallel Connection	97 Numbers
Battery Capacity	291,667 Ah
Total Capacity	7,000 kWh
Battery Charging Hours	12Hr
Battery Type	Lead Acid
Battery Voltage	24V
Battery DOD	50%
Battery Efficiency	85%

However, in this scenario the battery charges according to the output of each hour of the solar irradiation instead. The charged battery will then discharge for peak shaving which mean that during the peak hour between time 11:00 – 21:00.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 NEM NOVA Without Battery Storage

With the PVsyst simulation, the results match the earlier preliminary calculation.

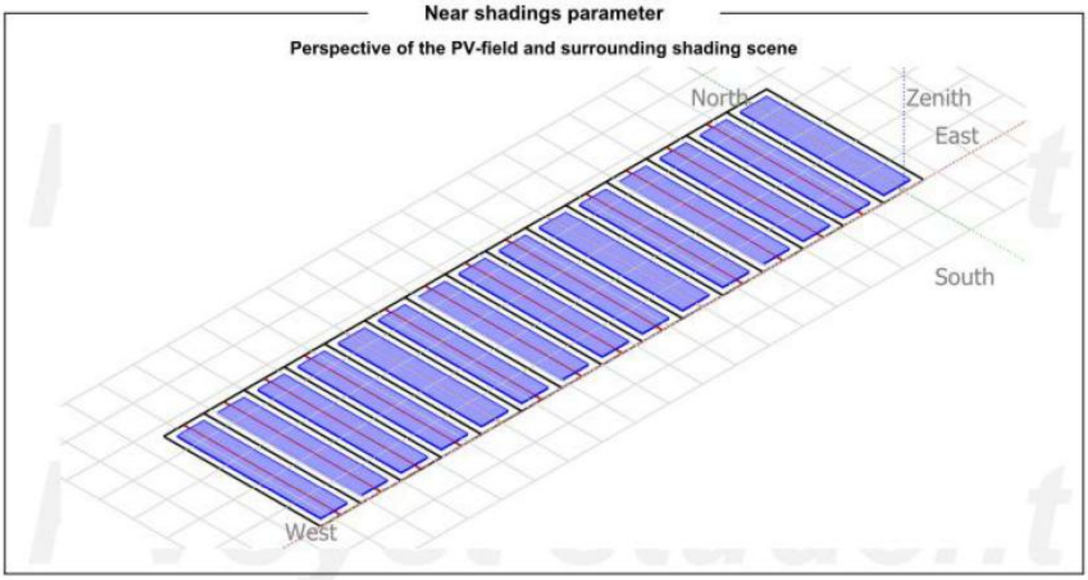


Figure 14: Perspective of the PV Arrangement

Figure 14 shows the arrangement of the solar PV via PVsyst perspective design.

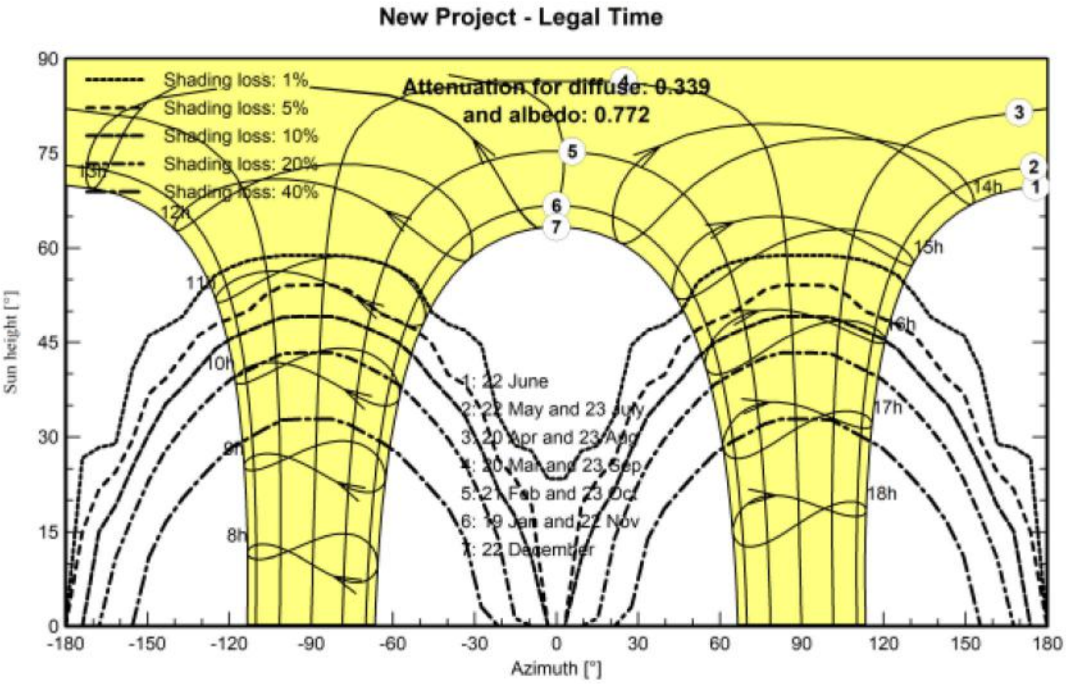


Figure 15: Shed Mutual Shading of the Site

Shading percentage from 1% losses up to 40% losses is shown in Figure 15.

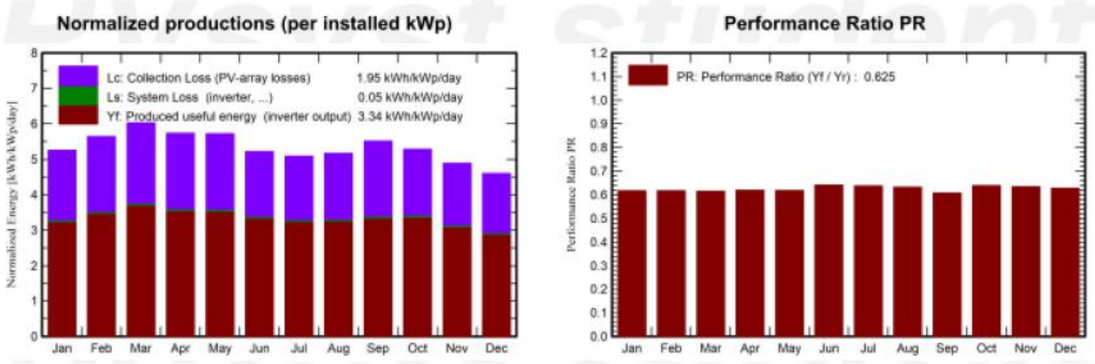


Figure 16: Normalized Production and Performance Ratio

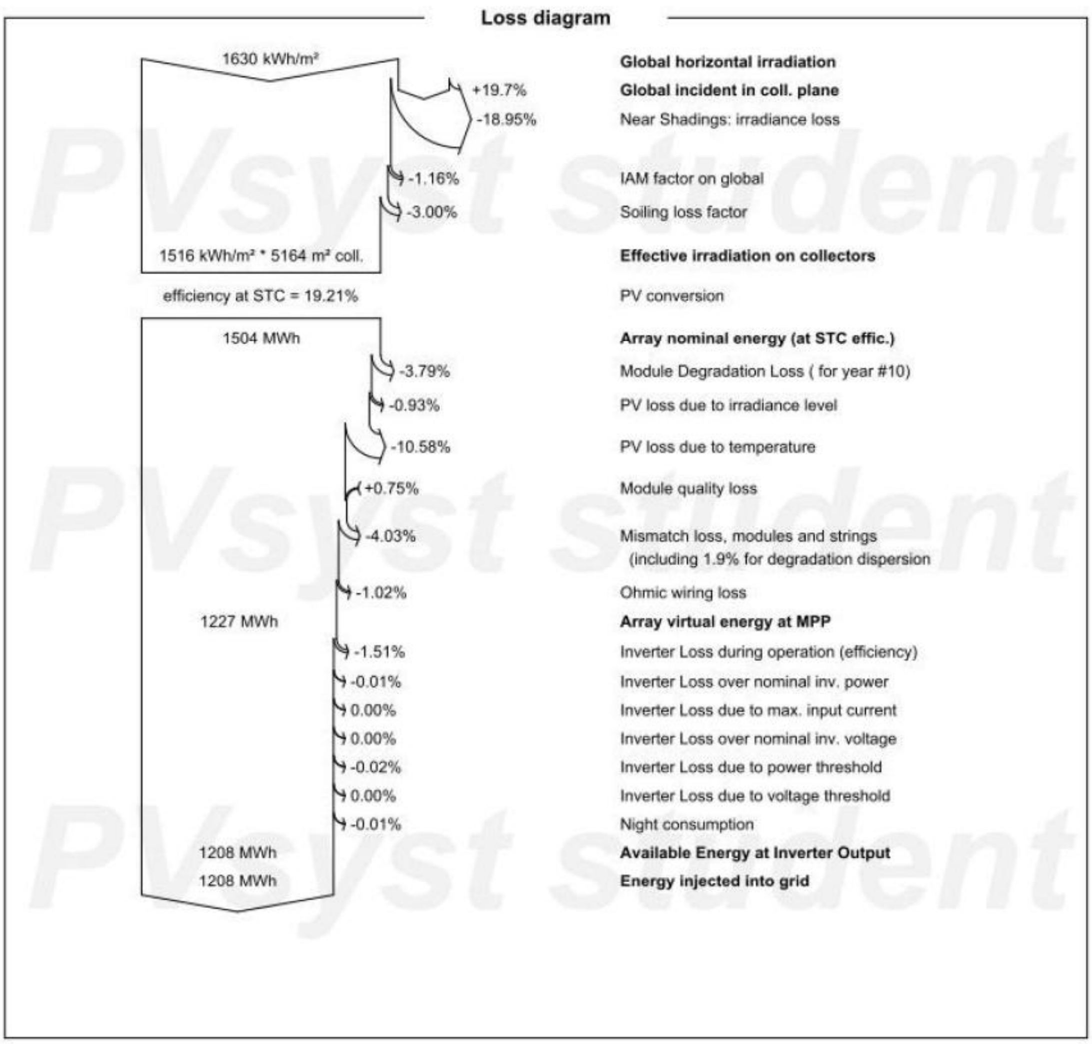


Figure 17: Loss Diagram

Based on Figure 16 and 17, we can see the total output of 1630 kWh//m^2 of global horizontal irradiation reduces along with the loss's parameters specified in the figure. The net output of the global horizontal irradiation is 1516 kWh/m^2 and the output is higher than the earlier calculation in the preliminary design. This may cause by higher performance ratio parameters.

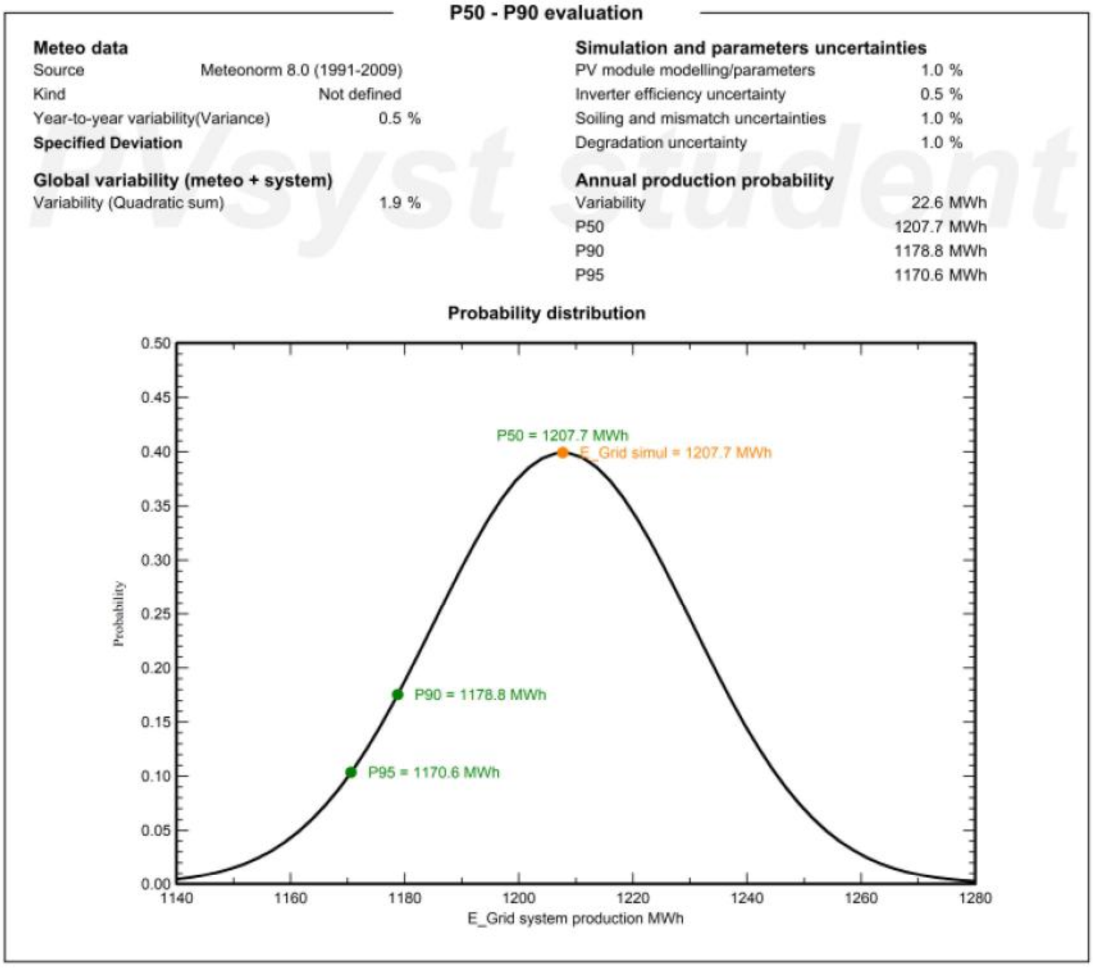
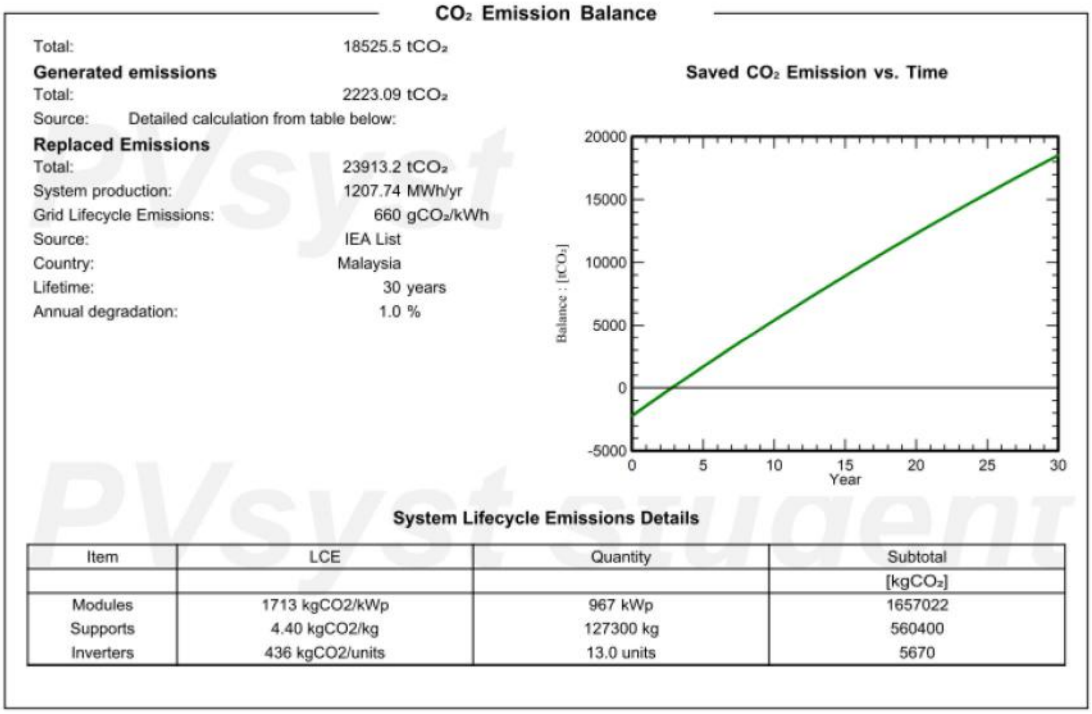


Figure 18: Evaluation Probability of Distribution

With the calculation of losses and net global horizontal irradiation output, the probability of the simulation shows that 50 percent that the development able to achieve 1,207.7 MWh, 90 percent that will goes above 1,178.8 MWh and 95 percent will produces 1,170.6 MWh. Figure 18 shows the overall probability of the distribution annually.



Item	LCE	Quantity	Subtotal [kgCO₂]
Modules	1713 kgCO2/kWp	967 kWp	1657022
Supports	4.40 kgCO2/kg	127300 kg	560400
Inverters	436 kgCO2/units	13.0 units	5670

Figure 19: CO_2 Emission Balance

With such a huge PV capacity installation, the development is expected to have bigger impact to the environment in saving CO_2 emission from the electricity consumption. Figure 19 shows that the system production of 1,207.74 MWh/ year, it is expected to have reduced at least 20,000 tCO_2. The full report generated via PVsyst is shown in Appendix C.

To sum up, the generated output of the software is very close to the values calculated in the manual calculation since the parameters used are similar including the solar modules and inverter selection.

4.1.1 Estimated Return of Investment (ROI) - For 25 years

NEM NOVA Without Battery Storage

PV Capacity :	990	kWp		
Investment Cost/W*:	2.80	RM/W		
Investment Cost:	(PV Capacity * Investment Cost) + NEMAS Fee			
	= 2,772,000.00	RM		
NEMAS Fee:	8,000.00	RM		
Total Investment Cost:	2,780,000.00			
Tariff Rate Applied:	0.365	RM/kWh		
Annual Electricity Yield:	1,258	kWh/year	or	kWp/year

Year	Energy Yield, MWh	Energy Cost Saving/ Year, RM/year	Acc. Cost Saving, RM	Expected Yearly Maintenance Fee, RM/year	Acc. Maintenance Fee, RM/year	PV Effciency	Net Saving Cost, RM/year	Acc. Net Saving Cost, RM/year	
1	1,226.55	447,690.75	447,690.75	8,953.82	8,953.82	0.975	438,736.94	438,736.94	
2	1,222.78	446,313.24	894,003.99	8,926.26	17,880.08	0.972	437,386.98	876,123.91	
3	1,220.26	445,394.90	1,339,398.89	8,907.90	26,787.98	0.970	436,487.00	1,312,610.91	
4	1,213.97	443,099.05	1,782,497.94	8,861.98	35,649.96	0.965	434,237.07	1,746,847.98	
5	1,207.68	440,803.20	2,223,301.14	8,816.06	44,466.02	0.960	431,987.14	2,178,835.12	
6	1,201.39	438,507.35	2,661,808.49	8,770.15	53,236.17	0.955	429,737.20	2,608,572.32	Payback Period
7	1,195.10	436,211.50	3,098,019.99	8,724.23	61,960.40	0.950	427,487.27	3,036,059.59	
8	1,188.81	433,915.65	3,531,935.64	8,678.31	70,638.71	0.945	425,237.34	3,461,296.93	
9	1,172.46	427,946.44	3,959,882.08	8,558.93	79,197.64	0.932	419,387.51	3,880,684.44	
10	1,163.65	424,732.25	4,384,614.33	8,494.65	87,692.29	0.925	416,237.61	4,296,922.04	
11	1,147.30	418,763.04	4,803,377.37	8,375.26	96,067.55	0.912	410,387.78	4,707,309.82	SELCO
12	1,141.01	416,467.19	5,219,844.56	8,329.34	104,396.89	0.907	408,137.85	5,115,447.67	
13	1,132.20	413,253.00	5,633,097.56	8,265.06	112,661.95	0.900	404,987.94	5,520,435.61	
14	1,128.43	411,875.49	6,044,973.05	8,237.51	120,899.46	0.897	403,637.98	5,924,073.59	
15	1,122.14	409,579.64	6,454,552.69	8,191.59	129,091.05	0.892	401,388.05	6,325,461.64	
16	1,115.85	407,283.79	6,861,836.48	8,145.68	137,236.73	0.887	399,138.11	6,724,599.75	
17	1,109.56	404,987.94	7,266,824.42	8,099.76	145,336.49	0.882	396,888.18	7,121,487.93	
18	1,104.52	403,151.26	7,669,975.68	8,063.03	153,399.51	0.878	395,088.23	7,516,576.17	
19	1,096.98	400,396.24	8,070,371.92	8,007.92	161,407.44	0.872	392,388.32	7,908,964.48	
20	1,090.69	398,100.39	8,468,472.31	7,962.01	169,369.45	0.867	390,138.38	8,299,102.86	
21	1,084.40	395,804.54	8,864,276.85	7,916.09	177,285.54	0.862	387,888.45	8,686,991.31	
22	1,075.59	392,590.35	9,256,867.20	7,851.81	185,137.34	0.855	384,738.54	9,071,729.86	
23	1,063.01	387,998.65	9,644,865.85	7,759.97	192,897.32	0.845	380,238.68	9,451,968.53	
24	1,052.95	384,325.29	10,029,191.14	7,686.51	200,583.82	0.837	376,638.78	9,828,607.32	
25	1,045.40	381,570.27	10,410,761.41	7,631.41	208,215.23	0.831	373,938.86	10,202,546.18	

Figure 20: Estimated ROI NEM NOVA Without Battery Storage

Note:

**Investment Cost based on reference from NEM Calculator provided by SEDA. Where, 991.5kWp proposed capacity installation, estimated cost at RM2,776,200. Hence, cost in RM/W = RM 2,776,200/ 991,500W = RM2.80. Appendix D shows the preliminary cost of solar PV installation by SEDA.*

***Above cost saving excluded the consideration below:*

i) ITA Tax saving which could be up to 24% savings.

ii) CA Tax saving which could be up to 24% savings.

iii) Electricity tariff adjustment (usually increase in tariff rate every few year)

Based on the investment cost above, the expected payback period shall fall between Year 6 and Year 7, where the savings per year accumulated at Year 6 is RM 2,554,336.63 and RM2,965,776.31 for Year 7.

With total capacity installed at 990 kW for the development, the energy savings per year shall provide a breakeven point at 6.5 years, leaving 3.5 years before SELCO implementation. Figure 20 shows that the savings accumulated are insufficient to cover the development's electricity consumption with a huge gap between the generation and consumption. Hence, there will be no electricity generated excessively for NEM purposes for reselling the electricity.

At Year 11, the SELCO implementation will be implemented without the NOVA NEM scheme for the development. The tabulation shows that the development continues to enjoy electricity bill saving for the next 15 years at an average of approximately RM360,000 each year during the SELCO scheme. This shows that the Solar PV benefits the development even without the NOVA NEM.

Simple LCOE

$$\frac{\text{Total Investment Cost + Operation Cost}}{\text{Total Energy Yield}}$$

$$\frac{2{,}988{,}215.23}{28{,}522{,}634.00} = 0.105 \text{ RM/kWh}$$

A simple LCOE calculation shows that the NEM NOVA scheme without battery storage is generating electricity at the cost of 0.105 RM/kWh compared to TNB's tariff at 0.365 RM/kWh.

4.2 NEM NOVA With Battery Storage

Scenario 1

With the solar PV generation and battery storage system supply to the development's load, we are able to bring down the overall load to a maximum of 655kW compared to the highest MD ranging from 700 – 800 kW. Table 12 shows the summary of the load after compensation from PV generation output and battery storage discharge.

Table 10: Load Summary After Compensation (Scenario 1)

Time (24hr)	(kW)					
	Load	Load +Battery	PV Load	Load-PV	(Load-PV)-PS	Load Shaved
00:00	220.23	470.23	0	220.23	220.23	0
01:00	193.58	443.58	0	193.58	193.58	0
02:00	190.22	440.22	0	190.22	190.22	0
03:00	195.08	445.08	0	195.08	195.08	0
04:00	214.28	464.28	0	214.28	214.28	0
05:00	155.36	405.36	0	155.36	155.36	0
06:00	173.81	423.81	0	173.81	173.81	0
07:00	207.56	457.56	0	207.56	207.56	0
08:00	221.84	471.84	43.27	178.56	178.56	0
09:00	351.45	0	103.53	247.93	247.93	0
10:00	642.68	0	258.57	384.11	384.11	0
11:00	755.87	0	406.4	349.47	349.47	0
12:00	990.74	0	521.06	469.67	469.67	0
13:00	966.58	0	531.69	434.89	434.89	0
14:00	941.52	0	527.96	413.56	413.56	0
15:00	955.46	0	427.70	527.77	527.77	0
16:00	906.51	0	336.26	570.25	570.25	0
17:00	947.85	0	218.22	729.63	655.00	74.63
18:00	961.36	0	137.73	823.63	655.00	168.63
19:00	938.68	0	34.10	904.58	655.00	249.58
20:00	945.00	0	0	945.00	655.00	290.00
21:00	909.81	0	0	909.81	655.00	254.81
22:00	588.28	0	0	588.28	588.28	0
23:00	294.43	544.43	0	294.43	294.43	0

With the battery storage system of designed capacity at 2,500 kWh, the battery DOD and efficiency contribute to additional losses to the electricity supply. Hence, 2,500 kWh is providing a net output of approximately 1,062.5 kWh. With this amount generated, the battery storage is then used to shave the peak MD of the development to a maximum of 655 kW.

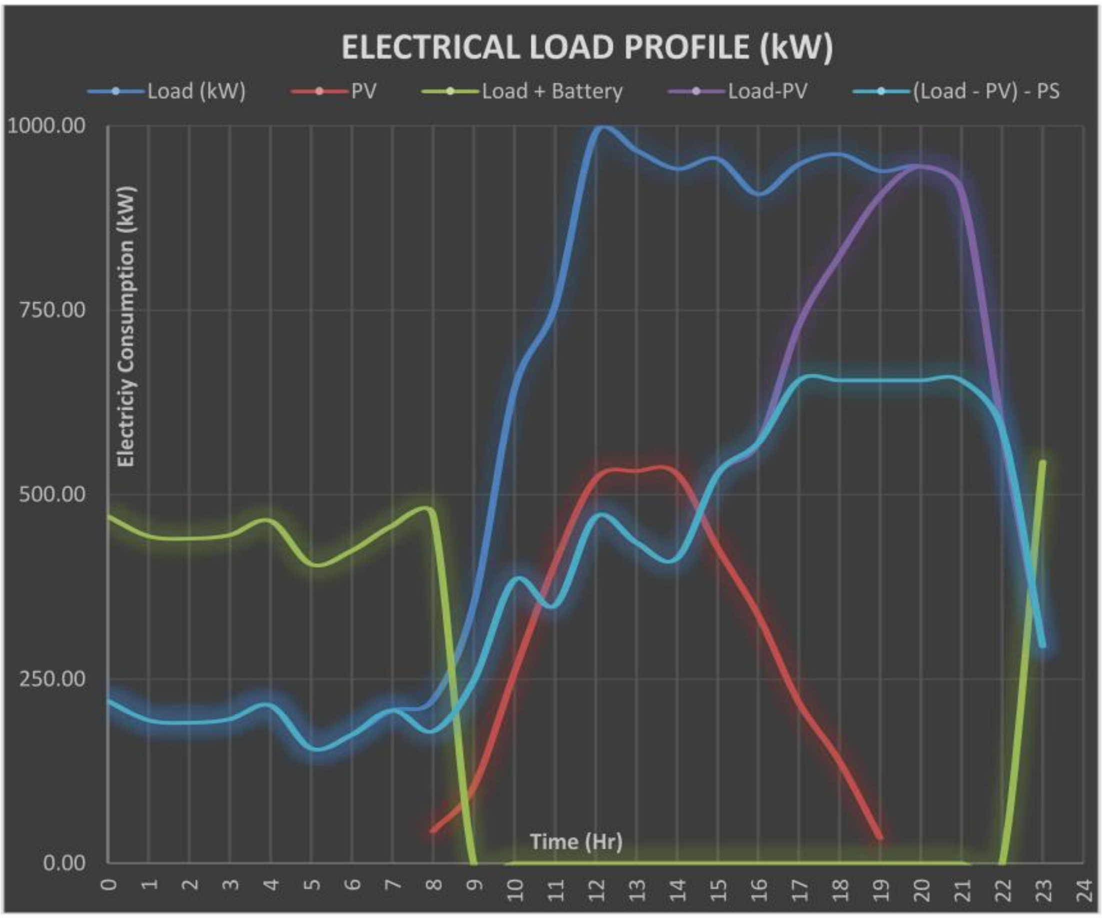


Figure 21: Electrical Load Profile (Scenario 1)

Figure 21 shows the electrical load profile with each compensation. From "Load (kW)" which shows the original load profile to the "PV" showing the solar PV generation output and the load increment after using night hours to charge the battery "Load + Battery". Then, the "Load – PV" shows the original load profile after compensating with PV-generated output. Lastly, the "(Load – PV) – PS" indicates the final load profile using the battery discharge bringing down the MD.

Scenario 2

From the generated electricity from the PV, the development will then use it to charge the battery. Unlike Scenario 1, the capacity of the battery storage system is then increased to 7,000 kWh based on the full output of the PV capacity.

Table 11: Load Summary After Compensation (Scenario 2)

Time (UTC +8)	(kW)			
	Load	PV Load	Load – Peak Shaving	Shaved Load
00:00	220.23	0	220.23	0
01:00	193.58	0	193.58	0
02:00	190.22	0	190.22	0
03:00	195.08	0	195.08	0
04:00	214.28	0	214.28	0
05:00	155.36	0	155.36	0
06:00	173.81	0	173.81	0
07:00	207.56	0	207.56	0
08:00	221.84	43.27	221.84	0
09:00	351.45	103.53	351.45	0
10:00	642.68	258.57	642.68	0
11:00	755.87	406.4	660.00	95.87
12:00	990.74	521.06	660.00	330.74
13:00	966.58	531.69	660.00	306.58
14:00	941.52	527.96	660.00	281.52
15:00	955.46	427.70	660.00	295.46
16:00	906.51	336.26	660.00	246.51
17:00	947.85	218.22	660.00	287.85
18:00	961.36	137.73	660.00	301.36
19:00	938.68	34.10	660.00	278.68
20:00	945.00	0	660.00	285.00
21:00	909.81	0	660.00	249.81
22:00	588.28	0	588.28	0
23:00	294.43	0	294.43	0

Since the battery storage system design capacity increases to 7,000 kWh, the required amount of charging time now increases according to the PV generation electricity hours. The amount charges are also according to the "PV Load" in Table 11, where the charging hours range from 34.10 kW up to 531.69 kW between the time 08:00 – 19:00.

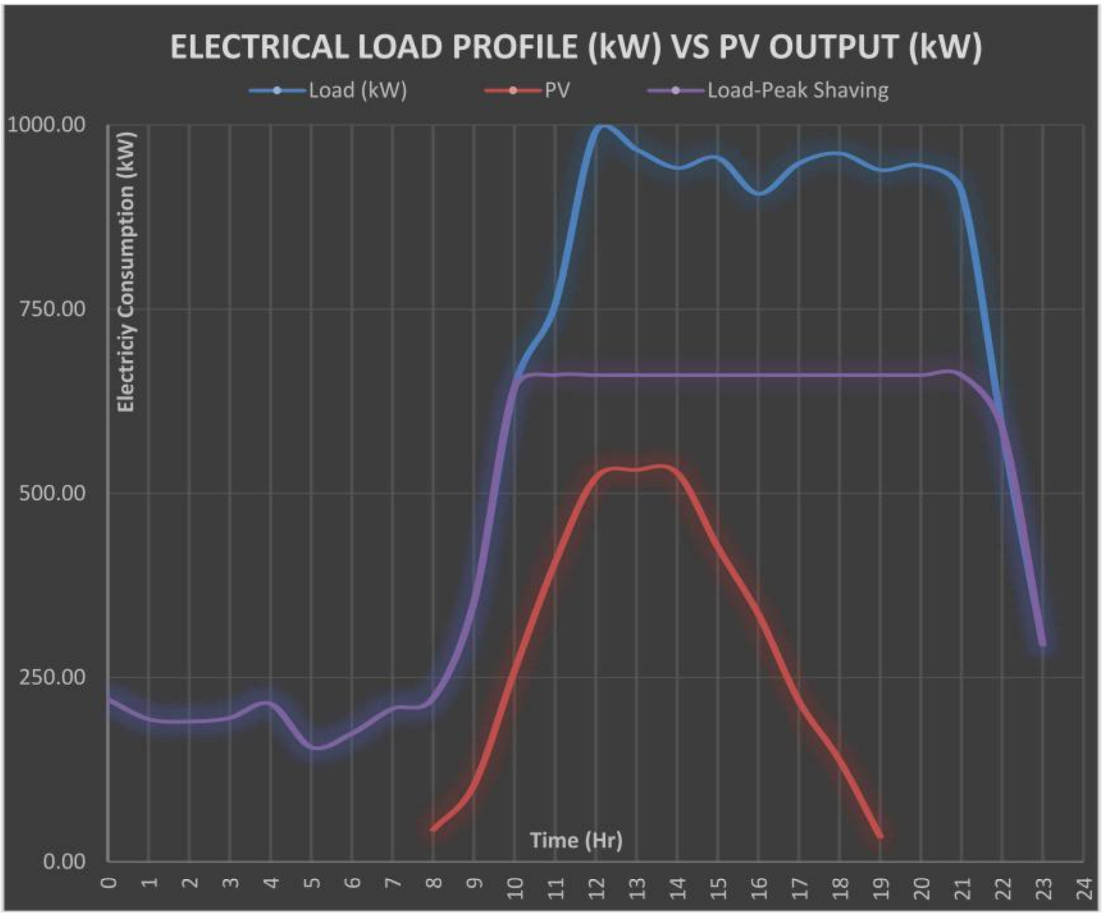


Figure 22: Electrical Load Profile (Scenario 2)

Figure 22 now shows the load profile after peak shaving with the battery storage system. In this scenario, the peak shaving at 660 kW with longer discharge hours from time 12:00 to 21:00. This will then keep the MD for the development not exceeding 660 kW in order to achieve savings.

4.2.1 Estimated Return of Investment (ROI) – For 25 years

NEM NOVA With Battery Storage (Scenario 1)

PV Capacity	:	975	kWp		
Investment Cost/W*	:	2.80	RM/W		
Investment Cost	:	(PV Capacity * Investment Cost) + NEMAS Fee			
		= 2,730,000.00	RM		
NEMAS Fee	:	8,000.00	RM		
Battery Storage Cost	:	875,700.00	RM		
Total Investment Cost	:	3,613,700.00			
Tariff Rate Applied	:	0.365	RM/kWh		
Annual Electricity Yield	:	1,240	MWh/year	or	MWp/year

Year	Energy Yield, MWh	Energy Cost Saving/ Year, RM/year	Acc. Cost Saving, RM	Expected Yearly Maintenance Fee, RM/year	Acc. Maintenance Fee, RM/year	PV Effciency	Net Saving Cost, RM/year	Acc. Net Saving Cost, RM/year
1	1,209.00	441,285.00	441,285.00	8,825.70	8,825.70	0.975	432,459.30	432,459.30
2	1,205.28	439,927.20	881,212.20	8,798.54	17,624.24	0.972	431,128.66	863,587.96
3	1,202.80	439,022.00	1,320,234.20	8,780.44	26,404.68	0.970	430,241.56	1,293,829.52
4	1,196.60	436,759.00	1,756,993.20	300,635.18	327,039.86	0.965	136,123.82	1,429,953.34
5	1,190.40	434,496.00	2,191,489.20	300,589.92	627,629.78	0.960	133,906.08	1,563,859.42
6	1,184.20	432,233.00	2,623,722.20	300,544.66	928,174.44	0.955	131,688.34	1,695,547.76
7	1,178.00	429,970.00	3,053,692.20	300,499.40	1,228,673.84	0.950	129,470.60	1,825,018.36
8	1,171.80	427,707.00	3,481,399.20	300,454.14	1,529,127.98	0.945	127,252.86	1,952,271.22
9	1,155.68	421,823.20	3,903,222.40	300,336.46	1,829,464.45	0.932	121,486.74	2,073,757.95
10	1,147.00	418,655.00	4,321,877.40	300,273.10	2,129,737.55	0.925	118,381.90	2,192,139.85
11	1,130.88	412,771.20	4,734,648.60	300,155.42	2,429,892.97	0.912	112,615.78	2,304,755.63
12	1,124.68	410,508.20	5,145,156.80	300,110.16	2,730,003.14	0.907	110,398.04	2,415,153.66
13	1,116.00	407,340.00	5,552,496.80	300,046.80	3,030,049.94	0.900	107,293.20	2,522,446.86
14	1,112.28	405,982.20	5,958,479.00	300,019.64	3,330,069.58	0.897	105,962.56	2,628,409.42
15	1,106.08	403,719.20	6,362,198.20	299,974.38	3,630,043.96	0.892	103,744.82	2,732,154.24
16	1,099.88	401,456.20	6,763,654.40	299,929.12	3,929,973.09	0.887	101,527.08	2,833,681.31
17	1,093.68	399,193.20	7,162,847.60	299,883.86	4,229,856.95	0.882	99,309.34	2,932,990.65
18	1,088.72	397,382.80	7,560,230.40	299,847.66	4,529,704.61	0.878	97,535.14	3,030,525.79
19	1,081.28	394,667.20	7,954,897.60	299,793.34	4,829,497.95	0.872	94,873.86	3,125,399.65
20	1,075.08	392,404.20	8,347,301.80	299,748.08	5,129,246.04	0.867	92,656.12	3,218,055.76
21	1,068.88	390,141.20	8,737,443.00	299,702.82	5,428,948.86	0.862	90,438.38	3,308,494.14
22	1,060.20	386,973.00	9,124,416.00	299,639.46	5,728,588.32	0.855	87,333.54	3,395,827.68
23	1,047.80	382,447.00	9,506,863.00	299,548.94	6,028,137.26	0.845	82,898.06	3,478,725.74
24	1,037.88	378,826.20	9,885,689.20	299,476.52	6,327,613.78	0.837	79,349.68	3,558,075.42
25	1,030.44	376,110.60	10,261,799.80	299,422.21	6,627,036.00	0.831	76,688.39	3,634,763.80

Figure 23: Estimated ROI NEM NOVA With Battery Storage (Scenario 1)

Note:

**Investment Cost RM2.80/W as per Estimate ROI for NEM NOVA Without Battery Storage. Battery Cost estimated based on online source at approximately RM2,100 each.*

***Above cost saving excluded the consideration below:*

i) ITA Tax saving which could be up to 24% savings.

ii) CA Tax savings which could be up to 24% savings.

iii) Electricity tariff adjustment (usually increase in tariff rate every few years)

**** Battery cost expected to replace every 3 years (battery price subject to decrease every few years)*

Based on Figure 23, the ROI shows that with the battery storage system installed, the consumer was only able to get the return of investment for PV installation at RM 3,613,700.00. With the additional battery storage system cost and higher yearly maintenance. The consumer will only be able to get their payback period at Year 25, at RM 3,634,763.80 accumulated savings.

Simple LCOE

$$\frac{\text{Total Investment Cost + Operation Cost}}{\text{Total Energy Yield (25 Years)}}$$

$$\frac{10{,}240{,}736.00}{28{,}114{,}520.00} = 0.364 \quad \text{RM/ kWh}$$

Simple LCOE shows that the consumer is generating electricity cost at 0.364 RM/kWh which is slightly lower than the electricity cost purchased from TNB at 0.001 RM/kWh.

NEM NOVA With Battery Storage (Scenario 2)

PV Capacity	:	975	kWp		
Investment Cost/W*	:	2.80	RM/W		
Investment Cost	:	(PV Capacity * Investment Cost) + NEMAS Fee			
		= 2,730,000.00	RM		
NEMAS Fee	:	8,000.00	RM		
Battery Storage Cost	:	2,444,400.00	RM		
Total Investment Cost	:	5,182,400.00			
Tariff Rate Applied	:	0.365	RM/kWh		
Annual Electricity Yield	:	1,240	MWh/year	or	MWp/year

Year	Energy Yield, MWh	MD Saving Cost, RM/year	Acc. Cost Saving, RM	Expected Yearly Maintenance Fee, RM/year	Acc. Maintenance Fee, RM/year	PV Effciency	Net Saving Cost, RM/year	Acc. Net Saving Cost, RM/year
1	1,209.00	69,353.06	69,353.06	8,825.70	8,825.70	0.975	60,527.36	60,527.36
2	1,205.28	69,353.06	138,706.12	8,798.54	17,624.24	0.972	60,554.52	121,081.88
3	1,202.80	69,353.06	208,059.18	8,780.44	26,404.68	0.970	60,572.62	181,654.50
4	1,196.60	69,353.06	277,412.24	705,378.12	731,782.80	0.965	-636,025.06	-454,370.56
5	1,190.40	69,353.06	346,765.30	705,332.86	1,437,115.66	0.960	-635,979.80	-1,090,350.36
6	1,184.20	69,353.06	416,118.36	705,287.60	2,142,403.26	0.955	-635,934.54	-1,726,284.90
7	1,178.00	69,353.06	485,471.42	705,242.34	2,847,645.60	0.950	-635,889.28	-2,362,174.18
8	1,171.80	69,353.06	554,824.48	705,197.08	3,552,842.68	0.945	-635,844.02	-2,998,018.20
9	1,155.68	69,353.06	624,177.54	705,079.40	4,257,922.09	0.932	-635,726.34	-3,633,744.55
10	1,147.00	69,353.06	693,530.60	705,016.04	4,962,938.13	0.925	-635,662.98	-4,269,407.53
11	1,130.88	69,353.06	762,883.66	704,898.36	5,667,836.49	0.912	-635,545.30	-4,904,952.83
12	1,124.68	69,353.06	832,236.72	704,853.10	6,372,689.60	0.907	-635,500.04	-5,540,452.88
13	1,116.00	69,353.06	901,589.78	704,789.74	7,077,479.34	0.900	-635,436.68	-6,175,889.56
14	1,112.28	69,353.06	970,942.84	704,762.58	7,782,241.92	0.897	-635,409.52	-6,811,299.08
15	1,106.08	69,353.06	1,040,295.90	704,717.32	8,486,959.24	0.892	-635,364.26	-7,446,663.34
16	1,099.88	69,353.06	1,109,648.96	704,672.06	9,191,631.31	0.887	-635,319.00	-8,081,982.35
17	1,093.68	69,353.06	1,179,002.02	704,626.80	9,896,258.11	0.882	-635,273.74	-8,717,256.09
18	1,088.72	69,353.06	1,248,355.08	704,590.60	10,600,848.71	0.878	-635,237.54	-9,352,493.63
19	1,081.28	69,353.06	1,317,708.14	704,536.28	11,305,384.99	0.872	-635,183.22	-9,987,676.85
20	1,075.08	69,353.06	1,387,061.20	704,491.02	12,009,876.02	0.867	-635,137.96	-10,622,814.82
21	1,068.88	69,353.06	1,456,414.26	704,445.76	12,714,321.78	0.862	-635,092.70	-11,257,907.52
22	1,060.20	69,353.06	1,525,767.32	704,382.40	13,418,704.18	0.855	-635,029.34	-11,892,936.86
23	1,047.80	69,353.06	1,595,120.38	704,291.88	14,122,996.06	0.845	-634,938.82	-12,527,875.68
24	1,037.88	69,353.06	1,664,473.44	704,219.46	14,827,215.52	0.837	-634,866.40	-13,162,742.08
25	1,030.44	69,353.06	1,733,826.50	704,165.15	15,531,380.68	0.831	-634,812.09	-13,797,554.18

Figure 24: Estimated ROI NEM NOVA With Battery Storage (Scenario 2)

The estimated ROI for Scenario 2 shows that the consumer not only is not able to retrieve the invested cost, the consumer also sees their losses every year due to higher capital investment cost and maintenance cost of the batteries.

Simple LCOE

$$\frac{\text{Total Investment Cost + Operation Cost}}{\text{Total Energy Yield (25 Years)}}$$

$$\frac{20{,}713{,}780.68}{28{,}114{,}520.00} = 0.737 \quad \text{RM/ kWh}$$

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In summary, PV investment brings huge cost savings to the consumers and the cost of investing in PV is becoming cheaper with a faster rate of investment. The analysis shows that the consumers can find a payback period of 6.5 years and benefit from savings for another 18 years. Although the solar PV efficiency declines gradually over time, on the datasheet the module can maintain an efficiency of more than eighty percent throughout the 25 years. Commercial consumer PV systems like shopping centers cannot benefit from the NEM scheme with battery storage system. The main reason is that the load consumption in this category is very high compared to the solar PV capacity output that can be installed in the building. If the solar PV capacity cannot be increased beyond the MD consumption of 75 percent, there will be no excess electricity generated for the battery storage system, unless, the consumer take consideration charging via supply grid and discharge during peak hour of the consumption as analyzed in Scenario 1. The consumer then able to enjoy saving electricity from peak shaving but with the cost of replacing batteries over the years of usage. Even after 10 years under the NEM NOVA scheme, the consumer then switch to the SELCO scheme, which they will enjoy the same savings compared to the NEM NOVA scheme.

Similarly, with a battery storage system, the consumer has to increase the capital cost for the system, which extends the payback period at least twice as long as the payback period of solar PV without battery storage. This is where the development may require additional funding such as bank loans which directly increase the cost of the system. Any ROI which takes more than 10 years is considered long and most consumers will not invest in such a long ROI especially for PV systems with battery storage, where the equipment wear and tear started at 15 years or so.

To fully utilize the solar PV integrated with battery storage system under the NEM NOVA scheme, the consumer requires an in-depth study in the development's load profile and propose a suitable battery capacity and load scheduling such as charging hours, discharge hours, electrical load shaving of MD and also the cost of the system. Based on Scenario 1, the development can achieve savings if both the PV and battery storage are used to compensate for the electrical load consumption of the building. However, the amount of savings gained is not sufficient to accumulate to the total of money invested in the system. The consumer will require a longer period than the expected 25 year period to fully get their hands on the return of investment. Whereas for Scenario 2, the consumers are barely achieving little to no savings, and it shows that the consumer suffered losses every year by using the solar PV generated electricity to charge the battery and then to compensate the development's electrical consumption.

The study and analysis can meet the aims and objectives in providing the feasibility data to the commercial consumers in the solar PV installation under the NEM NOVA scheme. The cost effectiveness under the NEM NOVA scheme shows that consumers are able to gain profits with or without the battery storage system integrated with the PV and the accumulative profits may continue further under the SELCO scheme.

5.2 Recommendations

Although generally, the NEM NOVA scheme with and without a battery storage system seems to be beneficial to the consumers, not all categories of consumers may be able to enjoy full savings with such an arrangement. It is recommended that a proper study of the consumer's category based on the footprint of the buildings, load consumption, load profile, and investment cost required before selecting the correct scheme and system for their development. The consumers may also consider installing an off-grid solar PV system to break through the limitation set by the guideline for the NEM NOVA applicants. This allows the consumers to install a higher capacity of solar PV. In the analysis, the installation of the PV is on the rooftop considering the allowance of vehicle movement and parking spaces, if the development structure allows, the solar PV can be installed fully on top of the rooftop under a new layer of structure maximizing the footprint and gaining bigger capacity for the solar PV. The consumers must understand all the criteria and parameters of their usage in conjunction with the solar PV system installed for their development.

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APPENDICES

Smart String Inverter

SUN2000-60KTL-HV-D1-001

Smart

- 8 strings intelligent monitoring and fast trouble-shooting
- Power Line Communication (PLC) supported
- Smart I-V Curve Diagnosis supported

Efficient

- Max. efficiency 99.0%
- European efficiency 98.8%
- 4 MPPT per unit, effectively reducing string mismatch

Safe

- DC switch integrated, safe and convenient for maintenance
- Residual Current Monitoring Unit (RCMU) integrated
- Fuse free design

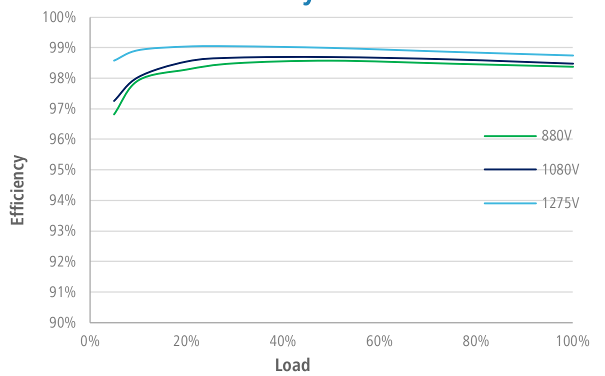
Reliable

- Natural cooling technology
- Protection degree of IP65
- Type II surge arresters for both DC and AC

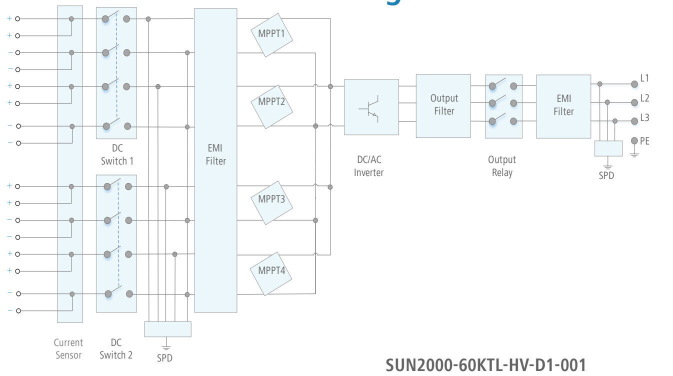
Smart String Inverter (SUN2000-60KTL-HV-D1-001)

Technical Specifications	SUN2000-60KTL-HV-D1-001
	Efficiency
Max. Efficiency	99.0%
European Efficiency	98.8%
	Input
Max. Input Voltage	1,500 V
Max. Current per MPPT	22 A
Max. Short Circuit Current per MPPT	30 A
Start Voltage	650 V
MPPT Operating Voltage Range	600 V ~ 1,450 V
Rated Input Voltage	1,080 V
Number of Inputs	8
Number of MPP Trackers	4
	Output
Rated AC Active Power	60,000 W
Max. AC Apparent Power	66,000 VA
Max. AC Active Power (cosΦ=1)	66,000 W
Rated Output Voltage	800 V, 3W + PE
Rated AC Grid Frequency	50 Hz / 60 Hz
Rated Output Current	43.3 A
Max. Output Current	48 A
Adjustable Power Factor Range	0.8 LG ... 0.8 LD
Max. Total Harmonic Distortion	< 3%
	Protection
Input-side Disconnection Device	Yes
Anti-islanding Protection	Yes
AC Overcurrent Protection	Yes
DC Reverse-polarity Protection	Yes
PV-array String Fault Monitoring	Yes
DC Surge Arrester	Type II
AC Surge Arrester	Type II
DC Insulation Resistance Detection	Yes
Residual Current Monitoring Unit	Yes
	Communication
Display	LED Indicators, Bluetooth + APP
RS485	Yes
USB	Yes
Power Line Communication (PLC)	Yes
	General
Dimensions (W x H x D)	930 x 600 x 270 mm (36.6 x 23.6 x 10.6 inch)
Weight (with mounting plate)	62 kg (136.7 lb.)
Operating Temperature Range	-25°C ~ 60°C (-13°F ~ 140°F)
Cooling Method	Natural Convection
Max. Operating Altitude	4,000 m (13,123 ft.)
Relative Humidity	0 ~ 100%
DC Connector	Amphenol UTX
AC Connector	Waterproof PG Terminal + OT Connector
Protection Degree	IP65
Topology	Transformerless
	Standard Compliance *(more available upon request)*
Certificate	EN 62109-1/-2, IEC 62109-1/-2, EN 50530, IEC 62116, IEC 60068, IEC 61683
Grid Code	IEC61727, G59/3, PEA, Resolution No. 07

Efficiency Curve



Circuit Diagram



SUN2000-60KTL-HV-D1-001

JinKO Solar
Building Your Trust in Solar

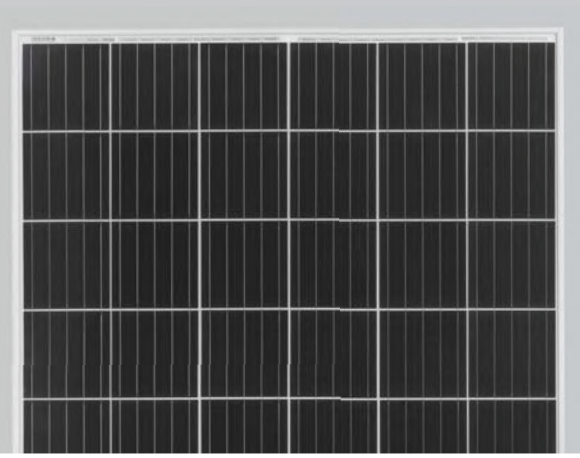
Cheetah 72M
380-400 Watt
MONO PERC MODULE

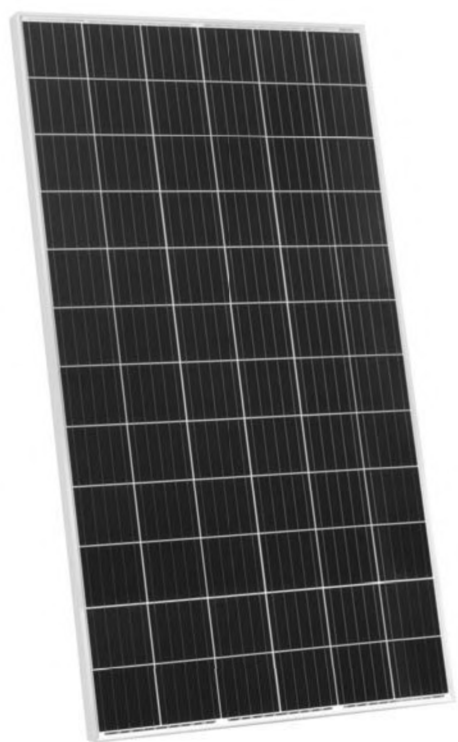
Positive power tolerance of 0~+3%

ISO9001:20015, ISO14001:2015, OHSAS18001 certified factory

IEC61215, IEC61730, UL1703 certified product

PERC
Cheetah





KEY FEATURES

5 Busbar Solar Cell
5 busbar solar cell adopts new technology to improve the efficiency of modules , offers a better aesthetic appearance, making it perfect for rooftop installation.

High Efficiency
Higher module conversion efficiency (up to 20.17%) benefit from Passivated Emmiter Rear Contact (PERC) technology.

PID Resistance
Excellent Anti-PID performance guarantee limited power degradation for mass production.

Low-light Performance:
Advanced glass and surface texturing allow for excellent performance in low-light environment.

Severe Weather Resilience
Certified to withstand: wind load (2400 Pascal) and snow load (5400 Pascal).

Durability Against Extreme Environmental Conditions
High salt mist and ammonia resistance certified by TUV NORD.

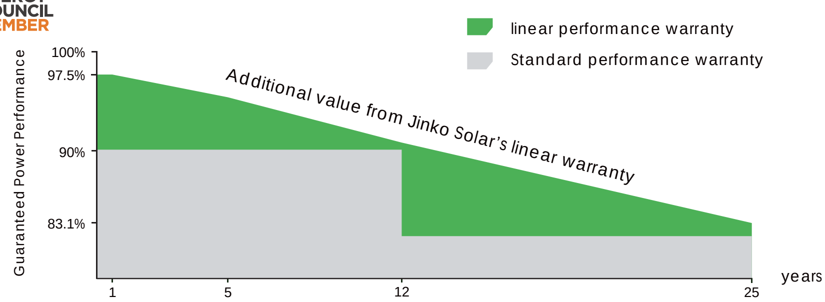
LINEAR PERFORMANCE WARRANTY

12 Year Product Warranty • 25 Year Linear Power Warranty

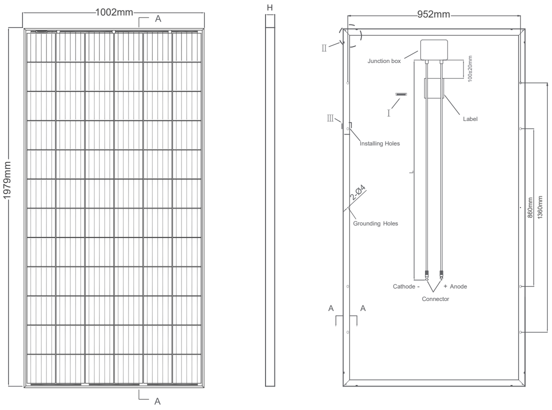
PV CYCLE · TÜVRheinland CERTIFIED · CE · POSITIVE QUALITY Continuous Quality Assurance · CLEAN ENERGY COUNCIL MEMBER

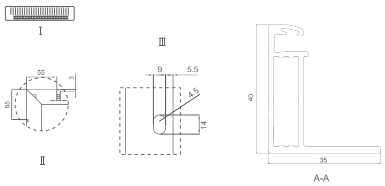
Nomenclature:
JKMxxxM-60/72H-V

Code	Cell		Code	Certification
null	Full		null	1000V
H	Half		V	1500V



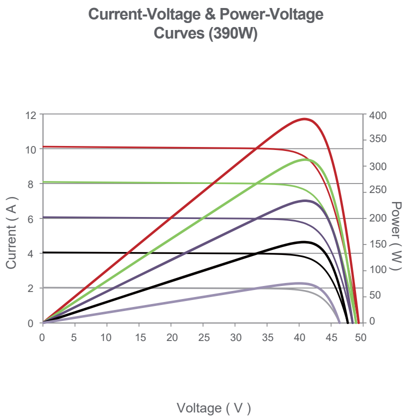
Engineering Drawings

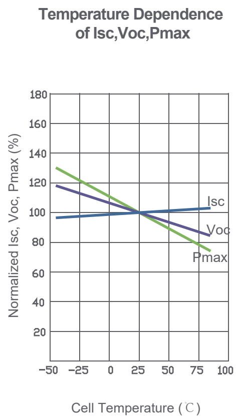




Lenth: ±2mm
Width: ±2mm
Height: ±1mm
Row Pitch: ±2mm

Electrical Performance & Temperature Dependence





Packaging Configuration

(Two pallets=One stack)

27pcs/pallet, 54pcs/stack, 594pcs/40'HQ Container

Mechanical Characteristics

Cell Type	Mono PERC 158.75×158.75mm
No.of cells	72 (6×12)
Dimensions	1979×1002×40mm (77.91×39.45×1.57 inch)
Weight	22.5 kg (49.6 lbs)
Front Glass	3.2mm, Anti-Reflection Coating, High Transmission, Low Iron, Tempered Glass
Frame	Anodized Aluminium Alloy
Junction Box	IP67 Rated
Output Cables	TÜV 1×4.0mm², Length 900/1200mm or Customized Length

SPECIFICATIONS

Module Type	JKM380M-72 JKM380M-72-V		JKM385M-72 JKM385M-72-V		JKM390M-72 JKM390M-72-V		JKM395M-72 JKM395M-72-V		JKM400M-72 JKM400M-72-V	
	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT
Maximum Power (Pmax)	380Wp	286Wp	385Wp	290Wp	390Wp	294Wp	395Wp	298Wp	400Wp	302Wp
Maximum Power Voltage (Vmp)	40.5V	38.6V	40.8V	38.8V	41.1V	39.1V	41.4V	39.3V	41.7V	39.6V
Maximum Power Current (Imp)	9.39A	7.42A	9.44A	7.48A	9.49A	7.54A	9.55A	7.60A	9.60A	7.66A
Open-circuit Voltage (Voc)	48.9V	47.5V	49.1V	47.7V	49.3V	48.0V	49.5V	48.2V	49.8V	48.5V
Short-circuit Current (Isc)	9.75A	7.88A	9.92A	7.95A	10.12A	8.02A	10.23A	8.09A	10.36A	8.16A
Module Efficiency STC (%)	19.16%		19.42%		19.67%		19.92%		20.17%	
Operating Temperature (℃)	-40℃~+85℃									
Maximum System Voltage	1000/1500VDC (IEC)									
Maximum Series Fuse Rating	20A									
Power Tolerance	0~+3%									
Temperature Coefficients of Pmax	-0.37%/℃									
Temperature Coefficients of Voc	-0.29%/℃									
Temperature Coefficients of Isc	0.048%/℃									
Nominal Operating Cell Temperature (NOCT)	45±2℃									

STC: Irradiance 1000W/m² Cell Temperature 25°C AM=1.5

NOCT: Irradiance 800W/m² Ambient Temperature 20°C AM=1.5 Wind Speed 1m/s

* Power measurement tolerance: ± 3%

Version 7.2.8

PVsyst - Simulation report

Grid-Connected System

Project: New Project

Variant: New simulation variant

Trackers single array

System power: 990 kWp

Kampong Kelang Gates Baharu - Malaysia

Author

Kok Ping Yeng (Malaysia)

Project summary

Geographical Site	Situation		Project settings	
Kampong Kelang Gates Baharu	Latitude	3.21 °N	Albedo	0.20
Malaysia	Longitude	101.75 °E		
	Altitude	64 m		
	Time zone	UTC+8		

Meteo data
Kampong Kelang Gates Baharu
Meteonorm 8.0 (1991-2009) - Synthetic

System summary

Grid-Connected System
Simulation for year no 10

Trackers single array

PV Field Orientation
Tracking plane, horizontal N-S axis
Axis azimuth 0 °

Near Shadings
Linear shadings

User's needs
Unlimited load (grid)

System information

PV Array		Inverters	
Nb. of modules	2604 units	Nb. of units	11.8 units
Pnom total	990 kWp	Pnom total	705 kWac
		Pnom ratio	1.404

Results summary

Produced Energy	1208 MWh/year	Specific production	1221 kWh/kWp/year	Perf. Ratio PR	62.55 %

Table of contents

General parameters

Grid-Connected System — **Trackers single array**

PV Field Orientation

Orientation		Trackers configuration		Models used	
Tracking plane, horizontal N-S axis		Nb. of trackers	15 units	Transposition	Perez
Axis azimuth	0 °	Single array		Diffuse	Perez, Meteonorm
		Sizes		Circumsolar	separate
		Tracker Spacing	12.0 m		
		Collector width	7.98 m		
		Ground Cov. Ratio (GCR)	66.5 %		
		Left inactive band	2.00 m		
		Right inactive band	2.00 m		
		Phi min / max.	-/+ 90.0 °		
		Shading limit angles			
		Phi limits	+/- 79.9 °		

Horizon	Near Shadings	User's needs
Free Horizon	Linear shadings	Unlimited load (grid)

PV Array Characteristics

PV module		Inverter	
Manufacturer	Generic	Manufacturer	Generic
Model	JKM380M-72	Model	SUN2000-60KTL-HV-D1
(Custom parameters definition)		(Original PVsyst database)	
Unit Nom. Power	380 Wp	Unit Nom. Power	60.0 kWac
Number of PV modules	2604 units	Number of inverters	47 * MPPT 25% 11.8 units
Nominal (STC)	990 kWp	Total power	705 kWac
Modules	93 Strings x 28 In series	Operating voltage	600-1480 V
At operating cond. (50°C)		Max. power (=>30°C)	66.0 kWac
Pmpp	900 kWp	Pnom ratio (DC:AC)	1.40
U mpp	1034 V		
I mpp	870 A		

Total PV power		Total inverter power	
Nominal (STC)	990 kWp	Total power	705 kWac
Total	2604 modules	Nb. of inverters	12 units
Module area	5164 m²		0.3 unused
Cell area	4668 m²	Pnom ratio	1.40

Array losses

Array Soiling Losses		Thermal Loss factor		DC wiring losses	
Loss Fraction	3.0 %	Module temperature according to irradiance		Global array res.	20 mΩ
		Uc (const)	20.0 W/m²K	Loss Fraction	1.5 % at STC
		Uv (wind)	0.0 W/m²K/m/s		

Module Quality Loss		Module mismatch losses		Strings Mismatch loss	
Loss Fraction	-0.8 %	Loss Fraction	2.0 % at MPP	Loss Fraction	0.1 %

Module average degradation

Year no	10
Loss factor	0.4 %/year
Mismatch due to degradation	
Imp RMS dispersion	0.4 %/year
Vmp RMS dispersion	0.4 %/year

Array losses

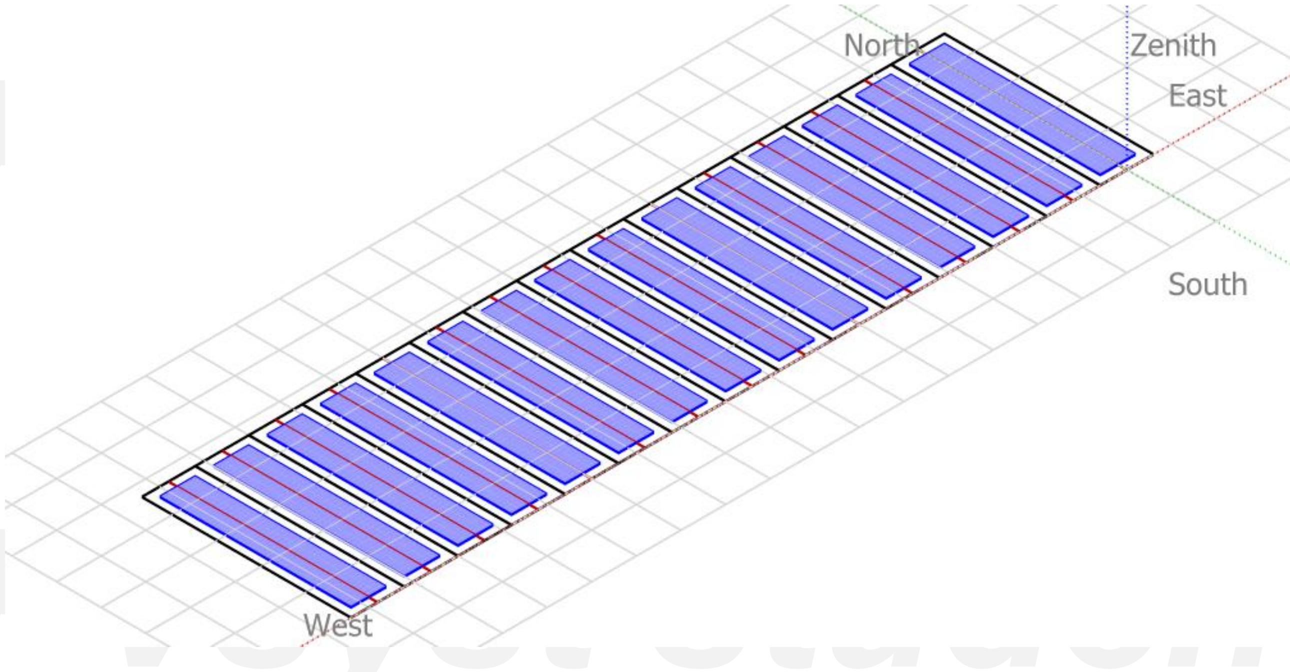
IAM loss factor

Incidence effect (IAM): Fresnel AR coating, n(glass)=1.526, n(AR)=1.290

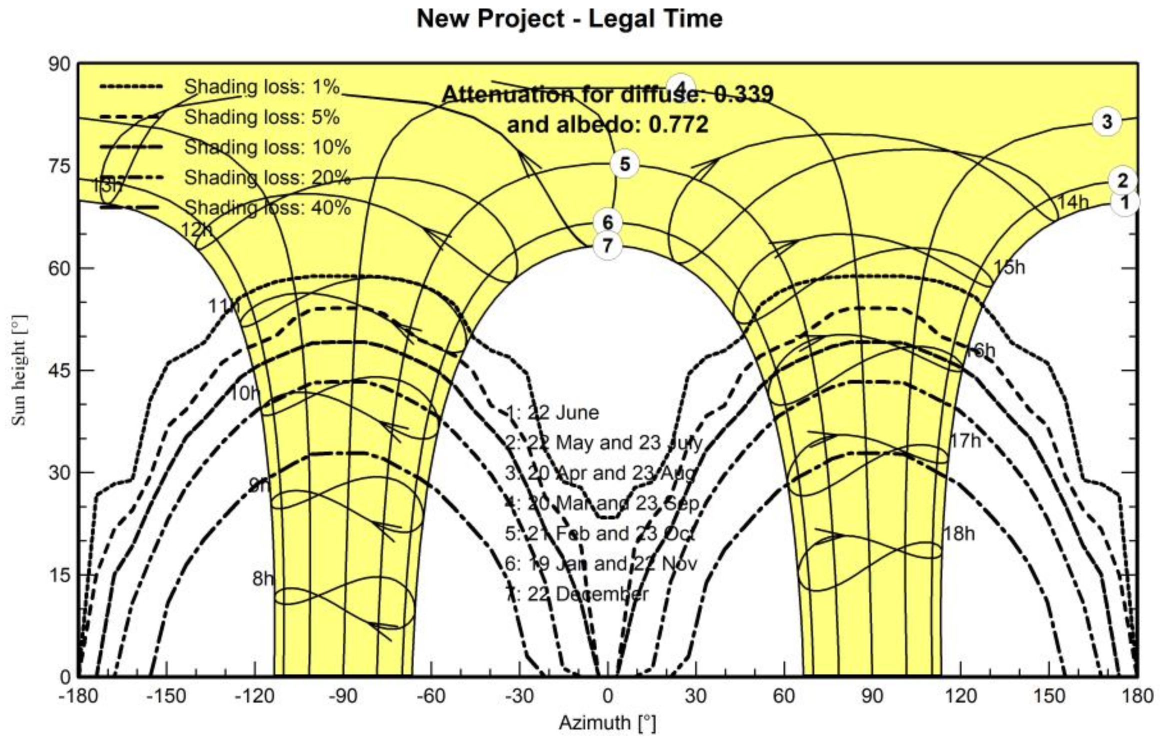
0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.999	0.987	0.962	0.892	0.816	0.681	0.440	0.000

Near shadings parameter

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram

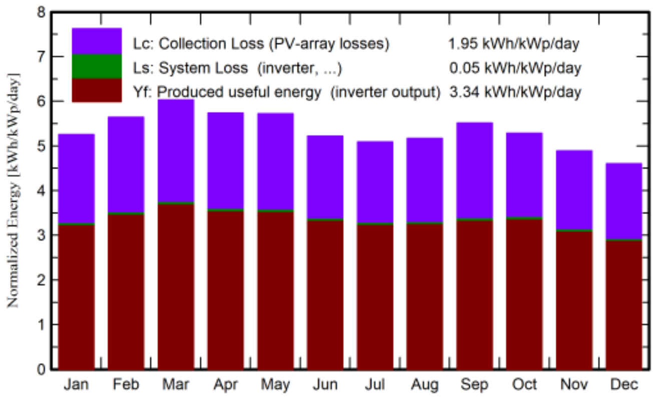


Main results

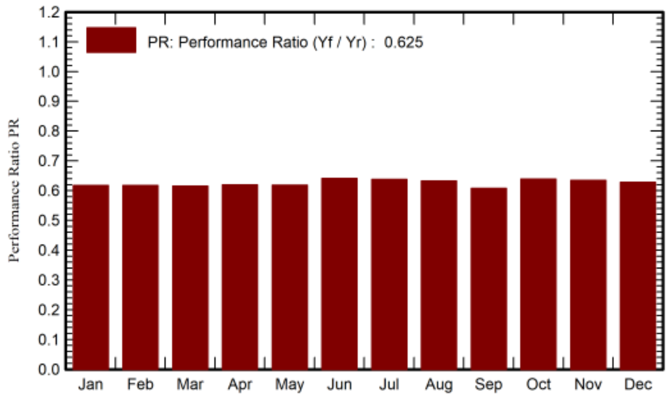
System Production

Produced Energy	1208 MWh/year	Specific production	1221 kWh/kWp/year
		Performance Ratio PR	62.55 %

Normalized productions (per installed kWp)



Performance Ratio PR



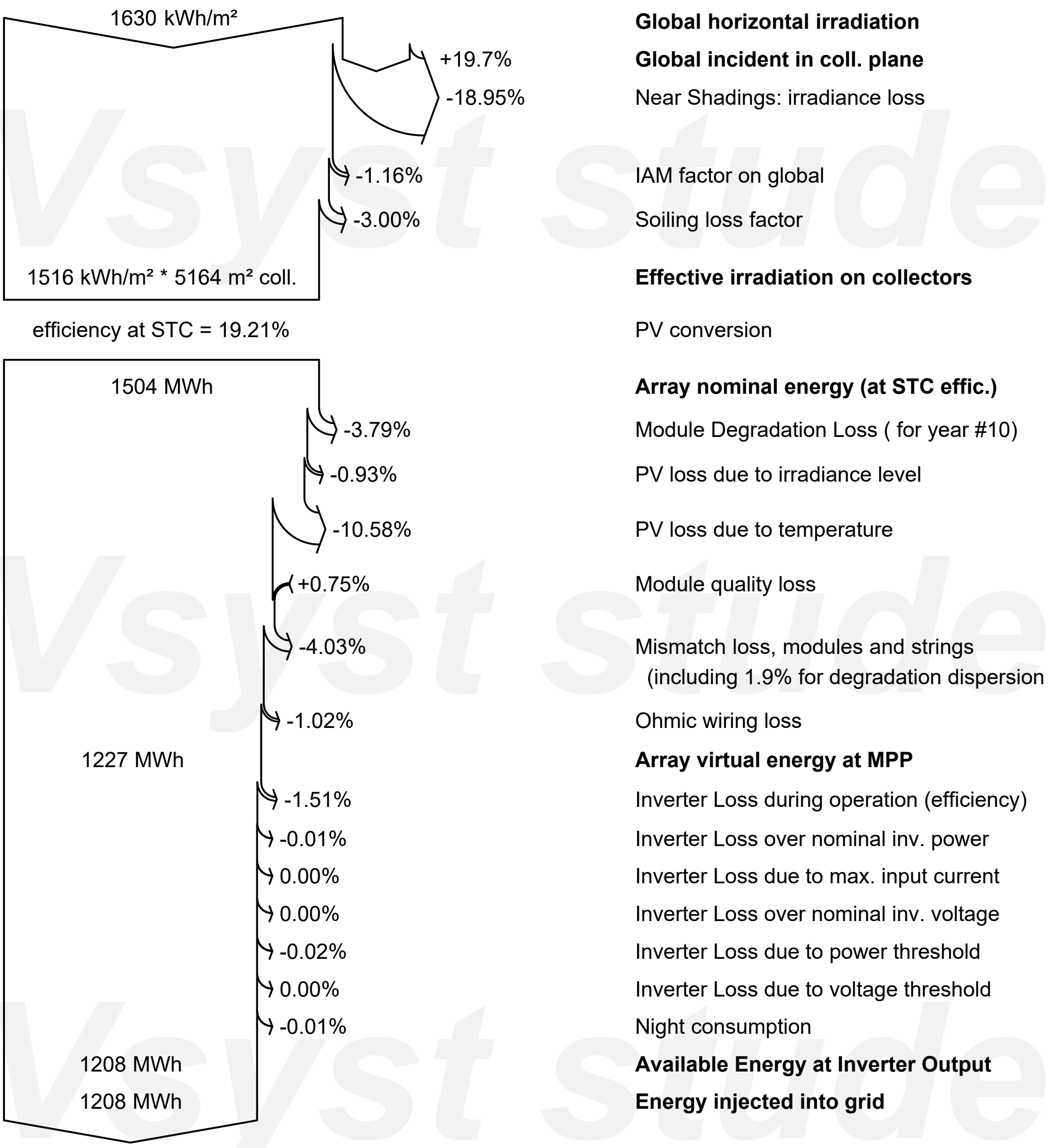
Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	133.3	73.50	27.23	163.0	124.9	101.1	99.5	0.617
February	131.3	76.94	27.82	158.1	121.4	98.0	96.5	0.617
March	153.7	83.09	28.17	187.1	144.7	115.8	114.0	0.616
April	142.8	82.90	27.77	172.0	132.8	107.2	105.6	0.620
May	145.0	77.87	28.61	177.5	137.2	110.4	108.7	0.619
June	133.3	78.93	28.09	156.6	123.9	100.8	99.3	0.641
July	134.7	79.50	28.09	157.9	124.9	101.3	99.8	0.638
August	136.8	84.35	28.09	160.3	125.7	101.9	100.4	0.633
September	133.5	72.36	27.28	165.4	125.4	101.0	99.4	0.608
October	140.4	82.90	27.56	164.0	130.4	105.3	103.7	0.639
November	123.9	72.06	26.75	146.7	115.2	93.6	92.2	0.635
December	120.9	77.34	27.16	142.8	109.9	90.2	88.8	0.629
Year	1629.6	941.73	27.72	1951.4	1516.4	1226.6	1207.7	0.625

Legends

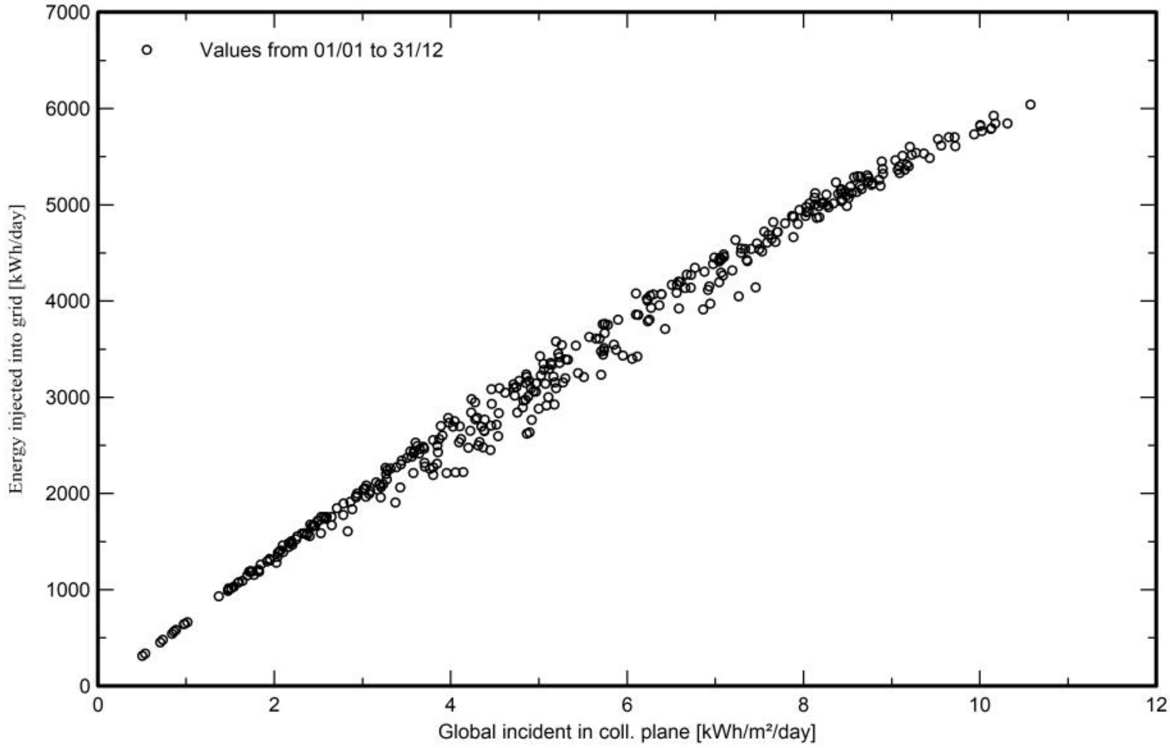
GlobHor	Global horizontal irradiation
DiffHor	Horizontal diffuse irradiation
T_Amb	Ambient Temperature
GlobInc	Global incident in coll. plane
GlobEff	Effective Global, corr. for IAM and shadings
EArray	Effective energy at the output of the array
E_Grid	Energy injected into grid
PR	Performance Ratio

Loss diagram

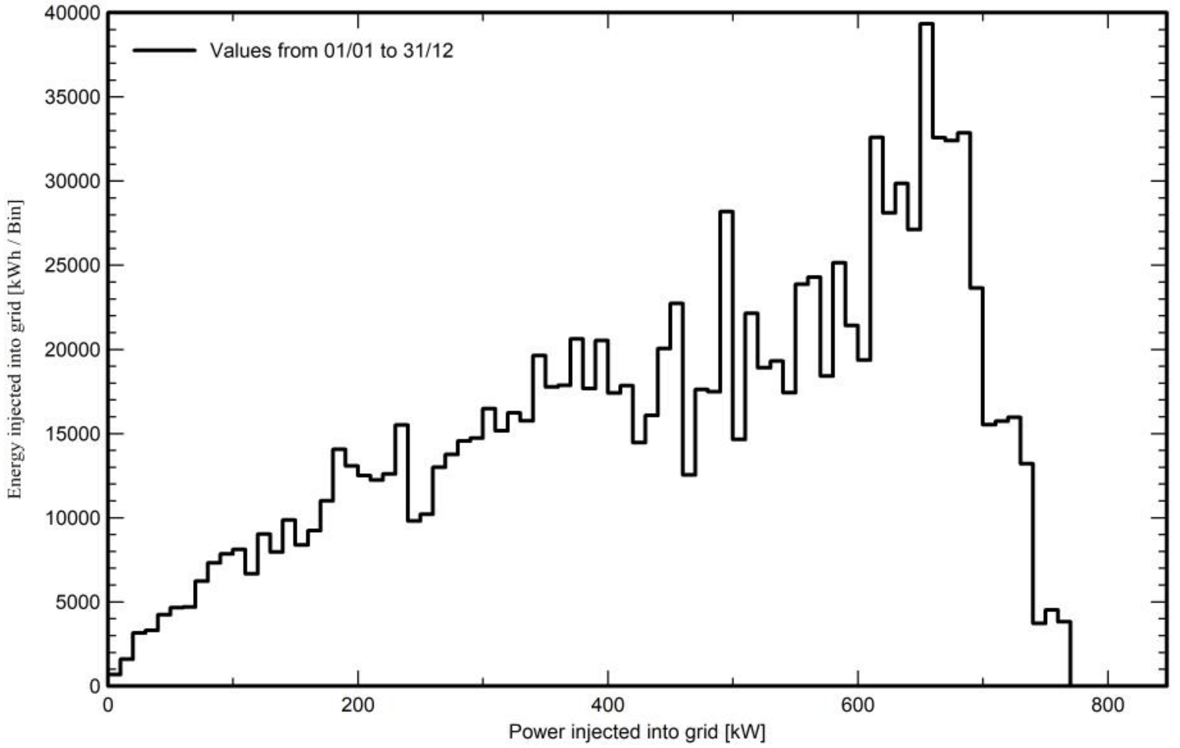


Special graphs

Daily Input/Output diagram



System Output Power Distribution



P50 - P90 evaluation

Meteo data

Source	Meteonorm 8.0 (1991-2009)
Kind	Not defined
Year-to-year variability(Variance)	0.5 %
Specified Deviation	

Global variability (meteo + system)

Variability (Quadratic sum)	1.9 %

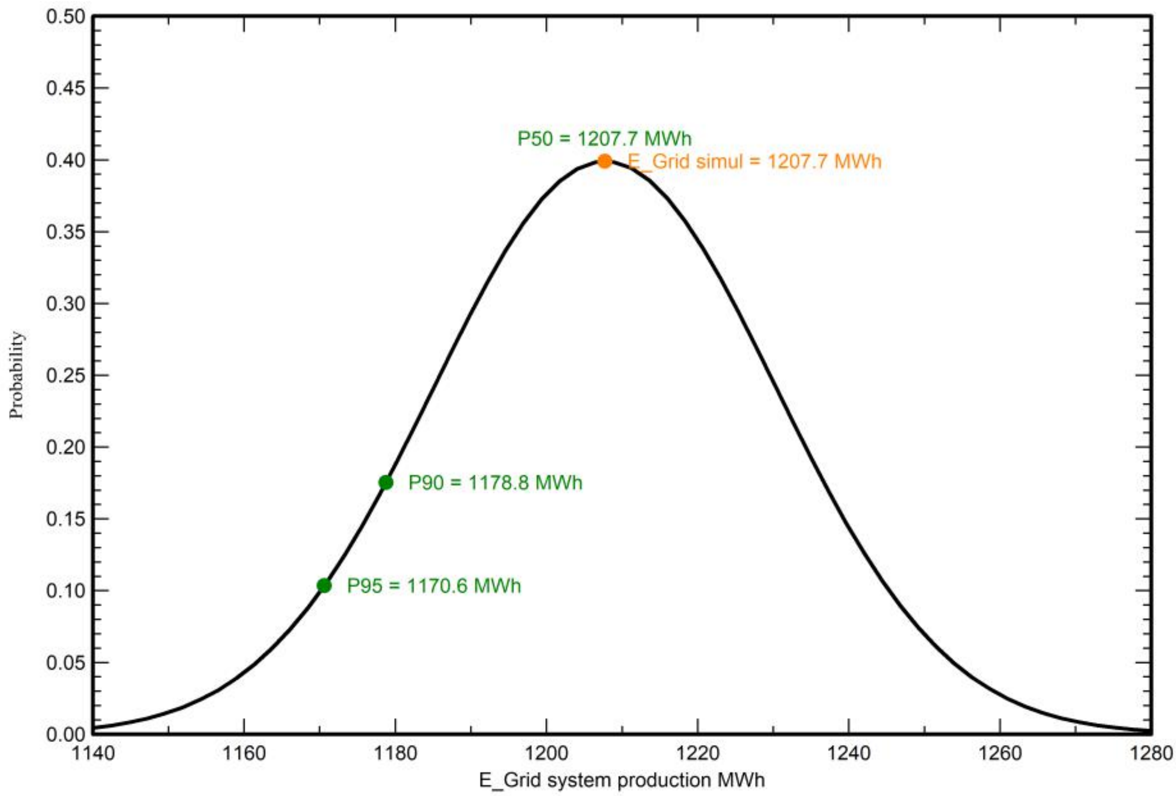
Simulation and parameters uncertainties

PV module modelling/parameters	1.0 %
Inverter efficiency uncertainty	0.5 %
Soiling and mismatch uncertainties	1.0 %
Degradation uncertainty	1.0 %

Annual production probability

Variability	22.6 MWh
P50	1207.7 MWh
P90	1178.8 MWh
P95	1170.6 MWh

Probability distribution



Cost of the system

Installation costs

Item	Quantity units	Cost MYR	Total MYR
Total Depreciable asset			0.00 0.00

Operating costs

Item	Total MYR/year
Total (OPEX)	0.00

System summary

Total installation cost	0.00 MYR
Operating costs	0.00 MYR/year
Produced Energy	1208 MWh/year
Cost of produced energy (LCOE)	0.000 MYR/kWh

CO_2 Emission Balance

Total: 18525.5 tCO_2

Generated emissions

Total: 2223.09 tCO_2

Source: Detailed calculation from table below:

Replaced Emissions

Total: 23913.2 tCO_2

System production: 1207.74 MWh/yr

Grid Lifecycle Emissions: 660 gCO_2/kWh

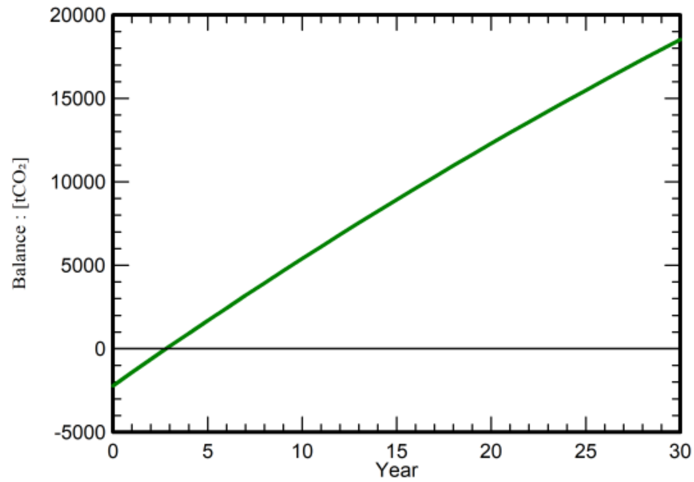
Source: IEA List

Country: Malaysia

Lifetime: 30 years

Annual degradation: 1.0 %

Saved CO_2 Emission vs. Time



System Lifecycle Emissions Details

Item	LCE	Quantity	Subtotal
			[$kgCO_2$]
Modules	1713 kgCO2/kWp	967 kWp	1657022
Supports	4.40 kgCO2/kg	127300 kg	560400
Inverters	436 kgCO2/units	13.0 units	5670

NEM Calculator

Mode of Purchase: **Outright Purchase**
Category: **Tariff C1 - Medium Voltage General Commercial Tariff** View Tariff
Building Type: **Shopping Mall/Complex**
Maximum Demand: **6402kWac**

Your Current Monthly Bill	Your Monthly Bill after NEM	Your Monthly Saving
RM822,483	RM786,293	RM36,190

Proposed Installed Capacity (adjustable)	Simple Payback Period	* Estimated Minimum Upfront Cost
991.50kWp	6.4Years	RM2,776,200

Space Required

Rooftop Area
5,949.0m²
1 kWp approximately 6m²

Environmental Impact **

Carbon Dioxide (CO_2) Avoidance		Distance travel avoidance by car (petrol)		No. of tree seedlings grown for 10 years to absorb the CO_2
20,643 tonne CO_2	=	79.4 million km	=	327,195 trees

Print Result →

Outright Purchase →

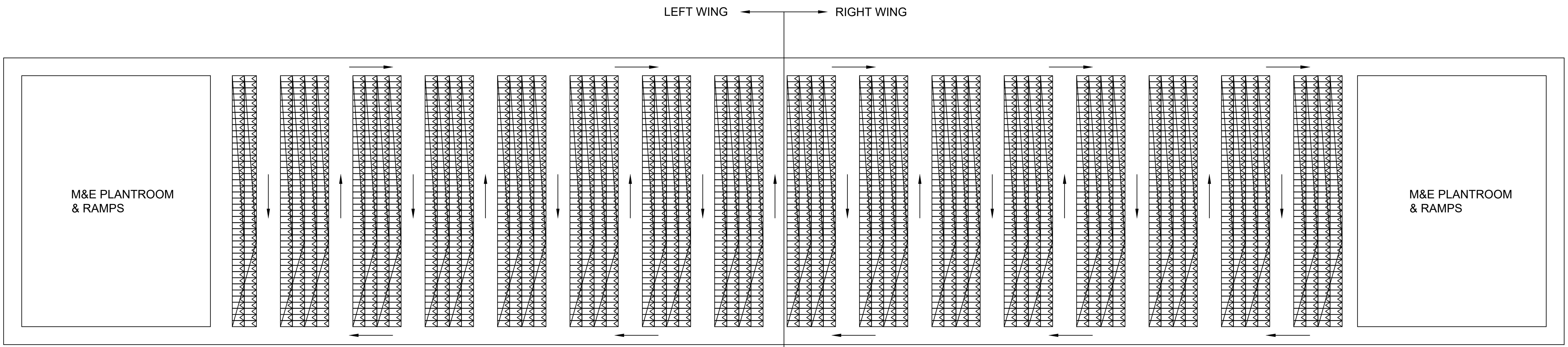
New Calculation →

Disclaimer :

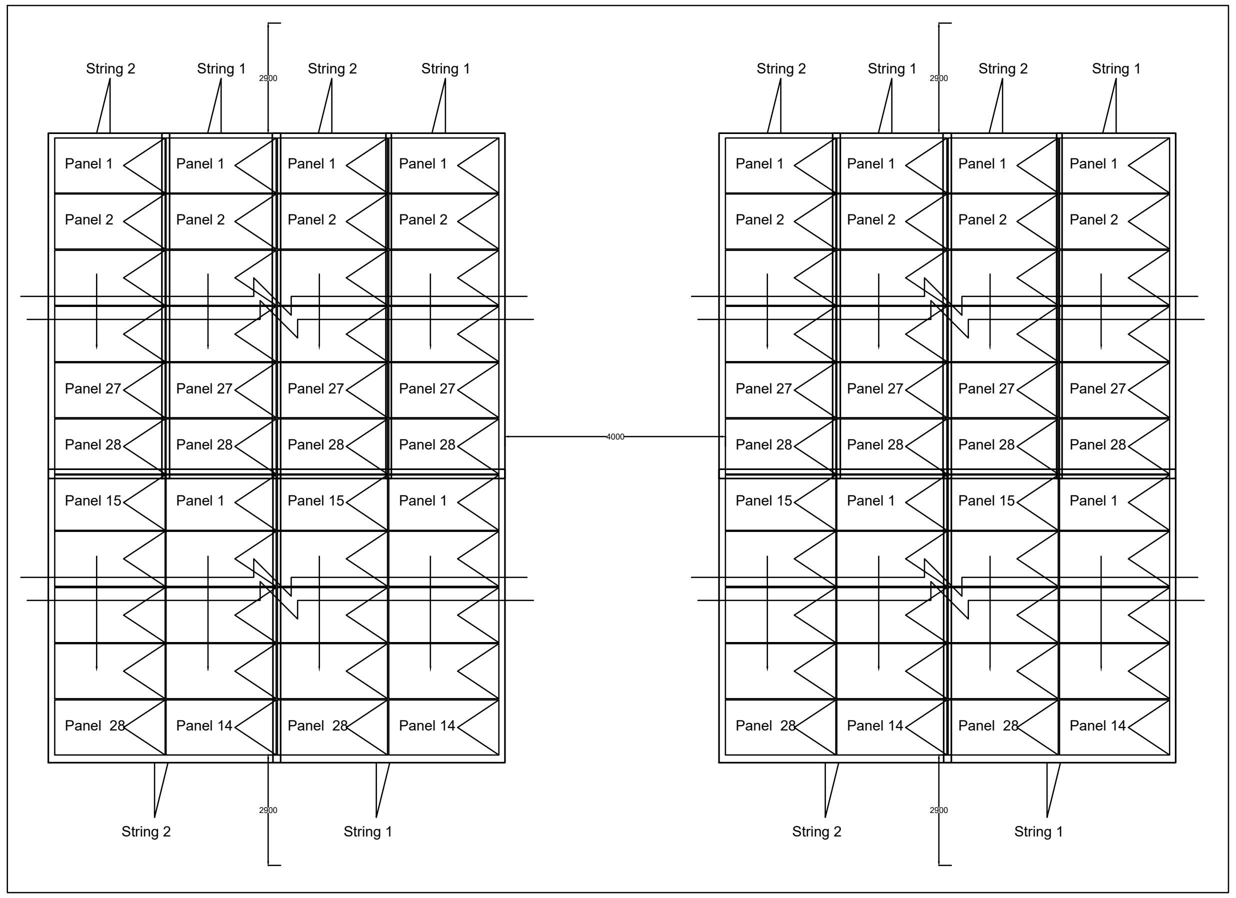
For **detailed proposals**, kindly contact your **PV service providers** for more consultation. While SEDA Malaysia strives to ensure the data is correct, no warranty expressed or implied is given as to the completeness, accuracy or timeliness of the given data. The above data may be updated, changed or modified from time to time. Users should take action to independently confirm the data available before relying on it. In no event shall SEDA Malaysia be liable to any person for any special, indirect or consequential damages relating to this data.

* This is based on minimum cost and it will vary by PV technologies, site conditions, etc.

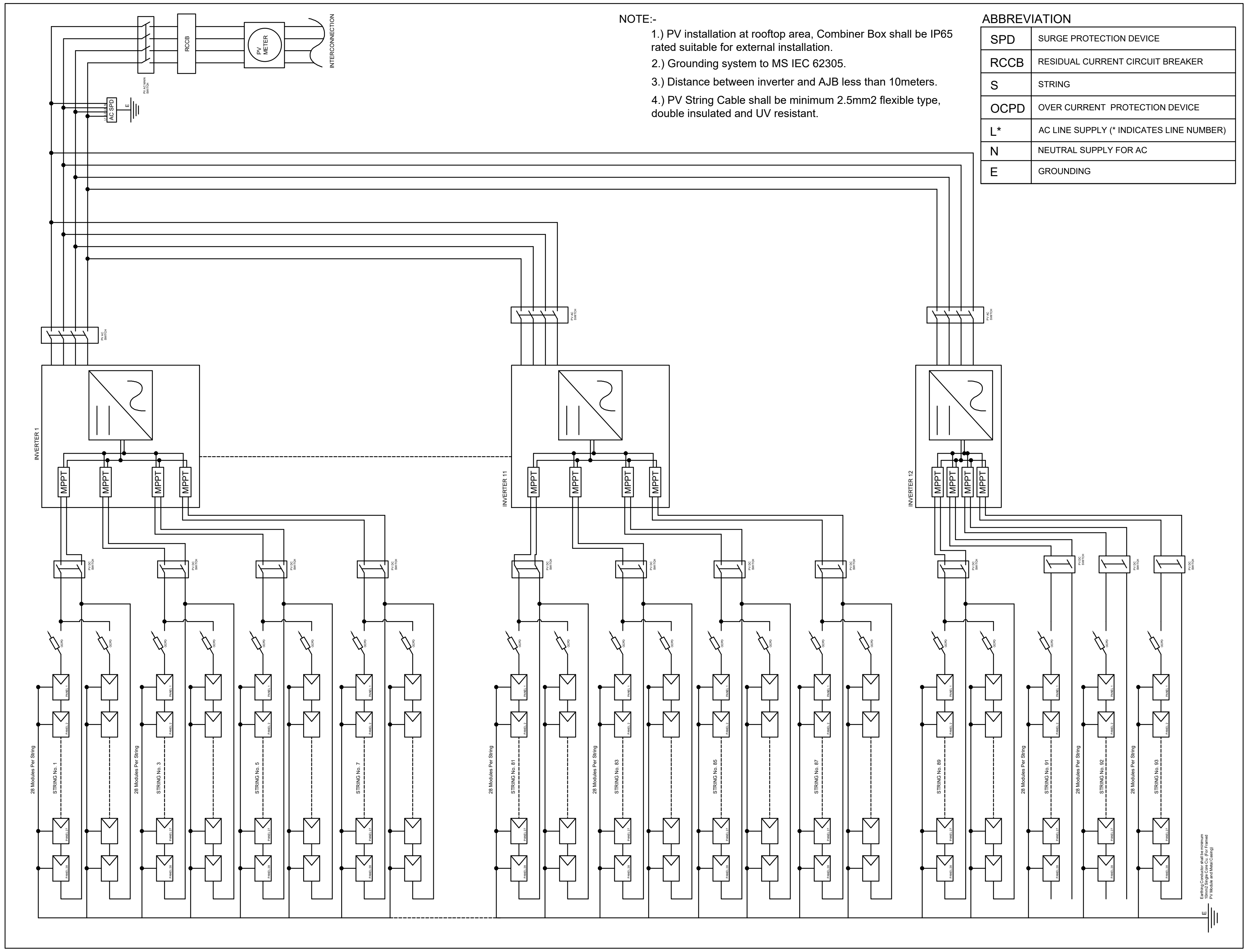
** The environmental impact is with the assumption that Solar PV system lifespan is 25 years.



OVERALL ARRANGEMENT LAYOUT



ENLARGED LAYOUT



NOTE:-

1.) PV installation at rooftop area, Combiner Box shall be IP65 rated suitable for external installation.

2.) Grounding system to MS IEC 62305.

3.) Distance between inverter and AJB less than 10meters.

4.) PV String Cable shall be minimum 2.5mm2 flexible type, double insulated and UV resistant.

ABBREVIATION

SPD	SURGE PROTECTION DEVICE
RCCB	RESIDUAL CURRENT CIRCUIT BREAKER
S	STRING
OCPD	OVER CURRENT PROTECTION DEVICE
L*	AC LINE SUPPLY (* INDICATES LINE NUMBER)
N	NEUTRAL SUPPLY FOR AC
E	GROUNDING

SINGLE LINE DIAGRAM

DRAWING TITLE :	990kW PV CAPACITY OVERALL ARRANGEMENT LAYOUT, ENLARGED LAYOUT, ABBREVIATION & SINGLE LINE DIAGRAM
PROJECT TITLE :	NEM SCHEME WITH AND WITHOUT BATTERY STORAGE ANALYSIS
PRODUCED BY :	YENG KOK PING