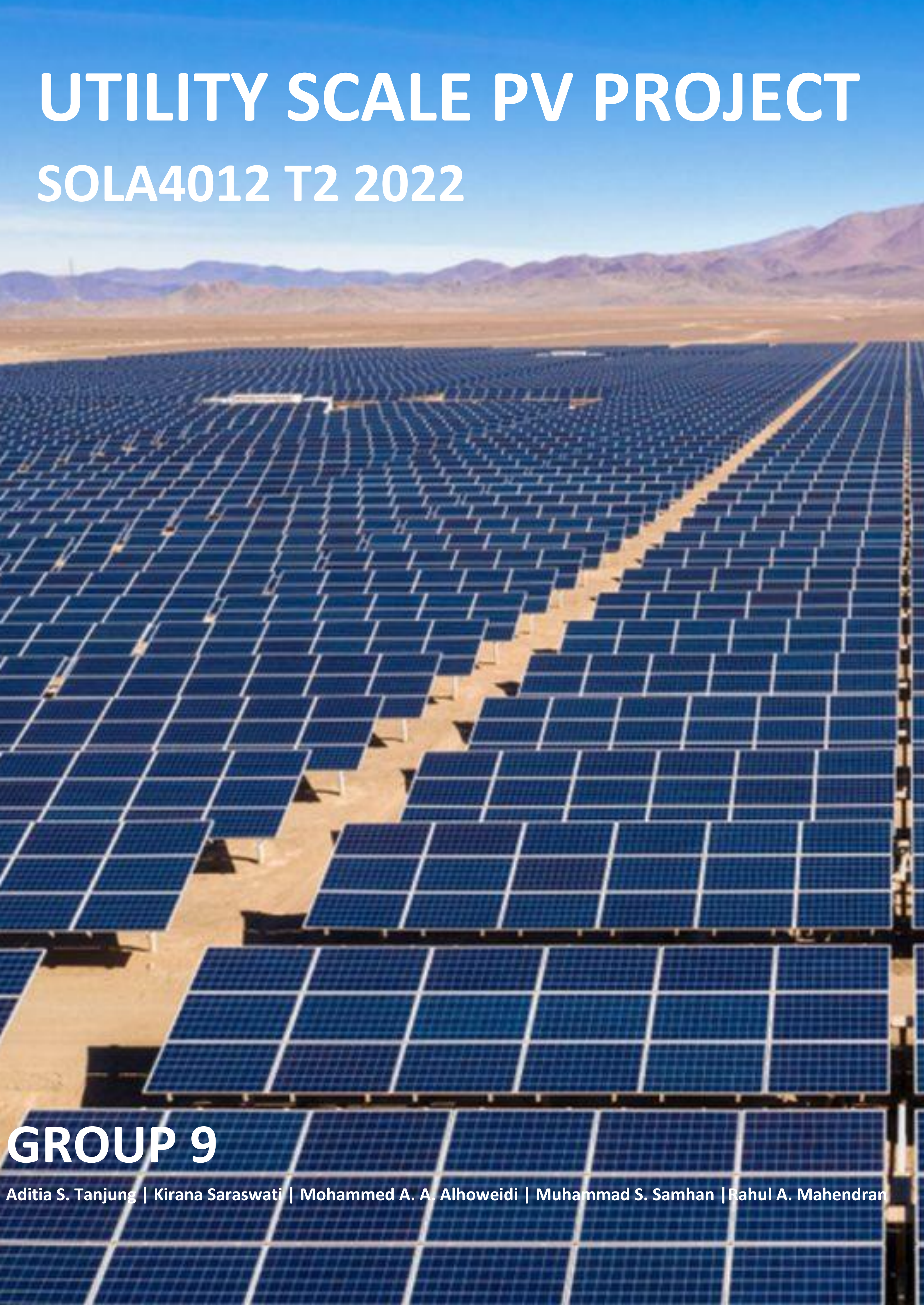
UTILITY SCALE PV PROJECT

SOLA4012 T2 2022



GROUP 9

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1. Executive Summary

SPREEnergy is the division of development for renewable energy that known as integrator since we are compiling any perspectives and recommend a tailored renewable energy power plant. For this system, we have objectives for adaptation and providing of clean energy to the industrial customer, in particular for net zero carbon emission. Selection of the locations for the power plant considering several aspects and appointed at Kianga, Queensland Renewable Energy Zone.

The PV system has 32.5 MW_{ac} inverter capacity and 37.75 MW_{p} module capacity with 1.2 for DC to Ac ratio. We choose Trina TSM-DE20 605 (605 W_{p}) for the module and Sungrow SG2500HV-MV (2500kW_{ac}) for the inverter. We select equipment and configuration that accordance with AS/NZS or being approved by Clean Energy Council (CEC). On the design perspective, fix and matching of the equipment already considered on the current specification of the items. Some manufactures may have new technical specifications of the product for the system. The project plan will consume less than 2 years of the timeline and expected to be energized before the summer period. All the project risk are considered and the plan of the mitigation is set up.

A power purchase agreement (PPA) has been signed with the local energy retailing company for a fixed price of ȼ13.00/kWh or $130/MWh over a 25-year period, with a Large-Scale Generation Certificates (LGCs) price of $0.45/MWh provided by the solar farm. The project will be financed through an investment company at a 10% annual interest rate and 14.78% internal rate of return (IRR) over a 25-year period.

Altogether, the proposed system offers the following projected performance indicators, as evaluated using SAM:

- Annual Energy of 65,325 MWh
- Net Capital Cost of $56,113,084
- NPV of $4,596,061
- Levelized Cost of Electricity (LCOE) of ȼ12.11/kWh or $121.1/MWh
- Interest Rate of Return (IRR) of 14.78%

2. Context

The demand for clean energy supply for industry has been increasing annually, some companies based in Australia recognized their initiative in the group of RE100. This group have been committed about their transition of energy use in renewable energy for net positive carbon emission. Their target year is ranging from 2020 to 2040 with industry category from the services, materials, hospitality, food, manufacturing, retail and infrastructure [1]. We are notified within the business case that we offer will be highly attracted and tailored for the market demand

We arrange that commercial of the generated electricity on the Power Purchase Agreement, the agreement between the power generator and the customer for supplying the clean energy. Between parties will receive beneficial about the expected clean energy and projecting long term of financial review. We apply the scenario of Large-scale Generation Certification (LCG) for register with those compliance review or assessment process.

3. Site Selection

On the extend of the selecting on the site for the solar farm location, SPREE examined several locations based on their variables and properties with the minimum capacity of 5 MWP. We found out a perfect location in Kianga, Queensland (-24.51, 150.06). The table comparison is shown on the table 1, for site clearance has been assessed and applicable (not included for aboriginal site, endangered species, natural reserve and others) for solar farm. The potential benefit is also from the location which the site is located in the priority of renewable energy zone and nearby the electricity substation.

Table 1. Site Selection Matrix

	Kianga QLD	**Dalby QLD**	**Bright SA**	**Burdett SA**	**Wellington SA**
Coordinate	**-24.51, 150.06**	-27.21, 151.31	-33.95, 139.12	-35.12, 139.46	-32.53, 149.53
Global Horizontal Irradiation (kWh/m²) [2]	**5.52**	5.42	5.18	5.46	5.08
Distance to potential farm from substation [3]	**< 3km**	< 3km	< 3km	10 - 15 km	<5 km
Land Price (Comparison)	**Low**	Low	Low	High	Medium
Policy	**50% Renewable Energy Target by 20230 Central QREZ (Queensland Renewable Energy Zones)**	50% Renewable Energy Target by 20230	High Risk of Power Curtailment	High Risk of Power Curtailment	High Risk of Power Curtailment

On detail of the site of Kianga can be seen on the below table, it shows some characteristics. Relates to proposed capacity of the power plant, grid connection available capacity, the variability of temperature, weather condition, geotechnical of the location and another related location which appropriate for the implementation of the power plant. On the other side, there is some cons for the location of the dust from the nearby coal mining are which can reduce the performance of the system. Structure plan for the regular cleaning with variability of the wind direction is accounted with this project.

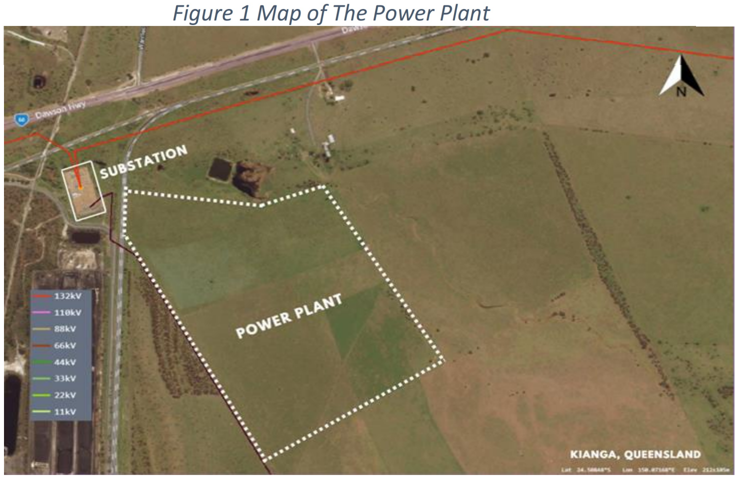
Table 2. Location Characteristics

Kianga QLD	
Capacity (MWP)	37.75
Lowest Daily Temperature (°C)	10.5 (June)
Highest Daily Temperature (°C)	43.8 (January)
Mean Temperature (°C)	20 (Annual)
Annual Rainfall (mm)	509.6
Type of Terrain	Flat Land with Grass
Distance to Nearby Seaport	Rockhampton (160 km)
Substation Indicative New Generation Capacity (MW) [4]	10 to 30
Economy Growth of State	2 -3 %

4. Grid Connection

The zone substation of crucial Electricity is located 3km north - west of the project location and will facilitate the project's grid connection to Moura distribution network. A 69 kV overhead utility line will be installed to replace the existing line, which has limited capacity transferring electricity from the substation which can be seen in the figure below.

Figure 1 Map of The Power Plant



The project's location presents only minor land access issues. The site is close to Dawon highway. The project site also has only one route which allows heavy vehicles to access, especially during construction. A new 66 kV utility line utility line will be constructed not only to ensure the project's power output is delivered reliably but will also strengthen Kianga's existing distribution network. The capital costs have been considered associated with above-mentioned Kianga site features such as solar resource, weather conditions, appropriate ground conditions, and low potential land access issues, this location is expected to support the construction to drive the successful project.

A. High Voltage Substation

The power will be delivering a 66 kV zone substation, located approximately 3 km north-west, via the new overhead utility line once connected to the grid   The Forecasted figures show that the zone substation has enough capacity to accommodate the solar farm's output. The associated marginal loss factor (MLF) for this particular generator is another indicator of a reliable connection. The utility line that will be replaced is the only system constraint recognized by essential Energy for the distribution network in Kianga supplying area. Available studies on the total average MLF for PV generators over 5 MW in the NEM indicate that MLFs ranged from 0.91 to 1.03 in recent solar farm commissioning. As a result, a 0.95 upwards MLF estimate is a estimate that will ensure adequate output delivery from the solar farm [5].

B. Grid Connection Cost

Table 7 details the costs associated with electrical connection to the distribution network, which include land pricing, clearance & preparation, land tax, system inspection and monitoring, grid interconnection, developer overhead and other costs (insurance, etc.) are expected to total $21,441,623. Given that a large system capacity, connecting to the distribution network rather than small capacity as it will   more appropriate and offers significant reliable electricity transmission. Furthermore, the underground power cables from the transformer to the utility pole will be more expensive than overhead power cables, there will be fewer associated losses due to the high voltage and current capacity required. Therefore, an overhead power cable will be considered in this project.

5. System Design

To design the system, **the first step we do is choosing the PV module product**. To minimize LCOE and maximize NPV, we aim to get a product with lowest price/Wp. To do that, we compare three top brands based on its global market share which are Longi, Trina Solar, and Jinko Solar. We take the biggest capacity product from each brand because big capacity module leads to lower number of module, hence lower BoS cost. We determine the module with the biggest capacity from CEC website, then from market research, we got this result:

Table 3. PV Module Price Comparison

Brand	Product Name	Capacity (W_p)	Price/Wp ($/$W_p$)	Reference
Longi	LR5-72HPH-555M	555	0.41	[i]
Trina Solar	Trina TSM-DE20 605	605	0.38	[ii]
Jinko Solar	JKM615N-78HL4-V	615	0.43	[iii]

All $ price written here are a AU$ value, and we have converted from US$ into AU$ if the price information we got is a US$ value. From the table above, we can clearly see that Trina Solar has the lowest cost/Wp, so we choose Trina Solar 605 W_p for this project. This product is a module with half-cut cell technology, consists of 120 cells, has 12 years product warranty and 25 years power warranty. The annual degradation over 25 years is only 0.4%. The more detailed information about this module is given in Appendix B, datasheet.

The second step is to choose inverter product. To minimize the cost, central inverter is preferrable than multistring or string inverter because the price/kW is cheaper for central inverter. From several top brands producing central inverter, we consider only three top brands which are SMA, ABB, and Sungrow. Despite their relatively high price, we choose them because those two brands are already reputable, thus reduce the risk of malfunction in the operation.

SMA central inverter product, has high $V_{mp,min}$ value, which is > 900 V. Following AS/NZS 5033 2021 regarding PV and inverter matching, we need to put 10% safety factor for $V_{mp,min}$ value. This results in very narrow MPP voltage range of the inverter. Thus, when we try to match SMA with Jinko 615 W_p module, there is no possible number of module per string to match the inverter. It always doesn't match either because the array V_{mp} is too low compared to the MPP range, or array $V_{oc,max}$ is too high compared to inverter $V_{input,max.}$ Firstly we would like to choose ABB 500 kW, which $V_{mp,min}$'s value is only 450 V. So, the safety factor requirement from the standards doesn't make problem when matching the PV module. However, we want to use higher capacity inverter, so the number of inverter could be minimized.

So, we choose Sungrow SG2500HV-MV (2500kW_{ac}). With this inverter, we can build a 30 MW_{ac} system with only 12 inverters. Had we chosen ABB 500 kW inverter, we would have need 60 inverters. This sungrow inverter is also very good because it includes transformer, AC and DC overcurrent protection, and also lightning protection.

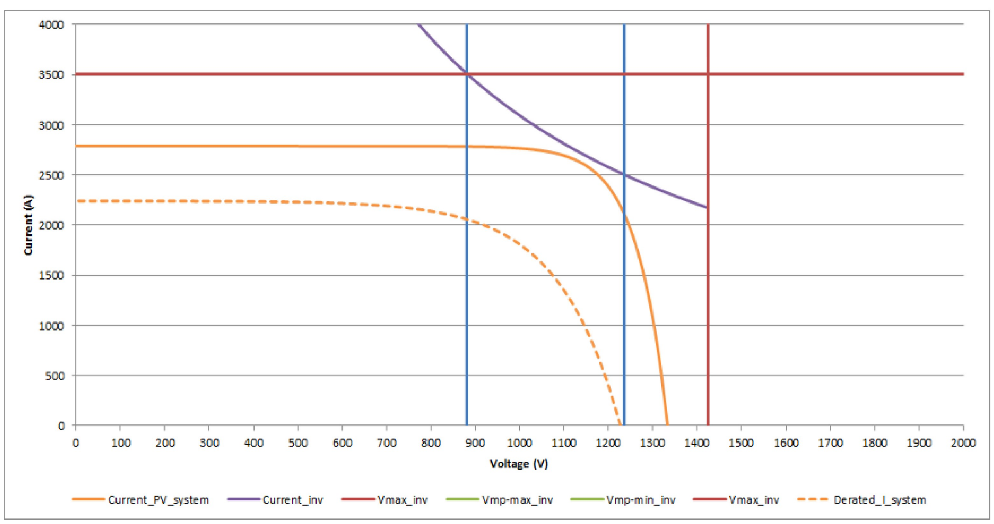
The third step is we determine the PV configuration for an inverter. To do this, we deploy SOLA4012 PV

Tool V3 2022, which already follows all the required standard for cabling, protection, and PV-inverter matching. We maximize the number of modules per string first before maximizing the number of strings. The reason is that it is best for a certain power to have higher voltage, thus lower current and minimize cable size and losses.

The result is for an inverter, we use 15 DC input ports, or 15 PV arrays. Each array consists of 5 subarrays, while each subarray consists of 2 strings. We put 2 strings together into 1 subarray because we use single axis tracker 2P, so one tracking will be exactly consist of 2 subarrays. Lastly, each string consists of 32 modules connected in series. We use single axis tracking 2P because the land seems so big, thus power produced/sqm land is not an important issue to consider. Apart from that, most utility PV project installed in Australia uses single axis tracker, so we assume it is a best practice to use single axis tracker instead of not using any tracker or using double axis tracker. With this configuration, we get 1.2 DC to AC ratio, which is good in terms of optimization of inverter capacity.

Each of two strings are connected in parallel to form a subarray using a combiner box placed near the PV modules. Then, 5 subarrays are connected in parallel to form an array using another combiner box near the inverter. The detailed system configuration can be seen in appendix a, workshop drawing, where we put PV layout drawing and Single Line Diagram. This PV configuration matches the inverter, and the illustration can be seen in the following graph.

Figure 2. PV and Inverter IV-Curve



This graph shows the IV curve of the PV array, denoted by orange curve, and the IV curve of the inverter, denoted by purple curve. From the graph above, we can see that all the required matching criteria from AS/NZS 5033 2021 is satisfied. First, the array V_{mpp} in inverter $V_{mpp, input}$ range, which is denoted by 2 vertical blue lines. Second, the array $V_{oc,max}$ is less than inverter $V_{input,max}$. It is seen from the orange curve intersection with horizontal axis, which is less than red vertical line intersection with horizontal axis. Third, the array I_{max} is less than inverter $I_{input, max}$. This can be seen from the orange curve intersection with the vertical axis, which is less than the red horizontal line intersection with the vertical axis. Last but not least, $P_{array} < P_{inverter}$. It is denoted by the position of orange curve, which is below the purple curve. It is good to note that the voltage and current values of the array are already considering the temperature effect.

The fourth step, is to determine the total the whole system size. Considering the substation available capacity and land availability near the substation, we choose to go with 37.75 $MW_{ac,}$, 36.2 MW_p system. In other words, we will use 13 inverters, and total of 57,600 PV modules. We prefer to have high value of system size because it leads to more cost-efficient transformer, BoS, and most importantly, higher NPV.

The fifth step, which is the last step, is to determine all the remaining BoS. For the overcurrent protection device, isolator, and voltage drop calculation, we deploy again, SOLA4012 PV Tool V3 2022, which already in accordance with AS/NZS 5033 2021. For the cable sizing, we follow AS/NZS 3008 2017 to choose the cable cross sectional area (CSA). As required by AS/NZS 5033 2021, we need to use double insulated cable for PV cable, so we choose to use Multi-core 2C Cu, all buried underground using wiring enclosure. We deploy JCal Cable Size Calculator[iv], which was built in accordance with AS/NZS 3008 2017. To sum up, we give the design summary of this system in the following tables. Due to page limitation, the wind and lightning assessment, the voltage drop, and the system optimization information and put in appendix.

Table 4. System Summary

Name	Value	Name	Value
System Capacity	37.75 MW_p / 32.5 MW_{ac}	PV Configuration in an inverter	15 arrays/inverter | 5 subarrays/array 2 strings/subarray | 32 modules/string
Module	Trina TSM-DE20 605 (605 W_p)	DC to AC Ratio	1.2
Inverter	Sungrow SG2500HV-MV (2500kW_{ac})		

Table 5. Balance of System Summary

Name	Value	Name	Value
String fuse	30 A, 1500 V	String cable & frame earthing cable	Multi-core 2C Cu, 4 mm^2, 42 m/string, 50 m/string
Sub-array fuse	50 A, 1500 V	Sub-array cable	Multi-core 2C Cu, 16 mm^2, 221 m/sub-array
Array fuse	N/A (no battery)	Array cable	Multi-core 2C Cu, 95 mm^2, 5 m/array
String isolator	N/A	AC cable	Multi-core 3C+E 50 mm^2, 500/inverter
Sub-array isolator	50 A, 1500 V	Cable installation (all)	Underground wiring enclosure
Array isolator	250 A, 1500 V	Transformer	22 kV to 66 kV, 30 MVA
AC MCB output inverter, DC & AC SPD	N/A, available in inverter	PV Mounting	East-West, Single Axis Tracking, 2P

As seen above the orientation of Appendix Drawing “PV System Orientation and Layout” of the solar panels in the PV Plant is set 90 azimuth enabling single axis tracking capability to enhance the effective output of the system. To ensure maximum utilization of land, 2P Single axis tracker with (backtracking) is used. The Substation is located in the north-east part of the utility plant closer to the grid station, to reduce the usage of High Voltage cables reducing the overall capital of the project. A Power station monitoring center is located besides the substation, to control and monitor the energy yield, from the system through SCADA. A water pumping station is designed to the northwest of the PV project (closer to the water table) which could be used in cleaning PV modules, at times of high soiling rate. The SLD in the DC side of the PV system on the Appendix Drawing “AC Single Line Diagram and DC Single Line Diagram”, is designed in compatible with AS/NZS 3008 standards to ensure reliable and robust protection of the system. As seen from the SLD in the AC Side, to diversify the target market , the system is designed to output energy at 2 voltages levels of 22 kV for distribution and 66 kV for transmission.

6. Economics

The project has undergone a complete economic analysis, including a 25-year modelling period for the estimated system lifetime. The economic analysis considers installation, operation and maintenance expenses, as well as component replacement. Along with system expenses, the funding mechanism and revenue plan are analyzed, and finally, the summary of the system's economic performance is determined by modelling in the NREL System Advisory Model (SAM).

A. Capital Costs

Table 6. Direct Capital Costs

Cost Parameter	Pricing Condition	Subtotal	Economic Assumption
Module	$0.32/Wp	$12,080,640	According to the estimated price listed on the marketplaces (Appendix)
Inverter	$0.16/Wp	$5,080,286	According to the estimated price listed on the marketplaces (Appendix)
Balance of System (BoS)	$0.04/Wp	$1,598,113	According to the estimated price listed on the marketplaces (Appendix)
EPC Overhead	$0.04/Wp	$1,623,110	Benchmark EPC Overhead as per NREL Q1 2021 [6]
Install Labor & Equipment	$0.09/Wp	$3,320,786	Benchmark Install Labor and Equipment as per NREL Q1 2021 [6]
Installer Overhead	$0.04/Wp	$1,623,110	Benchmark Installer Overhead as per NREL Q1 2021 [6]
Contingency (3%)	$0.02/Wp	$759,781	Benchmark contingency recommendation of 3% as per NREL Q1 2021 [6]
GST (10%)	$0.07/Wp	$2,608,583	Broad-based tax of 10% on most goods, services, and other items sold or consumed in Australia [7]
Direct Capital Costs	**$0.76/Wp**	**$28,694,410**	

Table 7. Indirect Capital Costs

Cost Parameter	Pricing Condition	Subtotal	Economic Assumption
Land Price	$145,679/ha	$13,141,703	Price based on local area Real-Estate [8]
Land Clearance & Preparation	$29,136/ha	$2,628,341	20% of Land Price
Land Tax		$218,909	According to QLD Government Land Tax Rates of $1,450 plus ¢1.7 for each $1 more than $350,000 [9]
System Inspection & Monitoring	$0.04/Wp	$1,560,763	Utility-Scale One-Axis System Cost Benchmark NREL Q1-2021 [6]
Grid Interconnection	$100,000/Km	$200,000	As per Utility-Scale Project Brief
Developer Overhead	$0.05/Wp	$1,742,670	Benchmark Overhead as per NREL Q1-2021 [6]
Other Cost (Insurance, etc.)		$1,949,238	10% of Indirect Cost
Indirect Capital Costs		**$21,441,623**	

Table 8. Initial Capital Cost

Initial Capital Cost	**$50,136,033**
Installed Cost per Capacity	**$1.33/Wp**

B. Project Funding and Revenue Strategy

Power Purchase Agreement

SPREEnergy has negotiated a competitive power purchase agreement (PPA) with a local energy retailer company with a focus on renewables generating. Their financial portfolios qualify as the potential off-taker for the whole production of the solar farm. Over a 25-year period, the contract output will be provided at ¢13.00/kWh or $130/MWh. This pricing was reached by negotiating the internal rate of return (IRR) of 14.78% on the 30MW power plant.

Large-scale Generation Certificate (LGCs)

The SPREEnergy project of 30MW power plant may claim up to $2,887,137 LGCs per year. The current LGC spot price is in the $0.45/MWh [10] with assumption of no escalation each year, which will be sold in a bundle to the PPA off-taker to generate revenue.

Funding

Furthermore, the combination of the system's relatively modest capital cost and the 25-year secure PPA allows for a low-interest loan from an investment company. This interest rate was made achievable by the project's low risk, which provided a highly probable return guarantee. The funding company will supply 80% of the project debt with required refinance in approximately of 8 years and annual interest rate of 10% which the rate used is conservative estimate, where a review will commence, aligning with the internal rate of return is achieved.

C. Economic Analysis

The system has been simulated in the System Advisory Model (SAM) software to calculate economic performance of the 25-year system lifetime after identifying the projected system expenses, project funds, and revenue streams. The rate of inflation for the 25-year model was determined by averaging the previous inflation in Australia which was around 4.7% percent [11]. A real discount rate of 6.4% was also applied [12]. Furthermore, according to the NREL PV system benchmark, an annual DC degradation rate of 0.5% was chosen during the system lifespan [6].

Table 9. Economic Summary

Economic Metric	Value	Justification
Annual Energy (Year 1)	65,325 MWh	Calculated from local weather data and system size
Power Purchase Agreement (PPA) Price	¢13.00/kWh	Competitive PPA compared to QLD Government PPA estimates ranging from $22 to $24/kWh [13]
Levelized Cost of Electricity (Nominal)	¢12.11/kWh	Competitive LCOE compared to the Australian Energy Council Analysis Q3 2021 [4]
Net Present Value (NPV)	$4,596,061	A positive NPV represents a healthy, low-risk project.
Internal Rate of Return (IRR)	14.78%	The higher the IRR of a project, the more desirable it is to pursue the project.
Year IRR Achieved	25 years	Return realized before the end of system life
IRR at Project-End	14.78%	Profitable return on investment for the equity group
Net Capital Cost	$56,113,084	Realistic 30MW project cost confirmed with other project with the same system installation [14]
Equity	$11,222,617	20% of the net capital cost
Size of Debt	$44,890,468	80% funding from an Investment Company with tenor of 8 years

7. Project Risks

There are several risks have been identified for this project, it includes several aspects from the financial, construction and administration. Every item has their impact to the project and we have already declare the plant for mitigation the risks. The quantitative risk has been accommodated at the project finance at contingency sub items. We analyzed the severity and likelihood of the items, correspondence with the PMBOK risk management overview at Figure 3. The risk assessment identification might be seen on the below table

Figure 3. Project Risk Overview

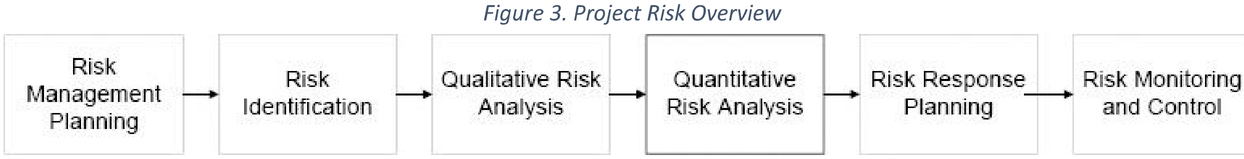


Table 10. Project Risks

Risk	Description	Severity	Likelihood	Impact	Mitigate Plan
Financial (Interest rate, Hedging and Cost Escalation)	Interest rate is significantly sensitive for the financial. The exchange rate and price of commodities currently is unstable	High	Medium	Increment of the expense	Contractual documents for the financials are verified completely and assess the option. Quotation price from the vendor should have longer validity, this protects increment on the timeframe
Stakeholders (Investors, Consumer, Community and Others)	No integration between stakeholders. Some development of RE projects are rejected by the nearby community.	High	Medium	Delay of the project completion	Using one gate system of the communication of the stakeholders, reduces any redundant issues.
Specification of The Equipment	Some equipment tends to have their new version or updated version, this impacts the slightly change of the specification	Medium	Low	Unsuitable matching the between equipment or reducing the specification of the equipment	Periodically update the status of the equipment from the vendor and justified the technical specs that they offered
Delay of the Project	The project is proposed to be finished before the summer to absorb the highest resources of annual solar	High	Low	Delay for the income of selling the power and generating additional expense	Monitoring and supporting of the project running is mandatory to make sure no delay, good communication and teamwork with the verified EPC contractors
Administration (Permitting and Regulation)	Administration process tends to consume time. Some Amendment tends to be occurred on the contract documents	High	Medium	Unavailable to export electricity	Put the detail for the process and make sure comply of regulation required. The contract team should be sensitive with the amendment and notified to the other teams
Grid Connection and Capacity	It is essential to have the grid connection finished before the energization to make sure the exported energy can be received and sold to the customer	High	Medium	Unavailable to export electricity	Intensively reviewing the resources of the manpower of the materials, since transmission line consumes manpower and data for the capacity

8. Project Plan

We plan to have the system is energized before the summer period for power generation, there are some milestones to be achieved among the stakeholders. The project plan is estimated on 16 months, include with 13.5 months of the construction project for the power plant and transmission line. Before the construction, robust administration and strong financial agreement are needed. For the process group that the timeline has been consider for the initiating, planning, monitoring and controlling, executing and closing. For the vendor of the construction, we examined several EPC (Engineering, Procurement and Construction) contractor that is capable for this on-grid system. The Gantt chart of the project is seen on the below figure.

Figure 4. Project Timeline

	Duration (Week)	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23
Project Site Selection	16																
Site Assessment	2																
Land Agreement	4																
Site Clearance	4																
Project Tender	10																
Submission of The Tender Documents	8																
Signing of the Contract	2																
Project Finance	10																
Investment Distribution Proposal	10																
Agreement of the Financial Stakeholders	2																
Project Construction	50																
Power Plant	50																
Engineering Design	18																
Procurement of Materials	16																
Installation and Commisioning	30																
Transmission Line	48																
Engineering Design	10																
Procurement of Materials	20																
Erection and Installation	28																
Energization	4																
Permit Process Approval	6																
Energize	2																
Project Handover	4																
Documents for handover	2																
Training of the equipment	4																
Completion Certificate	2																

9. Recommendations and Conclusion

After completion of the calculation of the project design, there are some recommendations that can be implemented on the system in terms of the design and economic outputs.

Design

To sum up the design, we can see that the PV system has 37.75 MW_p module capacity and 32.5 MW_{ac} inverter capacity. With the chosen module and inverter, we already ensured the lowest cost possible in the market to minimize the LCOE. Apart from that, we still make sure that the product we chose is a CEC approved product. The system configuration of each inverter consists of 15 arrays/inverter, 5 subarrays/array, 2 strings/substring, and 32 modules/string, which leads to a very good DC to AC ratio which is 1.2. Apart from choosing the PV configuration and the inverter, we have also done choosing cable size, OCP device, isolator, and also wind & lightning assessment. All of the choice are done in accordance with AS/NZS 5033 2021, AS/NZS 3008 2017, AS/NZS 1170 2021, and AS/NZS 1768 2021. The detailed PV layout drawing and single line diagram are also given in the report as appendix. We also put the detail of wind and lightning assessment in appendix.

Economic

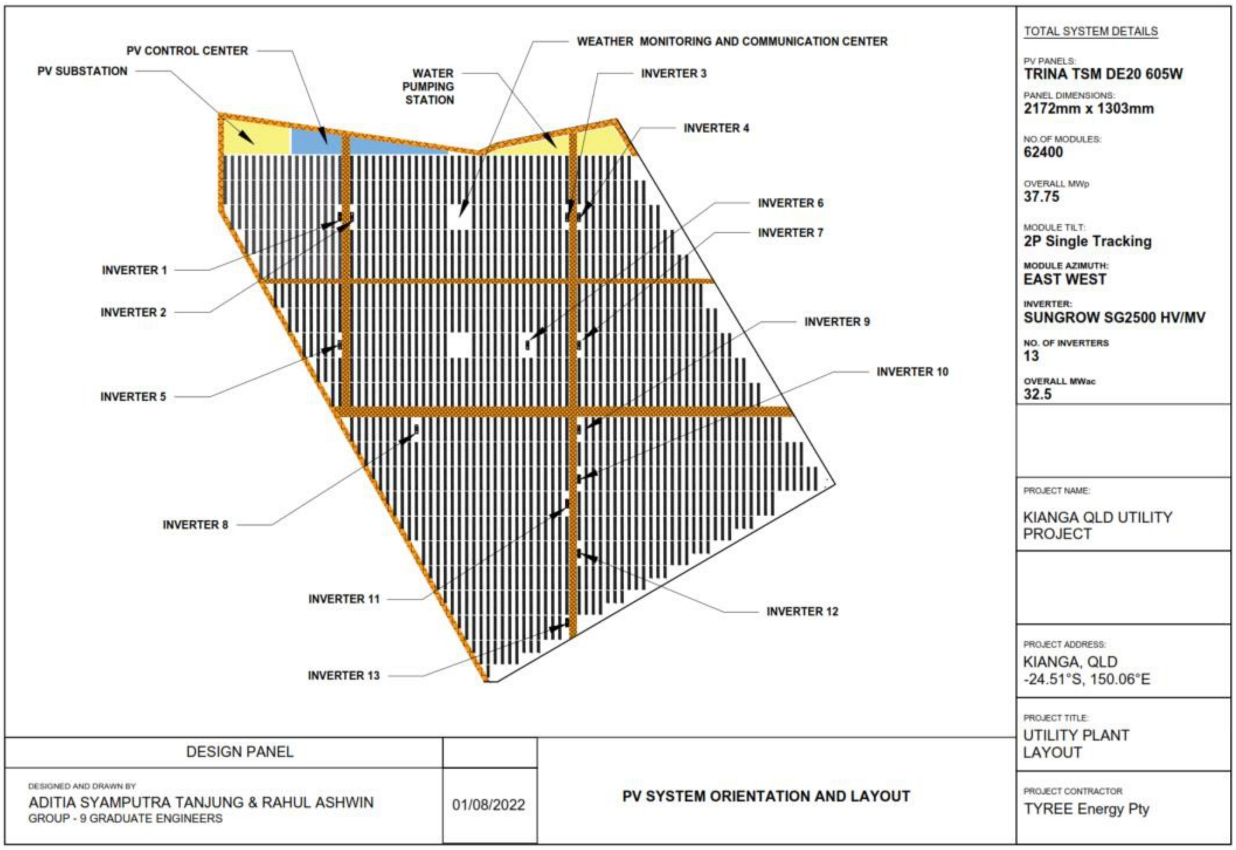
On the perspective of economic analysis on the projected time period, we highlighted the interest rate can greatly affect the both the NPR and IRR of the system. Some depreciation and inflation are essential to consider of projection. Optimizing the portion share of for liability and equity to get the optimum value. LGC or other policy that affects the economy value should consider. Price of the unit items for the module is almost half of the direct capital cost, any commercial agreement with the vendor for the price and extended warranty is beneficial point.

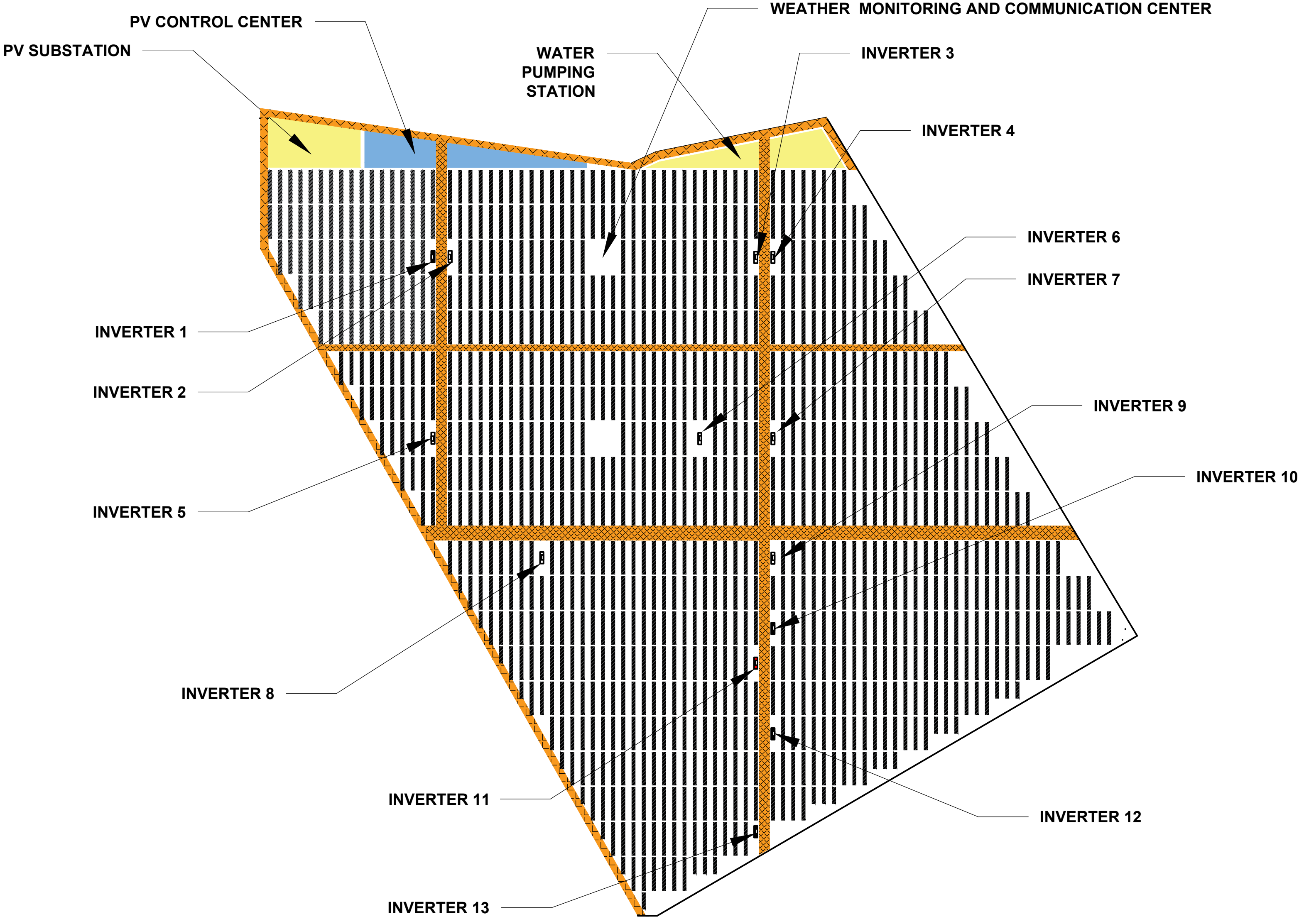
Conclusion

The objectives of the project for reducing the emissions, increase the renewable energy in energy mix portion, accommodate the clean power generation supply for targeted customer. Proposed location is situated at Queensland in Renewable Energy Zone. The projected capacity of the power plant is 37.75 MWp with the on-grid system. Several standards referred to AS/NZS have been accounted for the system design. Any detail of the specification selection is compactible and optimize according to the system requirement. All risks have been accounted with integrate solutions to significantly reduce the impact. Projected timeline of system construction of the utility PV will take 13.5 months after the contract signing and estimated for 2.5 months for initial preparation. With the extensive financial calculation, the IRR is 14.78% with NPV $4,596,061 for the 25 years is an excellent bargain to penetrate the market and become the leader of this business sector.

10. Appendix

A. Workshop Drawing





TOTAL SYSTEM DETAILS

PV PANELS:
TRINA TSM DE20 605W

PANEL DIMENSIONS:
2172mm x 1303mm

NO.OF MODULES:
62400

OVERALL MWp
37.75

MODULE TILT:
2P Single Tracking

MODULE AZIMUTH:
EAST WEST

INVERTER:
SUNGROW SG2500 HV/MV

NO. OF INVERTERS
13

OVERALL MWac
32.5

PROJECT NAME:
KIANGA QLD UTILITY PROJECT

PROJECT ADDRESS:
KIANGA, QLD
-24.51°S, 150.06°E

PROJECT TITLE:
UTILITY PLANT LAYOUT

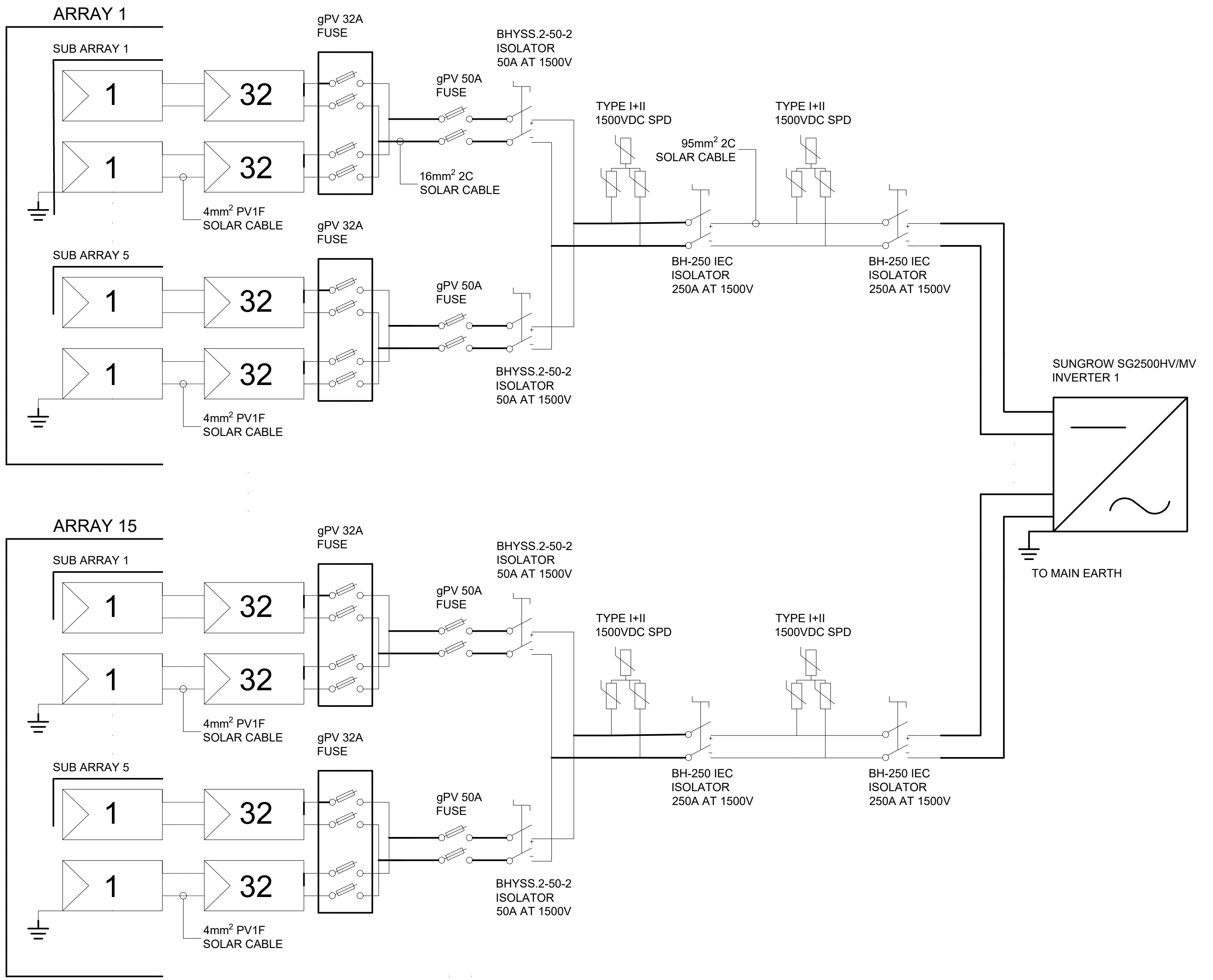
PROJECT CONTRACTOR
TYREE Energy Pty

DESIGN PANEL

DESIGNED AND DRAWN BY
RAHUL ASHWIN
GROUP - 9 GRADUATE ENGINEER

01/08/2022

PV SYSTEM ORIENTATION AND LAYOUT



TOTAL SYSTEM DETAILS

PV PANELS:
TRINA TSM DE20 605W

PANEL DIMENSIONS:
2172mm x 1303mm

NO.OF MODULES:
62400

OVERALL MWp
37.75

MODULE TILT:
2P Single Tracking

MODULE AZIMUTH:
EAST WEST

INVERTER:
SUNGROW SG2500 HV/MV

NO. OF INVERTERS
13

OVERALL MWac
32.5

PROJECT NAME:
KIANGA QLD UTILITY PROJECT

PROJECT ADDRESS:
KIANGA, QLD
-24.51°S, 150.06°E

PROJECT TITLE:
DC SINGLE LINE DIAGRAM

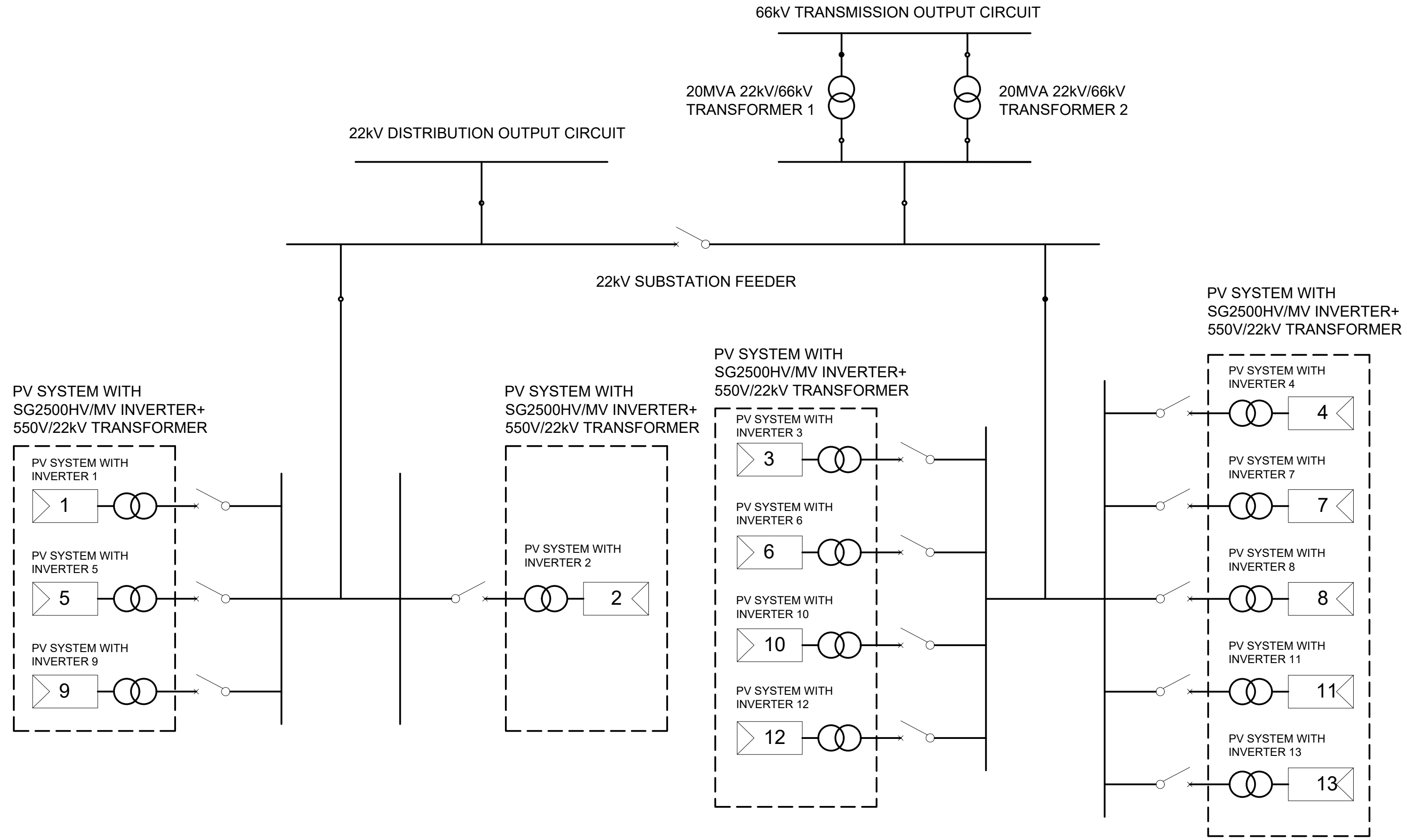
PROJECT CONTRACTOR
TYREE Energy Pty

DESIGN PANEL

DESIGNED AND DRAWN BY
RAHUL ASHWIN
GROUP - 9 GRADUATE ENGINEER

01/08/2022

DC SINGLE LINE DIAGRAM



TOTAL SYSTEM DETAILS

PV PANELS:
TRINA TSM DE20 605W

PANEL DIMENSIONS:
2172mm x 1303mm

NO.OF MODULES:
62400

OVERALL MWp
37.75

MODULE TILT:
2P Single Tracking

MODULE AZIMUTH:
EAST WEST

INVERTER:
SUNGROW SG2500 HV/MV

NO. OF INVERTERS
13

OVERALL MWac
32.5

PROJECT NAME:
KIANGA QLD UTILITY PROJECT

PROJECT ADDRESS:
KIANGA, QLD
-24.51°S, 150.06°E

PROJECT TITLE:
AC SINGLE LINE DIAGRAM

PROJECT CONTRACTOR
TYREE Energy Pty

DESIGN PANEL

DESIGNED AND DRAWN BY
RAHUL ASHWIN
GROUP 9 - GRADUATE ENGINEER

01/08/2022

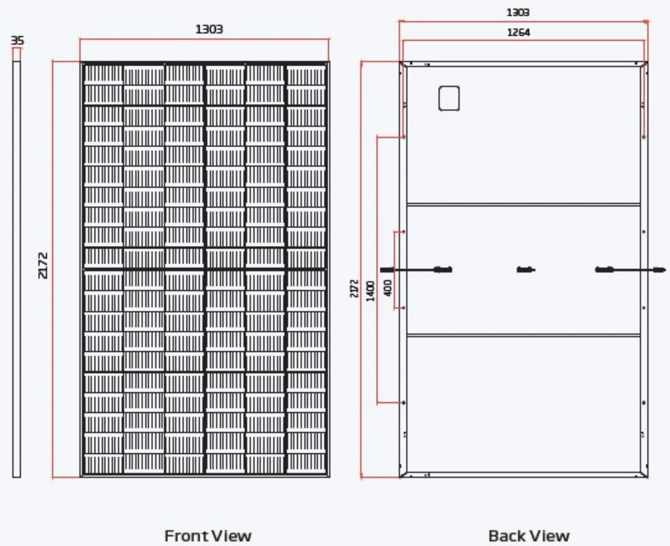
AC SINGLE LINE DIAGRAM

B. Datasheets & Warranties

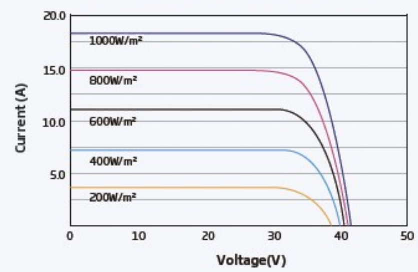
Module Datasheet

Vertex BACKSHEET MONOCRYSTALLINE MODULE

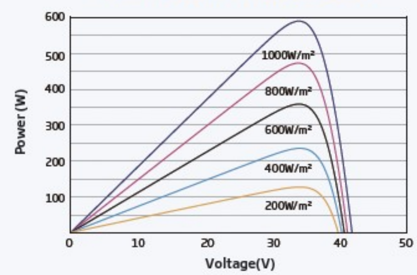
DIMENSIONS OF PV MODULE(mm)



I-V CURVES OF PV MODULE(595W)



P-V CURVES OF PV MODULE(595W)



ELECTRICAL DATA (STC)

Peak Power Watts-PMAX (Wp)*	585	590	595	600	605
Power Tolerance-PMAX (W)			0 ~ +5		
Maximum Power Voltage-VMPP (V)	33.8	34.0	34.2	34.4	34.6
Maximum Power Current-IMPP (A)	17.31	17.35	17.40	17.44	17.49
Open Circuit Voltage-Voc (V)	40.9	41.1	41.3	41.5	41.7
Short Circuit Current-Isc (A)	18.37	18.42	18.47	18.52	18.57
Module Efficiency η m (%)	20.7	20.8	21.0	21.2	21.4

STC: Irrdiance 1000W/m2, Cell Temperature 25°C, Air Mass AM1.5. *Measuring tolerance: ±3%.

MECHANICAL DATA

Solar Cells	Monocrystalline
No. of cells	120 cells
Module Dimensions	2172×1303×35 mm (85.51×51.30×1.38 inches)
Weight	30.9 kg (68.1 lb)
Glass	3.2 mm (0.13 inches), High Transmission, AR Coated Heat Strengthened Glass
Encapsulant material	EVA
Backsheet	White
Frame	35mm(1.38 inches) Anodized Aluminium Alloy
J-Box	IP 68 rated
Cables	Photovoltaic Technology Cable 4.0mm² (0.006 inches²), Portrait: 280/280 mm(11.02/11.02 inches) Landscape: 1400/1400 mm(55.12/55.12 inches)
Connector	MC4 EVO2 / TS4*

*Please refer to regional datasheet for specified connector.

ELECTRICAL DATA (NOCT)

Maximum Power-PMAX (Wp)	443	447	451	454	458
Maximum Power Voltage-VMPP (V)	31.5	31.7	31.9	32.0	32.2
Maximum Power Current-IMPP (A)	14.05	14.09	14.13	14.18	14.22
Open Circuit Voltage-Voc (V)	38.5	38.7	38.9	39.1	39.3
Short Circuit Current-Isc (A)	14.81	14.85	14.88	14.92	14.96

NOCT: Irradiance at 800W/m², Ambient Temperature 20°C, Wind Speed 1m/s.

TEMPERATURE RATINGS

NOCT (Nominal Operating Cell Temperature)	43°C (±2°C)
Temperature Coefficient of PMAX	- 0.34%/°C
Temperature Coefficient of Voc	- 0.25%/°C
Temperature Coefficient of Isc	0.04%/°C

MAXIMUM RATINGS

Operational Temperature	-40~+85°C
Maximum System Voltage	1500V DC (IEC) 1500V DC (UL)
Max Series Fuse Rating	30A

WARRANTY

12 year Product Workmanship Warranty
25 year Power Warranty
2% first year degradation
0.55% Annual Power Attenuation

(Please refer to product warranty for details)

PACKAGING CONFIGUREATION

Modules per 40' container: 512 pieces

TrinaPro

SG2500HV-MV

SG3000HV-MV

SUNGROW Inverter, Designed For TrinaPro

High Yield

- Efficient three-level topology,max.system efficiency up to 99%
- 1or2 MPPT,wide MPP voltage range
- Full power opwer operation without derating at 50℃
- One inverter unit fails,the other units continue operation

Easy O&M

- Integrated zone current monitoring function for fast trouble shooting
- Module design and front service,easy for maintenance
- DC circuit breaker design for convenient maintenance

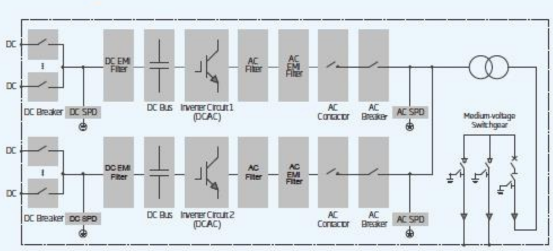
Saved Investment

- DC 1500V， AC 600V,low system initial investment
- 20-foot container design,no need to build extra inverter house
- Integrated MV transformer and LV auxiliary power supply

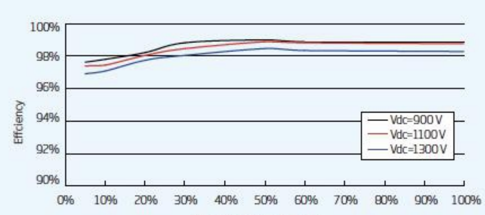
Grid Support

- Compliance with standards:CE,IEC 62109
- Low/High voltage ride through(L/HVRT)
- Active&reactive power control and power ramp rate comtrol

Circuit Diagram



Inverter Efficiency Curve



SG2500HV-MV/SG3000HV-MV

Input(DC)	SG2500HV-MV	SG3000HV-MV
Max.PV input voltage	1500V	
Min.PV input voltage/Startup input voltage	800V/840V	900V/940V
MPP voltage range for nominal power	800-1300V	900-1300V
No.of independent MPP inputs	1 or 2	
No.of DC inputs	16-24	
Max.PV input current	3508A	
Max.DC short-circuit current	4210A	

Output(AC)		
Nominal AC power	2500KW(at 50°C)	3000KW(at 50°C)
Max.AC output power at PF=1	2750KW(at 50°C)	3000KW(at 50°C)
Max.AC apparent power	2750KVA(at 50°C)	3000KVA(at 50°C)
Max.AC output current	2886A	
AC voltage range	550V	600V
Nominal grid frequency/Grid frequency range	50Hz/45-55Hz,60Hz/55-65Hz	
THD	<3%(at nominal power)	
DC current injection	<0.5%In	
Power factor at nominal power/Adjustable power factor	>0.99/0.8 leading-0.8 lagging	
Feed-in phases/Connection phases	3/3	

Efficiency		
Inverter Max. efficiency/Inverter Euro.efficiency	99.0%/98.7%	

Transformer		
Transformer rated power	2500KVA	3000KVA
Transformer max power	2750KVA	3000KVA
LV/MV votage	0.55KV/10-35KV	0.6KV/10-35KV
Transformer vector	Dy11	
Oil type	Mineral oil(PCB free) or degradable oilon request	

Protection		
DC reverse connection protection	Yes	
DC input protection	Circuit breaker	
Inverter output protection	Circuit breaker	
AC output protection	Circuit breaker*/Load switch + fse**	
Overvoltage protection	DC Type II/AC Type II	
Grid monitorting/Ground fault monitoring	Yes/Yes	
Insulation monitoring	Yes	
Overheat monitoring	Yes	
Anti-PID function	Optional	

General Data		
Dimensions(W*H*D)	670*2896*2438mm	
Weight	17T	
Degree of protection	IP54	
Auxiliaey power supply	220Vac,2KVA/Optional:380Vac,up to 15KVA	
Operating ambient temoerature range	-35 to 60°C(>50°C derating)	
Allowable relative humidity range(non-condensing)	0-95%	
Cooling method	Temperature controlled forced air cooling	
Max.operating altiude	1000m(standard)/>1000m(optional)	
Display	Touch screen	
Connection	Standard:RS485,Ethernet;Optional:optical fiber	
Compliance	CE,IEC 62109	
Grid Support	LVRT,HVRT,active & reactive power control and power ramp rate control	
Type designation	SG2500HV-MV-S-10/SG2500HV-MV-C-10 SG3000HV-MV-S-10/SG3000HV-MV-C-10	

Trinasolar

CAUTION: READ SAFETY AND INSTALLATION INSTRUCTIONS BEFORE USING THE PRODUCT.

Version number: TSM_EN_2018_A
www.trinasolar.com

C. Wind and Lightning Assessment

The result of wind and lightning assessment are given as follows.

Name	Value
Wind region	A0
Aerodynamic shape factor (Cshp)	2.85
Terrain Category	TC2
Terrain Multiplier	0.91
Topographic Multiplier	1

Name	Value
DC SPD	N/A, available in inverter
AC SPD	N/A, available in inverter

The detailed determination of wind assessment parameter is given in the following screencapture.

B.6.2 Panels mounted on ground

The use of this Section shall be limited to the calculation of wind loads on solar panel arrays with the following restrictions as shown in Figure B.11:

(a) Panels attached to a ground mounted frame with aspect ratios $2 \leq d/h \leq 5$ and $b/d \geq 2$.

(b) Panels attached to the frame at an inclination to ground, $\alpha \leq 30°$.

(c) Panel arrays with a spacing of $3.5 \leq s/h \leq 10$.

(d) Panels with a minimum gap between the underside of the panel and the ground surface $c/h \geq 0.2$.

NOTE Tracking, ground-mounted, solar panel arrays have occasionally experienced severe vibrations due to aeroelastic forces (flutter). These effects are not covered in this Standard; specialist advice should be sought.

The aerodynamic shape factor (C_{shp}) for net pressures normal for solar panels, satisfying the above conditions, shall be calculated from Equation B.6:

$$C_{shp} = C_{p,n} K_a K_\ell \qquad \text{B.6}$$

where

Table B.13 — Net pressure coefficients ($C_{p,n}$) for solar panel array — θ = 0° (see Figure B.11)

Panel pitch (α) degrees	θ = 0 degrees							
	$C_{p,w}$		$C_{p,l}$		$C_{p,w}$		$C_{p,l}$	
	B1	B2, B3	A1	A2, A3	D1	D2, D3	C1	C2, C3
0	0.45	0.45	0.25	0.10	0.40	0.25	0.25	0.10
15	1.20	1.20	0.80	0.45	1.40	0.80	0.90	0.40
20	1.30	1.20	0.80	0.45	1.50	0.75	0.90	0.45
25	1.45	1.35	0.95	0.60	1.60	0.85	1.00	0.55
30	1.50	1.25	0.95	0.70	1.70	0.85	1.10	0.65

Table B.14 — Net pressure coefficients ($C_{p,n}$) for solar panel array — θ = 180° (see Figure B.11)

Panel pitch (α) degrees	θ = 180 degrees							
	$C_{p,w}$		$C_{p,l}$		$C_{p,w}$		$C_{p,l}$	
	A1	A2, A3	B1	B2, B3	C1	C2, C3	D1	D2, D3
0	−0.50	−0.55	−0.35	−0.20	−0.50	−0.35	−0.35	−0.15
15	−1.20	−1.40	−0.60	−0.85	−1.40	−1.45	−0.70	−0.65
20	−1.40	−1.45	−0.75	−0.90	−1.40	−1.40	−0.70	−0.70
25	−1.50	−1.45	−0.75	−0.95	−1.50	−1.35	−0.75	−0.80
30	−1.60	−1.50	−0.80	−0.95	−1.55	−1.30	−0.90	−0.85

B.1.2 Area reduction factor (K_a)

For the design of freestanding roofs and canopies, the area reduction factor (K_a) shall be as defined in Clause 5.4.2. For all other cases in this Appendix, $K_a = 1.0$.

B.1.3 Local net pressure factor (K_ℓ)

For the design of cladding elements and elements that offer immediate support to the cladding in free roofs and canopies, the values of local net pressure factor (K_ℓ) given in Table B.1 shall be used. For other elements in free roofs and canopies and for all other cases in this Appendix, $K_\ell = 1.0$. If an area of cladding is covered by more than one case in Table B.1, the largest value of K_ℓ shall be used. The largest aspect ratio of any local pressure factor area on the roof shall not exceed 4.

Table B.1 — Local net pressure factors (K_ℓ) for open structures

Case	Description	Local net pressure factor (K_ℓ)
1	Pressures on an area between 0 and $1.0a^2$ within a distance $1.0a$ from an upwind roof edge, or downwind of a ridge with a pitch of 10° or more	1.5
2	Pressures on an area of $0.25a^2$ or less, within a distance $0.5a$ from an upwind roof edge, or downwind of a ridge with a pitch of 10° or more	2.0
3	Upward net pressures on an area of $0.25a^2$ or less, within a distance $0.5a$ from an upwind corner of a free roof with a pitch of less than 10°	3.0
NOTE	Where a is 20 % of the shortest horizontal plan dimension of the free roof or canopy.	

4.2.1 Terrain category definitions

Terrain, over which the approach wind flows towards a structure, shall be assessed on the basis of the following category descriptions:

(a) *Terrain Category 1 (TC1)* — Very exposed open terrain with very few or no obstructions, and all water surfaces (e.g. flat, treeless, poorly grassed plains; open ocean, rivers, canals, bays and lakes).

(b) *Terrain Category 2 (TC2)* — Open terrain, including grassland, with well-scattered obstructions having heights generally from 1.5 m to 5 m, with no more than two obstructions per hectare (e.g. farmland and cleared subdivisions with isolated trees and uncut grass).

(c) *Terrain Category 2.5 (TC2.5)* — Terrain with some trees or isolated obstructions, terrain in developing outer urban areas with scattered houses, or large acreage developments with more than two and less than 10 buildings per hectare.

(d) *Terrain Category 3 (TC3)* — Terrain with numerous closely spaced obstructions having heights generally from 3 m to 10 m. The minimum density of obstructions shall be at least the equivalent of 10 house-size obstructions per hectare (e.g. suburban housing, light industrial estates or dense forests).

(e) *Terrain Category 4 (TC4)* — Terrain with numerous large, high (10 m to 30 m tall) and closely-spaced constructions, such as large city centres and well-developed industrial complexes.

Selection of the terrain category shall be made with due regard to the permanence of the obstructions that constitute the surface roughness.

NOTE The aerodynamic roughness length, z_0, in metres, is related to the terrain category number by the following relation: $z_0 = 2 \times 10^{(TC\ \text{number}-4)}$

Table 4.1 — Terrain/height multipliers for gust wind speeds in fully developed terrains — All regions except A0

Height (z) (m)	Terrain/height multiplier ($M_{z,cat}$)				
	Terrain Category 1	Terrain Category 2	Terrain Category 2.5	Terrain Category 3	Terrain Category 4
≤ 3	0.97	0.91	0.87	0.83	0.75
5	1.01	0.91	0.87	0.83	0.75
10	1.08	1.00	0.92	0.83	0.75
15	1.12	1.05	0.97	0.89	0.75
20	1.14	1.08	1.01	0.94	0.75
30	1.18	1.12	1.06	1.00	0.80
40	1.21	1.16	1.10	1.04	0.85
50	1.23	1.18	1.13	1.07	0.90
75	1.27	1.22	1.17	1.12	0.98
100	1.31	1.24	1.20	1.16	1.03
150	1.36	1.27	1.24	1.21	1.11
200	1.39	1.29	1.27	1.24	1.16

NOTE 1 In Region A0, use $M_{z,cat\ 2}$ for all $z \leq 100$ m in all terrains. For 100 m < $z \leq 200$ m, take $M_{z,cat}$ as 1.24 in all terrains.

NOTE 2 For all other regions, for intermediate terrains use linear interpolation.

NOTE 3 For intermediate values of height z, use linear interpolation.

4.4.1 General

The topographic multiplier (M_t) shall be taken as follows:

(a) For sites in Regions A4, NZ1, NZ2, NZ3 and NZ4 over 500 m above sea level, use Equation 4.4(1):

$$M_t = M_h M_{lee} (1 + 0.00015E) \quad 4.4(1)$$

where

M_h = hill shape multiplier

M_{lee} = lee (effect) multiplier (taken as 1.0, except in New Zealand lee zones, see Clause 4.4.3)

E = site elevation above mean sea level, in metres

(b) For sites in Region A0, use Equation 4.4(2):

$$M_t = 0.5 + 0.5M_h \quad 4.4(2)$$

(c) Elsewhere, the larger value of the following:

(i) $M_t = M_h$

(ii) $M_t = M_{lee}$

4.4.2 Hill-shape multiplier (M_h)

The hill-shape multiplier shall be taken as 1.0 outside of the local topographic zones shown in Figures 4.3 to 4.5, and for $H < 10$ m. Within the local topographic zones, the hill shape multiplier (M_h) shall be assessed for each cardinal direction considered, taking into account the most adverse topographic cross-section that occurs within the range of directions within 22.5° on either side of the cardinal direction being considered. The values shall be as follows:

D. Voltage Drop

With the chosen PV configuration, we deployed SOLA4012 PV Tool V3 2022 to compute the losses in the system. The result is as follows:

String voltage drop	2.90 V
Subarray voltage drop	0.00 V
Array voltage drop	0.07 V
Max voltage drop	2.98 V
Max voltage drop as percentage	0.32 %

Hence, the voltage drop in every array is only 0.32%, which is much below the required maximum voltage drop by standard.

E. Miscellaneous Information on System Design and Economics

This section will explain some of the decision on system design that was not written in the main body of the report. First, the system size choice. We chose 32.5 MW_{ac} as the system size because we want to maximize the NPV and IRR as much as possible. The bigger the size, the better the figures because economies of scale make the cost of BoS cheaper. However, we are constrained by the land size and the substation new generator capacity. We cannot increase the system size further because the limitation of the land size, and we already put all the modules, inverter, and transformer in one area of land as illustrated in the PV layout design.

For the tracking, we chose single axis tracking because in Australia, that is how PV modules in majority of the utility project are installed. Thus, we assume, this is the best practice for utility project in general. In addition to that, the land price in our chosen site is relatively cheap, so it would be favorable to use tracker and low ground coverage ratio than to have fixed tilt and higher ground coverage ratio. For the spacing between modules, we chose around 8 m to avoid shading until 60 degrees of tilt.

For the revenue model, we choose 100% PPA because we want to minimize risk. By choosing PPA as our model, we can expect exactly how much revenue we will get in the operational time of the project. Also, we choose the PPA price to be lower than some PPA price in Australia to make sure that the PPA can be closed easier than we choose higher price. FCAS may be a more interesting market when the battery price is lower. However, for the current battery cost and battery expected lifetime, our group chose not to consider this market for now.

F. SOLA 4012 PV Tool V3 2022

In this section, we provide some of the output of SOLA 4012 PV Tool V3 that we used to compute the PV-inverter matching, OCP device, and voltage drop.

Voltage and current matching of PV and Inverter:

	V_mp_min	V_mp_max	V_max
Array 1	936	1193	1411
MPPT 1	880	1235	1425
Check (Yes/No)	Yes	Yes	Yes

Power and current matching of PV and Inverter:

Power and current check			
	Max Current	**Max Power**	**Rated Power (include average c**
Array 1	232.13	193,600.00	160,646.49
MPPT 1	3,508.00	3,437,500.00	2,500,000.00
Check (Yes/No)	Yes	Yes	Yes

OCP Device:

Fuse Rating				
MPPT 1	**Required (Yes/No)**	**Min Current (A)**	**Max Current (A)**	**Min Voltage (V)**
Strings	Yes	28	30	1411
Sub-arrays	Yes	47	N/A	1411
Array	No	233	N/A	1411

Switch / Isolator:

Switches/Isolator Rating			
MPPT 1	**Required (Yes/No)**	**Min current rating (per pole)**	**Voltage rating (per pole)**
Strings	No	28	1410.7944
Sub-arrays	Yes	47	1410.7944
Array	Yes	233	1410.7944

Voltage Drop:

Cables		
Min current rating	**Voltage rating**	**Max Voltage Drop (V)**
28	1410.7944	2.90
47	1410.7944	0.00
233	1410.7944	0.07

Max total Vdrop	2.98
Max total Vdrop as percentage (%)	0.32

G. Desk Research of Component Costs

Module and Inverter

Name	Brand	Product	Value (W)	Price ($) / item	Price ($) /Wp	Total Item	Total ($)	Reference Link
Module	Trina Solar	TSM-DE20 605	605	193.600	**0.32**	62,400	**12,080,640**	https://moruiersolar.en.made-in-china.com/product/vOftnqbrHQVS/China-Best-Price-Trina-Solar-Panel-605W-Large-Solar-Cell-Mono-605W-Flexible-Solar-Panel-Price.html
Inverter	Sungrow	SG2500HV-MV	2,500,000	390,791	**0.1600**	13	**5,080,286**	https://ubsenerji.online/product/sungrow-sg2500u-2500kw-inverter/
						Total	**17,160,926**	

BoS

Name	Value			Product Name	Price($) /item	Items/ meters	Total($) /Inverter	No. of Inverter	Subtotal	Source
String Fuse	30 A	1500 V		Solarson 10X85 r	0.44	150	65.9	12	790	https://m.alibaba.com/product/60838538610/-TUV-CE-10X85-mm-1500V.html
Sub-Array Fuse	50 A	1500 V		SUNTREE DC 150	1.76	75	132	12	1,584	https://www.alibaba.com/product-detail/SUNTREE-DC-1500V-30A-to-63A_1600150667501.html
Sub-Array Isolator	50 A	1500 V		BENY Solar DC is	17.39	75	1,304	12	15,651	https://www.alibaba.com/product-detail/solar-DC-isolator-switches-2P-50A_1600131597222.html
Array Isolator	250 A	1500 V		SuntreeSolar PV	36.58	15	549	12	6,584	https://www.alibaba.com/product-detail/Solar-PV-electric-1500V-250A-DC_1600190959099.html
String Cable	Multi-core 2C Cu	4 mm2	42m /string	Slocable 2 PfG 1	1.75	150	263	12	3,150	
Frame Earthing Cable	Single-core Cu	4 mm2	50m /string	Woquan Single	2.54	75	191	12	2,286	https://www.alibaba.com/product-detail/4mm2-6mm2-Single-Core-Wire-Copper_1600568035656.html?spm=a2700.7724857.0.0.3604ae45UOSzl5&s=p
Sub-Array Cable	Multi-core 2C Cu	16 mm2	221m /sub-array	Electrical Wire E	4.20	75	315	12	3,776	
Array Cable	Multi-core 2C Cu	95 mm2	5m /array	Ali Copper Powe	5.86	15	88	12	1,055	
AC Cable	Multi-core 3C+E	50 mm2	500 m	RNEDA circular	1.47	1	1.47	12	17.64	https://www.alibaba.com/product-detail/600V-3C-E-70mm2-95mm2-orange_1600130808006.html
Transformer	22 kV	66 kV		Yawei China fact	548657	1	548,657	2	1,097,314	
PV Mounting	Single Axis Tracking	2P		SunChaser One	107.9	75	8,093	12	97,110	https://www.alibaba.com/product-detail/One-axis-solar-tracking-system_60779210250.html
Delivery Fee	30%								368,795	
				Grand Total ($)					**1,598,113**	
								/Panel	**25.61**	

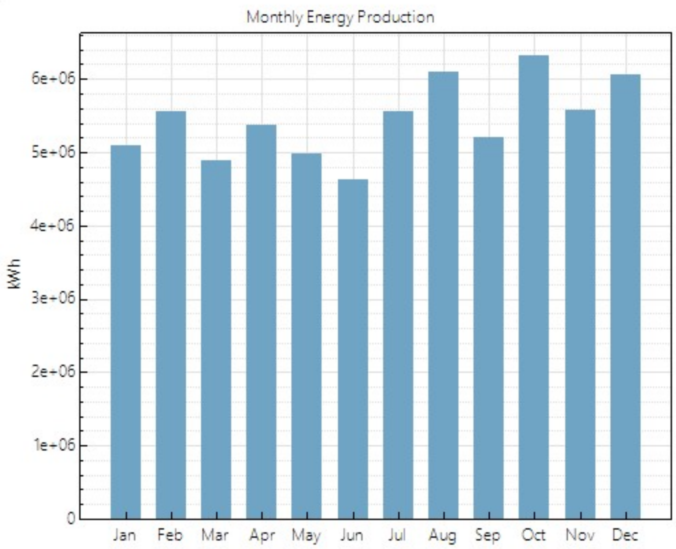
Capital and Economic Analysis

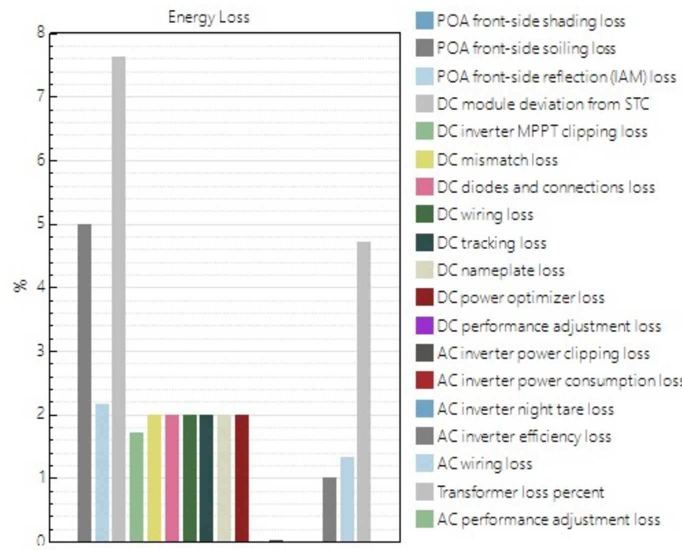
Cost Parameters	Price($) /Wp	Subtotal ($)
Modules	0.32	12,080,640
Inverter	0.16	5,080,286
Balance of System (BoS)	0.04	1,598,113
EPC Overhead	0.04	1,623,110
Install Labor & Equipment	0.09	3,320,786
Installation Overhead	0.04	1,623,110
Contingency (3%)	0.02	759,781
GST (10%)	0.07	2,608,583
Direct Capital Costs	**0.76**	**28,694,410**

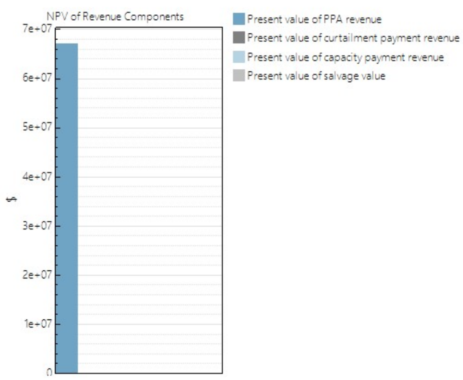
Cost Parameters	Price	Unit	Price($) /Wp	Qty	Subtotal ($)	
Land Price	145,679	ha	0.35	90.21	13,141,703	
Land Clearance & Preparation	29,136	ha	0.07	90.21	2,628,341	20% of Land Price
System Inspection and Monitoring	1.73	Wdc	0.04	902,175	1,560,763	Utility-Scale One-Axis System Cost Benchmark NREL Q1-2021
Land Tax			0.01		218,909	According to QLD Government Land Tax Rates: $1,450 plus 1.7 cents for each $1 more than $350,000
Grid Interconnection	100,000	km	0.01	2	200,000	
Developer Overhead	0.04	wp	0.05		1,742,670	
Other Cost (Insurance, etc.)			0.05		1,949,238	10% of Indirect Costs
Indirect Capital Costs			0.57		**21,441,623**	
Initial Capital Costs			1.33		**50,136,033**	
					1.33	Wp

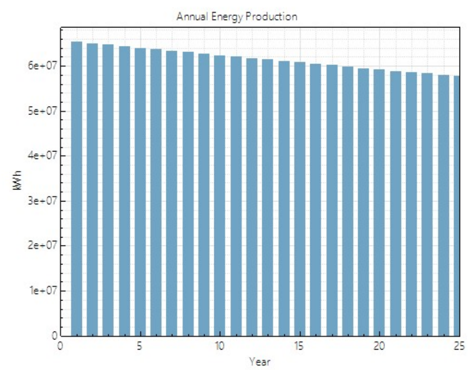
H. SAM Calculation

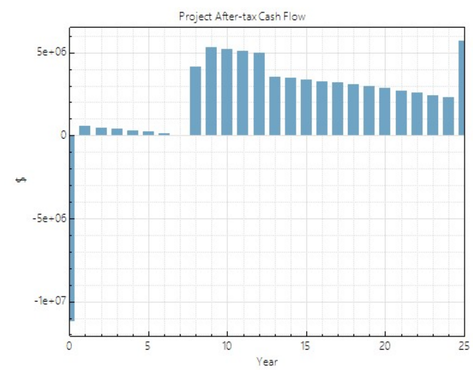
Metric	Value
Annual energy (year 1)	65,324,836 kWh
Capacity factor (year 1)	19.7%
Energy yield (year 1)	1,730 kWh/kW
Performance ratio (year 1)	0.68
PPA price (year 1)	13.00 ¢/kWh
PPA price escalation	0.00 %/year
Levelized PPA price (nominal)	13.00 ¢/kWh
Levelized PPA price (real)	8.72 ¢/kWh
Levelized COE (nominal)	12.11 ¢/kWh
Levelized COE (real)	8.13 ¢/kWh
Net present value	$4,596,061
Internal rate of return (IRR)	14.78 %
Year IRR is achieved	25
IRR at end of project	14.78 %
Net capital cost	$56,113,084
Equity	$11,222,617
Size of debt	$44,890,468
Minimum DSCR	0.62


Monthly Energy Production
kWh
0
1e+06
2e+06
3e+06
4e+06
5e+06
6e+06
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Energy Loss
%
0
1
2
3
4
5
6
7
8
POA front-side shading loss
POA front-side soiling loss
POA front-side reflection (IAM) loss
DC module deviation from STC
DC inverter MPPT clipping loss
DC mismatch loss
DC diodes and connections loss
DC wiring loss
DC tracking loss
DC nameplate loss
DC power optimizer loss
DC performance adjustment loss
AC inverter power clipping loss
AC inverter power consumption loss
AC inverter night tare loss
AC inverter efficiency loss
AC wiring loss
Transformer loss percent
AC performance adjustment loss


NPV of Revenue Components
$
7e+07
6e+07
5e+07
4e+07
3e+07
2e+07
1e+07
0
Present value of PPA revenue
Present value of curtailment payment revenue
Present value of capacity payment revenue
Present value of salvage value


Annual Energy Production
kWh
6e+07
5e+07
4e+07
3e+07
2e+07
1e+07
0
0 5 10 15 20 25
Year


Project After-tax Cash Flow
$
5e+06
0
-5e+06
-1e+07
0 5 10 15 20 25
Year

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