INDEPENDENT ENGINEERING REPORT

PV Module Evaluation

PREPARED FOR:
PHILADELPHIA SOLAR

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BANKABILITY STUDY OF PHILADELPHIA SOLAR PV MODULES
Jordan

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DOCUMENT HISTORY

ISSUE	DATE	SUMMARY
A	25 April 2023	Initial Draft
B	08 May 2023	Additional Client documents
C	15 May 2023	Additional Client documents
D	06 May 2024	Nexus Modules Technical Specifications and Certificates Review
F	26 June 2026	Nexus modules updated datasheets

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LIST OF ACRONYMS

Acronym		Description
A	AC	Alternating Current
	A_{DC}	DC Current
	AOI	Automatic Optical Inspection
B	BOP	Balance of Plant
C	°C	Celsius
	CAPEX	Capital Expenditure
	CBB	Common Building Block
	C&I	Commercial and Industrial
D	DC	Direct Current
E	EPC	Engineer, Procure, and Construction
	EVA	Ethylene – Vinyl Acetate
	EL	Electroluminescence
G	GW	Gigawatt
H	HSE	Health Safety Environment
I	IEC	International Electrotechnical Commission
	ISC	Isolated Secondary Circuit
	ISO	International Organization for Standardization
K	kW	Kilowatt
	Kg	Kilogram
M	m	meter
	mmsq	Square millimeter
	MBB	Multi-busbar
	MV	Medium Voltage
	MW	Megawatt
	MPP	Maximum Power Point
	MPPT	Maximum Power Point Tracker
	M/C	Machine Control
	MENA	Middle East and North Africa
O	O&M	Operations and Maintenance
	OPEX	Operational Expenditure
P	Pa	Pascals
	PERC	Passive Emitter and Rear Cell
	PMP	Project Management Profession
	PO	Purchase Order
	PID	Proportional, Integral, Derivative
	PV	Photovoltaic
Q	QAQC	Quality Assurance, Quality Control
R	R&D	Research and Development
S	STC	Standard Temperature and Test Conditions
	SOP	Standard Operating Procedure
T	TSL	Trina Solar Limited
	TSM	Translucent Solar Module

	TUV	Technical Inspection Association
	TAR	Technical Advisory Report
U	UL	UL Solutions
	USD	United States Dollar
	USD/kW	United States Dollar per Kilowatt
V	V_{DC}	DC Voltage
	VOC	Open Voltage Temperature Coefficient
	VDR	Virtual Data Room
W	Wp	Watt Peak
	W_{DC}	DC Power

1. INTRODUCTION

UL Middle East FZ-LLC ("**UL Solutions**" or "**UL**"), a UL company, is pleased to provide Philadelphia Solar (the "**Client**") with the following technical advisory report ("**TAR**" or the "**Report**") for the independent technology review of a new solar PV Module (the "**Product**" or "**Modules**") manufacturer.

The details for the PV Modules under review are summarized in the Table 1.1.

Table 1.1: Philadelphia Solar Modules

Series	Model	Power range (Wp)	Technology	Max Efficiency (%)	Bifaciality ratio (%)
Black-IRIS	PS- M108(HC)	400-410	Half-Cell Mono- Crystalline	21.0	NA
Dark-PHENEX	PS- M108(HCBF)	400-410	Half-Cell Mono- Crystalline	21.0	65±5
PHENEX	PS-M132(HCBF)	500-510	Half-Cell Mono- Crystalline	21.5	65±5
IRIS	PS- M144(HC)	540-555	Mono-Crystalline modules	21.5	NA
PHENEX	PS- M144(HCBF)	540-555	Mono-Crystalline modules	21.5	65±5
PHENEX Double Glass	PS- M144(HCBF)-GG	535-550	Mono-Crystalline modules	21.29	65±5
PHENEX	PS- M156(HCBF)	580-590	Mono-Crystalline modules	21.06	65±5
PHENEX Double Glass	PS- M156(HCBF)-GG	580-590	Mono-Crystalline modules	21.0	65±5
Nexus	PS-MNB144(HCBF)	570-590	Half-Cell N-Type 16BB Bifacial Modules	22.83	80±5
Nexus	PS-MNB156(HCBF)	615-635	Half-Cell N-Type 16BB Bifacial Modules	22.75	80±5
Nexus	PS-MNB108(HCBF)	425-440	Half-Cell N-Type 16BB Bifacial Modules	22.57	80±5
Nexus	PS-MNB108(HCBF)	420-435	Half-Cell N-Type 16BB Bifacial Modules	22.29	80±5
Nexus	PS-MNB132(HCBF)	510-530	Half-Cell N-Type 16BB Bifacial Modules	22.27	80±5
Nexus	PS-MNG144(HCBF)	565-580	Half-Cell N-Type 16BB Bifacial Modules	22.45	80±5

This report analyzes the information shared by the Vendor in the data room ("**VDR**") and updates through e-mails up to 08 April 2023. New certificates and technical datasheets for Nexus series of PV modules have been provided for UL Solutions review on 17 April 2024.

UL has visited the Philadelphia Solar factory located in Amman, Jordan on 20st March. This report summarizes the walk-through the factory installations as well as the discussions held with different company members during the site visit.

All capitalized terms within this report have the meaning given to them in the Project documents unless otherwise defined. All provision of **[Bold and Bracketed]** statements within the report represents requests for clarification and all provisions of **<Bold and Angle Bracketed>** statements within the report represent pending updates or follow-up items of the report.

The scope of work performed by UL and shown in this report is according to the agreed proposal ("OPP-2023-02-0327736_IE_PV_Philadelphia_Jordan_B.pdf" signed and shared by the Client on 28 February

2023 by email. Scope of work covered by UL and included in this report is summarized in the following Table 1.2:

Table 1.2: Summary of the Scope of Work Covered by UL

Section	Status	Comments
Section 1 – Module technology Review		
Company Review	Completed	-
Production Review	Completed	-
Module Technology Review	Completed	-
Section 2 – Factory Site Visit		
Factory Site Visit	Completed	-
Section 3 – Report Update		
Report Update	Completed	Nexus series of modules technical specification and certificates review

2. EXECUTIVE SUMMARY

2.1 Company Review

Philadelphia Solar is a Tier-1 solar panel manufacturer and the largest manufacturer of solar panels and steel mounting structures in the Middle East, Europe, and Africa. The company was established in Jordan in 2007, and it exports PV modules to over 52 countries through more than 220 distributors worldwide. The company's Jordan factory has a production capacity of 580 MW per year and plans to increase it to up to 870 MW by the end of 2023. Philadelphia Solar is also an EPC contractor specializing in the design and execution of solar power plants. The company has developed and invested in various power generation projects in the Middle East, Africa, and Asia. The financial reports for the company for the last six years show a positive net profit after tax and that the profit is increasing year over year. Philadelphia Solar's photovoltaic modules have received full IEC and UL certifications and along with additional certifications, demonstrating the company's commitment to delivering high-quality products.

2.2 Production Review

The Philadelphia Solar manufacturing facility uses equipment from Chinese and European manufacturers and suppliers, with a maximum production capacity of 180 modules per hour. The production process involves ten workstations, including cutting, stringing, lay-up, laminating, framing, and packaging. The company has implemented Quality Management Systems as per ISO 9001, ISO 14001, & ISO 45001 certificates, and all processes have applicable Standard Operating Procedures in place. UL has reviewed the documentation and found the manufacturing facility's QAQC and HSE to be updated and appropriate, recommending regular monitoring and reviewing of health and safety measures and quality controls.

2.3 Module Technology Review

UL has reviewed the key specifications and test certificates for five models of Philadelphia Solar PV modules provided by the client and listed in the table below:

Table 2.1: Philadelphia Solar Modules

Series	Model	Max Power range (W)	Technology	Efficiency (%)	Bifaciality ratio (%)
Black-IRIS	PS- M108(HC)	400-410	Half-Cell Mono- Crystalline	21.0	NA
Dark-PHENEX	PS- M108(HCBF)	400-410	Half-Cell Mono- Crystalline	21.0	65±5
PHENEX	PS-M132(HCBF)	500-510	Half-Cell Mono- Crystalline	21.5	65±5
IRIS	PS- M144(HC)	540-555	Mono-Crystalline modules	21.5	NA
PHENEX	PS- M144(HCBF)	540-555	Mono-Crystalline modules	21.5	65±5
PHENEX Double Glass	PS- M144(HCBF)-GG	535-550	Mono-Crystalline modules	21.29	65±5
PHENEX	PS- M156(HCBF)	580-590	Mono-Crystalline modules	21.06	65±5
PHENEX Double Glass	PS- M156(HCBF)-GG	580-590	Mono-Crystalline modules	21.0	65±5
Nexus	PS-MNB144(HCBF)	580-600	Half-Cell N-Type 16BB Bifacial Modules	22.83	80±5
Nexus	PS-MNB156(HCBF)	630-650	Half-Cell N-Type 16BB Bifacial Modules	22.75	80±5

Nexus	PS-MNB108(HCBF)	425-440	Half-Cell N-Type 16BB Bifacial Modules	22.57	80±5
Nexus	PS-MNB108(HCBF)	445-460	Half-Cell N-Type 16BB Bifacial Modules	23.60	80±5
Nexus	PS-MNB132(HCBF)	520-540	Half-Cell N-Type 16BB Bifacial Modules	22.27	80±5
Nexus	PS-MNG144(HCBF)	580-600	Half-Cell N-Type 16BB Bifacial Modules	23.22	80±5

Philadelphia Solar's modules offer a combination of P-type and N-type cells, with the latter boasting a higher efficiency and long-term degradation warranty. The design also incorporates multi-busbar and half-cut cell technology, which improves the reliability, maximizes peak power, and minimizes power loss. UL has reviewed the module specifications and certifications, confirming that they meet industry standards. In addition, Philadelphia Solar offers a comprehensive limited product warranty and a limited peak power warranty for up to 30 years, with degradation rates that are consistent with industry standards. UL also assessed the company's approach to customer satisfaction and claims handling, adding an extra layer of assurance. Overall, Philadelphia Solar's PV modules and warranties meet the typical standards found in the industry.

2.4 Site Visit

UL visited Philadelphia Solar's module manufacturing facility in Amman, Jordan and gained a comprehensive understanding of the manufacturing process. The facility uses both automatic and manual inspection methods and implements advanced smart inspection technology to ensure high-quality products. UL inspected all the areas for the production process and review other aspects such as production, quality, and HSE, and found the production process to be in line with industry standards. The factory operates with three shifts per day and runs six days per week. Employees undergo regular trainings, and protective safety measures are in place. Philadelphia Solar plans to expand production by the end of the year. UL suggests that more automated machines or additional equipment could improve the process in some areas.

3. COMPANY REVIEW

3.1 Company Background

Philadelphia Solar was established in Jordan in 2007 with a built-up area of 14,200 m2 and has a current investment of US$ 165 million. Philadelphia Solar is a Tier-1 solar panel manufacturer [1] and the largest manufacturer of solar panels and steel mounting structures in the Middle East, Europe and Africa. [2] Philadelphia was the first MENA region company to manufacture, develop, design, construct, own, and operate utility-scale commercial and industrial photovoltaic plants. With Free Trade Agreements between Jordan, the EU, the U.S., Canada, Morocco, and throughout the MENA region, Philadelphia Solar exports PV modules to over 52 countries through more than 220 distributors worldwide and has 4 regional offices in the US, Iraq, Morocco, and Jordan. Philadelphia Solar is currently employing more than 400 team members worldwide. [3]

Philadelphia Solar is a steel mounting structure and photovoltaic panel manufacturer, which includes monocrystalline, polycrystalline, and bifacial module types. Philadelphia Solar is also an EPC contractor specializing in the design and execution of solar power plants.

3.2 Company Production

Jordan factory has an expected sales capacity of 520 MW for 2023, according with Sales and Product history report [4] , sales capacity has been increased and improved along the years as per data provided. Philadelphia Solar has planned a factory upgrade by end of 2023 and expects to increase the capacity to up to 870 MW.

Philadelphia Solar has submitted their production reports for the last three years [5] [6] [7] with detailed manufacturing capacity of modules in units and in MW. The production is summarized in the Table 3.1:

Table 3.1: Philadelphia Solar production

Year	Number of Modules	Annual production (MW)	Sales (MW)	Difference Sales/Production (MW)
2022	514,288	242.09	317	74.91
2021	266,064	107.54	218	110.46
2020	320,113	107.79	180	72.21

UL notes that there is a difference between the Sales MW and Production MW. Philadelphia Solar clarifies that this difference is due to production stock as well as imported production form other factories.

3.3 Company Modules

Philadelphia Solar's photovoltaic (PV) products cover a range of different technology iterations. Philadelphia Solar specializes in the production of monocrystalline, mono-facial and bifacial solar modules summarized in the Table 3.2 below.

Table 3.2: Philadelphia Solar Modules

Series	Model	Max Power range (W)	Technology	Efficiency (%)	Bifaciality ratio (%)
Black-IRIS	PS- M108(HC)	400-410	Half-Cell Mono- Crystalline	21.0	NA
Dark-PHENEX	PS- M108(HCBF)	400-410	Half-Cell Mono- Crystalline	21.0	65±5
PHENEX	PS-M132(HCBF)	500-510	Half-Cell Mono- Crystalline	21.5	65±5
IRIS	PS- M144(HC)	540-555	Mono-Crystalline modules	21.5	NA
PHENEX	PS- M144(HCBF)	540-555	Mono-Crystalline modules	21.5	65±5
PHENEX Double Glass	PS- M144(HCBF)- GG	535-550	Mono-Crystalline modules	21.29	65±5
PHENEX	PS- M156(HCBF)	580-590	Mono-Crystalline modules	21.06	65±5
PHENEX Double Glass	PS- M156(HCBF)- GG	580-590	Mono-Crystalline modules	21.0	65±5
Nexus	PS-MNB144(HCBF)	580-600	Half-Cell N-Type 16BB Bifacial Modules	23.22	80±5
Nexus	PS-MNB156(HCBF)	630-650	Half-Cell N-Type 16BB Bifacial Modules	23.26	80±5
Nexus	PS-MNB108(HCBF)	425-440	Half-Cell N-Type 16BB Bifacial Modules	22.57	80±5
Nexus	PS-MNB108(HCBF)	445-460	Half-Cell N-Type 16BB Bifacial Modules	23.60	80±5
Nexus	PS-MNB132(HCBF)	520-540	Half-Cell N-Type 16BB Bifacial Modules	22.69	80±5
Nexus	PS-MNG144(HCBF)	580-600	Half-Cell N-Type 16BB Bifacial Modules	23.22	80±5

PHENEX and IRIS modules are built using the advanced M10 wafer and monocrystalline PERC cell technology. These modules feature 144 cells and are designed with bifacial technology, which allows for an additional power output on the power output that is produced from the front side. Bifacial technology is an evolution of monofacial module technology that uses the same materials and solar cells, with the addition of busbars to the back of the cells to allow light capture instead of covering the entire back of the cell with conductive. Black IRIS and Dark PHENEX are designed for rooftop use and feature lightweight black modules. Philadelphia solar is up to date with the evolving market technology and willing to adopt the latest technology always such as N-type Products.

3.4 Company Projects

Philadelphia Solar has undertaken development and investment in diverse power generation initiatives across Middle East, Africa, and Asia, with a selection of local ventures detailed in Table 3.3. Notable among these are Al-Baydia Power Generation, with a output power rating of 23 MWp, and Al-Husainiyah with an output rating of 66 MWp. Additionally, Philadelphia Solar has exported their PV modules for deployment in international projects located in Canada, Lebanon, and the USA, among various other countries. These details are furnished within Table 3.4.

Table 3.3: Jordan Projects References

Project	MW
Al-Badiya Power Generation	23.0
Al-Hussainiyah	66
Social Security Corporation	18.75
Taybah Metal Industries	14.7
Abdali Medical Center	8.2
United Cable Industries Company	4.5
Giant Industrial Group Factory	2.7
Istishari Hospital	2.5
North Gate Mills Factory	2.2
Al Zaytoonah University	1.77
The University of Jordan	4.7
Gaza Central Wastewater	4.7
Al Tahooneh Chicken Projects	4

Table 3.4: International References

Location	MW
Canada	102.96
Lebanon	88.35
USA	17.83
Morocco	13.31
Turkey	11.96
UK	8.02
Germany	2.44
Iraq	2.15

3.5 Company Factory

Philadelphia Solar factory is located in Al Qastel Industrial Area, Airfreight Road, Amman, Jordan. The factory is equipped with Chinese and European state-of-the-art equipment as specified in Section 4.1 of this report.

3.6 Company Organization chart

UL has reviewed the documentation provided regarding staff organization [8] as illustrated in Figure 3.1 and training records [9] [10] and considers the organizational chart suitable for the company's scope and operations, and the training for each employee category to be appropriate.

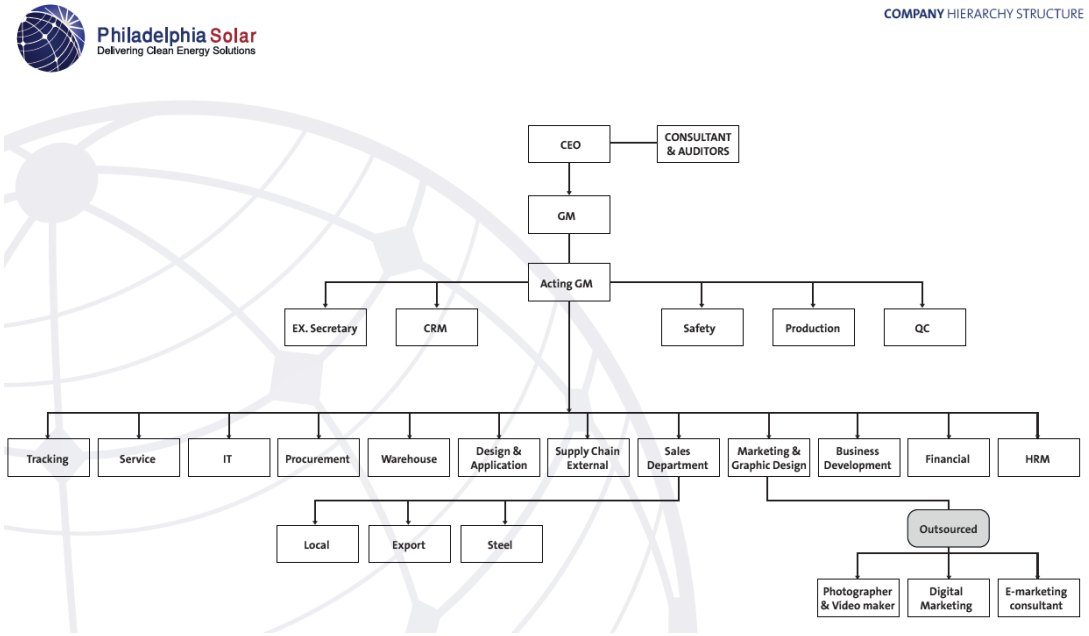

Figure 3.1: Philadelphia Solar Organization Chart

3.7 Company Financial Status

UL reviewed the Client's audited financial independent reports issued by a third party (Ernst & Young Jordan) for the last five years from 2017 up to 2021. Financial statement for 2022 was issued by Philadelphia Solar, a third-party audited report was not provided for this specific year.

The table below summarizes the key financial metrics reviewed provided by Philadelphia Solar. Figures reported in the third-party reports are in Jordanian Dinar (JOD), the Table 3.5 show those figures in USD considering a currency converter of 1.41044 USD.

Table 3.5: Audited financial summary for last 6 years

Item	Audited	Audited	Audited	Audited	Audited	-
	2017	2018	2019	2020	2021	2022
Operating income (USD)	6,435,862.82	6,200,295.36	43,945,574.14	6,668,425.74	60,965,943.19	107,832,183.14
Operating profit (USD)	2,521,092.39	867,327.51	2,466,945.60	5,037,974.61	5,553,617.37	5,584,223.92
Net profit after tax (USD)	2,403,527.98	392,085.39	2,298,502.39	4,591,223.39	4,874,277.54	4,857,606.14
Operating margin (%)	9.54%	3.31%	5.61%	10.80%	9.11%	5.18%
Net margin (%)	9.09%	1.50%	5.23%	9.84%	8.00%	4.50%
Net cash flow from operating activities (USD)	722,912.56	9,440,544.60	,277,595.99	7,455,571.74	2,416,546.34	Not provided

3.8 Company Quality Certificates

Philadelphia Solar's photovoltaic modules have undergone extensive testing and have received full International Electrotechnical Commission (IEC) certification, including IEC61215, IEC61730, IEC TS

62804-1, IEC 60068-2, IEC 61701, IEC 62716, IEC 62782 , UL61215 and UL 61730. The company also holds additional certifications, including ISO 9001:2015, ISO 14001, and ISO 45001, demonstrating the commitment to delivering high-quality products.

4. PRODUCTION REVIEW

4.1 Equipment

According to Philadelphia Solar manufacturing equipment report [11] [12], the machine manufacturers are from China and the machine suppliers are Jinchen, ATW, and Endeas. There are various equipment capacities available, with a range capacity production between 75 and 180 modules per hour. The workshop sections and accompanying equipment are shown in the Table 4.1 below:

Table 4.1: Equipment

Workshop Section	Equipment name	Machine Supplier	Machine Type	Capacity
Preparation	EVA cutting machine	Jinchen	-	100pcs/ hour
Laser Cutting	Laser Cutting	ATW	HC40A-185	3300cell/ hour
Glass Loading	Automatic glass feeding machine	Jinchen	-	150 modules/hour
EVA Cutter	EVA Cutter	Jinchen	Inline with Glass Loader	150 modules/ hour
Soldering	1 String Soldering	ATW	MS100B	5400cell/ hour
	2 String Soldering	ATW	AM050E	6400cell/hour
Layup	Lay up	DR-Link Jinchen	HS-ALM-2842H02-PH01	150 modules/ hour
	AutoBussing	DR-Link Jinchen	AutoBussing 3 in 1 HCC	150 modules/ hour
	Auto Tapping Machine	DR-Link Jinchen	Tapping Machine	150 modules/ hour
	EVA cutting machine	Jinchen	-	150 modules/ hour
	EL1tester	Jinchen	EL&FAOI-MIS-2	110 modules/ hour
	EL2tester	Jinchen	EL&FAOI-MIS-2	110 modules/ hour
	Edge sealing Tapping	Jinchen		150 modules/ hour
Lamination	Lamination 1	Jinchen	JCCY2774-DST Automatic Laminator	75 modules/ hour
	Lamination 2	Jinchen	JCCY2774-DST Automatic Laminator	75 modules/ hour
Post Lamination	Post EL	Jinchen	-	Sample Size Testing
	Trimming Machine	Jinchen	-	100 modules/ hour
	Visual Inspection 90 Deg	Jinchen	-	150 modules/ hour
Frame	Framing Machine	Jinchen	-	85 modules/hour
	Auto Silicone Dispenser	Jinchen	-	120 modules/hour
	Framing machine and auto silicone dispenser	Jinchen	-	80 modules/hour
	Frame potting machine	Jinchen	-	150 modules/hour
	J-Box potting machine	Jinchen	-	150 modules/hour
	Glue coating for J-box	Jinchen	-	150 modules/hour
	Curing Handler	Jinchen	-	180 modules/hour
	Corner Filing Machine	Jinchen	-	150 modules/hour

Table 4.1: Equipment

Workshop Section	Equipment name	Machine Supplier	Machine Type	Capacity
Testing	Flash tester QS 600 and Post EL an Hipot tester	Endeas	-	180 modules/ hour
Sorting	Auto Sorting Machine	Jinchen	-	180 modules/hour
Transportation	Transportation	HELI and Hyundai	HELI CBD15	NA

4.2 Production Process

According to the documentation provided [13] the production Engineers shall create a report, to sum up, the outcomes and findings of the ten working stations listed below:

- **Production preparation stage:** The PV laser cutting machine cuts the full cell into two halves using a highly concentrated laser beam. The technician and production engineers check and report the received cells from the warehouse, cut cells, and broken cells on daily basis.

Philadelphia solar has implemented a colored T-shirt procedure to identify the position of each employee on the production area:

- **First Workstation:**
  Tabbing and Stringing M/C: The ATW MS100B stringer machines are used with the productivity of up to 5500 cells/ hour for each one whose function is to string the cells using ribbons and flux. Then, the EL tests to check each string is free of any defect.
- **Second Workstation:**
  Lay-up M/C: There are two stages, one of which is the auto-bussing machine, which has productivity of up to 120 modules/hour and is used to buss the strings to form an electrical circuit based on the design drawing. In the second stage which is EL Tester and AOI, each module shall be checked 100% by EL tester to be free of any defect. The AOI detects internal foreign material, cell gaps, corner defects, breakage, scratch, and ribbon misalignment.
- **Third workstation:**
  Laminator M/C: The modules shall be laminated according to the EVA cycle. The lamination cycle depends on the technical data sheet of each EVA used which can be examined by Gel content results and the behavior of EVA on laminators and adhesion test (Peel test). It is performed the lamination temperature profile test to verify the uniformity of the temperatures inside laminator.
- **Fourth workstation:**
  EL after lamination: QC team select samples of one cycle from each laminator/shift to do the EL test.
  Trimming: Two automatic trimming machines are used to trim the remaining back sheet and EVA along the module. The technicians at the Framing stage should inspect the trimming quality on a regular basis
  Visual Inspection: Modules are checked using visual inspection flip-over machines.
- **Fifth workstation:**
  Framing Modules: All machines should operate to test machine performance, and raw materials for the framing stage, and to install frames and junction boxes with silicone. The production engineers and technicians must put the frames on automatic framing M/C for assembly and pressing and then install the junction box using a fixture on the cleaned back sheet and cut excessive ribbons from the junction box. Lastly, a fully automatic farming and

dispensing machine must be utilized to fill the groove in the frame for the module with silicone from the beginning to the end of the groove without gaps or discontinuous flow, allowing the robot to pick the four aluminum frames and automatically install them on the framer.

- **Sixth workstation:**
  Curing and Cleaning: The framing modules are kept in curing for four hours at 25±3 C temperature degrees and 60±20%. The module cleaning will be completed first by removing the protection tape from the aluminum frames and excess silicone from the edges of the frame, this will be followed by cleaning the module surface and frames with Ethanol, finally the edges of the aluminum frame will be filed to remove any sharp edges.
- **Seventh workstation:**
  Hi-pot and Insulation Tester: Total 100% of the production is tested in this stage with an automatic Hi-pot and insulation tester machine.
  QS600 Module Tester M/C Post EL tester: Each module must be 100% tested by a Post EL tester for microcracks, faulty soldering, and other issues.
- **Eighth workstation:**
  Grounding tester: the grounding test shall be done 100% of the modules.
  Part A: auto sorting machine: modules are placed automatically on the pallet.
  Part B: wet leakage current test: wet leakage current etst Is performed one module per shift
- **Ninth workstation:**
  Packaging modules: A packing list paper is attached to each pallet. The manufacturing crew should examine the packing list and compare it to the pallet number barcode and verify that the numbers match. The production engineers shall arrange with the forklift driver to follow the delivery process with warehouse technicians

4.3 QAQC and HSE

UL has reviewed the documentation provided for QAQC and HSE [14] [15] [16] and the independent third-party report performed by Solar PTL, LLC [17] in December 2022 and TUV Austria in August 2022. [18] .

Staff members in the Quality Department are qualified to ensure implementation of all Quality Management Systems as per ISO 9001, ISO 14001, & ISO 45001 certificates.

Standard Operating Procedures have been provided by Philadelphia Solar. UL has verified that all the processes have an applicable procedure in place. In addition, SOP are placed at the factory for each specific area. All provided SOP are summarized in the table below:

Table 4.2: Standard Operating Procedures

SOP	Code
PV cell Laser Cutting Machine (HC-40A)	QP-03-SOP01
Dual Line High Speed Stringing Machine MS100B	QP-03-SOP02
Module Tester Machine	QP-03-SOP04
Gel content Procedure	P-04-SOP05
Ribbon peel test SOP	P-04-SOP07
Framing Process Measurements and Defects	P-04-SOP08
Grounding Test SOP	P-04-SOP11
Peel test for EVA and Backsheet SOP	P-04-SOP17
Final Packaging Standard Operating Procedure (SOP)	QP-03-SOP18
Stringing Machine Quality Defects	QP-04-SOP26

SOP of Testing incoming materials	QP-04-SOP27
Robustness of termination test	QP-04-SOP29
JINCHEN Automatic Framing Machine	QP-04-SOP30
JINCHEN Automatic EVA Cutting Machine	QP-04-SOP31
JINCHEN Automatic Glass Loading Machine	QP-04-SOP32
JINCHEDual Line High Speed Stringing Machine MS100BN Automatic Trimming Machine	QP-04-SOP33
General Calibration SOP	QP-04-SOP34
Dielectrics withstand Test (Hipot and Insulation tests)	QP-03-SOP35
Nameplate SOP	QP-04-SOP36
Glass Sheets Quality Guidelines SOP	QP-03-SOP38
Wet insulation Resistance Test SOP:	QP-04-SOP38
Auto silicone machine	QP-04-SOP42
Laminator	QP-03-SOP45
Bussing ribbon peel test SOP	QP-04-SOP47
Silicone test SOP	QP-04-SOP48
Auto-Bussing machine	QP-03-SOP49
Prepare Silver Calibration Module	QP-03-SOP50
Calibration soldering gun SOP	QP-04-SOP50
Tapping machine	QP-03-SOP53
EVA Cutting Machine	QP-04-SOP51
Junction Box Silicone Machine	QP-04-SOP57
Quality of Defective and Repaired Strings	QP-03-SOP51

All Modules receive an I-V test, a dry Hi-Pot test, a final visual inspection, and an electroluminescence test. Additional tests are performed as per requirements such as pull tests, gel content and wet leakage current tests. UL has reviewed the last updated provided Quality logs of current year 2023 for the below listed tests. Quality tests have been performed on a regular basis with no major production issues registered.

- Bussing Ribbon;
- Frame Dimensions;
- Gel Content Test;
- Grounding Test;
- Peel Test Ribbon;
- Potting Test;
- Pull Test EVA +Backsheet;
- Silicone Test;
- Soldering Guns Temperature;
- Wet HI-pot test;
- Measuring laser cutting depth;
- In Process Quality Control;
- Mechanical Load Test;
- Testing Incoming Materials;
- Out of Box Audit; and,
- Outgoing Quality Control.

UL has reviewed the third-party calibration certificates provided by Philadelphia Solar. All equipment used for testing at the Quality lab and at the Factory are calibrated on a regular basis internally and by a third-party company according to Calibration Devices Log provided [19] and summarized in the tables below.

Table 4.3: Calibration Device Log for Quality Lab Equipment

Device	Type	Manufacturer	Serial Number	Calibrated By.	Accuracy	Range
Force Meter /peel tester	DS2-200N	IMADA	383041	Rum	±0.0.2%	0-200 N
Digital balance-1	PCB600-3	KERN	WD140009632	Rum	±0.005 g	0-100 g
Oven	PCD-C6(5)000 series	-	-	Rum	±2ºC	0~400℃
Digital balance-2	FA2004	Electronic Balance	190327534	Rum	0.1mg	0-200 g
Digimatic Micrometer	Mitutoyo/MDC-1" SX	Mitutoyo	4131248665	Specialized for calibration	±0.001 mm	0 to 25 mm
Digital caliper	F 2013	FERVI	-	Rum	± 0.02 mm	0 to 150 mm
Digital balance-3	WT30000X	Electronic Balance	131015057	Rum	± 1g	0-30 g
Temperature and humidity data logger	RC-51H	Elitech	EL1711300569	Rum	±1 c	0-40 c 20 to 90%
Temperature and humidity data logger	RC-51H	Elitech	EL1711300564	Rum	±1 c	0-40 c 20 to 90%
Temperature and humidity data logger	RC-51H	Elitech	EL1809000482	Internally	±1 c	0-40 c 20 to 90%
Temperature and humidity data logger	RC-51H	Elitech	EL1809000586	Internally	±1 c	0-40 c 20 to 90%
Temperature and humidity data logger	RC-51H	Elitech	EL1809000481	Internally	±1 c	0-40 c 20 to 90%
Temperature sensor-Hall C	N/A	N/A	N/A	Rum	±1 c	0-40 c
Temperature sensor-Hall B	N/A	N/A	N/A	Rum	±1 c	0-40 c
Temperature sensor-Hall A	N/A	N/A	N/A	Rum	±1 c	0-40 c
Thermometer for soldering guns	FG-100	RST	2018080900071	Rum	±3 c for range 300-600 c ±5 c other above	0-700 c
Tape measure	TRP	FINDER	1	Internally	± 1mm	0-3 m

Tape measure	TRP	FINDER	2	Internally	± 1mm	0-3 m
Tape measure	ABS+TRP	MOB	1	Internally	± 1mm	0-3 m
Tape measure	ABS+TRP	MOB	2	Internally	± 1mm	0-3 m
Tape measure	ABS+TRP	MOB	3	Internally	± 1mm	0-3 m
Tape measure	ABS+TRP	SALI	S08022316	Internally	± 1mm	0-3 m
Temperature sensor of heater	N/A	ZNHW	1	Specialized for calibration	c	0-150C
Temperature sensor of heater	N/A	ZNHW	2	Specialized for calibration	±1℃	0-150C
Temperature sensor of heater	N/A	ZNHW	3	Specialized for calibration	±1℃	0-150C
Temperature sensor of heater	N/A	ZNHW	4	Specialized for calibration	±1℃	0-150C
Temperature sensor of heater	N/A	ZNHW	5	Specialized for calibration	±1℃	0-150C
Temperature sensor of heater	N/A	ZNHW	6	Specialized for calibration	±1℃	0-150C
Optical density meter	LS117	Linshang	117000867	Specialized for calibration & Measurement	0.20%	0-100%
Anodization tester	BCT-210C	-	-	Specialized for calibration	0.1 µm	0-10000 µm
Digital shore hardness	HT-6510	landtek	N783409	Specialized for calibration	<± 1H	10-90 HA
WIFI data logger	2-H1	Testo	54779527	Specialized for calibration & Measurement	±0.5℃ ±5%RH	_30 - +50 ℃ 0 - 100 %RH
WIFI data logger	2-H1	Testo	54779538	Specialized for calibration & Measurement	±0.5℃ ±5%RH	_30 - +50 ℃ 0 - 100 %RH
WIFI data logger	2-H1	Testo	54779543	Specialized for calibration & Measurement	±0.5℃ ±5%RH	_30 - +50 ℃ 0 - 100 %RH

WIFI data logger	2-H1	Testo	54779522	Specialized for calibration & Measurement	±0.5℃ ±5%RH	_30 - +50 ℃ 0 - 100 %RH
WIFI data logger	2-H1	Testo	54778691	Specialized for calibration & Measurement	±0.5℃ ±5%RH	_30 - +50 ℃ 0 - 100 %RH
WIFI data logger	2-H1	Testo	54779388	Specialized for calibration & Measurement	±0.5℃ ±5%RH	_30 - +50 ℃ 0 - 100 %RH
WIFI data logger	2-H1	Testo	54778699	Specialized for calibration & Measurement	±0.5℃ ±5%RH	_30 - +50 ℃ 0 - 100 %RH

Table 4.4: Calibration Device Log for Factory Equipment

Device	Type	Manufacturer	Serial Number	Calibrated By.	Accuracy	Range
Hipot device	CHT9981A	Hope Tech	CHT9881A1907143	RSS	1.50%	0-1500 v
Insulation Device	CHT9981A	Hope Tech	CHT9881A1907144	RSS	1.50%	0-1500 v
Wet leakage current test	CS2676CH	Changsheng	1912143-008	RSS	± 1%	0-1500 V
electronics unit	Quick sun EUM64	Endeas	12165	Endeas	<0.2% <0.2%	1-100 v 1-20 A
IR thermometer	QS-IR/15,QS07403B	Endeas	9020338	Specialized for calibration	< 1C	0-35 C
Wet leakage current test temp sensor	N/A	N/A	1	Specialized for calibration	±0.5℃	0-30 C
Conductivity meter	3173	Jenco	JC01681	Specialized for calibration	±5 µs/cm	0-1413 µs/cm
Electrical safety tester	951i	Vitrek Corporation	34145	LaboTest	0.25% + 0.5V 0.25% + 0.5nA + ½ digit 0.5% + 0.002ohm + ½ digit	20V to 6500V 0 to +/-200mA 0 to 150Kohm
Digital Multi Meter	Fluke/117	Fluke	25680921	Specialized for calibration	DC V: ± (0.05 % + 1) AC V: ± (1% + 4)	Voltage: 0.1 mv to 600 v Current: 0.001 to 10 Amp

					DC A: ± (1% of reading + 3 counts) AC A: ± (1.5% of reading + 3 counts) Resistance DC A: ± (0.2% + 1)	Resistance: 0.1 ohm to 6 M ohm
Data Acquisition System	Fluke 2638A Hydra Series lll	Fluke	48085021	Specialized for calibration & Measurement	± 0.5 °c	-270 °c to 400 °c
IR Thermometer	TES/3260	Testo	220700411	Specialized for calibration & Measurement	±2 °c	-35 °c to +550 °c

Philadelphia Solar manufacturing facility is certified to International Organization for Standardization (ISO):

- ISO 9001:2015 – Quality Management System, effective until 26 August 2024 [20]
- ISO 14001:2015 – Environmental Management System, effective until 26 June 2024 [21]
- ISO 45001:2018 – Occupational Health and Safety Management System, effective until 06 July 2023 [22]

UL has reviewed the certificates for the above-mentioned standards issued by TUV Austria which is an independent certification organization.

UL considers the QAQC and HSE applied in Philadelphia Solar updated and appropriate for the products produced. QAQC and HSE are a critical aspect of any workplace, and it is essential to prioritize the well-being of employees and customers. UL recommends monitoring and reviewing the health and safety measures regularly to ensure that they remain effective and up to date to provide a safe environment as well as to perform Quality controls on a regular basis.

5. MODULE TECHNOLOGY REVIEW

5.1 Key Specifications

UL has reviewed the information about the 5 models of Philadelphia Solar PV modules provided in the data room by the Client.

Key Specifications are based on the information included in the Client provided datasheets [23] [24] [25] [26] [27] [28] [29] [30] :

- Black Iris 400-410W (M108-HC)
- Iris 540-555W (M144-HC)
- Dark Phenex 400-410W (M108-HCBF)
- Phenex 540-555W (M144-HCBF)
- Phenex GG 535-550W (M144-HCBF-GG)
- Phenex 500-510 W (M132-HCBF)
- Phenex 580-590W (M156-HCBF)
- Phenex 580-590W (M156-HCBF-GG)
- Nexus 580-600W (PS-MNB144(HCBF))
- Nexus 6130-650W (PS-MNB156(HCBF))
- Nexus 425-440W (PS-MNB108(HCBF))
- Nexus 445-460W (PS-MNB108(HCBF))
- Nexus 520-540W (PS-MNB132(HCBF))
- Nexus 580-600W (PS-MNG144(HCBF))

A summary of products' details and their key specification are provided in tables below. The module efficiency, voltage and current values given below are variable and dependent on the output of the module; the value within the table relates to the highest wattage modules as a representative of each series of PV module.

Table 5.1: Black Iris Module Characteristics

Black Iris		
Item	**Unit**	**Description**
Module	-	PS-M108(HC)
Technology	-	Half-Cell Mono-Crystalline 10BB Black
Power	W	400-410
No. cells	-	108 (54 x 2)
Type of cells	-	Grade A – Mono PERC Crystalline Silicon/10 BB
Cell size	mm	182*91
Front Surface	-	3.2mm Tempered AR Coated Glass
Encapsulant	-	PID Free EVA
Back Cover	-	Backsheet
Frame	-	Anodized Aluminum (Black)
Junction Box	-	IP68, 3 Bypass Diodes
Dimensions	mm	1721 x 1133x 30
Weight	Kg	20.5
Max. System Voltage	V_{DC}	1500
I_{SC}	A_{DC}	13.68 -13.76

I_{MP}	A_{DC}	12.94 - 13.06
V_{OC}	V_{DC}	37.0 - 37.60
V_{MP}	V_{DC}	30.92 - 31.40
Peak Efficiency	%	21.0
Open Voltage Temperature Coefficient VOC	%/C°	-0.26
Short Circuit Current Temperature Coefficient ISC	%/C°	+0.04
Power Temperature Coefficient PMP	%/C°	-0.30
1st Year Performance Warranty	%	98
Degradation Warranty	%	84.8
Annual Degradation	%	-0.55

Table 5.2: Iris Module Characteristics

Iris		
Item	**Unit**	**Description**
Module	-	PS-M144(HC)
Technology	-	Half-Cell Mono-Crystalline 10BB
Power	W	540-555
No. cells	-	144 (72 x 2)
Type of cells	-	Grade A – Mono PERC Crystalline Silicon/10 BB
Cell size	mm	182*91
Front Surface	-	3.2mm Tempered AR Coated Glass
Encapsulant	-	PID Free EVA
Back Cover	-	Backsheet
Frame	-	Anodized Aluminum (Black/Silver)
Junction Box	-	IP68, 3 Bypass Diodes
Dimensions	mm	2277 x 1133x 35
Weight	Kg	29
Max. System Voltage	V_{DC}	1500
I_{SC}	A_{DC}	13.72 - 13.84
I_{MP}	A_{DC}	13.0 - 13.12
V_{OC}	V_{DC}	49.72 - 50.45
V_{MP}	V_{DC}	41.55 - 42.33
Peak Efficiency	%	21.5
Open Voltage Temperature Coefficient VOC	%/C°	-0.26
Short Circuit Current Temperature Coefficient ISC	%/C°	+0.04
Power Temperature Coefficient PMP	%/C°	-0.30
1st Year Performance Warranty	%	98
Degradation Warranty	%	84.8
Annual Degradation	%	-0.55

Table 5.3: Dark Phenex Module Characteristics

Dark Phenex		
Item	**Unit**	**Description**
Module	-	PS-M108(HCBF)
Technology	-	Half-Cell Mono-Crystalline 10BB Black
Power	W	400-410
No. cells	-	108 (54 x 2)
Type of cells	-	Grade A - Mono PERC Crystalline Silicon/10 BB
Cell size	mm	182*91
Front Surface	-	3.2mm Tempered AR Coated Glass
Encapsulant	-	PID Free EVA
Back Cover	-	Transparent Backsheet
Frame	-	Anodized Aluminum (Black)
Junction Box	-	IP68, 3 Bypass Diodes
Dimensions	mm	1721 x 1133x 30
Weight	Kg	20.5
Max. System Voltage	V_{DC}	1500
I_{SC}	A_{DC}	13.55 - 13.66
I_{MP}	A_{DC}	12.92 - 13.01
V_{OC}	V_{DC}	37.15 - 37.55
V_{MP}	V_{DC}	31.0 - 31.52
Peak Efficiency	%	21.0
Bifaciality Ratio	%	65±5
Open Voltage Temperature Coefficient VOC	%/C°	-0.22
Short Circuit Current Temperature Coefficient ISC	%/C°	+0.05
Power Temperature Coefficient PMP	%/C°	-0.35
1st Year Performance Warranty	%	98
Degradation Warranty	%	86
Annual Degradation	%	-0.5

Table 5.4: Phenex Module Characteristics

Phenex		
Item	**Unit**	**Description**
Module	-	PS-M144(HCBF)
Technology	-	Half-Cell 10BB Bifacial
Power	W	540-555
No. cells	-	144 (72 x 2)
Type of cells	-	Grade A – Mono PERC Crystalline Silicon/10 BB
Cell size	mm	182*91
Front Surface	-	3.2mm Tempered AR Coated Glass
Encapsulant	-	PID Free EVA
Back Cover	-	Transparent Backsheet

Frame	-	Anodized Aluminum (Black/Silver)
Junction Box	-	IP68, 3 Bypass Diodes
Dimensions	mm	2277 x 1133x 35
Weight	Kg	29
Max. System Voltage	V_{DC}	1500
I_{SC}	A_{DC}	13.59 - 13.73
I_{MP}	A_{DC}	12.96 - 13.09
V_{OC}	V_{DC}	49.78 - 50.50
V_{MP}	V_{DC}	41.69 - 42.42
Peak Efficiency	%	21.5
Bifaciality Ratio	%	65±5
Open Voltage Temperature Coefficient VOC	%/C°	-0.22
Short Circuit Current Temperature Coefficient ISC	%/C°	+0.05
Power Temperature Coefficient PMP	%/C°	-0.35
1st Year Performance Warranty	%	98
Degradation Warranty	%	86
Annual Degradation	%	-0.5

Table 5.5: Phenex Module Characteristics

Phenex		
Item	**Unit**	**Description**
Module	-	PS-M144(HCBF)-GG
Technology	-	Half-Cell10BB Bifacial Double Glass
Power	W	535-550
No. cells	-	144 (72 x 2)
Type of cells	-	Grade A – Mono PERC Crystalline Silicon/10 BB
Cell size	mm	182*91
Front Surface	-	Semi -Tempered Pattern Coated Glass
Encapsulant	-	EVA and PO
Back Cover	-	Semi -Tempered Pattern /Porcelain Glass
Frame	-	Anodized Aluminum
Junction Box	-	IP68
Dimensions	mm	2278 x 1134x 30
Weight	Kg	32.5
Max. System Voltage	V_{DC}	1500
I_{SC}	A_{DC}	13.63 - 13.83
I_{MP}	A_{DC}	12.79 - 12.96
V_{OC}	V_{DC}	49.99 - 50.63
V_{MP}	V_{DC}	41.83 - 42.44
Peak Efficiency	%	21.29
Bifaciality Ratio	%	65±5
Open Voltage Temperature Coefficient VOC	%/C°	-0.267
Short Circuit Current Temperature Coefficient ISC	%/C°	+0.049

Power Temperature Coefficient PMP	%/C°	-0.349
1st Year Performance Warranty	%	98
Degradation Warranty	%	83.5
Annual Degradation	%	-0.5

Table 5.6: Phenex Module Characteristics

Phenex		
Item	**Unit**	**Description**
Module	-	PS-M132(HCBF)
Technology	-	Half-Cell10BB Bifacial
Power	W	500-510
No. cells	-	144 (66 x 2)
Type of cells	-	Grade A – Mono PERC Crystalline Silicon/10BB
Cell size	mm	182*91
Front Surface	-	3.2 Tempered AR Coated Glass
Encapsulant	-	PID Free EVA
Back Cover	-	Transparent Backsheet
Frame	-	Anodized Aluminum
Junction Box	-	IP68 3 Bypass Diodes
Dimensions	mm	2098 x 1134x 35
Weight	Kg	26
Max. System Voltage	V_{DC}	1500
I_{SC}	A_{DC}	13.48 - 13.58
I_{MP}	A_{DC}	12.89 - 13.00
V_{OC}	V_{DC}	45.78 – 46.18
V_{MP}	V_{DC}	38.80 – 39.28
Peak Efficiency	%	21.5
Bifaciality Ratio	%	65±5
Open Voltage Temperature Coefficient VOC	%/C°	-0.22
Short Circuit Current Temperature Coefficient ISC	%/C°	+0.05
Power Temperature Coefficient PMP	%/C°	-0.35
1st Year Performance Warranty	%	98
Degradation Warranty	%	86
Annual Degradation	%	-0.5

Table 5.8: Phenex Module Characteristics

Phenex		
Item	**Unit**	**Description**
Module	-	PS-M156(HCBF)
Technology	-	Half-Cell 10BB Bifacial
Power	W	580-590

No. cells	-	156 (78 x 2)
Type of cells	-	Grade A - Mono PERC Crystalline Silicon/Bifacial/10BB
Cell size	mm	182*91
Front Surface	-	3.2mm Tempered AR Coated Glass
Encapsulant	-	EVA
Back Cover	-	Transparent Backsheet
Frame	-	AL 6063-T5/6005-T6
Junction Box	-	Protection Degree IP68
Dimensions	mm	2471 x 1134x 35
Weight	Kg	32.5
Max. System Voltage	V_{DC}	1500
I_{SC}	A_{DC}	13.59 - 13.73
I_{MP}	A_{DC}	12.96 - 13.09
V_{OC}	V_{DC}	49.78 - 50.50
V_{MP}	V_{DC}	41.69 - 42.42
Peak Efficiency	%	21.06
Bifaciality Ratio	%	65±5
Open Voltage Temperature Coefficient VOC	%/C°	-0.267
Short Circuit Current Temperature Coefficient ISC	%/C°	+0.049
Power Temperature Coefficient PMP	%/C°	-0.349
1st Year Performance Warranty	%	98
Degradation Warranty	%	86
Annual Degradation	%	-0.5

Table 5.7: Phenex Module Characteristics

Phenex		
Item	**Unit**	**Description**
Module	-	PS-M156(HCBF)-GG
Technology	-	Half-Cell10BB Bifacial Double Glass
Power	W	580-590
No. cells	-	156 (78 x 2)
Type of cells	-	Grade A - Mono PERC Crystalline Silicon/Bifacial/10BB
Cell size	mm	182*91
Front Surface	-	Semi -Tempered Pattern Coated Glass
Encapsulant	-	EVA /POE +POE
Back Cover	-	Semi -Tempered Pattern /Porcelain Glass
Frame	-	AL 6063-T5/6005-T6
Junction Box	-	Protection Degree IP68
Dimensions	mm	2471 x 1134x 30
Weight	Kg	35.3
Max. System Voltage	V_{DC}	1500
I_{SC}	A_{DC}	13.65 – 13.72

I_{MP}	A_{DC}	12.79 – 12.9
V_{OC}	V_{DC}	54.12 – 54.6
V_{MP}	V_{DC}	45.35 – 45.74
Peak Efficiency	%	21.06
Bifaciality Ratio	%	65 ±5
Open Voltage Temperature Coefficient VOC	%/C°	-0.267
Short Circuit Current Temperature Coefficient ISC	%/C°	+0.049
Power Temperature Coefficient PMP	%/C°	-0.349
1st Year Performance Warranty	%	98
Degradation Warranty	%	85
Annual Degradation	%	-0.45

Table 5.6: Nexus Module Characteristics

Nexus		
Item	**Unit**	**Description**
Module	-	PS-MNB144(HCBF)
Technology	-	Half Cell N-Type 16BB Bifacial Modules
Power	W	580-600
No. cells	-	144 (72 x 2)
Type of cells	-	N type Mono-Crystalline
Front Surface	mm	3.2 Tempered AR Coated Glass
Encapsulant	-	PID Free
Back Cover	-	Transparent Backsheet
Frame	-	Anodized Aluminum
Junction Box	-	IP68 with Original MC4
Dimensions	mm	2278 x 1134 x 35
Weight	Kg	29 ±1Kg
Max. System Voltage	V_{DC}	1500
I_{SC}	A_{DC}	14.010- 14.26
I_{MP}	A_{DC}	13.33 - 13.47
V_{OC}	V_{DC}	51.65 – 52.21
V_{MP}	V_{DC}	43.64 – 44.57
Peak Efficiency	%	23.23
Bifaciality Ratio	%	80±5
Open Voltage Temperature Coefficient VOC	%/C°	-0.25
Short Circuit Current Temperature Coefficient ISC	%/C°	+0.045
Power Temperature Coefficient PMP	%/C°	-0.29
1st Year Performance Warranty	%	99
Degradation Warranty @30 years	%	87.4
Annual Degradation	%	-0.4

Table 5.7: Nexus Module Characteristics

Nexus		
Item	**Unit**	**Description**
Module	-	PS-MNB156(HCBF)
Technology	-	Half Cell N-Type 16BB Bifacial Modules
Power	W	630-650
No. cells	-	156 (78 x 2)
Type of cells	-	N type Mono-Crystalline
Front Surface	mm	3.2 Tempered AR Coated Glass
Encapsulant	-	PID Free
Back Cover	-	Transparent Backsheet
Frame	-	Anodized Aluminum
Junction Box	-	IP68 with Original MC4
Dimensions	mm	2464 x 1134 x 35
Weight	Kg	32.5 ±1kg
Max. System Voltage	V_{DC}	1500
I_{SC}	A_{DC}	13.33 - 14.26
I_{MP}	A_{DC}	13.33 - 13.48
V_{OC}	V_{DC}	55.95 – 56.55.
V_{MP}	V_{DC}	47.27 – 48.22
Peak Efficiency	%	23.26
Bifaciality Ratio	%	80±5
Open Voltage Temperature Coefficient VOC	%/C°	-0.25
Short Circuit Current Temperature Coefficient ISC	%/C°	+0.045
Power Temperature Coefficient PMP	%/C°	-0.29
1st Year Performance Warranty	%	99
Degradation Warranty @ 30years	%	87.4
Annual Degradation	%	-0.4

Table 5.8: Nexus Module Characteristics

Nexus		
Item	**Unit**	**Description**
Module	-	PS-MNB108(HCBF)
Technology	-	Half Cell N-Type 16BB Bifacial Modules
Power	W	425-440
No. cells	-	108 (54 x 2)
Type of cells	-	N type Mono-Crystalline
Front Surface	mm	3.2 Tempered AR Coated Glass
Encapsulant	-	PID Free
Back Cover	-	Transparent Backsheet
Frame	-	Anodized Aluminum
Junction Box	-	IP68 with Original MC4
Dimensions	mm	1721 x 1133 x 30

Weight	Kg	20.5 ±1kg
Max. System Voltage	V_{DC}	1500
I_{SC}	A_{DC}	14.05 – 14.30
I_{MP}	A_{DC}	13.23 – 13.36
V_{OC}	V_{DC}	38.29 – 38.63
V_{MP}	V_{DC}	32.23 – 32.98
Peak Efficiency	%	22.57
Bifaciality Ratio	%	80±5
Open Voltage Temperature Coefficient VOC	%/C°	-0.25
Short Circuit Current Temperature Coefficient ISC	%/C°	+0.046
Power Temperature Coefficient PMP	%/C°	-0.30
1st Year Performance Warranty	%	99
Degradation Warranty @ 30years	%	87.4
Annual Degradation	%	-0.4

Table 5.9: Nexus Module Characteristics

Nexus		
Item	**Unit**	**Description**
Module	-	PS-MNB108(HCBF)
Technology	-	Half Cell N-Type 16BB Bifacial Modules
Power	W	445 - 460
No. cells	-	108 (54 x 2)
Type of cells	-	N type Mono-Crystalline
Front Surface	mm	3.2mm Tempered AR Coated Glass
Encapsulant	-	PID Free
Back Cover	-	Transparent Backsheet
Frame	-	Anodized Aluminum
Junction Box	-	IP68 with Original MC4
Dimensions	mm	1721 x 1133 x 30
Weight	Kg	20.5 ±1kg
Max. System Voltage	V_{DC}	1500
I_{SC}	A_{DC}	14.38 – 14.62
I_{MP}	A_{DC}	13.40 – 13.52
V_{OC}	V_{DC}	38.76 – 39.15
V_{MP}	V_{DC}	33.23 – 34.03
Peak Efficiency	%	23.60
Bifaciality Ratio	%	80±5
Open Voltage Temperature Coefficient VOC	%/C°	-0.25
Short Circuit Current Temperature Coefficient ISC	%/C°	+0.046
Power Temperature Coefficient PMP	%/C°	-0.29
1st Year Performance Warranty	%	99
Degradation Warranty @ 30years	%	87.4
Annual Degradation	%	-0.4

Table 5.10: Nexus Module Characteristics

Nexus		
Item	**Unit**	**Description**
Module	-	PS-MNB132(HCBF)
Technology	-	Half Cell N-Type 16BB Bifacial Modules
Power	W	520-540
No. cells	-	132 (66 x 2)
Type of cells	-	N type Mono-Crystalline
Front Surface	mm	3.2mm Tempered AR Coated Glass
Encapsulant	-	PID Free
Back Cover	-	Transparent Backsheet
Frame	-	Anodized Aluminum
Junction Box	-	IP68 with Original MC4
Dimensions	mm	2099 x 1134 x 35
Weight	Kg	26 ±1kg
Max. System Voltage	V_{DC}	1500
I_{SC}	A_{DC}	14.21 – 14.4
I_{MP}	A_{DC}	13.27 – 13.48
V_{OC}	V_{DC}	46.30 – 46.97
V_{MP}	V_{DC}	39.27 – 40.13
Peak Efficiency	%	22.69
Bifaciality Ratio	%	80±5
Open Voltage Temperature Coefficient VOC	%/C°	-0.25
Short Circuit Current Temperature Coefficient ISC	%/C°	+0.046
Power Temperature Coefficient PMP	%/C°	-0.30
1st Year Performance Warranty	%	99
Degradation Warranty @ 30years	%	87.4
Annual Degradation	%	-0.4

Table 5.11: Nexus Module Characteristics

Nexus		
Item	**Unit**	**Description**
Module	-	PS-MNG144(HCBF)
Technology	-	Half Cell N-Type 16BB Bifacial Modules
Power	W	580-600
No. cells	-	144 (72 x 2)
Type of cells	-	N type Mono-Crystalline
Front Surface	mm	2mm Semi-Tempered Pattern Coated Glass
Encapsulant	-	PID Free
Back Cover	-	2mm Semi- Tempered Pattern/Porcelian Glass
Frame	-	Anodized Aluminum
Junction Box	-	IP68 with Original MC4
Dimensions	mm	2278 x 1134 x 30

Weight	Kg	32.5 ±1kg
Max. System Voltage	V_{DC}	1500
I_{SC}	A_{DC}	14.22 – 14.25
I_{MP}	A_{DC}	13.42 – 13.46
V_{OC}	V_{DC}	51.41 – 52.18
V_{MP}	V_{DC}	43.22 – 44.58
Peak Efficiency	%	23.22
Bifaciality Ratio	%	80±5
Open Voltage Temperature Coefficient VOC	%/C°	-0.25
Short Circuit Current Temperature Coefficient ISC	%/C°	+0.045
Power Temperature Coefficient PMP	%/C°	-0.29
1st Year Performance Warranty	%	99
Degradation Warranty @ 30years	%	87.4
Annual Degradation	%	-0.4

Two of the PV modules reviewed, Black Iris and Dark Phenex, are half-cell monocrystalline, framed modules. Half-cut cell modules consist of twice the number of smaller cells instead of the original number of larger cells. In a traditional silicon cell-based PV module, the ribbons interconnecting neighboring cells can cause a significant loss of power during the current transport. Cutting solar cells in half has been proven to be an effective way to lower the resistive power loss. The other advantages of half-cut cells include, reduced resistance and hence reduced power loss, a higher fill factor and better shading performance.

All the cells have a MBB (multi-busbar) design. Modules with MBB design are typically equipped with 10 or more busbars and a round-shaped wiring compared to traditional busbar design with a smaller number of busbars and flat-ribbons. The multi-busbar design supports an increase in module's reliability and peak power by lowering the series resistance and the rounded design results in higher reflectance, where light can be more easily reflected into the cell for higher cell absorption. Other advantages of MBB can include a lower impact of possible microcracks that might occur during the modules' lifetime.

The modules listed include P-type cells and N-type cells. Crystalline silicon solar cells are semiconductor devices and in order to produce power the pure silicon must be doped with additional elements to create the photoelectric effect while will in turn allow the cells to produce power. The most common P-type solar cells are typically doped with Boron which has one less electron than silicon thus creating a net positive charge in the cell. N-type cells are doped with phosphorous which has one more electron than silicon, creating a net negative charge in the cell. P-Type cells are the most common solar cells on the market due to the lower production costs, however N-type cells typically have higher efficiencies and lower rates of degradation. PV Magazine predicts that by 2028, N-type modules will be the dominant technology in the market due to their efficiency and manufacturing benefits. Apart from providing a higher module efficiency, the other advantages of N-type cells are improved (lower) long-term degradation and that N-type cells are not affected by LID (Light-Induced Degradation). P-type cells use PERC (Passivated Emitter Rear Contact) technology which is currently the dominant technology in the market.

The Phenex series of modules PS-M108(HCBF), PS-M144(HCBF) and PS-M108(HCBF)-GG are framed bifacial PV and PS-M108(HCBF)-GG series of modules are double glass. The bifaciality ratio is the percentage of additional energy that can be generated from the back side of the solar panel, compared to the energy produced by the front side. The datasheets indicate that these series of

modules can achieve a potential rear power gain of 65%, which means that the panel is highly efficient in generating electricity from both sides, with the back side contributing significantly to the total energy output. In practice these values are theoretical and the actual energy contribution from the rear side of the modules depends on the row spacing, the albedo of the ground and the height of the PV modules. UL estimates that in a typical system configuration the power contribution from the back side will be between 5% and 20% of the front side and the corresponding annual energy contribution being between 2% and 8%.

The Nexus series of modules PS-MNB144(HCBF), PS-MNB156(HCBF), PS-MNB108(HCBF), PS-MNB132(HCBF), PS-MNG144(HCBF), and are Half Cell N-Type 16BB Bifacial Modules. According to the datasheets, these modules have the ability to generate 5-25% more electricity from the rear, resulting in a much lower localized cost of energy (LCOE) and rate of return (IRR). The PS-MGB module's front surface is 3.2 mm tempered AR-coated glass, while the back cover is a clear sheet. In contrast, the PS-MNG module's front surface is 2mm semi-tempered pattern-coated glass, while the back cover is 2mm semi-tempered/proclamated glass. The modules can endure significant mechanical loads from the front (5,400 Pascal) and back (2,400 Pascal).

UL considers that the module specifications for all series are typical for PV modules used in large scale utility-scale PV plants.

5.2 Test Certificates

UL has reviewed the test certificates and reports provided by Client for the series of PV models considered for review. Test certificates reviewed by UL are in Table 5.12:

Table 5.12: List of Test Certificates

Standard	Standard Description
IEC 61215	Standard for field performance of the modules through stress tests and accelerated life cycle testing.
IEC 61730	Standard for safety against electrical shock, fire and other hazards.
IEC 62716	Standard for resistance to corrosion from ammonia which is important to ensure long PV module lifetime in various environments.
IEC 62804-1-1	Standard that evaluates the PV modules' resistance to Potential Induced Degradation ("PID").
IEC 62782	Standard for cyclic (Dynamic) mechanical load testing for photovoltaic (PV) modules.
IEC 60068-2-68	Standard for resistance to abrasion from airborne dust and sand and ingress of dust into the photovoltaic module.
IEC 61701	Standard for resistance to corrosion from salt mist in marine environments.
IEC 61853-1	Standard for module performance testing and energy rating – Part 1: Irradiance and temperature performance measurements and power rating
IEC 60904	Standard for Photovoltaic devices –Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices
UL 61215	UL Standard for Safety Crystalline Silicon Terrestrial Photovoltaic (PV) Modules – Design Qualification and Type Approval
UL 61730	UL New Harmonized Standard for Safety

Table 5.13: Test certificates for Iris modules

Series	Black Iris			Iris			
Model	PS-M108(HC)			PS-M144(HC)			
Wp	400	405	410	540	545	550	555
IEC 62782:2016	✓	✓	✓	✓	✓	✓	✓
IEC TS 62804	✓	✓	✓	✓	✓	✓	✓
IEC 60068	✓	✓	✓	✓	✓	✓	✓
IEC 62716	✓	✓	✓	✓	✓	✓	✓
IEC 61701	✓	✓	✓	✓	✓	✓	✓
IEC 61215	✓	✓	✓	✓	✓	✓	✓
IEC 61730	✓	✓	✓	✓	✓	✓	✓
UL 61215	✓	✓	✓	✓	✓	✓	✓
UL 61730	✓	✓	✓	✓	✓	✓	✓
IEC 61853				✓	✓	✓	✓
IEC 60904				✓	✓	✓	✓
DEWA	✓	✓	✓	✓	✓	✓	✓

Table 5.14: Test certificates for Phenex modules

Series	Dark Phenex			Phenex				Phenex			
Model	PS-M108(HC)			PS-M144(HCBF)				PS-M144(HCBF)-GG			
Wp	400	405	410	540	545	550	555	535	540	545	550
IEC 62782:2016	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IEC TS 62804	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IEC 60068	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IEC 62716	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IEC 61701	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IEC 61215	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IEC 61730	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
UL 61215	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
UL 61730	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IEC 61853								✓	✓	✓	✓
IEC 60904								✓	✓	✓	✓
DEWA	✓	✓	✓					✓	✓	✓	✓

UL Solutions has received the certifications for the Nexus mono-crystalline bifacial PV modules dated 02 April 2024 certified by Intertek Testing Services NA Inc [31]. The certificates included the following:

Table 5.15: Test certificates for Nexus PS-MNB modules

PV Module	Certificates
PS-MNB156(HCBF)-followed by 615, 620, 625, 630, 635 or 640 Wp; PS-MNB144(HCBF)-followed by 570, 575, 580, 585 or 590 Wp; PS-MNB132(HCBF)-followed by 520, 525, 530, 535 or 540 Wp; PS-MNB120(HCBF)-followed by 470, 475, 480, 485 or 490 Wp; and PS-MNB108(HCBF)-followed by 425, 430, 435, 440 or 445.	• Photovoltaic (PV) Module Safety Qualification - Part 1: Requirements for Construction [UL 61730-1:2022 Ed.2] • Photovoltaic (PV) Module Safety Qualification - Part 2: Requirements for Testing [UL 61730-2:2022 Ed.2+R:25Apr2023] • Photovoltaic (PV) Module Safety Qualification - Part 1: Requirements for Construction [CSA C22.2#61730-1:2019 Ed.2] • Photovoltaic (PV) Module Safety Qualification - Part 2: Requirements for Testing [CSA C22.2#61730-2:2019 Ed.2] • Terrestrial Photovoltaic (PV) Modules - Design Qualification and Type Approval - Part 1: Test Requirements [UL 61215-1:2021 Ed.2] • Terrestrial Photovoltaic (PV) Modules - Design Qualification and Type Approval - Part 1-1: Special Requirements for Testing of Crystalline Silicon Photovoltaic (PV) Modules [UL 61215-1-1:2021 Ed.2] • Terrestrial Photovoltaic (PV) Modules - Design Qualification and Type Approval - Part 2: Test Procedures [UL 61215-2:2021 Ed.2]

UL Solutions has received the certifications for the Nexus N-Type mono-crystalline bifacial PV modules dated 27 March 2024 certified by Intertek Testing Services NA Inc [32]. The certificates included the following:

Table 5.16: Test certificates for Nexus PS-MNG modules

PV Module	Certificates
PS-MNG156(HCBF)-followed by 605, 610, 615, 620 or 625 Wp PS-MNG144(HCBF)-followed by 555, 560, 565, 570, 575 or 580 Wp PS-MNG132(HCBF)-followed by 510, 515, 520, 525 or 530 Wp; PS-MNG120(HCBF)-followed by 460, 465, 470, 475 or 480 Wp. PS-MNG108(HCBF)-followed by 415, 420, 425, 430 or 435 Wp.	• Photovoltaic (PV) Module Safety Qualification - Part 1: Requirements for Construction [UL 61730-1:2022 Ed.2] • Photovoltaic (PV) Module Safety Qualification - Part 2: Requirements for Testing [UL 61730-2:2022 Ed.2+R:25Apr2023] • Photovoltaic (PV) Module Safety Qualification - Part 1: Requirements for Construction [CSA C22.2#61730-1:2019 Ed.2] • Photovoltaic (PV) Module Safety Qualification - Part 2: Requirements for Testing [CSA C22.2#61730-2:2019 Ed.2] • Terrestrial Photovoltaic (PV) Modules - Design Qualification and Type Approval - Part 1: Test Requirements [UL 61215-1:2021 Ed.2] • Terrestrial Photovoltaic (PV) Modules - Design Qualification and Type Approval - Part 1-1: Special Requirements for Testing of Crystalline Silicon Photovoltaic (PV) Modules [UL 61215-1-1:2021 Ed.2] • Terrestrial Photovoltaic (PV) Modules - Design Qualification and Type Approval - Part 2: Test Procedures [UL 61215-2:2021 Ed.2]

- **IEC 61215**, which provides requirements of module design suitability for long-term operation in open-air climates and IEC 61730, the standard for modules' electrical and mechanical safety qualifications for operation in systems with maximum voltage of 1500 V. Based on the documents received, this standard is tested by third party Solar PTL for all the selected series of PV modules. [33] [34] [35] [36] [37] [38] [39] [40] [41] [42] [43] [44] [45] [46] [47] [48] [49] [50] [51] [52] [53] [54] [55] [56] [57] [58] [59] [60] [61] [62] [63] [64] [65] [66].
- **IEC 62716**, which tests the module to determine resistance against ammonia corrosion. The test certificate is issued by UL. [67] [68] and it is available for all the models except for PS-M144(HCBF).

- **IEC 62804-1-1**, which tests the module for the detection of potential-induced degradation (PID). The test certificate is issued by UL [69] [70] and it is available for all the models.
- **IEC 62782**, which tests the resistance of modules for cycling (dynamic) mechanical load. CHSM66M-HC, CHSM66M(DG)/F-BH, CHSM60M-HC, and CHSM60M(DG)/F-BH series were tested to this standard. The test certificate is provided by UL [71] [72] for the models PS-M144(HC), PS-M108(HC) and PS-M144(HCBF)-GG and by Kiwa [73] [74] for the model PS-M144(HCBF).
- **IEC 60068-2-68**, the environmental testing of modules against dust and sand. The test certificate is provided by UL [75] [76] and it is available for all the models.
- **IEC 61701**, which tests the module to determine the resistance to salt mist corrosion. The test certificate is provided by UL [77] [78] the models PS-M144(HC), PS-M144(HCBF)-GG and PS-M108(HC) and for Kiwa [79] [80] for the model PS-M144(HCBF).
- **IEC 61853**, which define measurement procedures for the effects of angle of incidence of the irradiance on the output power of the device, determine the operating temperature of a module for a given set of ambient and mounting conditions and measure spectral responsivity of the module. It also provides a characteristic set of parameters used for detailed energy predictions. The test certificate is provided by UL [81] [82] and it is available for all the models except for PS-M144(HCBF) and PS-M108(HC).
- **IEC 60904-1-2**, the measurement of photovoltaic current-voltage characteristics. The test certificate is provided by UL [83] [84] and it is available for all the models except for PS-M144(HCBF) and PS-M108(HC).
- **DEWA certificate**, the solar equipment to be installed in Dubai needs to undergo a process of certification to ensure compliance to IEC-61215, IEC-61646, IEC-61730-1/2, IEC-61701 and DEWA DRRG standards. [85]. The test certificate is available for all the models except for PS-M144(HCBF).

UL considers the tests listed above to be industry standard certifications for safety. **[UL request to update pending certificates to all module series].**

5.3 Procurement

UL has reviewed the Procurement Procedure QP-01 [86] which outlines the process to ensure that sufficient and adequate review of purchase orders is accomplished through Philadelphia Solar's authorized personnel and that purchased materials are being produced from approved suppliers.

Philadelphia Solar has provided the list of the approved Suppliers for the modules production [87] for 2023 which are summarized in the Table 5.17 below:

Table 5.17: Approved PV Modules suppliers list 2023

Item	Vendor Name
Solar Cells	Tongwei Solar CO., LTD.
	United Renewable Energy Co. Ltd .
	Jiangsu Huaheng New Energy Co., Ltd
	T.S Solar Energy
	Zhejiang Aiko Solar Energy Technology CO., LTD
	Shangrao Jietai New Energy Technology Co.,Ltd
Solar Glass	Guangxi Xiny Photovolatic Industry Co.ltd
	XINYI SOLAR (MALAYSIA) SDN.BHD
	Wujiang CSG Glass Co., Ltd.
	Flat Glass Group Co., Ltd

	Changzhou Almaden Co.,Ltd
	Dongguan CSG solar Glass Co., Ltd.
	CHENZHOU KIBING PHOTOVOLTAIC & ELECTRONIC GLASS CO., LTD
Aluminum	Jiangsu Yuejia Metallic Technology Co., LTD
	Jiangsu Goodsun New Energy Co.,Ltd
	Yonz Technology Co., Ltd
	JIANGYIN YUANSHUO METAL TECHNOLOGY CO., LTD.
	Akome Solar
Backsheet	Cybrid Technologies Inc
	Jolywood(Suzhou)Sunwatt Co.,Ltd.
	Endurans Sunshine Solar Technology Company. Ltd.
EVA	Hangzhou First Applied Material Co., Ltd
	Changzhou Sveck photovoltaic New Material Co.,Ltd
	Filmtec Solar Pvt. Ltd.
	betterfilm
Junction Box	Zhejiang Jiaming Tianheyuan Photovoltaic Technology Co,. Ltd
	Ningbo GZX Pv Technology co,ltd
	QC Solar(Vietnam)Electronic Company
Flux	MacDermid Alpha Hungary Kft.
	Shenzhen Vital New Material Company Limited
	MacDermid Alpha Electronic Solutions
Ribbons	Taicang Juren International Trade Co. LTD.
	Xian Telison New materials
Silicon	SHANGHAI HUITIAN NEW MATERIAL CO.,LTD.
	SUZHOU TONSAN ADHESIVE LTD
Labels	SUZHOU ZhengAo Packing Materal CO., LTD
Solder wire	Jiangsu Huaheng New Energy Co., Ltd
	Deema Building Materials LLC
Tape,EPE	Ever-thriving New Energy Technology Co.,Ltd

Vendor performance evaluation is done according to format QP-01-F5 which has not been provided.

5.4 Product Warranty

According to the Limited Warranty document [88], Philadelphia Solar provides the following warranty, subject to the exclusions and limitations in the warranty document:

- Limited product warranty: Philadelphia Solar has a limited product warranty of 144 months from the warranty start date.
- Limited peak power warranty: Philadelphia Solar provides to the customer a Limited Peak Power Warranty with a term of 25 years for single glass modules or 30 years for the double glass modules from the Warranty Start Date
  - Mono-Crystalline single glass product:
    - 1st year –actual power output will be no less than 98% of the nominal power output;
    - 2nd year to 25th year – actual power output will decline no more than 0.55% annually; and

        - End of 25th year – actual power output will be no less than 84.8% of the nominal output.
    - Bifacial Mono-Crystalline single glass product:
        - 1st year –actual power output will be no less than 98% of the nominal power output;
        - 2nd year to 25th year – actual power output will decline no more than 0.50% annually; and
        - End of 25th year – actual power output will be no less than 86% of the nominal output.
    - Poly-Crystalline single glass product:
        - 1st year –actual power output will be no less than 97.5% of the nominal power output;
        - 2nd year to 25th year – actual power output will decline no more than 0.70% annually; and
        - End of 25th year – actual power output will be no less than 80.7% of the nominal output.
    - Bifacial Mono-Crystalline double glass product:
        - 1st year –actual power output will be no less than 98% of the nominal power output;
        - 2nd year to 30th year – actual power output will decline no more than 0.50% annually; and
        - End of 30th year – actual power output will be no less than 83.5% of the nominal output.
    - Mono-Crystalline double glass product:
        - 1st year –actual power output will be no less than 98% of the nominal power output;
        - 2nd year to 30th year – actual power output will decline no more than 0.50% annually; and
        - End of 30th year – actual power output will be no less than 83.5% of the nominal output.

UL notes that the performance warranty is only applicable for the actual power output of the front-side of the modules.

UL considers the overall warranty offered by Philadelphia Solar to be typical of an industry standard warranty for both product and performance warranty.

UL also considers that the degradation rate of the modules to be consistent with industry standard for modules.

5.5 Customer Feedback Management

UL reviewed Philadelphia Solar ’s procedure for Customer Satisfaction and Claims [89]. The document describes the methodology and approach that shall be adopted to handle customers’ complaints to minimize them. The team members responsible for this include:

- Quality Assurance Engineer;
- Quality Control Engineer;
- Management Representative; and,
- Sales Representative.

Process is segregated into different steps:

- Customer Satisfaction Survey;
- Analysis of Customer Satisfaction Surveys; and,
- Customer Complaint.

Another document related to this procedure QP-18 is listed below. UL has also reviewed the below listed documents.

- Customer Satisfaction Survey - QP-18-F1;
- Customer claim form - QP-18-F2;
- Corrective Action form - QP-16-F1;
- Corrective and Preventive Action Procedure - QP-16; and,
- Warranty Claims Record.

6. FACTORY SITE VISIT

UL visited Philadelphia Solar module manufacturing facility in Amman, Jordan on 20 March 2023. During the visit, UL gained a comprehensive understanding of the manufacturing process, which we verified against the documentation. During an interview with facility's quality manager which was conducted during the visit, UL learned that Philadelphia Solar uses both automatic and manual inspection methods to assess the product at different stages of PV module assembly.

UL witnessed the use of state-of-the-art smart inspection equipment and techniques such as EL inspection using artificial intelligence to inspect the product. This smart inspection system used is industry-leading technology and allows early detection of errors thereby preventing re-work at a later stage and greatly reducing human errors in fault detection, this will ensure high quality end products with performance that meets expectations.

The following areas and aspects were inspected during the site visit:

- Storage area
  - Raw material reception area
  - Storage area
- Production area A & B:
  - Auto glass and EVA cutting machines
  - Cell sorting
  - Stringing area
  - Lay-up area
  - Bussing area
  - Auto tapping Machine
  - Lay-up stage
  - EL 1, repair station and rework workshop.
- Production area C:
  - Lamination
  - Auto Trimming Machine
  - Visual Inspection stage
  - Framing
  - Junction box fitting
  - Curing area
  - Cleaning and Finishing stage
  - Final testing, EL 2 and IV Curves
  - Sorting area, Labeling, and packaging
- Quality
  - Quality laboratory
  - Quality inspections
- HSE
- Production

The factory production operates with three shifts per day, each lasting 8 hours, and runs six days per week. Preventive and corrective maintenance may take place on Fridays if necessary. The number of employees in each section is appropriate according to UL. After discussions with some of the employees, UL determined that they are trained and skilled for their work. Standard Operating Procedures are posted in English in each required working location, but UL recommends adding Arabic translations since some employees may not speak English well. The temperature in all manufacturing areas is maintained at 24 °C and is indicated by large sensors hanging from the ceiling.

Philadelphia solar has implemented a colored T-shirt procedure to identify the position of each employee on the production area:

- Light blue: Production team
- Dark blue: Maintenance team
- Black: Engineering team
- Red: Quality team
- Green: Services team
- Silver: Store te

All operators and technicians wore gloves and caps, additionally, they wear masks while using a soldering gun or chemicals and electrical discharge device while using soldering gun. UL finds these protective measures acceptable for the work being performed. Different internal training sessions are conducted for employees based on their assigned workstation. New employees receive training, and existing employees undergo training updates as needed. The training plan is divided by areas, such as cell sorting, stringing, lay-up, framing, cleaning, and sorting, and employees can only work in their designated area. UL interviewed some staff members and noted their good knowledge of their tasks and relevant procedures. UL is satisfied with the production observed during the site visit and considers the manufacturing process in line with industry standards. However, UL suggests that additional equipment could improve the process in some areas. Philadelphia Solar is planning an expansion by the end of the year, which is expected to increase the production by 50%.

6.1 Storage Area

There are two cold storage rooms on the warehouse premises, one of which UL has inspected. The inspected room stores raw materials such as silicon, EVA, and flux, and UL has confirmed that the temperature inside the room was below 25°C and the humidity was below 60%, with sensor output indicating a temperature of 16.8°C and humidity of 56.4% at the time of inspection. However, UL was unable to inspect the second cold storage room due to it being blocked by materials. **[UL recommends adequate the storage areas in order to be accessible. The material necessary for the production needs to be always reachable].**

The central area of the warehouse is designated for the storage of additional raw materials such as junction boxes, glass, and equipment to be used by employees, as well as finished module pallets. UL discussed the storage area with the logistic manager during their inspection.

During the site visit, UL observed that the area inside the warehouse designated for finished module pallets was empty, and that finished modules were instead being stored outside the facility in sets of two boxes stacked on top of each other. UL was informed that the warehouse is currently being upgraded to better accommodate module size, and that production is temporarily stored outside for one to two days before being moved to a new rented warehouse in the same industrial area. UL did not inspect the temporary warehouse.

UL saw the use of a lift truck to load and unload finished modules outside. UL is satisfied with the safety aspects of this process and the storage adequacy of raw materials. However, UL did note a significant quantity of finished modules stored outside and found that storage area needs to be arranged and upgraded. **[UL recommends using OnSite facilities for storing modules to prevent wasting time on transportation to temporary storage areas. In addition, UL recommends speeding up the process to place finished modules inside the facilities in order to reduce congestion outside and prevent potential damage or deterioration of materials].**

Figure 6.1: Indoor Warehouse Temperature

Figure 6.2: Outdoor Modules Storage

6.2 Production Area A & B:

6.2.1 Auto glass and EVA cutting machines

Located close to the Sorting Area but belonging to Area A & B there are the auto glass and EVA cutting machines.

Figure 6.3: Auto Glass Loading Machine

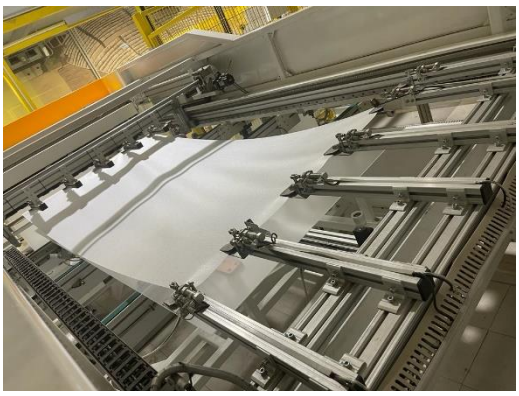

Figure 6.4: Auto Cutting EVA Machine

6.2.2 Cell Sorting

UL has inspected the cell sorting area and monitored the process. The cells are received from selected manufacturers and marked with different colors based on predefined standards by Philadelphia Solar and aligned with industry standards. There are four cell sorting machines identified by lasers as A1, B1, A2, B2, A3, B3, A4, or B4, corresponding to the stringer machines. After cutting, the pieces are separated in boxes and manually identified with the string machine outside the box by the operator.

The temperature inside the room is monitored with a sensor and during the site visit, it was recorded as 25 ºC, which is within acceptable limits for the work performed in the room. Rejected raw materials are reported and returned to the manufacturer once identified, and there is a table in the same room where rejected ribbons and cells are placed.

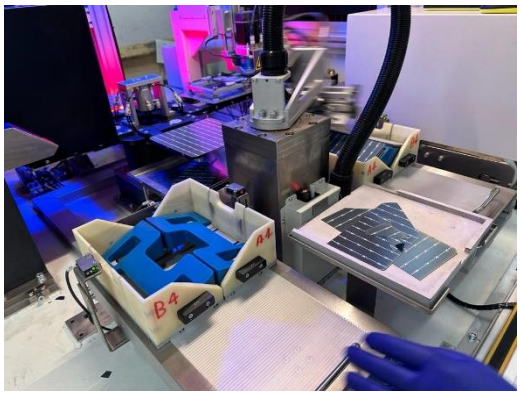

Figure 6.5: Cell Machine

Figure 6.6: Cell Machine

Figure 6.7: Defective Cells and Ribbons

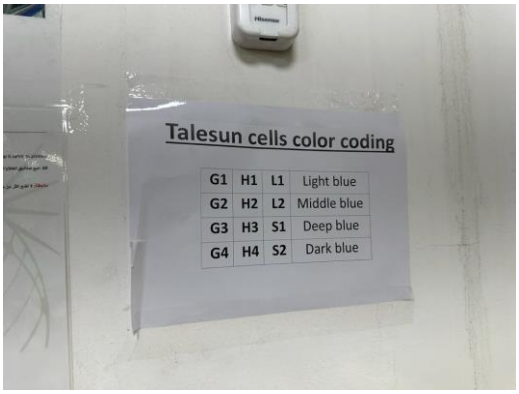

Figure 6.8: Cells Color Coding

6.2.3 Stringing Area

UL observed the automated process of cell stringing during the visit. The operator manually opened the boxes and the cells' integrity was automatically inspected before placing them into the cell feeder machine for stringing. The machine applied flux to the cells, and the ribbons were soldered to the front and back of the cells by the machine. There are There are four stringer machines with two lines per machines that correspond to each of the cell sorting machines.

During the visit, UL interviewed the responsible engineer who explained the production procedures and preventive maintenance for the stringing area. The team in this specific area consists of 2 engineers and 8 technicians per shift. In case the machines shut down, a safety light is switched on and an alarm is immediately sounded to alert the operators.

An operator also performs visual inspection of the pieces to detect any defects such as misalignments, white spots, gaps between cells, or visual cracks. Additionally, one of the machines is equipped with artificial intelligence inspection for Electroluminescence, and UL was informed that this system was recently incorporated with plans to install it in all the machines. Rejected pieces are sorted out and sent to the repair area for further action.

Figure 6.9: String Machine

Figure 6.10: String Machine

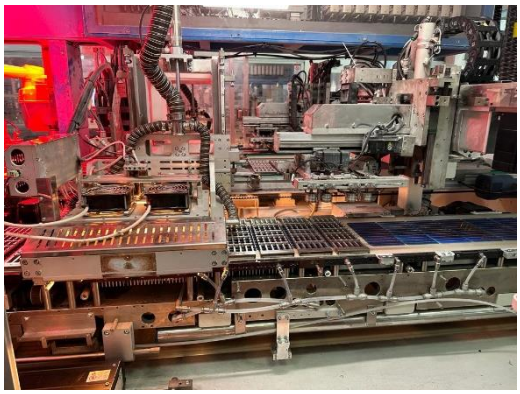

Figure 6.11: String Machine

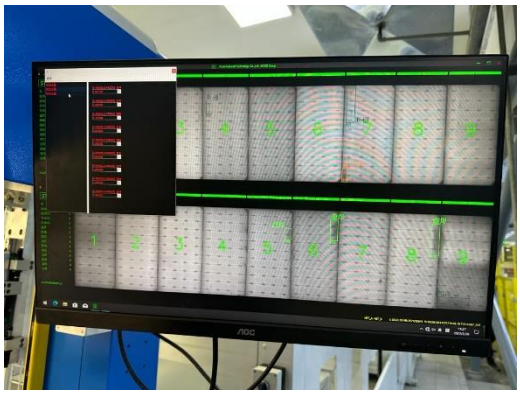

Figure 6.12: Artificial Intelligence EL test

6.2.4 Lay-up Area

In the cell stringing area, each cell string is placed onto the glass and Ethylene Vinyl Acetate (EVA) set, in preparation for soldering to the module busbar in the next stage. There is one lay-up machine corresponding to each stringer machine. In this area, 3 operators and 1 engineer perform the necessary tasks.

Figure 6.13: Lay-up area

Figure 6.14: Lay-up area

6.2.5 Bussing Area

The auto bussing machine is an automated machine used to solder cell strings reliably and efficiently to the busbars using an electromagnetic welding process. There is one auto bussing machine for the 4 lay-up machines, with three buffers for modules waiting to be processed.

In this area, there is one operator and one engineer who perform the tasks. The engineer is responsible for checking the welding time, which may be set between 1 and 1.6 seconds at the beginning of the shift to prevent any fold-back or potential defects during the soldering process. This ensures that the soldering is done accurately and to the required standards.

Figure 6.15: Auto Bussing Machine

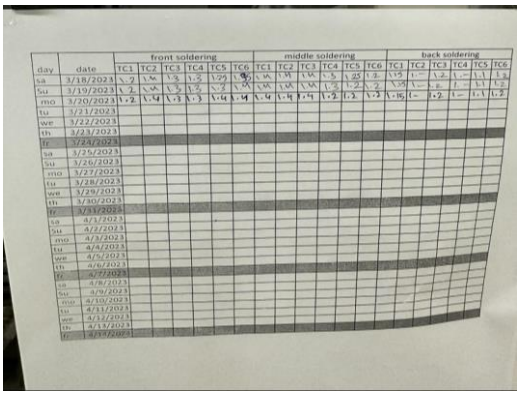

Figure 6.16: Welding Time Checklist

6.2.6 Auto tapping Machine

Close to the auto bussing Machine there is the auto tapping machine which is used for drilling or threading holes in the surface.

Figure 6.17: Auto tapping Machine

Figure 6.18: Auto tapping Machine

6.2.7 Lay-up Stage

After the cell lay-up and busbar soldering process, the modules are moved to the lay-up stage where a visual quality inspection of the soldering is performed by 2 employees. These employees wear gloves, hats, and masks due to the potential use of a soldering gun for immediately repair the module defects without removing the module from the production line.

In this area, there is a subsequent stage where a second layer of Ethylene Vinyl Acetate (EVA) is applied, and modules are labeled. Two employees check the modules and identify which production

line they belong to (A1, B1, A2, B2, A3, B3, A4, or B4), and manually label them with a barcode accordingly. This labeling process allows the modules to be tracked in the system from this point onwards.

A final step in this area involves two employees installing a Teflon sheet for isolation, to prevent any sticking of the ribbon to the metallic parts during lamination, ensuring proper insulation and quality of the modules.

Figure 6.19: Visual Quality Check

Figure 6.20: Bar Code Scanning

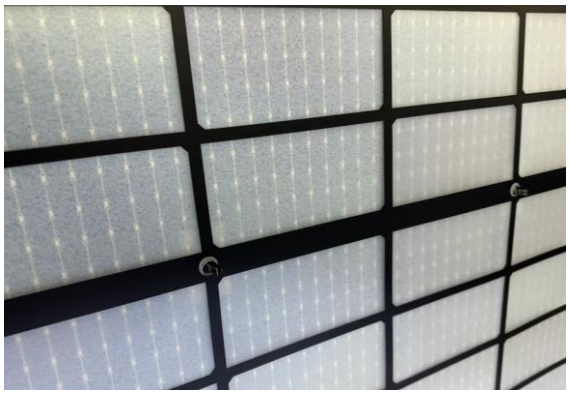

Figure 6.21: Module without Teflon Sheet

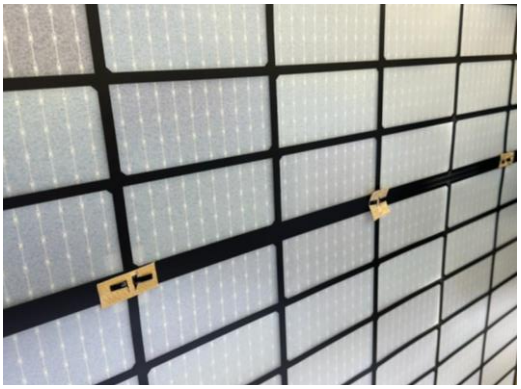

Figure 6.22: Module with Teflon Sheet

6.2.8 EL 1, Repair Station and Rework Workshop.

The Electroluminescence Test (EL) is an important step in the solar module production process to identify any potential defects in cells or soldering before lamination. This allows for early detection and rectification of any issues. The EL testing is conducted in 2 stations with one technician assigned to each station. Defective modules can be repaired in the same area at a local Repair Station, or sent to a designated Rework Workshop, depending on the severity of the issue. This helps ensure that only high-quality modules proceed to the next stage of lamination.

Figure 6.23: Repair Station

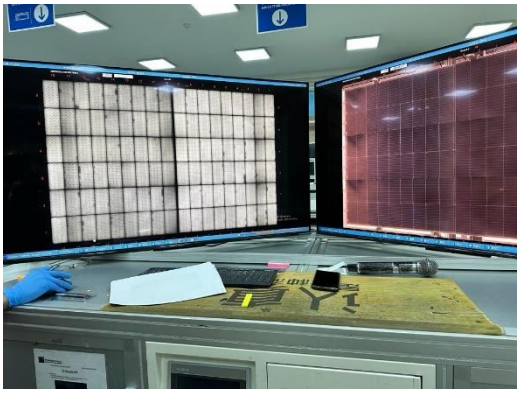

Figure 6.24: EL Test

Figure 6.25: Rework Workshop

Figure 6.26: Piece Repaired

6.3 Production Area C:

6.3.1 Lamination

The lamination capacity is 12 modules per cycle, with six modules in the buffer and six modules being laminated at a time. The lamination process takes 18 minutes, followed by a cooling time of 5 minutes. There are a total of 4 laminators in the area, and no operators are required during the lamination process. The temperature during lamination is monitored at 5 points across the laminator surface.

Figure 6.27: Lamination Monitoring

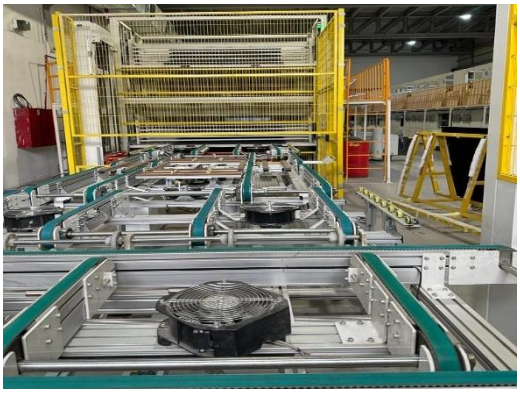

Figure 6.28: Lamination Machine

6.3.2 Auto Trimming Machine

After the lamination process, the modules are automatically passed on to the auto trimming machine where excess material is cut.

Figure 6.29: Auto Trimming Machine

Figure 6.30: Module with Exceeding Material

6.3.3 Visual Inspection Stage

Two employees at two different Visual Inspection Stations perform random checks on the modules to identify any broken cells or misalignments. Defects are classified into three categories:

- Category A for no defect;
- Category B for minor aesthetic defects that do not affect performance, and
- Category C for major defects that will impact performance and cannot be guaranteed.

The results of the visual inspection are recorded in a database for documentation and tracking purposes.

Figure 6.31: Module Visual Inspection

Figure 6.32: Category C Defect

6.3.4 Framing

At this stage, the module frame is produced and installed in two different stations. In one station, the process is semi-automatic with one operator responsible for aluminum frame production and two employees for frame installation into the module. In the other station, the process is automatic, with one operator overseeing the aluminum frame production machine and its installation into the module.

Figure 6.33: Semi-automatic Framing Machine

Figure 6.34: Framing installation

6.3.5 Junction Box Fitting

During this stage cables are soldered to the module and the junction box is installed to protect the cable terminations. Two employees solder the diodes to the terminals of the module busbars to complete the module electric circuit. Once the circuit is completed, the module is transferred to an automated machine where the silicon bead is applied. Philadelphia Solar mentioned that some tests, including measuring the quality of the cable connection and the quality of the silicon, are performed twice per shift. However, UL did not witness these tests during the site visit.

Figure 6.35: Diodes Soldering

Figure 6.36: Silicon Bead Filling

6.3.6 Curing Area

After the soldering and potting process, the modules are transferred to an isolated room for curing. The curing room is set to a temperature of 25 ±3ºC and 60±20% humidity, which is measured through three independent devices. The curing room has a capacity of 945 modules at one time. The modules remain in the room for a total time of 4 hours before being transferred to the cleaning area. A special label is sticked on the last module's frame of the pallet to monitor the curing time.

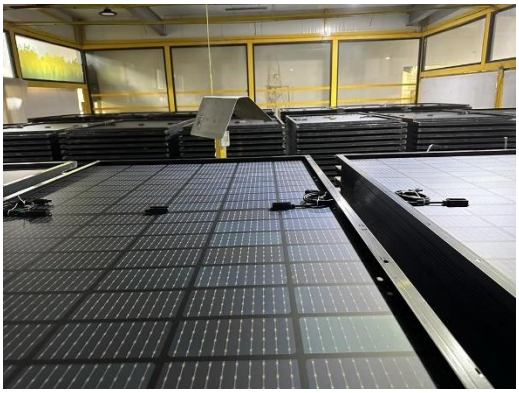

Figure 6.37: Curing Area

Figure 6.38: Label for monitoring curing time

6.3.7 Cleaning and Finishing Stage

At this stage, the modules are cleaned from any excess tape, and corners are filed to remove any sharp elements. The junction box cover is also closed, and the front and back sides of the module are visually checked. A total of 10 employees works in this area.

Figure 6.39: Module Cleaning

Figure 6.40: Module Finishing

6.3.8 Final testing, EL 2 and IV Curves

At the final testing stage, three simultaneous tests are performed:

- Electroluminescence test 2;
- Hipo test;
- IV Curves; and,
- Insulation test.

Wet leakage Current Test is performed in a separate room, testing one module per shift. The results from the tests are recorded for every single module and shared with the Client upon delivery. There is one engineer and two technicians at the testing station.

Figure 6.41: High Voltage Test

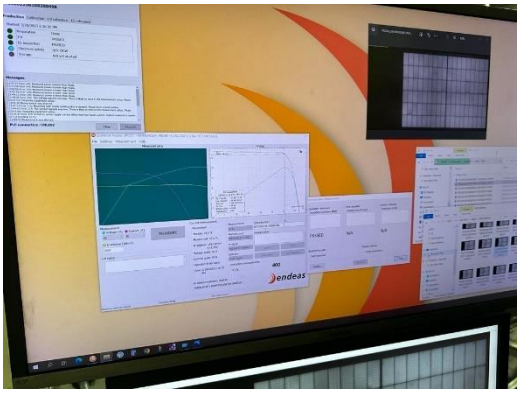

Figure 6.42: EL 2 and IV Curves

6.3.9 Sorting Area, Labeling and Packaging.

The modules are sorted using an automated machine, which was installed recently as an improvement of the process. A total of 37 modules are placed on each pallet. Two employees place the module label and a cardboard on every other corner module to protect them from nicks and scratches. All modules are strapped prior to being placed in the cardboard box and strapped again around the box. The box is wrapped with plastic to protect it from damages caused by outdoor exposure.

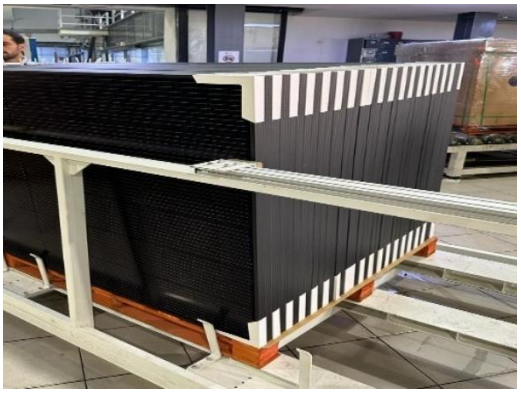

Figure 6.43: Pallet of Modules

Figure 6.44: Modules Labeled

Figure 6.45: Modules Strapped

Figure 6.46: Modules Prepared

6.4 Quality Assurance and Quality Control

6.4.1 Quality Laboratory

UL has visited the Quality laboratory where parallel to the production, laboratory tests are carried out. These tests include gel content measurements, EVA and back-sheet peel tests, and ribbon peel tests. Additionally, they have equipment such as microscopy, harness and coating tester, and an optical density meter. UL considers the equipment that Philadelphia Solar has for carrying out the necessary tests, as well as the system to maintain digital and hard copy log records, to be appropriate.

Figure 6.47: Laboratory Equipment

Figure 6.48: Laboratory Equipment

Figure 6.49: Laboratory Equipment

Figure 6.50: Laboratory Equipment

6.4.2 Quality Inspections

The QAQC checklist inspection [90] is conducted at the beginning of each shift by quality inspectors for different areas of the production process. The data collected during these inspections is recorded in digital format for further analysis and tracking. This allows for systematic monitoring of the production process to identify any potential issues or areas for improvement in terms of quality control and assurance

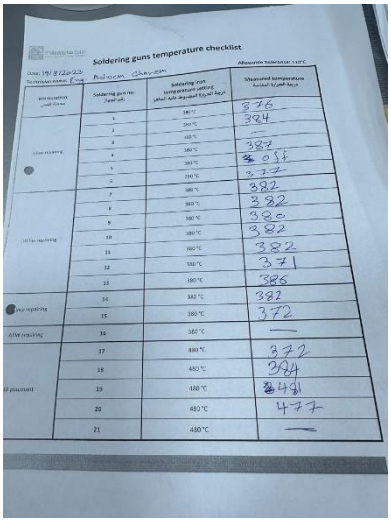

Figure 6.51: QAQC Check List

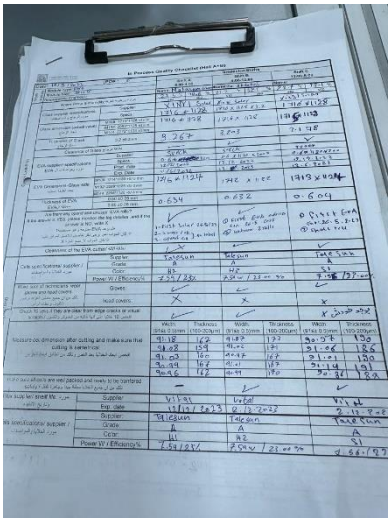

Figure 6.52: QAQC Check List

6.5 Health, Safety and Environment

UL observed that Philadelphia Solar has implemented safety measures throughout the facility, including general safety warning signages, posters, and specific safety warnings for each machine. The emergency evacuation plan is also displayed on the walls, and fire-fighting equipment is updated and unobstructed. There are two assembly points at the facility for emergency situations.

[UL has noted that safety marks for the stringing machines are not well indicated on the floor and recommends updating this safety element according to the size of the machine to ensure clear visibility and adherence to safety protocols].

UL was informed by the HSE manager that Philadelphia Solar conducts periodic inductions and HSE trainings, as well as performing 2 emergency drills per year. There are 3 HSE technicians working at the facility who perform inspections per a safety checklist in all areas to ensure compliance with health, safety, and environmental regulations.

Figure 6.53: Office Access Stair

Figure 6.54: Evacuation Map

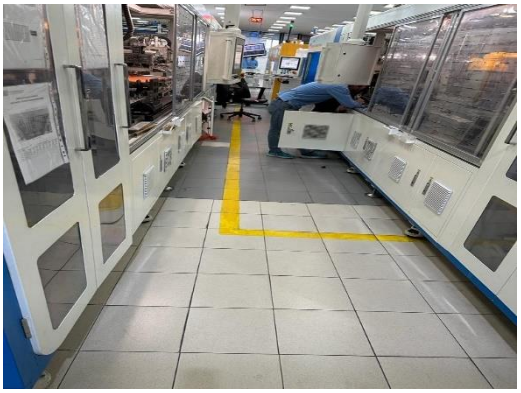

Figure 6.55: Stringing Machine Safety Mark

Figure 6.56: Fire Extinguisher

6.6 Production

According to the production capacity information provided by the production manager at the time of the visit, Philadelphia Solar has a production capacity range between 75 and 180 modules per hour, resulting in a total of 3600 modules per day, with variations depending on the module type being produced. The factory operates 24 hours a day, 6 days a week, in three shifts. The production output is based on previous demand, with supply mainly to the USA, Lebanon, and Canada.

Philadelphia Solar has plans for factory expansion in quarter 3 of 2023, which includes adding two more stringing lines to the existing four lines. This expansion will allow for production of two types of modules simultaneously, as opposed to the current process which allows only one type of module to be produced. UL understands that during the expansion process, production will be halted for approximately 8 hours to adapt all the lines to the new production process.

Once the expansion is completed, UL was informed that Philadelphia Solar's potential annual production capacity is expected to increase from 520 MW to 870 MW, resulting in a significant increase in annual module production. It is important for Philadelphia Solar to carefully manage the expansion process to ensure smooth transition and maintain product quality and safety standards. UL will continue to monitor the progress of the planned expansion during subsequent visits to the facility.

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