DNV·GL

INDEPENDENT TECHNOLOGY REVIEW OF A PV MODULE MANUFACTURER IN JORDAN

Bankability Report

Philadelphia Solar

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Table of contents

Appendices

List of tables

List of figures

List of abbreviations

Abbreviation	Meaning
A	Amps
AR	Antireflection
BB	Bus Bars
BoM	Bill of Material
C	Celsius
DNV GL	DNV GL Entity
EL	Electroluminescence
EPC	Engineering, Procurement & Construction
EVA	Ethylene-Vinyl Acetate
Isc	Short Circuit Current
IEC	International Electromechanical Commission
ISO	International Organization for Standardization
JD	Jordanian Dinar
KSA	Kingdom of Saudi Arabia
Kg	Kilogram
LID	Light Induced Degradation
m	meter
mm	millimeter
MW	Megawatt
MWp	Megawatt peak
Pa	Pascal
PID	Potential Induced Degradation
Pmax	Maximum Power
Pmp	Maximum Power
PV	Photovoltaic
R&D	Research and Development
STC	Standard Test Condition
UAE	United Arab Emirates
UL	Underwriters Laboratories
V	Volt
Voc	Open Circuit Voltage
W	Watt

1 EXECUTIVE SUMMARY

1.1 Introduction

DNV GL Dubai AS ("DNV GL") has been contracted by Philadelphia Solar ("the customer") to undertake a review of its manufacturing facility located in Jordan. The aim of the report is to provide and independent technology review of Philadelphia Solar as PV module manufacturer. This report presents the results of DNV GL's analysis and it can be used by potential investors and buyers of Philadelphia Solar PV modules as an independent technical review.

DNV GL visited the Philadelphia Solar module manufacturing facility in Amman, Jordan on October 17th 2018. The report is based on the information provided by the customer, face to face meetings and an extensive walk-through of the factory in Jordan.

1.2 Company Evaluation

1.2.1 Company overview

Philadelphia Solar is a Photovoltaic PV module manufacturer producing monocrystalline and polycrystalline (or multi-crystalline) solar modules for use in a range of residential, commercial and utility scale solar power generation systems. The company also manufactures steel mounting structure, as well as EPC contractor for design and execution of solar power plants. The company is headquartered in Amman, Jordan and exports products to Turkey, United Kingdom, Syria, Yemen, Germany, Netherlands, Egypt, Lebanon and around 33 other countries worldwide (total 41 countries worldwide).

Philadelphia Solar's main management positions are handled by engineers, economists and high-level educated employees.

1.2.2 Financials and strategy

Philadelphia Solar total amount of sales up to the end of 2017 is about $21.11 M. the company has a total of 332 employees including both production & management team and design & installation team. Female presence in Philadelphia Solar has been increasing in recent years up to 26 of the 332 current work positions covered by women, among which 8 of them belong to managing positions.

Philadelphia Solar has exported products to around 41 countries worldwide. Table 1-1 below represents the total sales, exports and profits for Philadelphia Solar over the past three years.

Table 1-1: Philadelphia Solar trends of sales, export and profits in the last three years /3/

Trend indicator	2015	2016	2017
Total Sales ($)	33,276,000	12,510,930	21,093,600
Total exports ($)	5,076,000	1,410,000	5,640,000
Total profits ($)	7,810	6,186,751	424,410

According to found information about PV system pricing in H2 2018, Watt prices for Jordan keep the threshold below 0.89$/Wdc (0.89$/Wdc-0.80$/Wdc).

Philadelphia Solar has not a dedicated R&D team, but the R&D work is undertaken by staff overlapping their day-to-day working activities to research by themselves or in cooperation with other research teams in certain topics such as bifacial technology, glass with anti-soiling properties and research on new backsheet materials. This is considered acceptable for a non-vertical integrated PV module manufacturer. However, DNV GL recommends implementing a program for R&D activities focused on quality control.

The company long term strategy passes by expanding capacity in Amman to cover Middle East and Indian markets and installing a new factory in USA to facilitate their expansion in that country. Total sales of 520 MWp in 2022 are considered by Philadelphia Solar strategic route map. DNV GL considers this plan quite ambitious but still feasible.

1.2.3 Product history and intellectual property

Philadelphia Solar was established in 2007 with 4MW annual capacity. Afterwards, Philadelphia Solar worked in the development of production lines based on the state of the art automated Japanese and European production line. The production capacity by 2013 reached the 40MW with a current capacity of 170 MW.

There is little intellectual property with respect to crystalline silicon module technology. The material set, lay-up, and assembly methods have been used for many years, and while significant progress has been achieved in workmanship, power stability, and reliability, most improvements have not resulted in patents.

1.3 Technical Evaluation

DNV GL has evaluated the PV module product lines of Philadelphia solar and compared their specifications with similar products in the market space. It can be concluded that the specifications provided by Philadelphia Solar are comparable to other leading manufacturers and, in some cases, better than the industry standard.

All PV module models have a 5-busbar solar cell design which contributes to the improvement in the efficiency compared to other 3 busbar solar cell PV modules. Moreover, monocrystalline PV modules are composed by PERC (Passivated Emitter Rear Cell) mono-crystalline cells which contributes to the increase in the efficiency of the PV module. PERC technology is relatively new in the monocrystalline technology. However, the selected supplier of PERC cells has a relatively long track record in the industry.

The PERC technology features higher efficiency than the standard technology. Additional steps in the manufacturing process for the rear side passivation and contact layer (so called dielectric PERC layer) involves additional cells' processing, hence higher costs.

PERC technology is still considered by many as 'new', but it already accounts for over 30% of all crystalline cells produced. Furthermore, PERC technology appears to have more efficiency potential as manufacturers are developing higher cell efficiencies. The main issue which historically held back deployment of PERC was the light-induced degradation (LID), which most manufacturers have sufficiently solved.

The system voltage allowable for analysed PV modules is 1,000V whereas current system voltage of similar PV modules is already 1,500V. As stated by Philadelphia Solar, 1,500 voltage systems are under testing and certification procedure by TUV Rheinland Laboratory in Germany. DNV GL highlights the importance of achieving this 1,500V voltage system certification to better adapt to the market evolution.

After analysis of main electrical parameters of the PV modules based on the data specified in the datasheets, module performance criteria's such as temperature coefficient, voltage characteristics, current characteristics of the poly-crystalline and mono-crystalline PV modules are comparable, and in some cases better, than other leading suppliers in the PV industry.

LID results document was provided. Tested PV modules belong to the analysed PV module family in the present report. LID results for monocrystalline PV modules present a maximum LID degradation of -2.2%, whereas polycrystalline PV modules manifest a LID degradation no higher than -1.06%. DNV GL finds these values within the standard range in the industry. The irradiation used in the tests is 5.85kWh/m^2 which is considered rather low, since it is usually recommended to undertake the study after an irradiation of 60kWh/m^2 with several intermediate measurements for confirming the stabilization of LID.

Independent test reports of specific modules were provided for DNV GL review and these were found to be acceptable. All certificates have been tested with 1,000V.

DNV GL recommends performing and updated test according to Guidelines for California's Solar Electric Incentive programs CEC of the inspected PV modules.

Although AR glass characteristics were provided, no IAM test results were shared. DNV GL would require IAM results in order to provide an opinion on the reflective behaviour of the analysed PV modules.

The low light performance test released was performed in 2015. DNV GL would recommend performing this type of test at least once per year. Moreover, the test results showed flashed power below the nominal power stated in the datasheet. DNV GL understands that this power difference is caused by LID already presence in the tested PV modules. It is recommended to avoid this situation in future low light measurements.

Tolerance range of the PV modules are within the range or even better than comparable modules. However, this tolerance range is given in percentage where current trend is to state power tolerance in Watts not in %.

1.4 Quality and reliability

1.4.1 Production line and quality checks to incoming materials

In general terms, the production line design is modern, professional, and it uses good quality production equipment. The lay-out of the production line is very similar to other manufacturers in the market. In that sense, having double electroluminescence checking is the best practice in the industry.

The real annual capacity working 7,128 hours per year is approximately 90 MWp/year at the time of the visit but it will be 170 MWp after the ongoing expansion is completed. Philadelphia Solar is therefore considered as a small manufacturer in a globalized PV market industry.

DNV GL has identified the following aspects to improve in the production line:

1. It is recommended making traceable the ambient conditions recorded on manufacturing areas with the serial numbers of the modules being produced to anticipate potential quality issues.
2. It is recommended increasing the dust control up to a monthly basis as a minimum.
3. It is recommended reviewing the curing process of the modules just before the Flash Tester to allow a more automated process.
4. Finally, at the packing area, it is recommended avoiding light penetration through the small space between modules using a card box covering the entire pallets rather than transparent plastic film as Philadelphia Solar default packing system. Philadelphia Solar has confirmed that they are in the process of implementing another packaging method using Cardboard boxes which will prevent light penetration.

DNV GL did not witness any of the tests at the factory laboratory as the laboratory was being renovated and expanded. Philadelphia Solar has confirmed that tests were still undertaken during the renovation works of the laboratory.

DNV GL has been provided by the Quality check procedure by Philadelphia Solar.. DNV GL highlights the importance of implementing a day-to-day routine for the testing of incoming materials to avoid situations with inferior quality batches entering the PV module manufacturing process. Philadelphia Solar has confirmed that they apply a rigid quality plan for incoming materials.

1.4.2 Finished product reliability checks

Philadelphia Solar applies a very good manufacturing production line quality checks with the application of two levels of electroluminescence checks among others. However, there is no in-house reliability monitoring program. This type of checks is typically seen in well-established manufacturers that regularly test samples of produced modules at more demanding conditions than the IEC 61215 standard covering even PID behaviour. Philadelphia Solar sends equipment samples to Fraunhofer for testing in order to be able to compare the results obtained by a third party with the in-house testing results and update, consequently, their certifications according to the latest IEC standards.

1.5 Manufacturing factory visit

DNV GL visited the Philadelphia Solar module manufacturing facility in Amman, Jordan on 17th October 2018.

It can be concluded that the lay-up operation is consistent with industry standards in general, but it is also subject to some improvement regarding quality checks and traceability.

The tabbing operations are automated, but the bussing is manually undertaken. DNV GL could not witness the tabbing ribbons quality check consisting on a daily pull test because the factory laboratory was being renovated.

Philadelphia Solar has confirmed the full automation of the framing process has been implemented by installing a Jinchen framing machine.

The cross-tie ribbons are manually soldered onto the terminals of the junction box. Philadelphia Solar has commented, soldering temperature of the soldering iron is checked 3 times per shift. However, DNV GL has not seen this checking procedure to be performed during the site visit. DNV GL also recommends to perform a mechanical pull test by the operator on each tab to ensure that a solid soldered connection has been achieved.

Philadelphia Solar has confirmed diode properties located in the junction boxes are evaluated by using diode test mode and resistance mode. However, DNV GL did not see these tests being implemented during the site visit.

A silicone bead is applied to the junction box at an automated station. Philadelphia Solar has confirmed there is a template to control the horizontal placement of the junction box on the back side of the module, in order to achieve proper placement. However, DNV GL has not seen this template usage during the site visit.

Philadelpha Solar has confirmed that strain relief test on the cables is performed for a proper tightness on a sampling basis during incoming inspection. The strain relief test consists on hanging the PV module for one minute from cables letting it withstand its own weight (around 22kg) However, DNV GL did not see neither of the mentioned tests being implemented during the site visit.

The calibration of the tester every 250 modules approximately as per the best practice in the industry is recommended.

DNV GL has been informed by Philadelphia Solar that used labels for binning the PV modules have been installed for the last 8 years without any claim.

1.6 Product support

Product support and complaints management is handled by a dedicated team of Philadelphia Solar. Customer Satisfaction Survey and Customer Claim forms can be downloaded from Philadelphia Solar's website. DNV GL has been provided with an oversight of the mechanism involved. DNV GL highlights warranty claim procedures are defined and followed. No major recall issues for the supplied modules have been provided.

Nowadays, whereas Philadelphia Solar is offering a first-year power warranty of at least 97% and 97.5% and a degradation of 0.65% and 0.7% for monocrystalline and polycrystalline respectively, some PV manufacturers are offering first year warranty of at least 97.5% and a degradation of 0.5%. DNV GL would recommend improving warranty terms to follow the best practice in the industry.

The twelve-year workmanship warranty is quite a new trend in the PV market industry which places Philadelphia Solar at the upper range of the PV module manufacturers in terms of product warranty conditions. Product manuals are reasonable well documented and established, highlighting risks and safe operating procedures. Additionally, DNV GL has made few recommendations on improvements, like for instance the description of allowed automatic cleaning equipment for their modules or robots.

2 INTRODUCTION

DNV GL Dubai AS ("DNV GL") has been contracted by Philadelphia Solar ("the customer") to undertake a review of its manufacturing facility located in Jordan. The intent of the report is to provide and independent technology review of a PV module manufacturer. This report presents the results of DNV GL's analysis and it can be used by potential investors and buyers of Philadelphia Solar PV modules as an independent technical review.

DNV GL visited the Philadelphia Solar module manufacturing facility in Amman, Jordan on October, 17th 2018. The report is based on the information provided by the customer, face to face meetings and an extensive walk-through of the factory in Jordan.

Philadelphia Solar has been forthcoming in sharing the required information for the assessment as requested by DNV GL. DNV GL is relying on the accuracy of the information provided by Philadelphia solar for this report.

3 COMPANY EVALUATION

3.1 Company Overview

Philadelphia Solar is a Photovoltaic PV module Manufacturer. The company was first established in Jordan in 2007. The company is headquartered in Amman, Jordan and exports products to Turkey, United Kingdom, Syria, Yemen, Germany, Netherlands, Egypt, Lebanon (total 41 countries worldwide).The company's products include a range of standard monocrystalline and polycrystalline solar modules for use in a range of residential, commercial and utility scale solar power generation systems.

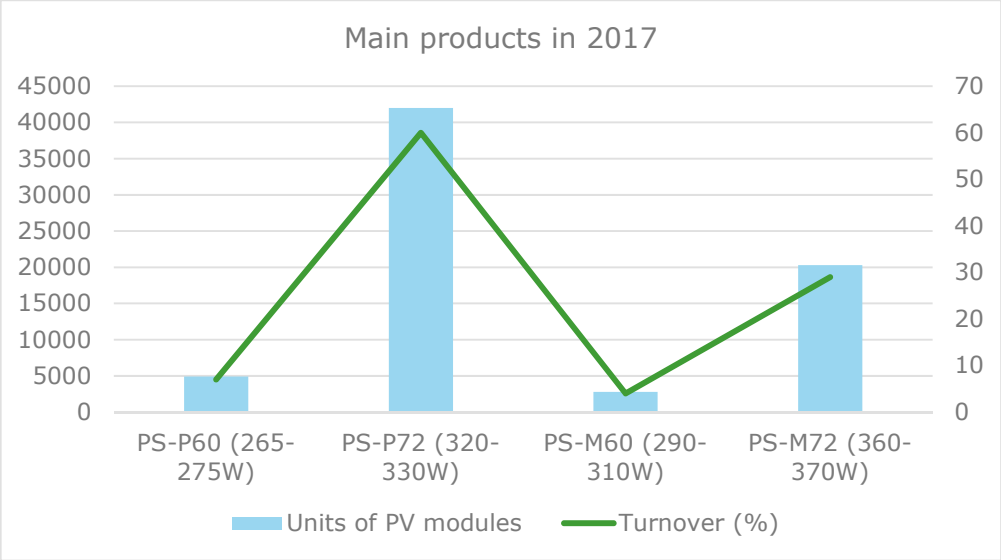


Figure 3-1 Philadelphia Solar's main products in 2017 Source: Philadelphia Solar

Philadelphia Solar is also a steel mounting structure manufacturer, as well as EPC contractor for design and execution of solar power plants.

Philadelphia Solar total amount of sales up to the end of 2017 is about 21.11M$.

The company started with a production line with capacity up to 10MW in 2008 with 32 employees. Current production capacity has increased up to 170MW. The company now has around 332 employees, 214 of them belong to the Production & Management team and 118 to de Design & Installation Team. Female presence in Philadelphia Solar has been increasing in recent years up to 26 of the 332 current work positions covered by women, among which 8 of them belong to managing positions.

Philadelphia Solar's main export market is shown in table below.

Table 3-1 Philadelphia Solar's main market export

Export market	Exported products	Share of exports [%]	Type of buyers
Turkey	PS-P72-320W	21	distributor
UAE	PS-P72-320W PS-P60-265W	5	distributor
Others	PS-P60-265W	1	distributor
Local market	**Production**	**Local sales [%]**	**Type of buyers**
Jordan	PS-P60-265W	73	distributor

The pipeline of the sales forecast plan of Philadelphia Solar considers reaching 170MW by 2019 and the 220MW by 2022. Bearing in mind the current production of the plant is to be 170MW, achieving the 2022 milestone is slightly difficult. In parallel, the company is studying the possibility of increasing sales by expanding to new markets in EU, US, India and GCC. Specifically, part of the proposed strategy is installing a factory in the US whose production evolution is expected to be 75MW by 2019 up to 300MW by 2022.

3.2 Organization chart

Philadelphia solar organigram is shown in the Figure 3-2 and the managing staff educational records are provided in Table 3-2. DNV GL considers that the organizational chart is adequate for a company of its size not vertically integrated in the PV module supply change.

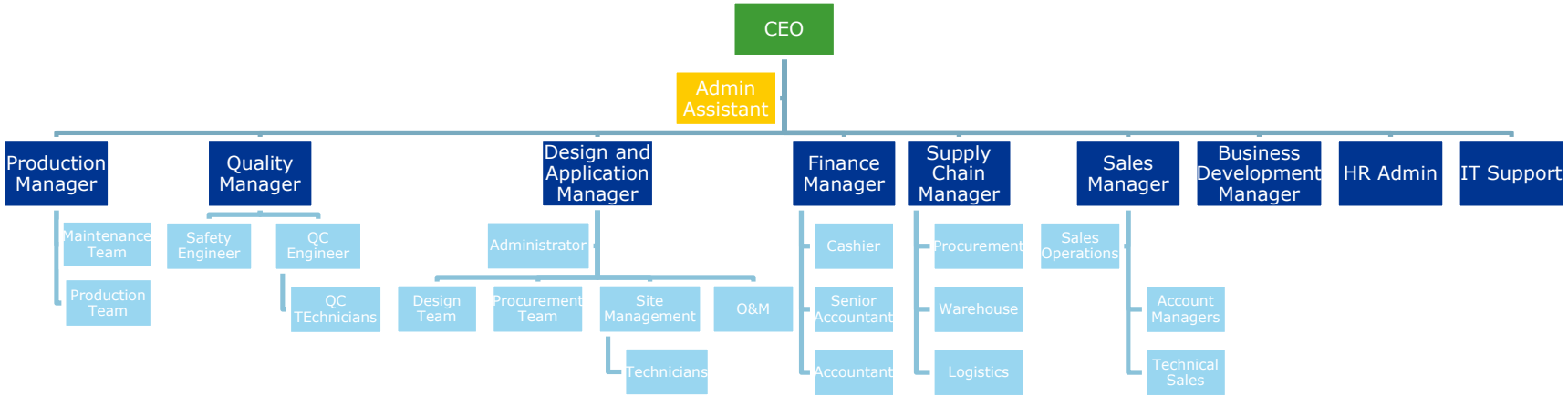


Figure 3-2 Philadelphia Solar organization chart /8/

Table 3-2 Managing staff educational records

Position	Name	Education
CEO	Mr. Abdul Rahman Shehadeh	B.A in commerce
General Manager	Nael Fahad Al-Husami	PhD in Business Economics
Sales and Marketing Manager	Eng. Mohammed Saleh Shehadeh	Master Degree in RE Management BSc Degree in Mechanical Engineering Certified Energy Manager
Business Development Manager	Eng. Ahmad Nahar Al-Somadi	BSc Degree in Electrical Engineering
Financial Manager	Mr. Eyad Arafat	BS degree in Accounting in Economics CFM Certificate 2007 CMA Certificate 2005 JACPA Certificate 2000 CPA Certificate
Design and Application Manager	Eng. Mohammad Ahed Ghodayyah	BSc Degree in Electrical Power Engineering
Production Manager	Eng. Laith Malkawi	BSc Degree in Mechatronics Engineering
Supply Chain Manager	Ms. Asmaa Mehdawi	BSc Degree in English language
Quality Manager	Eng. Aseel Sa'di	BSc Degree in Industrial Engineering

As shown in Table 3-2 Philadelphia Solar's main management positions are handled by engineers, economists and high-level educated employees.

3.3 Company Financials and Sales Revenues

Philadelphia Solar exported products to Turkey, United Kingdom, Syria, Yemen, Germany, Netherlands, Egypt, Lebanon and around 33 other countries worldwide (total 41 countries worldwide). Figure 3-3 shows the main export market.

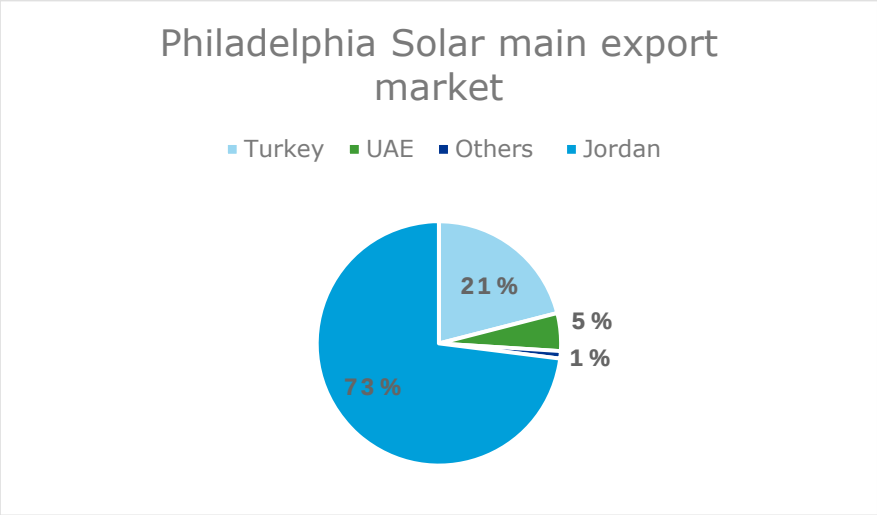


Figure 3-3: Philadelphia Solar main export market /3/

Table 3-3 below represents the total sales, exports and profits for Philadelphia Solar over the past three years.

Table 3-3: Philadelphia Solar trends of sales, export and profits in the last three years /3/

Trend indicator	2015	2016	2017
Total Sales ($)	33,276,000	12,510,930	21,093,600
Total exports ($)	5,076,000	1,410,000	5,640,000
Total profits ($)	7,810	6,186,751	424,410

Due to the constant increase with the production line capacity, total sales increased significantly from 2009 till 2017 as shown in Figure 3-4below.

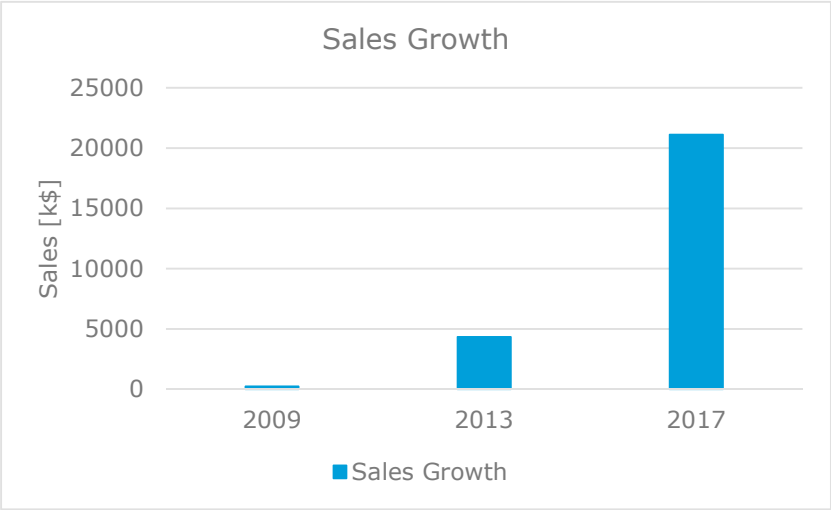


Figure 3-4 Philadelphia Solar's Sales growth from 2009 to 2017 /3/

3.4 Product History

Philadelphia Solar was established in 2007 with 4MW annual capacity. Afterwards, Philadelphia Solar worked in the development of production lines based on the state of the art automated Japanese and European production line. The production capacity by 2013 reached the 40MW with a current capacity of 170 MW .

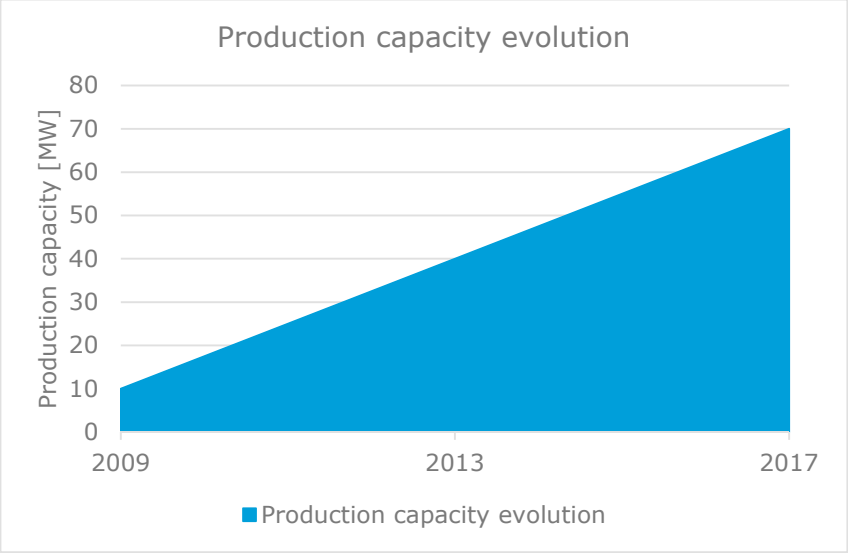


Figure 3-5 Production capacity evolution /13/

Table below explains the progress of Philadelphia Solar factory since it was established in 2007 up to present. Philadelphia Solar Company has obtained several certificates according to standards of quality, security and PV module behavior in certain environmental conditions.

Table 3-4: Philadelphia Solar milestones /3/

Main achievement	Year
Company establishment	2007
Installing State of the art production line with capacity up to 10MW	2008
Starting production	2009
Establishment of ISO 9001:2008	2010
Establish export certifications: UL / IEC 61215 / IEC 61730	2011
Increase production Line capacity up to 40 MW	2012
Establish new export certifications: UL / IEC 61215 / IEC 61730 / PID / Salt Mist / Ammonia	2016
Increase production line capacity up to 170 MW	2018

Table 3-5 and Table 3-6 below show some of the main local and international project reference of Philadelphia Solar. Most of the shown references are PV installations that belong to a commercial level, not utility level.

Table 3-5: Local Project References /1/

Project	Location	Size [MWp]	Year of completion
Al-Badiya Power Generation	Jordan	23	2015
United Cable Industries Company	Jordan	4.5	2018
Giant Industrial Group Factory	Jordan	2.7	2017
Istishari Hospital	Jordan	2.5	2018
Philadelphia University	Jordan	0.853	N/A
Al Zaytoonah University	Jordan	1.77	N/A
Zarqa and Irbid mosques	Jordan	0.8	2018
Children's Museum	Jordan	0.42	N/A
Water authority	Jordan	0.24	N/A
Annoor sanatorium	Jordan	0.15	N/A
Majid Saedi	Jordan	0.055	N/A
TOTAL		36.99	

Table 3-6:International Project References /1/ /2/

Location	Size [MWp]
Turkey	10
United Kingdom	8.05
Syria	4
Yemen	2.4
Germany	2.2
Netherlands	1.7
Lebanon	1.3
Egypt	1.3
Italy	1.1
UAE	1.1
KSA	1.1
Spain	0.6
Romania	0.5
TOTAL	35.35

Although it does not appear in Philadelphia Solar's website, the company claims to have provided PS-P60-250W PV modules for a 12MWp installation in AlMafraq with the production features stated in the Table 3-7.

Table 3-7 Generation data for th AlMafraq installation

Year	Generation [GWh]	GHI [kWh/(m^2*year)]
2016	21,058	2,260.81
2017	21,396	2,270.30
2018	21,528	2,336.00

Due to the capacity of the mentioned PV plant, DNV GL would recommend adding this reference to Philadelphia Solar's website.

3.5 Intellectual Property

Philadelphia Solar was established in 2007 with 4MW annual capacity. Afterwards, Philadelphia Solar worked in the development of production lines based on the state of the art automated Japanese and European production line. The production capacity by 2013 reached the 40MW with a current capacity of 170 MW.

There is little intellectual property with respect to crystalline silicon module technology. The material set, lay-up, and assembly methods have been used for many years, and while significant progress has been achieved in workmanship, power stability, and reliability, most improvements have not resulted in patents.

Philadelphia Solar has not a dedicated R&D team, but the R&D work is undertaken by staff overlapping their day-to-day working activities to research by themselves or in cooperation with other research teams in certain topics such as bifacial technology, glass with anti-soiling properties and research on new backsheet materials This is not the best situation for R&D work, but it is considered acceptable for a non-vertical integrated PV module manufacturer. If Philadelphia Solar passes to manufacturer cells at some moment, then the R&D will be necessary to increase the efficiency every year as per market demanding criteria.

DNV GL recommends implementing a program for R&D activities focused on quality control. DNV GL considers that the R&D activities of Philadelphia Solar would require an extra effort to keep their quality unaffected by future expansion in Amman and USA.

3.6 Philadelphia solar in the market

Nowadays the main PV module technologies present in the market are Crystalline silicon, thin film and hybrid HIT cells.

To understand the presence of these technologies in the current market situation, Figure 3-6 shows the recent evolution of the PV module technology share, worldwide, and its evolution from the last decade. As can be seen, crystalline technologies have dominated the solar PV industry historically, accounting for above 90% of the worldwide market share for 2016. From those, poly-crystalline silicon technology leads this market segment.

The market share for thin-film technologies slightly increased in 2009, but it has decreased since then. Amongst thin-film technologies, CdTe leads the market.

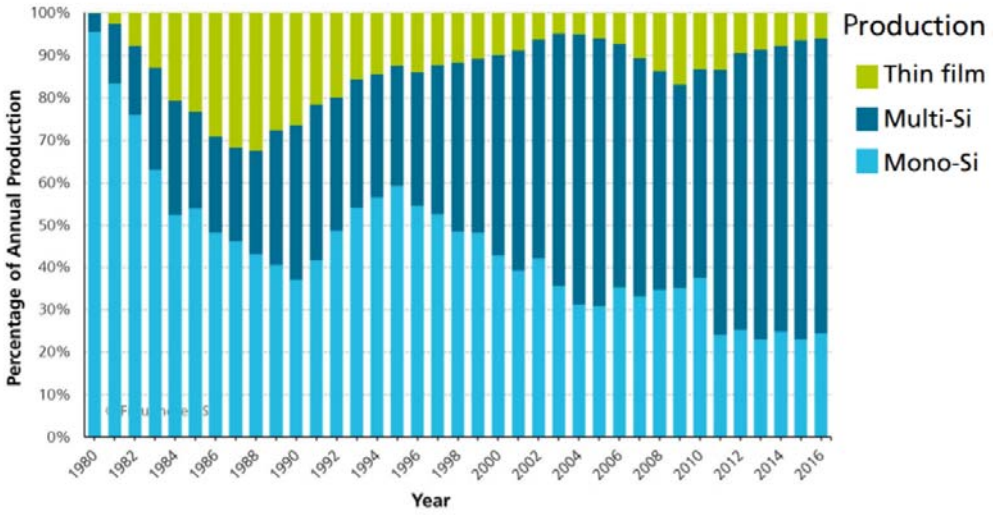


Figure 3-6: PV cell technology shares 1980-2016 (source: ISE Fraunhofer)

The above trend is expected to continue in the coming years, with the crystalline technologies clearly dominating the market. The production capacity of crystalline silicon PV modules is expected to continue growing steadily, whilst thin-film production is expected to remain stable.

Regarding the origin of the technology, most of the manufacturing capacity and production is concentrated in Asia, with a focus on China, for c-Si technologies especially. In the case of thin-film, an important share of the production capacity remains in the Asia Pacific Region (APAC), where several Japanese manufacturers are based.

Table 3-8 shows the ranking of module manufacturers in 2017, regarding shipments. Most of the companies listed are Chinese c-Si manufacturers. Within the ranking, none of the companies are manufacturing thin-film products.

Table 3-8: Ranking of module suppliers worldwide for 2017

2017rank	Module supplier	Change from 2016
1	Jinko Solar	1
2	Trina Solar	2
3	JA Solar	4
4	Canadian Solar	3
5	Hanwha Q Cells	5
6	GCL	6
7	LONGi Solar	-
8	Risen	10
9	Yingli Green	8
10	Shunfeng (incl. Suntech)	-

Source: DNV GL´s review of publicly available information

Focusing on crystalline silicon manufacturers, the greater the integration in the supply chain (see Figure 3-7), the lower the number of companies offering the same range of services within the market. This is due to the high investment required, as well as to other technical, environmental and administrative issues that may arise in the execution of the entire infrastructure required for complete vertical integration of the company.

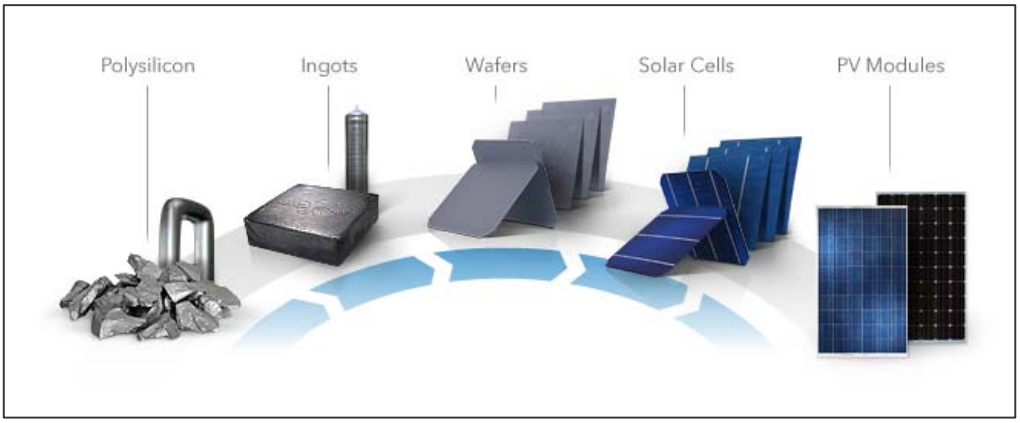


Figure 3-7: Complete silicon crystalline supply chain

According to last report of Wood Mackenzie about PV system pricing in H2 2018, Watt prices for Jordan keep the threshold below 0.89$/Wdc (0.89$/Wdc-0.80$/Wdc) see Figure 3-2.

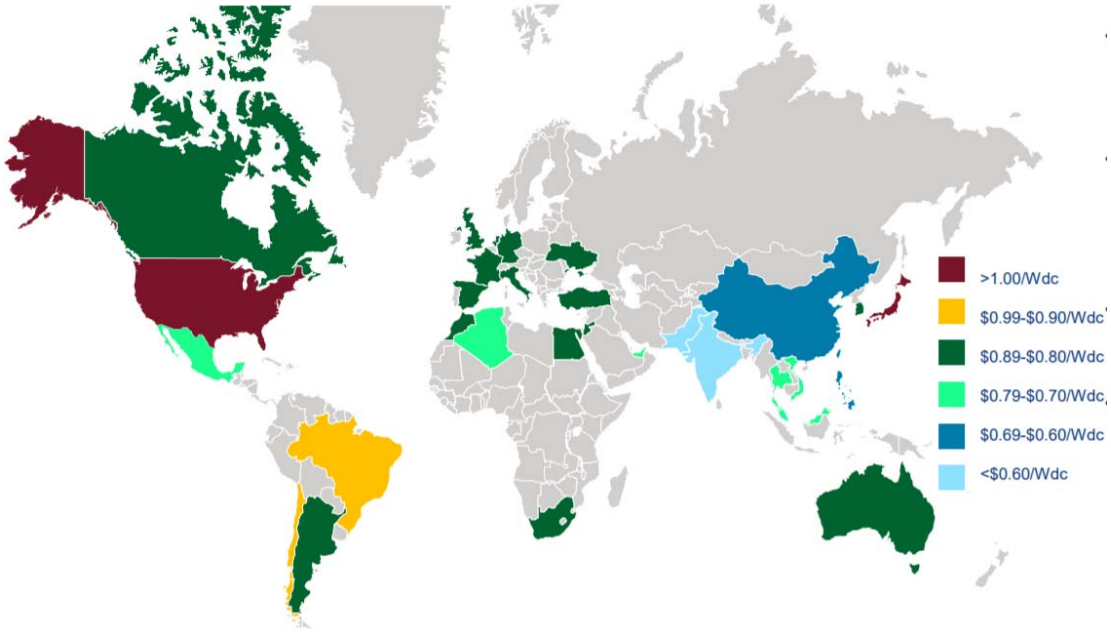


Figure 3-8 Global PV System Pricing H2 2018 (source Wood Mackenzie)

3.7 Company Strategy

Philadelphia Solar has communicated the following company strategy for the future:

1) Doubling the existing manufacturing capacity at the Amman facility. This expansion was already in progress at the date of DNV GL inspection.

2) Opening a fully automatized facility in USA with a capacity of 300 MWp/year. In that sense, UL and IEC certificates will be updated to enter the American market. The interest for the American market is based on the high prices of modules and the special taxing regulations between USA and Jordan.

3) They have started already the accreditation process in India where they have a pipeline of projects of 30 MWp. Their position in the Indian market is good due to the anti-dumpling measures from the Indian Government.

4) Serving Turkish market where Jordan PV modules have some taxing privileges compared to other foreign suppliers and Tunisia where they have a zero-tax policy to their modules is part of the Middle East company strategy. Serving also the Syrian market during the future reconstruction of the country is also part of this strategy.

The sales forecast in MWp provided by Philadelphia Solar is provided in Table 3-9.

Table 3-9: Sales forecast (MWp)

Facility	2019	2020	2021	2022
Jordan Factory	170	170	220	220
American factory	75	200	300	300

Source: Philadelphia Solar

Philadelphia Solar expansion in Amman and USA will be supported by their project development activities like in Egypt where they have reached 68 MW of project pipeline.

DNV GL considers the strategy provided is quite ambitious but solidly supported by the relatively good prices of the American market and the stable market growth in this market. On the other hand, financing its expansion in manufacturing with development activities is not new in the PV industry where Chinese manufacturers have used that combination to facilitate their expansion.

Philadelphia Solar has no immediate plans to increase their verticality by manufacturing PV cells and they do not have any established Research and Development program but rather collaboration projects like a researching project with a Spanish company to develop glass with anti-soiling properties. DNV GL considers that this strategy is relatively common in non-vertical integrated manufacturers.

Finally, Philadelphia Solar was member of an insurance company in the past to assure the warranty coverage of their customer in the event of a business closure. DNV GL considers that it is beneficial for future customers this type of insurance policies especially coming from small manufacturers.

4 TECHNICAL EVALUATION

4.1 Product Evaluation

The PS-M60, PS-M72, PS-P60 and the PS-P72 module series are the focus of this product evaluation. All models use 156.75 x 156.75 mm multi-crystalline (mono and poly) silicon cells, and different component suppliers. Table 4-1 shows the main characteristics of the analysed PV modules.

Table 4-1: Philadelphia PS-P60, PS-P72, PS-M60 and PS-M72 family of modules

Parameter				
Model	**PS-P60**	**PS-P72**	**PS-M60**	**PS-M72**
Number of cells	60	72	60	72
Type of cells	Multi crystalline	Multi crystalline	Mono crystalline PERC	Mono crystalline PERC
Cell dimensions [mm]	156.75x156.75	156.75x156.75	156.75x156.75	156.75x156.75
Layout	6x10	6x12	6x10	6x12
Dimensions [mm]	1648x990x40	1968x990x40	1648x990x40	1968x990x40
Front surface	Anti-reflective coated tempered 3.2mm glass	Anti-reflective coated tempered 3.2mm glass	Anti-reflective coated tempered 3.2mm glass	Anti-reflective coated tempered 3.2mm glass
Encapsulant	PID free EVA	PID free EVA	PID free EVA	PID free EVA
Glass thickness [mm]	3.2	3.2	3.2	3.2
Number of Bypass diodes/cells	3/20	3/24	3/20	3/24
Weigh [kg]	19	22	19	22
Power [W]	265-275	320-330	290-310	350-370

All module sizes and technologies utilize the same electrical wiring scheme. The cells are connected in a series string, with bypass diodes connected in parallel across every third of the cells. The number of cells bypassed per diode is shown above in Table 4-1 for each module size. The maximum number of cells per diode is 24 for P72 and M72 modules and 20 for P60 and M60 modules. The wiring and number of diodes conform to standard industry practice. All PV module models have a 5-busbar solar cell design which contributes to the improvement in the efficiency compared to other 3 busbar solar cell PV modules.

Moreover, mono-crystalline analyzed PV modules are composed by PERC (Passivated Emitter Rear Cell) mono-crystalline cells. PERC technology increases the efficiency of the solar cells as current generated inside is raised due to the reflected light thanks to the passivation film applied at the rear side of the PV module. Moreover, the analyzed PV module datasheet claims to perform well in low-light environment thanks to the texture of the glass and solar cell surface of the PV module.

DNV GL highlights the system voltage of the analysed PV modules is 1,000V whereas current system voltage of similar PV modules is already 1,500V. As stated by Philadelphia Solar, the PV modules are undergoing 1,500 voltage system tests performed by TUV Rheinland. DNV GL highlights the importance of reaching 1,500V voltage system in order to be comparable with other current PV modules.

Datasheets /1//19/ for analysed modules can be found inAPPENDIX A: . As shown inTable 4-2 and Table 4-3, the P72 and M72 modules are compared to similar competitor products. The electrical and mechanical characteristics are closely matched with competitive products from well-regarded companies.

Table 4-2: Comparison of Philadelphia PS-P72 to Competitor Products

Parameter	PS-P72	Manufacturer 1	Manufacturer 2	Manufacturer 3	Manufacturer 4
Pmax [W]	330	330	330	330	330
Power tolerance [W]	0~9.9	0~5	0~5	0~9.9	0~5
Voc [V]	45.9	46.98	45.6	46.9	46.1
Isc [A]	9.27	9.31	9.45	9.14	9.38
Operating voltage Vmpp [V]	37.4	37.16	37.2	37.8	37.3
Operating current Impp [A]	8.83	8.88	8.88	8.74	8.87
Module efficiency [%]	17.00	17.00	16.97	17.01	17.00
Power temperature coefficient [%/°C]	-0.41	-0.39	-0.41	-0.40	-0.41
Voltage temperature coefficient [%/°C]	-0.33	-0.31	-0.31	-0.30	-0.32
Current temperature coefficient [%/°C]	+0.05	+0.07	+0.053	+0.06	+0.05
Maximum system voltage [V]	1,000	1,500	1,500	1,500	1,500
NOCT [°C]	46±2	45±2	45±2	45±2	44±2
Temperature range [°C]	-40ºC to 85ºC	-40ºC to 85ºC	-40ºC to 85ºC	-40ºC to 85ºC	-40ºC to 85ºC
Dimensions	1968x990x40	1962x992x35	1960x992x40	1956×992×40	1956×992×40
Glass thickness [mm]	3.2	3.2	3.2	4.0	3.2
Maximum certified load [Pa]	5,400	5,400	5,400	5,400	5,400

Table 4-3: Comparison of Philadelphia PS-M72 to Competitor Products

Parameter	PS-M72	Manufacturer 5	Manufacturer 3	Manufacturer 4
Pmax [W]	370	370	370	370
Power tolerance [W]	0~11.1	0~5.0	0~11.1	0~5.0
Voc [V]	48.0	47.50	48.5	48.3
Isc [A]	10.00	9.97	9.61	9.83
Operating voltage Vmpp [V]	38.66	39.3	39.9	39.7
Operating current Impp [A]	9.60	9.44	9.28	9.33
Module efficiency [%]	19.00	19.10	18.66	19.00
Power temperature coefficient [%/°C]	-0.393	-0.39	-0.37	-0.39
Voltage temperature coefficient [%/°C]	-0.291	-0.29	-0.28	-0.29
Current temperature coefficient [%/°C]	+0.033	+0.05	+0.048	+0.05
Maximum system voltage [V]	1,000	1,000 / 1,500	1,000	1,500
NOCT [°C]	46±2	44±2	45±2	44±2
Temperature range [°C]	-40ºC to 85ºC	-40ºC to 85ºC	-40ºC to 85ºC	-40ºC to 85ºC
Dimensions	1968x990x40	1956x992x40	1979×1002×40	1960×992×40
Glass thickness [mm]	3.2	3.2	3.2	3.2
Maximum certified load [Pa]	5,400	5,400	5,400	5,400

Based on the data specified in the datasheets, module performance criteria's such as temperature co-efficient, voltage characteristics, current characteristics are comparable and, in some cases, better than other leading suppliers in the PV industry and are reasonable.

Philadelphia uses the Bill of Materials set in Table 4-4..

Table 4-4: Components in the PS-P72 & PS-M72 modules Source: Philadelphia Solar.

SOLAR CELL	
Manufacturer 1	
Name	NEO Solar Power (NSP)
Technology	Mono crystalline
Type designation	MONO-NS6WL2130
Dimensions [mm]	156.75x156.75
Active area [cm^2]	N/A
Thickness [µm ± tolerance]	200±30
Power classes [W]	≥5.03
Manufacturer	Neo Solar Power: is a Solar cells and PV module manufacturing company headquartered in Taiwan..
Certificates	According to Neo Solar Power website, company installations are ISO 9001:2015, ISO 14001:2004 and OHSAS 18001:2007 certified.
Manufacturer 2	
Name	Gintech Energy cooperation
Technology	Poly crystalline
Type designation	G156S4
Dimensions [mm]	156.75x156.75
Active area [cm^2]	N/A
Thickness [µm ± tolerance]	200±20
Power classes [W]	N/A
Manufacturer	Gintech Energy cooperation: the company was first established in August 2005 and started commercial production of solar cells in 2006. Gintech's products are distributed within Germany, Spain, Italy, the United States, Japan, China, India, Korea, to mention a few. Gintech exports more than 95% of its products to overseas markets. By 2011, annual production capacity reached 1.2GW.
Certificates	According to provided information by Philadelphia Solar /9/, Gintech Energy cooperation company holds the following certificates: ISO 9001, ISO 14001, OSHAS 18001, TUV and JET.
FRONT COVER	
Name	Xinyi group company limited
Material	Glass
Type designation	Low iron solar patterned glass
Thickness [mm]	3.2 and 4
Surface treatment	Low-iron patterned glass
Tempering method	Tempered glass
Manufacturer	Xinyi group company limited: the company was founded in 1988 listed on the main board of the Hong Kong Stock Exchange in February 2005. Xinyi focusses its activity in glass manufacture with manufacturing locations in Shenzhen, Dongguan, Jiangmen, Wuhu, Tianjin, Yingkou and Deyang. The company has

	more than 12,000 employees.
Certificates	According to provided information by Philadelphia Solar /9/, Xinyi group company limited holds ISO 9001 certificate./9//9/, Xinyi group company limited holds ISO 9001 certificate./9/
BACKSIDE COVER	
Name	Cybrid Technologies
Type designation	N/A
Backsheet structure	
Thickness [µm]	315µm
Max. system voltage [V]	N/A
Backsheet certifications	N/A
Manufacturer	Cybrid: in 2005 Macropoly Laboratory was created in Kyoto to begun R&D activities in polymer functional material. In 2010, Cybrid entered the PV business
Certificates	According to Cybrid website, operates under ISO 9001 guidelines..
CELL ENCAPSULATION	
Frontside and backside of cells	
Name	Changzhou SVECK PV New Material Co. LTD
Type designation	SV-15296P (frontside) / SV-15297P (backside)
Thickness [mm]	500
UL listed	E334244
Manufacturer	Changzhou SVECK PV New Material Co.LTD : the company was founded in 2005 and is focussed in the manufacture of ethylene vinyl acetat (EVA) films to be used for encapsulant in PV modules. The company is headquartered in Changzhou.
JUNCTION BOX	
Name	Zhejiang Jiaming Tianheyuan Photovoltaics Technology Co., Ltd.
Type designation	JMB13-1
Nominal current [A]	13
Nominal voltage [V]	N/A
Certificates	IEC 62790:2014
Manufacturer	Zhejiang Jiaming Tianheyuan Photovoltaics Technology Co., Ltd. : the company was established by Jiaming Group in 2005, specialized in solar battery, module junction boxes, connectors and cables.

Philadelphia Solar has provided Storage Conditions of the different components of the PV module. Please refer to APPENDIX F: .

4.2 Light Induced Degradation (LID)

Light Induce Degradation effect is the loss of efficiency that occur in PV modules at the first hours of exposition to sunlight. This effect has a high notoriety as it reduces the efficiency of the PV modules in a permanent way.

Philadelphia Solar offers a standard warranty against Light induced degradation of 97% for its mono-crystalline based products and 2.5% for poly-crystalline based products. Although many of PV module manufacturers offer a 2.5% LID, these values are within the industry standard values.

LID testing data was provided for review, measurement of LID was undertaken up to 5.85kWh/m^2 /6/ and the loss in energy of analysed PV modules is within 1.06% for polycrystalline PV modules and within 2.20% for monocrystalline PV modules, which are considered reasonable and comparable to other suppliers. However, DNV GL highlights to arrive at an accurate representation of LID, it is usually recommended to undertake the study for a minimum of 60kWh/m^2 for the stabilization of LID.

4.3 Passivated Emitter Rear Cell (PERC)

The Passivated Emitter Rear Cell or PERC technology features higher efficiency than the standard technology. Additional steps in the manufacturing process for the rear side passivation and contact layer (so called dielectric PERC layer) involves additional cells' processing, hence higher costs.

The main reasons why the dielectric passivation PERC layer contributes to the increase of efficiency are the following ones:

- The extra dielectric passivation layer reduces electron recombination: Electron recombination is the tendency of electrons to recombine and block the electrons from freely flowing through the solar cell, which means it can't reach its potential efficiency. Electrons generated near the back of the solar cell are now free to move up to the emitter and contribute to more electrical current.
- The extra dielectric passivation layer increases the solar cell's ability to capture light: The dielectric layer reflects the light that passes through the solar cell without generating any electrons. By reflecting this light, the photons are given more opportunity to generate electrical current.

The PERC architecture can be implemented on both multi-crystalline and mono-crystalline wafers. Like the standard technology, the mono-PERC is more efficient than the multi-PERC. PERC modules have a higher energy density per square foot and perform well under low-light conditions and high temperatures resulting in greater energy yield. One of the issues with PERC technology (both multi and mono) has been the Light-Induced Degradation or LID. Multi-PERC exhibits a slightly different form of LID that occurs with elevated temperatures (Light and elevated Temperature Induced Degradation - LeTID). Some manufacturers of multi-PERC cells have shown data suggesting that this degradation has also been reduced and controlled. However, at this stage Poly-PERC has significant bankability challenges to be proven.

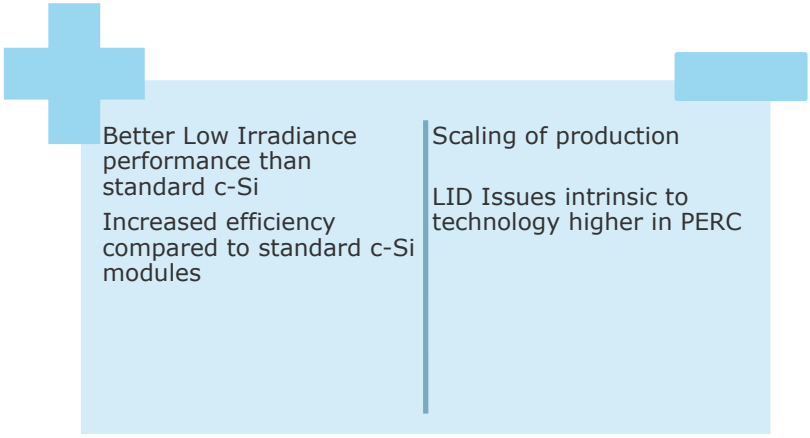


Figure 4-1 Advantages / Disadvantages of PERC technology

PERC technology is still considered by many as 'new', but it already accounts for over 30% of all crystalline cells produced. Furthermore, PERC technology appears to have more efficiency potential as manufacturers are developing higher cell efficiencies. The main issue which historically held back deployment of PERC was the light-induced degradation (LID) as indicated above, which most manufacturers have sufficiently solved. A summary of crystalline silicon technology is shown below. A summary on the key features of PERC modules is given in Table 4-5:

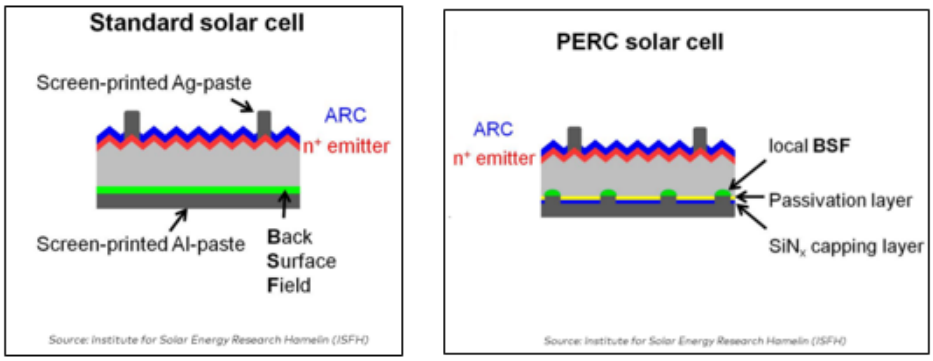


Figure 4-2 Key features of Al-BSF and PERC modules

Table 4-5: Key features of PERC modules

	Standard technology	PERC
Multi	Module Efficiencies: ~16.5% Well established technology Pmax Temperature Coefficient -0.40%/C	Module Efficiencies: ~18 ~11 GW of production in 2017 Pmax Temperature Coefficient -0.39%/C
Mono	Module Efficiencies: ~18% Well established technology Pmax Temperature Coefficient -0.40%/C	Module Efficiencies: ~19+% ~24 GW of production in 2017[1] Pmax Temperature Coefficient -0.38%/C

4.4 Certificates

DNV GL has been provided with the following certifications applicable to the manufacturing process:

- ISO 14001:2015 Standard for Environmental Management System
- ISO 9001:2015 Standard for Quality Management System
- ETIMAD accreditation for PV systems larger than 2 MWp (awarded by CESA, The Coalition of Energy Services Associations)

Related to the certifications held by the PS-M72 and PS-P72 PV modules, certificates in the Table 4-6 are applicable.

Table 4-6 PV module certificates

Certificate				
	PS-P60	**PS-P72**	**PS-M60**	**PS-M72**
IEC 61701 Salt mist corrosion	✔	✔	✔	✔
IEC 61215 Design qualification	✔	✔	✔	✔
CEC	✔	✔	✔	✔
IEC 62716	✔	✔	✔	✔
IEC 61730	✔	✔	✔	✔
IEC 62804-1 (2PfG 2387/04.14)*	✔	✔	✔	✔
UL 1703	✔	✔	✔	✔
DEWA	✔	✔	✘	✘

*Certificate provided ensures PV modules have been tested according to 2PfG 2387/04.14 standard, however, the TÜV letter /15/ declares that the 2PFG 2387/04.14 was tested in accordance to the IEC TS 62804-1.

- IEC 61701 Salt mist corrosion testing of PV modules
- IEC 61215 Standard for Design qualification and type approval. Test requirements
- Guidelines for California's Solar Electric Incentive programs CEC 2nd Ed.

- IEC 62716 Standard for Ammonia corrosion testing
- IEC 61730 Standard for PV module Safety qualification
- 2PfG 2387/04.14 System voltage durability qualification test for crystalline silicon modules (Potential Induced Degradation PID)
- IEC 62804-1 Test methods for the detection of potential induced degradation. Crystalline silicon
- UL 1703
- DEWA (Distributed Renewable Resources Generation program) (Shams Dubai)

All certificates have been tested with 1,000V which is the voltage system which PV modules are designed for. As stated by Philadelphia Solar, 1,500 voltage systems are under testing and certification procedure by TUV Rheinland Laboratory in Germany. DNV GL highlights the importance of achieving this 1,500V voltage system certification to better adapt to the market evolution.

4.5 Independent Test Results

DNV GL has been provided with independent test data from Fraunhofer ISE providing deviations from module nominal values, the effective deviation in power and efficiency was 0.2% which is reasonable and within the expected range of deviations. /4/

4.6 Anti-Reflective (AR) Glass Performance

Light reflection that may occur in PV modules surface leads to an energy loss reducing the efficiency of the PV modules. This is the reason why best industry practices are incorporating anti-reflective glass products in order to avoid this evitable additional loss of energy.

The knowledge of the Anti-Reflective glass performance is of high importance due to its impact to the production.

According to provided information /17/, the analysed Anti-Reflective coating glass presents the following properties:

Parameter	
Light Transmittance (380~1,100nm) [%]	≥ 93.5*
Pencil Hardness	≥ 4H
Coating addhesion	Class 0
Anti acid	Transmittance loss less than 1%
Salt spray	Transmittance loss less than 1%
Damp Heat test (double 85)	Max power loss less than 5%
Exposure to UV Light	Max power loss less than 5%

*For both 3.2mm and 4.0mm, according to ISO 9050:2003

Although above mentioned characteristics of the AR glass were provided, no IAM test results were shared. DNV GL would require IAM results in order to provide an opinion on the reflective behaviour of the analysed PV modules.

4.7 Low Irradiance Performance

DNV GL has been provided test reports from the customer undertaken by TUV Rheinland. Test procedures were undertaken according to IEC61215 and IEC61730 /14/. The low light performance based on the test data provided (see Table 4-7) are better than the industry standards which stands typically around 3.5%.

Table 4-7 PV modules Performance at low irradiance test

Parameter	Nominal power [W]	Power (@1000 W/m²) [W]	Power (@200W/m²) [W]	**Low light irradiance performance factor [%]**
PV module 1	325	306.9	60.4	1.59
PV module 2	300	299.3	59.7	0.27
PV module 3	270	264.2	51.6	2.35
PV module 4	255	249.2	49.5	0.68

DNV GL would recommend performing more updated tests as this test was done in 2015 /14/. Moreover, test results show tested PV modules power is below the nominal power stated in the datasheet. DNV GL understands, as the PV modules where stored wrapped in transparent film, this power difference is caused by LID already existing in tested PV modules.

A characterization of low light performance will need a higher sampling size to verify performance across the product portfolio.

4.8 STC Rating

The module power ratings provided in the product catalogue is comparable to other manufacturers. The modules are provided with a positive tolerance of up to 3% over the nameplate rating. The tolerance of the modules is in-line with the technology considered. Current trend is to state power tolerance in Watts not in %.

5 QUALITY AND RELIABILITY

5.1 Manufacturing production line and incoming inspection quality checks

The manufacturing process line is sketched in Figure 5-1. The production facility has a built-up area of approximately 12,000 m^2 located near Amman city in Jordan. The manufacturing production facility is flexible to handle poly (or multi) and mono crystalline silicon modules of 60 cells and 72 cells per module. A total of 332 employees are working in the manufacturing facility from which a total of 118 staff are part of the Engineering, Procure and Construction (EPC) department.

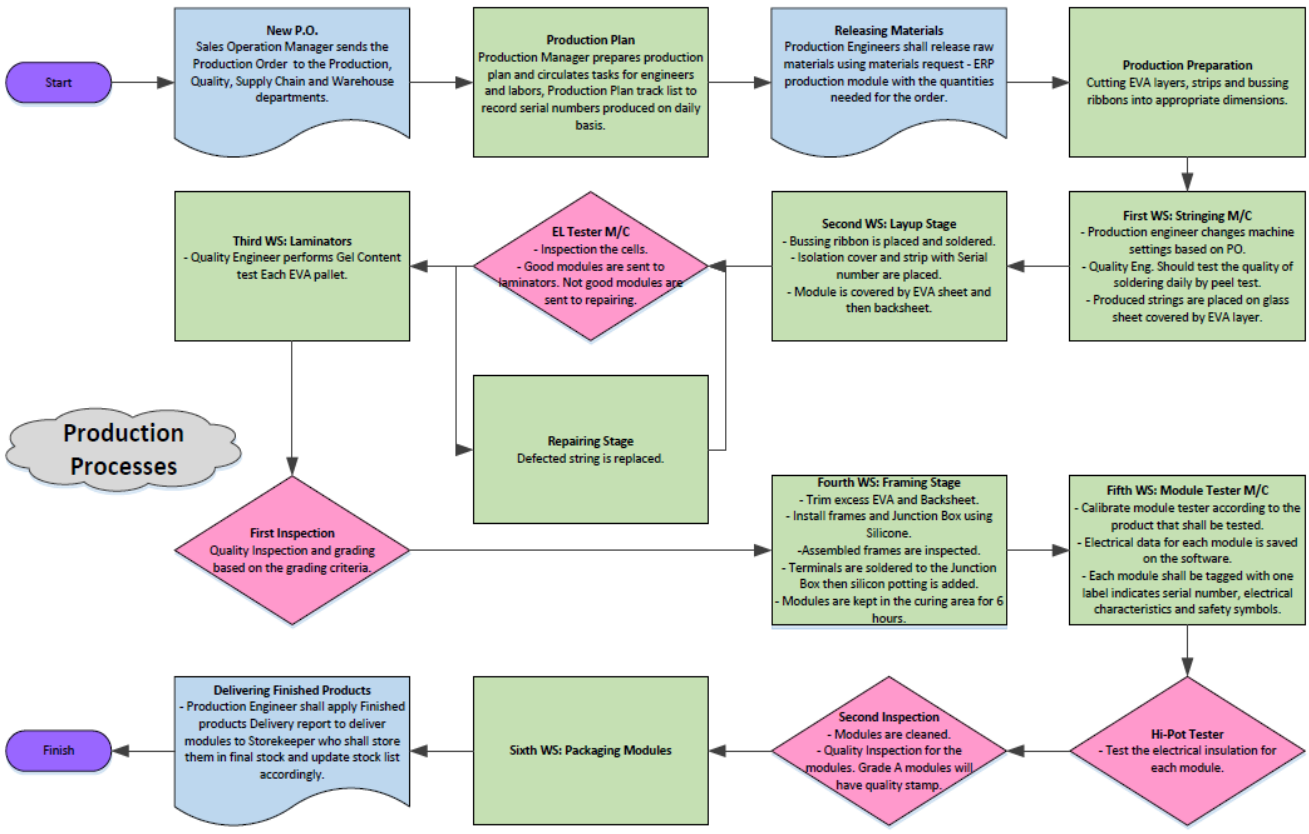


Figure 5-1: Production follow chart. Source: Philadelphia Solar.

Giving the location of the manufacturing facility in a hot climate, Philadelphia Solar is monitoring with dedicated sensors in the facility the temperature (between 20ºC and 30ºC) and the humidity (between 30% and 60%). The results for the last 104 days (summer) give a couple of alarm triggered episodes by the first week of July with a record temperature in the period of 28.4ºC. DNV GL understands that the works are

stopped in the affected area with triggered alarm until the conditions are back to normality. DNV GL recommends making traceable the ambient conditions recorded on manufacturing areas with the serial numbers of the modules being produced to anticipate potential quality issues.

Regarding dust control, Philadelphia Solar has informed that it is undertaking a couple of times per year. DNV GL recommends increasing the dust control up to a monthly basis as a minimum. The cleaning of the facilities is undertaken 4 hours per day during 5 days per week. DNV GL highlights the importance to keep a daily cleaning routine process on every key element of the manufacturing process.

Operators are wearing full suits, caps, booties, gloves and masks. No difference in wearing has been observed between operations, quality control or maintenance.

Solar cells are received pre-sorted by colors and efficiency from the manufacturer. Philadelphia Solar has implemented a working procedure to avoid mixing different cell texture and/or color in each module.

Tabbing and lay-up are done automatically using Somont machinery. Bussing is done manually, and an EL inspection is undertaken just before the lamination. The embedded serial number is attached, and insulation pieces installed. EVA and back sheet are placed to complete layup. Slits for interconnect wiring are precut by the manufacturer in the back sheet and the wires are pulled through by the operators.

The Electro-Luminescence inspection undertaken just before the lamination is helping to replace defective cells not captured in automatic camera of the tabbing process or generated by the manual bussing process. A visual inspection is undertaken additionally before lamination.

Three parallel laminators able to handle up to 48 modules per hour were used at the time of the visit. As commented by Philadelphia Solar, another laminator has been added on November, with a total of 4 laminators installed in the factory. The manufacturer of the three laminators existing at the time of the visit was NPC-Japan, whereas the supplier of the last laminator is Jinchen. Both manufacturers are well recognized in the industry. Three samples per week are taking for gel content measurement. DNV GL could not visit the laboratory as it was being readapted for the factory expansion. However, records of the gel content measurements from January to October 2018 have been provided by Philadelphia Solar. The minimum and maximum gel content pass criteria are 76% and 94%, respectively. DNV GL notes that there are several gel content results outside the limits above. It seems that re-testing was needed in most cases because of a laboratory false result. Philadelphia Solar has confirmed that as soon as a gel content failure may arise, the test was repeated.

During the visit, after the lamination, the modules were trimmed manually, and were transported to the framing area. Trimming was undertaken by trained staff only to avoid injuries using highly dangerous tool for the trimming. Later on, in order to eliminate the risk for the workers at the trimming stage, Philadelphia Solar has provided documentation proving the trimming procedure is performed automatically by an appropriate trimming machine installed in the factory since November.

At the time of the visit, junction box application was performed manually . The junction box is procured as a component, complete with diodes, cables and connectors. According to Philadelphia Solar information, silicone applied to the junction box is currently performed by a recently installed machine.

The modules are stored at controlled ambient conditions for the drying of the silicone before entering the Flash Tester. During the site visit Philadelphia Solar informed that a drying period of 8 hours is applied. The

drying time control is undertaken by attaching post-it to each batch of 25 modules. DNV GL recommends reviewing the drying control protocol to allow a more automated process.

The Flash Tester machine supplied by Endeas (Finland) is able to handle up to 78 modules/hour which is more than enough for the current and planned expansion capacity. The tester is a AAA class equipment as per IEC 60904-9:2007 with latest issue of calibration in 20th September 2018. The flash equipment is calibrated with a secondary calibrated module derived from a primary calibrated module by Fraunhofer (latest date of calibration: 22nd February 2018). DNV GL views the control and calibration of power testing to be aligned with industry standard practice.

A hi-pot test is performed on every module after flash test, meeting the requirements of UL 1703. Modules not sold with UL stamp are not grounded. DNV GL observed that the hi-pot test was run with an intentional faulty module to confirm that a failure was reported by the system at 3,600 V. DNV GL also observed the second test required under UL 1703 regarding grounding continuity test.

An electroluminescent image machine is used in order to confirm that no issues are detected. The automatic criteria to classify faulty modules are set at a higher filter than previous EL machine to avoid false rejections. A period of 30s has been set for this last EL inspection machine.

After final module cleanup and visual inspection, protective plastic separators are placed over the corners and the modules are stacked on the long side as per industry practice. DNV GL recommends avoiding light penetration through the small space between modules using a card box covering the entire pallets rather than transparent plastic film as Philadelphia Solar default packing system. Philadelphia Solar has confirmed that they are in the process of implementing another packaging method using Cardboard boxes which will prevent light penetration. The modules are packed with 25 units per pallet. To maximize container utilization, pallets are double stacked for shipping.

DNV GL has been provided with an Excel Sheet where the testing to incoming materials is summarized:

- Dimensional checking for aluminum frames
- Dimensional and gel content check for the EVA sheets
- Dimensional check and cutting length for the back sheet
- Dimensional check for the glass
- Dimensional check (width and thickness) for the ribbon
- Cells checking
- Other checking: silicone, label, flux, junction box and plastic corners separators

DNV GL highlights the importance of implementing a day-to-day routine for the testing of incoming materials to avoid situations with inferior quality batches entering the PV module manufacturing process. The quality control mentioned above is adequate and it is implemented a batch criteria testing according to ISO 28591-S4/AQL2.5 which means testing a sample of 80 cells every 448,000 pcs. Philadelphia Solar has also confirmed they apply a rigid quality plan for incoming materials.

Philadelphia Solar is open to use other component suppliers after an internal process of validation. DNV GL has been provided by procedure to be followed when approving a new component.

Finally, the in-house quality tests reported by Philadelphia Solar are listed in Table 5-1. DNV GL did witness any of the tests at the factory laboratory as the facility was being renovated and expanded. In general

terms, it can be concluded that the list of quality tests is comprehensive. However, DNV GL considers that the traceability of the quality tests representing production batches is subject to certain degree of improvement. Philadelphia Solar regularly sends equipment samples to Fraunhofer for testing in order to be able to compare the results obtained by a third party with the in-house testing results and update, consequently, their certifications according to the latest IEC standards.

Table 5-1 In house quality checks. Source: Philadelphia Solar

In-house quality Tests.					
Test	**Method**	**Frequency**	**PASS Criteria**	**Resources (machine/tool/human)**	**responsibility**
bus bar length.	ruler	every day	± 0.2 mm	tool	QC Engineer
Cells edge cracks / spots	CC camera	In-line	No defects	SOMONT machine.	QC Engineer
Check alignment, cell gap and bad soldering	Visual inspection to the strings / CA camera and lay up station	In-line	No defects	QC Technician .	QC Engineer
Cells; Microcracks / bad soldering / misalignment/short circuit /fault bussing.	EL Tester	In-line	No defects	EL tester -machine.	QC Engineer
humidity and temp of cutting EVA Room	data logger	recorded every hour by data logger	temp < 30 and humdity < 60 % shall be used within 12 h		QC Engineer
			temp > 30 and humdity > 60 % shall be used within 6h	Tool	QC Engineer
Soldering guns temp testing	data logger	daily visual check and monthy check by data logger	Tolerance ± 10C°	data logger type :OMRON ZR-RX25	QC Engineer
Laminators Temperatures	data logger	Monthly	±1.5C° than the actual temp.	data logger type :OMRON ZR-RX25	QC Engineer
Checking Modules Visual Defects	Ist Inspection / 2nd Inspection	In-line	According to grading criteria	QC Technician.	QC Engineer
Current leakage	Hipot Tester	In-line	< 50 µA	Hi- pot tester machine.	QC Engineer
Modules / cells power	Module Tester	In-line / new shipments	Mono CTM losses < 2.5% / Poly CTM losses < 1.5%	flasher machine.	QC Engineer
Framed modules dimension and corners	Using meter/filler gauge	Daily	L: 1968+-2mm / W:990+-2 mm	tool	QC Engineer
Silicon potting ratio	Weight at Digital Balance	Weekly	5:1 (4.5-5.5:1)	tool	QC Engineer
Wet current leakage	Wet hipot Tester	Weekly	< 50 µA	device type :T0S9201	QC Engineer
Ribbon Soldering	pull tester	Daily/ New shipments	F: > 1.3N/mm / B: > 1.3N/mm	device type : FGP-5 (50N).	QC Engineer
EVA curing	Gel content	3 samples per week / New shipments	> 76% and <94%	device : ECOPROGETTI	QC Engineer
Adhesion of EVA to glass/backsheet	EVA Peel Test	weekly / New shipments	G: > 80N/cm / B: > 80N/cm	device type : (IMADA DS2-200N).	QC Engineer
Raw materials dimensions (cells, EVA, glass, backsheet, frames).	Meter/caliper/micrometer/ruler /filler gauge.	New shipments.	According to specificatons	tools, meter , caliper	QC Engineer
Silicon dispenser extrusion rate	Weight at Digital Balance	Per Drum	> 40g/15s	tool, balance.	QC Engineer
Grounding test	using multimeter	100% for UL shipments.	0 – 0.1 Ω	Fluke/376	QC Engineer
Post EL tester	El tester	In-line	without defect/ cracks /dark cells / dark strings.	Gsolar Model no : GEL /M6Z	QC Engineer
Temp of modules	data logger	recorded every hour by data logger	25 ± 2C °	Digital Thermo-Hygrometer.	QC Engineer
Temp of testing room	data logger	recorded every hour by data logger	25 ± 2C °	Digital Thermo-Hygrometer.	QC Engineer

5.2 Finished product durability checks

It is important to make the distinction between manufacturing production line quality checks and finished product durability checks. No in-house reliability monitoring program has been implemented yet by Philadelphia Solar. DNV GL considers that this would be required to follow the best practice in the industry where UV pre-conditioning chamber, thermal cycling chamber and thermal/humidity chamber may be installed in the module fab building. Typically, this testing may include extensions beyond the standard IEC 61215 durations together with Potential Induced Degradation (PID) tests.

DNV GL also recognizes that the above finished product reliability checks are typically seen in manufacturers with a capacity above 200 MWp-500 MWp per year when the current capacity of Philadelphia solar is approximately 170 MWp. Therefore, the size of Philadelphia Solar does not justify a dedicated finished product durability programme. For that reason, DNV GL considers that Philadelphia Solar may consider adopting third party reliability program, externalising these activities as a mitigant. As previously explained, Philadelphia Solar regularly sends equipment samples to Fraunhofer for testing in order to be able to compare the results obtained by a third party with the in-house testing results and update, consequently, their certifications according to the latest IEC standards.

5.3 Potential Induced Degradation (PID) Testing

Potential Induced Degradation (PID) is a largely reversible power loss in modules that may occur when the voltage of the array is such that the cells are at a negative voltage with respect to the frame. As a relatively recent issue facing the PV industry an IEC standard (IEC 62804) was developed. The standard considers two methods for applying the voltage stress. See Table 5-2:

Table 5-2 IEC 62804 PID testing methods

Parameter	Stress method A	Stress method B
Module temperature	60ºC±2ºC	25ºC±1ºC
Relative humidity	85%±3%	60%
Duration	96h	168h

The standard is used to evaluate PV module durability to system voltage stress under certain conditions. In terms of mitigating risk of PID, the principal benefit of the IEC 62804 test is to demonstrate if a given PV module has an encapsulation that is suitable for minimizing leakage current. Many testing laboratories have developed their own PID tests that use similar test conditions.

DNV GL was provided with testing report for both poly-crystalline (or multi-crystalline) and mono-crystalline modules. Tests were undertaken as per 2 PfG 2387/04.14 standards. The results of the testing are well within the pass criteria's and all modules tested are deemed to pass the criteria's defined. /7/. Moreover, DNV GL has also been provided by a TÜV letter /15/ declaring that the 2PFG 2387/04.14 was tested in accordance to the IEC TS 62804-1.

6 MANUFACTURING FACTORY VISIT

DNV GL visited the Philadelphia Solar module manufacturing facility in Amman, Jordan on October, 17th 2018. A detailed review and inspection of the manufacturing facility is included in this section. A pictorial log is provided in Appendix E.

The following areas were inspected during the site visit:

- Raw material reception area: glass, EVA, back sheet, cells and aluminium
- Cell tabbing and bussing
- Lay-up
- Electroluminescence 1
- Lamination
- Framing
- Junction box application
- Drying area
- Flash testing
- UL testing
- Electroluminescence 2
- Final inspection
- Packaging

The production process at a glance is provided in Figure 6-1.

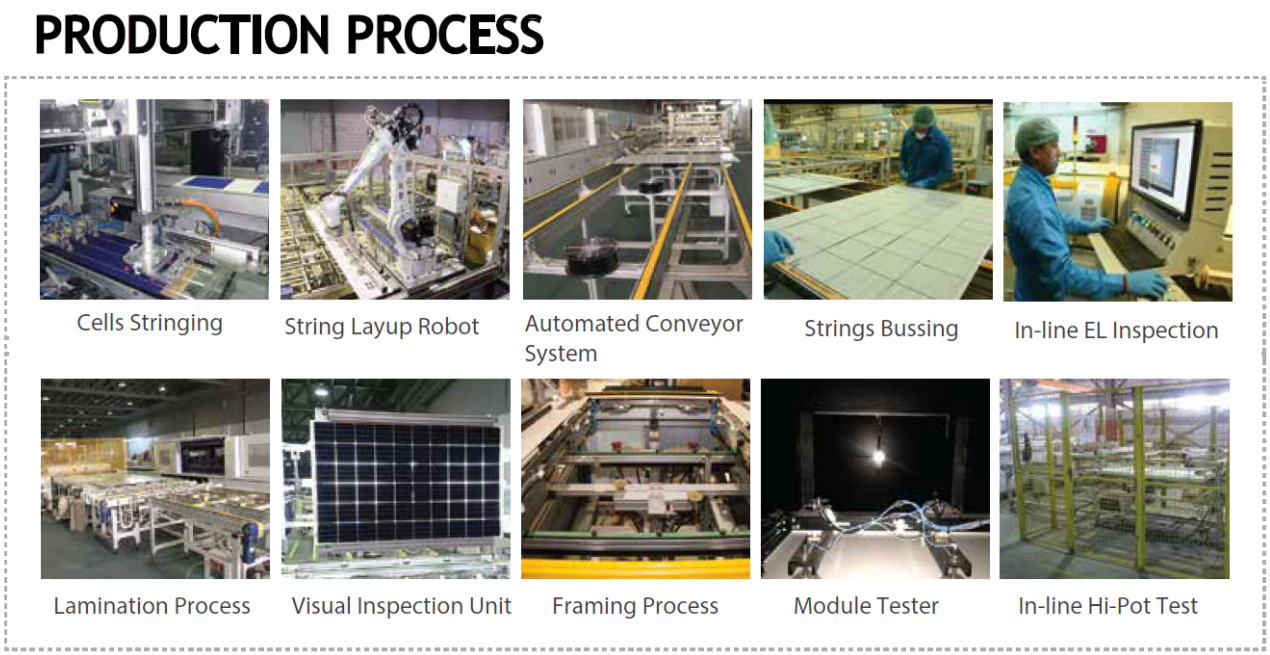


Figure 6-1: Production process at a glance. Source: Philadelphia Solar.

6.1 Material Storage

DNV GL visited the raw material storage area where materials such as EVA, requiring controlled temperature and humidity conditions, are stored. DNV GL observed that the area was monitored for temperature and humidity four times per day (every three hours) working on two shifts of 10 hour/shift and five days per week. These procedures are keeping with the industry standard practices. DNV GL recommends having a traceability of the serial numbers of the modules represented by each of the ambient conditions registers. This would allow a traceability of likely impact of ambient conditions on the quality of the components used.

Philadelphia Solar has confirmed that they are in the process of implementing another packaging method using Cardboard boxes which will prevent light penetration.

Philadelphia Solar has developed an in-house cutting system for the ribbon. DNV GL recommends having a back-up system to avoid bottle neck in the future.

6.2 Cell Sorting

Cells arrive from a selected number of manufacturers. They arrive in boxes binned by efficiency and colour by the outside supplier. Predefined colour categories have been defined by Philadelphia Solar. Modules are only produced from cells from a single efficiency bin at any one time. The cell thickness used is 200 microns (+/-10%). The colour sorting is aligned with industry standards.

6.3 Tabbing and Bussing

The tabbing operations are automated, but the bussing is manually undertaken. Previous module series having 3 Bus Bars (BB) instead of the current 5 BB had automated bussing but current one is fully manual.

DNV GL did witness the tabbing ribbons quality check consisting on a daily pull test because the factory laboratory was being renovated.

6.4 Lay-up

The lay-up is automated. After string placement, tape application, soldering of the crosstie ribbons, and application of the serial number is done manually. The work areas were very clean, and standard operating procedures were posted at each working station writing in both Arabic and English language. The temperature of the soldering irons is checked visually 3 times per shift and monthly using the data logger data.

EL imaging is performed on all modules prior to lamination. Modules with defective cells can be repaired manually replacing damaged cells or ribbon. Feedback to tabbing equipment staff allows to stop any of the four tabbing lines that may be not working well. DNV GL considers that the traceability of each cell with the tabbing lines should be more automated.

It can be concluded that the lay-up operation is consistent with industry standards in general, but it is also subject to some improvement regarding quality checks and traceability.

6.5 Lamination

The three existing laminators at the thime of the visit could manage up to 4 modules per batch in a maturing time of 15 minutes approximately at 145ºC. Temperature is monitored at 4 points across the laminator surface which is below the best practice in the industry with eight or more points. As commented by Philadelphia Solar, another laminator has been added on November, with a total of 4 laminators installed in the factory.

The gel content is scheduled 3 times per week which may be considered below the best practice in the industry with sampling every day. DNV GL did not witness any gel content test in the laboratory because it was in renovation for the facility expansion. However, we were provided with the results of gel content since January to October 2018. The minimum and maximum gel content pass criteria are 76% and 94%, respectively. DNV GL notes that there are several gel content results outside the limits above. It seems that re-testing was needed in most cases because of a laboratory false result. Philadelphia Solar has confirmed that as soon as a gel content failure may arise, the test was repeated.

6.6 Framing

Framing is done using a semi-automated process. Frame sealant is applied into the frames grooves using automatic appliances managed by operators. Philadelphia Solar has confirmed the full automation of the framing process has been implemented by installing a Jinchen framing machine.

The frame design observed in production does not have screwed corner connections which provide extra robustness to the frame in difficult loading conditions. In any case, DNV GL considers that the framing process is in line with the standard practices in the industry.

6.7 Junction Box

The junction box is mounted on the module by an automated procedure which is typical in the industry. Philadelphia Solar has confirmed there is a template to control the horizontal placement of the junction box on the back side of the module, in order to achieve proper placement. However, DNV GL has not seen this template usage during the site visit.

A silicone bead is applied to the junction box at an automated station, which is critical in achieving a consistent and uniform bead. At the time of the visit, the box was manually pressed by the operator, allowing for rocking or excessive pressing force that could cause sealant to extrude our and away from the box edge. Nowadays, DNV GL has received information confirming this last task is performed automatically by an appropriate machine, eliminating the possible risks related to sealant dissemination and controlling the gap between the junction box and the module.

The cross-tie ribbons are manually soldered onto the terminals of the junction box. Philadelphia Solar has commented, soldering temperature of the soldering iron is checked 3 times per shift. However, DNV GL has not seen this checking procedure to be performed during the site visit. DNV GL recommends to perform a mechanical pull test by the operator on each tab to ensure that a solid soldered connection has been achieved.

The box is potted after soldering and curing of the pottant is conducted in a separate room under controlled temperature and humidity conditions.

Philadelphia Solar has confirmed diode properties located in the junction boxes are evaluated by using diode mode and resistance mode testing. . Philadelpha Solar has confirmed strain relief test on the cables is performed for a proper tightness on a sampling basis during incoming inspection. The strain relief test consists on hanging the PV module for one minute from cables letting it withstand its own weight (around 22kg). However, DNV GL did not see neither of the mentioned tests being implemented during the site visit.

6.8 Flash Test

Power testing is conducted using an Endeas flash tester. The modules are tested vertically by two operators plus another operator on the computer screen. The calibration of the electronic unit is undertaken every two years. The temperature sensor and bulb are changed upon usage.

Primary calibration modules are sent to Fraunhofer for measurements which is the standard in the industry. Secondary modules are made internally from the primaries and they are recalibrated monthly. DNV GL recommends the calibration of the tester every 250 modules approximately as per the best practice in the industry. Modules are binned using a power tolerance of 4 W bins.

Modules are automatically binned at flash testing and are traceable to the module serial number. Bill of Materials (BoM) is provided on demand. The serial number is scanned prior to flash testing when the nameplate label is printed and applied, ensuring that the proper nameplate is applied.

DNV GL has been informed by Philadelphia Solar that used labels for binning the PV modules have been installed for the last 8 years without any claim.

6.9 Training / Worker Attire

All the working positions did have a clear instruction written in English and Arabic which is considered the best practice in the industry. Moreover, Philadelphia Solar confirmed that they have a training procedure for new employees using experienced workers. No specific training program was provided but Philadelphia Solar has commended these programs include exams and certificates.

Moreover, Philadelphia Solar has commented the company has an Academy which offer training for future trainers of any interested companies and individuals.

Regarding working attire, workers wear full suits, caps, booties, gloves and masks. Gloves were electrostatically discharged with a wiring system in the case of workers handling back sheet. This is the best practice of the market. A dress code has been installed within Philadelphia Solar premises:

- Production technicians: light blue sweater
- Maintenance technicians: black sweater
- Quality technicians: white sweater
- Engineers: lab coats and dark blue sweater

7 PRODUCT SUPPORT

7.1 Service Infrastructure Evaluation

Customer issues and service claims are under the purview of a dedicated department. Customer Satisfaction Survey and Customer Claim forms can be downloaded from Philadelphia Solar's website. Philadelphia stated during the inspection a low level of customer complaints. In cases, where warranty claims have been initiated, a root cause analysis is carried out to identify potential issues.

Additionally, Philadelphia shared with DNV GL an overview of number of claims until date /10/ see Table 7-1.

Table 7-1 Number of claims per year

Year	Claims under warranty
2014	4
2015	4
2016	6
2017	2
2018	3

The main problems detected in 2018 were the ones stated in Table 7-2:

Table 7-2 Detected problems 2018

Date	Problem description	Philadelphia Solar Root cause analysis
20/02/2018 and 01/04/2018	Snail trails due to microcracks. Bubbles on the corner of a module full of dust	Improper maintenance
09/08/2018	Dust on backsheet. Backside label attached in a different position. Bended frame	Philadelphia Solar's liability
13/08/2018	The power of the PV module is below the nominal power.	Tear backsheet. Philadelphia Solar assumed the responsibility as it could be caused by their installation team.

Philadelphia Solar also reports they have not made any major recall to their products. DNV GL highlights the number of reported problems is really low compared to the manufacturing capacity of Philadelphia Solar.

7.2 Warranty Evaluation

Philadelphia solar provides a linear warranty for its entire product range. Philadelphia Solar provided the limited warranty document for review.

Workmanship Warranty: 12 years, workmanship warranty.

Power Warranty: Linear warranty is provided for all the products.

The standard warranty offered by Philadelphia Solar for mono-crystalline products involves a first-year 97% of the nominal power and 0.65% degradation per year thereafter until year 25 reaching a performance of 81.7%.

Regarding poly-crystalline modules, Philadelphia Solar guarantees a 97.5% of the nominal power the first year and 0.7% degradation per year until year 25 where the output power will be at least 80.7% of the nominal power.

The twelve-year workmanship warranty is a relatively new trend in the PV market industry which places Philadelphia Solar at the upper range of the PV module manufacturers in terms of product warranty conditions.

Regarding degradation, the industry trend is moving towards a 0.5% as the lowest degradation rate till year 25 and in some cases even till year 30 and at least 97.5%first year power warranty. DNV GL would recommend improving warranty terms to follow the best practice in the industry.

7.3 Product Manuals

DNV GL has been provided with the product manuals and maintenance guidelines for the modules, specifically Installation and Operation manual/5/, the Guide to Cleaning PV modules /11/ and General Safety Instructions /12/. As many modules are sold in many primarily Arabic speaking countries, the manuals are made available in Arabic as well, which is considered beneficial. DNV GL considers the manuals reasonably well documented and highlights the potential risks and safety measures to be taken by personnel. DNV GL highlights the installation and operation manual 2018 is also made available in Arabic for specific markets. /5/

Philadelphia Solar claims to provide customers with PV modules cleaning training and advise them about the most suitable cleaning tools to be used. Philadelphia Solar has tested and approved cleaning machines manufactured by Jordanian company. DNV GL has been provided with a Test report evaluating the influence of the cleaning machine on the PV modules /18/.

7.3.1 Installation and Operation manual and General Safety Instructions

These manuals contain required information to allow electrical and mechanical installations to be performed in an efficient and safety way. The following paragraphs give an idea of the main elements of the Installation and Operation manual as well as the General Safety Instructions document:

7.3.1.1 Main general requirements/warnings:

- The installation must be performed by a certified installer/servicer
- Installation and commissioning shall be done in accordance with IEC 62446 & IEC 60346 and their associated codes and having all required permits.
- Each module has two labels (one on the backside and one laminated inside the glass from front side) with same serial number. Backside label includes model and electrical specifications.
- PV module cables shall be protected from direct sunlight.
- Placing objects over the PV modules should be avoided.
- PV module repairing, or disassembling attempts should be avoided.
- PV cables should be protected against Pests and small animals.

- PV modules should be replaced by components of the same characteristics as the original parts.
- Contact with electrical active parts of the PV module can result in burns, sparks…
- Single safety locking clip MC4 style connector should be used.
- PV modules must not be connected directly to loads.
- PV modules with same cell size within series should be installed
- Avoid shading parts of the PV modules for a long time, as hot spot phenomenon may arise.
- PV modules should be installed with at least a small tilt in order to avoid dust accumulation.
- PV module label should be checked before making connections in order to determine whether it is a 1,000Vdc or 1,500Vdc
    - It is recommended to use a suitably rated isolator (DC switch) to interrupt the current flow before disconnecting
    - Inverters and circuit breakers should be turned off when a problem arises.

7.3.1.2 Safety

Safety advice is given in the Installation and Operation Manual:

- Not excessive load must be applied on the PV module or in the backsheet as it can break
- Standing on the PV module is not recommended as it can be slippery.
- Touching terminal box or end of output cables should be avoided with bare hands.
- Output cable should not be bended
- Avoid drilling holes in the frame
- Insulation coating frame should not be damaged.
- Screws of the PV module should not be removed.
- Wear appropriate clothes, use appropriate tools and work under appropriate conditions.
- PV modules should be covered with an opaque material during PV module installation and wiring.
- Philadelphia Solar recommends periodic cleaning of the PV modules.

7.3.1.3 Tilt, wiring

A tilt of at least 5º is recommended for PV module maintenance.

PV modules must be connected correctly. In series connection, the positive wire of the PV module must be connected to the negative wire of the next module, whereas in parallel connection, all positive terminals must be connected together and the negative terminal as well. If not corrected correctly, bypass diode can be destroyed.

Grounding, earthing and insulation for DC cables must be implemented according to IEC60364-7-712 and requirements and regulations at the site of installation. The Figure 7-1 shows the grounding method to be implemented using a bolt, nut and washer retaining a ground lug. Conductor type is copper material with green colour with yellow stripe on it.

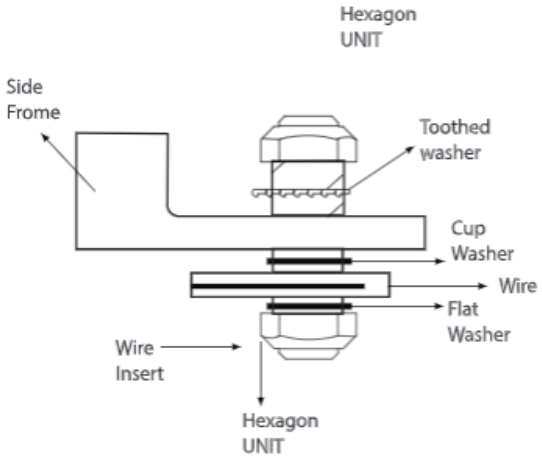


Figure 7-1 Grounding method /5/

7.3.1.4 Mounting

When mounting PV modules on supporting structures some considerations must be taken into account:

- the rigidity of those structures should be verified
- junction box shall be place in the uppermost position to reduce the ingress of water.
- verification that the wind or snow loads that the PV modules will suffer do not exceed the specified limits.
- A clearance of 15cm for 72 type PV modules between the modules frames and the surface of wall or roof should be kept.
- Minimum distance between PV modules should be at least 1.5cm

The analysed PV modules allow the use of two different fixing elements: bolts or clamps.

When using bolts, in the PV module frames, 4 holes can be found used to accommodate dedicated bolts used for attaching the PV modules to the corresponding frames.

However, when using clamps **Error! Reference source not found.**, installer must verify:

- PV module clamps do not contact module's glass
- Clamps do not create shadows on PV modules.
- Clamps do not modify PV module's frame
- The use of, at least, 4 clamps for each PV module

Figure 7-2 Middle and End clamps /5/

7.3.1.5 Unpacking and storage

Some recommendations are stated in /5/ regarding unpacking tasks and storage:

- PV modules must be left in their original box until installation and kept in clean and dry area
- Respect the maximum allowable number of pallets to be piled up.
- Electrical contacts with corrosion should not be installed.
- PV modules should not be placed directly over others.

7.3.2 Guide to Cleaning PV modules

Perform a proper cleaning of the PV modules is a task of high importance because, risk of shock is high when PV modules are wet, dirt and dust can be accumulated on PV modules and can reduce the module performance and can cause hot spot effect. Some recommendations have been provided in the Cleaning guide /11/:

- PV modules should not be cleaned when temperature difference between PV modules and the cleaner is high.
- PV modules with broken glass or exposed wiring should not be cleaned as they may present shock hazard.
- PV modules surface should be cleaned with a soft brush with a recommended pressure less than 5.4kPa.
- Water with high mineral content is not recommended. Philadelphia Solar PV modules are supposed to contain a hydrophobic anti-reflective coating on the glass. Nonabrasive / non-caustic detergent should be used.
- The use of steam or corrosive chemicals are not recommended.

DNV GL recommends including recommendations for the cleaning with robots or other automatic cleaning approaches.

8 REFERENCES

/1/ PV_Catalogues_2018_5-22-2018

/2/ https://www.philadelphia-solar.com/uploads/Philadelphia_Solar_-_References_(Countries).pdf

/3/ Overview about Philadelphia Solar

/4/ Test sample by fraunhofer laboratory

/5/ IEC Installation and Operation Manual 2018

/6/ No 3 LID degradation

/7/ 21243571.001_Report PID Philadelphia Solar_final.pdf

/8/ Philadelphia Solar_Organizational Structure-v1.pdf

/9/ Suppliers certificates.pdf

/10/ Warranty Claim record List 2018.xls

/11/ Guide to cleaning Rev2.xls

/12/ General Safety instructions E and A. compressed.pdf

/13/ PS History Presentation.pdf

/14/ No1_CEC_Report.pdf, point 3 and 7 CEC report.pdf

/15/ 21229802_ Philadelphia Solar_PID_Declaration_2pfg 2387_04.14.pdf

/16/ FI 2017_21183161.006_Factory inspection report_Philadelphia Solar.pdf

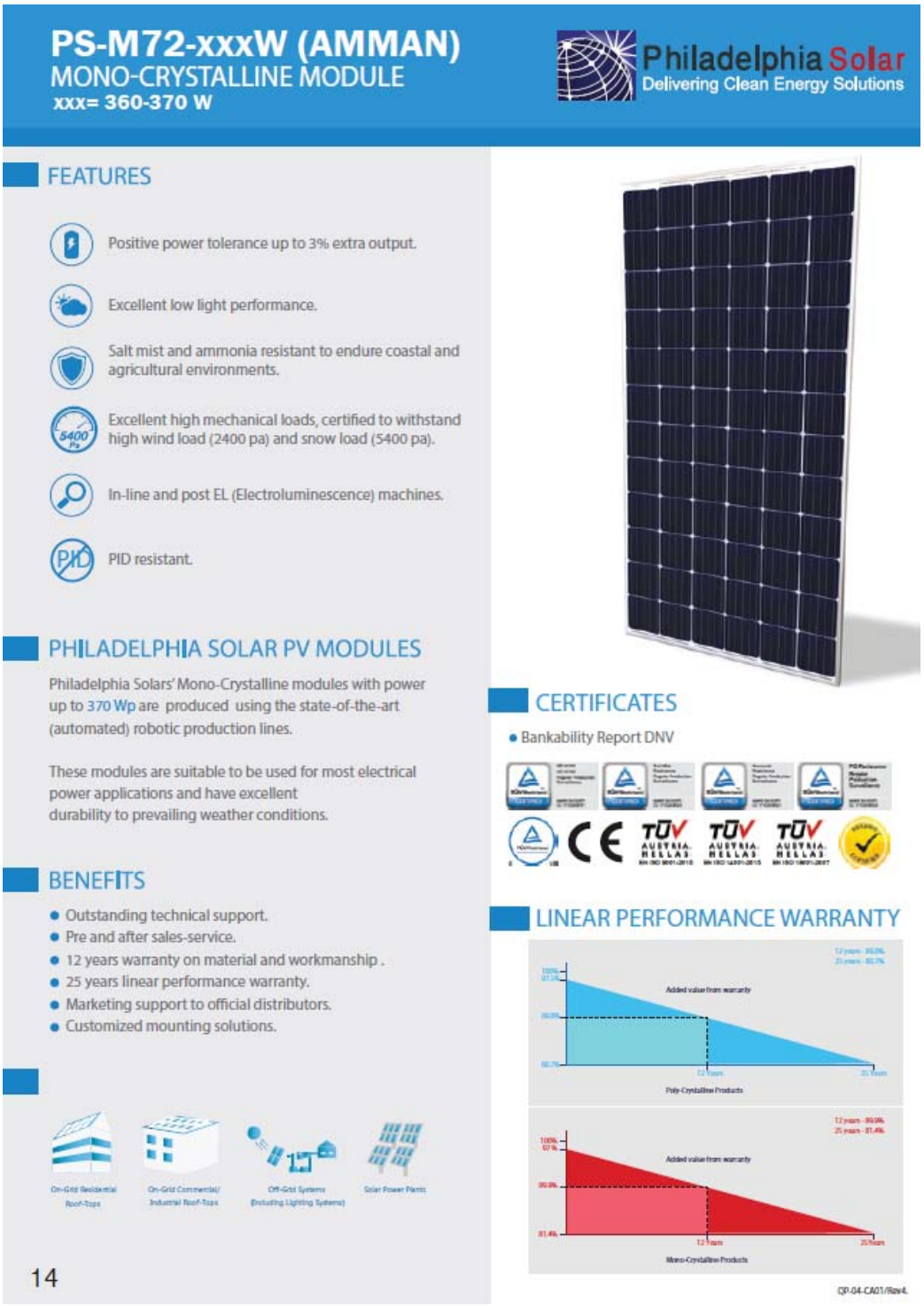
/17/ No2 AR coated Glass Specification.pdf

/18/ No 30 Philadelphia Solar – Cleaning Machine – Test Report.pdf

/19/ No 10 M72 datasheet

APPENDIX A: PRODUCT DATASHEET

1. Datasheet of PS-M72 module



PS-M72-xxxW (AMMAN)
MONO-CRYSTALLINE MODULE
xxx= 360-370 W

Philadelphia Solar
Delivering Clean Energy Solutions

FEATURES

- Positive power tolerance up to 3% extra output.
- Excellent low light performance.
- Salt mist and ammonia resistant to endure coastal and agricultural environments.
- Excellent high mechanical loads, certified to withstand high wind load (2400 pa) and snow load (5400 pa).
- In-line and post EL (Electroluminescence) machines.
- PID resistant.

PHILADELPHIA SOLAR PV MODULES

Philadelphia Solars' Mono-Crystalline modules with power up to 370 Wp are produced using the state-of-the-art (automated) robotic production lines.

These modules are suitable to be used for most electrical power applications and have excellent durability to prevailing weather conditions.

BENEFITS

- Outstanding technical support.
- Pre and after sales-service.
- 12 years warranty on material and workmanship .
- 25 years linear performance warranty.
- Marketing support to official distributors.
- Customized mounting solutions.

On-Grid Residential Roof-Tops | On-Grid Commercial/ Industrial Roof-Tops | Off-Grid Systems (Including Lighting Systems) | Solar Power Plants

14

CERTIFICATES

- Bankability Report DNV

LINEAR PERFORMANCE WARRANTY

Added value from warranty

Poly-Crystalline Products

Added value from warranty

Mono-Crystalline Products

PS-M72-xxxW (AMMAN)

MONO-CRYSTALLINE MODULE

xxx= 360-370 W

Philadelphia Solar
Delivering Clean Energy Solutions

ELECTRICAL CHARACTERISTICS

Characteristics (STC)	360W	365W	370W
Open Circuit Voltage - Voc (V)	47.7	47.8	48.0
Short Circuit Current - Isc (A)	9.86	9.90	10.0
Maximum Power Voltage - Vmpp (V)	38.28	38.50	38.66
Maximum Power Current - Impp (A)	9.43	9.49	9.60
Maximum Power - Pmax (W)	360	365	370
Module Efficiency - η (%)	18.5	18.7	19.0

Values at Standard Test Conditions STC (Air Mass AM1.5, Irradiance 1000W/m², Cell Temperature 25°C). Power measuring tolerance: ± 3%, other measurements tolerances: ± 5%

MATERIAL CHARACTERISTICS

Characteristics	Value
Cells per Module	72
Cell Type	Grade A - Mono-Crystalline Silicon (PERC), 156.75x156.75mm
Front Surface	Anti-Reflective Coated Tempered 3.2mm Glass
Encapsulant	PID Free EVA
Back Cover	Backsheet
Frame	Anodized Aluminum
Junction Box	IP68, 3 Bypass Diodes
Cable and Connector	1.2m Solar Cables with MC4 interconnection
Fire Classification	C

THERMAL CHARACTERISTICS

Characteristics	Value
Voltage Temperature Coefficient (%/°C)	- 0.291
Current Temperature Coefficient (%/°C)	+ 0.033
Power Temperature Coefficient (%/°C)	- 0.393
NOCT (°C)	46 ± 2

PACKAGING

Physical Characteristics	Value
Module Dimensions (mm)	1968 x 990 x 40
Module Weight (kg)	22
Pallet Dimensions (mm)	2010 x 1140 x 1130
Modules per Pallet	25
Container Capacity	**Value**
20 Feet Container	250 Modules
40 Feet High-Cube Container	550 Modules

OPERATING CONDITIONS

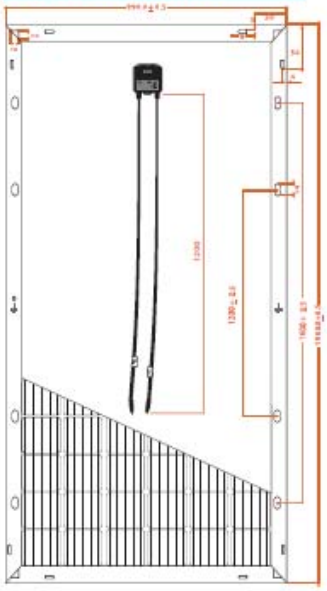
Maximum Sytem Voltage - Vmax (V)	1000/1500
Maximum Series Fuse (A)	15
Operating Temperature Range (°C)	IEC: -40 to + 85 / UL: -40 to + 90

WARRANTY

Product	12 Years
Power Output	12 Years; 89.9 % of Power Output 25 Years; 81.4 % of Power Output

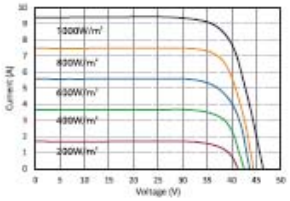
- Datasheet is subjected to changes without prior notice, always obtain the most recent version of the datasheet.
- Caution: For professional use only, the installation and handling of PV modules and cleaning modules require professional skills and should only be performed by qualified professionals, please read the Installation and Operation Manual before using the modules, also Cleaning Guidelines.

PS-M72 Dimensions



* DIMENSIONS ARE IN MM.

IV - CURVE



15

2. Datasheet of PS-P72

PS-P72
POLY-CRYSTALLINE MODULE
320-330W

Philadelphia Solar
Delivering Clean Energy Solutions

FEATURES

- Positive power tolerance up to 3% extra output.
- Excellent low light performance.
- Salt mist and ammonia resistant to endure coastal and agricultural environments.
- Excellent high mechanical loads, certified to withstand high wind load (2400 pa) and snow load (5400 pa).
- In-line and post EL (Electroluminescence) machines.
- PID resistant.

PHILADELPHIA SOLAR PV MODULES

Philadelphia Solars' Poly-Crystalline modules with power up to 330 Wp are produced using the state-of-the-art (automated) robotic production lines.

These modules are suitable to be used for most electrical power applications and have excellent durability to prevailing weather conditions.

BENEFITS

- Outstanding technical support.
- Pre and after sales-service.
- 12 years warranty on material and workmanship .
- 25 years linear performance warranty.
- Marketing support to official distributors.
- Customized mounting solutions.

CERTIFICATES

APPLICATIONS

LINEAR PERFORMANCE WARRANTY

PS-P72
POLY-CRYSTALLINE MODULE
320-330W

Philadelphia Solar
Delivering Clean Energy Solutions

ELECTRICAL CHARACTERISTICS

Characteristics (STC)	320W	325W	330W
Open Circuit Voltage - Voc (V)	45.5	45.7	45.9
Short Circuit Current - Isc (A)	9.10	9.19	9.27
Maximum Power Voltage - Vmpp (V)	37.0	37.2	37.4
Maximum Power Current - Impp (A)	8.65	8.74	8.82
Maximum Power - Pmax (W)	320	325	330
Module Efficiency - η (%)	16.4	16.7	17.0

Values at Standard Test Conditions STC (Air Mass AM1.5, Irradiance 1000W/m², Cell Temperature 25°C). Measuring tolerance: ± 3%

MATERIAL CHARACTERISTICS

Characteristics	Value
Cells per Module	72
Cell Type	Grade A - Multi-Crystalline Silicon, 156.75x156.75mm
Front Surface	Anti-Reflective Coated Tempered 3.2mm Glass
Encapsulant	PID Free EVA
Back Cover	Backsheet
Frame	Anodized Aluminum
Junction Box	IP68, 3 Bypass Diodes
Cable and Connector	1.2m Solar Cables with MC4 interconnection
Fire Classification	C

THERMAL CHARACTERISTICS

Characteristics	Value
Voltage Temperature Coefficient (%/°C)	- 0.33
Current Temperature Coefficient (%/°C)	+ 0.05
Power Temperature Coefficient (%/°C)	- 0.41
NOCT (°C)	46 ± 2

PACKAGING

Physical Characteristics	Value
Module Dimensions (mm)	1968 x 990 x 40
Module Weight (kg)	22
Pallet Dimensions (mm)	2010 x 1140 x 1130
Modules per Pallet	25
Container Capacity	**Value**
20 Feet Container	250 Modules
40 Feet High-Cube Container	550 Modules

OPERATING CONDITIONS

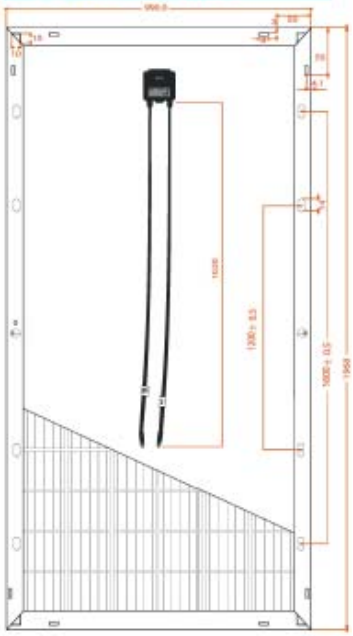
Maximum Sytem Voltage - Vmax (V)	1000
Maximum Series Fuse (A)	15
Operating Temperature Range (°C)	IEC: -40 to + 85 / UL: -40 to + 90

WARRANTY

Product	10 Years
Power Output	12 Years; 90% of Power Output 25 Years; 80% of Power Output

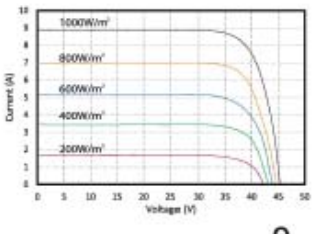
- Datasheet is subjected to changes without prior notice, always obtain the most recent version of the datasheet.
- Caution: For professional use only, the installation and handling of PV modules and cleaning modules require professional skills and should only be performed by qualified professionals, please read the Installation and Operation Manual before using the modules, also Cleaning Guidelines.

PS-P72 Dimensions



● DIMENSIONS ARE IN MM.

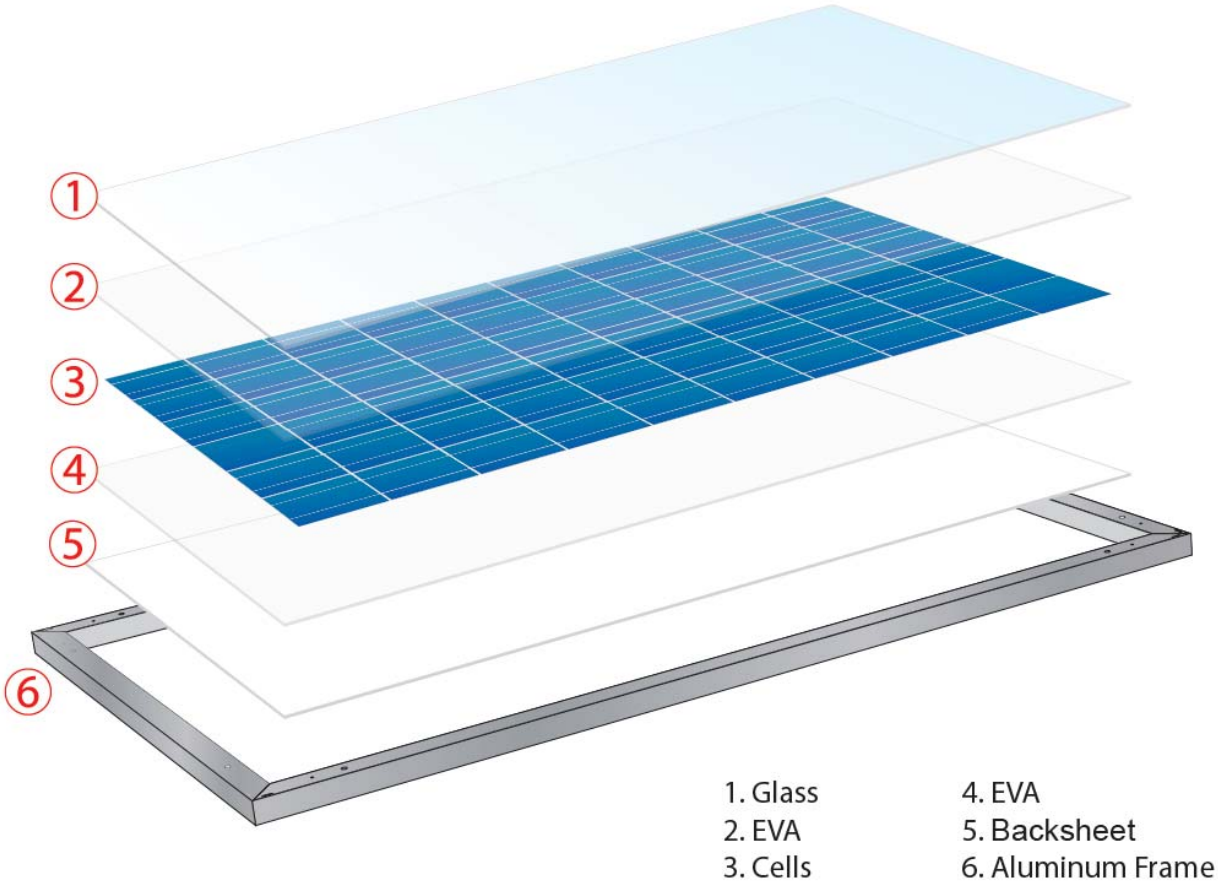
IV - CURVE



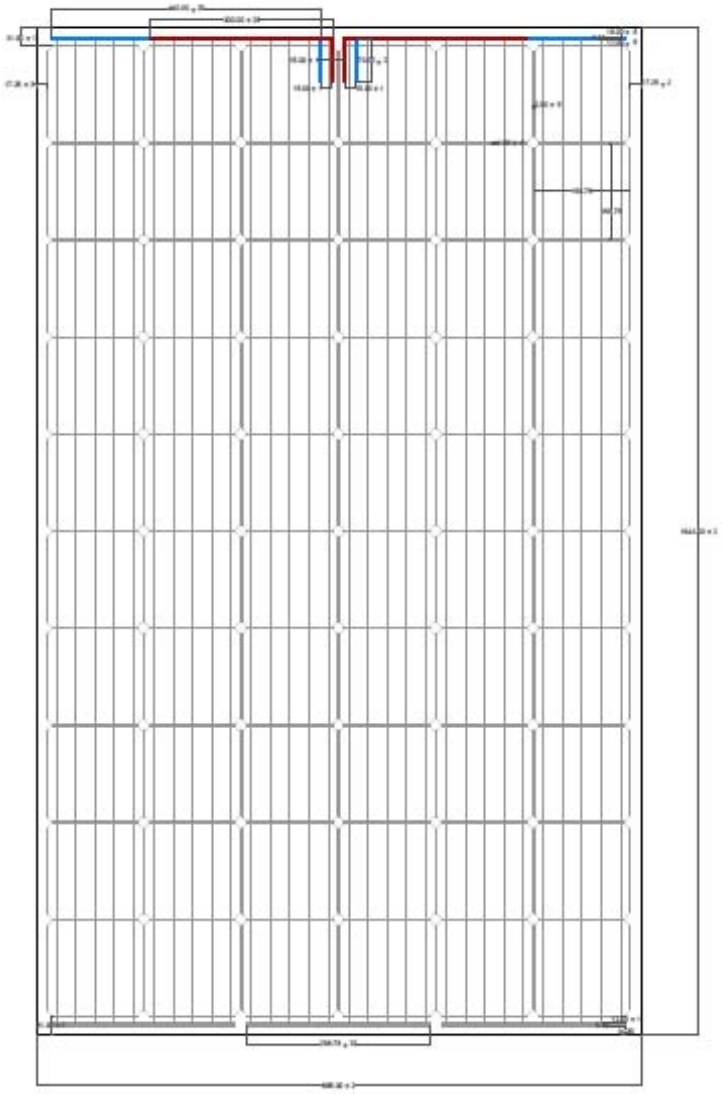
9

APPENDIX B: FRAME DRAWINGS

1. Main Layers of the PV module

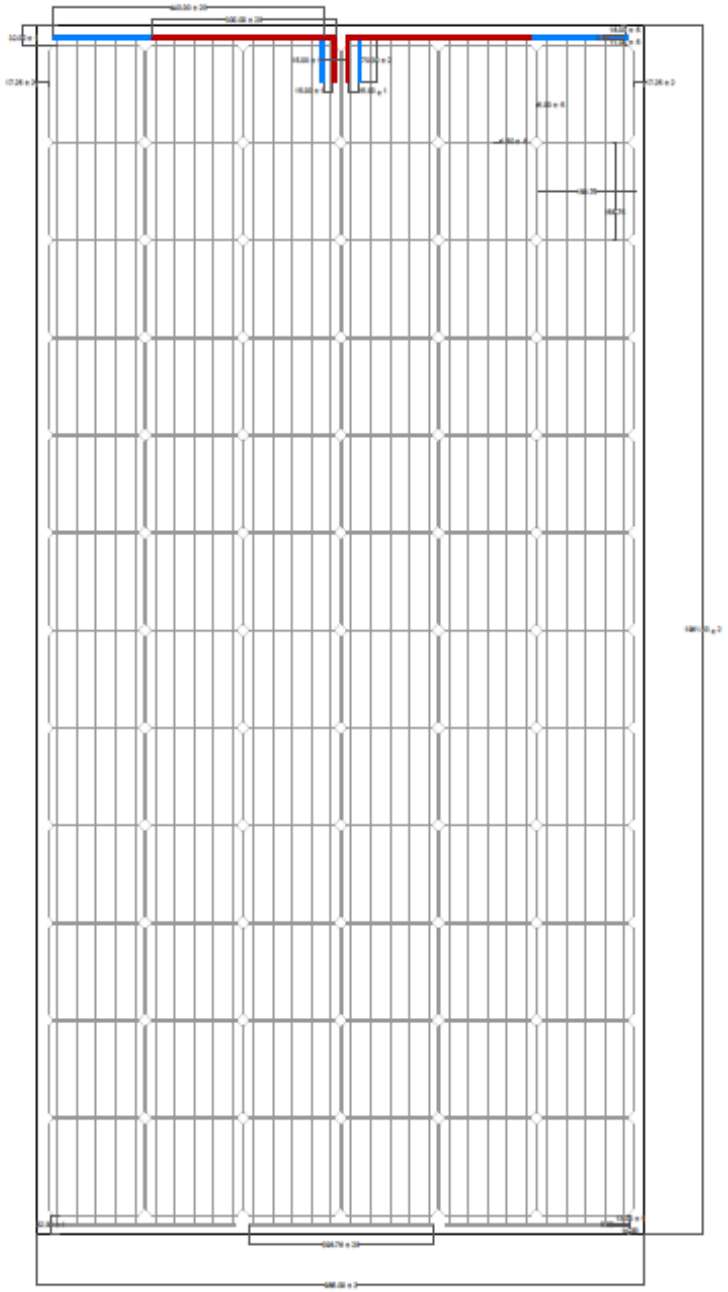


2. Frame drawing of M60 – 5BB



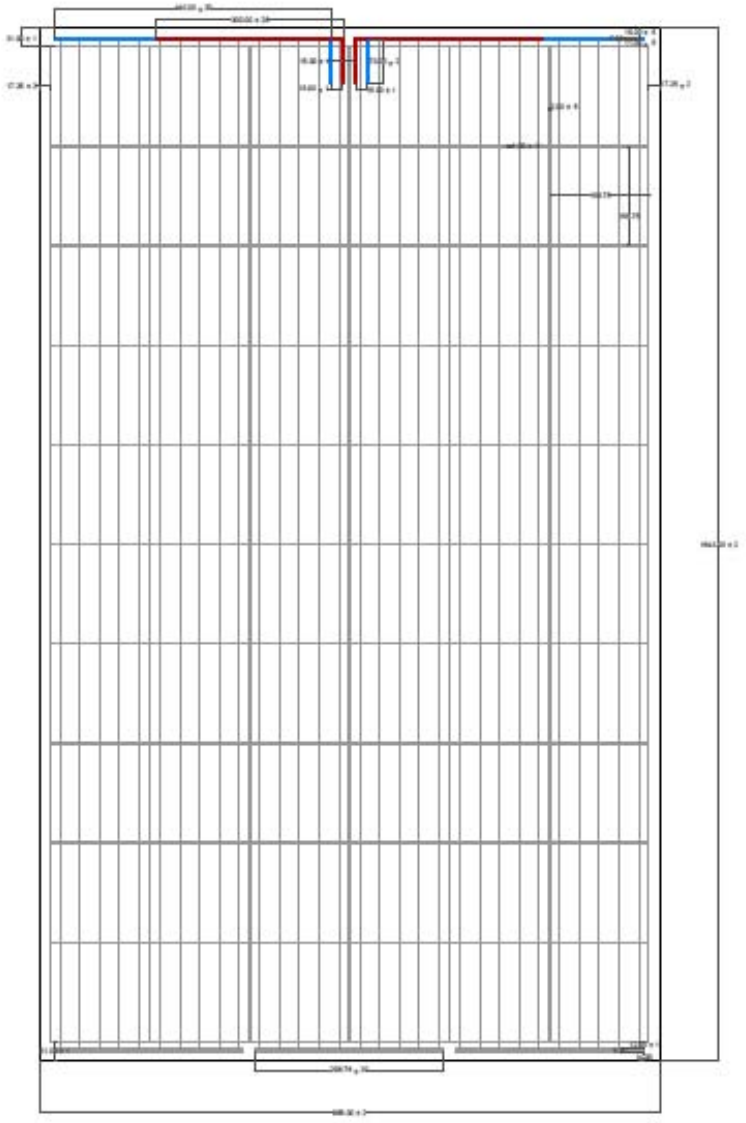
M60 - 5BB

3. Frame drawing of M72 – 5BB



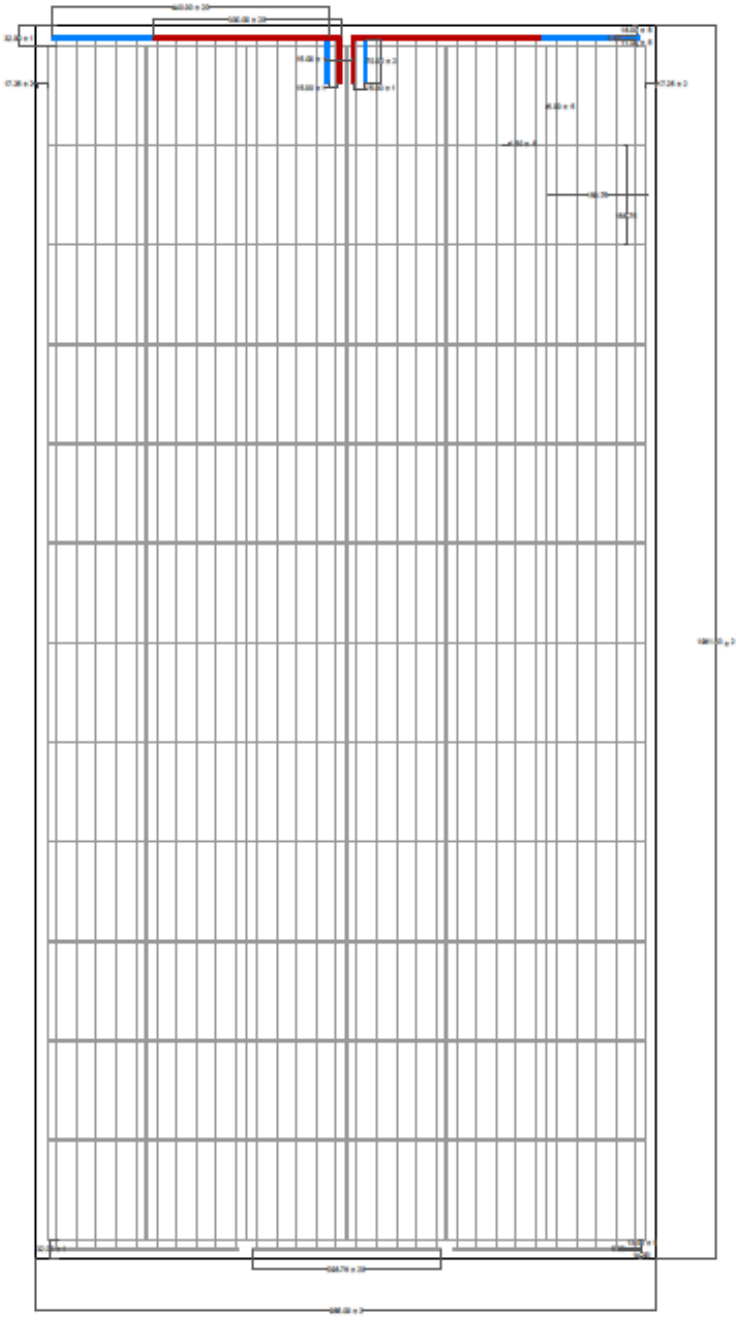
M72 - 5BB

4. Frame drawing of P60 – 5BB



P60 - 5BB

5. Frame drawing of P72 – 5BB



P72 - 5BB

APPENDIX C: LID TEST RESULTS

10.6.1	Performance at STC						
Test method			☒ indoor	☐ outdoor			—
Ambient temperature [°C]			25 ± 2				
Irradiance [W/m²]			1000 ± 50 corrected to 1000				
Module temperature [°C]			25 ± 2 corrected to 25				
Sample No.	P_{max} [W]	V_{mpp} [V]	I_{mpp} [A]	V_{oc} [V]	I_{sc} [A]	FF [%]	
HV2018001861	319.3	37.26	8.57	45.73	9.07	77.0	
HV2018001862	351.6	38.76	9.07	47.54	9.52	77.7	
HV2018002027	291.8	32.03	9.11	39.72	9.62	76.4	
HV2018002028	265.1	31.05	8.54	38.05	9.04	77.1	
Supplementary information: -							

10.7	Performance at low irradiance						
Test method			☒ indoor	☐ outdoor			—
Ambient temperature [°C]			25 ± 2				
Irradiance [W/m²]			200 ± 20 corrected to 200				
Module temperature [°C]			25 ± 2 corrected to 25				
Sample No.	P_{max} [W]	V_{mpp} [V]	I_{mpp} [A]	V_{oc} [V]	I_{sc} [A]	FF [%]	
HV2018001861	55.0	35.73	1.54	41.86	1.63	80.5	
HV2018001862	63.9	38.13	1.67	44.16	1.76	82.1	
HV2018002027	58.0	31.44	1.85	36.73	1.94	81.6	
HV2018002028	50.8	29.97	1.70	35.30	1.80	80.1	
Supplementary information: -							

APPENDIX D: AR GLASS PROPERTIES

5.3 AR Coating glass

Light Transmittance (380~1100nm)	≥93.5% (For both 3.2mm and 4.0mm, according to ISO 9050:2003)
Pencil Hardness	≥ 4H
Coating Addhesion	Class 0
Anti-acid	Transmittance Loss less than 1%
Salt Spray	Transmittance Loss less than 1%
Damp Heat test (double 85)	Moudle Max Power Loss less than 5%
Exposure to UV Light	Moudle Max Power Loss less than 5%

Note: For AR Coating Glass, for the other quality properties see item 5.1 & 5.2.

APPENDIX E: FACTORY INSTPECTION PICTURES

1. Ribbon cutting machine developed by Philadelphia Solar. Ribbon manufacturer: Ulbrich from Austria. Composition Sn60Pb40 □m peak.

2. Ribbon bending manual

3. EVA cutting process-semi-manual. EVA Manufacturer: Wahaj from Saudi Arabia. Thickness of the EVA sheet: 0.50 mm provided as 0.98m x 160 m.

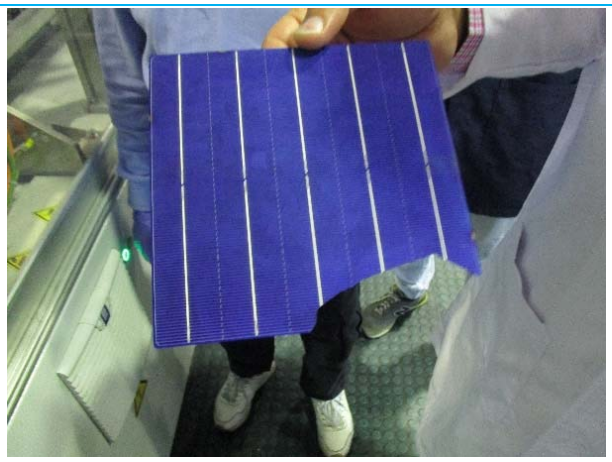
4. Portable temperature sensor located in several areas of the manufacturing facility. Stored data are uploading to a central server on a daily basis

5. Glass low iron tempered with AR coating, 3.2mm x 1963mm x 985 mm. Glass manufacturer: Xinyi Solar, Malaysia

6. Glass loading machine

7. Solar cells manufactured by Risun (156.75mm and 4.59 Wp) classified for the Somont cell connecting machine (stringing).

8. Example of broken cell detected by CC camera at the Somont cell connecting machine. Philadelphia Solar has informed that a percentage of 0.6% of cells are found broken which is below the agreed percentage to initiate a claiming procedure with their manufacturers.

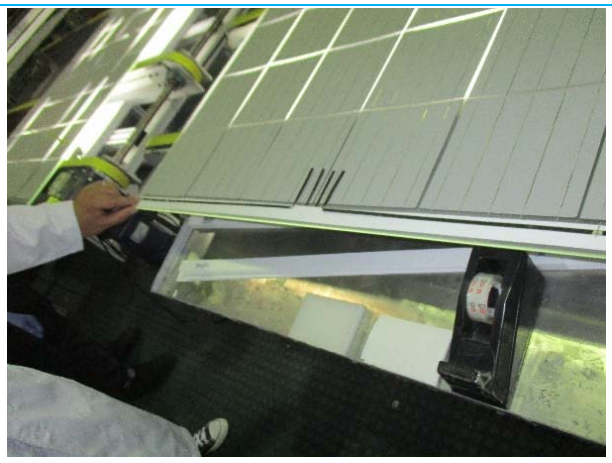


9. View of one of the lines of the Somont cell connecting machine (stringing) with a capacity up to 2,800 cells per hour. A new line will have an additional capacity of 2,500-2,600 cells/h as per Philadelphia solar information.

10. Visual inspection after string automatic lay-up. The Somont lay-up machine has a capacity of 43 mod/hour (72 cells module)

11. Module prepared for bussing ribbon manual soldering process. A yellow post-it is used for traceability of the stringing line used in order to give feedback in the case of systematic bad stringing work. Philadelphia Solar has informed that this manual system is going to be replace by an automatic one.

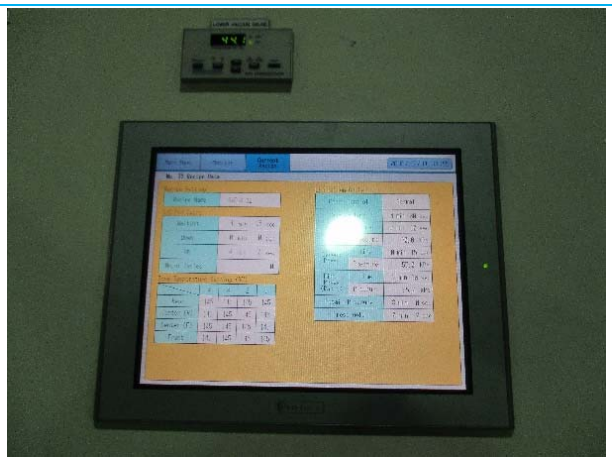
12. Bussing connectors for manual soldering. Worker hands are grounded to avoid unwanted electrostatic currents.



13. Electroluminescence of 100% PV modules prior to the laminator. Time used 41s that can be reduced up to 30s per module if new software is applied based on information from Philadelphia Solar. In the case of any cell problems, modules are manually processed to replace defective cells and EL tested again.

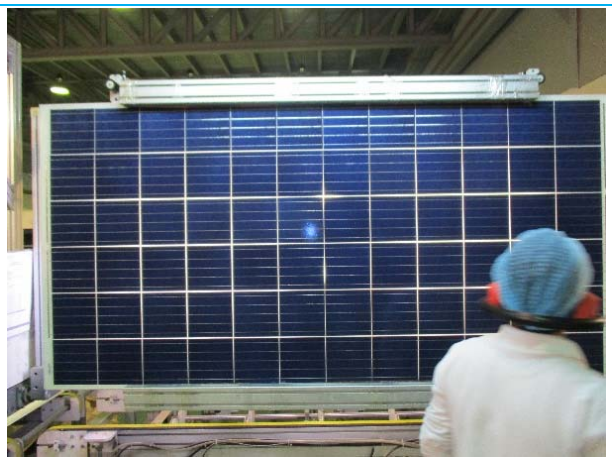
14. Four modules with back sheet ready for the laminator. Lamination process takes approximately 15 minutes at 145 ºC with three lines in parallel giving a total capacity of 48 mod/h.

15. Current lamination recipe with vacuum time, first, second and final press ending with a retain press. The laminator temperature is controlled at 4 points at the rear and front of the modules.

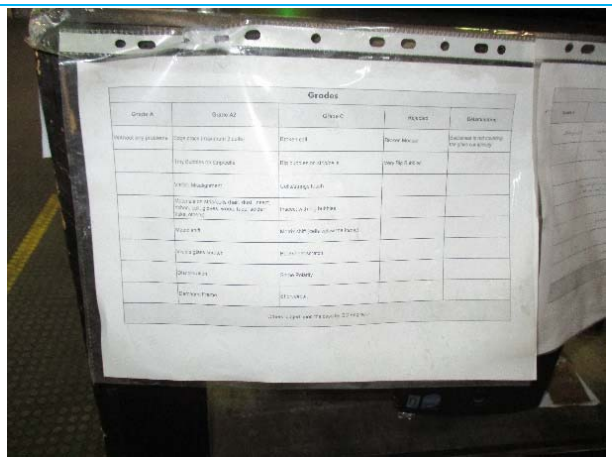


16. Detail of the laminator before closing to start a new lamination process.

17. Visual inspection after lamination just before framing. Inspection capacity of 90 modules/hour (40 seconds per module).



18. Grading of modules: grade A, grade A2, grade C and rejected module as per Philadelphia Solar working instruction.

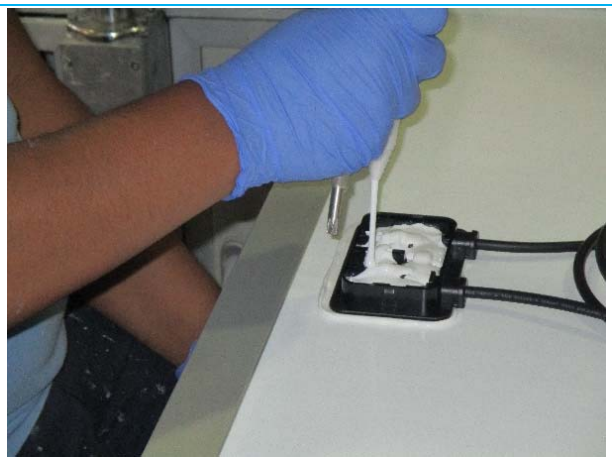


19. Semi-manual framing process with a capacity up to 60 modules/hour. Aluminum provider: Davin. Quality: silver anodized aluminum.

20. View of the junction box with diodes already soldered provided by JMTHY from China.

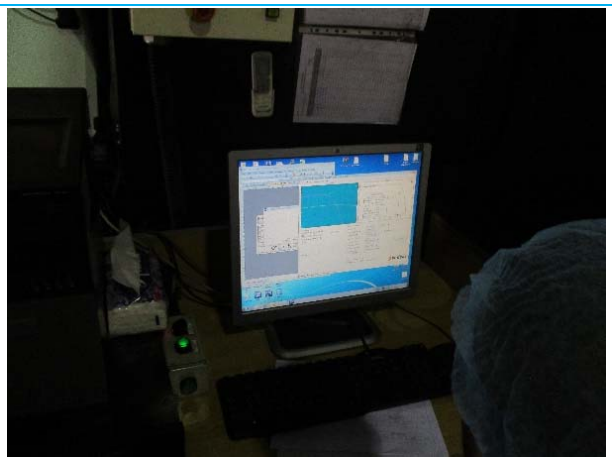
21. Silicone dispenser at the aluminum sides before framing. Silicone product HT906Z provided by Huitian from China.

22. Pouring silicone on the junction box after fixing and soldering the strings to it.



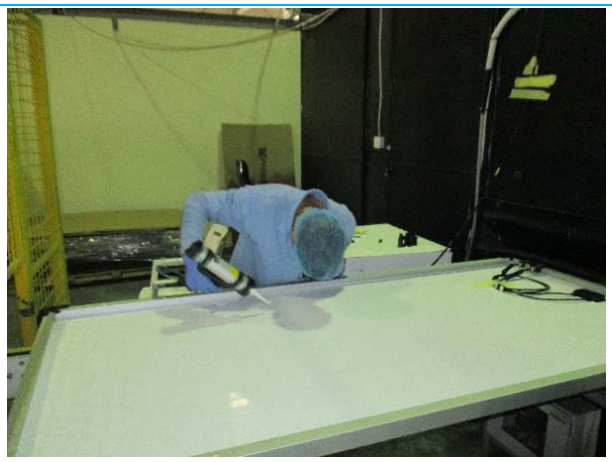
23. Storing of modules for silicone drying during 8h. Modules are grouped in 25 pcs per pile which matched the number of modules per pallet.

24. Flash tester by Endeas with a capacity of 78 modules/h. Every 100,000 hours of the bulb an uniformity test has to be undertaken.

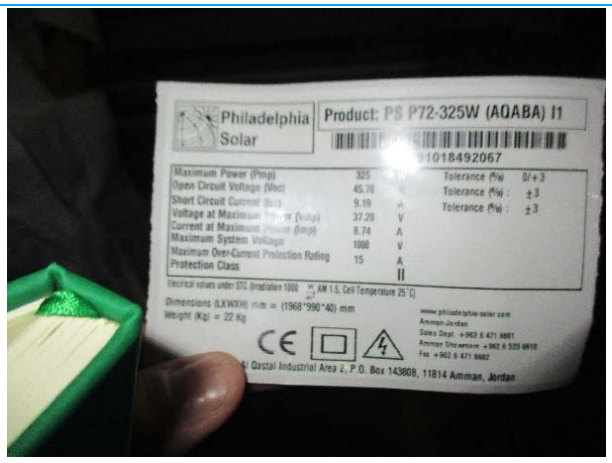


25. Dark storage of primary and secondary calibration modules for the Flash Tester.

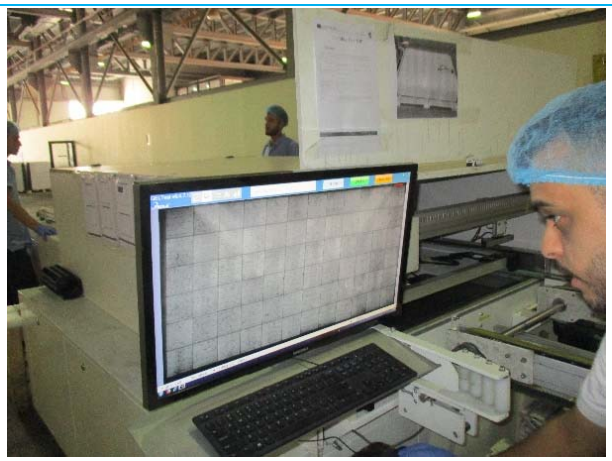
26. Silicone pouring before the high potential test just after the Flash Test.



27. Printing out of module labels to be attached to the back sheet. A second serial number label is located inside the module between the glass and the EVA layer.



28. Final EL testing to 100% of modules.



29. Packing area.

30. Detail of second serial number label

31. Piling of two pallets awaiting for uploading to trucks for transport.

32. Card box pallet ready to shipment

APPENDIX F: STORAGE CONDITIONS

Quality Department.					
Storage Conditions					
Material	Supplier	Storage Conductions			Notes
		Temp	Humidity	Shelf life	
PV solar panels	Philadelphia Solar	max 40C°	less than 85%		
Solar cells	All Suppliers.	Room Temp		to be used within one year	Away from sunlight , dust areas.
Backsheet	Ferrbatt	max 40C°	max 85%	2 years if stored in those mentioned conditions.	After the material is removed from filmcutter original packing , we recommend to use it within 6 months from unpacking date.
	Agfa Uniqoat	5-35C°	max 80%	1 year	
	Cybrid	max 80C°	max 80%	1 year	
EVA	SVECK	Max 30 C°	max 60%	6 months.	Must be stored in dry and cool environment. , EVA should be stored and sealed after cutting to avoid dust and pollution.
	Wahaj	Max 30 C°	max 60%	9 months.	
Ribbons	BRUKER	Max 50 C°	60%	18 months	Avoid storage in humid conditions, should be stored indoors, and the ribbon should be used in 18 months, if you do not open it , please keep the temp less than 50C° , and the humidity less than 60% . If you opened it, please keep the Temp less than 40C° and the humidity less than 55% and the user must use the rest of ribbon in next 3 months.
	Ulbrich	Max 50 C°	60%	12 months	
Silicone (Tubes, Drums)	Hultian	(8 -30)C°	50%	12 months	Under dry and cool place.
Silicone potting A and B	Hultian	(8 - 30)C°	50%	6 months	Under dry and cool place.
Junction Box	Jiaming				Under dry and cool place.
Tempered Glass	XINYI Solar Glass				Under dry and cool place, away from water.
Flux	Kester.	10-25C°		12 months	keep away from heat, sparks and open flame. Avoid spilling skin and eye contact.
	Alpha	0-30C°		12 months	protect from direct sunlight in a dry , cool ,and well-ventilated area, away from in-compatible materials. separate from oxidizing materials, keep container tightly closed and sealed until ready for use.
Aluminium Frame	Devin Solar	N/A	N/A	N/A	Under dry and cool place, away from water.
Eck Pack	Cardboard Packaging-	N/A	N/A	N/A	Room Temp.
Label	WS Packaging.	Room temp	50%	50%	One year when stored at 72°F (22C°) at 50% RH
Transferred Ink Ribbons	WS Packaging.	N/A	N/A	N/A	Room Temp.
QF-03-P02/Rev8					

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter, and greener.