Summary report for ACT Government

2107-ACT-001

Tuesday, September 5, 2023

Client
Chief Minister, Treasury and Economic Development Directorate (CMTEDD)
ACT Government

Consultant
Michelle McCann

Client reference:
Summary Report, Rounds 1 and 2
Contract Number: EP3222118

Report release:
Release 2

Making quality visible.

Michelle McCann +61 401 574 999
Lawrence McIntosh +61 400 476 759

ABN 18 166 787 800
www.pv-lab.com.au

Approval

Report approved by Michelle McCann
Date: Tuesday, 5 September 2023

Michelle McCann
Partner and Director

Table of contents

Introduction

The ACT Government engaged PV Lab Australia to test a sample of solar panels on the market in Canberra. This report is a summary of key findings and test results. It is supported by 42 detailed reports, 42 summary reports, a PID report and a technical summary report for each of the two rounds.

The purpose of the testing was to conduct independent testing of solar PV panels installed under the Sustainable Household Scheme (SHS) to help address two problems:

1) The quality of solar panels in the domestic market in Australia is variable.
2) Consumers and installers do not have enough appropriate information to make the best decision regarding the quality of their own solar panel purchases.

Sample sizes and test plan

A total of 121 solar panels were borrowed by PV Lab Australia directly from the market. Selection of panel types was informed by the ACT Government, based on their high-use in the Sustainable Household Scheme. Choice of actual panels was blind, in the sense that neither the manufacturer nor PV Lab Australia had any prior information regarding which panels would be used for testing. The panels represented 42 different models from 14 different brands.

The list below details the 5 different tests done, together with a very brief description of the purpose of the test.

- 121 visual inspections (checks for defects that may cause a risk of reliability loss),
- 121 standard test condition (STC) power tests (check of solar panel power output),
- 121 electroluminescence (EL) tests (check of inherent solar panel quality and transport / handling damage)
- 121 wet leakage tests (safety test) and
- 12 potential induced degradation tests (accelerated aging test).

A short description of each of these tests is included in Appendix A. As detailed in the appendix, the tests are defined by international standards.

The solar panels were tested at the PV Lab facility in Mitchell, Canberra, Australian Capital Territory, between November 2022 and May 2023.

Summary of Results

Table 1 shows a summary of the number of panels that passed (and failed) each test. The pass / fail criteria for the different tests is defined in the relevant international standard, except in the case of electroluminescence where no international standard exists. In this case, PV Lab Australia internal criteria were applied. These are based on pass/fail criteria that are widely used around the globe.

Table 1: Number of panels tested and number that passed and failed each test

Test	Number of panels tested	Number of panels that passed	Number of panels that failed
Visual Inspection	121	121	-
STC Power	121	121	-
Electroluminescence	121	90	31
Wet Leakage	121	121	-
Potential Induced Degradation	12	12	-

The results of the tests were used to give an overall score out of 100 to each of the different solar panel models. These are summarized in the rating system below. In some cases, more than one model of a brand was tested in each round. The reason for this was generally a reflection of the higher market share held by that brand.

Table 2: Rating results for different brands

Brand	Models tested in round 1 / round 2	Round 1 Testing Score / 100)	Round 2 Testing (Score / 100)
Canadian Solar	1 / 1	76	92
Chint Solar	1 / 1	95	88
EGing PV Technology	0 / 1		77
Hyundai Energy	1 / 1	100	79
JA Solar	1 / 1	78	89
Jinko Solar	3 / 4	86	89
Phono Solar	1 / 1	99	96
Q cells	2 / 4	72	74
Risen Energy	3 / 1	95	86
SolarEdge	2 / 2	89	96
SunPower	1 / 2	99	99
Talesun Solar	0 / 1		75
Tindo	1 / 0	95	
Trina Solar	3 / 2	85	85

Table key:

Overall score /100	Description
< 50	This batch encountered at least one significant problem, would not recommend
50-85	Some issues encountered, proceed with caution
>85	No Issues Encountered

Example reading of the table:

Jinko Solar had 3 models tested in round 1 and 4 models tested in round 2. The models scored quite well, on average, 86 and 89 for rounds 1 and 2.

From this grading system, we can draw some conclusions. It should be noted that a sample size of only two rounds may not be a good indicator of future performance. The main conclusions are:

- Differentiation between brands available on the ACT market is possible;
- Approximately half of the tested brands demonstrated a consistently high score over the two rounds;
- One brand demonstrated a consistently moderate score over the two rounds and
- Two of the tested brands showed variable quality across just two rounds.

Detailed Results

Visual Inspection

Why do this Test?

The purpose of the visual inspection is to check for defects that may cause a risk of reliability loss.

Procedure

See Appendix A

The Facts

All solar panels bar one passed the visual inspection. The failed solar panel failed due to a suspected puncture in the backsheet, possibly a result of transport or handling damage.

The visual inspection revealed minor features (unlikely to impact on future performance) on most (38 out of 42) of the tested models. Features were a mix of those likely caused by the manufacturer, for example inconsistent sealant near the backsheet, and those likely to be a result of handling, for example scratches on the frame and/or front glass and dents in the backsheet.

The Good News

Solar panels in the ACT market overwhelmingly delivered with no visual defects that could be considered likely to cause a risk of reliability loss.

The Bad News

The suspected backsheet puncture is serious as it presents a possible safety risk, which is concerning. The module did pass the wet leakage test (which is the relevant safety test), indicating that it is unlikely to be unsafe at present.

Standard Test Conditions (STC) Power Test

Why do this Test?

Standard Test Condition (STC) power measurement determines the output of the panel under standard test conditions (temperature of 25°C, spectrum of AM1.5G and illumination intensity of 1,000 W/m^2) compared to the manufacturer's stated output or label rating. Simply put, this test provides a measure of what was delivered compared with what was promised.

For solar panels imported for a solar farm, power performance can vary widely. Performance of less than 3% under nameplate would be considered unacceptable and performance above labelled power is unusual.

Procedure

See Appendix A

The Facts

STC power measurement showed that all but two models performed adequately. Note that reported STC power measurements are an average of solar panels tested for that model.

12 of the 42 models were at the manufacturers labelled power*

7 of the 42 models were above labelled power.

23 of the 42 models were under power on average but, if the laboratory measurement uncertainty is included, all but two of these were at stated power, the two outliers were almost 4% under.

*Manufactures state a power range or 'tolerance': usually a range of 0 to +5W.

The Good News

Consumers are generally getting what they paid for in terms of power on day one. 7 of the 42 tested models were over power (generally producing more than 5W above nameplate) on average.

The Bad News

Some modules are underperforming and two models were almost 4% under nameplate.

Electroluminescence

Why do this Test?

Electroluminescence (EL) detects damages in the solar panel that have occurred at a cell level. This includes, for example, microcracks which may occur on transport to site and are normally invisible to the naked eye.

Procedure

See Appendix A

The Facts

The results of the electroluminescence assessment on a per panel basis are summarised in Table 3.

Table 3: Electroluminescence assessment results on a per panel basis.

Total panels tested	**121**
Panels that passed electroluminescence assessment	90 (=74% of total tested)
Panels that failed electroluminescence assessment	31 (=26% of total tested)

The results of the electroluminescence assessment on a per model basis are summarised in Table 4.

Table 4: Electroluminescence assessment results on a per panel basis.

Total models tested	**42**
Good or excellent quality	29 (=69% of total tested)
Poor or moderate quality	13 (=31% of total tested)
Models with at least one panel that failed	23 (of these, 14 were likely due to transport damage and/or poor handling and the remainder (9) were likely due to defects that would have been present at point of manufacture).

For panels imported for a solar farm, we would expect failures due to transport or handling damage to be less than 3% and failures due to defects present at point of manufacture to be close to 0%.

The Good News

There are some high-quality solar panels available on the ACT market. 69% of the tested models were assessed to be of good or excellent as-manufactured quality.

The Bad News

Some very poor-quality solar panels from the ACT market were also seen and these present a risk of lower power output over their lifetime and are a low likelihood, but high consequence, safety concern.

There are two different, underlying reasons for the poor quality:

1) Transport or handling damage that is likely to have occurred after the solar panels left the manufacturer and
2) Defects that would have been present at point of manufacture.

In total 26% of the tested solar panels failed the electroluminescence inspection. This number should be under 3%.

Example Images

The figure below shows (left) a poor quality solar panel and (right) an excellent quality solar panel. The dark patches in the solar panel on the left are primarily defects that would have been present at point of manufacture. They may cause shunts and potentially hot spots in the solar panel in the future and are a likely to result in underperformance. They also present a low risk safety concern.

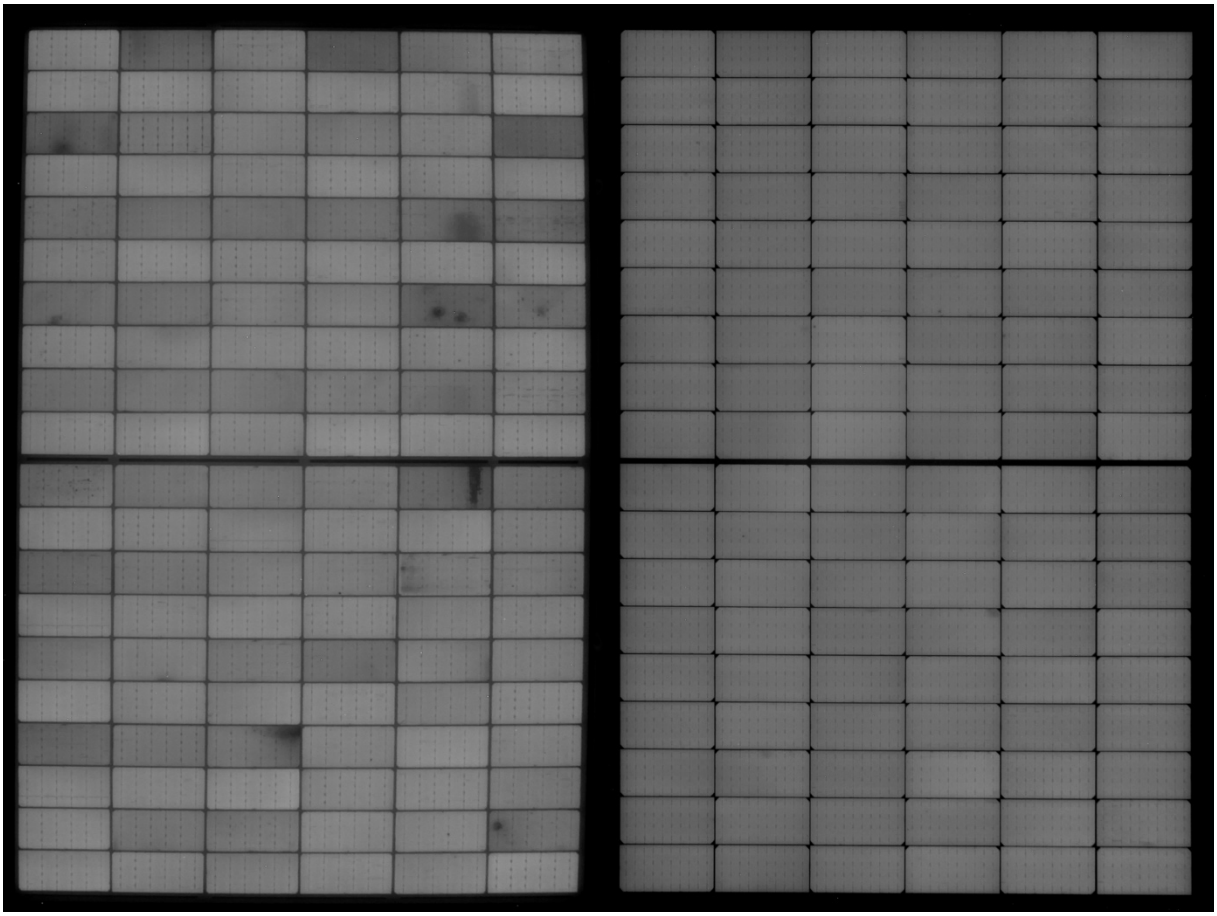

Figure 1: (Left) A very poor quality solar panel and (right) an excellent quality solar panel.

Wet Leakage

Why do this Test?

The wet-leakage test is relevant from a safety viewpoint and determines whether parts of the solar panel that should be electrically live (the cells) have any electrical pathway to parts of the solar panel that should not be live (anything that can be touched).

Procedure

See Appendix A

The Facts

All panels passed the wet leakage test.

The Good News

The wet leakage test is a safety test. It is excellent news to find that the sample of panels taken from the ACT market found no safety concerns.

Figure 2: Wet Leakage testing bath at PV Lab

Potential Induced Degradation

Why do this Test?

Potential induced Degradation (PID) is a failure mechanism for solar panels. Solar panels that exhibit PID can have a profoundly reduced output power, with complete failure possible. Many module manufacturers offer 'PID-free' modules, but not all modules marked 'PID-free' are free from the effects of PID. Testing for PID is a mandatory requirement for most solar farms built globally, but, like the other tests done in this work, there is currently no routine PID testing done for the solar panels used in the domestic market anywhere in Australia.

The PID test is also an accelerated aging test as it stresses solar panels with high temperatures, high humidity and high voltages.

Procedure

See Appendix A

The Facts - Background

A total of 12 of the Round 2 solar panels were chosen to undergo the PID test. The 12 modules covered 11 different manufacturers and the models were current and sourced directly from the Australian market.

The PID test is shown visually in the graphic below:

Figure 3: PID testing regime

To pass the PID tests, solar panels must pass the post testing, including a drop in STC power of less than 5%.

The Facts - Results

None of the tested solar panels failed PID testing.

- All 12 solar panels passed pre to post PID testing STC power measurement.
  - All solar panels had a loss in power after PID testing. The average power loss across all 12 solar panels was 1.3%.
  - The best performing solar panel was the Phono Solar Technology Co Ltd, which dropped only 0.7% (2.8W) after PID stress testing.
  - The largest drop in power was 2.7% (11W) for the Changzhou EGing Photovoltaic Technology Co Ltd solar panel.
- All 12 solar panels passed pre to post PID testing Electroluminescence analysis, although the degradation seen in the Changzhou EGing Photovoltaic Technology was almost sufficient to result in failure.
  - Four solar panels developed a likely shunt after PID stress testing (Canadian Solar, Jinko Solar, SunPower Corporation and Hanwha QCells Australia).
  - Solar panels from three manufactures exhibited degradation of cells along the edge of the panel (Trina Solar (mild), Hyundai Energy Solutions (moderate) and Changzhou EGing Photovoltaic Technology (high)).
- None of the solar panels failed pre to post PID testing Visual Inspection.
  - Minor features were noted in five of the solar panels, mostly some corrosion on the frame.
- All 12 solar panels passed post PID stress test wet leakage testing.

The Good News

All tested solar panel models ultimately passed the PID test indicating a high likelihood of good longevity of solar panels in the ACT market.

The Bad News

One of the tested solar panel models was very close to failure and, in a sample size of only 12, this does potentially represent a significant portion of the market. It is not possible to say how this statistic would translate to larger sample sizes, but for solar panels imported for a solar farm, we would expect zero failures.

Suggestions for future work

In the course of this work, we made some learnings that could be applied in the future.

Importance of an ongoing testing program

The conclusion of the project clearly showed:

- Differences between different brands and
- Variability within individual brands.

These conclusions support the original hypothesis, namely that the quality of solar panels in the domestic market is variable and the available information is not sufficient for consumers to make the most informed decision on their solar panel purchase.

It would seem imperative that any government supported project also took steps to make this information more widely available to consumers.

PID of all solar panel brands

To compare between different solar panel brands more fairly, inclusion of the PID test for all models should be considered.

Panel sourcing

Panel sourcing was more difficult (time consuming) than was anticipated.

It was also our observation that the vendors were not particularly motivated by any value in the testing that they were getting. We imagine that this would change in the future once results are made available on the public-facing website. We also think it could be a useful exercise to interview vendors that loaned solar panels and see if they derived any value from the provided reports.

Transport damage

The panels showed a much higher level of handling damage than expected. This is likely an issue with many of the installers across the ACT and a future program to address this would likely be worthwhile since this damage is not observable to the naked eye.

Overall quality under Electroluminescence

We have the impression that the panels that we saw in this work were substantially less 'clean' under electroluminescence imaging than comparable panels used in the larger farm market. Normally we would not expect any panels to fail electroluminescence imaging, except as a result of transport-related micro-cracks, yet we saw numerous failures due to other reasons in this work. If true, this would be a notable find as it would indicate that many lower quality panels are being sent into the residential market. Further investigation would be required to determine if this is a valid impression and to understand any underlying reasons.

Test logistics

Testing details

The testing was done at the PV Lab Australia testing facility in Mitchell, Canberra, Australian Capital Territory between February and May 2023.

Most of the solar panels were supplied by ACT installers.

Selection of solar panels

The sampling methodology used is set out in the presentation titled *Milestone 2: Testing design, approach, and methodology,* which was presented to the Sustainable Household Scheme team of EPSD on 9th August, 2022.

It was recommended that a sample of 60 panels, representing 20 brands be tested in each of rounds 1 and 2 with a basic set of four tests and a further 12 panels to receive climate chamber (accelerated aging) tests.

Solar panel type

Table 5 shows the number of panels purchased by manufacturer and model number. Also shown is P_{mpp} (W) or maximum power point as stated by the manufacturer, in Watts. This is also often called the nameplate rating. See Appendix B for a list of individual test reports for each of the models.

Table 5: Number of panels purchased by manufacturer and model number.

		loaned	*P_{mpp} (W)*
Hanwha Q CELLS (Qidong) Co Ltd	Q.MAXX-G3 390	3	
Hanwha Q CELLS (Qidong) Co Ltd	Q.PEAK DUO ML-G10+415	3	415
	SPR-P3-370-BLK-E3-AC		
Jinko Solar Co Ltd	JKM370N-6TL3	3	370
	JKM440M-6TL4		
Risen Energy Co Ltd	RSM132-6-370M	3	370
	TSM-390DE09.08		
Risen Energy Co Ltd	RSM40-8-390M	3	390
	CS3L-370MS (IEC1000V)		
Chint Solar Zhejiang Co Ltd	CHSM60M-HC-370	3	370
	TSM-400DE09.08		
Risen Energy Co Ltd	RSM40-8-390MB	3	390
	TSM-370DD08M.08(II)		
SolarEdge Technologies Ltd	SPV370-R60JWMG	3	370
	JAM60S20-390/MR/1000V	3	390

Manufacturer	*Model number*	*Panels loaned*	P_{mpp} (W)
Jinko Solar Co Ltd	JKM370M-60HLM	3	370
Hyundai Energy Solutions Co Ltd	HiE-S390UF	3	370
SolarEdge Technologies Ltd	SPV370-R60DWMG	3	370
Tindo Operations Co Pty Ltd	Karra-410G2H	3	410
Phono Solar Technology Co Ltd	PS390M7GFH-18/VH	1	390
Trina Solar Co Ltd	TSM-415NEG9.28	3	415
Trina Solar Co Ltd	TSM-415DE09R.08	3	415
Canadian Solar Inc	CS6R-415MS (IEC1000V)	3	415
Risen Energy Co Ltd	RSM40-8-415M	3	415
Jinko Solar Co Ltd	JKM475N-60HL4-V	3	475
Jinko Solar Co Ltd	JKM440M-6TL4	3	440
Phono Solar Technology Co Ltd	PS390M7GFH-18/VH	3	390
HANWHA Q CELLS AUSTRALIA PTY LTD	Q.MAXX-G3 390	3	390
Chint Solar Zhejiang Co Ltd	CHSM60M-HC-370	3	370
SunPower Corporation	SPR-P3-370-BLK	3	370
SolarEdge Technologies Ltd	SPV370-R60JWMG	3	370
Hanwha Q CELLS GmbH	Q.PEAK DUO-G6+ 350	3	350
SolarEdge Technologies Ltd	SPV365-R60LWMG	3	365
Hyundai Energy Solutions Co Ltd	HiE-S390UF	2	390
Hanwha Q CELLS GmbH	Q.PEAK DUO ML-G10+ 415	3	415
HANWHA Q CELLS AUSTRALIA PTY LTD	Q.MAXX-G4+ 410	3	410
SunPower Corporation	SPR-P6-410-BLK	3	410
Changzhou EGing Photovoltaic Technology Co Ltd	EG-415M54-HLV	3	415
Shanghai JA Solar Technology Co Ltd	JAM60S20-370/MR/1000V	2	370
Jinko Solar Co Ltd	JKM370M-60HLM	3	370
Jinko Solar Co Ltd	JKM370M-66H	3	370
Suzhou Talesun Solar Technologies Co Ltd	TP6L60M-370	2	370
TOTAL		121	

Report release history

Table 6 shows the history of reports relevant for this job.

Release Number	Date	Notes
Release 1	27.06.2023	
This report (Release 2)	05.09.2023	Addresses feedback from ACT Government

Table 6: Report release history

Appendix A: Test descriptions

VISUAL INSPECTION

[NB The text below is an extract from the standard. In this case module is used to mean solar panel].

The purpose of a visual inspection is to detect any visual defects in the modules that may cause a risk of reliability loss (unexpected loss in performance immediately or over time). Visual inspection is defined in IEC 61215-2 by MQT 01. The standard also lists a number of major defects. These are:

a) Broken, cracked, or torn external surfaces.
b) Bent or misaligned external surfaces, including superstrates, substrates, frames and junction boxes to the extent that the operation of the PV module would be impaired.
c) Bubbles or delaminations forming a continuous path between electric circuit and the edge of the module.
d) If the mechanical integrity depends on lamination or other means of adhesion, the sum of the area of all bubbles shall not exceed 1 % of the total module area.
e) Evidence of any molten or burned encapsulant, backsheet, frontsheet, diode or active PV component.
f) Loss of mechanical integrity to the extent that the installation and operation of the module would be impaired.
g) Cracked/broken cells which can remove more than 10 % of the cell's photovoltaic active area from the electrical circuit of the PV module.
h) Voids in, or visible corrosion of any of the layers of the active (live) circuitry of the module extending over more than 10 % of any cell.
i) Broken interconnections, joints or terminals.
j) Any short-circuited live parts or exposed live electrical parts.
k) Module markings (label) are no longer attached or the information is unreadable.

STC POWER MEASUREMENTS

Standard Test Condition (STC) power measurement determines the output of the panel under standard test conditions (temperature of 25°C, spectrum of AM1.5G and illumination intensity of 1,000 W/m^2) compared to the manufacturer's stated output or label rating.

STC power measurement is is defined in IEC 61215-2 by MQT 06. The laboratory measurement requires a sun simulator class BBA or better according to IEC 60904-9. Today all acknowledged laboratories worldwide (including PV Lab Australia) use class AAA sun simulators or better.

ELECTROLUMINESENCE MEASUREMENTS

Electroluminescence (EL) detects damages in the solar panel that have occurred at a cell level. This includes, for example, microcracks which may occur on transport to site and are normally invisible to the naked eye. The used procedure is an internal procedure, based on IEC/TS 60904-13.

WET LEAKAGE

The wet-leakage test is relevant from a safety viewpoint and determines whether parts of the solar panle that should be electrically live (the cells) have any electrical pathway to parts of the solar panel that should not be live (anything that can be touched).

The test is defined in IEC Standard 61215-2 by MQT 15, and measures resistance between the inner circuit of a solar panel and a water bath. For large area solar panels, the measured insulation resistance multiplied by the surface area of the solar panel must be greater than $40\,\mathrm{M\Omega\,m^2}$.

POTENTIAL INDUCED DEGRADATION (PID)

Potential induced degradation, or the voltage-dependent ageing of photovoltaic modules, is a type of power degradation that generally appears on the negative side of the module string and can affect almost any type of photovoltaic module. PID can have catastrophic consequences for module output power.

The PID test includes a before and after assessment of module performance.

PID testing is considered a destructive test, after completion of testing the modules will be disposed of responsibly. PV Lab Australia will not return modules that have undergone PID testing unless specially requested by the client. If requested, shipping charges may apply.