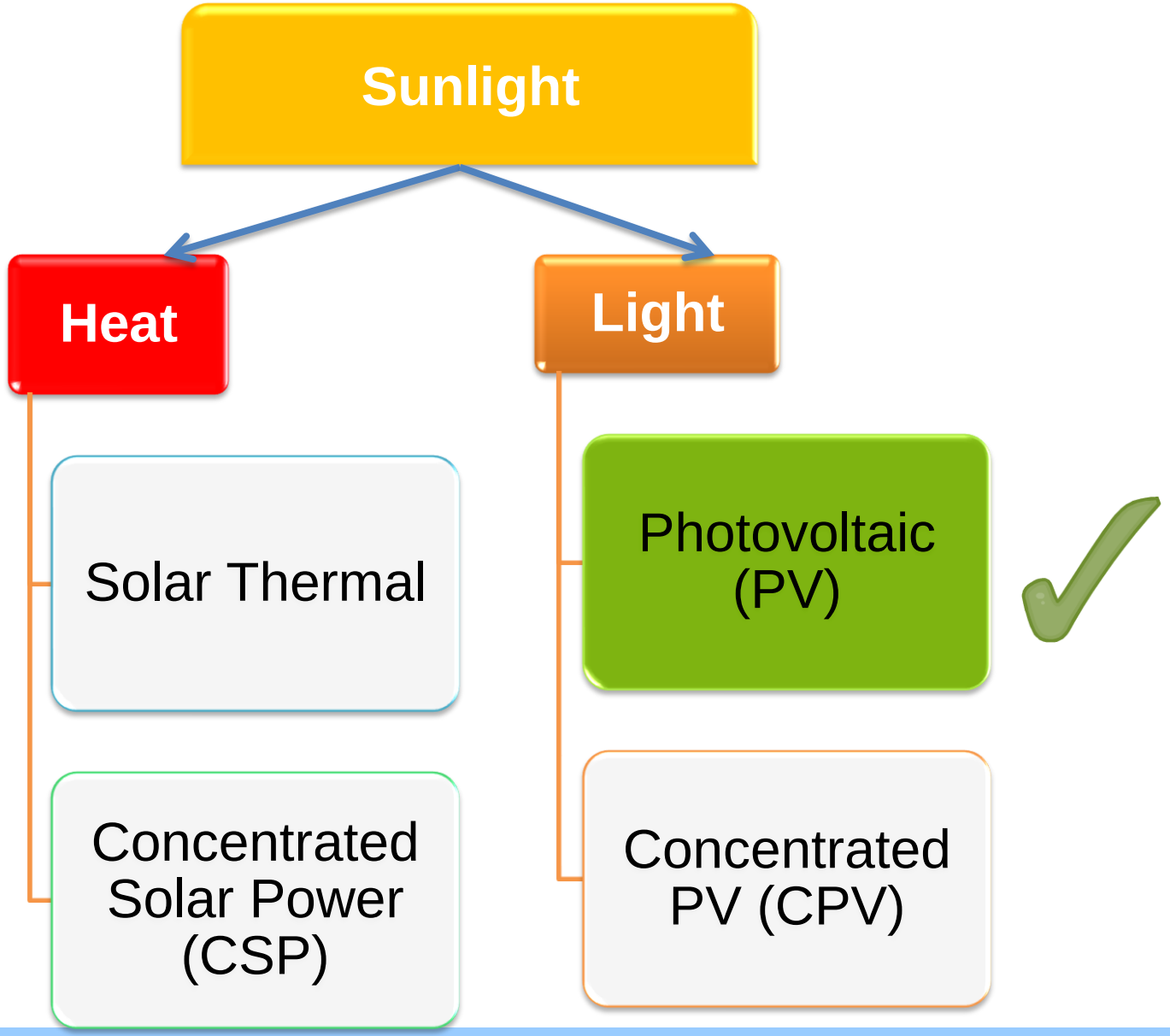
Solar Cell, Module, Array

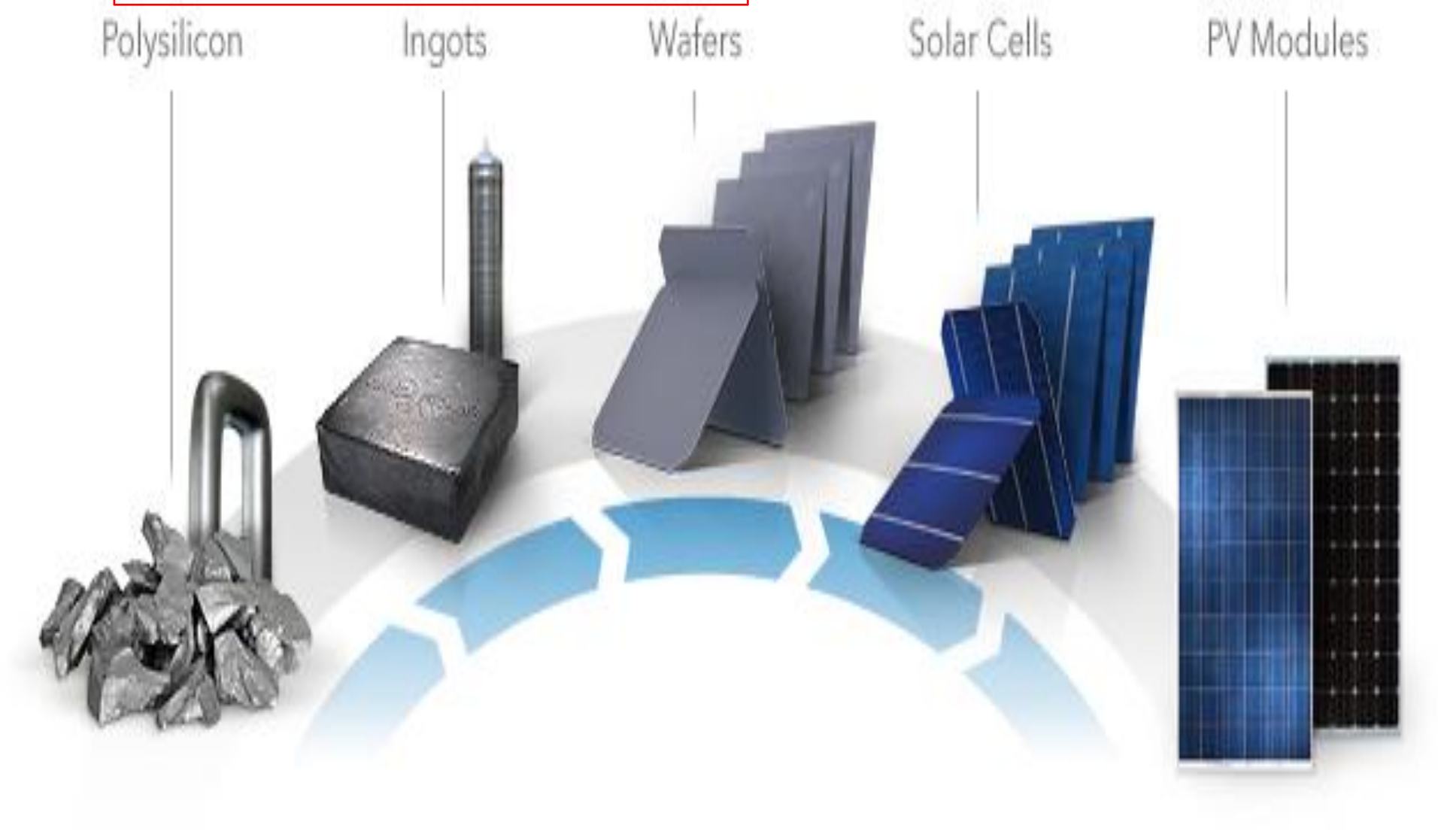
Sunlight Components



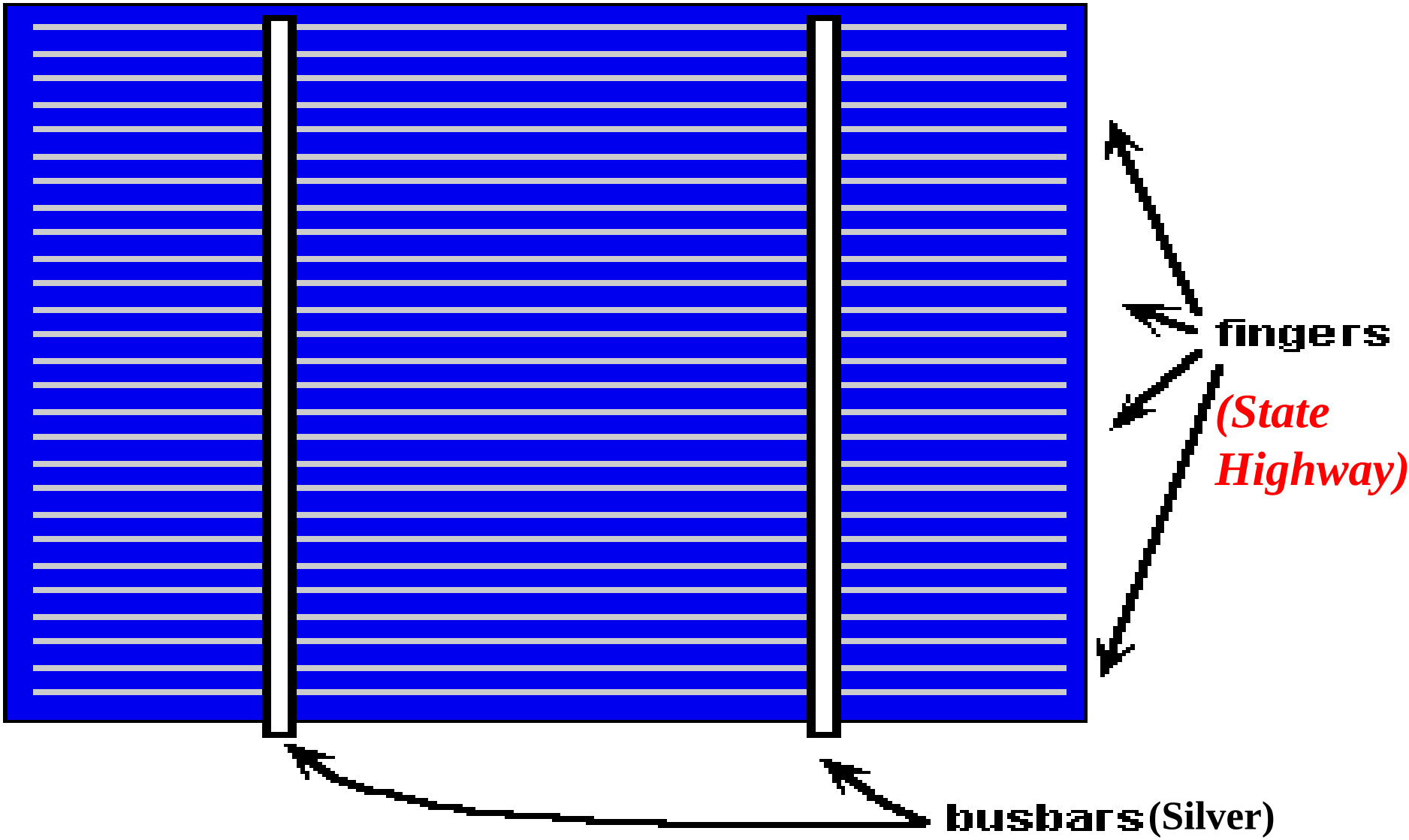
Solar Cell

Silicon to Module

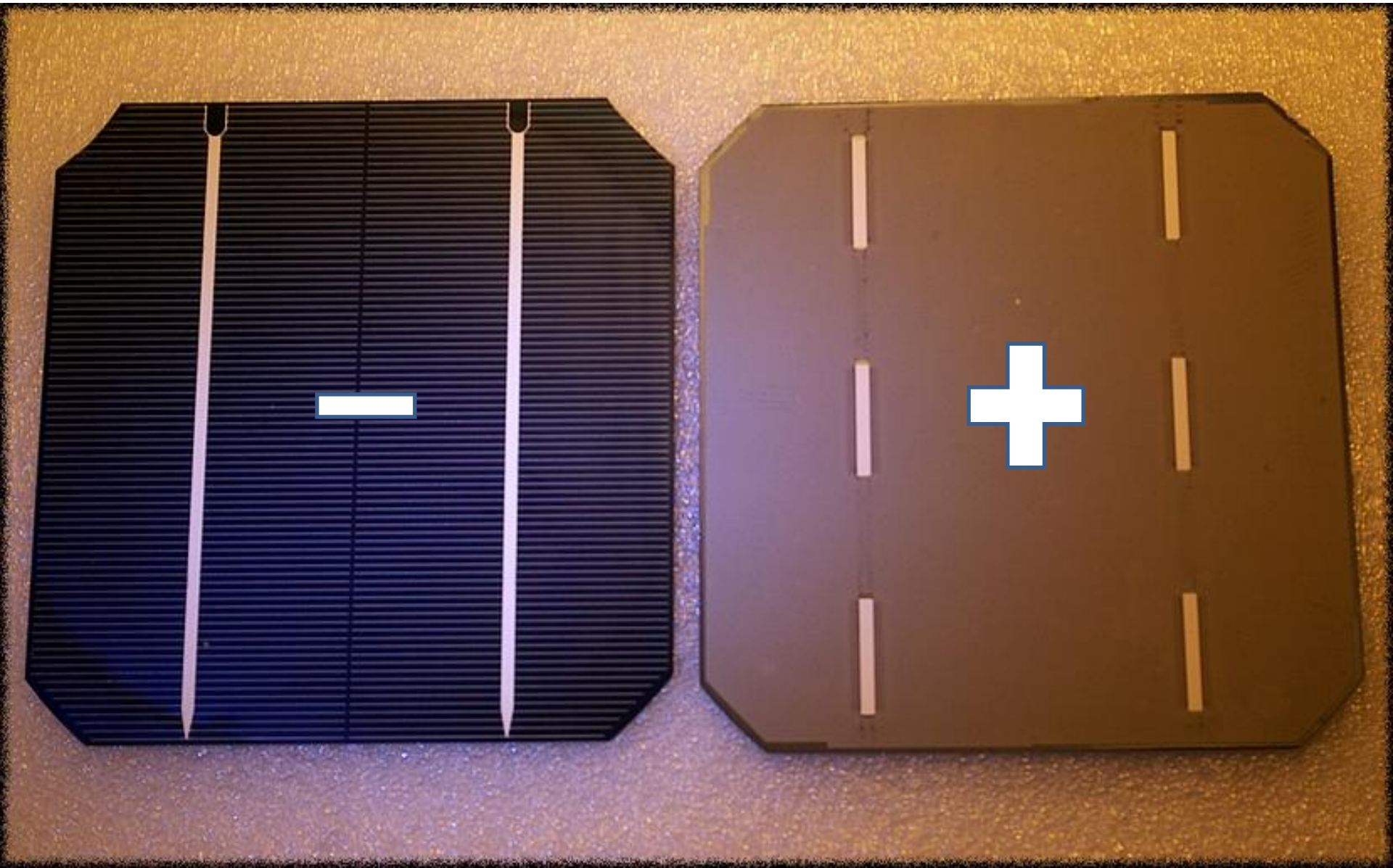
pveducation.org



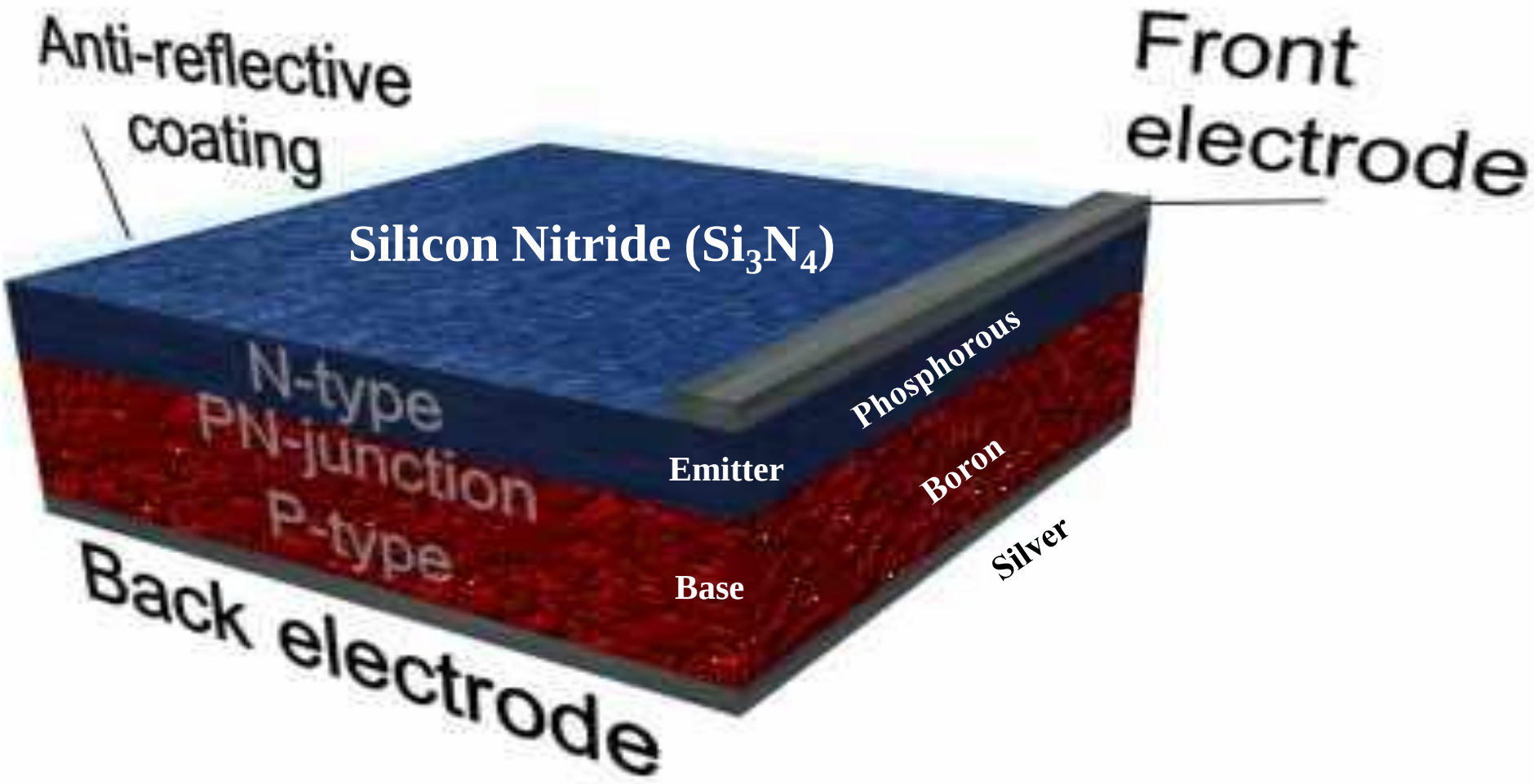
Cell Structure



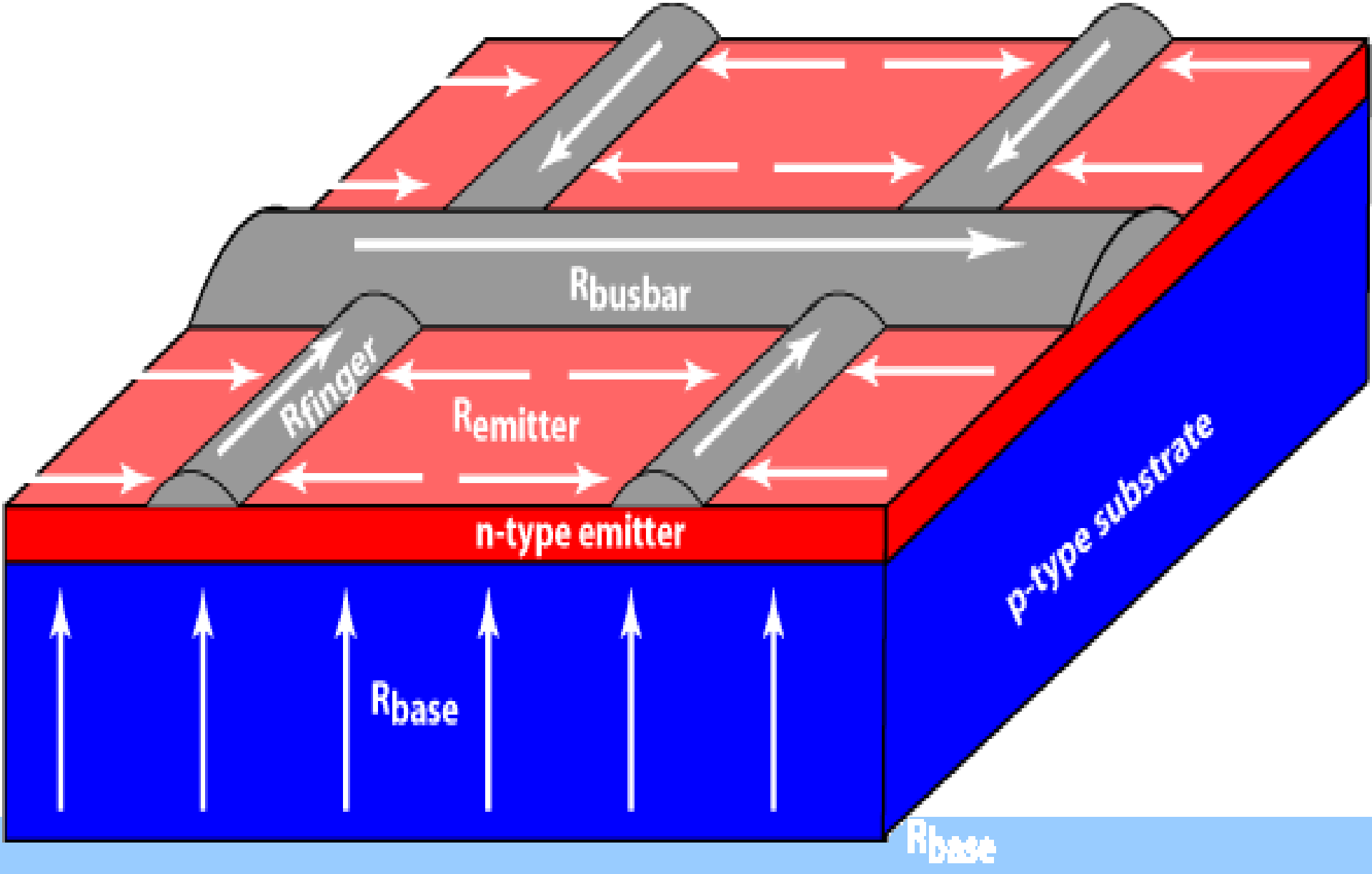
Cell Structure



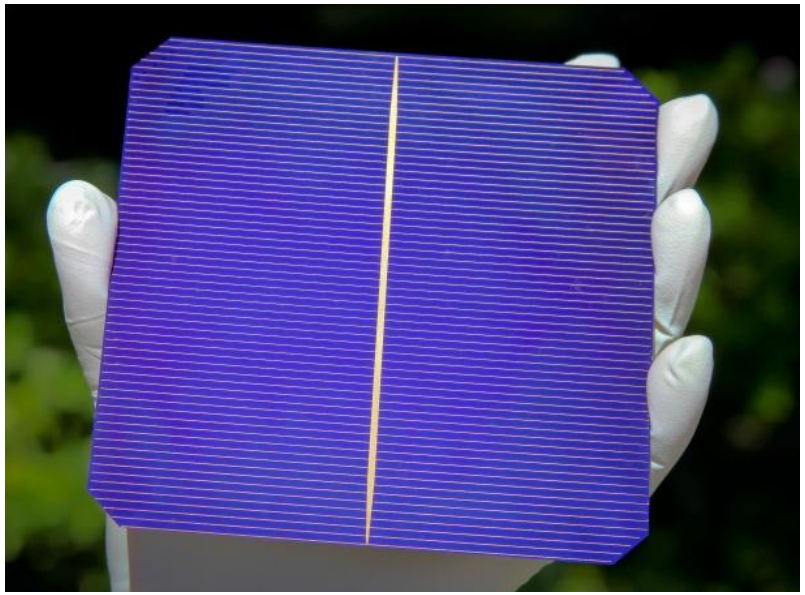
Solar Cell Structure

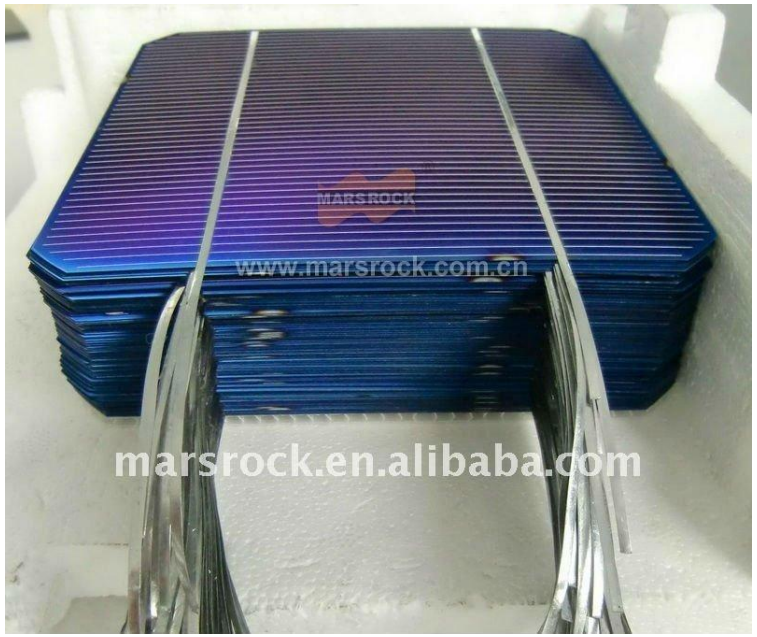


Current flow in a cell

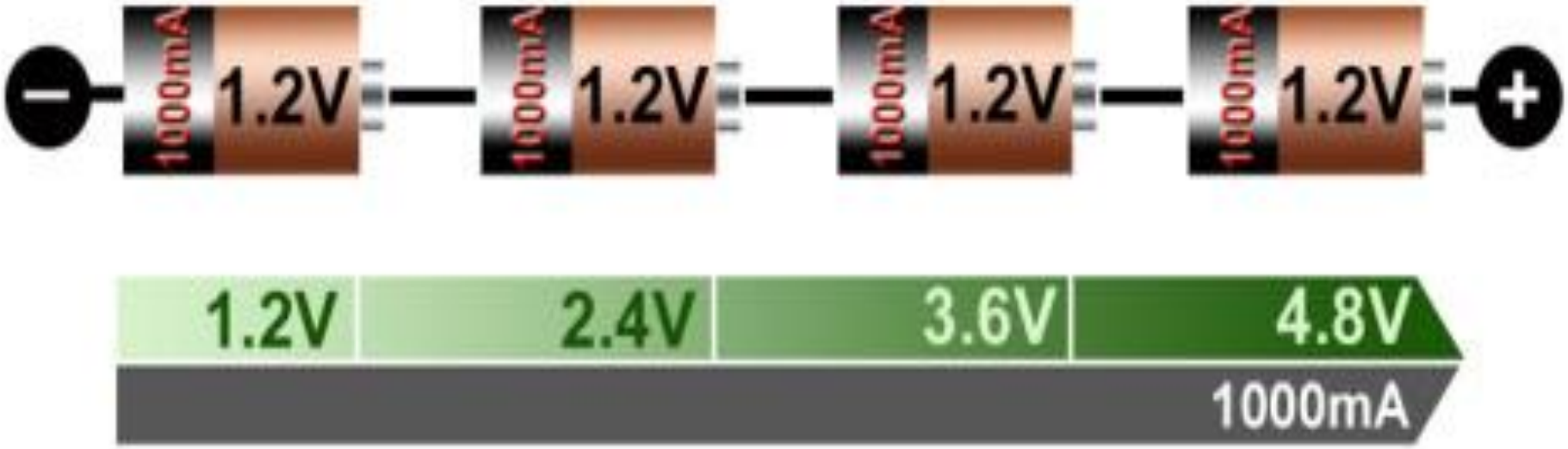


One, Two and Three Bus Bars



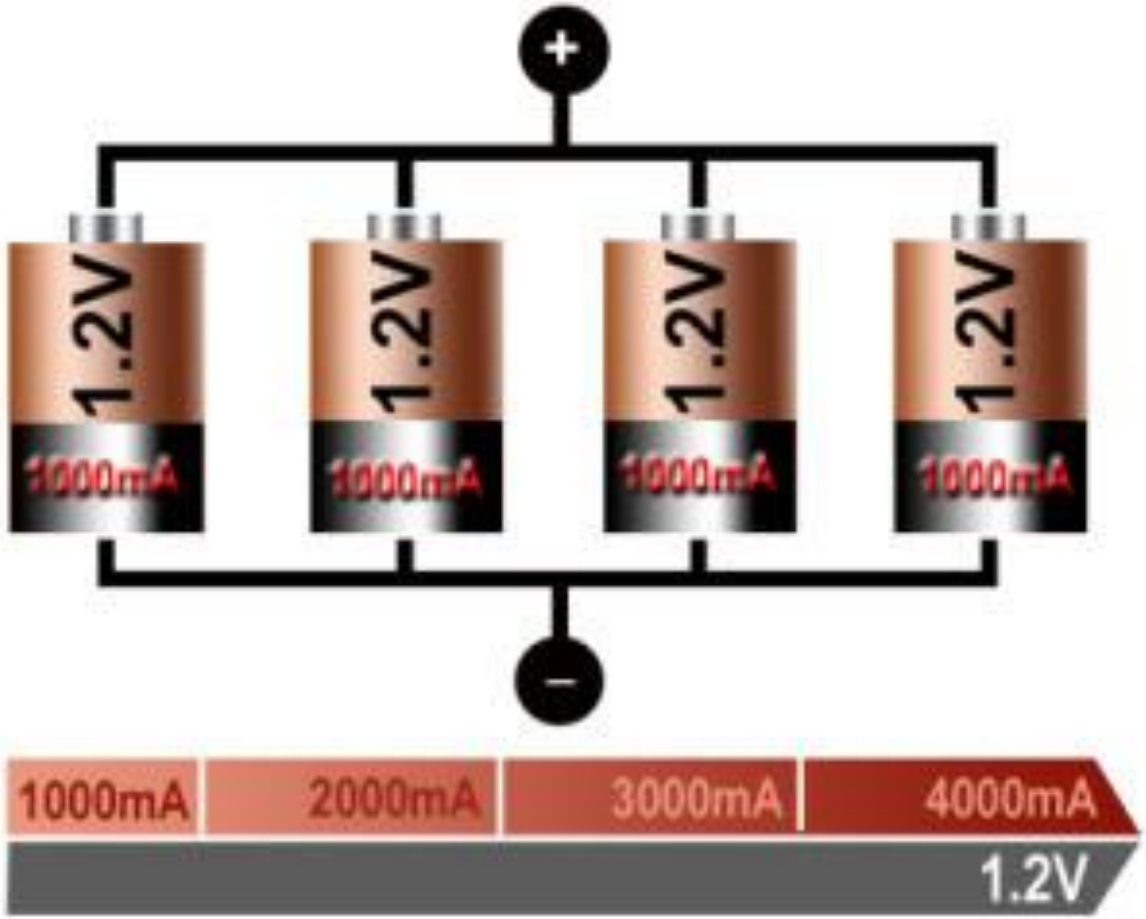


Series Connection



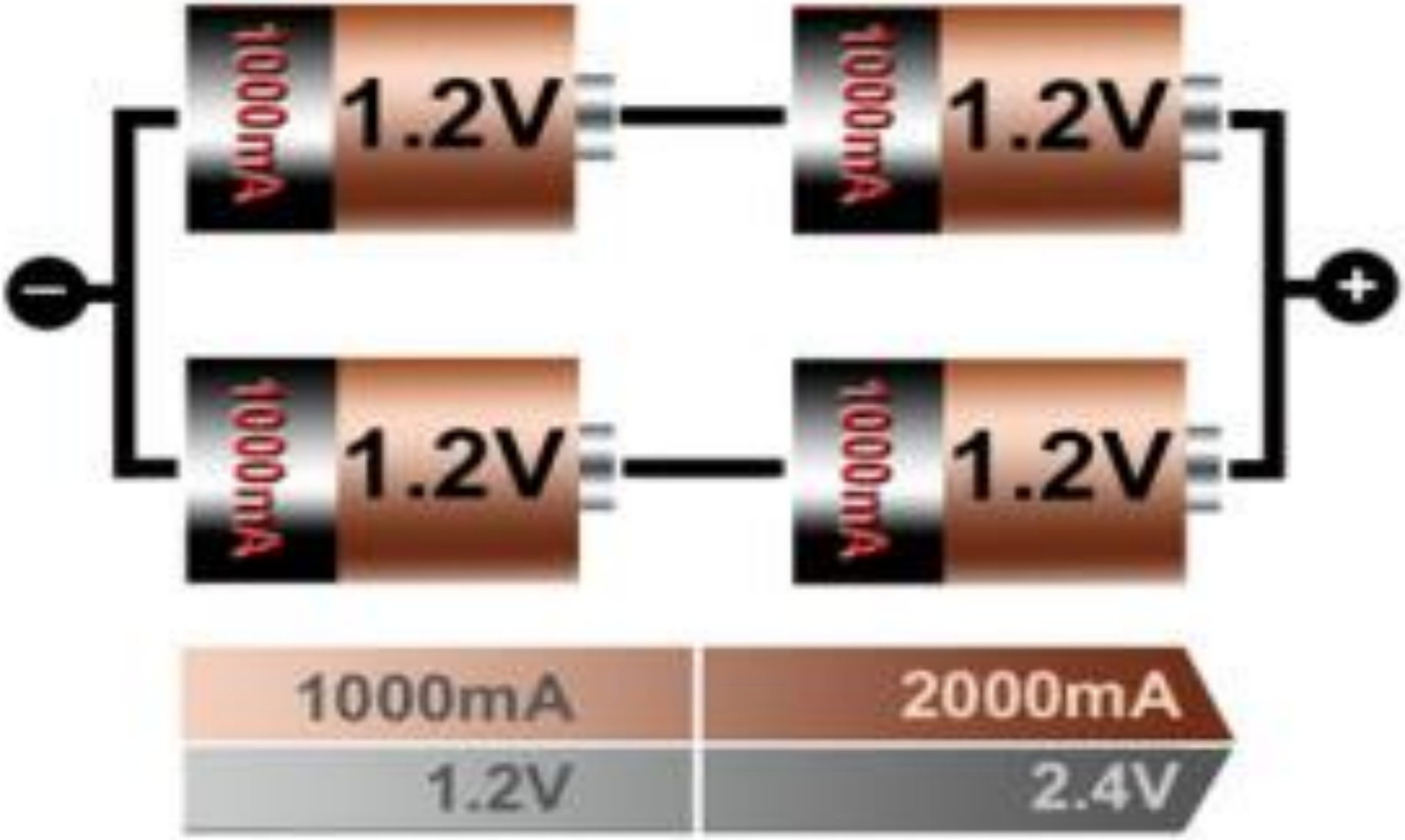
In series connection, voltage adds up but current remains the same

Parallel Connection

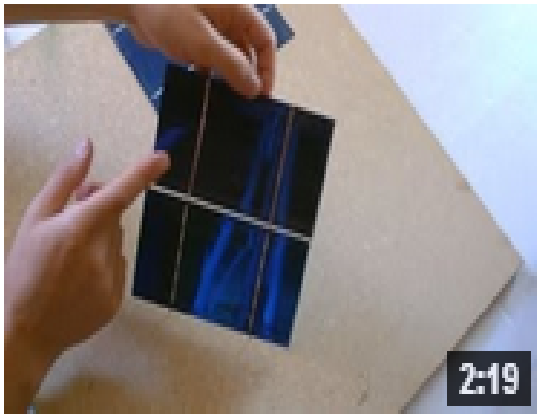


In parallel connection, voltage remains the same but current adds up

Series and Parallel Connection



Connecting solar cells in series - Video



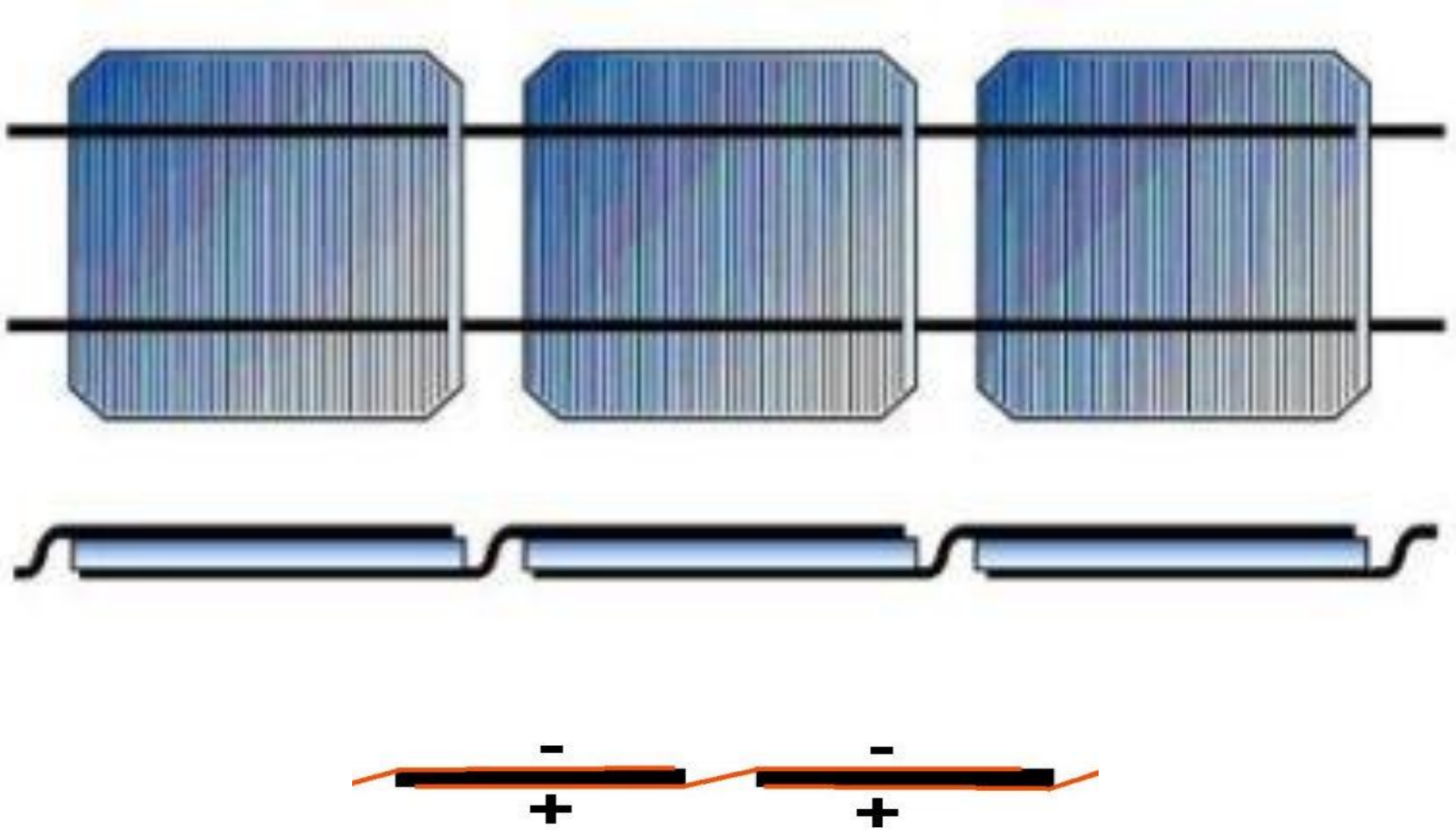
How to make a Solar Panel - First Step: Solar Cell "Tabbing" - How to "Tab" Solar Cells

by **desertsun02** • 7 months ago • 3,149 views

Video shows how to easily "Tab" untabbed **solar cells**. (the first step in building a **solar panel**). "Tabbing the cell" is the process of ...

HD

Connecting solar cells in series



Datasheet distribution

Specification for Solar Panel is given in terms of

Output Power (Wp) and Output Voltage (Vmpp)

Tata Power
Module Datasheet

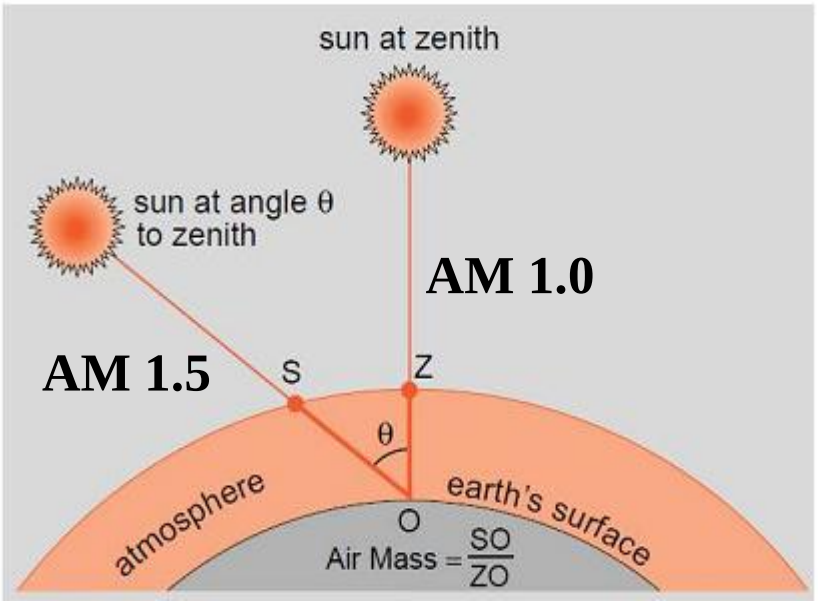
Emmvee Module
Datasheet

Sunpower
Module Datasheet

Standard Test Conditions (STC)

Industry standard for the conditions under which a solar cell is tested and rated.

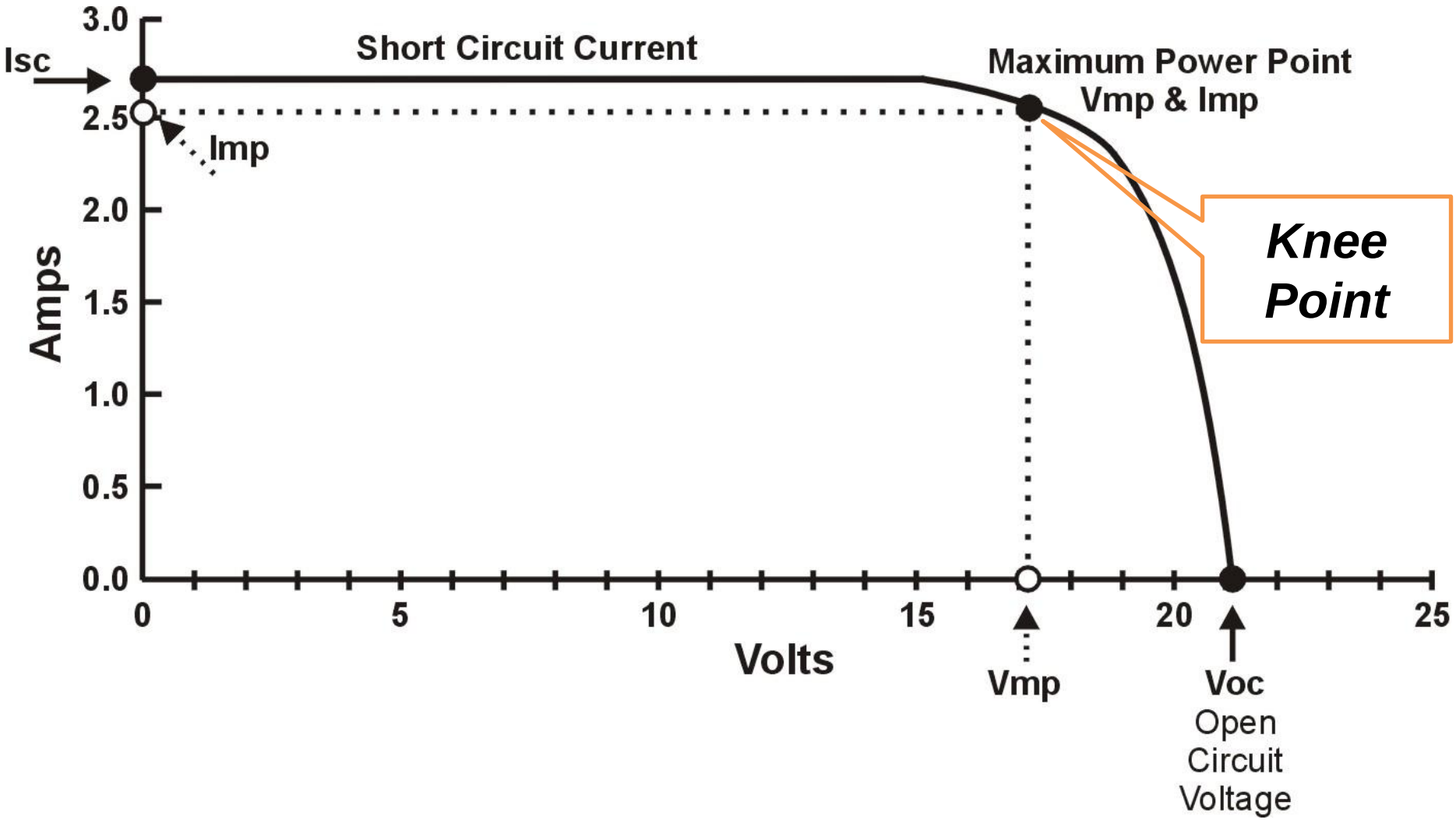
Test parameters	Value	Comments
Irradiance	1000 W/m^2	Amount of light falling on the solar cell
Temperature	25^o C	Cell temperature and **NOT** air temp
Air Mass (AM)	1.5	When solar radiation travels 1.5 times the thickness of the earth's atmosphere



Sun Chamber/Simulator

Sun Chamber/Simulator

Solar Cell Parameters and IV curve



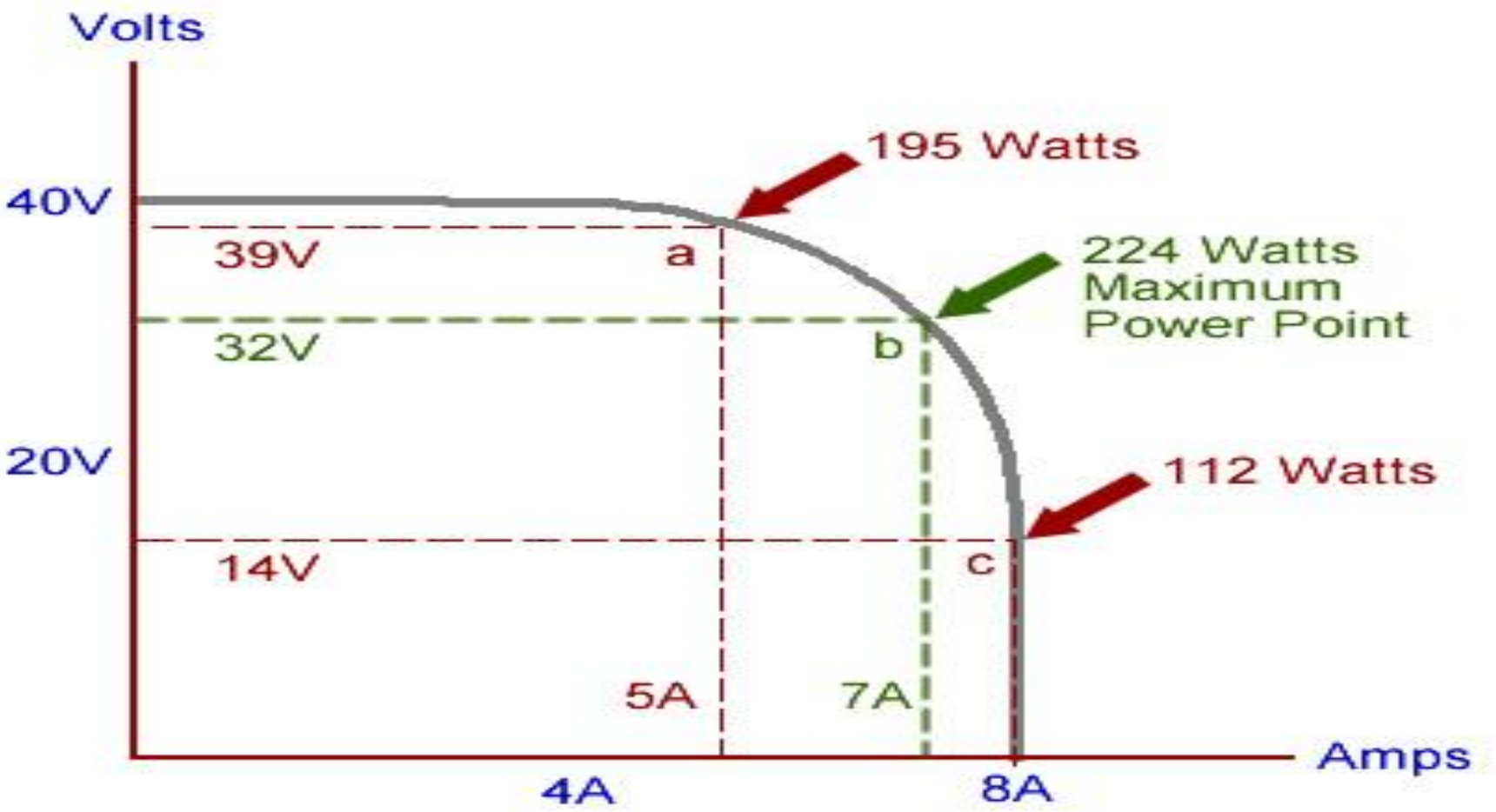
Solar Cell Parameters

Isc	Short Circuit Current	Max current a solar cell can produce	Higher the Isc – better is the cell
Voc	Open Circuit Voltage	Max voltage a solar cell can produce	Higher the Voc – better is the cell
Pmax	Maximum Power Point (MPP)	Max power a solar cell produces at STC	Also called Wpeak
Impp	Current at MPP		Impp < Isc
Vmpp	Voltage at MPP		Vmpp < Voc
η	Efficiency	Ratio of Pmax to input Power	η = Pmax/Pin

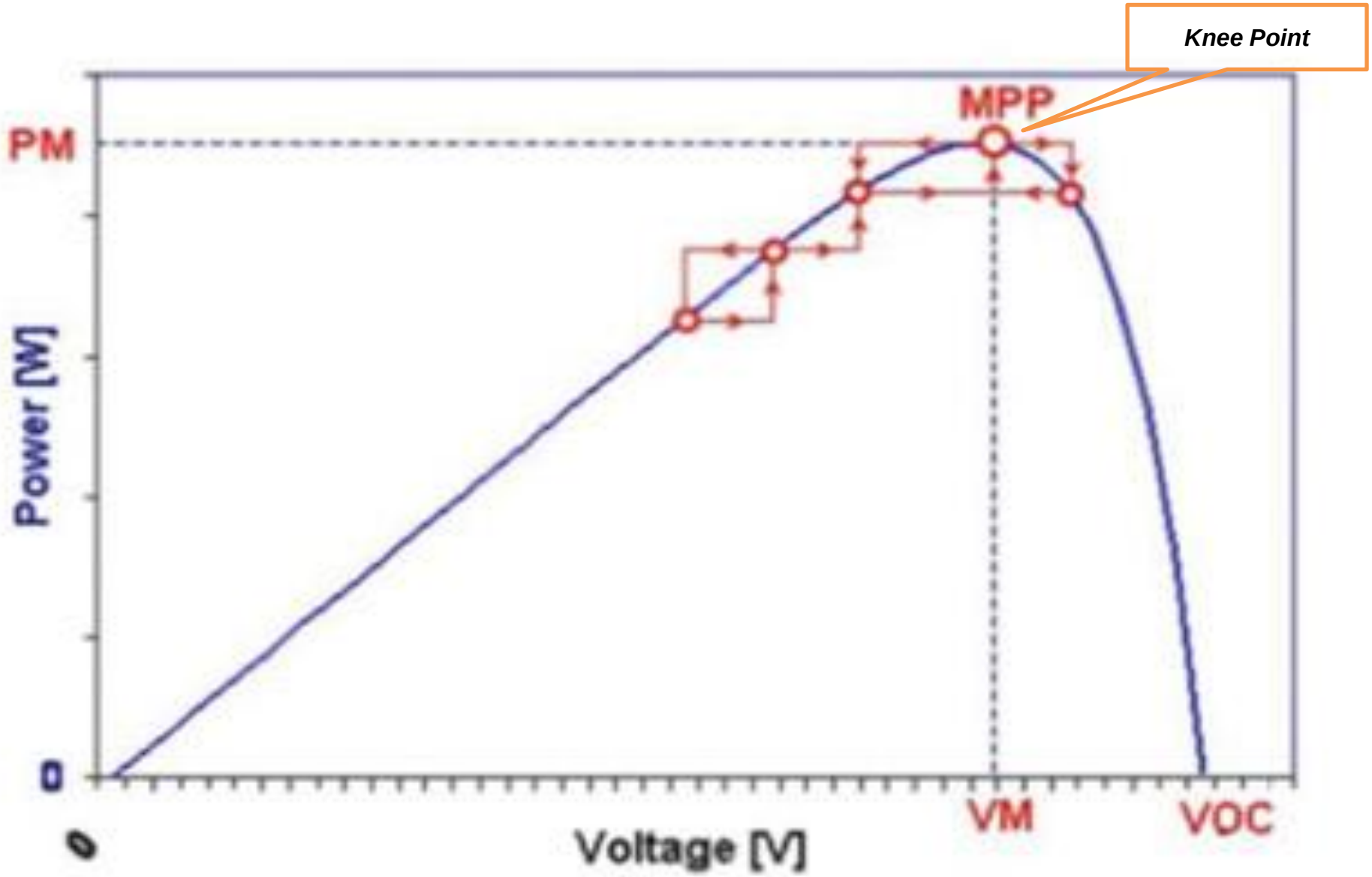
Exercise – Multiply Vmpp & Impp to get Wp

Electrical Data at 1000 W/m², 25 °C and AM 1.5 (STC in Accordance with EN 60		
rated power at STC [1]	230 Wp	235 Wp
module efficiency at STC [2]	14.0 %	14.3 %
cell efficiency	16.4 %	16.7 %
open-circuit voltage V_{oc}	36.42 V	36.60 V
short-circuit current I_{sc}	8.07 A	8.21 A
rated voltage V_{mpp}	30.00 V	30.13 V
rated current I_{mpp}	7.67 A	7.80 A

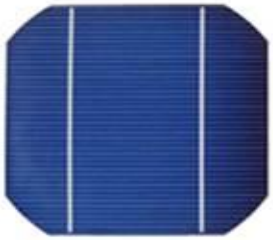
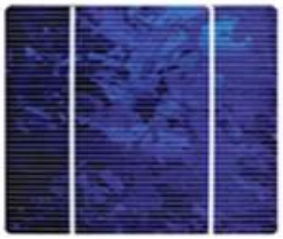
Maximum Power Point (MPP)



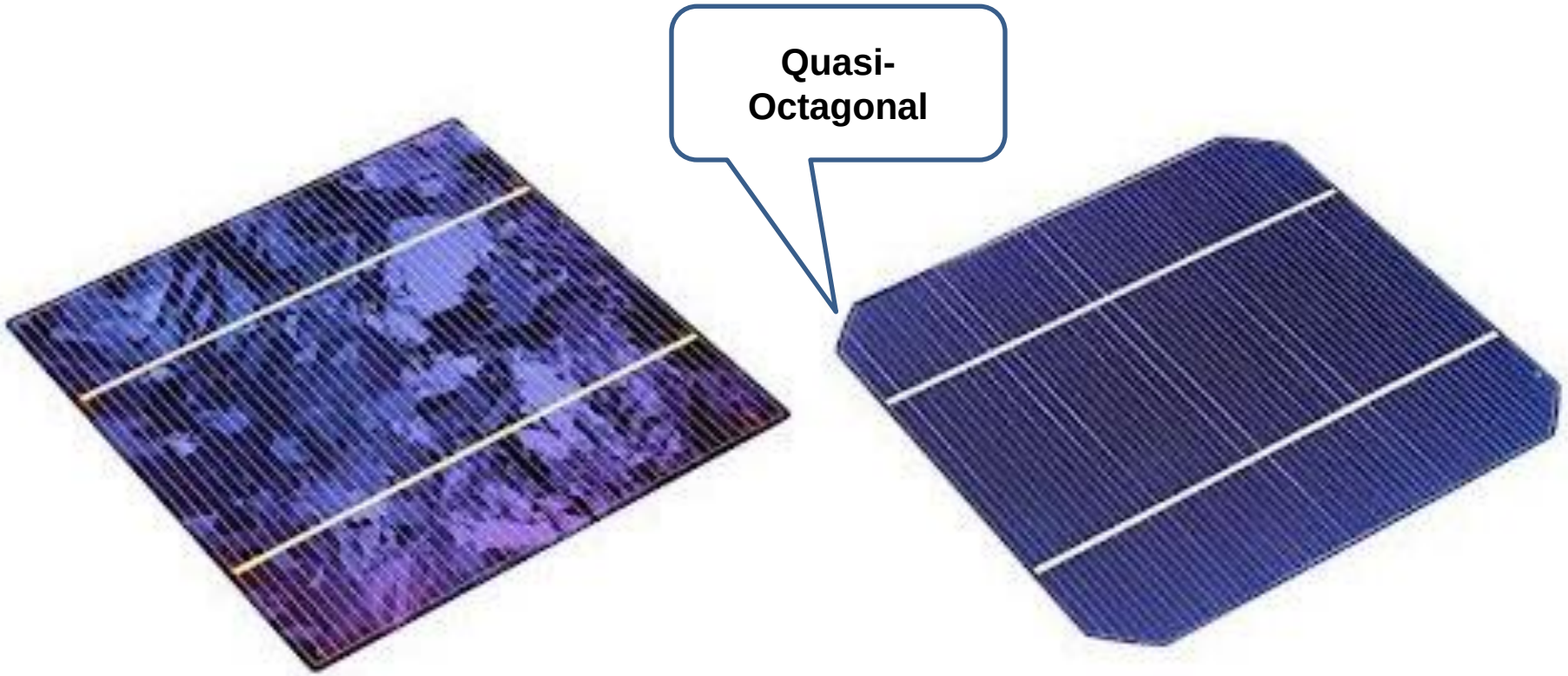
Maximum Power Point Tracking (MPPT) - Algorithm



Solar Cell Types

Solar cell technology	Characteristics
 Monocrystalline	Structure: Formed from single crystal of silicon Typical Module Efficiency: 13% - 20% Typical Module Price /Wp: Rs.75 – Rs.100
 Polycrystalline	Structure: Formed from multiple crystals of silicon Typical Module Efficiency: 14% - 16% Typical Module Price/Wp: Rs.50 – Rs.75
 Thinfilm	Structure: Formed from amorphous silicon Typical Module Efficiency: 6% - 12% Typical Module Price/Wp: Rs.40 – Rs.55

How to identify cells? – Mono and Poly



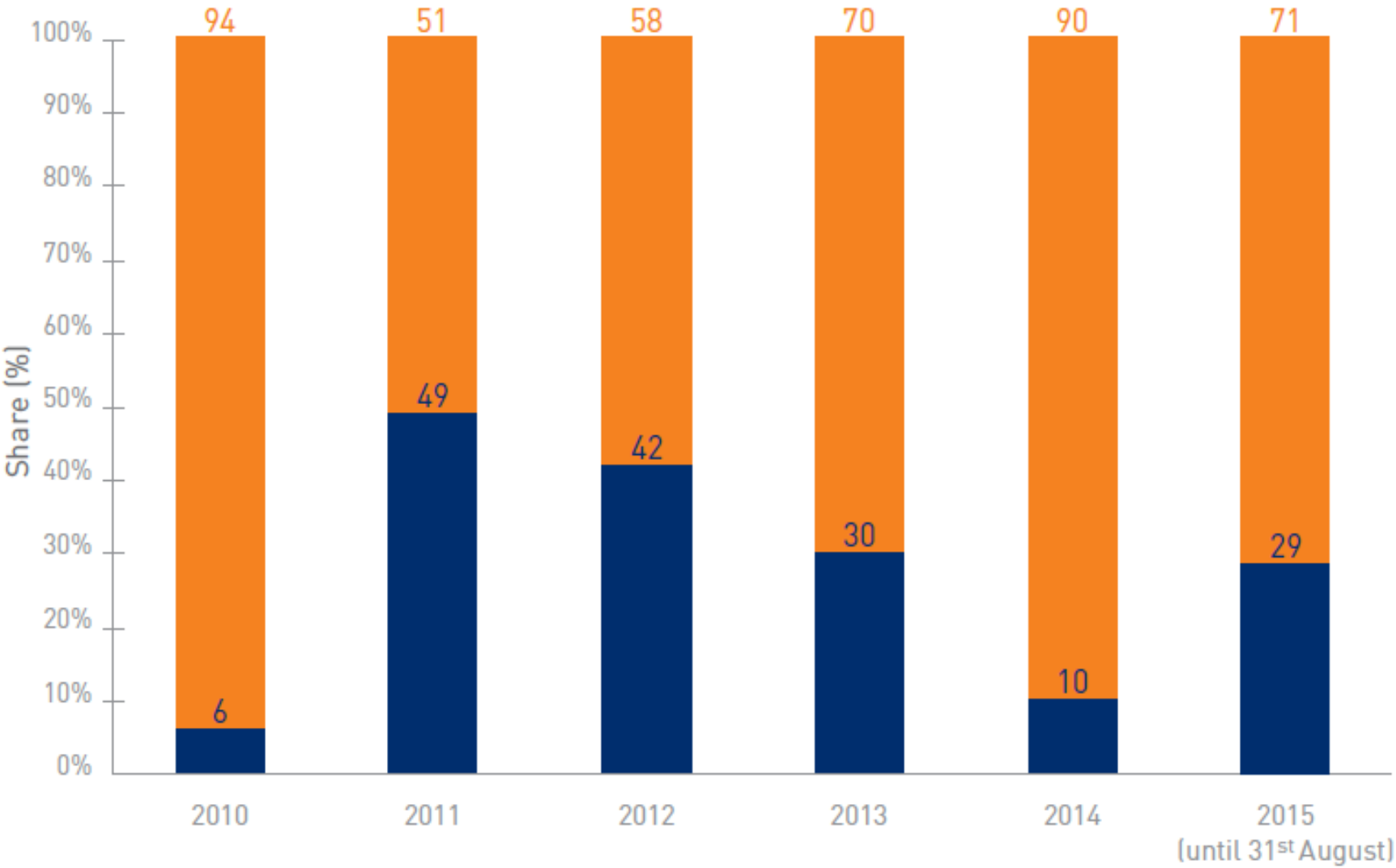
Poly-Crystalline
Solar Cell

Mono-Crystalline
Solar Cell

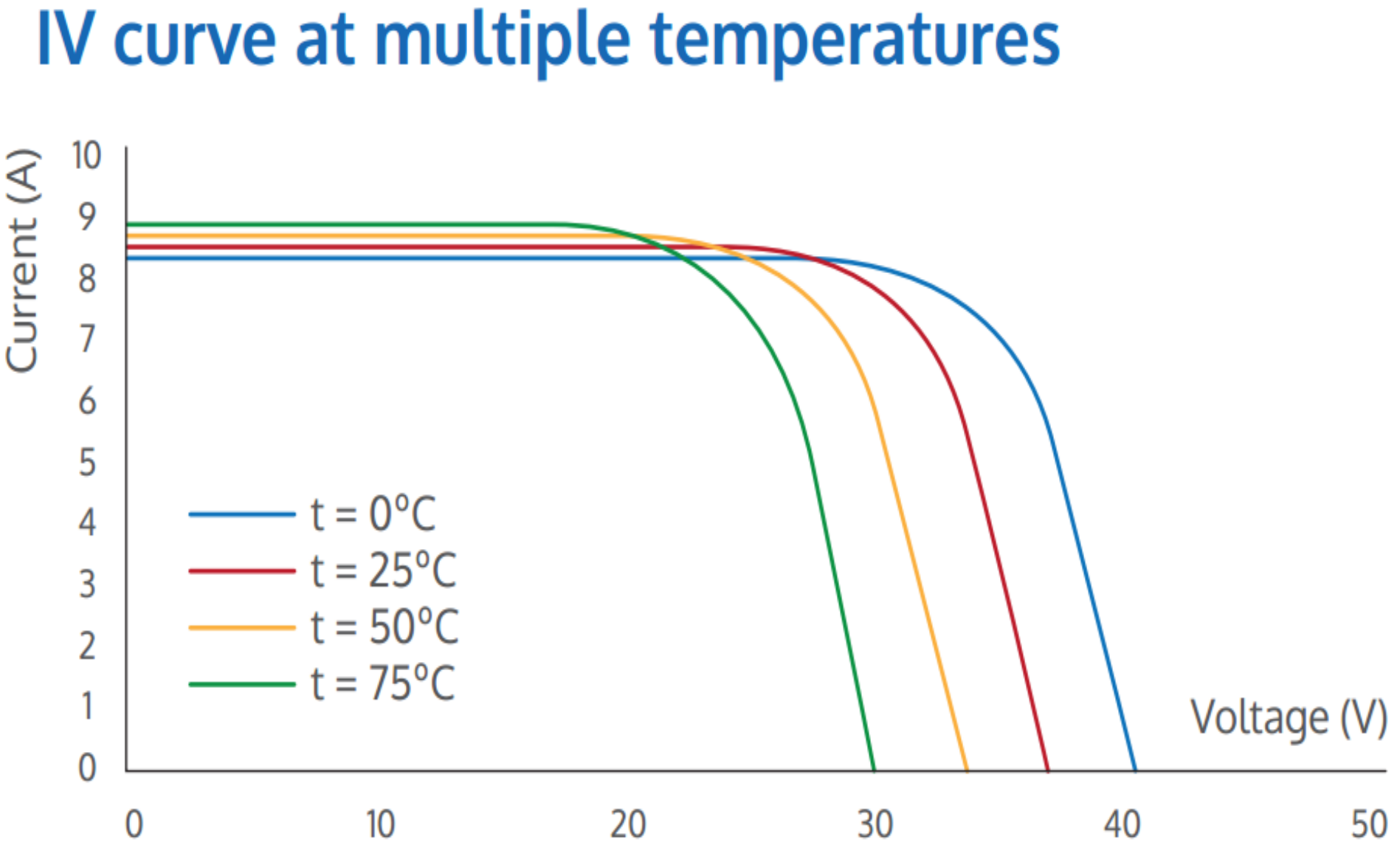
Solar Cell Types

PV Technology	Cell Type	Efficiency (in %)
Crystalline Silicon	Mono-crystalline	13 – 20
	Poly-crystalline	14 - 16
Thin Film	Amorphous Si	6 - 12
	Cadmium Telluride (CdTe)	8 – 11
	CIGS (Cu-Indium-Ga- Selenide)	
Multi-junction	GaInP (Ga-In-Phosphide)	30 – 35
	GaAs (Ga-Arsenide)	
	Ge (Germanium)	

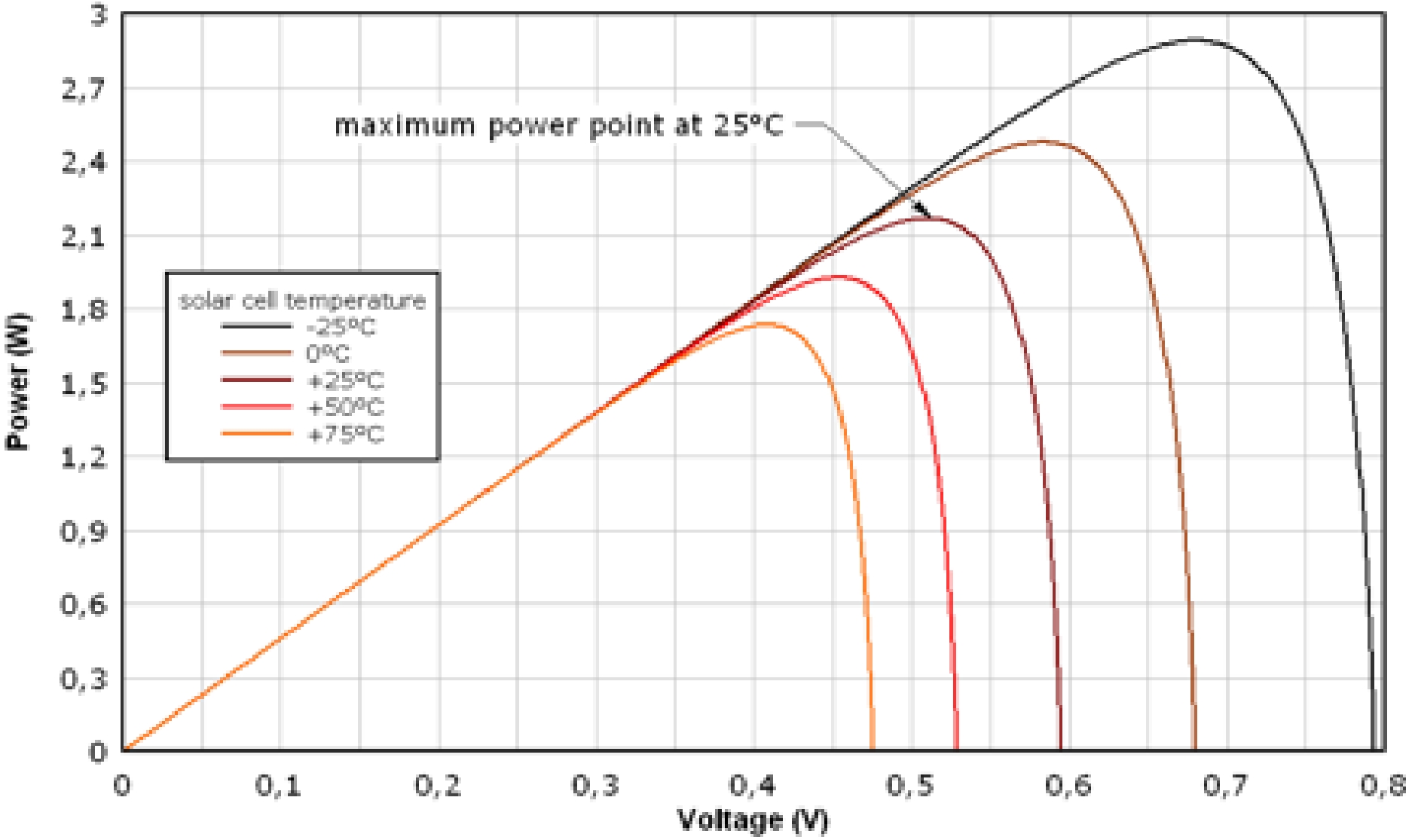
Year-wise share of thin film vs. crystalline modules (%)



Effect of temperature on solar cell



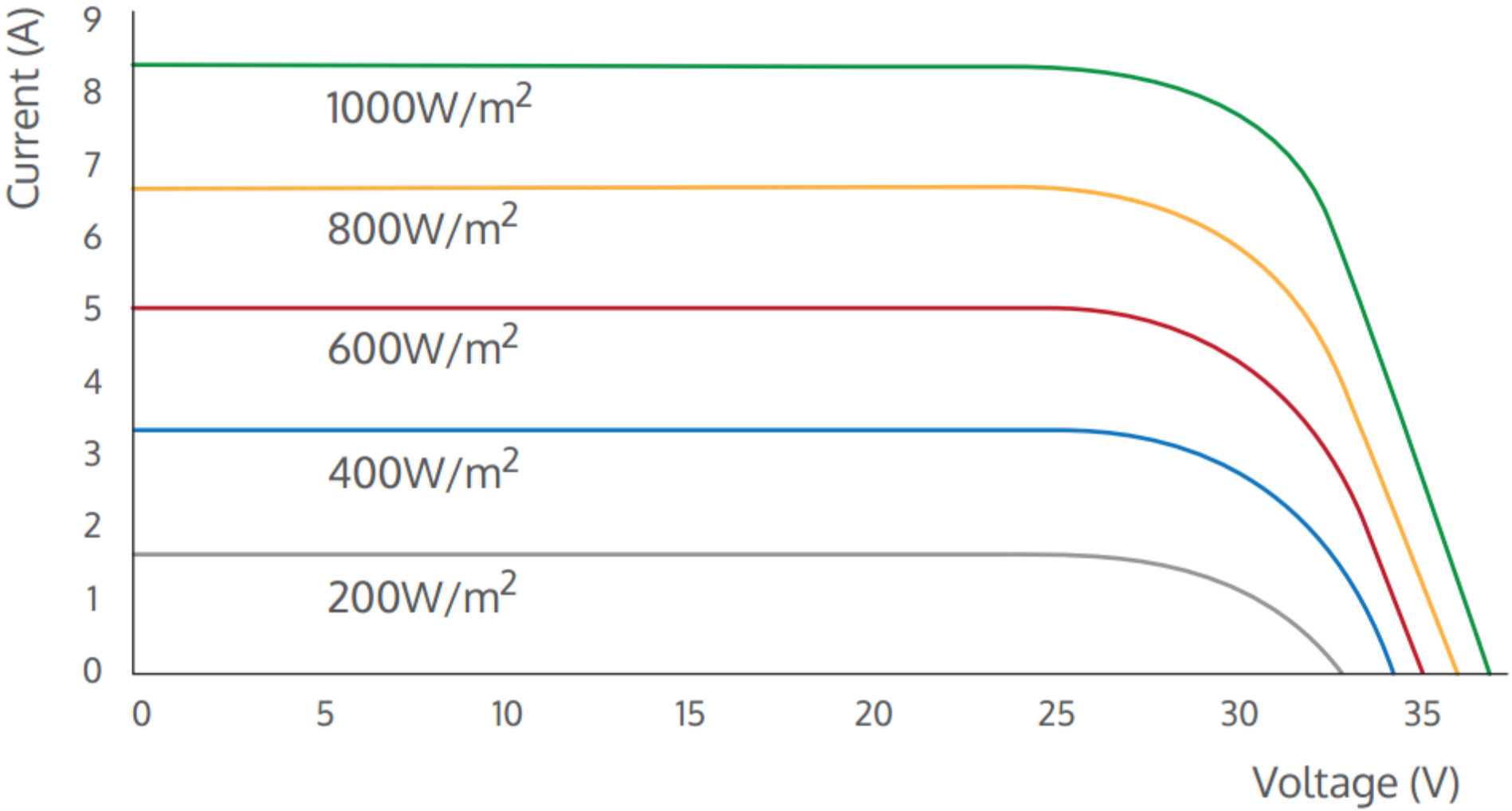
Effect of temperature on solar cell



Case study: Solar over Narmada Canal

Effect of irradiance on solar cell

IV curve at multiple irradiance

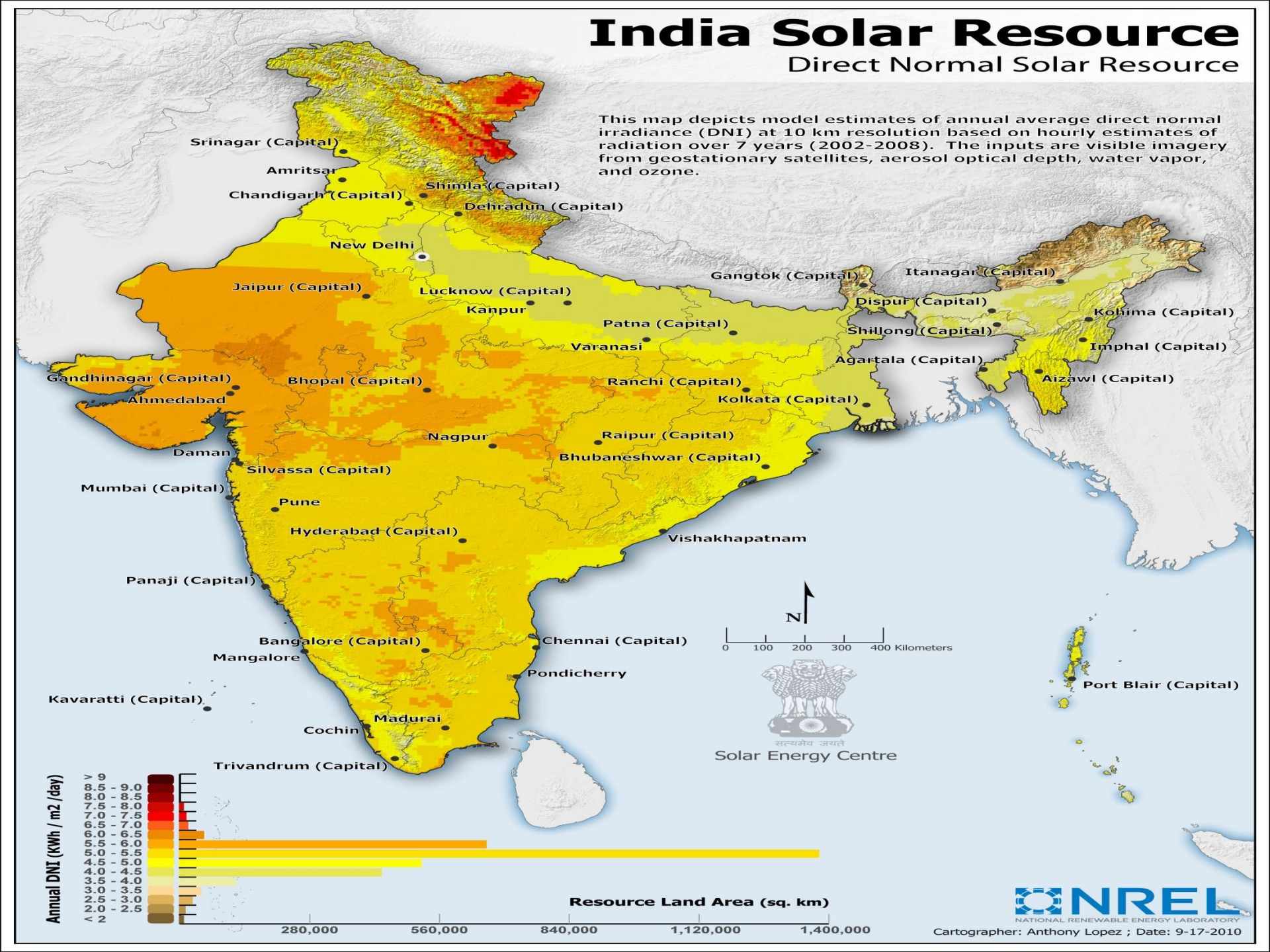


Solar Plant in Ladakh

India Solar Resource

Direct Normal Solar Resource

This map depicts model estimates of annual average direct normal irradiance (DNI) at 10 km resolution based on hourly estimates of radiation over 7 years (2002-2008). The inputs are visible imagery from geostationary satellites, aerosol optical depth, water vapor, and ozone.

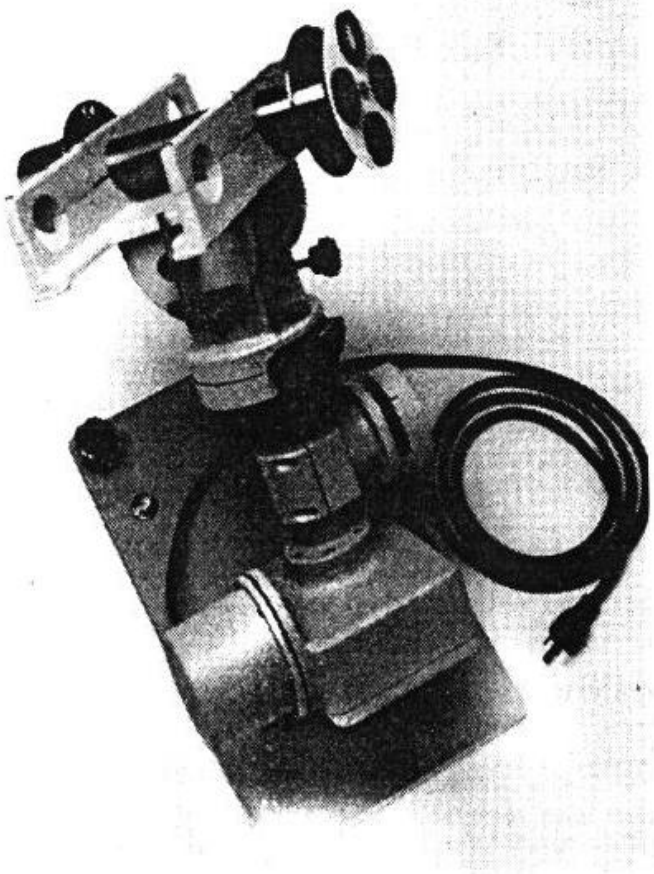


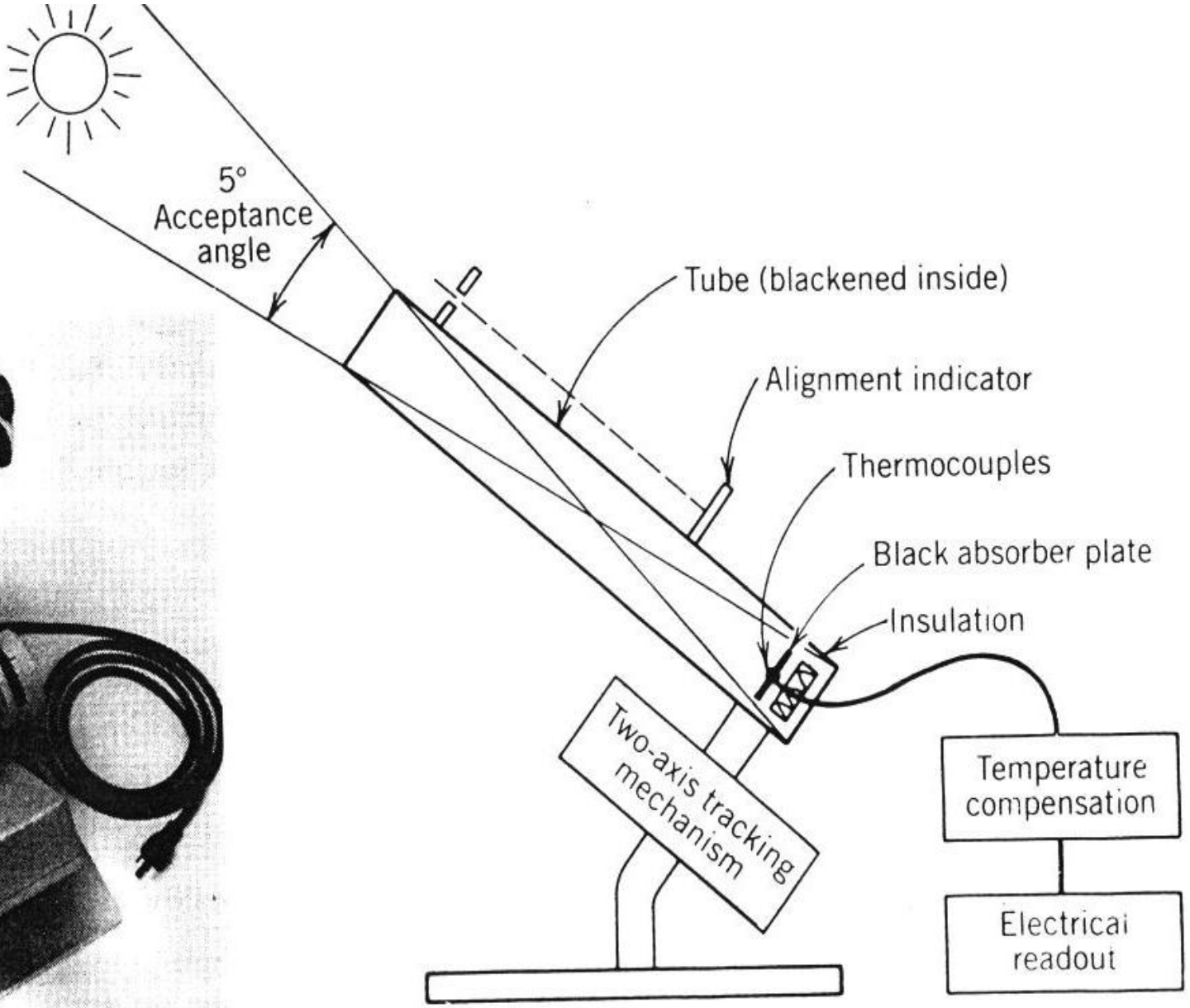
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Cartographer: Anthony Lopez ; Date: 9-17-2010

Measuring Global irradiance

Measuring Direct irradiance - Pyrheliometer

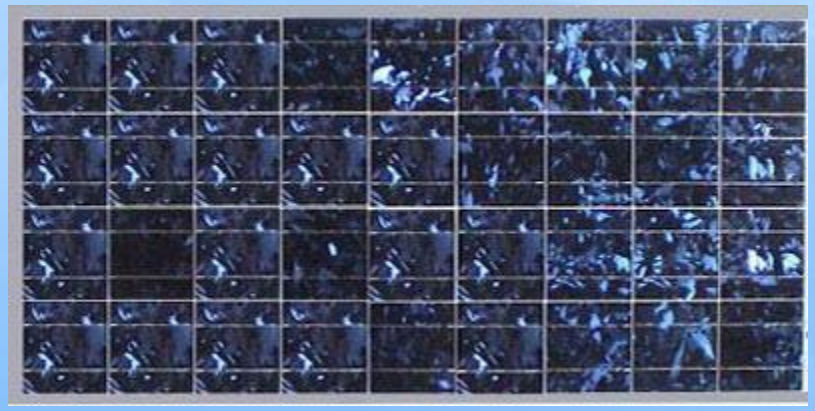




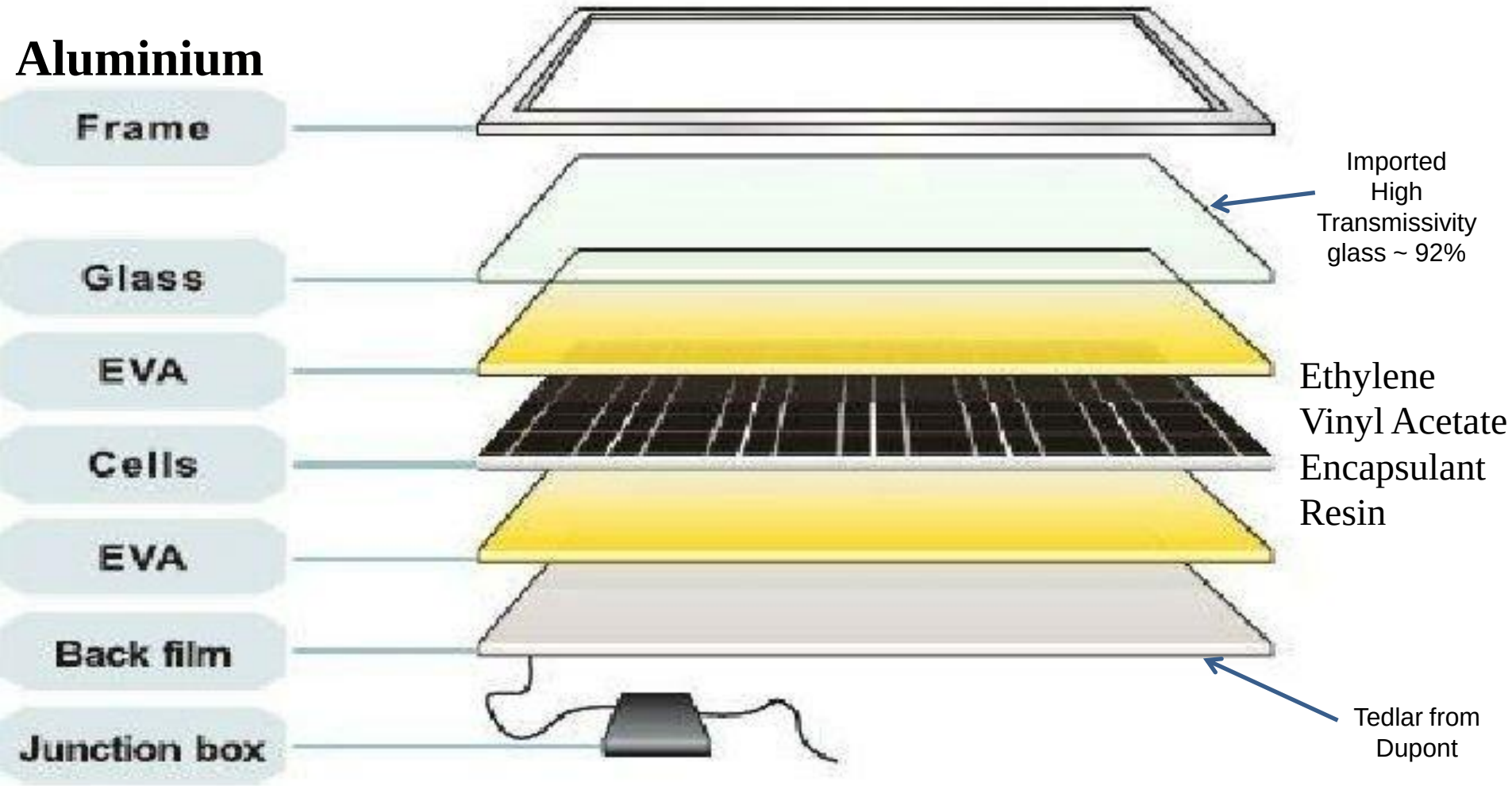
Measuring Direct irradiance - Pyrheliometer

Measuring Diffused irradiance - Pyranometer

Solar PV Modules

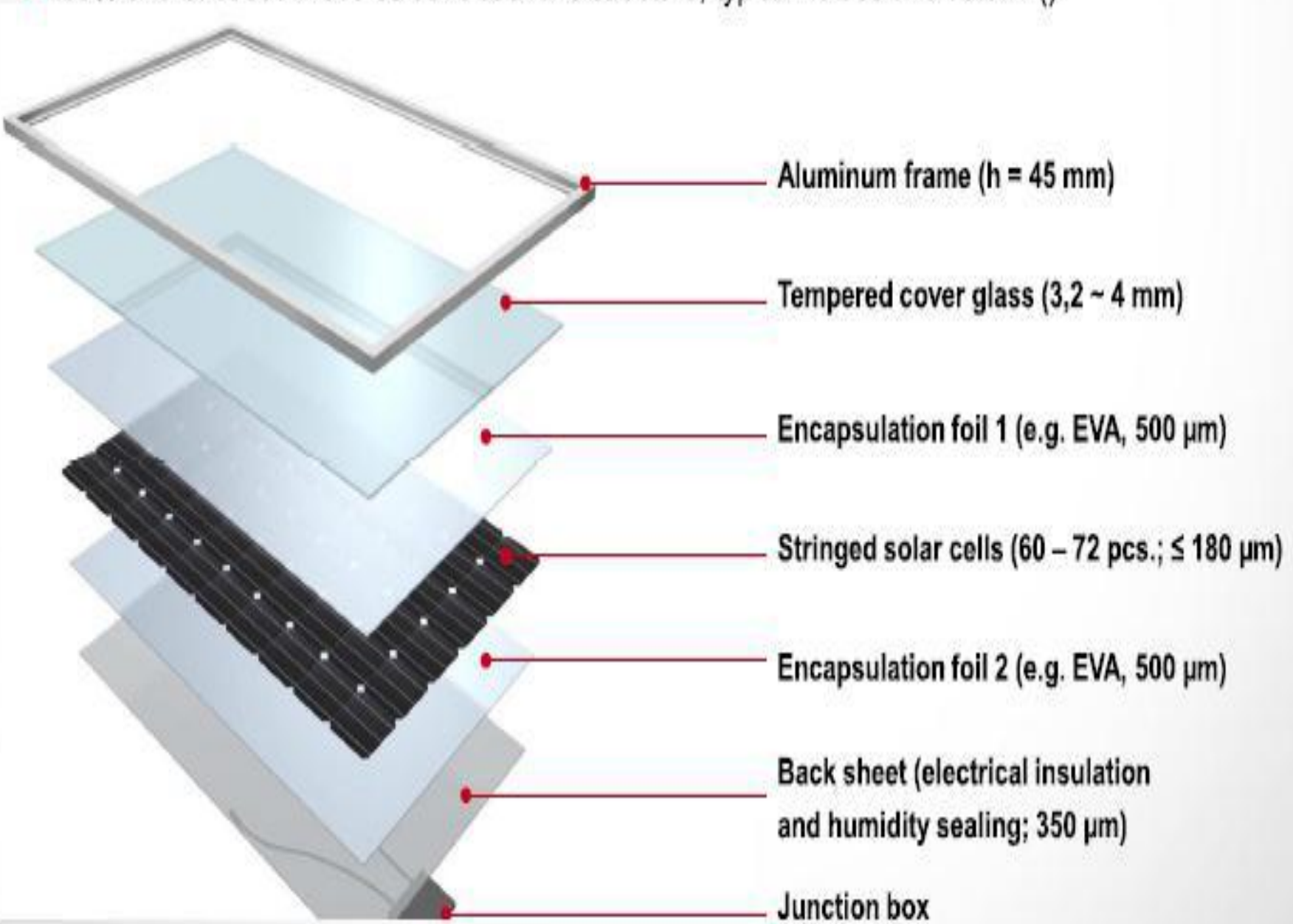


Module Structure



Module structure:

- >90% of c-Si based modules consist of this structure; typical values and data in ()



Automated Module Production - Video

Bosch Solar Panel Production Line (New)

by **BT Commercial** • 1 year ago • 20,863 views

Bosch **Solar Module** Production.

HD

How many cells in a module?

- Modules were initially designed to charge 12 V batteries
- Hence, module voltage has to be more than the battery voltage
- Later for 24V battery systems, higher module voltage had to be designed

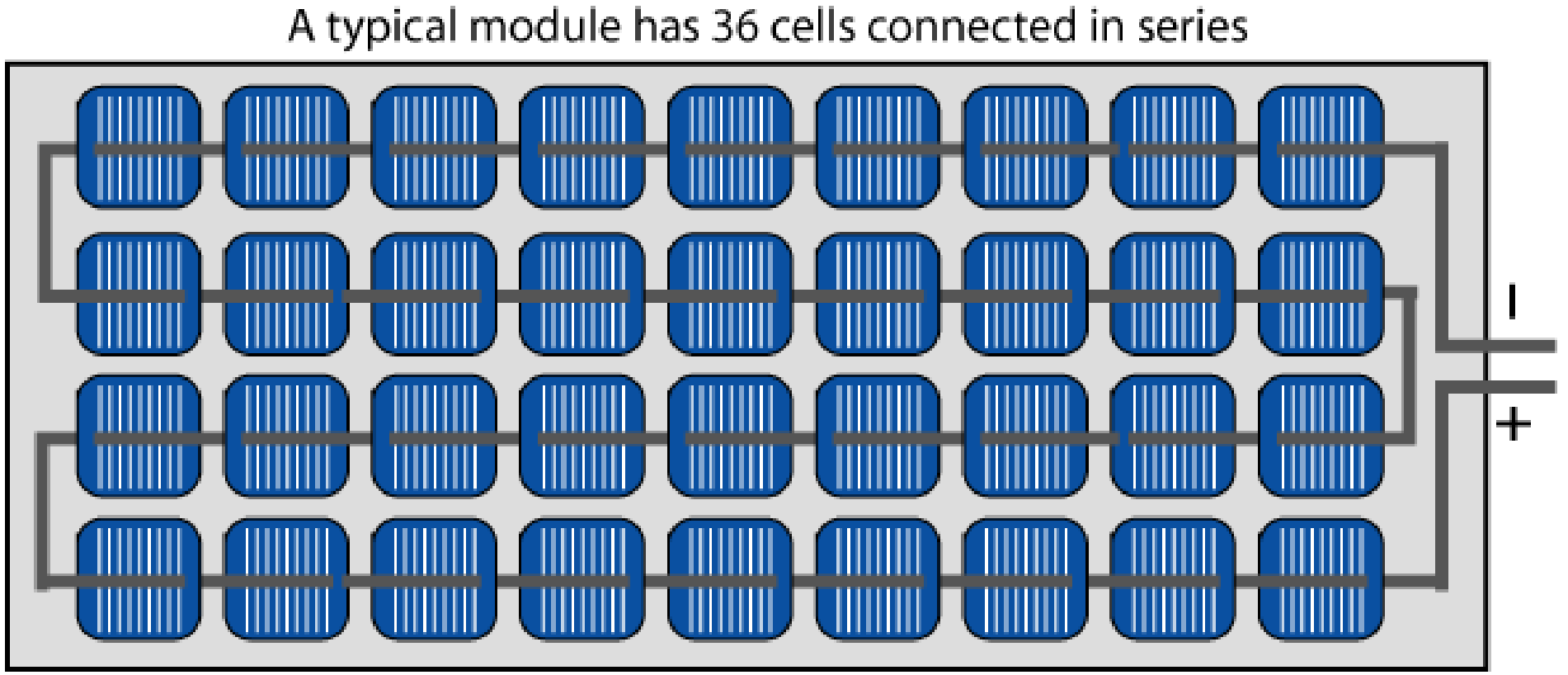
Battery Voltage	Corresponding module voltage at MPP conditions
12	15
24	30
36	45
48	60

How many cells in a module?

- For Si cells, Vmpp = 0.5 V at STC
- Loss of voltage at higher temperatures and encapsulation = 0.08V
- Available cell voltage Vmpp = Vmpp (STC) – Loss = 0.5 – 0.08 = 0.42V

Thus, required no. of cells in a module = Module voltage / Vm
= 15 V / 0.42
= 35.71
~ 36 cells

How many cells in a module?



Nominal Operating Cell Temperature (NOCT)

NOCT is Cell Temperature in a module under the below conditions:

1. Irradiance on cell surface = 800 W/m^2
2. Air Temperature = 20°C
3. Wind Velocity = 1 m/s
4. Mounting = open back side.

NOCT is typically 47ºC ± 2ºC

Significance of NOCT

- The lower the NOCT, the more efficient the panel is in high temperatures
- Typical NOCT in the market is 46 - 48ºC
- NOCT of 42ºC – Very good
- NOCT of 50ºC – Very poor

Types of solar panels - Monocrystalline

Advantages

- Have highest efficiency (15-20%)
- Are space-efficient.
- Durability is highest
- Tend to perform better at low-light conditions.

Disadvantages

- Most expensive
- Due to the Octagonal shape, not all of the incident light is captured

Types of solar panels - Polycrystalline

Advantages

- Manufacturing process is simpler and costs less. The amount of waste silicon is less
- Efficiency is typically 13-16%
- Due to rectangular shape, most of the incident light is captured

Disadvantages

- Lower space-efficiency

Types of solar panels – Thin Film

Advantages

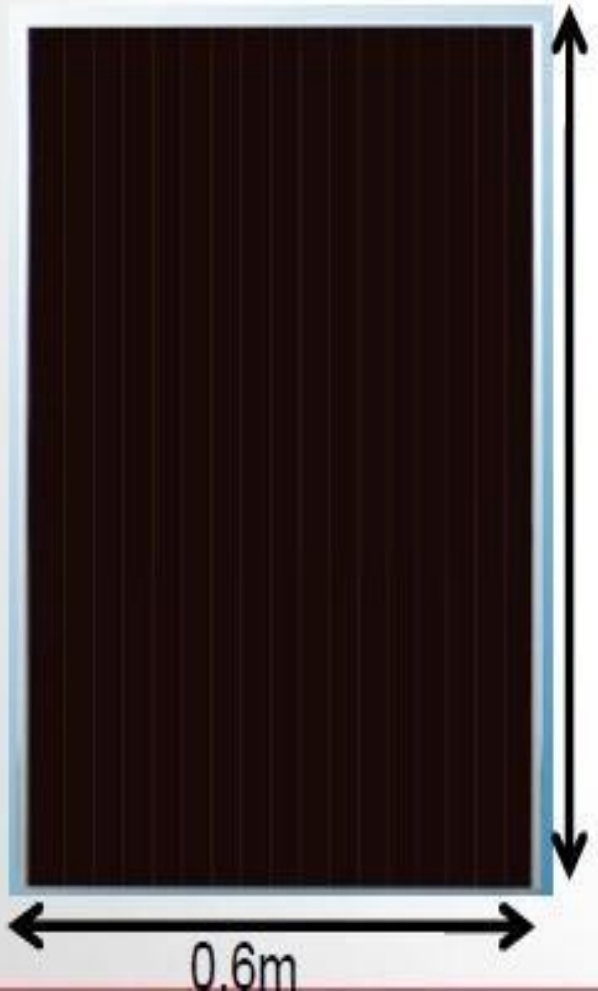
- Mass-production is simple
- Least cost
- Can be made flexible
- ***High temperatures and shading have less impact***
- Aesthetically pleasing

Disadvantages

- Least efficient (7-13%)
- Least space-efficiency
- Tend to degrade faster and have shorter warranty

Thin Film

Tech: a-Si
Temp. Coeff: -0.21%/°C



Weight : 18kg
Watts: 85Wp
Vmpp: 87.5V
Impp: 0.9A
efficiency: 8%

1.2m

0.6m

Crystalline

Tech: µc-Si
Temp. Coeff: -0.43%/°C

Weight : 20kg
Watts: 225Wp
Vmpp: 29.6V
Impp: 7.6A
efficiency: 13%

1.66m

0.99m

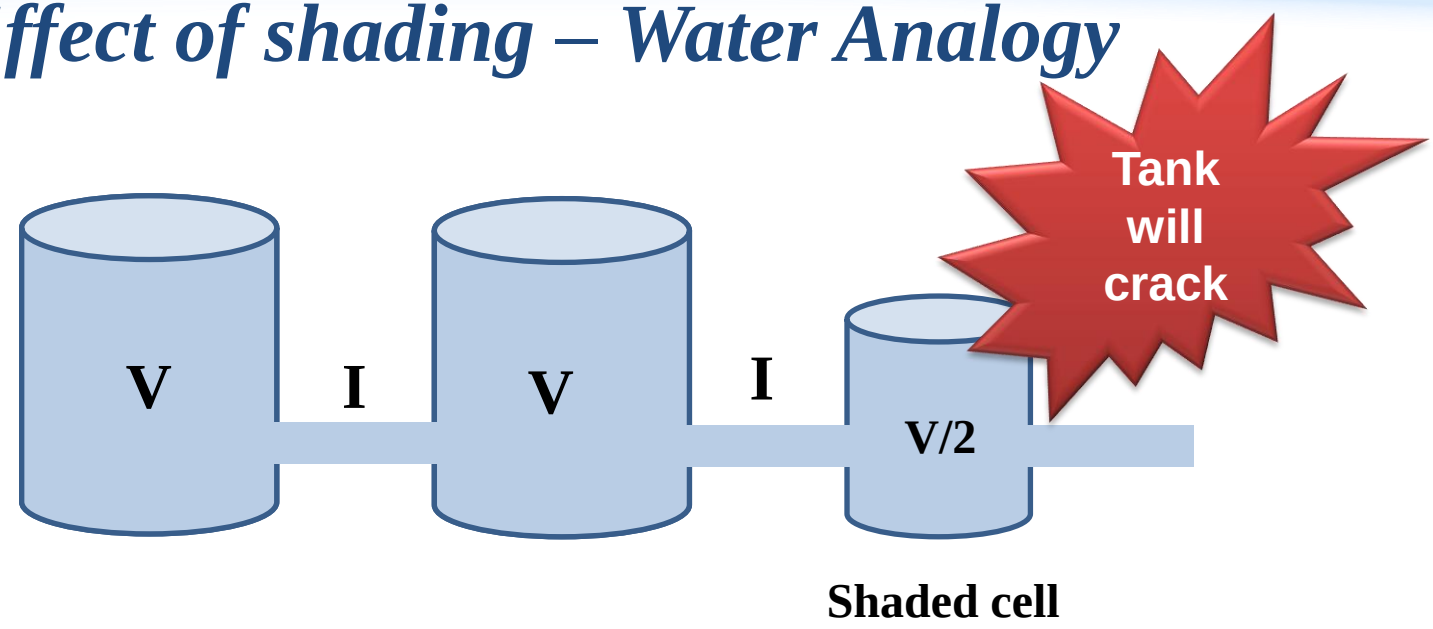
Thin Film	Crystalline
❑ Cell Thickness 0.3 - 0.7 µm	❑ Cell Thickness 180 - 200 µm
❑ Efficiency varies from 5.5 - 12%	❑ Efficiency varies from 12 - 18%
❑ Reliability, limited track record	❑ Proven reliability
❑ Both direct and diffuse light	❑ Direct light preferred, but diffuse light can be used
❑ Temperature Coefficient - 0.21%/°C	❑ Temperature Coefficient - 0.4%/°C
❑ Land 7.5 to 10 acres	❑ Land 3.5 to 4.5 acres
❑ Not economical with tracker	❑ Tracker advantage

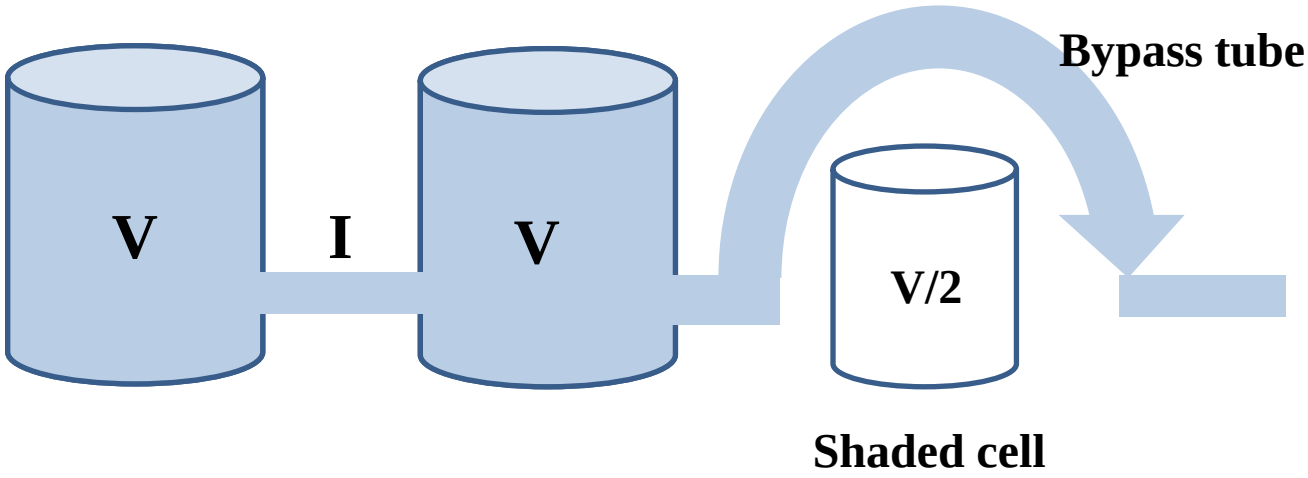
Panel Issues

Effect of shading on modules

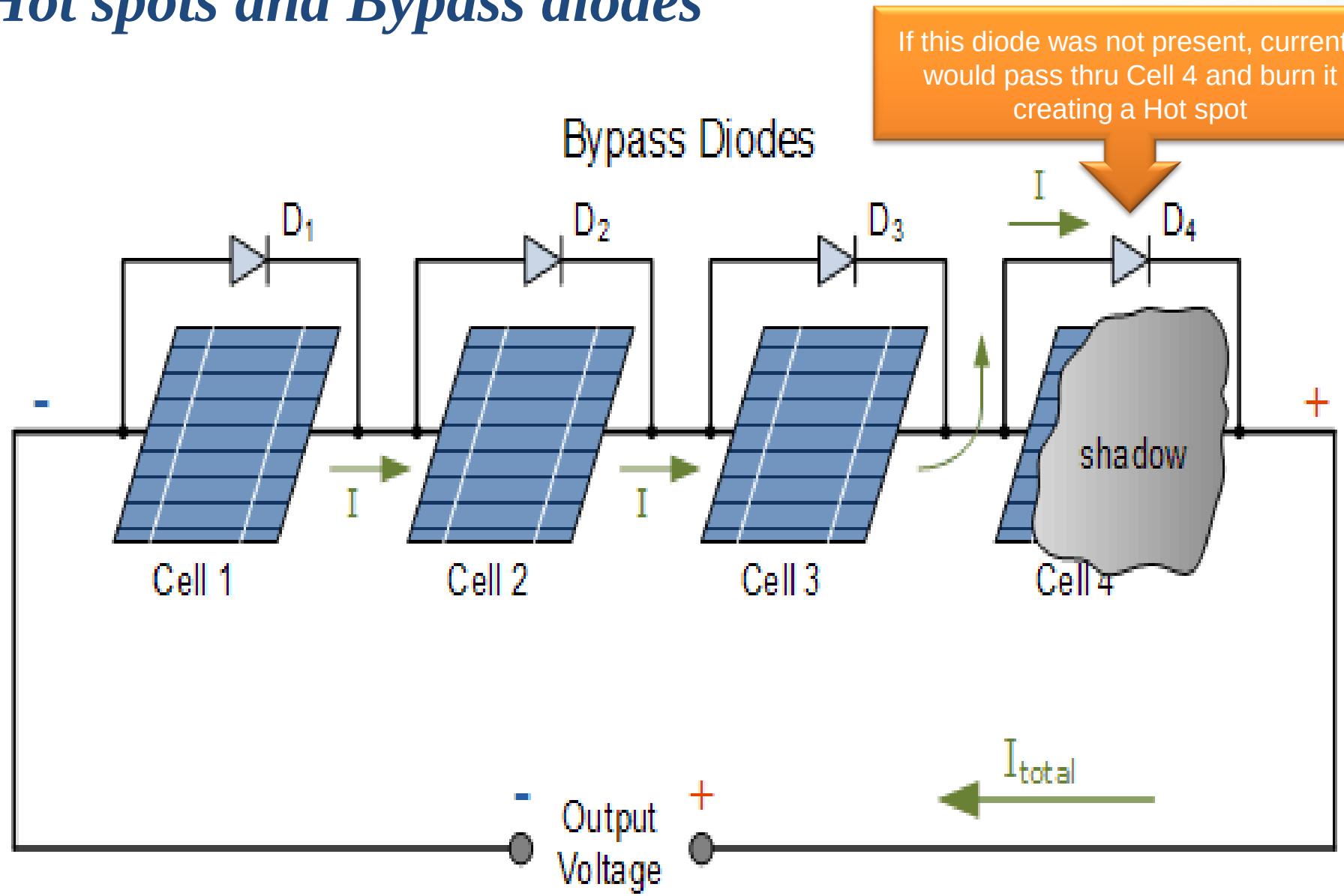
Figure 1: A multi-c-Si PV module which is shaded (red outline) from building services engineering.

Effect of shading – Water Analogy



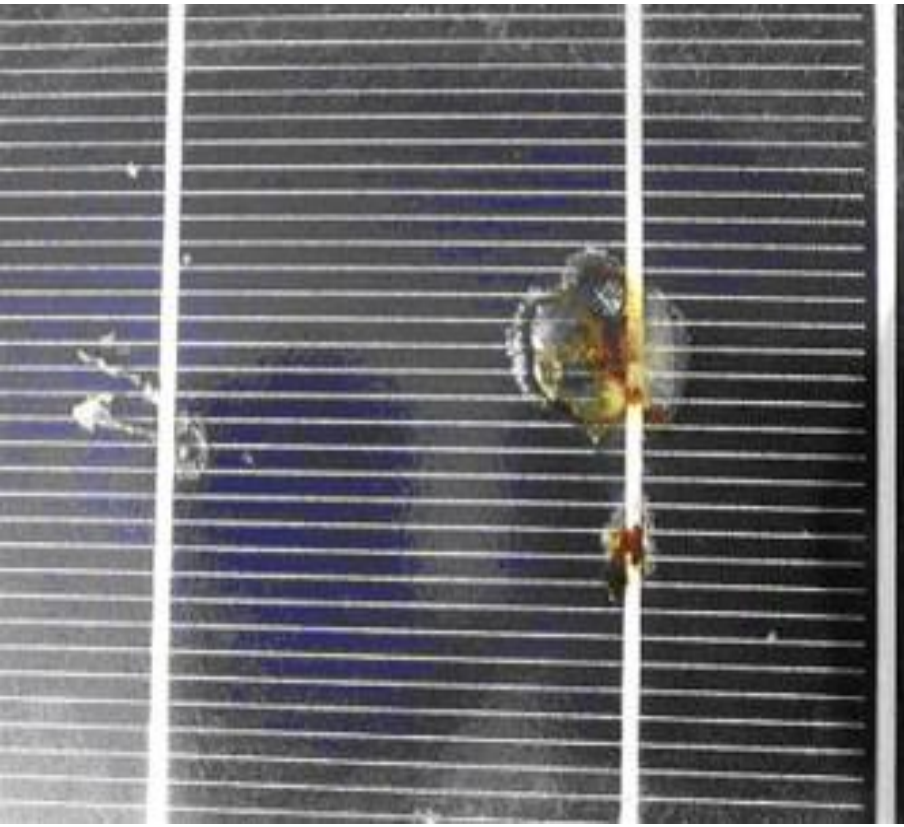


Hot spots and Bypass diodes



Hot spots and Bypass diodes

Cell Damage



Glass damage

And in extreme cases…

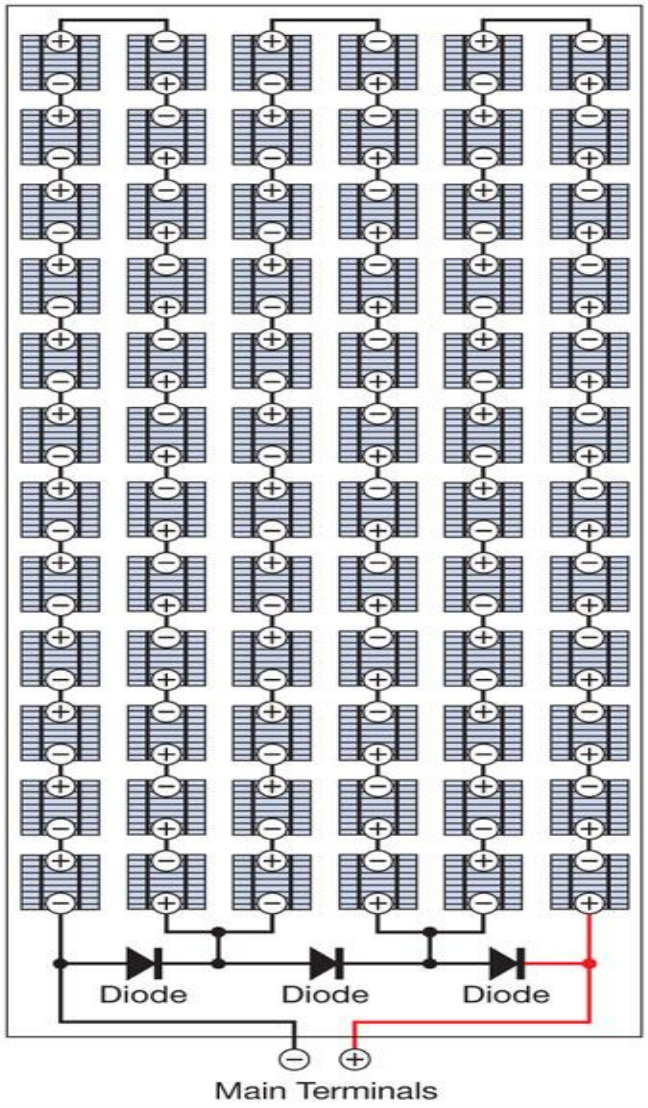
Hot spots and Bypass diodes

Bypass diodes

Ideally there should be a bypass diode for each cell.

However, it is not practical and also would increase the cost. So the next best option is…

Bypass diodes working with Video

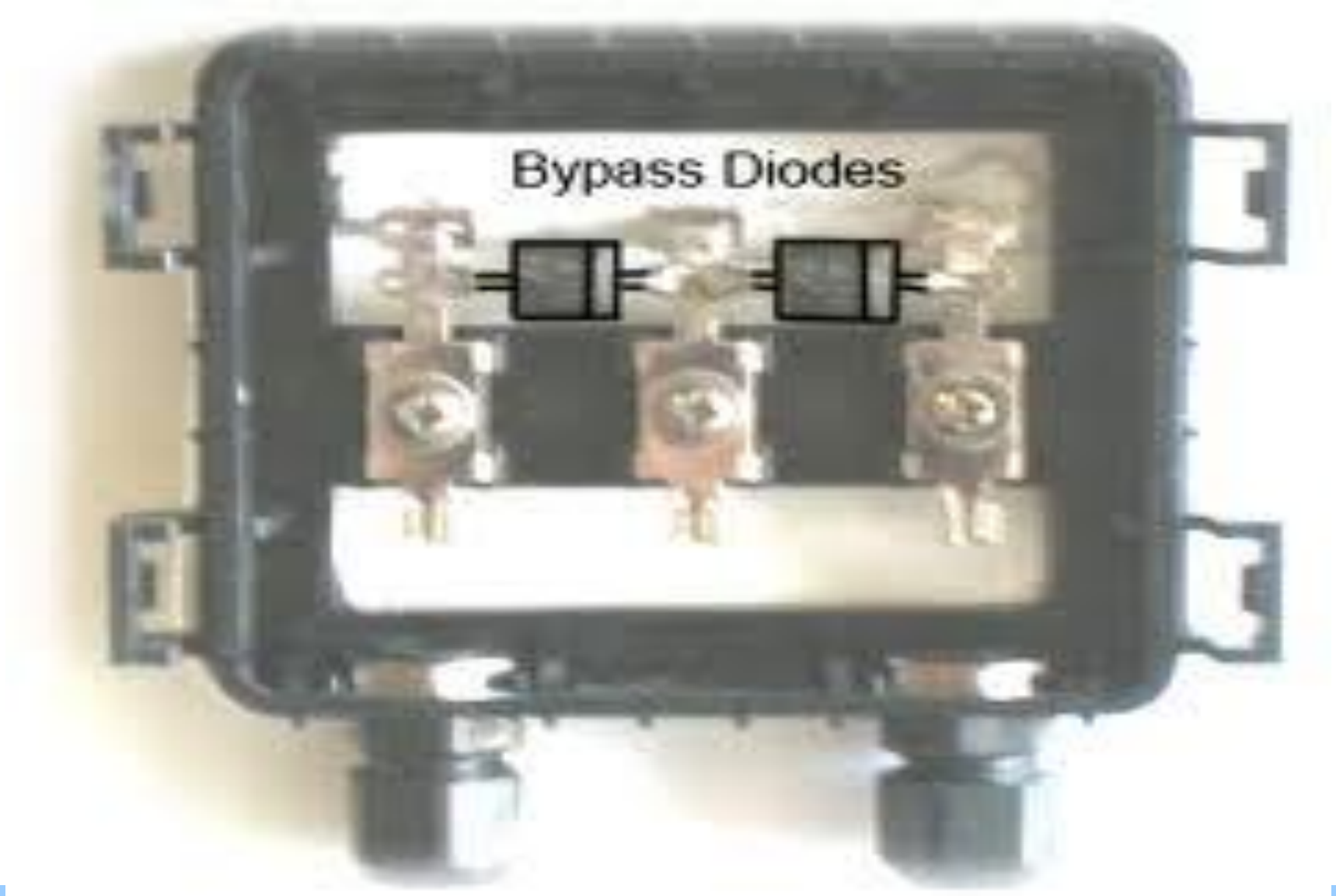


Circuit Theory

- **No cells shaded:** Current passes through all cells. No current passes through bypass diodes.
- **One cell shaded:** Current bypasses the 24-cell series string and passes through the bypass diode in parallel with that string.
- **One row of cells shaded:** Current bypasses three 24-cell series strings and passes through three bypass diodes.
- **One column of cells shaded:** Current bypasses the 24-cell series string and passes through the bypass diode in parallel with that string.
- **Entire module shaded:** Current bypasses all cells and passes through three bypass diodes.

72-cell PV circuit A bypass diode is typically installed in parallel with every 24 cells.

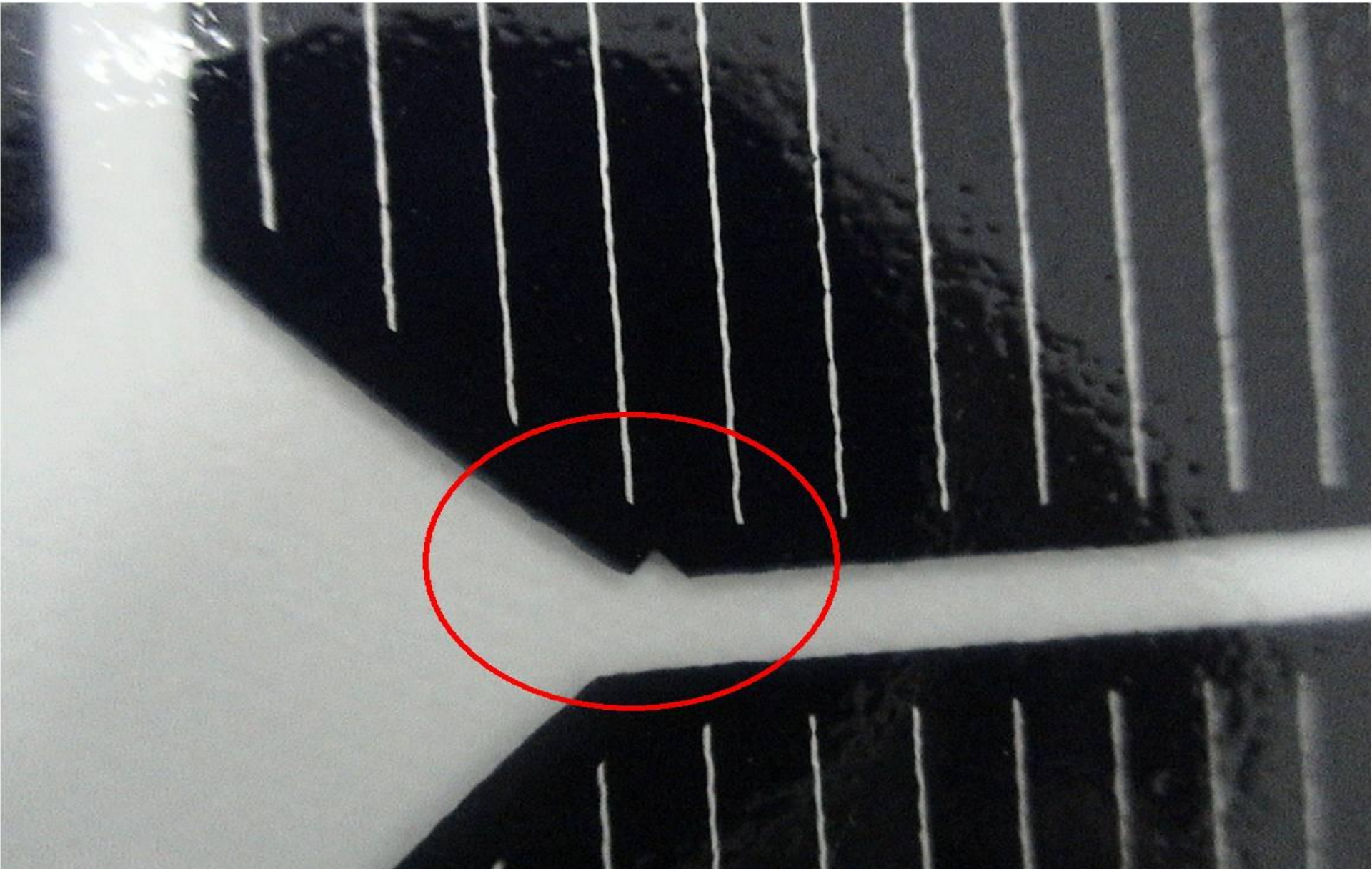
Bypass diodes in Junction Box



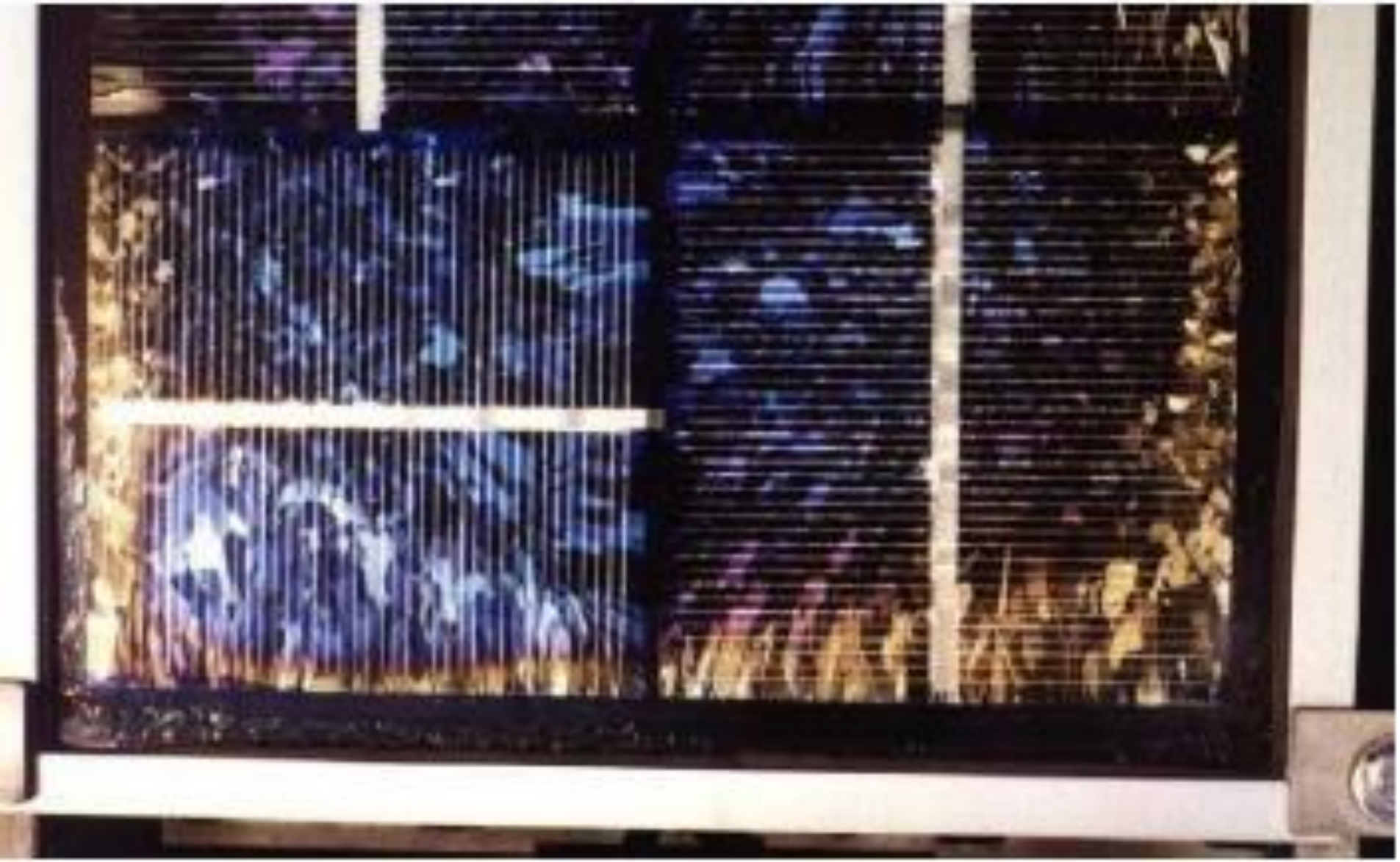
Delamination

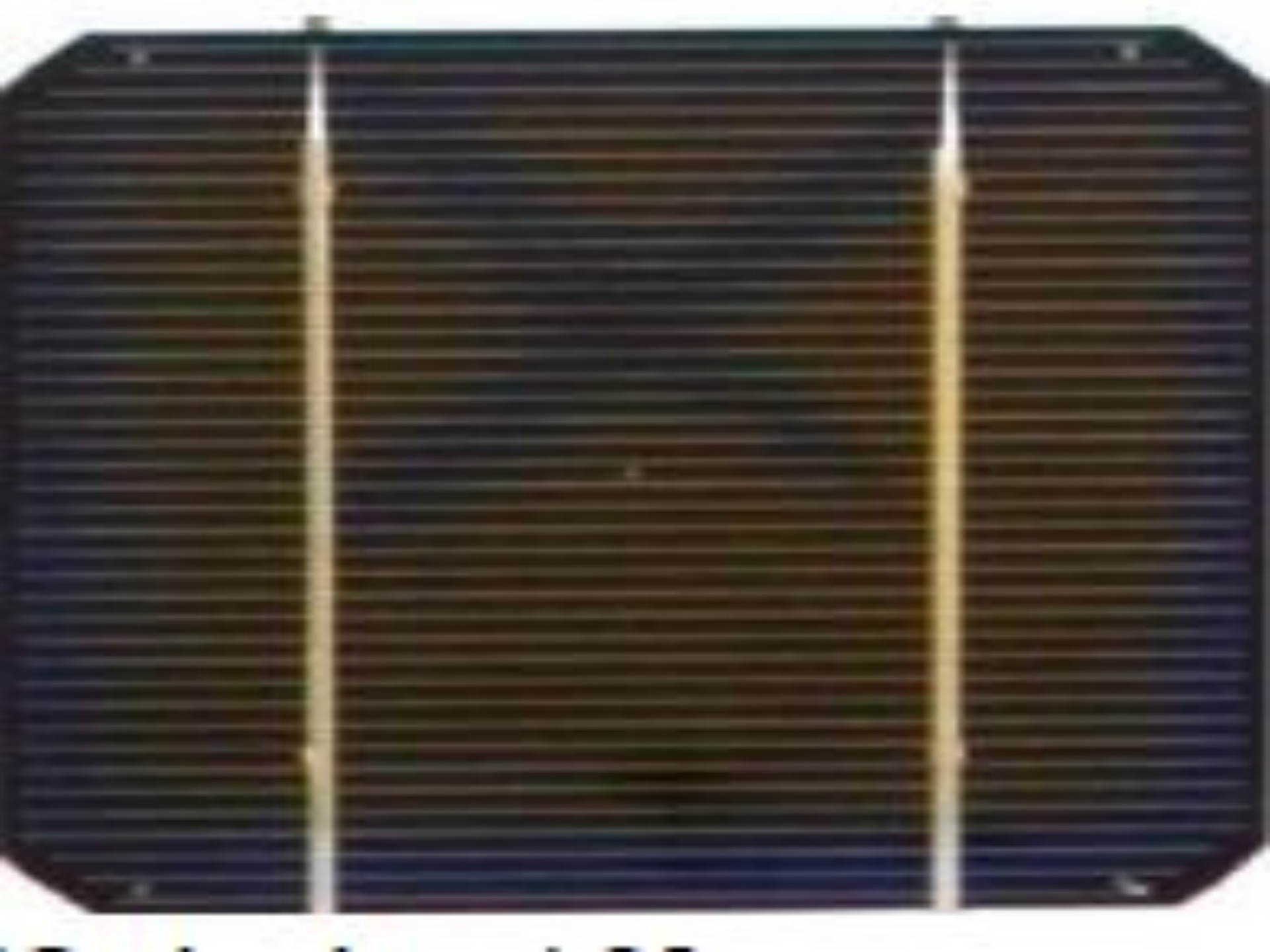
Delamination of the EVA: White ("milky") parts. In this case around the busbars.

Cell cracks and micro cracks



Browning of the EVA sheet due to heating of cell

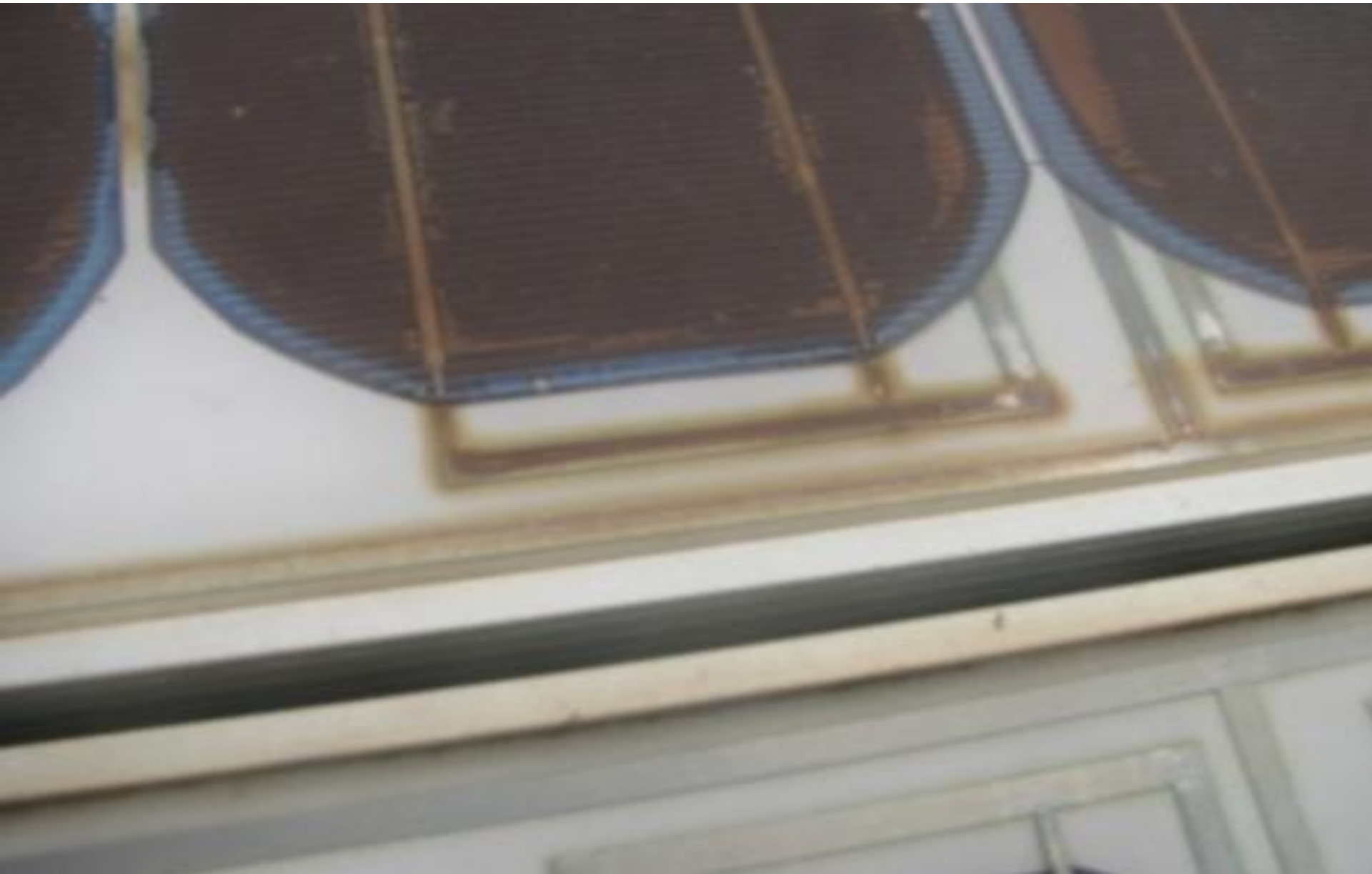




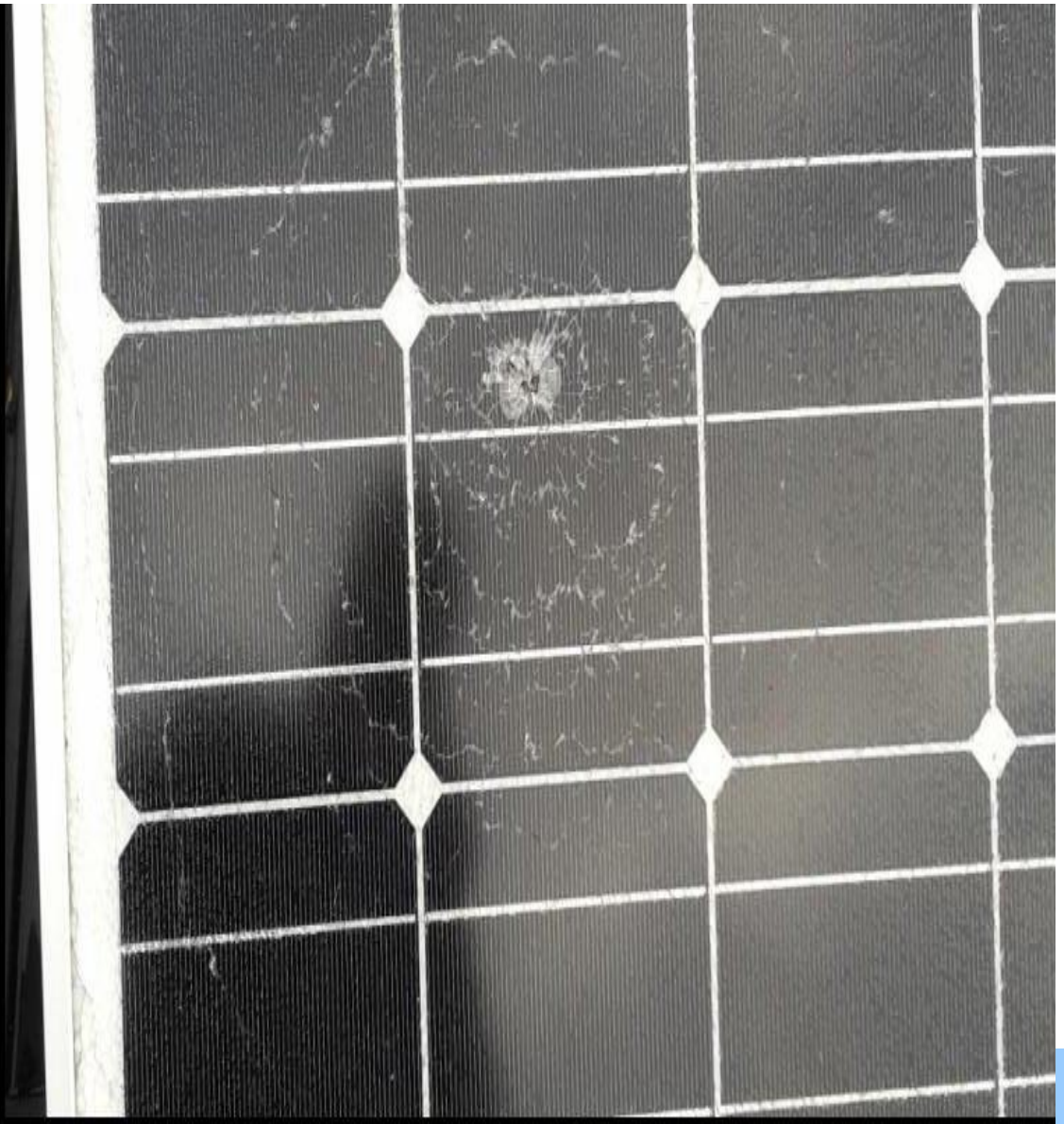
Corrosion on Busbars

Corrosion on String Interconnect

Corrosion on String Interconnect



Glass Breaks

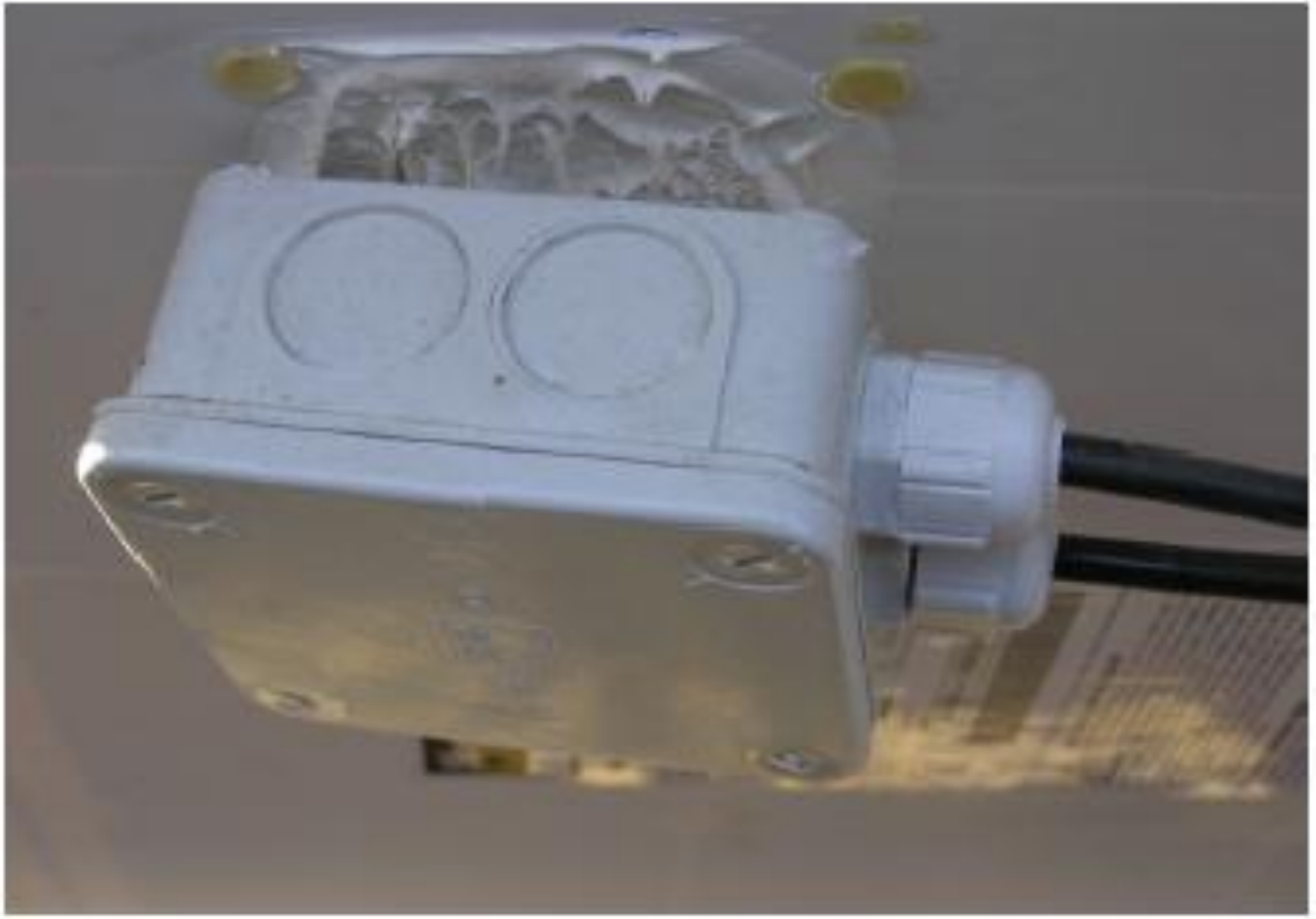


Snail Trails

Discoloration of the silver paste and it appears along the cell cracks

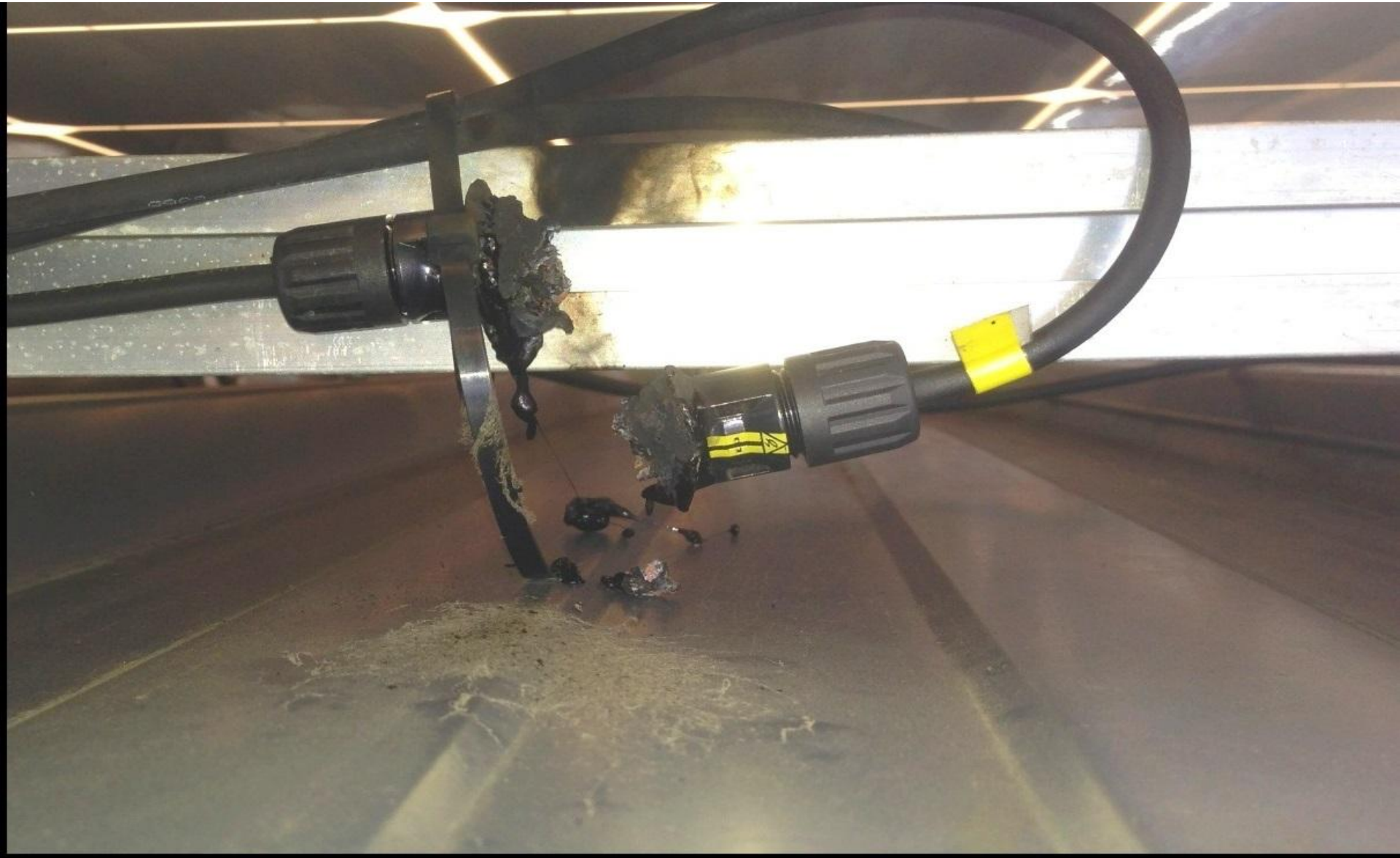
Corrosion in Terminals

Jbox – adhesion breakdown



Low Quality Cables

Defective MC4 Connectors



Quality of Modules

Module Quality Test - Standard

PV CYCLE

ISO 9001 DNV REGISTERED

ISO 14001 DNV REGISTERED

OHSAS 18001 DNV CERTIFIED FIRM

CE

www.tuv.com

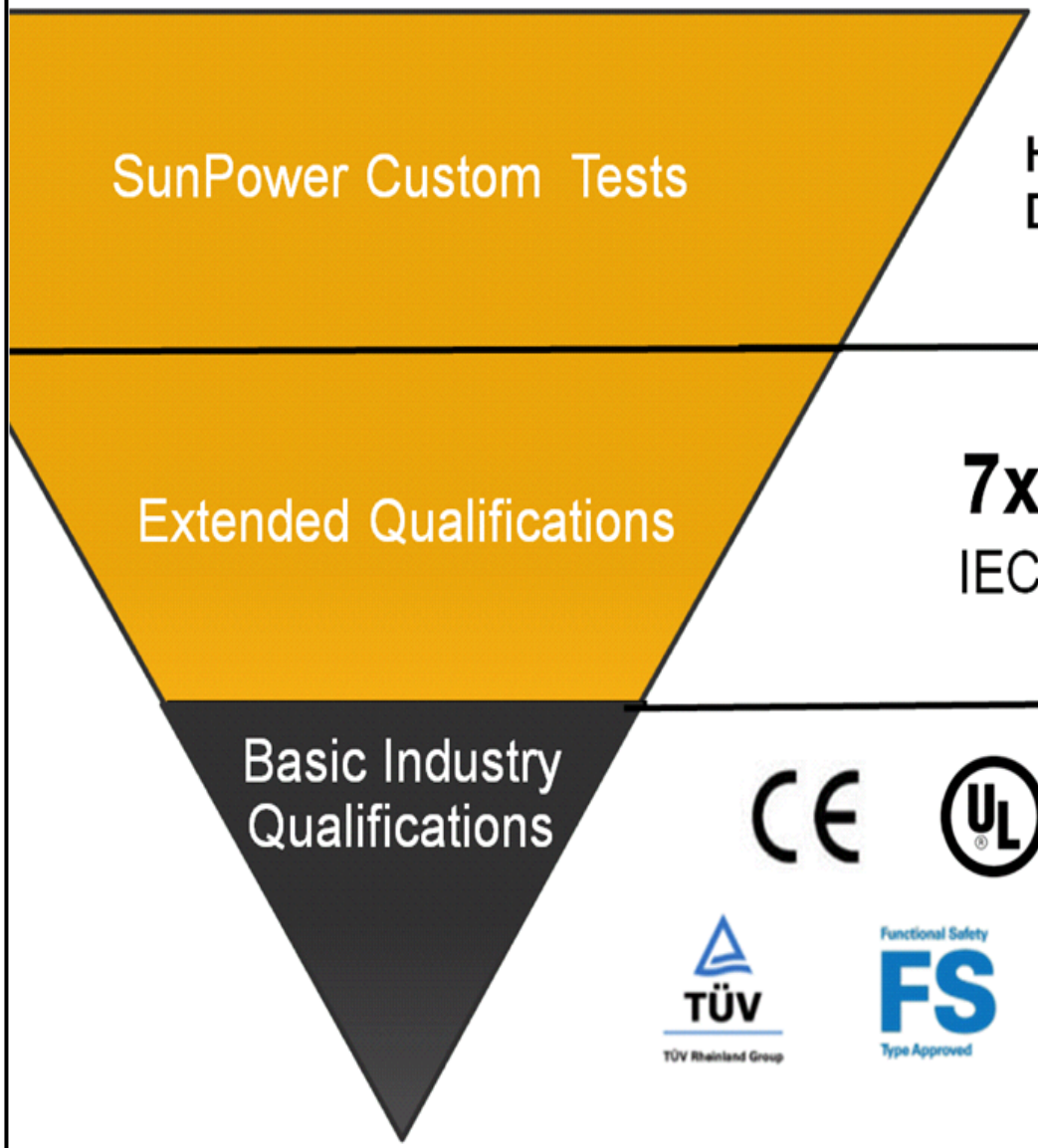
TÜVRheinland

ID. 000025744

- Qualified, IEC 61215
- Safety tested, IEC 61730
- Periodic Inspection

Clean Energy Council

Module Quality Test

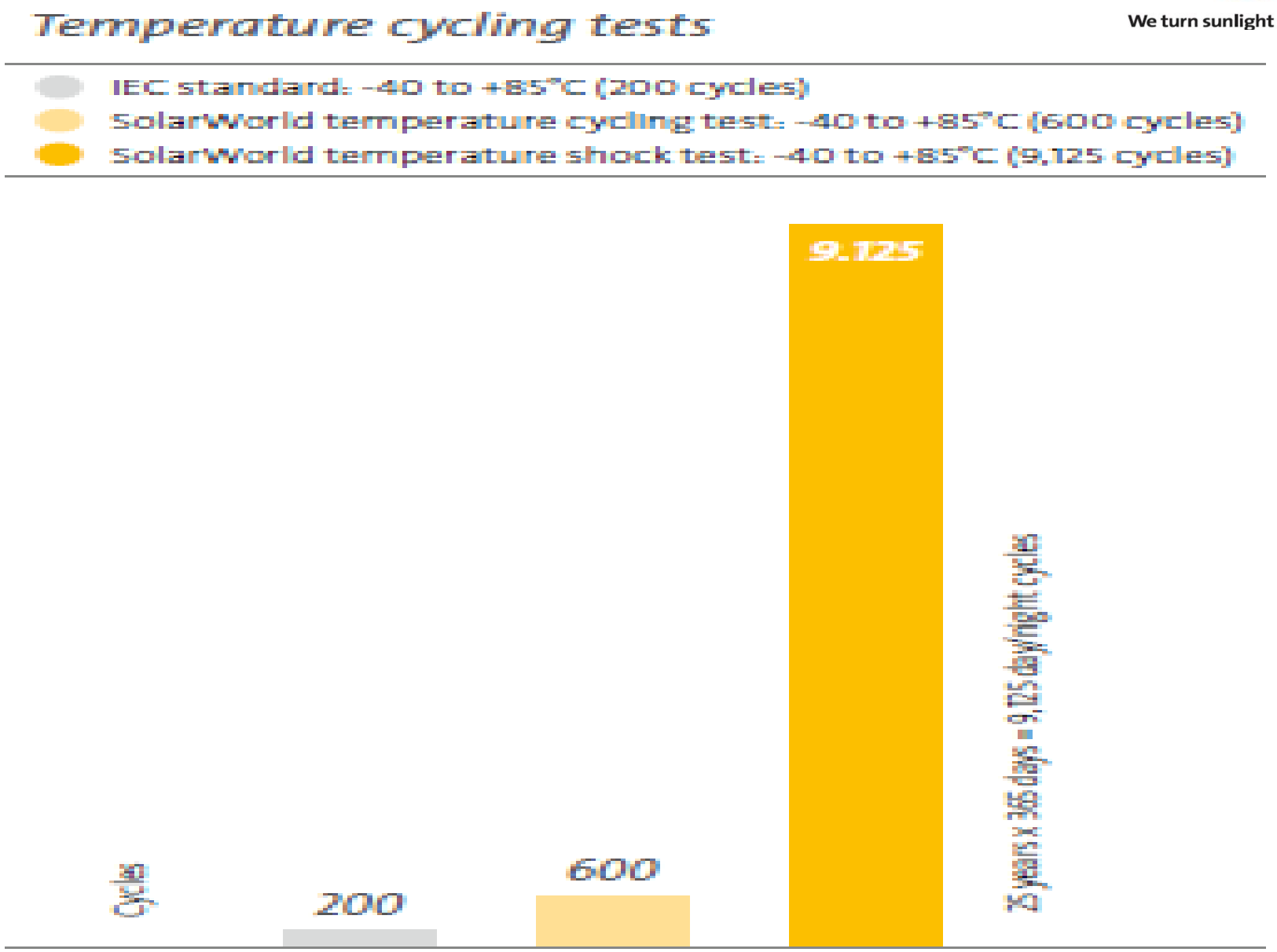


Highly Accelerated Life Test (HALT)
Design & Manufacturing Testing

7x IEC **12x** ISO **5x** UL

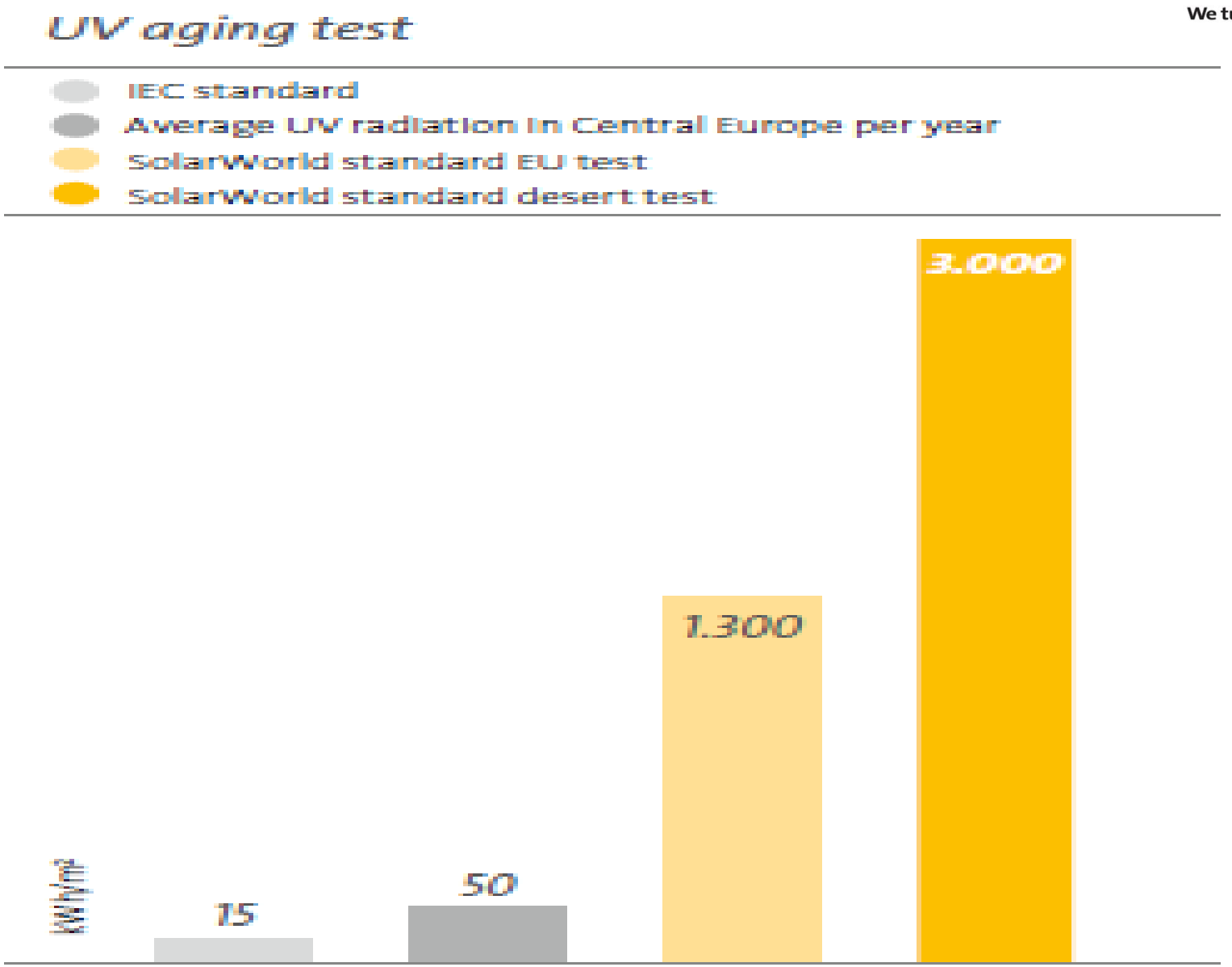
Module Quality Test

SolarWorld
We turn sunlight into power.



Module Quality Test

SolarWorld
We turn sunlight into power.



Module Quality Test

SOLARWORLD

We turn sunlight into power.

SGS CORROSIVE GAS (NH_3) RESISTANT

DLG FOKUS TEST 06/10 ammonia resistance

TOP QUALITY SOLARWORLD

www.tuv.com TÜVRheinland® ID: 0000022848 Power controlled

c UL us LISTED 1) 10SE Photovoltaic Module / Panel

1) Depending on the market

VDE

CE

VDE GS

www.tuv.com TÜV TÜV Rheinland ID:0000000001

- Qualified, IEC61215
- Safety tested, IEC61730
- Periodic Inspection
- Power controlled

ÖKO-TEST LIFE WORTH LIVING SolarWorld Sunmodule Plus SW 235 poly excellent issue 05/2010

Quality modules made in Germany

MADE IN USA

Module Quality Test

SOLARWORLD

STANDARDS AND DIRECTIVES

SolarWorld is certified according to:

- ISO 9001: Quality management systems
- ISO 14001: Environment management systems
- BS OHSAS 18001: Occupational health and safety management systems

Our products are certified according to:

- VDE certified safety: Sunmodule Plus in combination with the Sunfix Plus frame
- DIN 4102-1: Low flammability (category B1)
- IEC 61701: Salt mist corrosion testing of photovoltaic panels
- IEC 60068-2-60: Ammonia resistance
- IEC 61215: Crystalline silicon terrestrial photovoltaic (PV) panels—Design qualification and type approval
- IEC 61730: Photovoltaic panel safety qualification—Part 1: Requirements for construction
- UL 1703: Flat-plate photovoltaic panels

Our products are manufactured in accordance with:

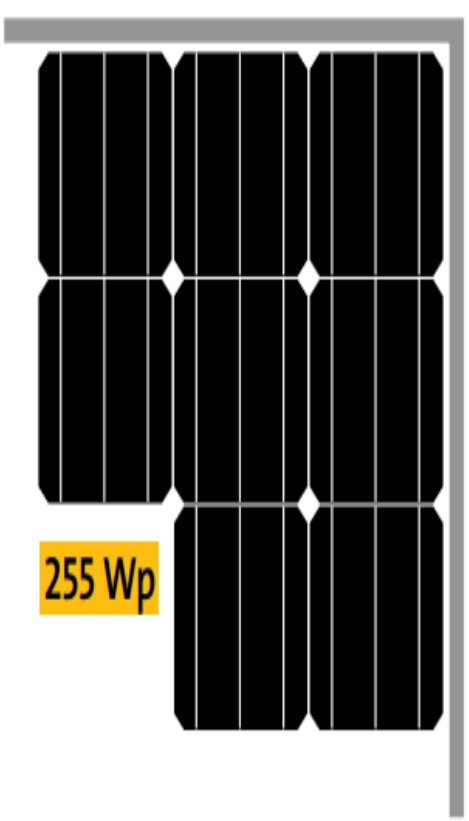
- ISO 60904 standard series: Photovoltaic devices

Solarworld Sunmodule Protect Panels

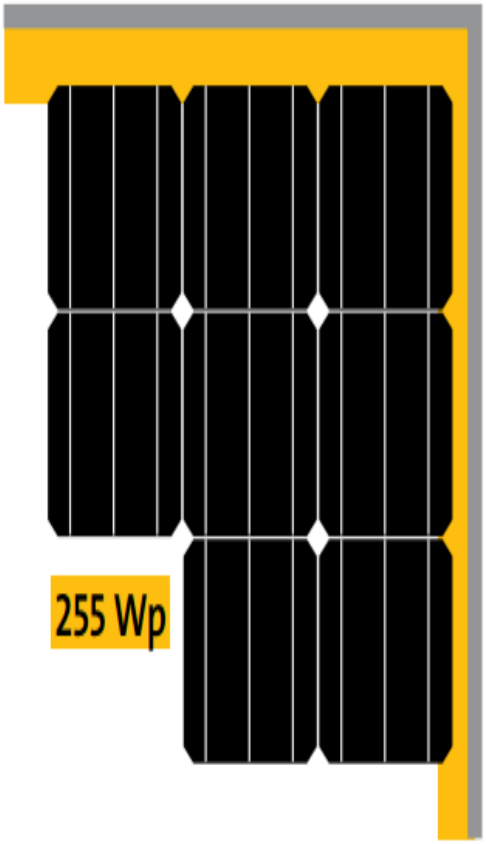
SOLARWORLD
We turn sunlight into power.

Sometimes two modules with the same nominal power rating can have different efficiency values. The only reason being the design and corresponding size of the modules may vary.

A difference of 2.5 cm or 1" in each direction of the module can change the efficiency value of a module 0.63 percentage points. (Based on example of 255 Wp modules).



Competitor's module



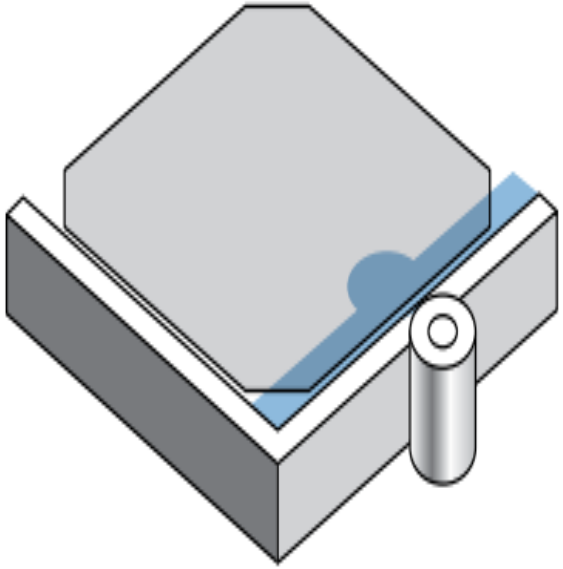
SolarWorld module

Solarworld Sunmodule Protect Panels

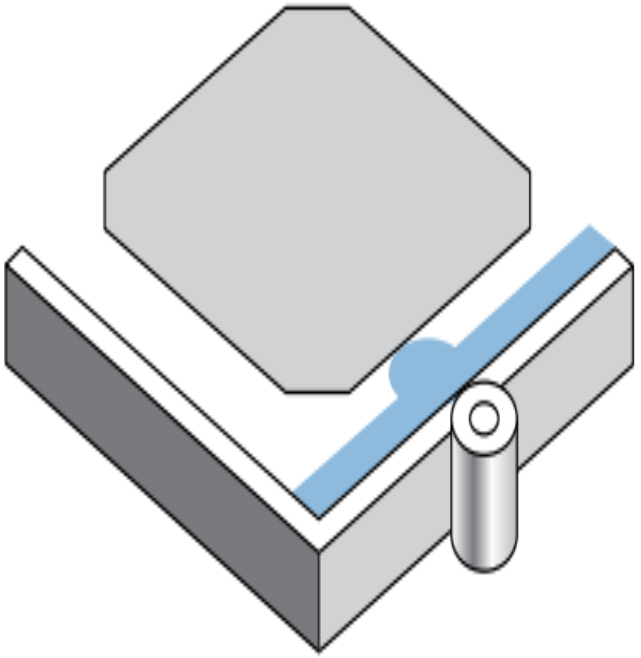
SolarWorld
We turn sunlight into power.

Mounting hardware used to affix the module to the mounting system can cause shading of the outer cells if they are placed close to the frame.

Mounting hardware can cause shadowing



SolarWorld modules avoid shadowing issues

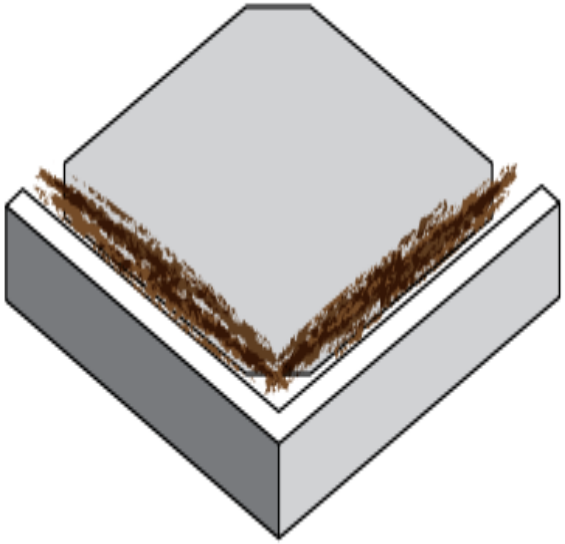


Solarworld Sunmodule Protect Panels

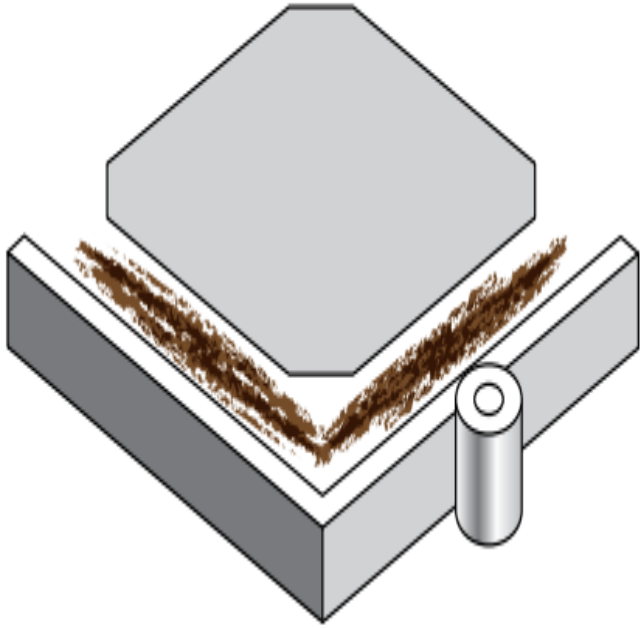
SolarWorld
We turn sunlight into power.

Dirt and debris can build-up on modules along the frame of a module. This build-up can start to shade the outer cells if they are placed close to the frame. Shading of the cells can reduce the overall output of a module and affect the performance of a string of modules.

Soil and debris build up, shading cells



SolarWorld module cell spacing prevents soil shading

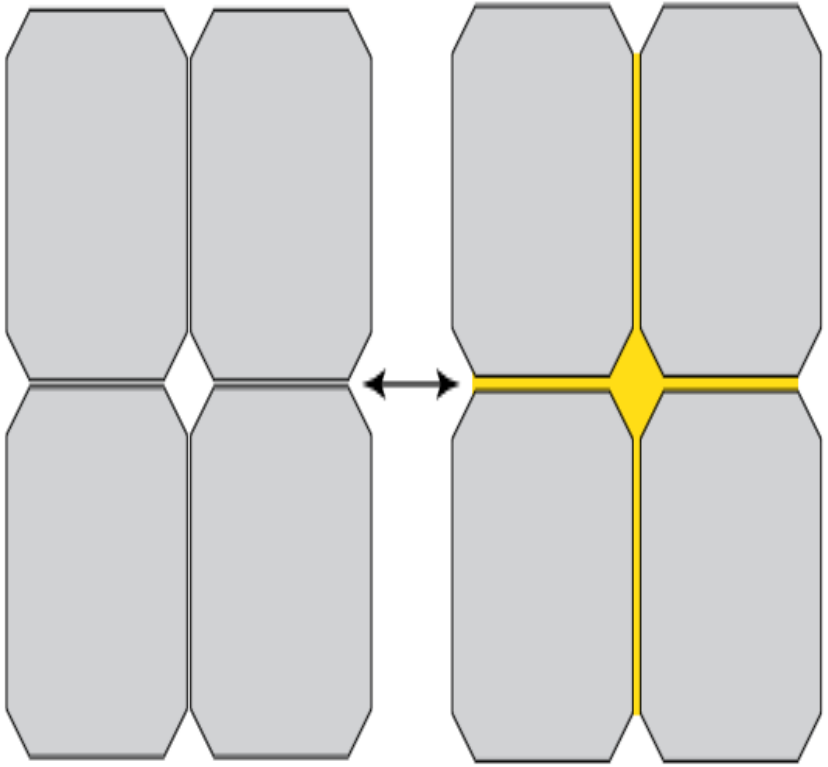


Solarworld Sunmodule Protect Panels

SOLARWORLD

We turn sunlight into power.

The spacing of cells is optimized for light capture, energy production, and the expansion and contraction of the materials. These considerations provide for long-term, reliable performance.



Cell spacing is optimized for circuit design and energy output

Durability Tests

SolarWorld Sunmodule solar panels exceed international testing standards for proven quality

by SolarWorld USA

2 years ago • 120,922 views

From hail storms, to water exposure, to wind and snow loads, SolarWorld solar panels are designed, built, and tested to withstand ...

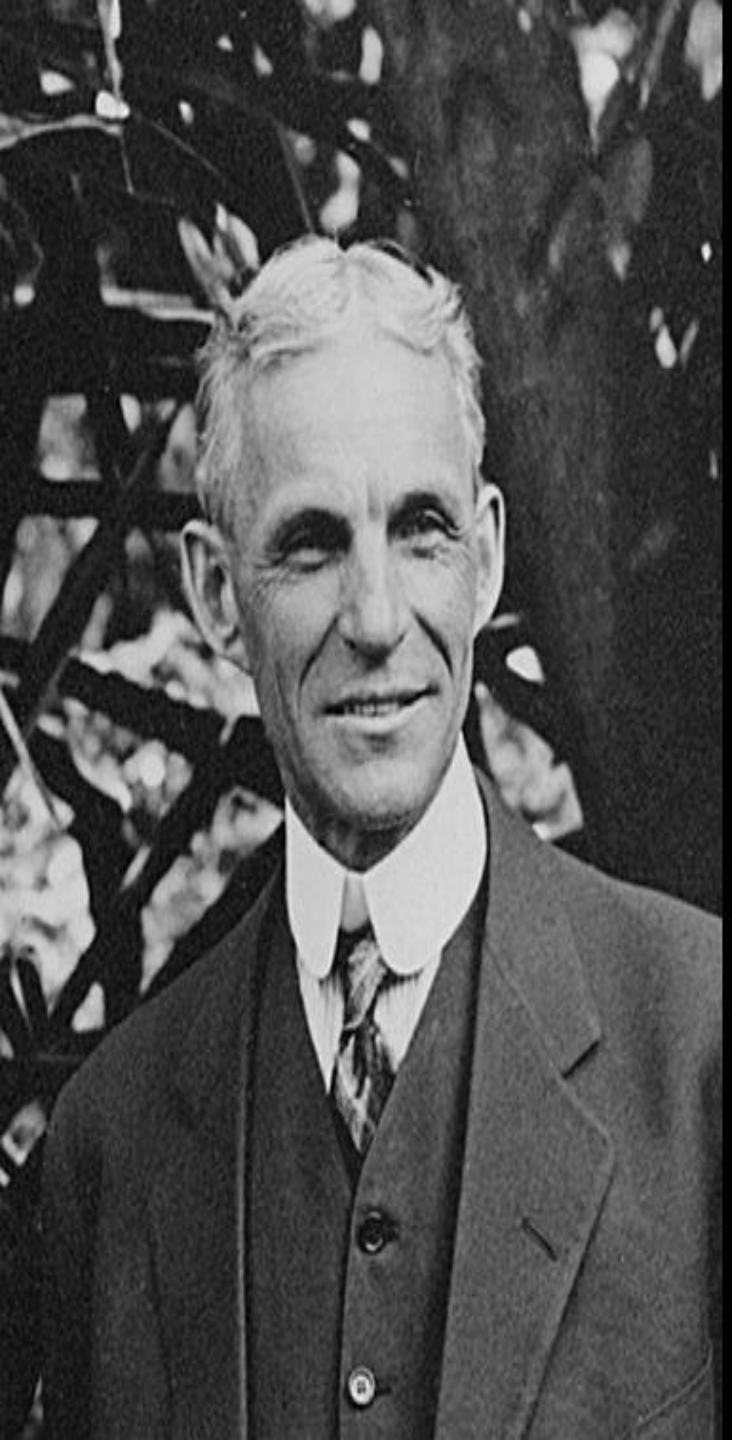
HD

LG Solar- Difference Is In The Details - YouTube

https://www.youtube.com/watch?v=ppKVFZg9_hY

Jan 31, 2012 - Uploaded by LG Benelux

LG Solar : Het bekende elektronicamerk LG introduceerde na 20 jaar research in 2008 haar eigen ...



Quality means doing it right when no one is looking.

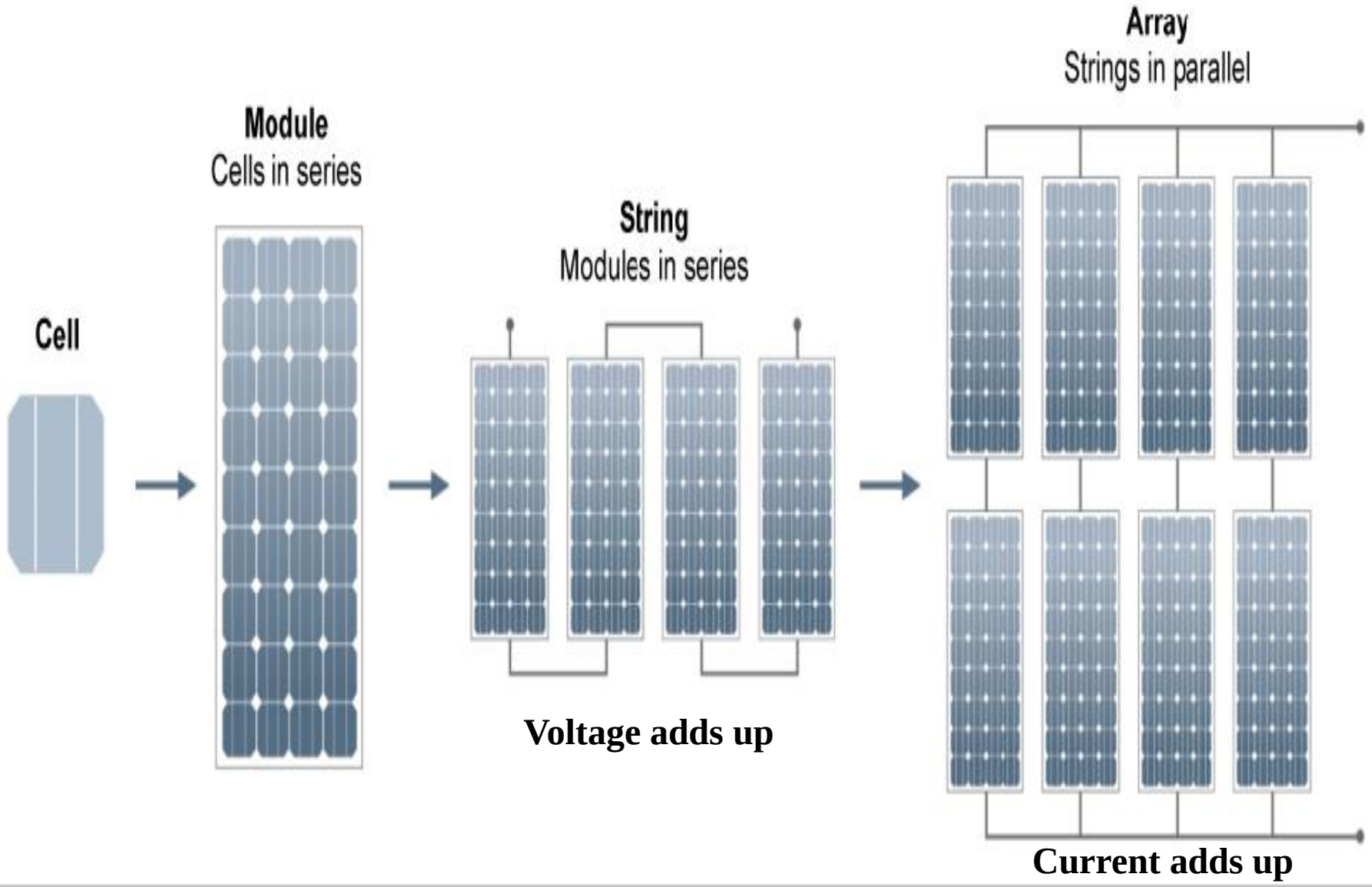
- Henry Ford

And letting others know about it later… ☺

- Venkat

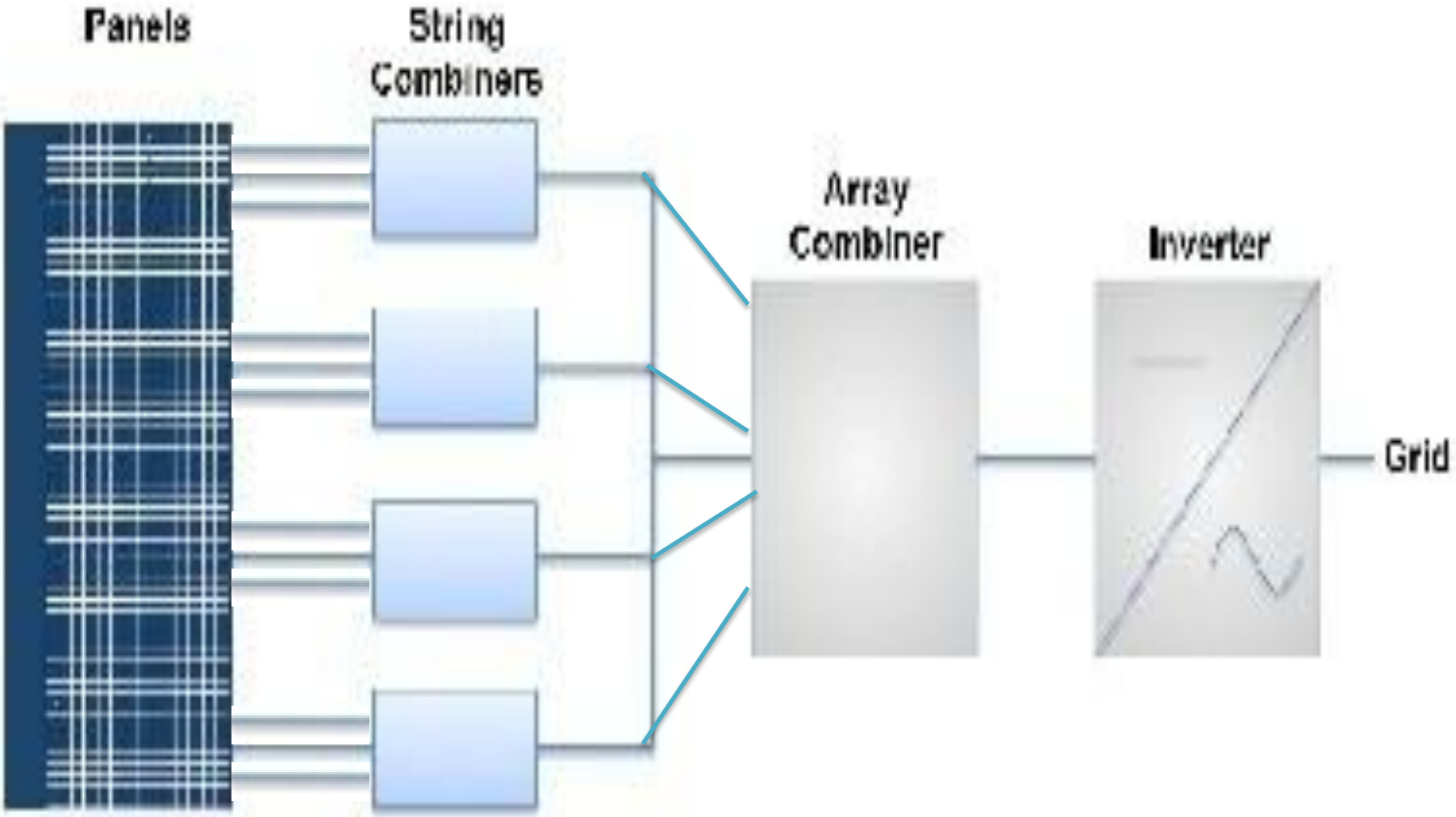
Solar Arrays

Strings and Arrays

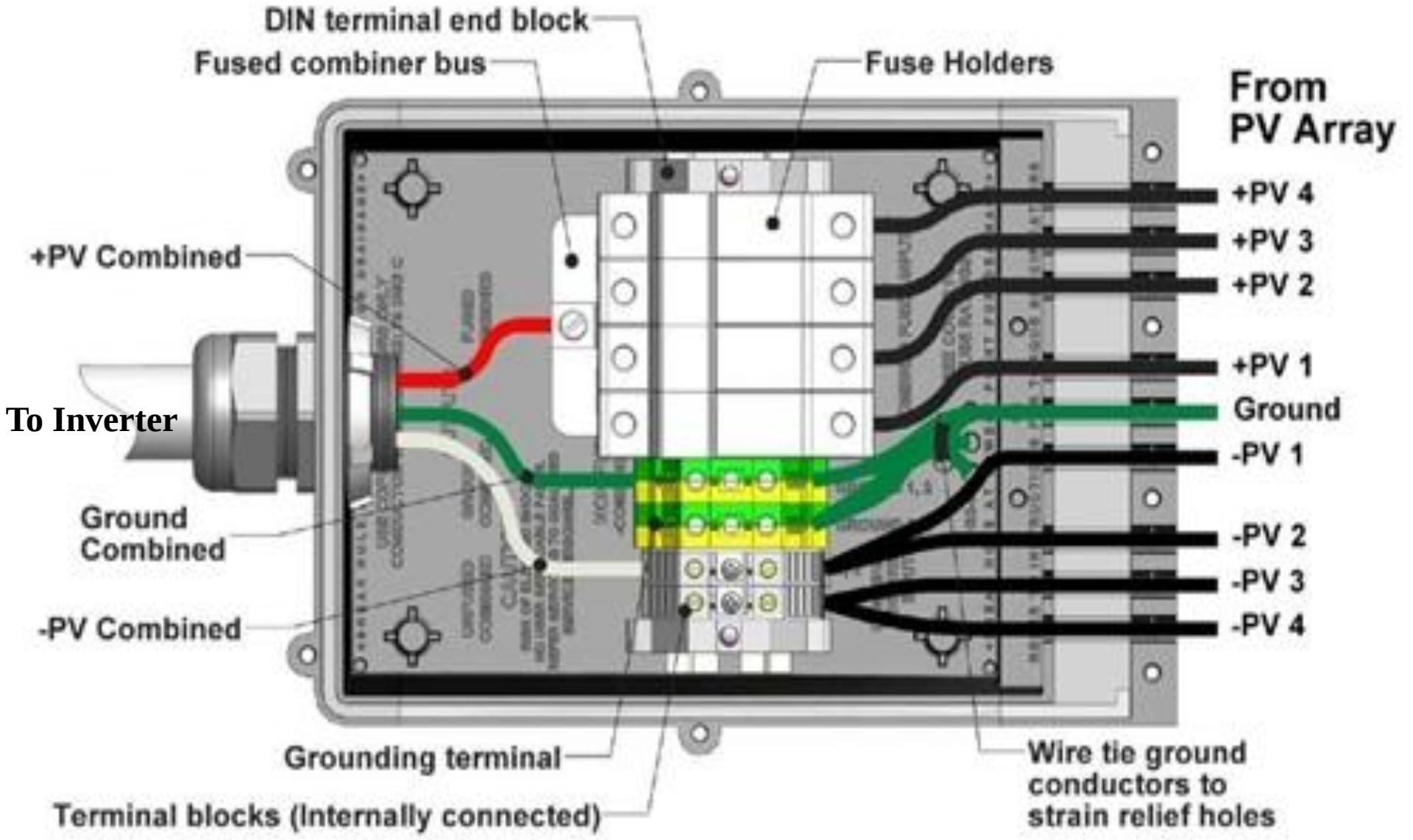


Strings and Arrays

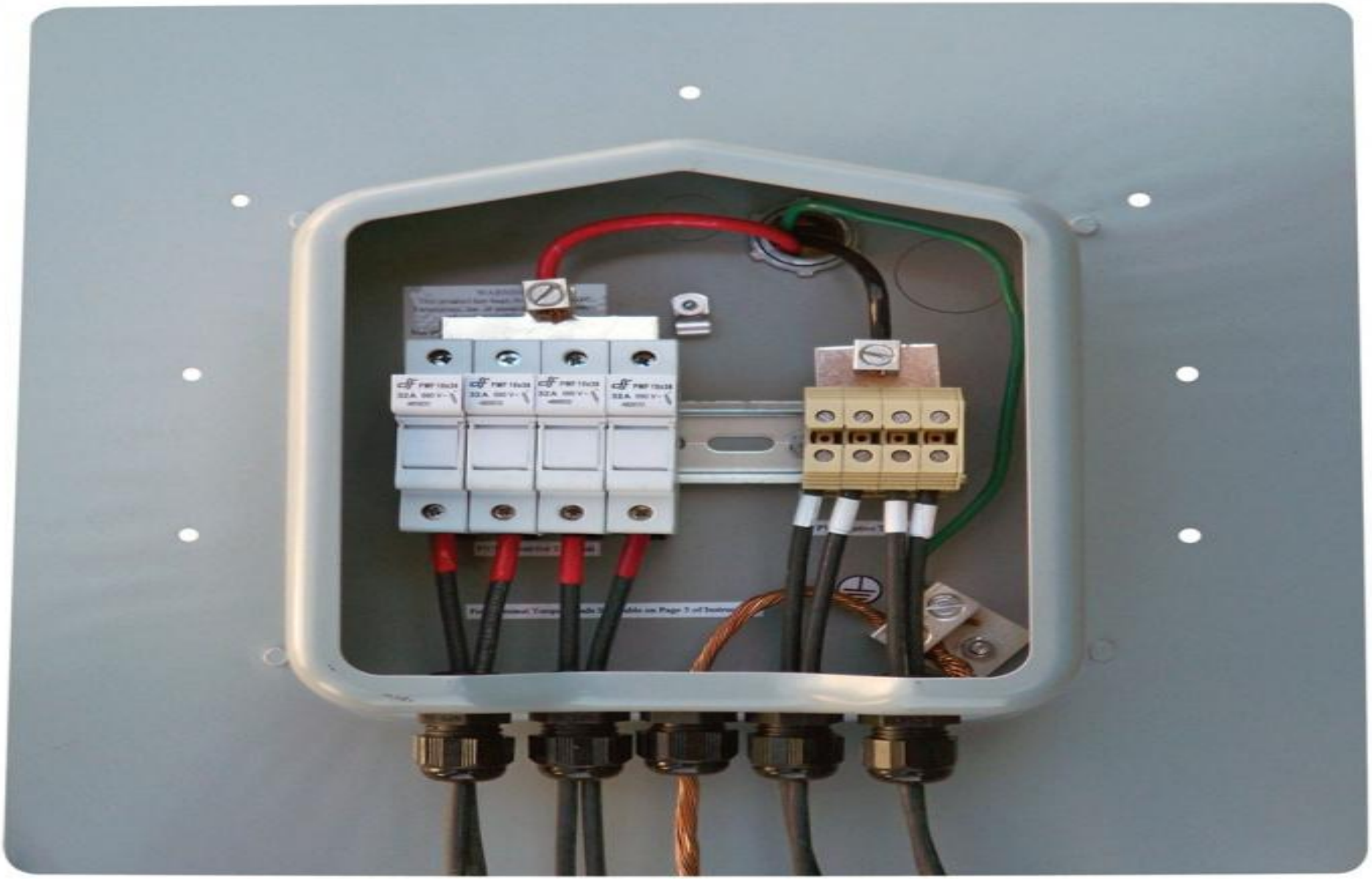
String and Array Combiner



String Combiner



String Combiner



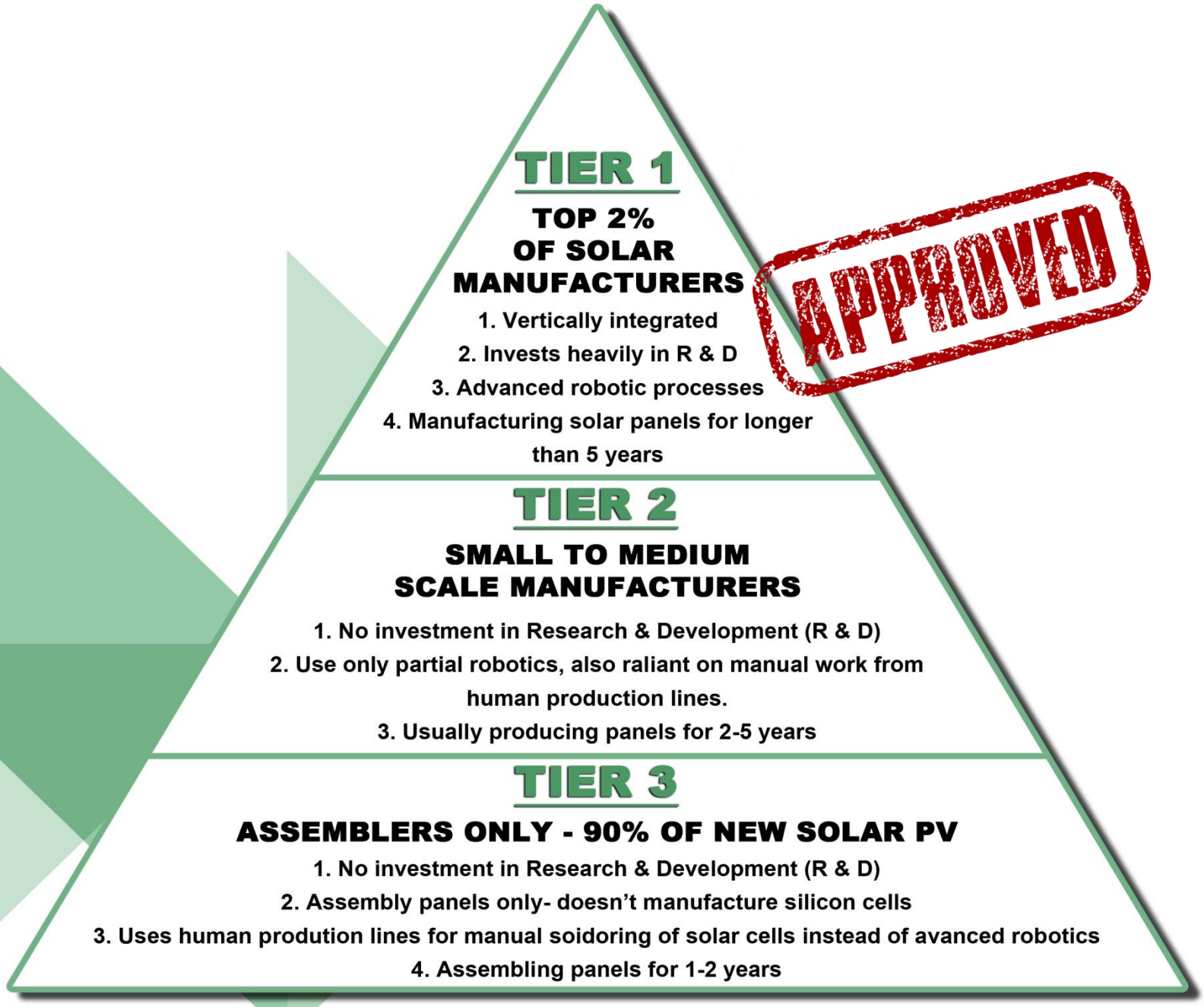
Key Performance Indicators

How to choose a solar panel?

Not All Solar Panels Are Equal

by Energy Matters

35,399 views


TIER 1
TOP 2%
OF SOLAR
MANUFACTURERS
1. Vertically integrated
2. Invests heavily in R & D
3. Advanced robotic processes
4. Manufacturing solar panels for longer than 5 years
APPROVED
TIER 2
SMALL TO MEDIUM
SCALE MANUFACTURERS
1. No investment in Research & Development (R & D)
2. Use only partial robotics, also raliant on manual work from human production lines.
3. Usually producing panels for 2-5 years
TIER 3
ASSEMBLERS ONLY - 90% OF NEW SOLAR PV
1. No investment in Research & Development (R & D)
2. Assembly panels only- doesn't manufacture silicon cells
3. Uses human prodution lines for manual soidoring of solar cells instead of avanced robotics
4. Assembling panels for 1-2 years

Bloomberg Solar PV Tier-I List

Bloomberg NEW ENERGY FINANCE

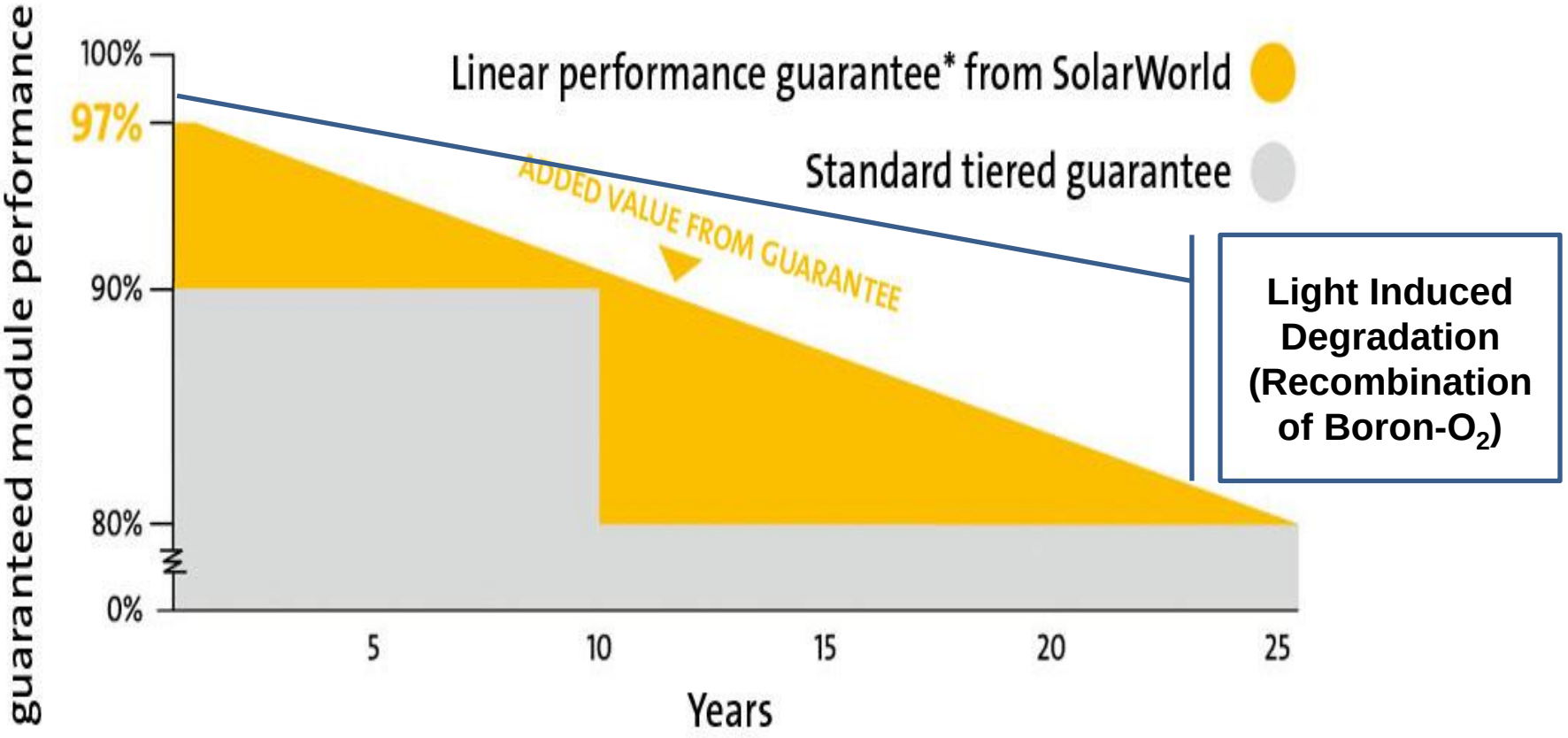
Tier 1 Module Maker List

Company	In-House module manufacturing capacity (MW/YEAR)
1. Trina	4,400
2. Hanwha Q Cells	4,300
3. Jinko	4,000
4. Canadian Solar	3,800
5. Yingli	3,400
6. First Solar	2,900
7. Zhongli Talesun	2,800
8. Suntech	2,400
9. Risen	2,100
10. Eging	1,600
11. SolarWorld	1,500
12. Chint/Astronergy	1,300
13. SunPower	1,300
14. Hareon	1,200
15. Renesola	1,200
16. China Sunergy	1,150
17. Seraphim	1,100
18. Solar Frontier	1,050
19. BYD	1,000
20. HT-SAAE	1,000
21. Hyundai Heavy	600
22. Vikram	500
23. AUO/BenQ	435
24. Heliene	250
25. Winaico	150


$5.95 2011 Issue 4
Photon
Photon
The Photovoltaic Magazine
A PV SYSTEM FOR EVERY ROOF
PHOTON survey finds few bright spots in the search for installation deals
FUKUSHIMA EFFECT: No change in US nuclear policy after the crisis in Japan
SKY HIGH: Some California integrators charge eye-popping PV installation prices
GEORGIA ON MY MIND: The Peach State's PV market needs time to ripen
Test Results
Conference and Event Calendar
Jobs and Internships
Vendors and Installers
$5.95

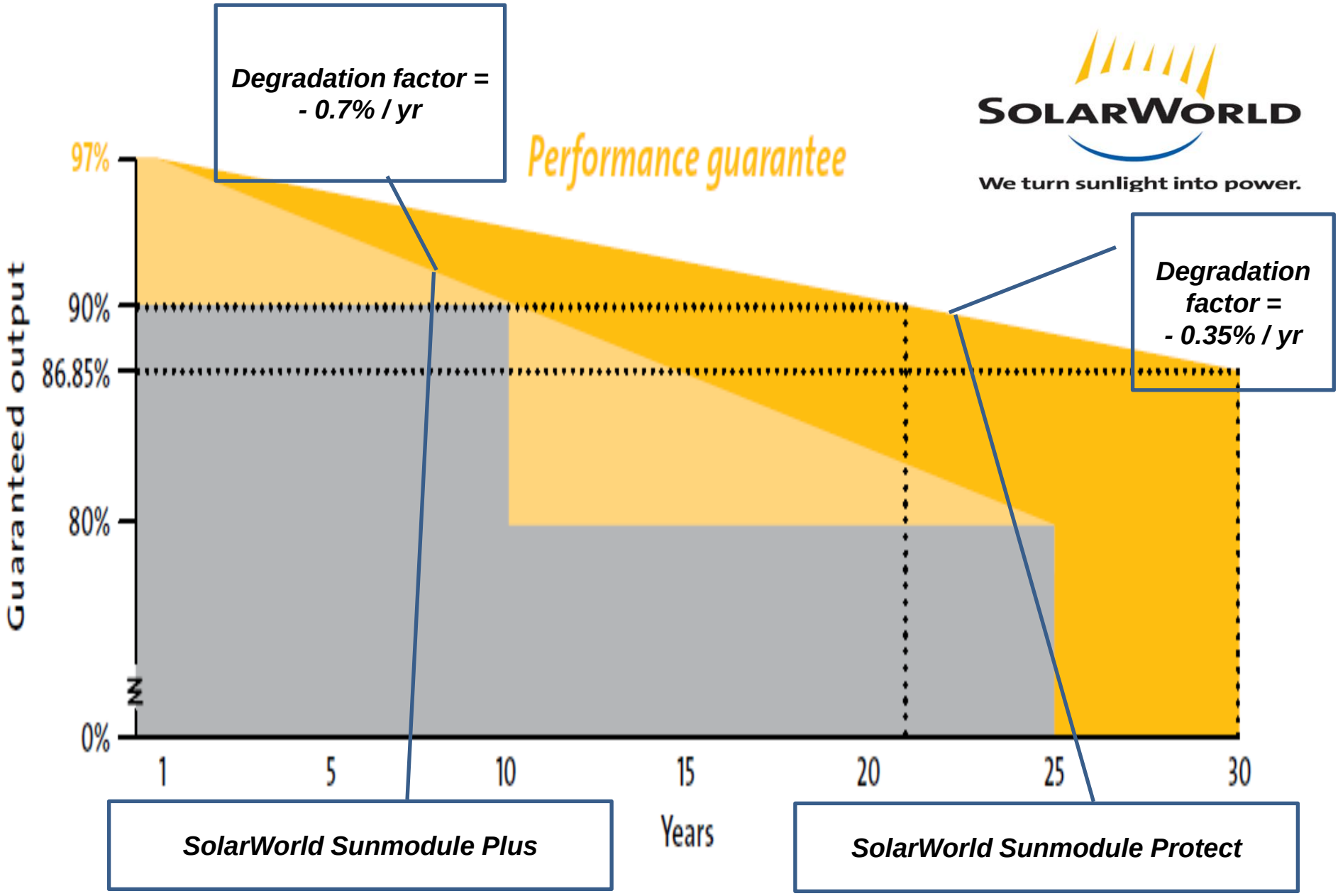
Linear Performance Guarantee

SolarWorld introduced the continually decreasing linear performance guarantee

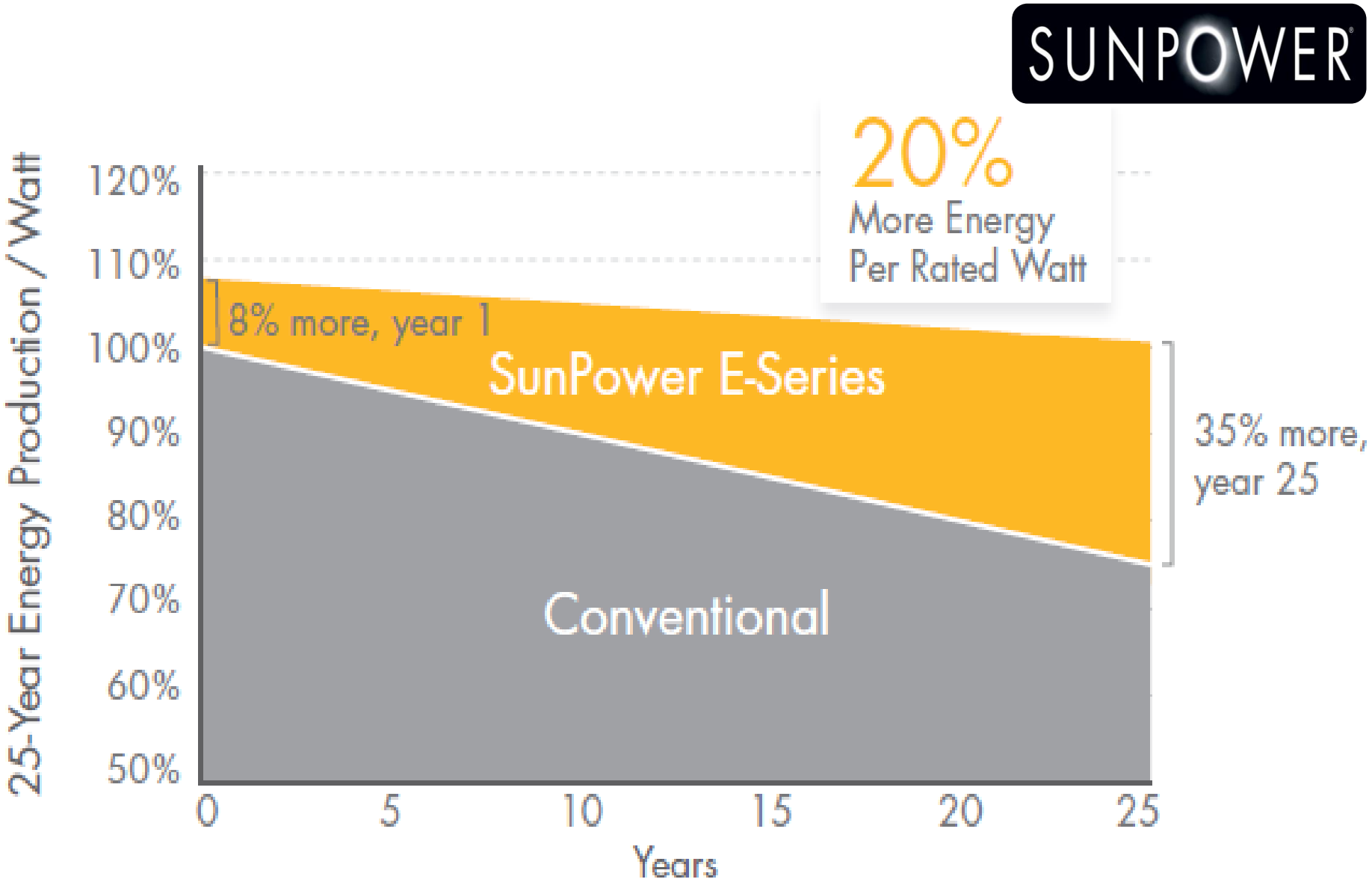


*25-year performance guarantee in accordance with the applicable SolarWorld service certificate upon purchase.

Linear Performance Guarantee – Impact of Low Degradation Factor



Linear Performance Guarantee – Impact of Low Degradation Factor



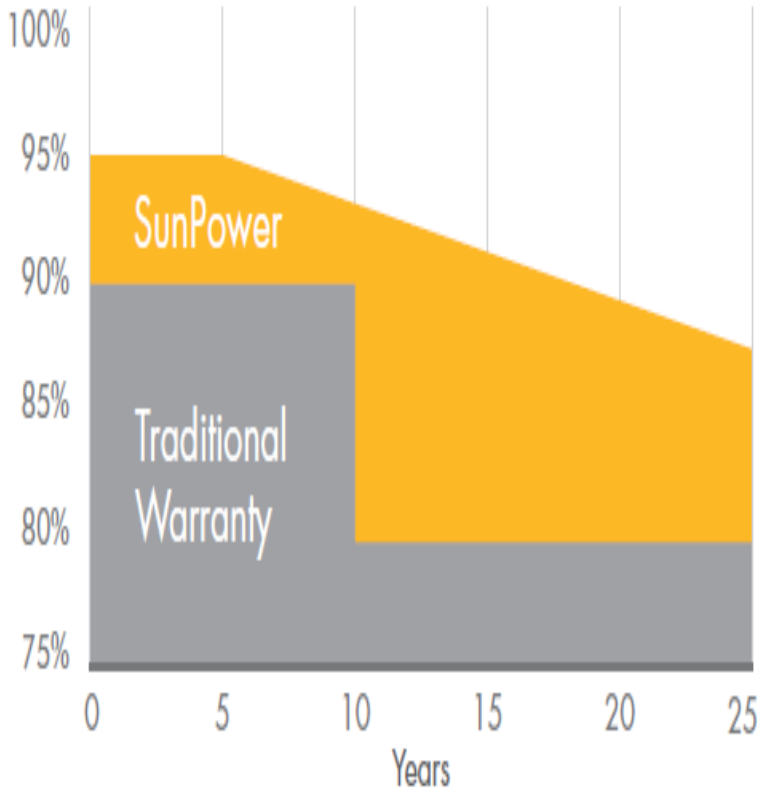
IV Checker from EKO INSTRUMENTS

Product Warranty

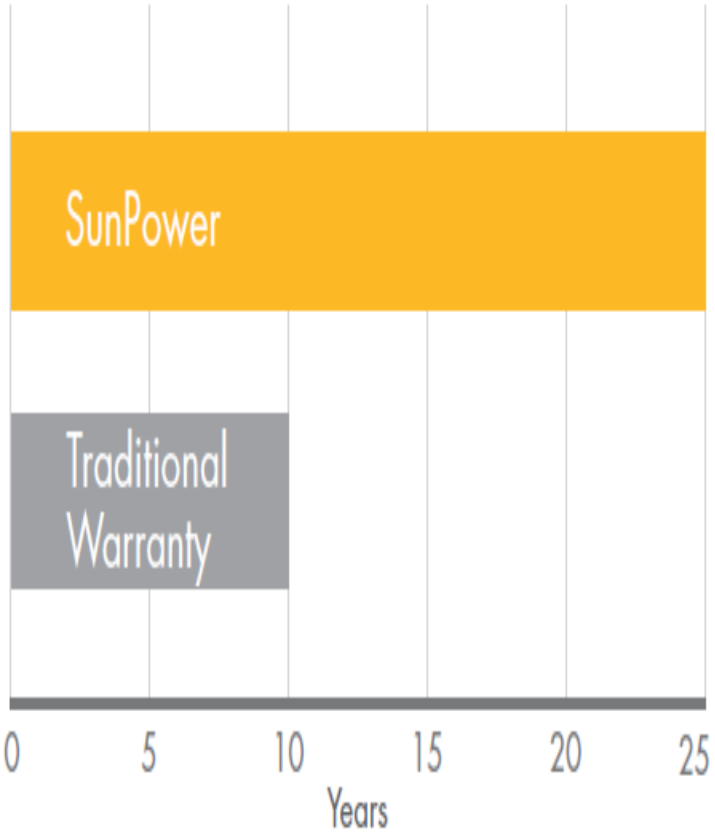
SUNPOWER

SUNPOWER OFFERS THE BEST COMBINED POWER AND PRODUCT WARRANTY

POWER WARRANTY



PRODUCT WARRANTY



CanadianSolar

PV MODULE | Warranty Insurance | USA

THE BEST IN CLASS

Canadian Solar's PV modules are manufactured with uncompromised quality, durability, performance and value. Our continuous innovation, meticulous design and production techniques, combined with rigorous quality control, in-house testing and adherence to strict international quality standards, ensures a high return on investment for our PV modules.

25-year Insurance-Backed Warranty

Canadian Solar PV modules feature plus only power tolerance for high reliability and output. We guarantee our PV modules and parts for 10 years and guarantee their linear power performance for 25 years.

In addition to our industry leading comprehensive PV module product warranty, we offer product warranty insurance to "back-stop" our product warranty. This insurance applies to our Limited Warranty and covers PV Modules against product defect and performance output. Our customers enjoy a global, irrevocable and immediate-backed warranty, which provides third-party rights to the insurance in case of insolvency or bankruptcy.

International Insurance Company of Hannover Limited

Rating: A.M.Best Credit Rating: A+ XV
Covers: Year 1 to 10
Policy #: PR0116815000
Website: www.inter-hannover.com

RSUI Indemnity Company

Rating: A.M.Best Credit Rating: A XIII
Policy #: NWD000122
Covers: Year 11 to 25
Website: www.rsui.com

Please contact Canadian Solar Inc.'s customer service department if you'd like more information about our insurance program. In the unlikely event that Canadian Solar, Inc. becomes insolvent, please contact PowerGuard for claims handling.

Warranty Insurance Highlights

- Immediate coverage (no waiting period)
- 25-yr. non-cancellable term (even if Canadian Solar, Inc. becomes insolvent or bankrupt)
- A.M. Best rated "A" XIII or better reputable insurance underwriters (enhanced bankability)
- Insurance program insures Canadian Solar, Inc.'s Limited Warranty, including PV Modules, against Product Defect and Performance output
- Third-Party policy rights (satisfies investors/bankers' requirements)
- Effective dates: April 1, 2015 to April 1, 2016

Warranty Insurance

The product warranty insurance, purchased through PowerGuard Specialty Insurance Services is underwritten by the following reputable A-rated Investment-grade insurance carriers;

Contact Details:

PowerGuard®
SPECIALTY INSURANCE SERVICES

Canadian Solar: P: 1 855 315 8915
E: sales.us@canadiansolar.com

PowerGuard: P: 1 949 224 1337
E: claims@powerguards.com

Serial number registration can be verified by simply visiting the PowerGuard's Solar Panel Program Warranty Verification Portal http://powerguardsnverify.com/, on which you will be able to input panel serial numbers and verify they have been reported and are eligible for coverage per the terms of Canadian Solar's module manufacturer's policy.

Canadian Solar Inc.

Founded in 2001 in Canada, Canadian Solar Inc., (NASDAQ:CSIQ) is one of the world's largest and foremost solar power companies. As a leading manufacturer of solar modules and PV project developer with about 10 GW of premium quality modules deployed around the world more than a decade, Canadian Solar is one of the most bankable solar companies in the world. Canadian Solar operates in six continents with customers in over 70 countries. Canadian Solar is committed to providing high-quality solar products, solar system solutions and services to customers around the world.

Type	Description
Machinery Breakdown	Electrical and or mechanical breakdown of any machinery or other equipment resulting in costly repairs or even replacement of the solar panels
Business Interruption	cover for periods of operational downtime as a result of an Insured peril e.g. fire or storm damage, machinery breakdown and equipment failure.
Property Damage	all risks cover to protect from any loss arising out of fire, etc.
Contract Works	protection against any loss arising from property damage caused during construction of the project. Cover starts while solar panels are in transit to the job site and ends once the job is completed or the owner accepts the work
Employers' Liability	provides cover against risk of accident from usual workplace risks such as working at height and manual handling
Public Liability	provides cover for any damage caused to third party property during installation of the panels. Essential for businesses engaged in Construction and Installation of solar panels and solar farms
Marine Cover	Covers include Marine Transit for any loss of goods and Marine Delay in Start up to protect from any consequential loss in revenue

Plus Sorting – Light Induced Degradation

Plus sorting — get all the watts you pay for

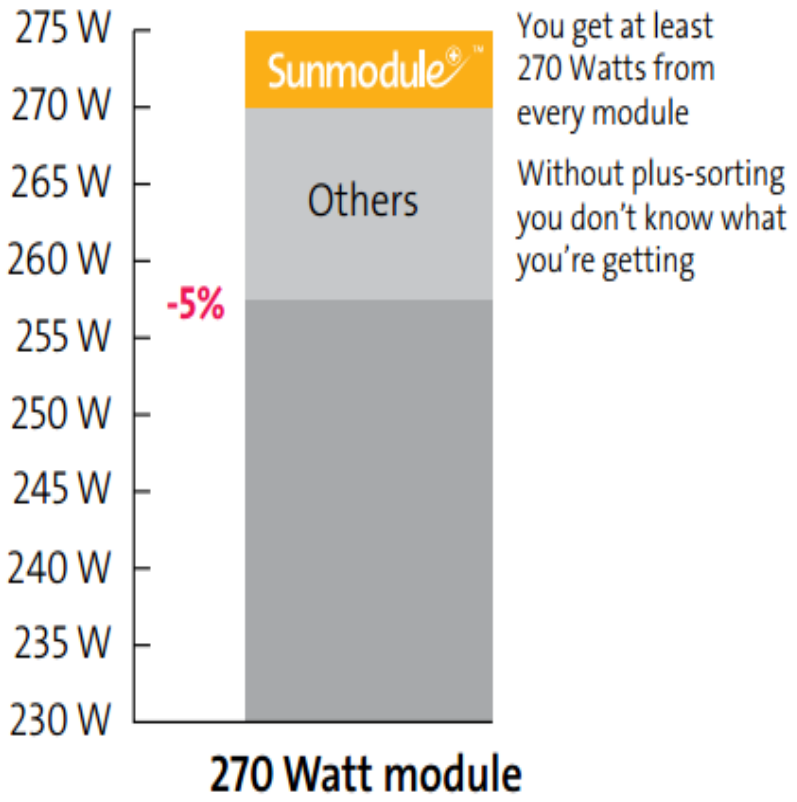
SolarWorld

We turn sunlight into power.

SolarWorld's unique plus-sorting method ensures that our customers receive the watts they pay for. Every module is factory flash-tested (at standard test conditions) to determine the peak rated power output, then sorted in 5-watt bin increments. SolarWorld's power rating accounts for initial light-induced degradation (LID) so there are no surprises after installation.

With plus-sorting, SolarWorld delivers only modules that have greater than or equal to the nameplate-rated power. These power ratings are backed up with the factory flash report.

By delivering actual power, plus-sorting ensures that systems operate at top efficiency which results in maximum energy yield year after year. Plus-sorting eliminates nameplate uncertainty and our 5 W bin size makes mismatch losses negligible. Therefore associated de-rate factors in system modeling programs, such as PVWatts, PVsyst, and OnGrid can be minimized, predicting up to 5% greater annual yield.



Potential Induced Degradation (PID)

Potential Induced Degradation (PID) - Vikram Solar CEO

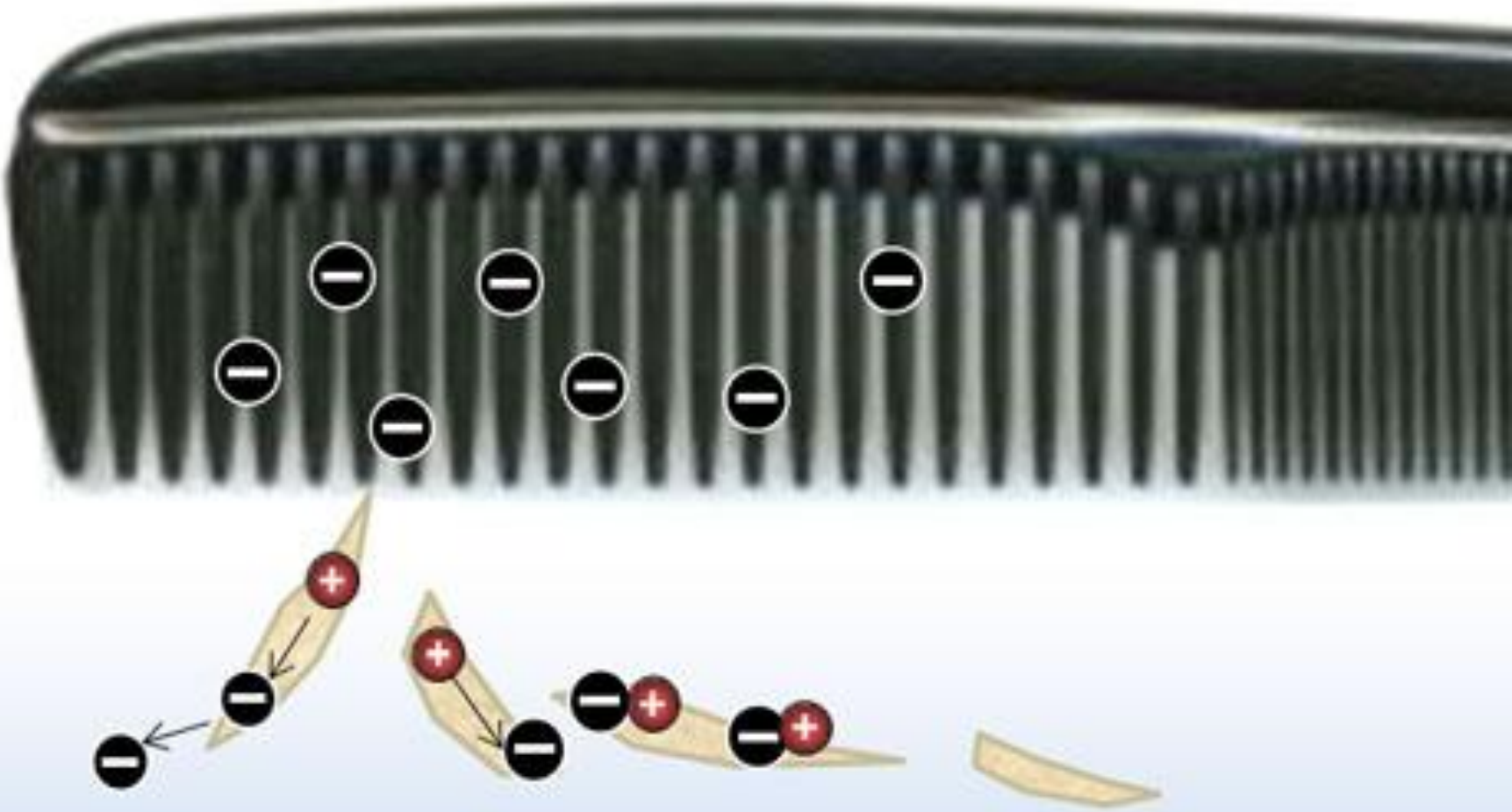
Vikram Solar interview at Solar Energy UK 2013 - YouTube

www.youtube.com/watch?v=s-flG5revnk

Oct 30, 2013 - Uploaded by PV-Tech

PV Tech spoke exclusively to Gyanesh Chaudary of **Vikram Solar** while at the Solar Energy UK **2013** ...

Electrostatic Induction



Potential Induced Degradation (PID)

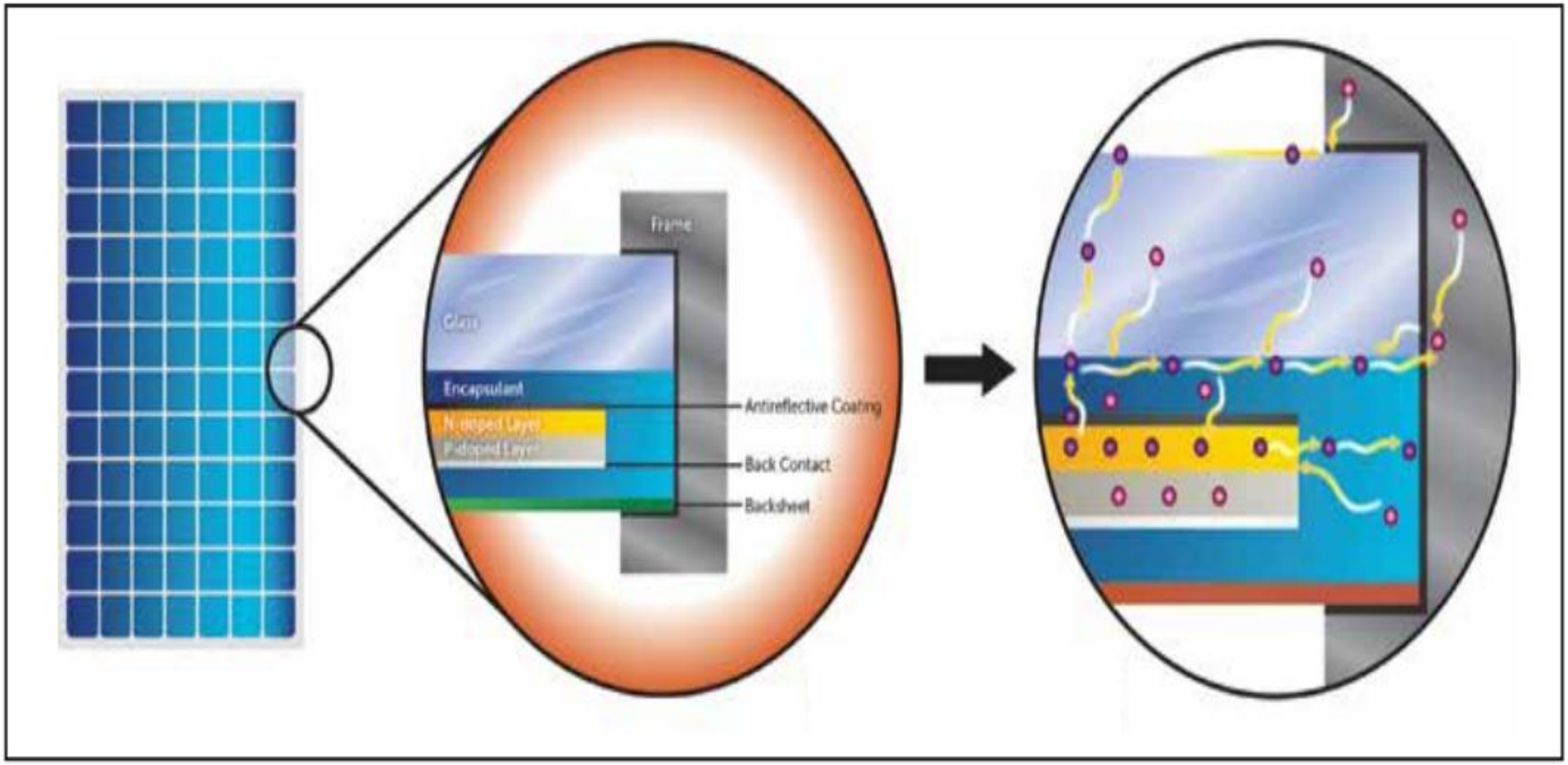
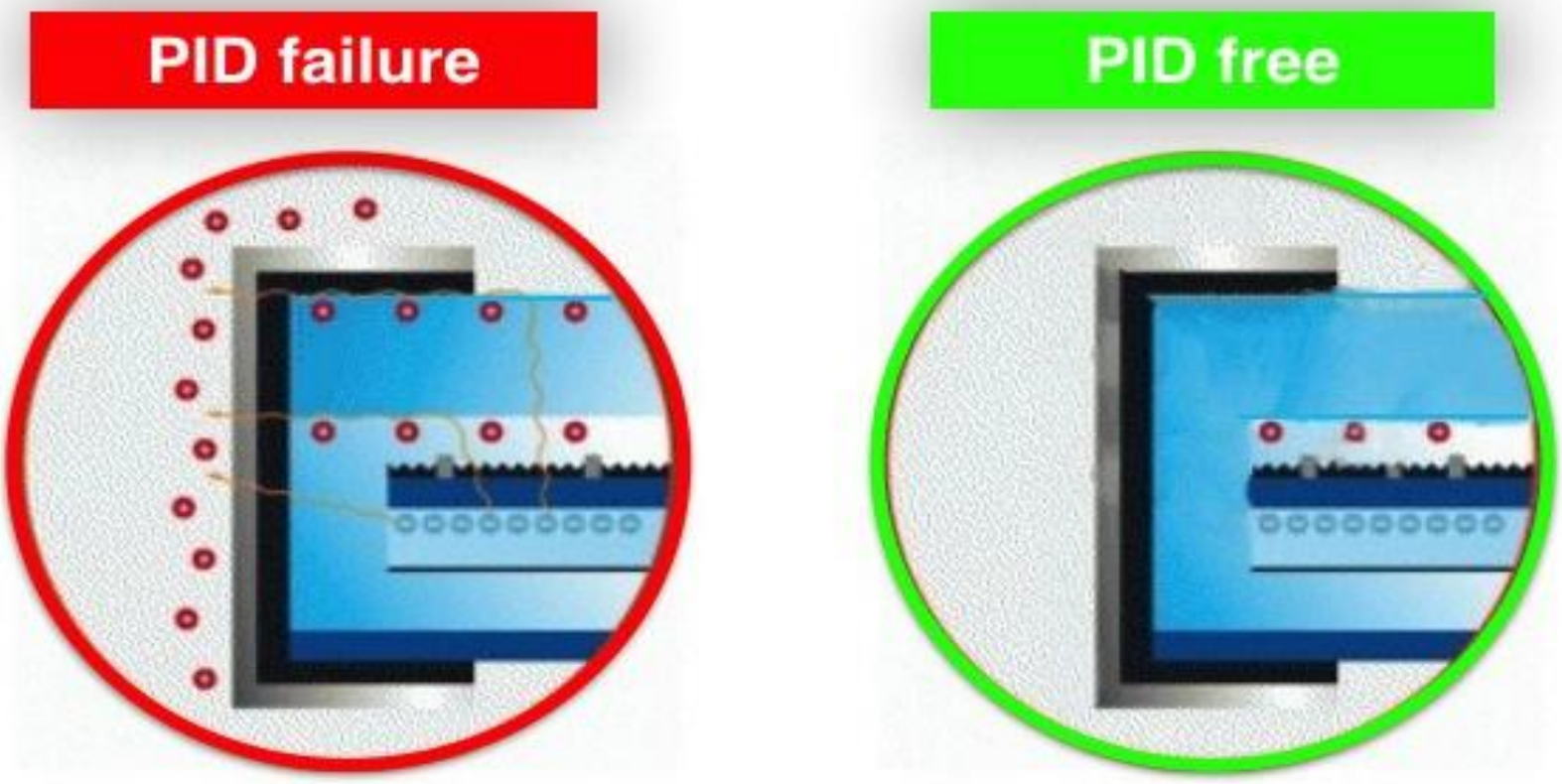
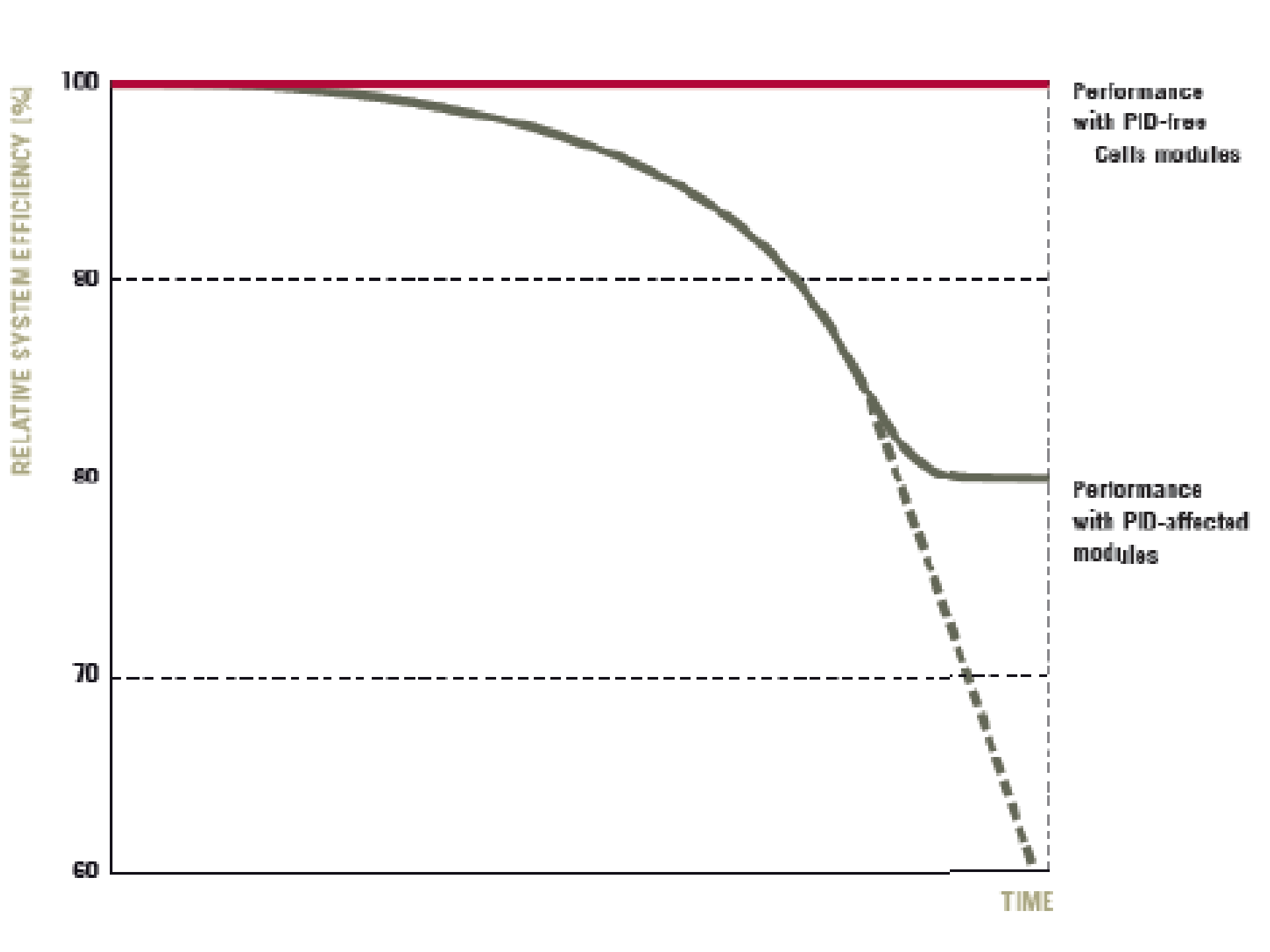


Figure 1 - Leakage current and voltage potential (negative potential shown) cause negative (-) (purple) ions to migrate away from the semiconductor, as positive (+) (pink) ions migrate toward the semiconductor from the glass and package, and the module's external environment.

Potential Induced Degradation (PID)




RELATIVE SYSTEM EFFICIENCY [%]
100
90
80
70
60
TIME
Performance with PID-free Cells modules
Performance with PID-affected modules

Potential Induced Degradation (PID)

- PID can be both irreversible and reversible. Irreversible PID has been documented primarily in Thin film technologies.
- There is no relationship between PID and the inverter principle used
- Sodium contained in soda-lime glass (but not in Quartz glass) is a suspect for causing PID
- PID causes the MPP point to be drastically lower than specified.
- Under the IEC 62804 standard, modules will be deemed to be PID-resistant if power loss is less than 5%.

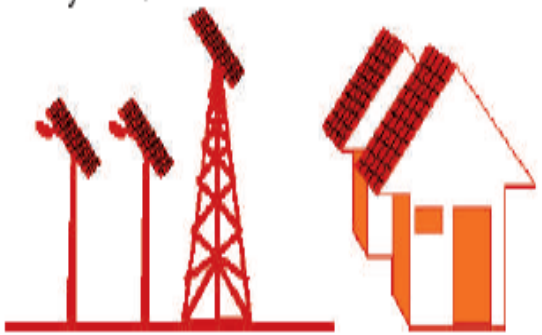
PID Certificate – IEC 62804 (Draft)

QUALITY AND SAFETY

- 25 years of limited power output warranty**
- Rigorous quality control meeting the highest international standards
- Certified for PID resistance
- 100% EL tested to ensure micro crack free modules
- Certified for salt mist corrosion resistance
- Certified for ammonia resistance*

CERTIFICATES

- Factory: ISO 14001:2004, ISO 9001:2008, BS OHSAS 18001:2007, SA 8000*
- Products: IEC 61215 Ed2, IEC 61730, IEC 61701, IEC 62716*, IEC62804 Ed1, UL1703*, CE, MCS, CEC*, PV Cycle, JET*



PID Resistance Certification

Solarworld PID
sistance Certificati

Canadian Solar
raunhofer PID Tes

Renesola PID Free
Test

PID Solutions

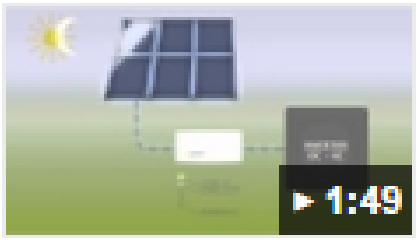
PID Solutions

iLUMEN

PID BOX - A box for every size of system.

PID Solution from iLumen

ILUMEN, PID BOX - YouTube



https://www.youtube.com/watch?v=SEuFMVZz8qQ

Jul 10, 2014 - Uploaded by Dimitri vg

ILUMEN, PID **BOX**. Dimitri vg. SubscribeSubscribedUnsubscribe 11. Loading... Loading... Working... Add to ...

Panels chosen should have…

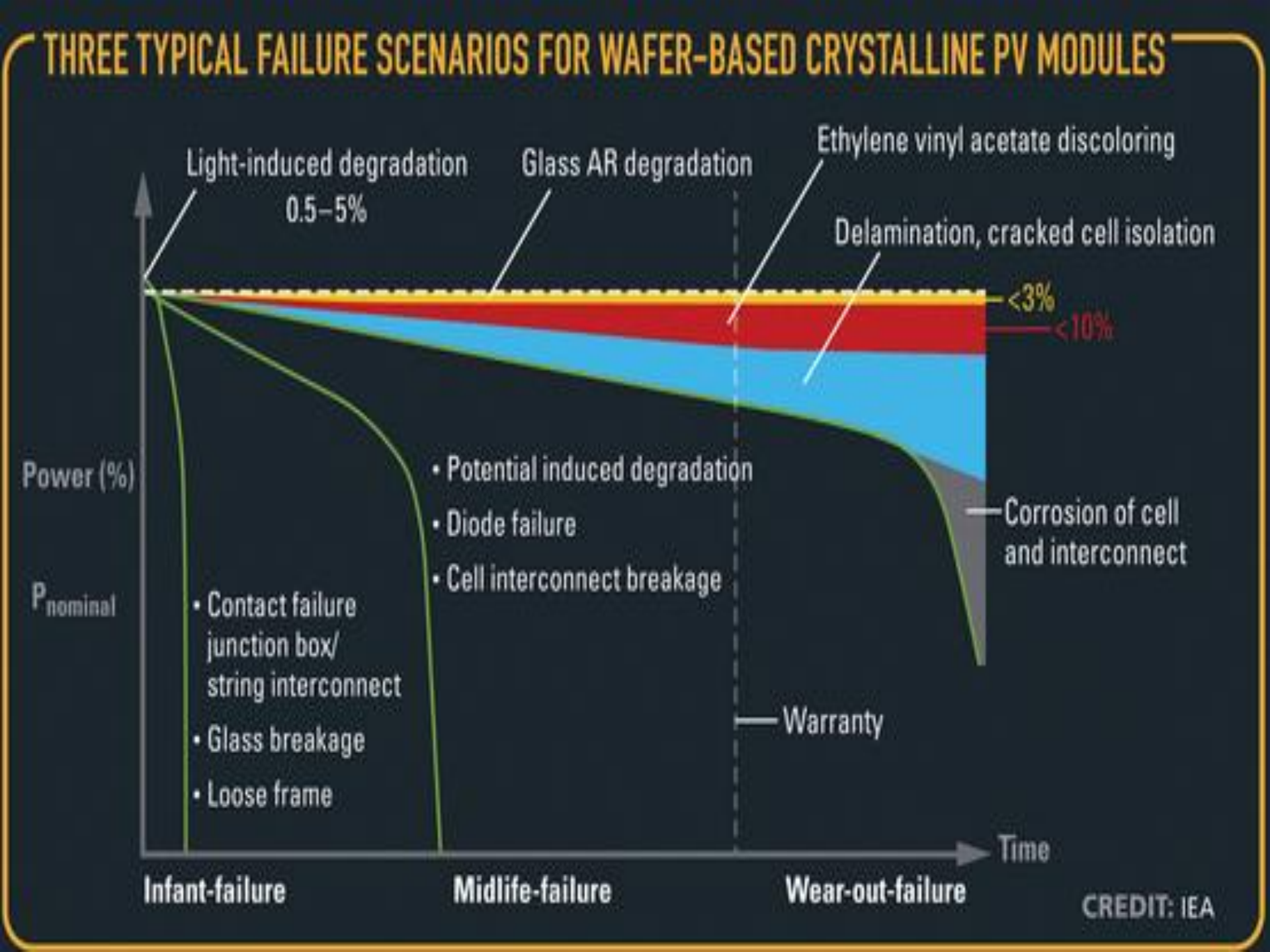
No LID and PID effects

- LID (light induced degradation) is caused by boron/oxygen complexes, which are only possible with B-doped p-type silicon. HJT technology, based on n-type silicon, is immune to this effect which can result in efficiency losses of 3%.
- PID (potential induced degradation) is induced by ions migrating from the glass to the cell surface. There, the ions with their electrical field interfere with the emitter. HJT cells have an extremely conductive ITO coating on both sides which electrically protects the cell like a Faraday cage. This eliminates the efficiency loss of 2% which would otherwise be incurred.

LID (Light Induced Degradation)

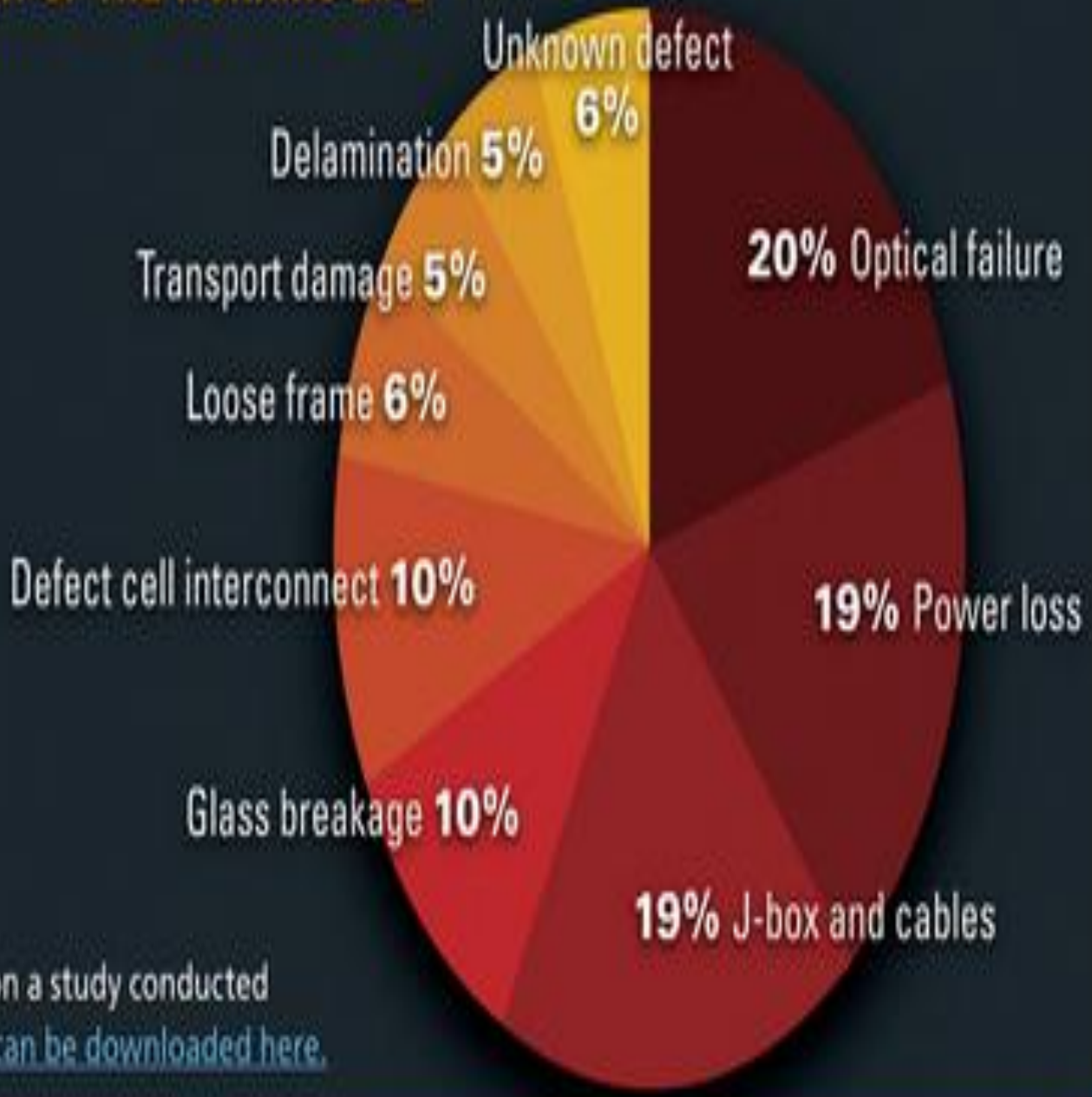
- Mon Crystalline 0-3%
- Poly Crystalline .2%
- Thin Film 5-15%
- CIGS/CIS -

THREE TYPICAL FAILURE SCENARIOS FOR WAFER-BASED CRYSTALLINE PV MODULES



FAILURE TYPES AT THE START OF THE WORKING LIFE

The most important failures in the field are j-box failure, glass breakage, defective cell interconnect, loose frame, and delamination. Other defects were not well defined. The rate is given as a percentage of the total number of failures over a 5-year period from 2006 to 2010 based on a volume of approximately 2 million modules.



CREDIT: IEA. Information is based on a study conducted by DeGraaff, et. al. for NREL, which can be downloaded here.

MNRE Accredited Test Labs

S. No.	Lab/ Organisation	Specifications	Address	Website
1	National Institute of Solar Energy (Formerly SEC)	(IEC 61215 upto100Wp) NABL Accredited	Gurgaon, Haryana	http://mnre.gov.in/centers/about-sec-2/
2	Electronics Regional Test Laboratory (ERTL)	STC Test Facility MNRE Accredited	Kolkata, West Bengal	http://www.stqc.gov.in/testing-and-calibration-lab-main-page/337
3	Electronics Test and Development Centre (ETDC)	IEC61215 under ICEEE- CB, IEC 61701 (upto 100Wp) NABL Accredited	Bengaluru, Karnataka	http://www.stqc.gov.in/testing-and-calibration-lab-main-page/344
4	Underwriters Laboratory (UL)	IEC 61730 Pt.II and IEC 61701) upto 400Wp NABL Accredited	Bengaluru, Karnataka	http://india.ul.com
5	TUV Rheinland (TUV)	(IEC61215 & 61730 Pt-II) upto400Wp NABL Accredited	Bengaluru, Karnataka	http://www.tuv.com/en/india/home.jsp

Temp. Coeff. Of Power - Solarworld

THERMAL CHARACTERISTICS

SOLARWORLD
We turn sunlight into power.

NOCT	46 °C
TC I_{sc}	0.04 %/°C
TC $_{Voc}$	-0.30 %/°C
TC P_{mpp}	-0.45 %/°C
Operating temperature	-40°C to 85°C

Temp. Coeff. Of Power

SUNPOWER

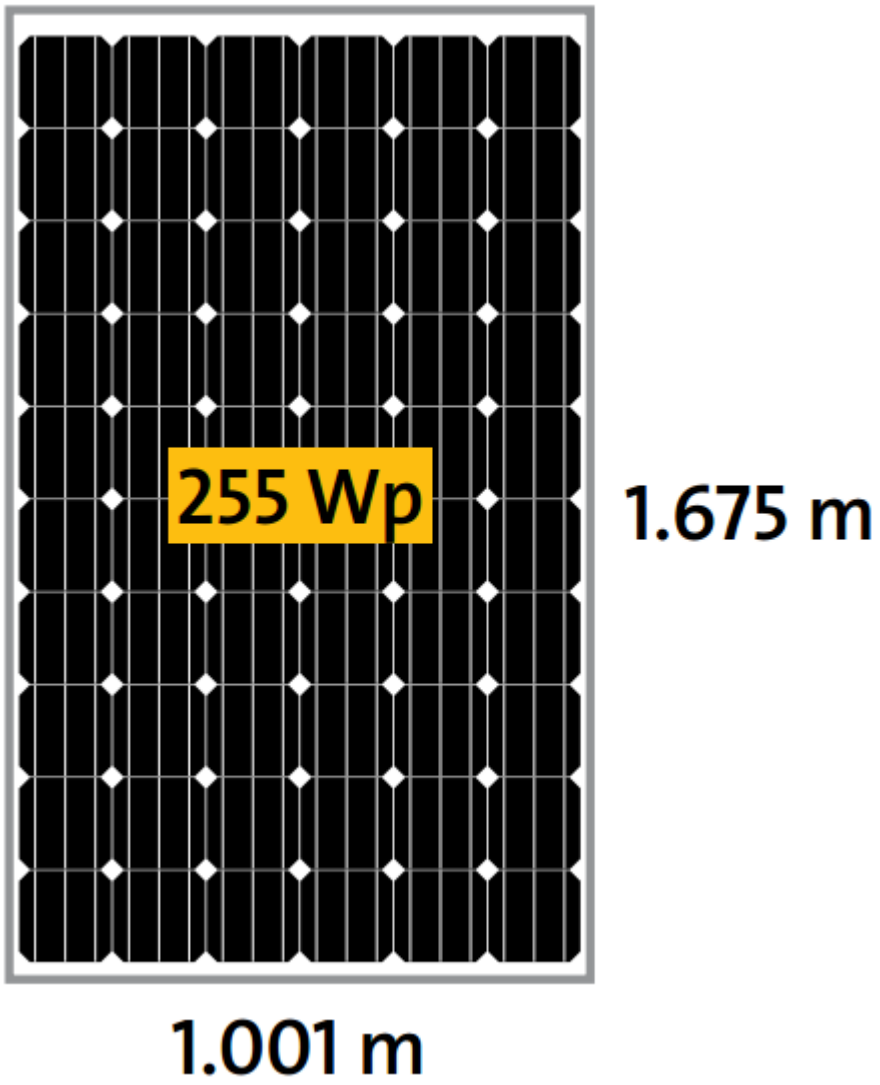
ELECTRICAL DATA Measured at Standard Test Conditions (STC): Irradiance 1000W/m², AM 1.5, and cell temperature 25° C		
Nominal Power (+/-5%)	P_{nom}	435 W
Cell Efficiency	η	22.4%
Panel Efficiency	η	20.1 %
Rated Voltage	V_{mpp}	72.9 V
Rated Current	I_{mpp}	5.97 A
Open-Circuit Voltage	V_{oc}	85.6 V
Short-Circuit Voltage	I_{sc}	6.43 A
Maximum System Voltage	IEC	1000 V
Temperature Coefficients	Power (P)	– 0.38%/K
	Voltage (V_{oc})	-235.5mV/K
	Current (I_{sc})	3.5mA /K

Module Efficiency

ADDITIONAL DATA

Power sorting[1]	-0 Wp / +5 Wp
J-Box	IP65
Module leads	PV wire per UL4703 with H4 connectors
Module efficiency	16.40 %
Fire rating (UL 790)	Class C
Glass	Low iron tempered with ARC

Module Efficiency



Module area = 1.675 x 1.001
= 1.68m^2

At STC, insolation = 1000W/m^2

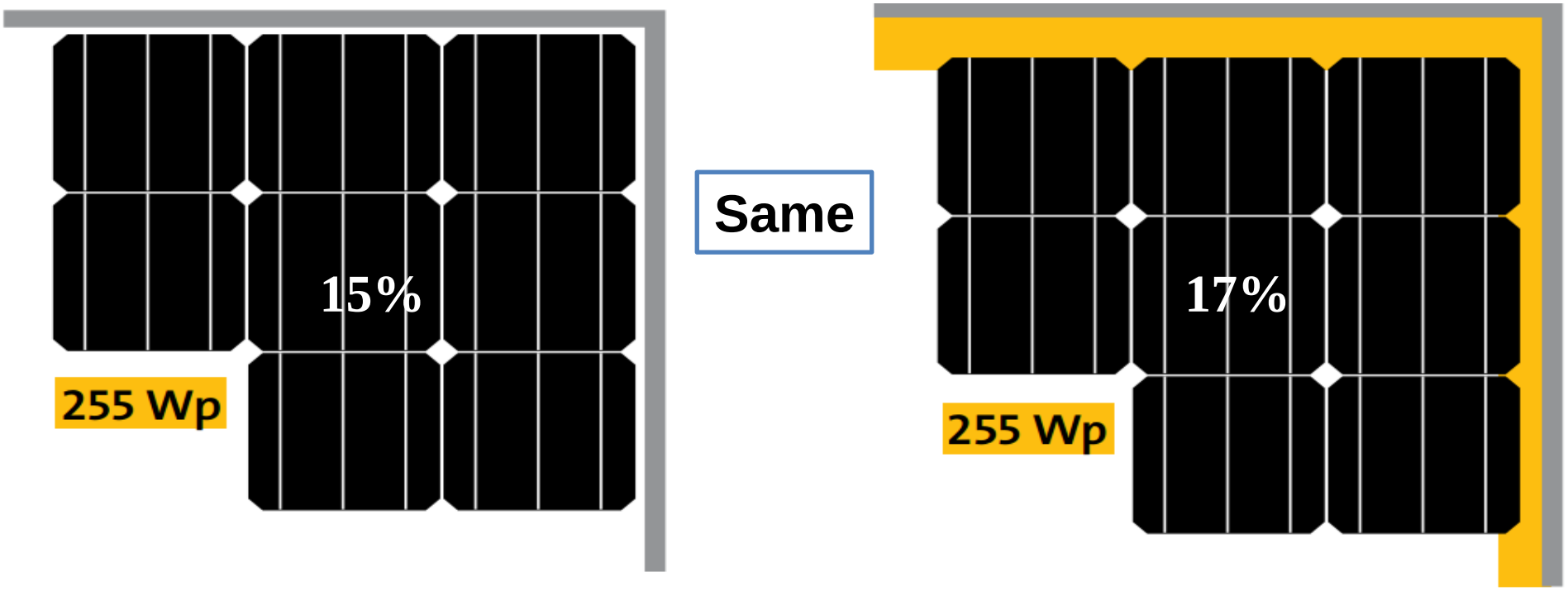
So for 1.68m^2, it is 1.68 x 1000
= 1680W (total incoming power)

Eff = 255 / 1680 = 15.2%

Module Efficiency

Question

If there are 2 modules with the same Wp rating of 255Wp but different efficiencies of 15% and 17%, which module will produce the most output at STC?



Area required

Plant capacity	1 kW	2 kW	5 kW	10 kW
Panel efficiency	**Rooftop space required (sq.ft)**			
12.0%	125	250	625	1,250
12.5%	120	240	600	1,200
13.0%	115	231	577	1,154
13.5%	111	222	556	1,111
14.0%	107	214	536	1,071
14.5%	103	207	517	1,034
15.0%	**100**	**200**	**500**	**1,000**
15.5%	97	194	484	968
16.0%	94	188	469	938

Module Wattage

Question

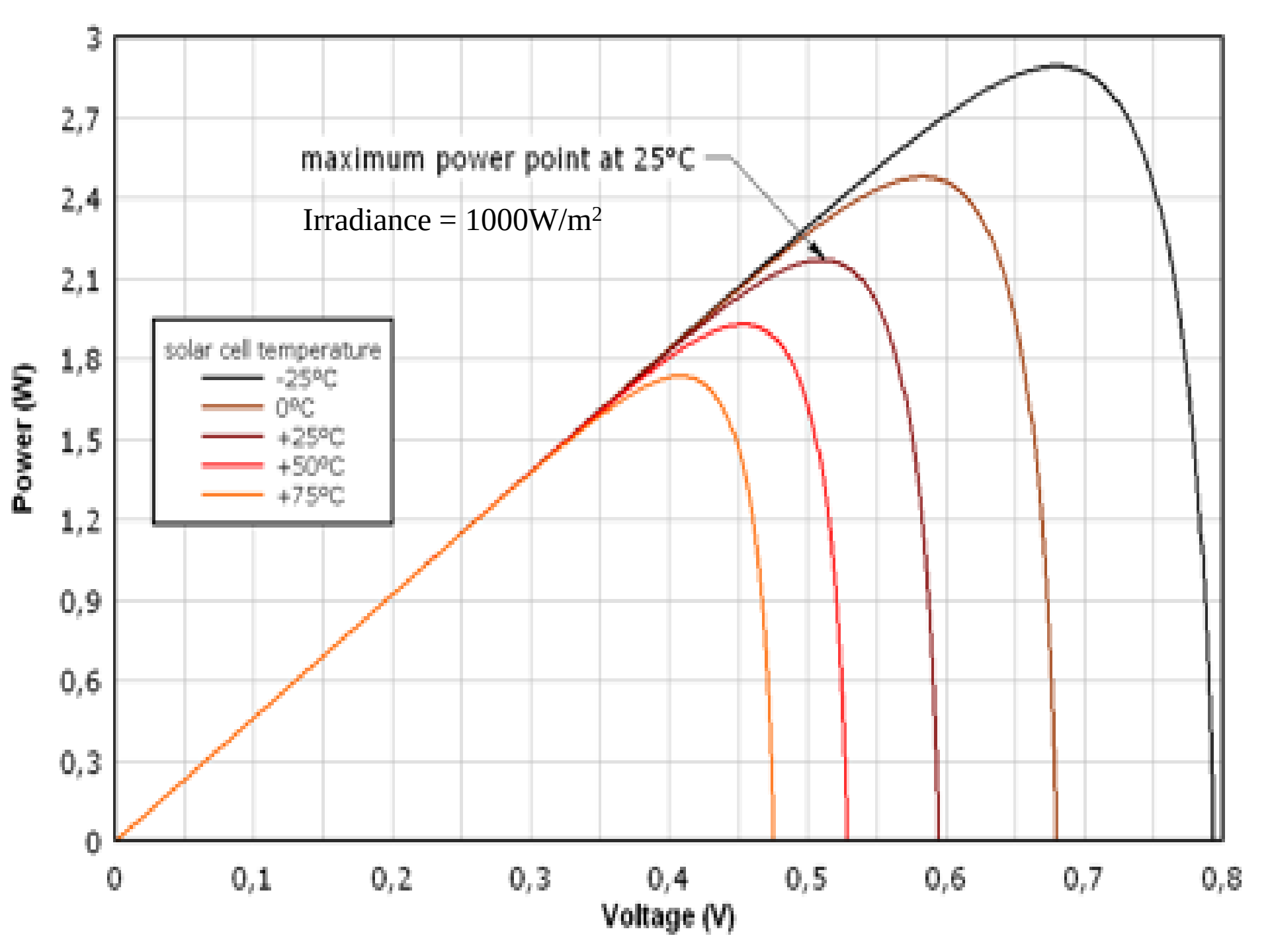
Can this module produce more than 255W?

Yes

Wp ≠ Wmax

$Wp = W_{STC}$

Power at STC ($1000W/m^2$, 25^0C)


maximum power point at 25°C
Irradiance = 1000W/m²
solar cell temperature
-25°C
0°C
+25°C
+50°C
+75°C
Power (W)
Voltage (V)
0
0,3
0,6
0,9
1,2
1,5
1,8
2,1
2,4
2,7
3
0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8

Thank You