Introduction on Hyundai PV module

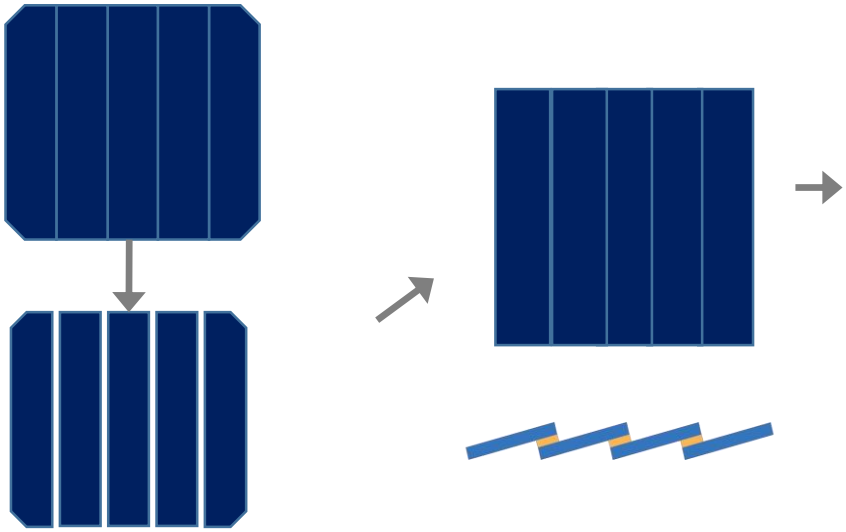
HYUNDAI ENERGY SOLUTIONS

Shingled Module Advantages

- Shingled technology is an innovation process of manufacturing for PV Modules since 1996.

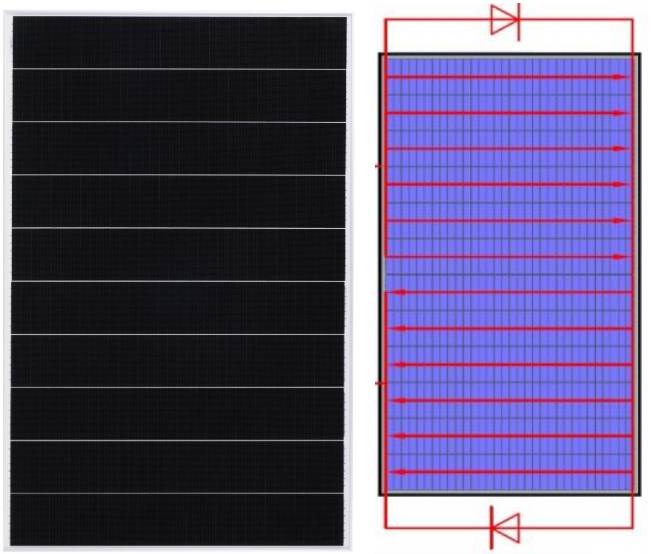
(Honda Dream, 1996 'World Solar Challenge' Solar Car Race winner, used UNSW shingled PERC cell modules)

1) Utilizing more space in a PV module → More power & Less BOS
2) Using ECA instead of soldering ribbon → Higher reliability
3) Parallel circuits system→ Less influences from shade
4) Low hot spot risk
5) Better mechanical withstand performance



Laser Cutting

ECA Overlap

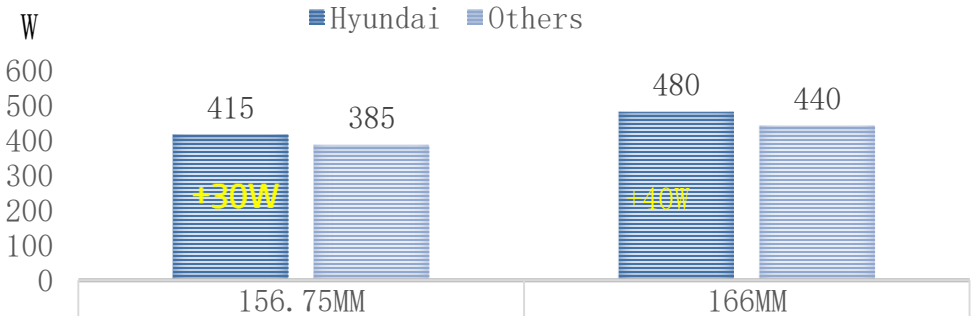


String assembly to shingled module

1) More Power & Less BOS

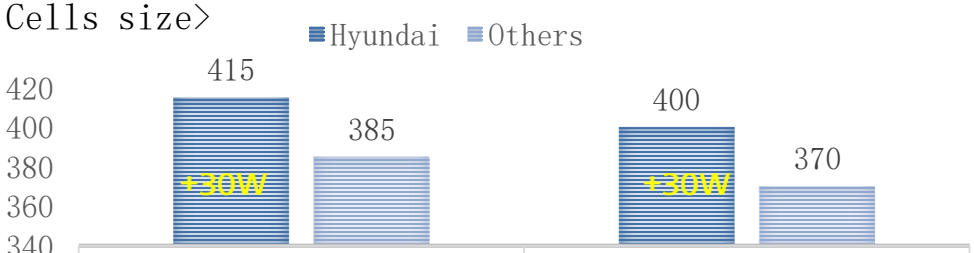
- Nearly 100% of the module is covered with solar cells to promote power, higher module efficiency
- Hyundai Shingled modules can be compatible with main technology of cells, like black silicon, PERC, HJT

<72 Cells size>



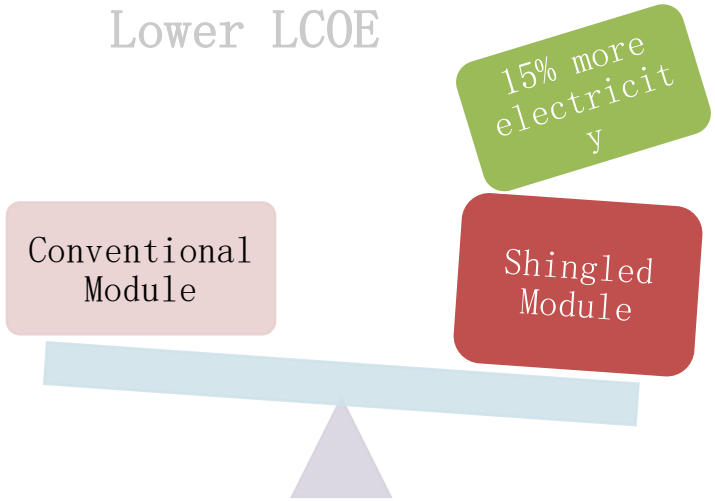
	156.75MM	166MM
Hyundai	415	480
Others	385	440

<60 Cells size>



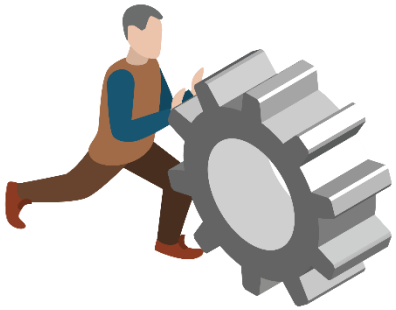
	156.75MM	166MM
Hyundai	415	400
Others	385	370

More Shingle modules have higher output per unit. For the same installation capacity, 8% less field is utilized

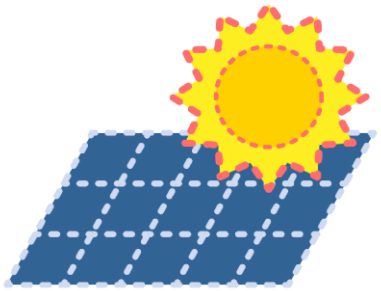


1) More Power & Less BOS

Lower logistics and transportation cost



Lower installation cost



Higher Capacity Installed

Less BOS

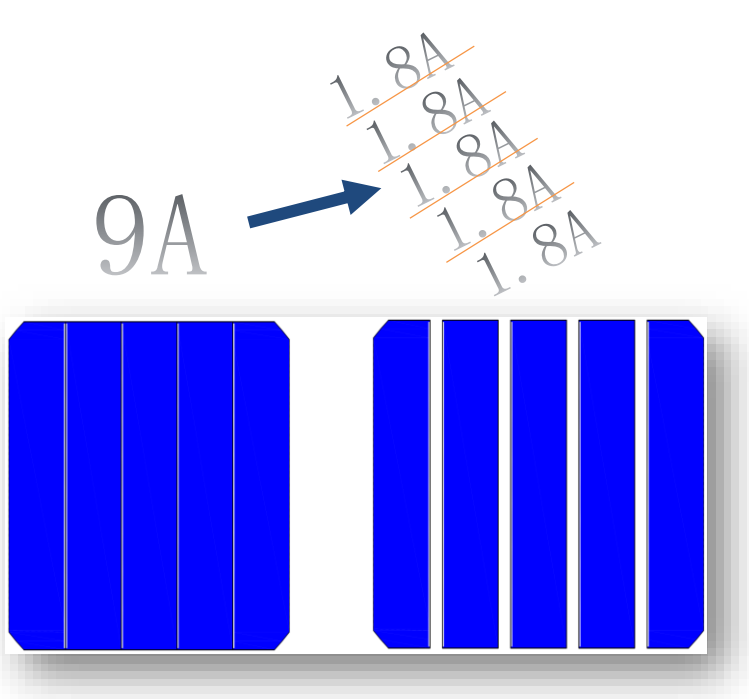
Take a Inner Mongolia project for example:

'50MW Poly Module' PK '50MW Shingled Module'

- Mounting & basement work costs reduce 0.075/W
- Construction cost reduces 0.015RMB/W

Total cost reduced by 10%

1) More Power & Less BOS



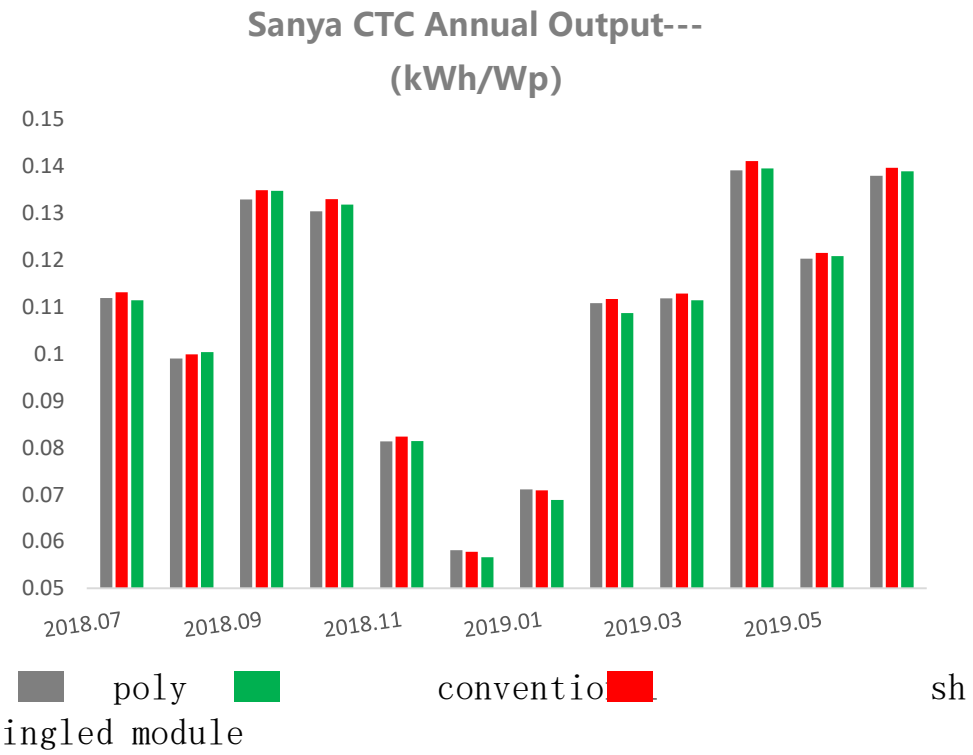
Isc of a full cell ~9A, and cut
1/5 shingled cell is ~1.8A

Shingles connected in series with the same current and accumulated voltages

$P_{loss} = I^2 \times R$ ⟶ Each small pc cell 'I' decreased (9A→1.8A), resistance loss become much lower.

1) More Power & Less BOS

Outdoor Performance Test —Hainan Province, China



- According to CTC outdoor performance test in Hainan Province:

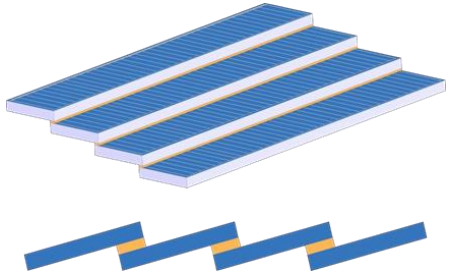
When comparing the annual average **electricity generated/W**, Shingle Modules outperformed the conventional polycrystalline & monocrystalline modules by 0.6% & 1.1%, respectively.

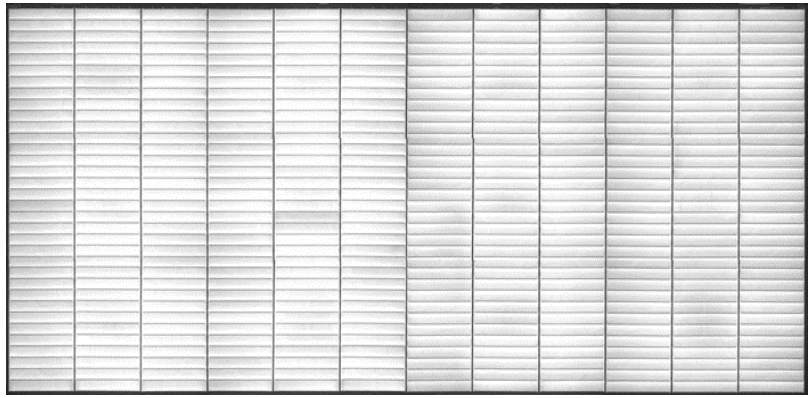
2) Higher Reliability

- Shingled modules use ECA instead of solder ribbon and reduce cracking among cells during production and it can also improve greatly the reliability outdoors.

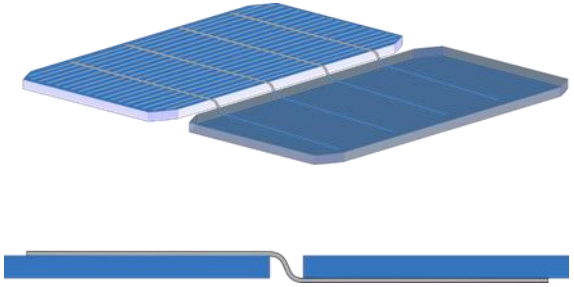
- As panels get hot in the day and cold at night, traditional ribbon copper expands but the silicon cell does not, over time, this repeated stress causes cells to crack and solder bonds to break.

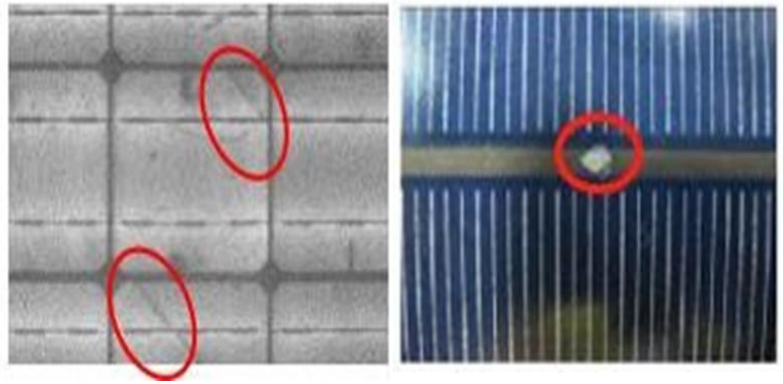
Hyundai Conductive Adhesive Method





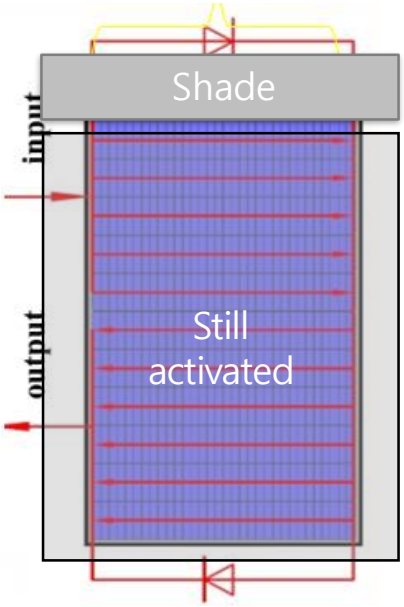
Conventional Welding Method





3) Less Influences from Shadows

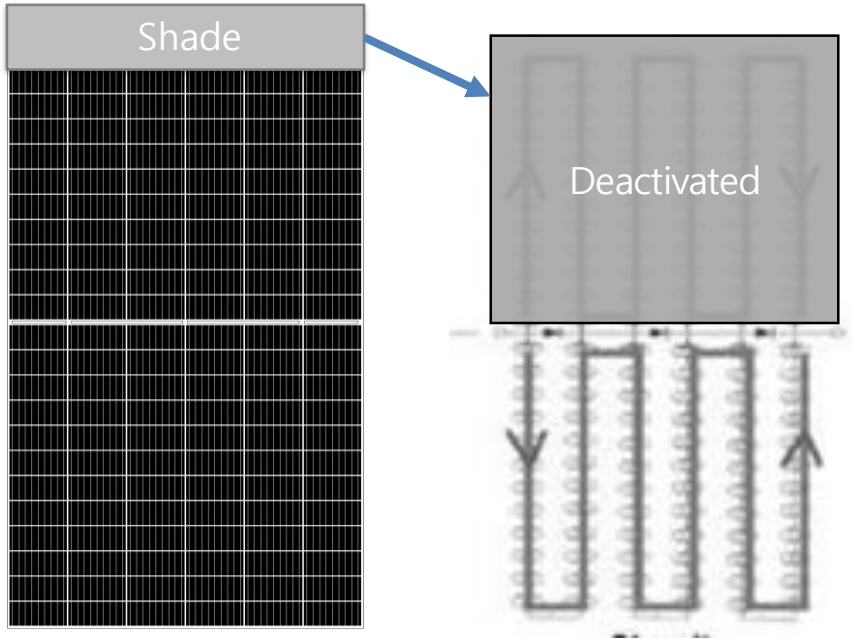
Power loss is linear with shade



- Hyundai shingled modules are made in **parallel circuits and brickwork layout design** which will make less influences from shade compared with full cell & half-cut cell modules.

Hyundai Shingled Module

Just a few inches of shad
e causes 50% power loss



Conventional Module

3) Less Influences from Shadows

When installed in portrait orientation, shingle modules have the best output under horizontal shadin g

- Diodes in conventional module have to work when just one string is covered and stop modules from working, while shingled modules still have 87% power generation.

NO. of Shaded rows	None	1 Row	2 Rows	3 Rows	4 Rows	5 Rows	6 Rows
Operating Current(A)	10.665	9.082	7.313	5.504	10.614	10.612	10.609
Max.Power(W)	400.5	348.0	258.1	216.2	192.4	191.5	191.4

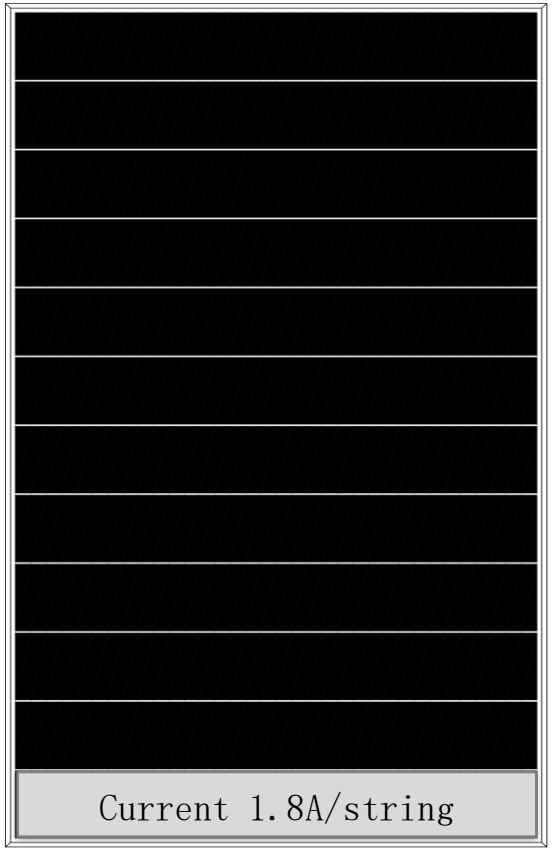
4) Low Hot Spot Risk

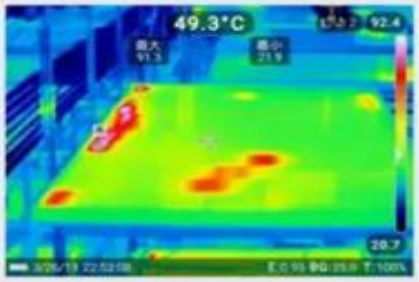
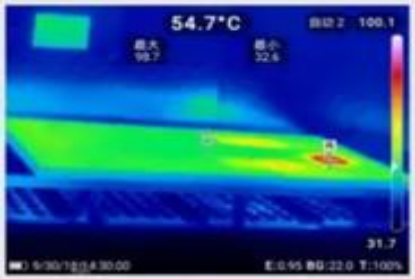
- Lower temperature coefficient
- BPDs in shingled modules minimize hot spot risks

Brand	Cell Size (MM)	Watt/PC (60/72)	Pmax./Temp. Coefficient	Product Warranty (Years)
Hyundai	156.75	350/415	-0.34%/℃	15/20/25
Others	156.75	320/385 (HC)	-0.39%/℃	10/12
Hyundai	166	400/480	-0.34%/℃	15/20/25
Others	166	400/370 (HC)	-0.37%/℃	10/12

4) Low Hot Spot Risk

- Full cells are cut into 5 small pcs, current of each string are shared in 1/5 compared with the convention module strings, reducing risk of hot spot

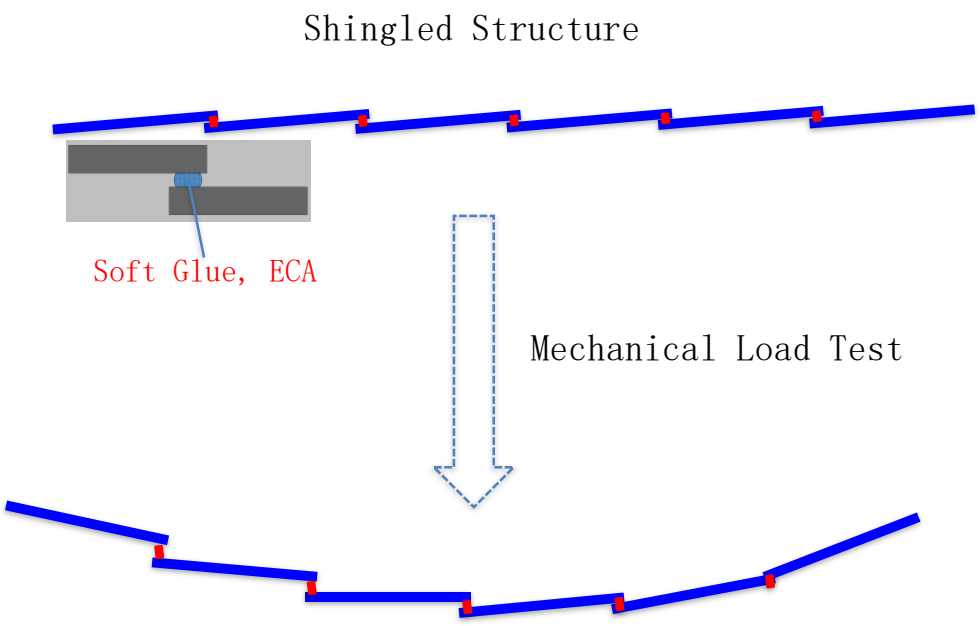


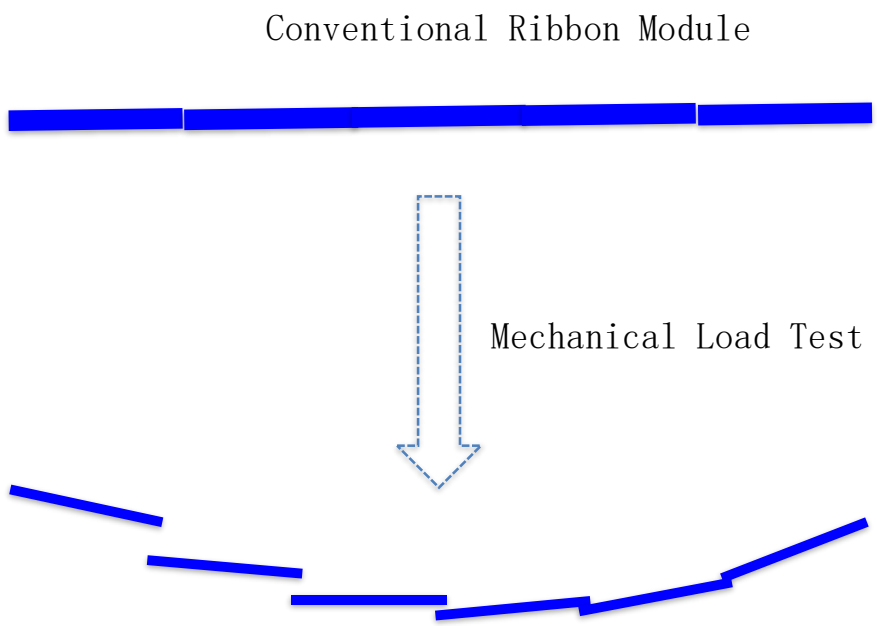
Module Type	Shingled Module	Standard Module
The highest Cell Temp.	91.3	98.7
IR Image		

•Lower hot spot temperature

•Lower string current results in lower cell operating temperature

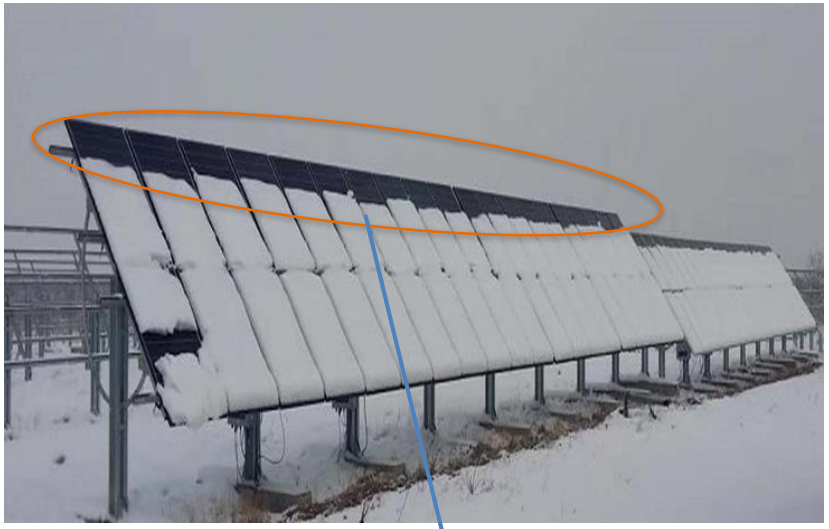
5) Better Mechanical Performance





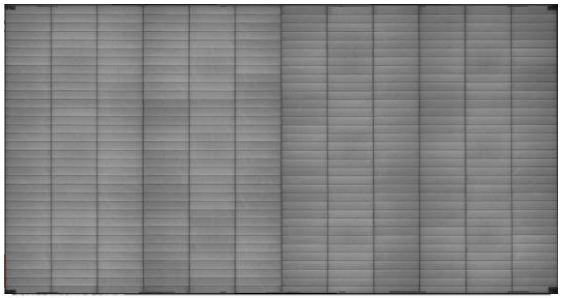
Mechanical load test: with shingled flexible cell joints and absence of metal ribbon, the shingle cell string handles load well---the flexible adhesive acts as a shock buffer and absorbs bending energy. In comparison the ribbon soldering joints of conventional cell strings develop cell cracks easily under external load.

5) Better Mechanical Performance



Vertical installation, ‘parallel circuits and brickwork layout design’ make sure module starts to work when only one string is not covered.

Faster snow melting speed, more electricity will be produced.



BEFORE LOAD

AFTER LOAD

Better mechanical withstand performance:

- No power degradation after the TUV 8100Pa test, passed the most strict -40 ℃ dynamic 1000Pa test, passed static load 3600Pa test with IEC62782

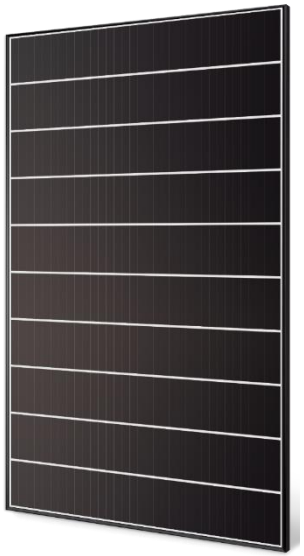
Quality Assurance

Certificates

TOP PERFORMER 2017 DNV·GL PV MODULE RELIABILITY SCORECARD

IEC 61215
IEC 61730 & CE

UL 61730 / 61215



KS C 8561

Salt Mist Corrosion
IEC 61701

PID
IEC TS 62804-1

Ammonia Corrosion
IEC 62716

Dust and Sand
IEC 60068-2-68

Test Standard

Item	IEC Standard	HES' Internal Standard
Damp Heat	85℃, 85%RH 1000hr	85℃, 85%RH 3000hr (x 3)
Thermal Cycling	-40℃~+85℃ 200cycle	-40℃~+85℃, 600cycle (x 3)
UV Exposure	60kWh/m^2	90kWh/m2 (x 1.5)
PID	85℃, 85%RH, 192hr, -1000V	85℃, 85%RH, 600hr (x 3), -1000V




[Hyundai test laboratory]

Elegant Appearance

Elegant Appearance