315W 60-CELL BIFACIAL MODULE USING N-TYPE CELLS

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Acknowledgement:

I would like to thank ISC Konstanz for the technical support and ramping up our pilot production line. Base on BiSON technology from ISC we co-developed the N-mono pilot line in REC solar.

Adam Hsu, Ph. D.

Head of Strategy,
Director of New Product and Technology
REC Solar Pte. Ltd.
joined REC in Jan 2015.

Adam Hsu has been served in cell and module manufacturers as technical management position for the past 14 years. After finishing 3 years research scientist at Solar Energy Research Institute of Sigapore (SERIS) and 4 years working in ChinaSunergy (Nasdaq:CSUN) as VP of technology, Adam joined REC solar holding a position of strategy head, director of new product and technology.
REC’s Integrated Manufacturing Facility in Singapore
US$2 billion investment with construction started in 2008, production ramp in 2010

REC Wafer Plant
- Wafer size: 156mm x 156mm x 180um
- P-type multi-crystalline
- 2 wafer factories, 30 operators/factory

REC Cell Plant
- mc-Si cell type
- 8 cell lines
- 8 operators/line

REC Module Plant
- 4 Module lines
- Highly automated assembly
- 25 operators/line

Utilities Support
- WWT
- Chiller, Fire Water
- Compress Air

Slurry Recovery Plant

Production Capacity
1 GW by end of 2014
1.3 GW by 2H 2015
Listed on Oslo Stock Exchange (“RECSOL”) with equity market cap. of ~USD 500m

REC is an integrated solar panel manufacturer

Silicon wafers
- Fully automated production facility
- Casting and sawing
- 640 MW capacity*

Cells
- Automated production facility
- Surface treatment
- 770 MW capacity*

Solar Panels
- Fully automated production facility
- Assembly
- 910 MW capacity*

Project development
- Partnering with top-tier project developers
- Limit resource requirements and risk exposure in new projects

State of the art production facility – one factory at one site

REC leverages high-quality solar panel manufacturing, R&D and trusted brand to develop leading market positions in Europe, Asia and the US

*As of 31.12.2013
Technology Benchmark: REC focuses on areas with highest success probability - High Performance Multi and N-Type Mono

Current and expected market share for crystalline Silicon from International Technology Roadmap for Photovoltaic (ITRPV)

Future Technology Platform - n-Type Mono: REC develops low cost high efficiency solution

Current Technology Platform - High Performance Multi: REC is world leader in module power

- p-type multi
- p-type HP-multi
- n-type HP-multi
- p-type monolike
- p-type mono
- n-type mono
Cell Efficiency Roadmap

- REC focused on PERC technology, currently 60% capacity is PERC
- Next focus is N-mono

Source: PV-tech.org_ISC-Konstanz-BC Paper- ENDGÜLTIG
N-type Bifacial Cell Technology

Low CTM Bifacial Module

System Performance
N-type Bifacial Cell Technology

Low CTM Bifacial Module

System Performance
N-mono Cell Technology Development in REC
BiSON vs N-PERC

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<td>Alkaline texture + Cleaning</td>
<td>Polishing + Cleaning</td>
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<td>POCl₃</td>
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<td>SiNx front</td>
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<td>Alkaline texture</td>
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<td>Metallization</td>
<td>Firing</td>
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→ Upgradable from standard P-type production line

→ CE: 21%
  → 676mV, 39.6mA/cm²

→ Cash cost:
  → =P-PERC + 0.5 USc/Wp

→ Bifacility:
  → 60%

→ Better bifaciality with low cost

→ CE: 21.4%
  → 664mV, 40.4mA/cm²

→ Cash cost:
  → =P-PERC -0.5 UsC/Wp
Efficiency and Wp Roadmap for BiSON

Cell cash cost:
\[ \times \text{USc/Wp} \]

- N-mono: 20.30
- Emitter: 0.30
- Metalisation: 0.30
- BSF: 0.20
- Black silicon: 0.60
- Selective BSF: 0.20
- N-mono target: 21.90

Module cash cost,
\[ \times \text{c/Wp} \]

- N-mono BL: 300
- Module optimisation: 3
- Half-cut: 6
- Larger cell spacing: 4
- White spacing: 2
- Target: 315

Cell cash cost:
\[ \times \text{USc/Wp} \]

- N-mono target: 21.90

Module cash cost,
\[ \times \text{c/Wp} \]

- Target: 315
N-type Bifacial Cell Technology
Low CTM Bifacial Module
System Performance
Half Cut Module
Minimizing CTM

- Reduces series resistance
- Improves shading performance
- Better temperature coefficient
- More suitable for 72-cell modules
- Compatible with most of cell technology
N-type Bifacial Cell Technology

Low CTM Bifacial Module

System Performance
Energy Yield Gain by Half Cut

- Energy yield increased by ~17% after half cut (red line)
1) Taking assumptions from part II

2) Majority of the reflected light component comes from light reflected from the surface directly below the module.

3) Angle of shadow was not taken into consideration in this modeling work. It is more crucial for single module modeling but not for module array modeling.

4) Clearance distance is important to allow light entering the gap between the surface and the module. The tilting angle of the module determines the clearance distance.

Bifacial Modules with Elevated Height

- $\alpha$: elevation
- $\beta$: tilt
- $d_1$: minimum clearance distance
- $o_1$: gap
- $o_2$: height of the object in front of the module array is also important
- $S_{\text{incident}}$: Sun’s array

Diagram shows the geometric relationships involving the module array, elevation, and clearance distance.
Simulation case I: Bifacial modules mounted directly on the ground surface, height $h = 0$

Assumptions

➤ Light is reflected evenly in every direction.

➤ Module mounted 90 deg (perpendicular) to the sun at noon

➤ Modules mounted in arrays at set distance

➤ Direct and diffuse reflected light considered
Simulation case II: Bifacial modules mounted at set height $h$ above the ground surface

- Majority of the reflected light from the surface directly below the module.

- Distance in between module arrays and mounting angle $\beta$ important to allow light entering the gap between the surface and the module.
Modeling work - module power with varied elevation height, using Singapore as an example
Summary

→ REC provides high efficiency N-type bifacial cells and half cut modules with zero CTM

→ Up to 370W (72-cell) and 315W (60-cell) are fabricated with cost effective enablers

→ Technical team also supports the system side by providing simulation and solid data from field test
THANK YOU

Welcome back information