Vietnam: the new powerhouse for cell manufacturing in Southeast Asia

Chung-Han Wu Ph.D. / CTO, Boviet Solar Technology
A brief and easy talk

字字珠璣

Word  Word  (like)  Pearl
Population: 94.5 million
From North to South: 1,600 km

- Combining cell and module: 8 GW;
- In the end of 2017: ~ 10.8 GW

- Solar cell capacity now: 3.3 GW;
- In the end of 2017: ~ 4.4 GW

- > 1GW wafer capacity after 2017
Solar industry cluster in Vietnam

80% of capacity in Vietnam, within ~ 10 km
<table>
<thead>
<tr>
<th>Origin (Country)</th>
<th>Company</th>
<th>End of 2016</th>
<th>Plan for 2017 capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>Boviet Solar Technology</td>
<td>Cell: 700 MW</td>
<td>Upgrade to Mono PERC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Module: 700 MW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vina Solar</td>
<td>Cell: 1 GW</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Module: 3.4 GW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trina (w/ Vina)</td>
<td>Cell: 700 MW</td>
<td>Cell: 1 GW</td>
</tr>
<tr>
<td></td>
<td>CSI</td>
<td>Module: 300 MW</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>CSUN</td>
<td>Cell: 100 MW</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Module: 100 MW</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>GCL (w/ Vina)</td>
<td>X</td>
<td>Cell: 600 MW</td>
</tr>
<tr>
<td></td>
<td>JA Solar</td>
<td>X</td>
<td>Wafer: 1 GW</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Module: 1 GW</td>
</tr>
<tr>
<td>Taiwan</td>
<td>Tainergy</td>
<td>Cell: 600 MW</td>
<td>Cell: 700 MW (Q3: PERC 300 MW)</td>
</tr>
<tr>
<td></td>
<td>NSP (w/ Vina)</td>
<td>Cell: 200 MW</td>
<td>Cell: 600 MW (PERC 200MW)</td>
</tr>
<tr>
<td>Vietnam</td>
<td>Red Sun Energy</td>
<td>Module: 75 MW</td>
<td>X</td>
</tr>
</tbody>
</table>

Resource: Energy Trend
Boviet Solar was founded in Bac Giang, North of Vietnam since 2013.

Boviet Solar Technology is the first Megawatt-sized, and the “Top 1~3” solar cell manufacturer in Vietnam.

Focusing on the production of c-Si (mono and multi) solar cell and module (module as the main product).

Boviet solar at present has ~ 1,500 employees, starting from the mid of 2016 the capacity had increased to ~700MW/year for both solar cell and module.
• **Boviet Solar Technology** is a subsidiary company of Boway (博 威) (Powerway) Group which was founded in 1987.

• **Boway Group** is a diversified group, involved a set of non-ferrous alloys, new materials, precision slicing wire, **new energy**, capital operation and other industries.

• **Boway Group** owns Powerway Alloy Material Co., Ltd. (listed on Shanghai Stock Exchange, 601137), The products cover the fields of aerospace, traffic, communication, **household appliance** and **new energy**, etc.
The advanced technology of Boviet Solar
Boviet Solar Efficiency Roadmap

- Conventional cell structure
- PERC technology
- n-type mono cell
- Plating metallization and Black silicon
- Monocrystalline series
- Multicrystalline series

Cell Efficiency

Module Power (72X)

- 400W
- 380W
- 360W
- 355W (340W)
- 340W (320W)
- 325W
- 310W

H1 2016
H2 2016
H1 2017
H2 2017
H1 2018
H2 2018
H1 2019
H2 2019

Conventional cell structure
PERC technology
n-type mono cell
Plating metallization and Black silicon
Monocrystalline series
Multicrystalline series
### 2016 ~ 2019 Target of Cell / Module Power

<table>
<thead>
<tr>
<th></th>
<th>Mono-crystalline</th>
<th>Multi-crystalline</th>
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</thead>
<tbody>
<tr>
<td><strong>Cell efficiency</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>20.2%</td>
<td>18.8%</td>
</tr>
<tr>
<td>2017</td>
<td>21.0%</td>
<td>19.4%</td>
</tr>
<tr>
<td>2018</td>
<td>21.7%</td>
<td>20.0%</td>
</tr>
<tr>
<td>2019</td>
<td>22.5%</td>
<td>20.5%</td>
</tr>
<tr>
<td><strong>Module power</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>335 W</td>
<td>325 W</td>
</tr>
<tr>
<td>2017</td>
<td>355 W</td>
<td>340 W</td>
</tr>
<tr>
<td>2018</td>
<td>375 W</td>
<td>350 W</td>
</tr>
<tr>
<td>2019</td>
<td>400 W</td>
<td>355 W</td>
</tr>
</tbody>
</table>
Advanced PERC production line

- PERC (passivated emitter and rear contact) structure can be applied to both mono- and multi-crystalline silicon (c-Si) solar cells.
- With PERC structure, the conversion efficiency of solar cells can be increased more than 1% abs., thus the PERC technology is best choice to improve the performance of c-Si solar cell/module so far.
- The efficiency of PERC cells of Boviet Solar can hit up to > 21% for mono- and 19.6% for multi- c-Si cells conservatively.

- Boviet Solar have installed an 100 MW PERC cell production line in the end of 2016, and now is installing another 300 MW PERC line, and completing before the H1 of this year.
- Before the end of 2017, 100% Boviet’s solar products will contain high efficiency PERC cell inside!
The progress of PERC @ Boviet Solar

60 Cell Mono
290-300W(4BB)

BVM6610M

High Quality and Reliable Modules Due to Thorough Design and Stringent Quality Control
- Withstand up to 5400 Pa snow load 2400 Pa wind load
- 1000V/1500V DC certified
- Two times of EL inspection on every cell and module for defect free
- Type 1 fire-rating per UL 1703 edition 3
- High salt and ammonia resistance Certified by TUV Rheinland
- 0-+5W guaranteed positive tolerance on nameplate power output

Warranty
- 12-year product warranty
- 25-year linear power output warranty

Comprehensive Certificates for Products and Management
- UL 1703, IEC 61215, IEC 61730, CEC listed, MCS and CE
- ISO 9001 for Quality Management Systems
- ISO 14001 for Environmental Management Systems
- ISO 18001 Occupational Health and Safety System

Electrical Characteristics STC

<table>
<thead>
<tr>
<th>Model</th>
<th>Maximum Power(Pmax)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BVM6610M-290</td>
<td>290W</td>
</tr>
<tr>
<td>BVM6610M-295</td>
<td>295W</td>
</tr>
<tr>
<td>BVM6610M-300</td>
<td>300W</td>
</tr>
</tbody>
</table>
R&D Team of Boviet Solar

About the team leader: Dr. Chung-Han Wu

Education
Cornell University, Materials Science and Engineering, Ph. D.
Cornell University, Materials Science and Engineering, Master
National Taiwan University, Chemical Engineering, Master
National Taiwan University, Chemical Engineering, Bachelor

Work Experience
2013 – present: Adjunct Professor of Department of Photonics, Feng Chia University.
2011 – 2012: Senior Principal Engineer of the Process Integration Engineering (PIE), Motech Inc.

Awards and Scholarships
2001 National Science Council Fellowship
2005 Taiwan Merit Scholarship (TMS) – First winner in the field of energy technology.
R&D Team of Boviet Solar

- We are building up a 20 ~ 30 people team to conduct the R&D of solar energy.

- At the start, we have recruited several experienced R&D engineers who get involved in c-Si solar cell technology for years and be familiar with the fabrication process.

- To localize here in Vietnam, we keep recruiting talented and knowledgeable Vietnamese R&D engineers (Master or Doctor degree) to join us as the main researching human resource.
Collaboration with the Universities

Collaboration with the Universities

Being the lecturer of the Top university in Vietnam – Hanoi University of Science and Technology (HUST), and introducing the field study at Boviet Solar.
R&D activities

Boviet’s TwinStar module

- Applying the half-cut cell technology, the CTM loss of our module product can be largely reduced.

- The power output of Boviet’s TwinStar module can be ~10W larger than the normal module products.
R&D activities

Only black mono module?

Boviet's Perfect Black poly module
The solar industry of Vietnam started increasing since 2013, and grew sharply last year. (tariff issue)

At present, in the North of Vietnam, the capacity combining solar cell and module is around 8 GW, and expected to increased to 10.8 GW in the end of this year.

Considering only the cell manufacturing, at present, the capacity is 3.3 GW already, and expected to increased 33% to 4.4 GW in the end of this year.

Not only factories, but also R&D department set in Boviet Solar.

The technologies to be developed in Boviet Solar are: mono-PERC, black silicon PERC, and n-type cell step by step.

The conditions for building up a R&D team is not easy in Vietnam, but we can try to create the conditions.
We will keep working on &

Thank you for your attention!