Rooftop & TOPCon: Appraising the benefits of TOPCon PV modules on LCOE for distributed generation project

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Welcome!

Do you have any questions? 🤔 🙋‍♂️‍♀️ Send them in via the Q&A tab. 🙋‍♂️ We aim to answer as many as we can today!

You can also let us know of any tech problems there.

We are recording this webinar today. 🎥

We’ll let you know by email where to find it and the slide deck, so you can re-watch it at your convenience. 📺💡
TOPCon Silicon Solar Cells

From Pilot Line to Fab


Fraunhofer Institute for Solar Energy Systems ISE
Freiburg, Germany

PV Magazine Webinar
April 20, 2022
TOPCon
From Pilot Line to Fab

- TOPCon – Introduction and status
- Results from ISE’s pilot line lab
- Cost and approaches to reduce cost
- Outlook
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Lab Results From ISE’s Clean Room Team
Experimental Solar Cell Results

- TOPCon technology introduced by ISE in 2013 [1]
- TOPCoRE technology introduced by ISE in 2021 [2]
- 2*2cm² large champion lab cells [2]
- Front Junction vs Rear Junction Cell Design

<table>
<thead>
<tr>
<th>Design</th>
<th>$V_{oc}$ (mV)</th>
<th>FF (%)</th>
<th>$J_{sc}$ (mA/cm²)</th>
<th>η (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front junction</td>
<td>724</td>
<td>83.1</td>
<td>42.9</td>
<td>25.8</td>
</tr>
<tr>
<td><strong>Rear junction</strong></td>
<td><strong>732</strong></td>
<td><strong>84.3</strong></td>
<td><strong>42.1</strong></td>
<td><strong>26.0</strong></td>
</tr>
<tr>
<td><strong>without FSF</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Certified by Fraunhofer ISE CalLab, designated area: 2x2 cm²

Large Area Solar Cells
Notable Efficiencies Within Pilot Lines

- Many players are active in this field
- Exceptionally high efficiencies by several companies

(Simplified schematic, actual layout might be different)

<table>
<thead>
<tr>
<th>Company</th>
<th>Wafer size</th>
<th>TOPCon Technology</th>
<th>Emitter</th>
<th>η</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trina Solar</td>
<td>210 mm</td>
<td>?</td>
<td>selective</td>
<td>25.5 %</td>
</tr>
<tr>
<td>Jolywood</td>
<td>182 mm</td>
<td>POPAID PVD</td>
<td>?</td>
<td>25.4 %</td>
</tr>
<tr>
<td>JinkoSolar</td>
<td>267.4 cm²</td>
<td>LPCVD</td>
<td>Passivated contact</td>
<td>25.4 %</td>
</tr>
<tr>
<td>Longi</td>
<td>Not disclosed</td>
<td>?</td>
<td>?</td>
<td>25.2 %</td>
</tr>
</tbody>
</table>

POPAGD: Plasma Oxidation and Plasma Assisted In-situ Doping

[1] https://en.solarbe.com/home/article/info/catId/36/id/5776.html?msclkid=15873c4ba91e11ec94b5046a0326abfb
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TOPCon Process at ISE
Baseline Process

- LPCVD TOPCon route as baseline process, using in-situ doping
- M2 wafers
- Production type equipment
- Ready for samplings

Screen printed AgAl contact
Screen printed Ag contact

n-type Cz-Si

SiN$_x$
AlO$_x$
p$^+$ emitter
SiO$_x$
n$^+$ poly-Si
SiN$_x$ : H

Process flow with in-situ doping

- Alkaline texturing
- BBr$_3$ diffusion
- Chemical edge isolation
- LPCVD: Tunnel oxide + a-Si (n)
- Poly single side etch on front by ADE [1]
- BSG etching + clean
- Annealing
- Front side passivation
- Rear side passivation
- SP front Ag/Al grid
- SP rear Ag grid
- FFO
- IV measurement

Introduction industrial (i)TOPCon solar cell
Amorphous silicon deposition

- Chemical vapor deposition CVD
  - Low pressure LPCVD (double sided)
  - Plasma enhanced PECVD
  - Atmospheric pressure APCVD
- Physical vapor deposition
  - Sputter
  - Evaporation

Industrial LPCVD manufacturing platform, courtesy of Semco

Liquid Silicon
Evaporation
PECVD, APCVD (no industrial implementation yet)
PVD (Jolywood *)
LPCVD (Jinko, Longi,...)

TRL
0 1 2 3 4 5 6 7 8 9

*proprietary know how of Jolywood
TOPCon Process at ISE

Bifaciality

- Quantum efficiency measured from front and rear
- High absorption coefficient in poly-Si
  - low EQE at low wavelengths for rear illumination
  - bifaciality of 84% (80nm) vs. 78% (160nm) vs. 70-80% (bifacial PERC)
- less severe in modules due to UV cut off in sodalime glass and rear encapsulant (85% bifaciality shown in solar modules from Jan 2021)
TOPCon Process at ISE

Champion cell

- For poly-Si of only 80nm: $\eta = 23.8\%$
- Low reverse current density $J_{rev,2} = 0.1 \text{ mA/cm}^2$ at -12V due to effective ADE edge isolation

<table>
<thead>
<tr>
<th>Poly Thickness</th>
<th>Area (cm²)</th>
<th>$\eta$ (%)</th>
<th>$J_{SC}$ (mA/cm²)</th>
<th>$V_{OC}$ (mV)</th>
<th>FF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 nm</td>
<td>244.5</td>
<td>23.8</td>
<td>41.3</td>
<td>706</td>
<td>81.6</td>
</tr>
</tbody>
</table>

Independently confirmed by CalLab
(GridTouch 30I wires, full area contacting gold chuck)

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Grübel et al., “Progress of Plated Metallization for Industrial Bifacial TOPCon Silicon Solar Cells”, Prog Photovolt (2021)
Cost of ownership - PERC vs TOPCon
Levelized Costs of Electricity (LCOE)

- Efficiency matters!
- Assuming similar uptime and yield for all production lines
- Based on our assumptions, efficiency gain of 0.4-0.6% needed vs. PERC

**Efficiency matters!**

**Assuming similar uptime and yield for all production lines**

**Based on our assumptions, efficiency gain of 0.4-0.6% needed vs. PERC**
Cost of ownership - PERC vs TOPCon

Total Cost of Ownership TCO

- Increased cost per W_p also due to use of Ag paste on both sides [1]
- Ag consumption might become an issue for large-scale market penetration [2]
- Already 10% of Ag world production used for PV

Modelled for a production output of 5 GWp using M4 wafers

TOPCon Solar Cells with Thin Poly-Si

Key Benefits of Plated Contacts

- Narrow front side contacts
  - Front side contact width down to 15 µm → $J_{sc}$ & $V_{oc}$ improvements
- Low laser damage on rear side → $V_{oc}$ improvements
- Low contact resistance on emitter & TOPCon → FF improvements
- Lead free & 90% Ag reduction compared to screen printing
- Decreased cost of ownership [1]

TOPCon Solar Cells with Thin Poly-Si
Cell Efficiency Plating vs. Screen Printing

- Champion solar cells
  - Industrial precursor
  - LCO, FFO & plating processes @FhG-ISE
  - Reference: Screen printing @supplier R&D line
  - 9 busbar grid design

CHAMPION CELLS
certified @Fraunhofer ISE Callab*

<table>
<thead>
<tr>
<th></th>
<th>Poly-Si thickness (nm)</th>
<th>η (%)</th>
<th>$J_{sc}$ (mA/cm²)</th>
<th>$V_{oc}$ (mA/cm²)</th>
<th>FF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen printing</td>
<td>125</td>
<td>23.5</td>
<td>40.7</td>
<td>705</td>
<td>81.9</td>
</tr>
<tr>
<td>Plating</td>
<td>125</td>
<td>24.0</td>
<td>41.0</td>
<td>715</td>
<td>82.0</td>
</tr>
</tbody>
</table>

*Front & rear grid resistance neglected, highly reflective chuck

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Trends for commercialization of TOPCon

- TOPCon train is accelerating and will replace PERC over time [1]
- N-type Si wafer is around 10% more costly than p-type Si wafer, R&D on TOPCoRE cell will accelerate [1]
- Throughput of polysilicon process will increase (lower thickness, higher loads, novel equipment) [1]
- Double sided Ag metallization is cost-driver
  - Replace Ag by Ni/Cu plated contacts (ISE 24% [2], SunDrive 25.5% [3])
  - Replace AgAl on front side by Al [4]
- Enable passivated contacts for new applications, such as Tandem

Passivating Contacts for Si-based tandems
Concepts and first demonstrators

POLO- and $n^+/p^+$ poly-Si tunnelling junction as Pk/PERC interface\[1\]

nc-Si$_x$(n)/nc-Si:H(p) tunnelling junction as interface for Si/Pk-tandem on textured surfaces - 25.1% (1sun, AMG1.5)\[2\]

\[1\] R. Peibst et al., IEEE J. of Photovolt. 9 (1), 49 (2019), S. Mariotti et al., Sol. RRL 2101066 (2022)
\[2\] G. Nogay et al., ACS Energy Letters 4, 844 (2019)
Passivating Contacts for Si-based tandem
Concepts and first demonstrators

- TOPCon as interface for bonding of III/V - 35.9% (1sun, AMG1.5)[1]

Thank you!
Current Status

a-Si Deposition Technologies

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Single-sided deposition</td>
<td>×</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>In-situ doping</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>–</td>
</tr>
<tr>
<td>Availability of industrial tool</td>
<td>✓✓✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>–</td>
</tr>
<tr>
<td>Process demonstrated in lab-size cells</td>
<td>✓✓✓</td>
<td>✓✓</td>
<td>✓</td>
<td>✓</td>
<td>–</td>
</tr>
<tr>
<td>Application in large-size industrial cell</td>
<td>✓✓✓</td>
<td>✓</td>
<td>–</td>
<td>✓</td>
<td>–</td>
</tr>
<tr>
<td>Deposition mode (Batch/Inline)</td>
<td>Batch</td>
<td>Both</td>
<td>Inline</td>
<td>Inline</td>
<td>Batch</td>
</tr>
</tbody>
</table>

adapted from [1]

[16] Schneiderlöchner et al., PVCelltech Malaysia (2019)
Industrialization of passivating contacts
Passivating contacts by PVD

- 23 % on 4 cm², 1 Ωcm p-type FZ wafers[^1]
- Deposition of p⁺ poly-Si with **PVD sputtering**
  - Single-side deposition technique
  - No hazardous gasses
- Challenge for n⁺ poly-Si[^2,^3]: so far no sputtering targets with sufficient high phosphorus concentration for industrial equipment
- However, POPAID seems to run in production at Jolywood

[^2]: L. David et al., 37th EUPVSEC (2020)
[^3]: L. Nasebandt et al., 38th EUPVSEC (2021)
Industrialization of passivating contacts
POLO Back Junction with Al front grid

- Alternative for integrating passivating contacts for mainstream $p$-type solar cells\[1\]
- Screen-printed Al front fingers
- $n^+$ poly-Si at rear side
- Lean process flow with less high temperature steps and less Ag consumption compared to other concepts
- Current status at ISFH\[1\]: 22.9 %, 714 mV, 39.6 mA/cm², 80.9 % with M2-sized Cz wafers
- Solderability of front side contact needs to be ensured

\[1\] Min et al., 38th EUPVSEC (2020).
LCOE Impact of Using N-Type TOPCon Modules in DG Projects

Waleed AlHallaj – Business Development Manager MENA
Introduction To JinKo Solar
No. 1 Total Shipments Globally

100GW+ Delivered Globally Until Q1 2022
14.3% Global Market Share Until end of 2021
18 World Records Until end of 2021
40GW+ Annual Module Capacity for 2022

Jinko Solar Co., Ltd.
Market Share Rankings in Top 10 Markets – 2020

1. China: 24%
2. United States: 21%
3. Vietnam: 17%
4. Japan: 14%
5. Germany: 16%
6. Australia: 11%
7. Brazil: 4%
8. Korea: 22%
9. India: 20%
10. Netherlands: 8%
Products & Technologies
What We Do – Our Products

Wafer

Cell

Panels

BiPV

Solar Business

Continuously expanding the production capacity of silicon wafers, cells and modules, to create a vertically integrated PV industrial chain
What We Do – Our Solutions

Solar Lighting

ESS

Pumping

Solar Solutions

Adding BiPV to existing BAPV with new variety of Energy Storage Systems (ESS) and full turn-key Pumping Systems
## Product Roadmap - Module Power

<table>
<thead>
<tr>
<th>Year</th>
<th>Module Power</th>
<th>Cell Size</th>
<th>Busbars</th>
<th>Solar Cell Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>~300W</td>
<td>156mm - 158mm</td>
<td>5BB-9BB</td>
<td>Polycrystalline - Monocrystalline</td>
</tr>
<tr>
<td>2014</td>
<td>~320W</td>
<td>156mm - 158mm</td>
<td>5BB-9BB</td>
<td>Polycrystalline - Monocrystalline</td>
</tr>
<tr>
<td>2016</td>
<td>~360W</td>
<td>156mm - 158mm</td>
<td>5BB-9BB</td>
<td>Polycrystalline - Monocrystalline</td>
</tr>
<tr>
<td>2017</td>
<td>~385W</td>
<td>156mm - 158mm</td>
<td>5BB-9BB</td>
<td>Polycrystalline - Monocrystalline</td>
</tr>
<tr>
<td>2018</td>
<td>~405W</td>
<td>156mm - 158mm</td>
<td>5BB-9BB</td>
<td>Polycrystalline - Monocrystalline</td>
</tr>
<tr>
<td>2019</td>
<td>~415W</td>
<td>156mm - 158mm</td>
<td>5BB-9BB</td>
<td>Polycrystalline - Monocrystalline</td>
</tr>
<tr>
<td>2020</td>
<td>~470W</td>
<td>156mm - 163mm</td>
<td>9BB-10BB</td>
<td>P-Type - N-Type</td>
</tr>
<tr>
<td>2021</td>
<td>~595W</td>
<td>163mm - 182mm</td>
<td>9BB-10BB</td>
<td>P-Type - N-Type</td>
</tr>
<tr>
<td>2022</td>
<td>~615W</td>
<td>163mm - 182mm</td>
<td>9BB-10BB</td>
<td>P-Type - N-Type</td>
</tr>
</tbody>
</table>

- Module Eff. 20.93%
- Module Eff. 21.38%
- Module Eff. 22.26%
Tiger Neo
N-Type TOPCon - A Notch Above
TOPCon Technical Specification

Nowdays, the N-type cells studied are mainly divided into: PERT, Topcon, HJT and IBC.

Among them, Topcon and HJT are the focus of attention of the current N-type technology and the focus of high-end products’ competition.
JinkoSolar sets new record for n-type solar cell efficiency

Manufacturing giant JinkoSolar has set another world record for n-type solar cell efficiencies with its TOPCon technology, this time pushing to 25.4%. The new world record was confirmed by JET laboratories in Japan, and surpasses JinkoSolar’s previous record of 25.25% set back in May.

JULY 12, 2021  EMILIANO BELLINI

JinkoSolar claims 23.53% efficiency for n-type, TOPCon, monocrystalline panel

The PV module relies on Jinko’s TOPCon mono cell technology, for which a record efficiency of 25.25% was announced in late May. TÜV Rheinland has confirmed the result.

JULY 12, 2021  EMILIANO BELLINI

JinkoSolar reaches record 25.25% efficiency with n-type monocrystalline TOPCon solar cell

The Chinese module manufacturer said the 0.35% improvement in efficiency was obtained through material upgrades integrated into the cell process and fabrication. The result was confirmed by China’s National Institute of Metrology.

JUNE 1, 2021  EMILIANO BELLINI
Tiger Neo Advantages
What is New in N-Type: Advantages

Product Advantage I
Optimized Degradation
Advanced Warranty

The power warranty could achieve 30 years compared with traditional P-type module. The first year degradation is lower than 1% which means the power output could remain over 87.4% compare with the 1st year.
What is New in N-Type: Advantages

**Product Advantage II**

**Optimized Temperature Coefficients**

-0.30%/ ºC

- Tiger Neo’s power output will increase with the better **temperature coefficient** (0.75% higher compared with PERC)

- Under the same external environment, Tiger Neo’s **operating temperature** is lower (>1% compared with the same specification P type)

- Under high temperature condition, the advantage will further expanded (~2% higher)

P-type -0.35%

N-type -0.30%
What is New in N-Type: Advantages

Product Advantage Ⅲ

Bifacial Factor

85%

N-type’s higher bifacial factor will bring significant power gain around 2.03%

\[ P_{\text{Integrated power}} = P_{\text{front}} \times (1 + BSI \times Bifi) \]

*BSI: Bifacial stress irradiance coefficient (depend on real irradiance & ground reflectivity)

Power gain contrast:
- PERC: BSI*70% = 9.45%
- HOT: BSI*85% = 11.48%
What is New in N-Type: Advantages

Product Advantage IV

Better Low Light Performance

N-type cell, higher internal resistance, longer minority carriers life, naturally better low light response

Compared with traditional PERC modules, N-type TOPCon modules have a better response to low light, extend the power generation period by about 1H in the morning and evening.

Low light coefficient, especially the performance below 600W/m², N-type products > P-type products
What is New in N-Type: Advantages

Product Advantage V
Enhanced Reliability

The N-type modules have better indicators than normal IEC standard and performs excellent during test process.

Tiger Pro N Reliability Test

*Jinko R&D Data
Testing Sample: Jinko N-type mono Module
Jinko P-type mono Module
<table>
<thead>
<tr>
<th></th>
<th>Monofacial</th>
<th>Bifacial</th>
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<tbody>
<tr>
<td><strong>Tiger Neo 54 Cell</strong></td>
<td>Up to 430 Wp</td>
<td>Up to 610 Wp</td>
</tr>
<tr>
<td></td>
<td>54 cells</td>
<td>78 cells</td>
</tr>
<tr>
<td></td>
<td>182mm wafer</td>
<td>182mm wafer</td>
</tr>
<tr>
<td></td>
<td>Efficiency up to</td>
<td>Efficiency up to</td>
</tr>
<tr>
<td></td>
<td>22.02%</td>
<td>21.82%</td>
</tr>
<tr>
<td></td>
<td>30 Year Linear</td>
<td>30 Year Linear</td>
</tr>
<tr>
<td></td>
<td>Power Warranty</td>
<td>Power Warranty</td>
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<tr>
<td><strong>Tiger Neo 60 Cell</strong></td>
<td>Up to 480 Wp</td>
<td>Up to 575 Wp</td>
</tr>
<tr>
<td></td>
<td>60 cells</td>
<td>72 cells</td>
</tr>
<tr>
<td></td>
<td>182mm wafer</td>
<td>182 mm wafer</td>
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<tr>
<td></td>
<td>Efficiency up to</td>
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<td>22.24%</td>
<td>22.07%</td>
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<td>30 Year Linear</td>
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<td><strong>Tiger Neo 72 Cell</strong></td>
<td>Up to 575 Wp</td>
<td>Up to 570 Wp</td>
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<td>72 cells</td>
<td>72 cells</td>
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<td>182 mm wafer</td>
<td>182 mm wafer</td>
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<td></td>
<td>Efficiency up to</td>
<td>Efficiency up to</td>
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<td>22.07%</td>
<td>22.26%</td>
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<td>30 Year Linear</td>
<td>30 Year Linear</td>
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<td></td>
<td>Power Warranty</td>
<td>Power Warranty</td>
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<tr>
<td><strong>Tiger Neo 78 Cell</strong></td>
<td>Up to 610 Wp</td>
<td></td>
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<td>78 cells</td>
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<td>182 mm wafer</td>
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<td>21.82%</td>
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<td>30 Year Linear</td>
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Tiger Neo Case Studies
### xxx152MW Project

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<td>Mounting system</td>
<td></td>
<td>2P single axis tracking system</td>
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<td></td>
</tr>
<tr>
<td>Module Power</td>
<td>Wp</td>
<td>540</td>
<td>555</td>
<td>555</td>
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<tr>
<td>1st yr Degradation</td>
<td>%</td>
<td>2</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Linear Degradation</td>
<td>%</td>
<td>0.45</td>
<td>0.4</td>
<td>0.4</td>
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<tr>
<td>No. of module</td>
<td>pcs</td>
<td>281,792</td>
<td>274,176</td>
<td>281,792</td>
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<tr>
<td>DC capacity</td>
<td>MW</td>
<td>152.167</td>
<td>152.167</td>
<td>156.394</td>
</tr>
<tr>
<td>DC/AC ratio</td>
<td></td>
<td>1.31</td>
<td>1.31</td>
<td>1.35</td>
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<tr>
<td>1st yr hours</td>
<td>h</td>
<td>1,366</td>
<td>1,407</td>
<td>1,407</td>
</tr>
<tr>
<td>1st yr power generation</td>
<td>MWh</td>
<td>207,880</td>
<td>214,116</td>
<td>220,047</td>
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<tr>
<td>1st yr power generation gain</td>
<td>%</td>
<td>Baseline data</td>
<td>3%</td>
<td>5.53%</td>
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<tr>
<td>20-yr power generations</td>
<td>MWh</td>
<td>3,976,230</td>
<td>4,118,782</td>
<td>4,232,864</td>
</tr>
<tr>
<td>20-yr power generations gain</td>
<td>%</td>
<td>Baseline data</td>
<td>+3.58%</td>
<td>+6.45%</td>
</tr>
<tr>
<td>Tariff</td>
<td>$/kWh</td>
<td>Baseline Data</td>
<td>Same capacity</td>
<td>Same land use</td>
</tr>
<tr>
<td>BOS cost</td>
<td>$/Wp</td>
<td>0.333</td>
<td>0.3263</td>
<td>0.3241</td>
</tr>
<tr>
<td>BOS cost difference</td>
<td>%</td>
<td>Baseline data</td>
<td>-2%</td>
<td>-2.74%</td>
</tr>
<tr>
<td>Module cost</td>
<td>$/Wp</td>
<td>0.2984</td>
<td>0.3087</td>
<td>0.3087</td>
</tr>
<tr>
<td>total EPC cost</td>
<td>$/Wp</td>
<td>0.6314</td>
<td>0.6351</td>
<td>0.6329</td>
</tr>
<tr>
<td>IRR (before tax)</td>
<td>%</td>
<td>7.13%</td>
<td>7.42%</td>
<td>7.48%</td>
</tr>
</tbody>
</table>

### Conclusion of Jinko N-type:
1. BOS cost save **0.0089/Wp**
2. 1st year generating hours increase **3%**
3. IRR increase **0.35%**

### Unit Cost:
- **Fixed tilt cost**: 0.0603, 0.0586, 0.3690
- **Cable**: 0.0290, 0.0283, 0.0283
- **Foundation**: 0.0256, 0.0248, 0.0248
- **Inverters**: 0.0194, 0.0194, 0.0189
- **Module Installation**: 0.0079, 0.0078, 0.0078
- **Fixed tilt Installation**: 0.0100, 0.0097, 0.0097
- **Land use cost**: 0.0479, 0.0467, 0.0467
- **Design cost**: 0.0032, 0.0032, 0.0032
- **Equipment**: 0.0210, 0.0210, 0.0203
- **Others**: 0.0011, 0.0011, 0.0011

**Total cost**: 0.2254, 0.2203, 0.2192
Case Study – Comparison Pro Vs Neo (Oman)

**Tiger Pro – 545 Wp**
- Module Efficiency: 21.10%
- Temperature Coefficient: -0.35%/C
- Light Induced Degradation: 1.45%
- Annual Degradation: 0.55%/Year

**Tiger Neo – 560 Wp**
- Module Efficiency: 21.68%
- Temperature Coefficient: -0.30%/C
- Light Induced Degradation: 0.60%
- Annual Degradation: 0.40%/Year
Case Study – Comparison Pro Vs Neo (Oman)

Location: International Airport – Muscat
Total Number of Modules: 2,700 Units
AC Capacity: 1,200 kW
Tilt Angle: 20°
Azimuth Angle: 0°
BOS Cost: Equal
Project Lifetime: 25 Years
Electrical Tariff: 30 Omani Besa / kWh
(0.078 USD/kWh)
Case Study – Comparison Pro Vs Neo (Oman)

<table>
<thead>
<tr>
<th></th>
<th>Tiger Pro</th>
<th>Tiger Neo</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC Capacity</td>
<td>1,471.5 kWp</td>
<td>1,512.0 kWp</td>
</tr>
<tr>
<td>Annual Yield</td>
<td>2,617 MWh/Y</td>
<td>2,769 MWh/Y</td>
</tr>
<tr>
<td>Specific Production</td>
<td>1,779 kWh/kWp.Y</td>
<td>1,831 kWh/kWp.Y</td>
</tr>
<tr>
<td>Performance Ratio</td>
<td>79.03 %</td>
<td>81.37 %</td>
</tr>
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</table>
# Case Study – Comparison Pro Vs Neo (Oman)

<table>
<thead>
<tr>
<th>Year</th>
<th>Tiger Pro</th>
<th>Tiger Neo</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MWh/Year</td>
<td>OMRA/Year</td>
<td>MWh/year</td>
</tr>
<tr>
<td>1</td>
<td>2,617</td>
<td>78,510</td>
<td>2,769</td>
</tr>
<tr>
<td>2</td>
<td>2,603</td>
<td>78,078</td>
<td>2,758</td>
</tr>
<tr>
<td>3</td>
<td>2,588</td>
<td>77,649</td>
<td>2,747</td>
</tr>
<tr>
<td>4</td>
<td>2,574</td>
<td>77,222</td>
<td>2,736</td>
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<tr>
<td>5</td>
<td>2,560</td>
<td>76,797</td>
<td>2,725</td>
</tr>
<tr>
<td>6</td>
<td>2,546</td>
<td>76,375</td>
<td>2,714</td>
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<tr>
<td>7</td>
<td>2,532</td>
<td>75,955</td>
<td>2,703</td>
</tr>
<tr>
<td>8</td>
<td>2,518</td>
<td>75,537</td>
<td>2,692</td>
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<tr>
<td>9</td>
<td>2,504</td>
<td>75,121</td>
<td>2,682</td>
</tr>
<tr>
<td>10</td>
<td>2,490</td>
<td>74,708</td>
<td>2,671</td>
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<tr>
<td>11</td>
<td>2,477</td>
<td>74,297</td>
<td>2,660</td>
</tr>
<tr>
<td>12</td>
<td>2,463</td>
<td>73,889</td>
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<tr>
<td>13</td>
<td>2,449</td>
<td>73,482</td>
<td>2,639</td>
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<tr>
<td>14</td>
<td>2,436</td>
<td>73,078</td>
<td>2,628</td>
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<tr>
<td>15</td>
<td>2,423</td>
<td>72,676</td>
<td>2,618</td>
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<td>16</td>
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<td>2,607</td>
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<td>17</td>
<td>2,396</td>
<td>71,879</td>
<td>2,597</td>
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<td>2,383</td>
<td>71,484</td>
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<tr>
<td>19</td>
<td>2,370</td>
<td>71,090</td>
<td>2,576</td>
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<tr>
<td>20</td>
<td>2,357</td>
<td>70,699</td>
<td>2,566</td>
</tr>
<tr>
<td>21</td>
<td>2,344</td>
<td>70,311</td>
<td>2,556</td>
</tr>
<tr>
<td>22</td>
<td>2,331</td>
<td>69,924</td>
<td>2,545</td>
</tr>
<tr>
<td>23</td>
<td>2,318</td>
<td>69,539</td>
<td>2,535</td>
</tr>
<tr>
<td>24</td>
<td>2,305</td>
<td>69,157</td>
<td>2,525</td>
</tr>
<tr>
<td>25</td>
<td>2,293</td>
<td>68,776</td>
<td>2,515</td>
</tr>
<tr>
<td>Total</td>
<td>61,284</td>
<td>1,838,509</td>
<td>66,002</td>
</tr>
</tbody>
</table>
Case Study – Comparison Pro Vs Neo (Oman)

123,500 OMR (320,766 USD) Extra Profit
Case Study – Comparison Pro Vs Neo (Palestine)

**Tiger Pro – 545 Wp**

- Module Efficiency: 21.10%
- Temperature Coefficient: -0.35%/C
- Light Induced Degradation: 1.45%
- Annual Degradation: 0.55%/Year

**Tiger Neo – 565 Wp**

- Module Efficiency: 21.87%
- Temperature Coefficient: -0.30%/C
- Light Induced Degradation: 0.60%
- Annual Degradation: 0.40%/Year
Location: Rafah, Gaza
Total Number of Modules: 2,700 Units
AC Capacity: 1,200 kW
Tilt Angle: 7°
Azimuth Angle: 88° & -92°
BOS Cost: Equal
Project Lifetime: 25 Years
Electrical Tariff: 0.35 USD/kWh
## Case Study – Comparison Pro Vs Neo (Palestine)

<table>
<thead>
<tr>
<th></th>
<th>Tiger Pro</th>
<th>Tiger Neo</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DC Capacity</strong></td>
<td>81.75 kWp</td>
<td>84.75 kWp</td>
</tr>
<tr>
<td><strong>Annual Yield</strong></td>
<td>131.6 MWh/Y</td>
<td>139.4 MWh/Y</td>
</tr>
<tr>
<td><strong>Specific Production</strong></td>
<td>1,610 kWh/kWp.Y</td>
<td>1,644 kWh/kWp.Y</td>
</tr>
<tr>
<td><strong>Performance Ratio</strong></td>
<td>81.57 %</td>
<td>83.35 %</td>
</tr>
</tbody>
</table>
Case Study – Comparison Pro Vs Neo (Palestine)

Cash Flow Diagram (USD)

87,685 USD
Extra Profit
Rooftop & TOPCon: Appraising the benefits of TOPCon PV modules on LCOE for distributed generation project

Q&A

Emiliano Bellini
Editor
pv magazine

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Business Development Manager – MENA
Jinko Solar

Sebastian Mack
PV Production Technology Researcher
Fraunhofer ISE
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by Emiliano Bellini

The Hydrogen Stream: Fuel cell engines for stationary power uses
by Sergio Matalucci
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11:00 am – 12:00 pm EEST, Athens

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5:00 pm – 6:00 pm CEST, Berlin
8:00 am – 9:00 am PDT, Los Angeles

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Emiliano Bellini
Editor
pv magazine