Large-format Modules (LFM) and Solar Trackers: Key Considerations and Impact on Plant LCOE

PRESENTED BY

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Nextracker

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Fichtner GmbH & Co

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Fichtner GmbH & Co

MODERATED BY

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Senior News Editor
PV Tech
Large Wafer Modules: considerations from the developer side

Tomaso Charlemont, Global Solar Procurement Leader

April 21, 2021
RES Overview

Large Wafer Modules: considerations from the developer side:

- An unprecedented revolution
- Plenty of interesting features
- Every medal has a reverse side

Conclusion
19 GW
PROJECT PORTFOLIO

40
YEARS OF EXPERIENCE

7 GW
OF OPERATIONAL ASSETS SUPPORTED

3,000
EMPLOYEES

ACTIVITIES

TECHNOLOGIES

DEVELOP

CONSTRUCT

OPERATE

WIND

SOLAR

STORAGE

T&D
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1981:</strong></td>
<td>RES (Renewable Energy Systems) established, performing research in wind technology.</td>
</tr>
<tr>
<td><strong>1992:</strong></td>
<td>RES develops and constructs UK’s second utility scale wind farm in Cornwall.</td>
</tr>
<tr>
<td><strong>2001:</strong></td>
<td>Creates the world’s largest wind farm at the time, the 278MW King Mountain Wind Project in Texas, USA.</td>
</tr>
<tr>
<td><strong>2010:</strong></td>
<td>First 5MWp Solar Project developed, constructed and operated by RES in France.</td>
</tr>
<tr>
<td><strong>2013:</strong></td>
<td>345km 300MW 230kV Montana - Alberta, US - Canada transmission line completed.</td>
</tr>
<tr>
<td><strong>2014:</strong></td>
<td>First 4MW (2.6MWh) energy storage project becomes operational in Ohio, US.</td>
</tr>
<tr>
<td><strong>2018:</strong></td>
<td>Understanding the unique needs of corporate clients, RES secured over 1.5GW of power purchase agreements (Corporate PPAs).</td>
</tr>
<tr>
<td><strong>2020:</strong></td>
<td>America’s largest bifacial solar project, 216MWp/160MWac begins commercial operations in Georgia, USA.</td>
</tr>
</tbody>
</table>
An Unprecedented Revolution

Source: SunPower
An Unprecedented Revolution

Source: PV Tech
EFFECTIVE WAFER SIZE DEVELOPMENT

<table>
<thead>
<tr>
<th>Wafer Size</th>
<th>Area in mm²</th>
<th>Percentage Increase</th>
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</thead>
<tbody>
<tr>
<td>M0</td>
<td>24.092</td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>24.383</td>
<td>+1%</td>
</tr>
<tr>
<td>M2</td>
<td>24.426</td>
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<tr>
<td>M3</td>
<td>24.991</td>
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<tr>
<td>G1</td>
<td>25.199</td>
<td>+5%</td>
</tr>
<tr>
<td>M4</td>
<td>25.805</td>
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<tr>
<td>M5</td>
<td>26.726</td>
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<td>M6</td>
<td>27.410</td>
<td>+14%</td>
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<tr>
<td>M8</td>
<td>34.212</td>
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<tr>
<td>M9</td>
<td>36.862</td>
<td>+42%</td>
</tr>
<tr>
<td>M10</td>
<td>39.997</td>
<td>+53%</td>
</tr>
<tr>
<td>M12</td>
<td>44.096</td>
<td>+66%</td>
</tr>
</tbody>
</table>

RENA Technologies ©
An Unprecedented Revolution

500+ W PV Module Producer Club

Photovoltaic Open Innovation Ecological Alliance (POIEA)
### 2GWp+ Ground-Mount Project Portfolio to date

<table>
<thead>
<tr>
<th>Country</th>
<th>State</th>
<th>MWp</th>
<th>Tracker</th>
<th>Module</th>
<th>Project type</th>
<th>Status</th>
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<tr>
<td>USA</td>
<td>Iowa</td>
<td>128</td>
<td>2 MIP</td>
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<tr>
<td>FRA</td>
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<td>10</td>
<td>1 MIP</td>
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<td>22-Q1</td>
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- Multiple PV manufacturers collaborate for an industry standard for PV modules.
Every medal has a reverse side

What highly convincing presentations, webinars and white papers do not show, is the reverse side of the medal (yes, every medal has one)
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- To optimize container loading, some larger modules require unusual packaging: the impact on handling is yet to be evaluated.
- Larger modules are up to 40% heavier; the installation cost per module may increase - but by how much?
- Different voltages/currents allow more modules per string:
  - this impacts the design of support structures / trackers
  - conventional electrical layout is no longer applicable
  - inverters require new DC protection fuse ratings
  - cable harnesses with over-molded fuses may face limits
What highly convincing presentations, webinars and white papers do not show, is the reverse side of the medal (yes, every medal has one)

✓ Larger (longer) modules imply an increase of tracker’s nominal height requiring resizing of piles and other components.
Every medal has a reverse side

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✓ Larger (longer) modules imply an increase of tracker’s nominal height requiring resizing of piles and other components.
✓ The arrival of LFM on the market can cause long lead times and waiting lists at 3rd party test labs.

<table>
<thead>
<tr>
<th>Reports</th>
<th>Number of Reports</th>
<th>Typical Contents</th>
<th>Tentative Timeline (from NTP date)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Witness Report</td>
<td>One</td>
<td>Detailed BOM listing, brief production overview</td>
<td>~1 month from witness date</td>
</tr>
<tr>
<td>Intake Report</td>
<td>One</td>
<td>Incoming inspection, initial flash and EL results</td>
<td>1.5 - 2 months</td>
</tr>
<tr>
<td>LID Report</td>
<td>One</td>
<td>Light soak test stabilization results on 17 modules</td>
<td>2 - 4 months</td>
</tr>
<tr>
<td>PAN File and Report</td>
<td>One</td>
<td>PAN measurement results with accompanying PAN file</td>
<td>3 - 4 months*</td>
</tr>
<tr>
<td>IAM Report</td>
<td>One</td>
<td>IAM measurement results</td>
<td>3 - 4 months*</td>
</tr>
<tr>
<td>Interim Reliability Report</td>
<td>One</td>
<td>At least: TC200; DH1000; SML+DML; PID96; LetID162</td>
<td>3 - 4 months</td>
</tr>
<tr>
<td>Final Reliability Report</td>
<td>One</td>
<td>TC400; DH2000; Full MSS PID192; Full LetID</td>
<td>6 - 7 months</td>
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<tr>
<td>Interim FE Report</td>
<td>One</td>
<td>6-month capacity test; interim characterizations</td>
<td>7 - 8 months</td>
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<tr>
<td>Final FE Report</td>
<td>One</td>
<td>12-month capacity test; final characterizations</td>
<td>14 - 15 months</td>
</tr>
</tbody>
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Source: PVEL
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✓ Some products are made available long before production lines are even up and running.

Source: Sinovoltaics
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✓ Many EPCs still lack solid experience building projects with large format modules.

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- The arrival of LFM on the market can cause long lead times and waiting lists at 3rd party test labs.
- Some products are made available for before production lines are even up and running.
- Many EPCs still lack solid experience building projects with large format modules.
- Some investors are still skeptical due to the limited track record of large format modules.
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✓ Larger (longer) modules imply an increase of tracker’s nominal height requiring resizing of piles and other components.
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✓ Some products are made available for before production lines are even up and running.
✓ Many EPCs still lack solid experience building projects with large format modules.
✓ Some investors are still skeptical due to the limited track record of large format modules.
✓ As manufacturing of modules with smaller cells is being phased out, asset management and O&M companies may face module replacement issues on existing sites.
The tidal wave of Large Format Modules comes at a cost with benefits to be proven over time in the field.
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Key equipment evaluation and selection needs to be in tandem with installation best practices for maximum optimization of Large Format Modules.
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Key equipment evaluation and selection needs to be in tandem with installation best practices for maximum optimization of Large Format Modules.

Collaboration with trusted industry partners and advisors is key to understand, evaluate and successfully implement the Large Format Modules deployment.
Questions?

Thank you!

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Global Solar Procurement Leader
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tomaso.charlemont@res-group.com

Kings Langley, UK
Lyon, France
www.res-group.com
1. Nextracker intro & track record
2. Nextracker Large format Module (LFM) preparedness
3. LCOE/LFM considerations
Company Overview

#1 Global Market Share Leader in Solar Tracking

- Shipped 13 GW in 2020 with 50 GW of solar tracker systems in operation or under construction in 6 years
- A Flex company
  - $25Bn annual revenue, $14Bn balance sheet
- Global presence
  - 400 staff worldwide, 8 global offices
- Robust product lines
  - Solar trackers, software and controls, digital O&M
- Deep PV expertise and experience
  - 350 years of collective PV experience on executive team

Our Vision - Renewable energy powers the world – delivering clean, affordable power to all.

Our Mission - To be the world’s leading energy solutions company delivering the most intelligent, reliable and productive solar power for future generations.

#1 market share leader six consecutive years: 2015-19

Source: IHS Markit, July 2020
Nextracker Industry Firsts

Nextracker has led the industry in features & capabilities that increase performance while reducing costs for customers and owners

- **Independent Rows Balanced Tracker**
  - 93 module row, 1500V 120° tracking range, torsional limiter each pier

- **Self Grounded Tracker**
  - UL2703 & 3703 certification, no need for separate grounding components

- **Self Powered & Smart Tracker**
  - Eliminates AC power; integrated UPS; wireless communications; smart module

- **Predictive Analytics & Digital O&M™**
  - Auto-commissioning, remote monitoring & control; NERC-CIP compliant

- **Smart Controls & Software**
  - Using machine learning and weather data, TrueCapture & NX Navigator™ enhance energy yield; and mitigates risk of hail stow, hurricane, and snow
Agenda

1. Nextracker intro & track record
2. Nextracker Large format Module (LFM) preparedness
3. LCOE LFM considerations
Nextracker: Going Big the Right Way
Preparing for a future of large format PV modules
The Evolution of PV Module Size Formats

Increasing cell size & efficiency to decrease costs

2015-2017
- Multi
- Full Cell
- 990 x 1950mm
- 10A Isc

2018
- 158mm
- 144 cell
- Mono-PERC
- Split-Cell
- 1,000 x 2,000mm
- 10.5A Isc

2019
- 166mm
- 144 cell
- Mono-PERC
- Split-Cell
- Bifacial
- 1,048 x 2,108mm
- 11.5A Isc

Today
- 182mm
- 144 cell
- 1,134 x 2,261mm
- 14A Isc

- 182mm
- 156 cell
- 1,134 x 2,443mm
- 14A Isc

- 210mm
- 120 cell
- 1,134 x 2,261mm
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- 210mm
- 132 cell
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- 14A Isc

- 210mm
- 144 cell
- 1,096 x 2,384mm
- 18A Isc

- 210mm
- 156 cell
- 1,229 x 2,384mm
- 18A Isc

- 305 x 2,173mm
- 18A Isc

Increasing cell size & efficiency to decrease costs.
Implications of LFM for Tracking Systems

Key considerations for tracker preparedness

Module Changes

- **Increased Size**
- **Increased Weight**
- **Higher Current**

Tracker Impact

- More torque on drive system
- Stronger module rails
- Higher static and dynamic wind loads
- More hardware for structural support
- Higher install time per module
- Larger conductor sizes
- Increased fuse and connector ratings
- Trending towards lower voltage per module and longer string lengths

Module Area: 3.19 m² +45%

Up to 1305 mm Wide

Up to 2445 mm Long
Large Module Preparedness

New Wind Tunnel Testing for Large Modules

• Updated wind tunnel testing by CPP
• Ensures stability with even the biggest module form factors

Advanced Dynamic Analysis
Developed by Nextracker and CPP

• Pioneered and completed the most advanced dynamic analysis in the industry
• Predicts and analyzes multiple dynamic modes for large modules with the most state-of-the-art methods
Future-proof: PV Module Validation Program

Nextracker Validates Each Module Type
by both Nextracker and Module Suppliers

- Module Brand
- Dimension
- Weight

Nextracker Test Lab: Nextracker goes to great lengths to test for each module in our very own test lab.

Supplier Test Lab: A load test with Nextracker’s system at JinkoSolar testing facility.
Future-proof: Taking No Chances

Testing for Each and Every PV Model Type with our Tracker

Ensuring the Highest Quality and Reliability in the Field:

- 100+ PV Module types tested and approved
- Written letter of approval from PV supplier

Approved PV Models

<table>
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<tr>
<th>Company</th>
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<td>Canadian Solar</td>
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<td>Trina</td>
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<td>Risen</td>
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<td>Waaree</td>
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<td>SunPower</td>
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<td>ET Solar</td>
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</table>
Future-proof: Maximum Size Approved

Approved for LARGEST module size forecast for the next 2-3 years

BiHiKu7
✓ 2384 * 1303 mm
✓ 660W

PV Supplier Approval Letters
Agenda

1. Nextracker intro & track record
2. Nextracker Large format Module (LFM) preparedness
3. LCOE/LFM considerations
LFM Impact on LCOE

Trackers and LFM Highlight:
• More power per tracker row
• More power per total area

Downstream Impact per MW:
• 18 to 22% labor reduction
• 13 to 16% pier reduction
• Less total wiring
• Less land area

<table>
<thead>
<tr>
<th>Module Type</th>
<th>Module Power</th>
<th># of Strings per row</th>
<th>Modules per String</th>
<th>Total # of panels</th>
<th>Power per Tracker Row</th>
<th>Total Panel Area</th>
<th>Power per Area</th>
<th>Power per Area Delta vs. 166mm</th>
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<tbody>
<tr>
<td>166mm</td>
<td>465W</td>
<td>3</td>
<td>28</td>
<td>84</td>
<td>39.0 kW</td>
<td>186 m²</td>
<td>207 W/m²</td>
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<tr>
<td>182mm</td>
<td>590W</td>
<td>3</td>
<td>26</td>
<td>78</td>
<td>46.0 kW</td>
<td>216 m²</td>
<td>212 W/m²</td>
<td>+17%</td>
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<tr>
<td>210mm</td>
<td>660W</td>
<td>2</td>
<td>31</td>
<td>62</td>
<td>40.9 kW</td>
<td>193 m²</td>
<td>212 W/m²</td>
<td>+4.9%</td>
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</table>

Typical Row Configurations
Nextracker + Top Tier Module Suppliers

1P/NX Horizon™
2P/NX Gemini™

Comprehensive LFM Compatibility

✓ Tiger Pro
✓ Hi-Mo 5
✓ DeepBlue 3.0
✓ BiHiKu6/7
✓ Vertex
✓ And more...

LFM Suppliers
Additional Resources – White Paper

- Available at www.nextracker.com

**White Paper: Mitigating Extreme Weather Risk**

**PART 1:** Understanding How Differentiated Design and Control Strategies Unlock New Opportunities for Solar Development

**Part 2:** Surviving High-Wind Events and Dynamic-Wind Effects with Differentiated Solar Project Design and Control Strategies

“\[At a minimum, owners and insurers need to ask for a simple explanation as to how companies are achieving lower cost without increasing risk.\]” – David Banks, President, CPP
Thank you!

Mario Riello
VP EMEA Sales
mriello@nextracker.com

www.nextracker.com
from the Advisor’s perspective:

Large-format Modules (LFM) and Solar Trackers: Key Considerations and Impact on Plant LCOE
Centers of PV expertise in Germany, Italy, Spain, Great Britain, Turkey, Saudi Arabia, UAE and Malaysia

> 500 projects in more than 70 countries with a capacity of >50 GW

- 200+ Lenders-Engineering-Projects
- 20+ Owners-Engineering-Projects
- 100+ Feasibility Studies
Range of Services

The Fichtner Group can call on a network of highly qualified engineers and consultants to cover all aspects of solar photovoltaic power generation and hybrid solutions.

- Owner’s Engineer (OE), all project phases
- Lender’s Technical Advisor (LTA)
- Transaction Advisor on large scale IPP projects
- Technical Due Diligence
- Feasibility Studies (concept design, yield simulation...)
- Construction supervision
- Witnessing the commissioning, acceptance and performance tests
- Monitoring of plant operation and maintenance

Recent project highlights
- Talasol PV plant in Spain, 300 MW
- Sweihan and Al Dhafra in Abu Dhabi, 1,170 MWp and 2,101 MWp
- MBR Solar Park Phases III and V in Dubai, 800 MW and 900 MW
- Ibri II and Manah PV IPP’s in Oman, 3x 500 MW
- Sakaka, Saudi Arabia, 300 MW
Can Large Format Modules (LFM) work reliably with trackers while meeting LCOE requirements?

- Proper design and quality control is essential for a successful project implementation and operation
- Different quality criteria in different phases of a project
- Early involvement of tracker supplier during all project phases
Pre-bidding stage

Bidding stage

Construction phase

Operation phase

Consideration of impact of larger modules on trackers, e.g.:

- PV module eligibility requirements
- Track record & certificates
- Confirmation of compatibility with the (pre-)selected tracker
- Structural requirements
- Track record & tests: wind tunnel tests, tracker dynamic analysis, full scale outdoor tests (module size, loads, bifacial operation)
- Adjustment of stow strategy
- Adjustment of module cleaning procedure (cleaning robots)
- **Option**: independent certification and due diligence for pre-qualification of tracker suppliers or product

Example for module eligibility requirements

- Track record / references from a renowned PV module supplier
- Relevant certificates, e.g.
  - IEC 61215 type approval
  - IEC 61730 module safety
  - IEC 60068-2-68 Environmental testing
  - IEC TS 62804-1 PID free
  - IEC 61701 Salt mist corrosion testing
  - product warranty > 10 years
  - power output warranty 30 years
Bidding stage:

- Minimum Function Specification (MFS) defines all requirements for the overall system and the components:
  - Site specific
  - Civil
  - Electrical

- Consideration of the site conditions for the bid-design:
  - Design wind speed (ref. at 10m as 3 sec gust and 10 min average)
  - Geotechnical survey (core samples, test pits: drilling / ramming)
  - Topographic study

- Responsibilities to be clarified for the site-specific design: structure, foundation, installation

- Warranties for the tracking system to be well structured with clearly defined interfaces
Requirements during the construction phase:

- Procedure and criteria to be defined for a potential PV module replacement during late procurement phase
- High-quality and complete set of documents available at early stage for the detail design review
- Commissioning with sufficient and experienced staff
- Role of the Owner’s Engineer
  - design review
  - check quality of supplied materials (e.g. coating thickness)
  - construction supervision (e.g. foundation, structure and module installation)
  - supervise the QA/QC procedure from the EPC contractor who must comply with the design and the specification
  - attend the commissioning, acceptance and performance tests

Source: Fichtner
Operation phase:

- On-site presence is the responsibility of the EPC contractor, but if required: tracker supplier stays at the site during the first weeks after PAC/COD for finetuning
  - Signal exchange, SCADA / monitoring
  - Quick reaction time for teething problems
- Frequent module cleaning (dry or water, manual or automatic) as well as high tracker availability can lead to the expected generation and a high PV plant performance (PR)
Lessons learnt:

▪ real site conditions are considered (design wind speed, soil conditions, topography)
▪ wind mast with sufficient height is installed at the site
▪ manpower is sufficient to unpack and mount large and heavy modules
▪ tracker unavailability is properly defined in the contracts
→ Avoidance of delay, downtime, underperformance, corrective actions, warranty claims, LD’s…
Thank you!

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