Global Wind Supply Chain Update 2015
Feng Zhao, Director
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About FTI Consulting
FTI Consulting at a Glance

GLOBAL REACH
With over 4,400 employees and offices in 27 countries on six continents, our breadth and depth extends across every major social, political and economic hub across the globe.

EXPERIENCED PROFESSIONALS
FTI are trusted advisors with diverse expertise and exceptional credentials serving clients globally including accountants, economists, engineers, former CFOs and strategists.

DEEP INDUSTRY EXPERTISE
FTI combines unparalleled expertise and industry knowledge to address critical challenges for clients. Our largest industry groups are:
- Energy, Power & Products
- Financial Institutions & Insurance
- Healthcare & Life Sciences
- Real Estate
- Retail & Consumer
- Telecom, Media & Technology

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<thead>
<tr>
<th>FCN</th>
<th>$1.7 BLN</th>
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<tr>
<td>Publicly traded – NYSE</td>
<td>Market Capitalization</td>
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<tr>
<td>1982</td>
<td>80</td>
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<tr>
<td>Year founded</td>
<td>Different disciplines</td>
</tr>
<tr>
<td>4,400+</td>
<td>700+</td>
</tr>
<tr>
<td>Employees worldwide</td>
<td>Industry specialists</td>
</tr>
<tr>
<td>440+</td>
<td>80</td>
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<td>Senior Managing Directors</td>
<td>Offices in 80 cities around the globe</td>
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<tr>
<td>2 Nobel Laureates</td>
<td>47/100</td>
</tr>
<tr>
<td>10/10</td>
<td>94/100</td>
</tr>
<tr>
<td>Advisor to the world’s top 10 bank holding companies</td>
<td>Advisor to 94 of the world’s top 100 law firms</td>
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Our Wind Energy Capability

Our team
- Senior with deep expertise
- Ex-BTM Navigant, MAKE Consulting, IHS-CERA, Recharge, EWEA leaders
- Leading industry professionals
- Hands-on operational experience
- Multi-disciplinary background

Subscription Service

Market Reports
Three (3) Market Sector Reports per year.
Reports include market forecasts, supply and demand analysis, supply chain analysis, policy and market analysis, market share rankings, and asset owner rankings.

Specialist Reports and Emerging Market Reports
Three (3) Specialist Reports and four (4) to six (6) Emerging Market Reports per year.
Specialist reports will cover special interest themes pertaining to clean energy such as innovation in storage technology and finance. Emerging market reports will provide a deep dive into key clean energy emerging markets and cover regulatory developments, market structure, supply chain, power market development, LCE forecast, project pipelines and market forecasts.

Spark – Energy Insights
40 to 50 Spark notes per year.
Spark notes are concise, high-value added assessments of key events and to give key decision makers a view of the future impact of key market, regulatory, technology and financial events and changes.

Databases
Seven (7) Databases per year.
Databases will contain FTI Intelligence's proprietary data and forecasts on all key markets and participants including installation forecasts, market share data for OEMs and asset owners, geographic distribution of turbine OEM and component suppliers, key market participant profiles and global offshore project pipeline.

Example Clients

- Vestas
- Siemens
- Gamesa
- Goldwind
- Nordex
- GDF Suez
- EDF
- EDP
- Centrica
- RWE
- DEIF
- Enel
- LiBa
- LIEBHERR
- Masdar
- CommBank
- Goldman Sachs
- Endesa
Global Wind Supply Chain Update 2015
This report:

- Examines the supply chain situation for 12 key components (350+ suppliers) and three key materials (150+ suppliers), which account for more than 95% of a wind turbine’s total cost;

- Includes an assessment of offshore wind farm balance of plant and the forecast for the global wind market growth to 2018; and

- Summarizes the world’s top 15 turbine manufacturers’ supply chain strategies and supplier relationship matrix.
Global Wind Supply Chain – Scope of Work

95% of turbine cost

Tower
Range in height from 40 metres up to more than 100 m. Usually manufactured in sections from rolled steel, a lattice structure or concrete are cheaper options.

Rotor blades
Varying in length up to more than 60 metres, blades are manufactured in specially designed moulds from composite materials, usually a combination of glass fibre and epoxy resin. Options include polyester instead of epoxy and the addition of carbon fibre to add strength and stiffness.

Rotor hub
Made from cast iron, the hub holds the blades in position as they turn.

Rotor bearings
Some of the many different bearings in a turbine, these have to withstand the varying forces and loads generated by the wind.

Main shaft
Transfers the rotational force of the rotor to the gearbox.

Main frame
Made from steel, must be strong enough to support the entire turbine drive train, but not too heavy.

Control system
The "brain" of the wind turbine controlling the performance of wind turbine.

Gearbox
Gears increase the low rotational speed of the rotor shaft in several stages to the high speed needed to drive the generator.

Generator
Converts mechanical energy into electrical energy. Both synchronous and asynchronous generators are used.

Yaw system
Mechanism that rotates the nacelle to face the changing wind direction.

Pitch system
Adjusts the angle of the blades to make best use of the prevailing wind.

Power converter
Converts direct current from the generator into alternating current to be exported to the grid network.

Transformer
Converts the electricity from the turbine to higher voltage required by the grid.

Brake system
Disc brakes bring the turbine to a halt when required.

Nacelle housing
Lightweight glass fibre box covers the turbine's drive train.

Source: FTI Intelligence and EWEA, January 2015
Europe is still the hub of wind turbine technologies and major European turbine vendors have built facilities in all major wind power markets.

More than half of the identified active OEMs in the world, however, come from China and India.

Eight of the global top 15 turbine OEMs based in China.

Europe used to be the supply chain center of key components and materials. Globalization has driven the major European suppliers to expand their business to North America, Asia and most recently in South America. The local content requirements (LCRs) is also one of the largest contributors for this transformation.

> 50% of the wind turbine component suppliers are currently from South & East Asia.
What is going on in global wind supply chain in the past two years

The slump in demand in 2013 caused by the economic recession and by policy uncertainty and inconsistency in Europe, the US, China and India.

- The wind industry saw 129 suppliers collapse or leave in the past 24 months, of which 88 from Asia, 23 from Europe, and 18 from North America.
- Top-5 components suffered the most: Towers, Castings, Forgings, Blades, Generators

### Suppliers out of wind industry by component type

<table>
<thead>
<tr>
<th>Component Type</th>
<th>Asia Pacific</th>
<th>Europe</th>
<th>Americas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gearbox</td>
<td>5</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Blade</td>
<td>4</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Bearing</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Generator</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Converter</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Controller</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Tower</td>
<td>15</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Pitch</td>
<td>11</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Yaw</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Transformer</td>
<td>16</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>Castings</td>
<td>1</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Forgings</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

### Location of suppliers collapsed or stayed out of wind sector

- Europe: 18%
- Americas: 14%
- Asia Pacific: 68%

Source: FTI Intelligence, January 2015
Trends of turbine OEMs supply chain strategies

Adopting appropriate supply chain strategies has gained OEMs' attention in 2010 when a dramatic turnaround, from a seller's market into a buyer's market, was completed.

- **Vertical integration**
  - To secure the supply both in terms of quantity and quality, vertical integration gained popularity in the 1996-2008 period.

- **Outsourcing**
  - In 2011-13, overcapacity of turbine manufacturing plus a prolonged market contraction have forced major turbine OEMs to divest in-house non-core production assets.
  - In order to insulate from market fluctuations while retaining flexibility of global reaching, major OEMs has opted for outsourcing.

- **Taper integration (Hybrid model)**
  - The taper integration, hybrid model of vertical integration and outsourcing, secures quality control while retaining flexibility of global reaching, which has become the mainstream sourcing strategy at present.
  - Large turbine vendors still retain core technologies for in-house manufacturing, such as turbine control system, converter, blades.

Source: FTI Intelligence, January 2015
Supply vs. Demand – Overview of current and near-term situation

In general, no constraints have been identified in the global supply chain. Supply of most components and materials is expected to exceed demand in 2015.

Most of key components and materials will continue to face the challenge of overcapacity, but bearings (ultra-large tapered roller bearings with almost all direct drive designs) and rare earth materials are expected to be in short supply through 2018.

A strong regional imbalance exists (for control system, castings, forgings and rare earth materials), which still causes a sourcing challenge in some regions.

LCOE will certainly play a role to decide the winners and losers.

Source: FTI Intelligence, January 2015
<table>
<thead>
<tr>
<th>Balance of plant</th>
<th>Status 2014</th>
<th>Status 2018</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monopile foundations</td>
<td><img src="#" alt="Green" /></td>
<td><img src="#" alt="Green" /></td>
<td></td>
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<tr>
<td>Non-monopile foundations</td>
<td><img src="#" alt="Green" /></td>
<td><img src="#" alt="Green" /></td>
<td></td>
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<tr>
<td>HVAC offshore sub-stations</td>
<td><img src="#" alt="Red" /></td>
<td><img src="#" alt="Red" /></td>
<td>» No expected constraint in supply due to low demand. However, a key supplier stayed out of the EPC business due to long lead times, considerable risk of delay and overrun costs.</td>
</tr>
<tr>
<td>HVDC offshore sub-stations</td>
<td><img src="#" alt="Green" /></td>
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<tr>
<td>Export cables</td>
<td><img src="#" alt="Green" /></td>
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<td></td>
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<tr>
<td>Array cables</td>
<td><img src="#" alt="Green" /></td>
<td><img src="#" alt="Green" /></td>
<td></td>
</tr>
<tr>
<td>Wind turbine installation vessels</td>
<td><img src="#" alt="Green" /></td>
<td><img src="#" alt="Green" /></td>
<td>» Overcapacity for installation of the current mainstream turbine (3-4MW), but a tight balance for next generation (6-8MW) offshore turbines to be installed in deeper waters. Finding enough crew members with ample experience is also a challenge.</td>
</tr>
<tr>
<td>Foundation installation vessels</td>
<td><img src="#" alt="Green" /></td>
<td><img src="#" alt="Green" /></td>
<td>» Sufficient supply at present, but constraints are likely to occur after 2020 if no investment are made for vessels with crane capacity, ≥1,200 tonnes, capable of operating at depth ≥50m.</td>
</tr>
<tr>
<td>Offshore sub-station installation vessels</td>
<td><img src="#" alt="Orange" /></td>
<td><img src="#" alt="Red" /></td>
<td>» Required crane capacity restricted the number of vessels.</td>
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<tr>
<td>Subsea cable installation vessels</td>
<td><img src="#" alt="Green" /></td>
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<td></td>
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Global Wind Supply Chain – Challenges and Opportunities
2015 will reach a new record of activity, but volatility over the next five years is still expected, before annual installations build to the next peak around 2021.

The dip in installations in 2016 and 2017 is primarily due to a contraction in the Chinese market (2016/2017) and slower US installations due to the PTC.

Total Installations between 2015 and 2024 are expected to be approximately 590GW.

The annual wind power installations are likely to grow from 47.6GW in 2017 to almost 72GW in 2024.

Asia Pacific will account for 49% of the new capacity added worldwide in 2015-2024, followed by Europe (24.5%), North America (12.5%) and Latin America (7.4%).

Source: FTI Intelligence, October 2015
Investment Opportunities in the Global Wind Supply Chain

The Top 15 largest wind markets in terms of new additions in 2015-2019

- The Top 15 largest wind markets are expected to add 231 GW, accounting for 88% of the new capacity added worldwide in 2015-2019.

- Among the top 15, China is going to add 112GW new capacity in 2015-2019, followed by the US, Germany, India and Brazil.

The Top 15 fastest growing wind markets in terms of CAGR in 2015-2019

- The Top 15 fastest growing wind markets are expected to install 12.8 GW in 2015-2019, account for 5% of the new capacity added worldwide.

- Most of those fastest growing markets are emerging markets in Asia, Africa and Latin America, but political and financial uncertainties remain in those markets.

Source: FTI Intelligence, October 2015
Q&A
**Critical Thinking at the Critical Time™**

<table>
<thead>
<tr>
<th>Aris Karcanias</th>
<th>Feng Zhao</th>
<th>Robert Clover</th>
<th>Ben Backwell</th>
<th>Victor Musuku</th>
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<tr>
<td>Managing Director</td>
<td>Director</td>
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<tr>
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