Photo: CESA

Supply Chain: The race to meet demand

Booming demand in the wind industry has focused attention on the complex supply chain of components which lies behind every turbine delivered to the market. *Crispin Aubrey* looks at where and why bottlenecks are occurring and how soon production can be expected to catch up again.

Many industries would love to be in the same position. In 2005 the level of global installed wind power capacity increased by 40 % compared to the year before. Last year it took another leap forward by a further 32 %. Since 2002, annual installations have more than doubled.

But the success of the world's leading renewable technology, particularly in the last two years, has brought pressures in its wake. Despite the transformation of the turbine manufacturing sector into a streamlined, efficient mass producer of high tech equipment, it has found it difficult to keep up with the surge in demand. The result has been some customers unable to source turbines for their projects and a rise in prices.

According to a new report from wind market analysts BTM Consult, the level of demand for turbine deliveries in 2007 is expected to rise to almost 20,000 MW. However close the industry might have come to meeting demand in 2006, it is unlikely to succeed this year, BTM predicts. The shortage of supply will probably not be resolved until at least 2009, it concludes.

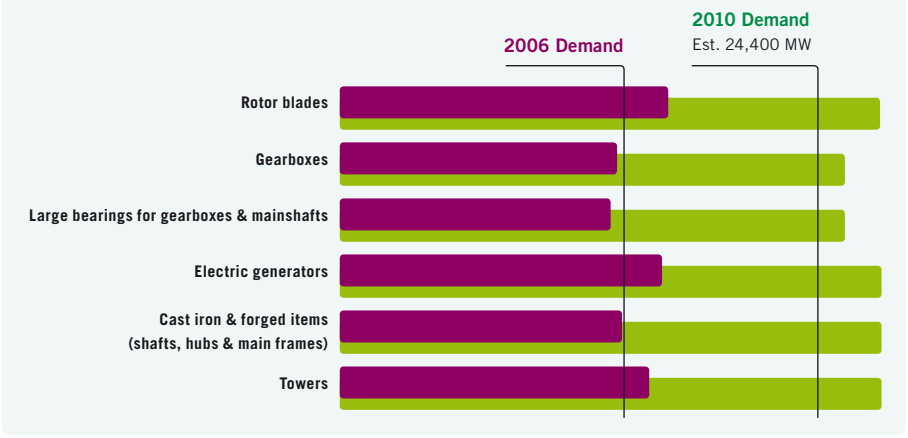
Using a different calculation process, business consultants Emerging Energy Research have come to a similar conclusion. Based on completed turbines to be delivered, EER expected demand for about 9,700 units in 2006. This could rise to more than 11,000 units in 2009. Can that level of demand be satisfied? "I think it's going to be tight," says EER's Keith Hays, "but by 2009 we should be getting much closer to an equilibrium."

If it was simply a matter of the turbine manufacturers being able to ramp up their production to reach new increased levels of demand, then the situation would be both understandable and potentially manageable. But in practice it is much more complicated than that. Reaching a balance between supply and demand depends on a number of factors, not all of which are directly within the control of the wind industry.

Demand surges

The biggest factor on the demand side is the industry's dependence on national incentive programmes whose shifting patterns are not always easy to predict. The most obvious example of this is the Production Tax Credit, which has been a major influence in encouraging the wind industry in the United States.

Key component supply: 2006 and 2010



Source: BTM Consult ApS – November 2006

In 2004, demand in the US wind market was for just 389 MW of new capacity. The previous PTC period had expired at the end of 2003, leaving the market in the doldrums. With the revival of the incentive at the end of that year, however, investment took off again, turning both 2005 and 2006 into record years of 2,400 MW+ and creating a massive surge in global demand for turbines. The effect of this continual threat of the PTC expiring within a limited timescale has also been to encourage turbine suppliers to target the US as a priority, effectively siphoning off turbines from European manufacturers which could have been destined for other markets.

On the supply side, the current situation has focused attention on the supply chain which lies behind the large turbine manufacturers. A long list of components goes into the production of a wind turbine (see illustration, p.32), not all of which are as readily available as others.

"There are particular bottlenecks in gearboxes and bearings," says Keith Hays of EER. "A crucial issue is that the size of turbines has been increasing dramatically from less than 1 MW up to 2 MW and larger. This means, for instance, that the number of gearbox suppliers who can satisfy the demand reliably is reduced considerably. The same applies to blades and bearings and towers. Increasing turbine size has a lot of implications in the supply chain."

A final factor is the price and availability of raw materials. This has both contributed to supply bottlenecks but also to the recent increase in the price of turbines. Examples of raw materials whose prices have increased substantially are steel (used in towers, gearboxes and rotors), copper (used in generators) and carbon (used in rotor blades). Global steel prices have risen by 15-20%, boosted by demand from growing economies like China.

7.5 MW test bench at Winergy gearbox factory

"The underlying issue is that nobody successfully foresaw that so many world markets would expand all at the same time," says Thorsten Herdan of VDMA, the German engineering business federation, whose members account for 40-50% of the global wind supply market. "So you had the United States, which was reasonably well expected, but you also had good markets in the UK, France, Italy and Portugal, as well as China and India.

Major wind turbine manufacturers and their suppliers

Turbine maker	Rotor blades	Gearboxes	Generators	Towers	Controllers
Vestas	**Vestas**, LM	Bosch Rexroth, Hansen, Winergy, Moventas	**Weier**, Elin, ABB, LeroySomer	**Vestas**, NEG,DMI	**Cotas (Vestas)**, NEG (Dancontrol)
GE Energy	LM, Tecsis	Winergy, Bosch, Rexroth, Eickhoff, **GE**	Loher, **GE**	DMI, Omnical, SIAG	**GE**
Gamesa	**Gamesa**, LM	**Echesa (Gamesa)**, Winergy, Hansen	**Indar (Gamesa)**, Cantarey	**Gamesa**	**Ingelectric (Gamesa)**
Enercon	**Enercon**	Direct drive	**Enercon**	KGW, SAM	**Enercon**
Siemens Wind	**Siemens**, LM	**Winergy**	ABB	Roug, KGW	**Siemens**, KK Electronic
Suzlon	**Suzlon**	**Hansen**, Winergy	**Suzlon**, Siemens	**Suzlon**	**Suzlon**, Mita Teknik
REpower	LM	Winergy, Renk, Eickhoff	N/A	N/A	Mita Teknik, ReGuard
Nordex	**Nordex**	Winergy, Eickhoff, Maag	Loher	**Nordex**, Omnical	**Nordex**, Mita Teknik

Notes: 1. Towers are often produced locally to where projects are built.
2. Names in bold indicate in-house supply or ownership of supplier by turbine manufacturer.

Source: BTM Consult

Photo: Winergy

"It's not just the customers who have been concerned by the shortage of turbines, the turbine manufacturers have also been disappointed that they haven't been able to get enough parts. And the component suppliers themselves are disappointed that they could have sold much more output last year if they had made an investment in machinery three years ago. The problem is that although it's relatively straightforward for those turbine manufacturers who aren't committed to total in-sourcing to increase their capacity, for component suppliers it requires a major investment in machinery, with up to two years lead-in time." Added to that, he points out, is the fact that the entire machine tools business has overflowing order books.

Supply chain

Taking each of the main components of a turbine in turn it is possible to identify where bottlenecks are occurring and how these are likely to be resolved.

• BLADES

A crucial component requiring sophisticated production techniques, global supply is dominated by independent blade maker LM Glasfiber, which has about 27 % of the market. All the major turbine manufacturers apart from GE Energy and REpower produce most of their own blades. No shortage of supply at present. To cope with demand a number of new blade factories were either opened or announced in 2006 by Gamesa, Vestas, Siemens and LM Glasfiber in China, the US, Denmark, Spain, India and Canada.

BTM Consult says global production capacity should increase from 20 GW now to 25-30 GW by 2010. This should be enough to satisfy demand.

• GEARBOXES

Most turbine manufacturers have traditionally outsourced their gearboxes to a shortlist of six or seven independent companies. This situation changed somewhat with the acquisition in 2005 of gearbox supplier Winergy by Siemens Wind and then in 2006, Hansen Transmissions by turbine maker Suzlon. Hansen has about 30 % of the global market for wind turbine gearboxes and Winergy about 40 %. Siemens specifically announced, however, that its acquisition was only part of a wider purchase of the parent company Flender and there would be no change in the relationship between Winergy and other turbine manufacturers.

Gearboxes are nonetheless the component for which most shortages of supply have occurred. Three reasons are given by BTM Consult for this: the limited number of production facilities tailored to the wind market, a shortage of large bearings and a bottleneck caused by unexpected repairs to operating gearboxes, including the replacement of bearings. BTM adds that although a number of gearbox manufacturers which normally supply other heavy industries have considered entering the wind market, they have often shied away because of uncertainty about the return they would achieve.

Keith Hays of EER says another important factor is that not enough of those gearbox manufacturers committed to the wind market have been able to ramp up their production lines quickly enough to cope with new multi-megawatt models. It can take several years to tool up and test for a new turbine size.

According to a recent report on gearbox supply by MAKE Consulting, however, most of the manufacturers are already in the process of expanding their capacity, with new production lines opening in both Europe and Asia. This should lead to a resolution of current delays by 2008.

BTM says global production capacity should increase from 15 GW now to 21-32 GW in 2010 – enough to satisfy demand.

• BEARINGS

There are particular shortages of large bearings used in gearboxes and the main shaft. BTM Consult says that the delivery time for large bearings can be 16-18 months where no framework (long term supply) agreement is in place. One reason for the shortage is that the boom in the wind industry has coincided with a generally increased level of activity across all heavy industry. For bearing manufacturers wind represents only a small fraction of their business.

LM Glasfiber blades: new factories opened in 2006

Photo: LM Glasfiber

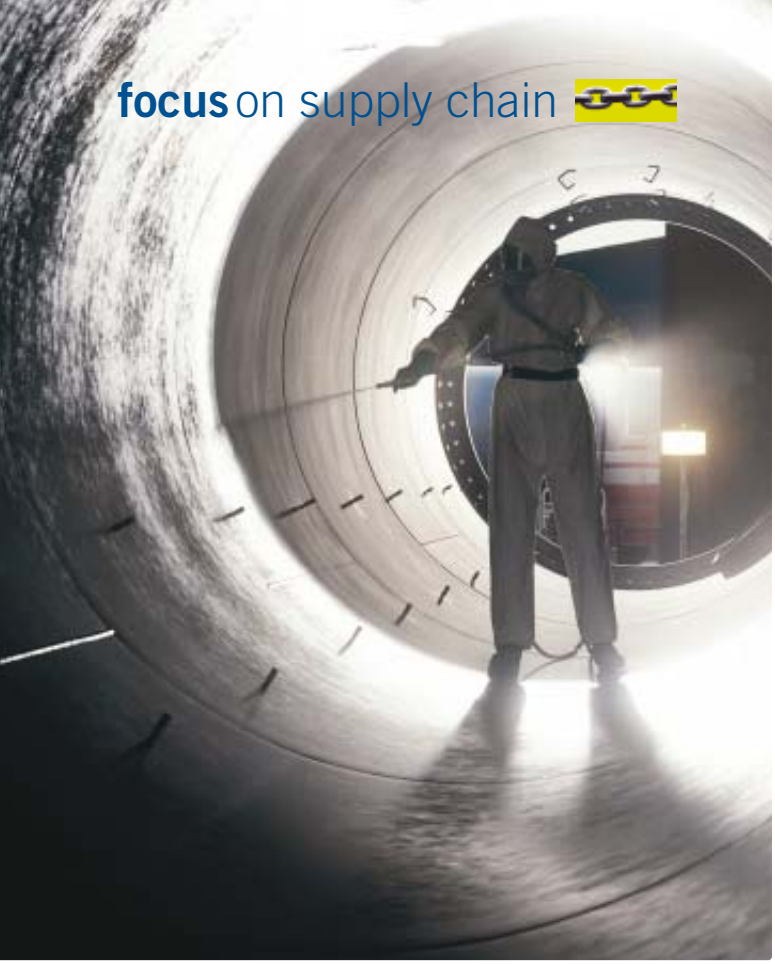


Photo: NEG Micon

Manufacture of towers is often done near wind projects

Two of the largest suppliers of bearings to the wind industry, the Swedish company SKF and the German FAG, have both reacted to this situation by expanding their production facilities. SKF expects a new factory in China to be fully operational during 2007. FAG is building a new factory in Romania and expanding its existing capacity in Germany and China.

- **GENERATORS**

Supplied to the wind industry by a number of large companies such as ABB and Siemens, and dedicated suppliers like Indar (Gamesa). No signs of a shortage of supply.

- **CAST IRON AND FORGED COMPONENTS**

This includes the main frames used to support the rotor hub and nacelle, the hubs themselves and the main shaft which links the rotor to the gearbox. The market here has again been affected by the high level of activity in the heavy industry sector, with increased demand for both forged steel and cast iron. BTM says that the lead time for supply of steel parts for gearboxes can be up to 40 weeks.

- **TOWERS**

Most turbine towers are made of rolled steel, although some manufacturers are turning increasingly to concrete as a cheaper alternative. Although manufacturing a wind turbine tower is an increasingly sophisticated process, the basic expertise is more widely available than for other components. It therefore often makes sense for suppliers to source towers locally to the eventual project. Nonetheless, the booming US market is reported to have soaked up the supply of towers from the four largest domestic manufacturers, requiring imports from already stretched European fabricators. Overall, according to BTM Consult, towers are unlikely to create supply problems.

Manufacturers' response

Given these bottlenecks what is the response of the main turbine manufacturers to the current shortage of supply in the market?

The Gearbox Manufacturer's View

With about 40% of the market, Winergy is the largest producer of gearboxes for the wind industry. A subsidiary of the German Flender group, the company was incorporated last year into the Siemens Automation and Drives Division. It supplies all the major turbine manufacturers.

Winergy's current products include combined planetary (low speed) and helical (high speed) gearboxes for wind turbines ranging from 600 kW up to 5 MW. The majority of its business is in the 1.5 to 2.5 MW range. Most of the components are sourced within the Flender group.

What is the company's explanation for the current shortage of supply? "There's huge pressure on the whole supply chain," says Chief Executive Stefan Tenbrock. "With gearboxes it's not as easy to increase capacity as it is with other components. You need a lot of equipment, from gear-cutting machines to heat treatment facilities. That makes it a very capital intensive business. So increasing capacity involves a huge investment compared with, say, blade manufacture. And that takes time."

"There's huge pressure on the whole supply chain,..."

There's also increased pressure on Winergy's component and raw material suppliers, such as bearings and forged steel for the gearbox pinion and wheels, says Tenbrock. He doesn't accept that repair work on existing gearboxes has been an important factor in slowing down the supply of new ones.

Winergy's response to the boom in demand has been to expand its production capacity in the US, China and India, as well as in Germany. There's also been investment right the way down the supply chain, says Tenbrock, including by its component suppliers, the castings foundries and in raw materials. "But it's difficult for the whole supply chain to follow this very strong growth in the market, which we've seen now for two years running. Whether we can get to a position where we can always meet requests for gearboxes depends very much on the strength of future growth."

The Bearing Manufacturer's View

Swedish company SKF is one of the main suppliers of bearings to the wind industry. This includes bearings for the main shaft, gearbox, generator, pitch and yaw systems. The company also supplies lubrication systems and condition monitoring equipment.

Although only about 2% of SKF's total business comes from the wind industry, wind business manager Stefan Karlsson says it is now its fastest growing sector. "Our volumes are expanding very, very quickly," he says. "Wind energy is a strategically important part of our business."

Karlsson doesn't accept that the shortages presently being experienced, especially of large main shaft bearings, are simply a result of the bearing manufacturers being unable to keep up with demand. "It puts a lot of pressure on the entire value chain when you've got an industry that's growing at 30 or 40% per year," he says. "But in fact our supply to the wind industry has been growing faster than the industry itself. The problem has been that with a fast expanding market, communication between the different players has not been sufficient.

"With our key customers, where we have close cooperation, we are expanding our capacity in line with their requirements and forecasts. Where we have long term arrangements with several turbine and gearbox manufacturers, we're fulfilling all our promises and planning ahead to 2008 and 2009. But what is happening is that some manufacturers are shopping around, looking for the best price, and then complaining that there's a shortage. We can't expand our business based on speculation."

"It's not just a growing industry there, it's exploding."

To meet the growing wind market SKF is expanding production at its existing plants in Sweden, Germany and the US, as well as opening up elsewhere. A new factory was opened at Dalian in China last September focused particularly on large bearings and with about half its output committed to the wind industry. This will serve the booming Asian market, relieving pressure on European plants. "We are very positive about development in China," says Karlsson, "It's not just a growing industry there, it's exploding."

Peter Kruse of Danish manufacturer Vestas says that the industry is doing what it can to improve the situation, but "it can't be done overnight. It will take several years. But it's one thing to source the investment and build the factories, another thing to find the people to run the industry effectively. There's a lot of talk about the shortage of physical assets, but we need brain capacity as well." During 2007 Vestas will open new blade production facilities in both the US and Spain, an electronics plant in Denmark and increase its workforce to 14,000.

German manufacturer Enercon says it is responding to the "enormous worldwide growth in demand for renewable energies" by increasing its manufacturing capacity through new production centres such as the one proposed at Viana do Castelo in Portugal. Others will follow. Spanish manufacturer Gamesa is also expanding its production capacity with new plants in the US, Spain and Portugal. The company says, however, that "if the market forecasts indicating a growing demand are fulfilled, we don't expect it to be less than five years before suppliers can match market demand".

Among the gearbox producers, Luc De Proost of Hansen Transmissions confirms that his company is working at the maximum limit of its current production capacity. "But raw materials are difficult to get hold of at the moment and bearings are extremely difficult," he says.

More than two thirds of Hansen's gearbox business now comes from the wind sector, and the company makes a point of ensuring control of all processes in house, making all its parts from supplied raw materials, right up to the finished gearbox. "That makes us special compared with other manufacturers," says De Proost, "who tend to buy in finished components from sub-suppliers."

Hansen built a new factory at Lommel in Belgium over three years ago specifically dedicated to the wind business, believing at the time that it would be more than big enough to cope with demand. But the company is already in the process of expanding the plant, investing €140 million in 50% more factory space, new research and testing facilities and 300 more jobs. The extended production line should start operation in early 2008.

Both Winergy, the largest gearbox supplier to the industry, and SKF, a leading supplier of bearings, say they are expanding their production capacity in the three key global markets of Europe, the US and Asia in order to catch up with demand (see boxes).

Gearbox manufacturing hall

Photo: Winergy

"Almost all the suppliers took a decision in 2006 to increase their capacity," says Thorsten Herdan of the German VDMA. "So they've put a lot of new investment into their production facilities, although it will still take some time for them to catch up."

How a wind turbine comes tog

A typical wind turbine will contain up to 8,000 different components. This guide shows the main parts and their contribution in percentage terms to the overall cost. Figures are based on a REpower MM92 turbine with 45.3 metre length blades and a 100 metre tower.

Tower 26.3%

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 22.2%

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 1.37%

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

Rotor bearings 1.22%

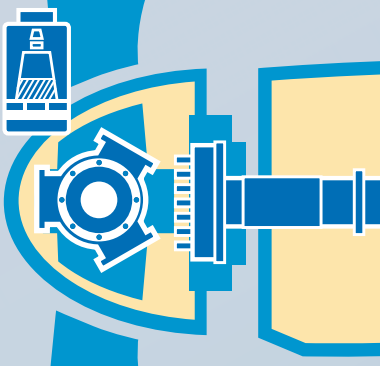
Some of the many different bearings in a turbine, these have to withstand the varying forces and loads generated by the wind.

Main shaft 1.91%

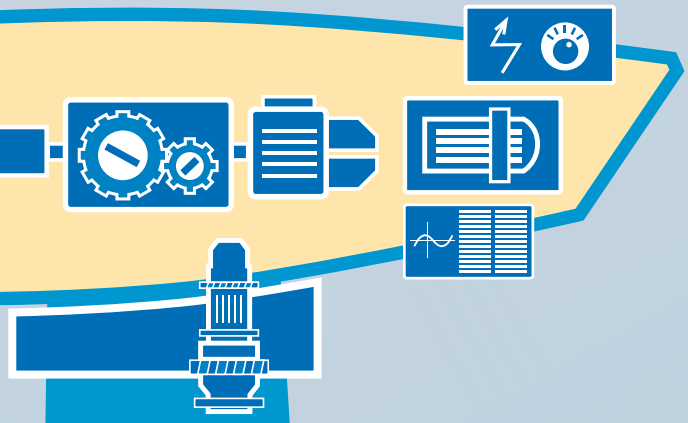
Transfers the rotational force of the rotor to the gearbox.

Main frame 2.80%

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



gether



Gearbox 12.91%

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

Generator 3.44%

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

Yaw system 1.25%

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

Pitch system 2.66%

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

Power converter 5.01%

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

Transformer 3.59%

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

Brake system 1.32%

Disc brakes bring the turbine to a halt when required.

Nacelle housing 1.35%

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

Cables 0.96%

Link individual turbines in a wind farm to an electricity sub-station.

Screws 1.04%

Hold the main components in place, must be designed for extreme loads.

Photo: Nordex

Official opening of new Nordex blade factory in China

Vertical integration

To cope with the continuing uncertainty of supply, some turbine manufacturers are having to make difficult strategic decisions about whether or not to produce more of their components in-house. Of the leading manufacturers, Enercon and Gamesa have historically produced all their main components within their own business structure (see table, p.28 and Gamesa breakdown below). After the purchase of gearbox manufacturer Hansen, Indian company Suzlon is also vertically integrated. GE, on the other hand, has outsourced more, including its blades, considered by many to be the most vital component. Outsourcing raises issues not just of secure supply but of quality control and design confidentiality.

Enercon says it has minimised the risk of shortages of components by increasing vertical integration and setting up long-term contracts with sub-suppliers. Gamesa, on the other hand, recently signed a deal with blade-maker LM Glasfiber to produce 1,000 MW of blades in Spain and the US whilst Vestas decided to outsource 1,500 MW of blades to LM in India. Both companies stress, however, that this is not indicative of a trend.

Gamesa says that the shortage of components will not seriously modify its current selective "make or buy" strategy. Depending on the situation, it will decide whether it is necessary to resort to external agreements, as with LM. "Technology alliances and internal skills will also be established to ensure the reliability and availability of gearboxes and electrical components," the company says. Vestas spokesman Peter Kruse says that "if someone can come up with a smart solution and beat us on our home turf, we obviously look at it. But although the growing market means we have sometimes had to go elsewhere, structurally our policy is still to keep the core components in-house."

Another important response to uncertainty of supply has been an increasing number of framework agreements – outline forward commitments by manufacturers to supply a set number of turbines to a particular wind farm developer over a series of delivery years. These have advantages from the both the buyers and sellers' point of view. For the project developers they offer the security that they will definitely receive the turbines, for the turbine suppliers they enable much better coordinated planning of production schedules. The largest framework agreement in the wind industry so far has been for 2,700 MW of turbines to be delivered by Gamesa to power utility Iberdrola between 2007 and 2009.

The same type of longer term agreements are now being drawn up between turbine manufacturers and their suppliers, such as gearbox and bearing companies, in order to ensure that they can satisfy their final customers.

Keith Hays of EER says that exactly when a more stable balance of supply and demand will be reached depends on issues such as the future US market, whether large offshore schemes take off in Europe and whether new quality manufacturing capacity is created in Asia. "But once that equilibrium is reached you're going to see more competition, more forward contracts, more consolidation among turbine suppliers and possibly more consolidation in the supply chain." EER also expects increasing component capacity and cost reduction measures to offset the "temporary upward pressure on turbine prices".

For more information:"Supply Chain Assessment, 2006-10" from BTM Consult, www.btm.dk;
Emerging Energy Research, www.emerging-energy.com;
MAKE Consulting, www.make-consulting.com

Breakdown of component supply for Gamesa Eolica turbines

	Blades	Central Software	Gearboxes	Generators	Power Electronics	Towers
Design	100% in house	100% in house	50% in house	50% in house	60% in house	100% in house
Manufacturing	100% in house	100% in house	50% in house	55% in house	60% in house	30% in house
O&M	100% in house	100% in house	100% in house	100% in house	100% in house	100% in house
% of WTG Cost	20%	5%	15%	10%	5%	20%

Source: Gamesa