2011

Wind Energy Industry Manufacturing Supplier Handbook

AWEA AMERICAN WIND ENERGY ASSOCIATION

BLUEGREEN ALLIANCE FOUNDATION Clean Energy MANUFACTURING CENTER

GLWN.org

NIST MEP • MANUFACTURING EXTENSION PARTNERSHIP NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY U.S. DEPARTMENT OF COMMERCE

About the Sponsors

AWEA is a national trade association representing wind power project developers, equipment suppliers, services providers, parts manufacturers, utilities, researchers, and others involved in the wind industry - one of the world's fastest growing energy industries.

The Association provides up-to-date information on wind energy projects operating, new projects in various stages of development, companies working in the wind energy field, technology development, and policy developments related to wind and other renewable energy development. People count on AWEA to provide up-to-date, accurate information about the domestic and international wind energy industry.

The BlueGreen Alliance Foundation (BGAF) is a 501(c)(3) organization that works with the BlueGreen Alliance — a national partnership of fourteen labor unions and environmental organizations dedicated to expanding the number and quality of jobs in the green economy — to conduct research and educate the public and media about solutions to environmental challenges that create economic opportunities for the American people.

BGAF's Clean Energy Manufacturing Center focuses on job creation opportunities in the emerging clean energy industries. The Center serves as 'one-stop shop' for public officials looking to develop clean energy strategies for their communities as well as manufacturers looking to participate in supply chains in the growing wind power and solar energy industries."

Global Wind Network is an international supply chain advisory group and network of manufacturers whose mission is to increase the domestic content of North America's wind turbines, onshore and offshore.

GLWN helps manufacturers identify and evaluate technical and business pathways in the wind sector and connect them with potential customers and their specific product needs. They also link wind industry OEM's and component suppliers to help them expand their businesses and keep pace with market demand as well as supporting smart public policy initiatives and integrated federal/state/industry efforts that are key to expanding the wind industry.

The National Institute of Standards and Technology's Hollings Manufacturing Extension Partnership (MEP) works with small and mid-sized U.S. manufacturers to help them create and retain jobs, increase profits, and save time and money. The nationwide network provides a variety of services, from innovation strategies to process improvements to green manufacturing. MEP also works with partners at the state and federal levels on programs that put manufacturers in position to develop new customers, expand into new markets and create new products.

MEP field staff has over 1,400 technical experts – located in every state – serving as trusted business advisors, focused on solving manufacturers' challenges and identifying opportunities for growth.

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Preface

This wind energy industry manufacturing supplier handbook is designed as a starting point for manufacturers interested in becoming suppliers to the industry. It provides information on the potential growth of wind energy markets, describes the 'anatomy' of a wind turbine and it's components and provides an understanding of the practices and OEM requirements that are relatively common in the utility scale turbine industry.

While the wind industry has seen remarkable growth in the U.S. over the past several years, a significant portion of the parts and components for wind turbines are currently still being manufactured overseas. The sponsors of this handbook are committed to building a strong domestic manufacturing sector in the wind energy industry and our goal through this handbook is to inform manufacturers of market opportunities and ultimately increase the number of component manufactures that participate in industry supply chains.

However, it's important to recognize that manufacturing components for the wind energy market is not necessarily an appropriate diversification strategy for many companies. OEM's have very rigorous supplier qualification and quality requirements due to the very high cost of repair in the field and entry barriers may be high for some components.

As a result, we have made an effort to provide you with information to help you decide if this is the right market for your company, where you might fit in and whether you might qualify as a 1st, 2nd or 3rd tier supplier.

The handbook has been divided into several sections, starting with an Introduction that provides you with an overview of wind turbines and basic terminology.

Section I identifies industry opportunities for manufacturers and covers the Wind Energy Markets, both in the U.S. and globally. It describes industry growth over the past decade and projections through 2020.

Section II offers a detailed review of the Anatomy of a Wind Turbine, which describes the major working components. A turbine is a collection of systems that converts wind energy into electrical energy and includes an estimated 8,000 components. Each of the major systems is reviewed with pictorials, schematics and descriptions of the major sub-components.

Section III focuses on the Structure of Supply Chains and requirements for component manufacturing. We describe a manufacturing model that has proven to be competitive and successful in this industry. Quality management system requirements are also reviewed,

Section IV outlines some Next Steps to help you decide the best fit for your company in this industry and how to get connected with existing supply chain partners. A listing of the major wind turbine OEMs and 1st Tiers companies is also provided.

Please feel free to contact us with any questions or comments.

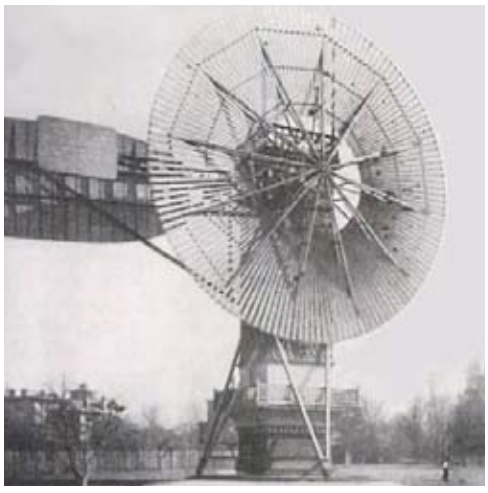
Introduction

Wind power as a commercial source of energy is an American invention. The first wind turbine was invented by Charles Brush of Cleveland, Ohio who constructed a 60 feet tall 12 kilowatt turbine in 1888 (see photo on the left). By the 1920s, U.S. factories were producing 100,000 wind turbines per year, mostly for agricultural and rural applications.

The first large commercial utility-scale turbine was developed at the NASA Glenn Space Center, also in Cleveland, in the 1970s, with funding from the Department of Energy and the National Science Foundation. The two-blade turbine (on the right), built in response to the emerging oil crisis, was a 3.2MW unit and installed in Oahu, Hawaii in 1980 If not decommissioned, due to funding cutbacks, this would still be considered North America's largest wind turbine.

Today in the U.S., wind turbines can be classified into three categories and this handbook will primarily address issues relating to utility scale turbines.

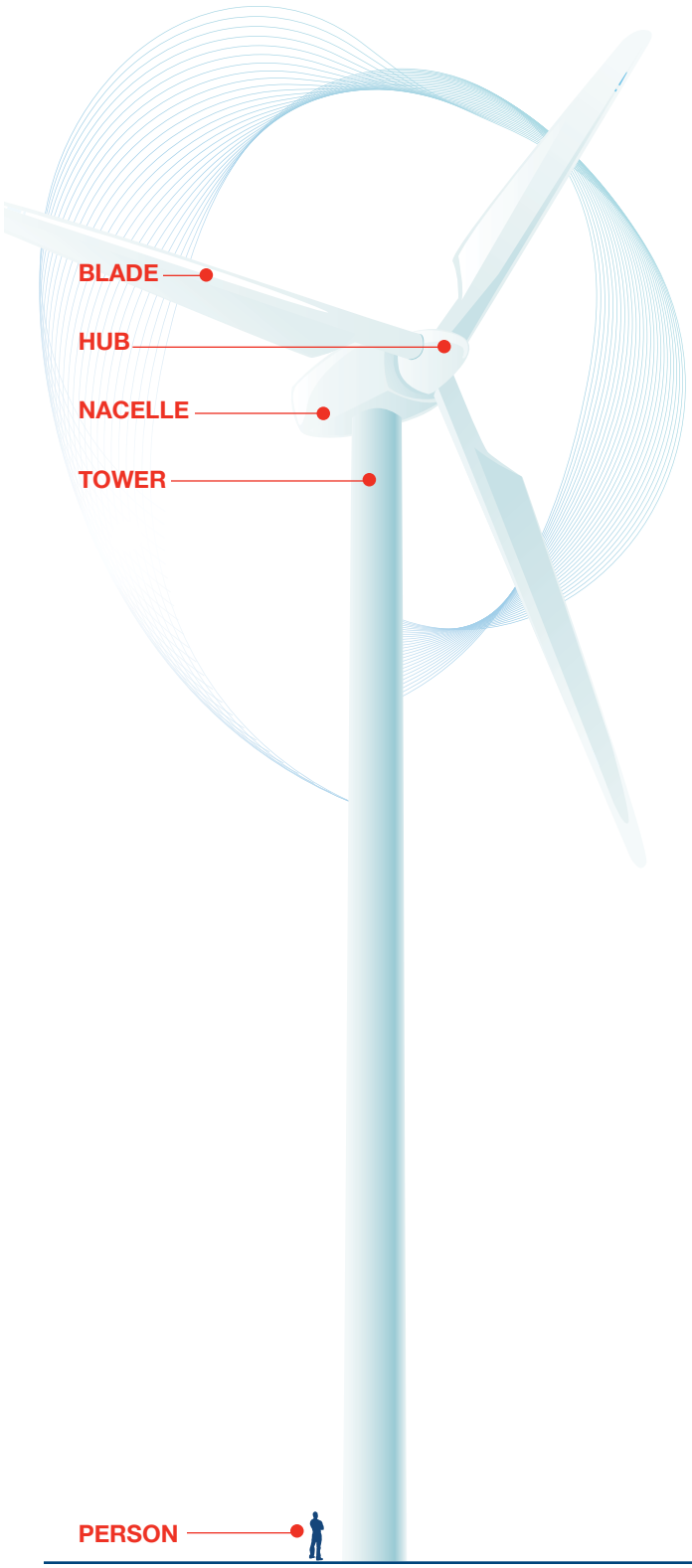
- Residential scale wind turbines are less than 100kW, typically used for a home, farm, or business and can be connected to the electric grid or connected only to a storage battery or a building. According to AWEA, an average American home would need a 5kW wind turbine for its electricity needs. These small turbines are typically about 80 feet tall with a rotor diameter of 18 feet (AWEA). They contain an average of 30 - 80 components.
- Community scale turbines are 100kW - 1000kW (1MW), typically used for a specific load, like several buildings of a school or a shopping complex, and supplies extra generated energy to the electric grid. They contain an average of 1,000 - 3,000 components.
- Utility scale turbines are greater than 1MW, typically connected to a transmission grid. The GE 1.5MW wind turbine, a common utility scale model, has a hub height of 262 feet (80 m) with a rotor diameter of 262 feet (80.5 m) (GE). They can contain as many as 8,000 components.



1888:
12 kilowatt wind turbine

1970-1980
3,200 kilowatt or
3.2 megawatt wind turbine

Terminology



BLADES: Most wind turbines have three blades, though there are some with two blades. Blades are generally 30 to 50 meters (100 to 165 feet) long, with the most common sizes around 40 meters (130 feet). Blade weights vary, depending on the design and materials — a 40 meter LM Wind Power blade for a 1.5 MW turbine weighs 5,780 kg (6.4 tons) and one for a 2.0 MW turbine weighs 6,290 kg (6.9 tons).

Blades are advanced in design, but labor intensive in the manufacturing process. OEMs usually have unique designs for blades, and may manufacture blades or purchase them from suppliers. Manufacturing includes labor-intensive processes like adding layers of fiberglass to blade molds and finishing the edges of the blades.

HUBS: The hub is the component to which the blades are attached; it connects the blades with the drivetrain. It is one of the single largest components of the turbine and each hub can weigh over 15 tons.

NACELLES: The nacelle houses the main components of the wind turbine, such as the controller, gearbox, generator, and shafts. The plants that produce nacelles are primarily assembly facilities. Nacelle components are produced (in-house or by outside suppliers) to the specifications of the OEM and then assembled at the nacelle plant.

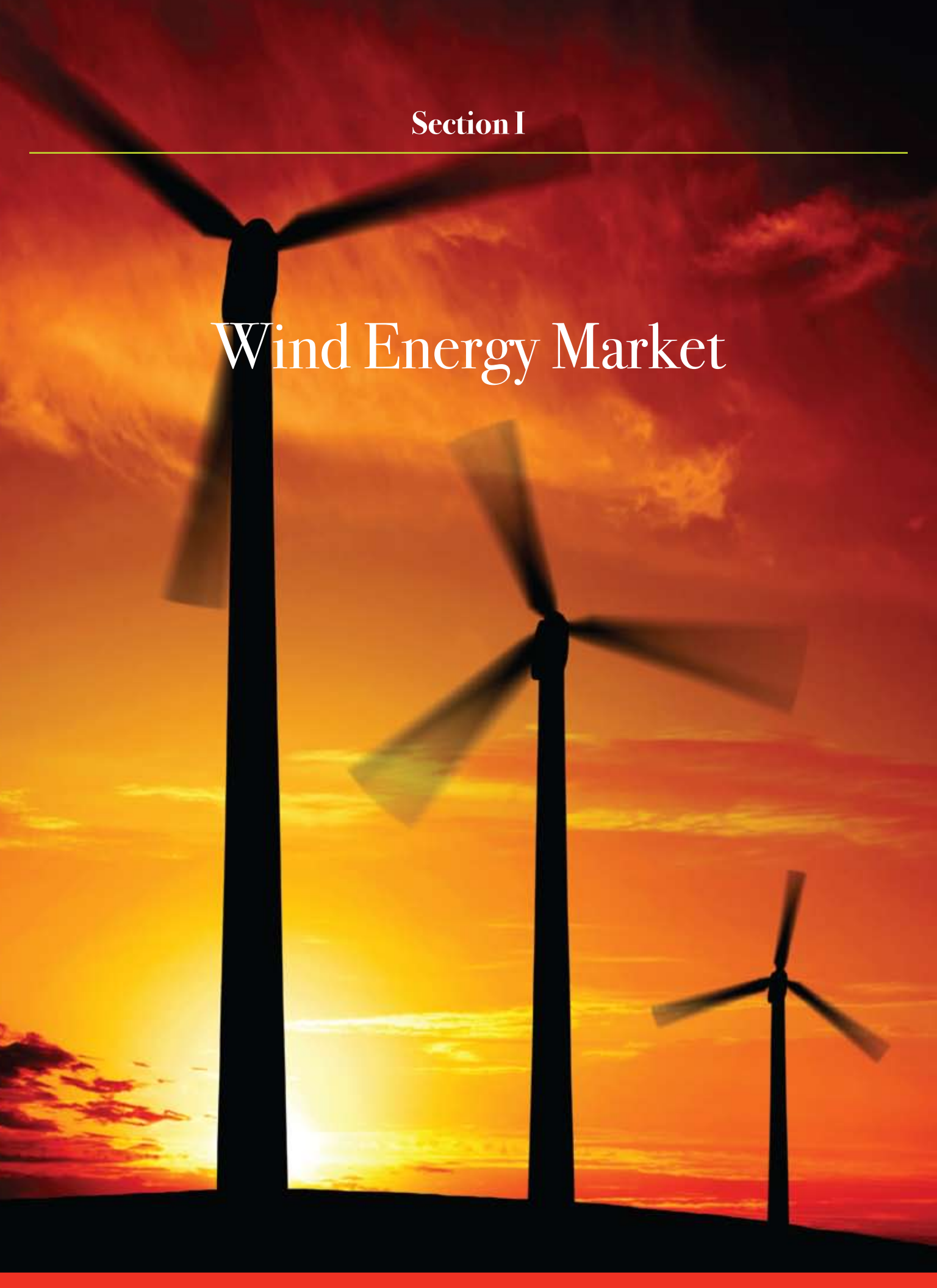
OEMs typically have unique designs for wind turbine nacelles and the leading global OEMs manufacture nacelles in-house. Some companies license wind turbine designs to other companies and several companies contract out nacelle manufacturing.

TOWERS: Towers are usually tubular steel towers 60 to 80 meters about 195 to 260 feet high that consist of three sections of varying heights. (There are some towers with heights around 100 meters (330 feet).

OEMs design towers. These usually have 3 sections, each consisting of metal rings that are thickest at the bottom of the tower and are conical in shape since towers taper slightly from the base to a narrower opening at the top. During the manufacturing process plated sheets are cut, rolled into the conical shape and then welded into rings. Rings are then welded together and painted.

Section I

Wind Energy Market



Global Wind Energy Market

US and China are the Leaders

Over the past decade, interest in wind energy has grown globally, with the U.S. and China having established themselves as global leaders. Until 2010, the U.S. had been global leaders in new installations for four years in a row, growing by almost 40% in 2009.The amount of electrical generating capacity worldwide available from windpower over the past 15 years has risen to close to 200,000MW.

Currently, over 35,000 turbines have been installed in the U.S. and one of every five wind turbines worldwide is serving U.S. electrical grids.

NEWLY INSTALLED CAPACITY (2010)

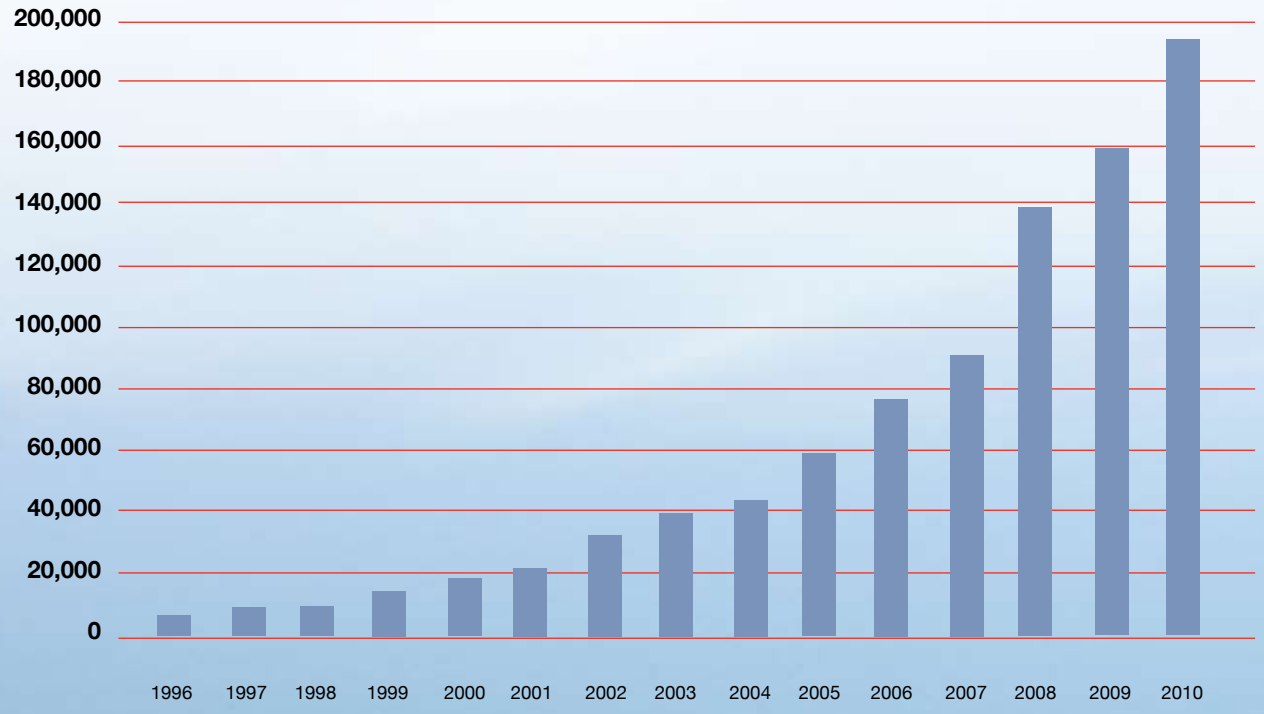
COUNTRY	MW	%
China	18,900	46.1
USA	5,116	14.3
India	2,139	6.0
Spain	1,516	4.2
Germany	1,493	4.2
India	1,086	3.0
UK	962	2.7
Italy	948	2.6
Canada	690	1.9
Sweden	603	1.7
Rest of the World	4,750	13.3
World Total	**35,802**	**100**

CUMMULATIVE CAPACITY (2010)

COUNTRY	MW	%
China	44,700	21.8
USA	40,181	20.7
Germany	27,214	14.0
Spain	20,676	10.6
India	13,065	6.7
Italy	5,797	3.0
France	5,660	2.9
UK	5,204	2.7
Canada	4,009	2.1
Denmark	3,752	1.9
Rest of the World	26,546	13.7
World Total	**194,390**	**100**

Source: AWEA and GWEC

Total Installed Global Capacity



Charts Source: GWEC

Opportunities in U.S. Wind Energy Market

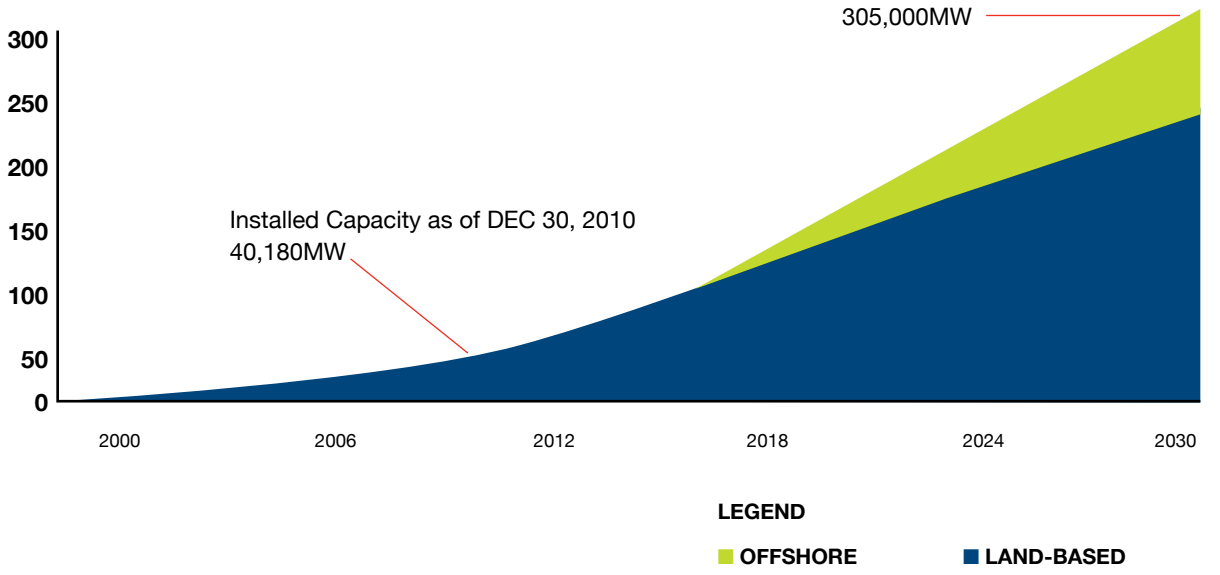
Over the past six years the U.S. wind energy market has seen significant growth and, despite the economic downturn, opportunities for wind power in the U.S. continue to exist. According to the U.S. Department of Energy's *"20% Wind Energy by 2030"* report, the U.S. possesses sufficient and affordable wind resources to obtain at least 20% of its electricity from wind by the year 2030.

According to these projections, the U.S. would have 305,000MW of installed capacity by 2030 – by the end of 2010, we were on track to meet these projections (see Chart A).

Driving growth is the fact that our nation wants more wind energy. According to a recent Harris Poll, 87% of American favor more wind power. And 29 states have already passed renewable energy standards (see Chart B).

CHART A

U.S. 20% WIND SCENARIO

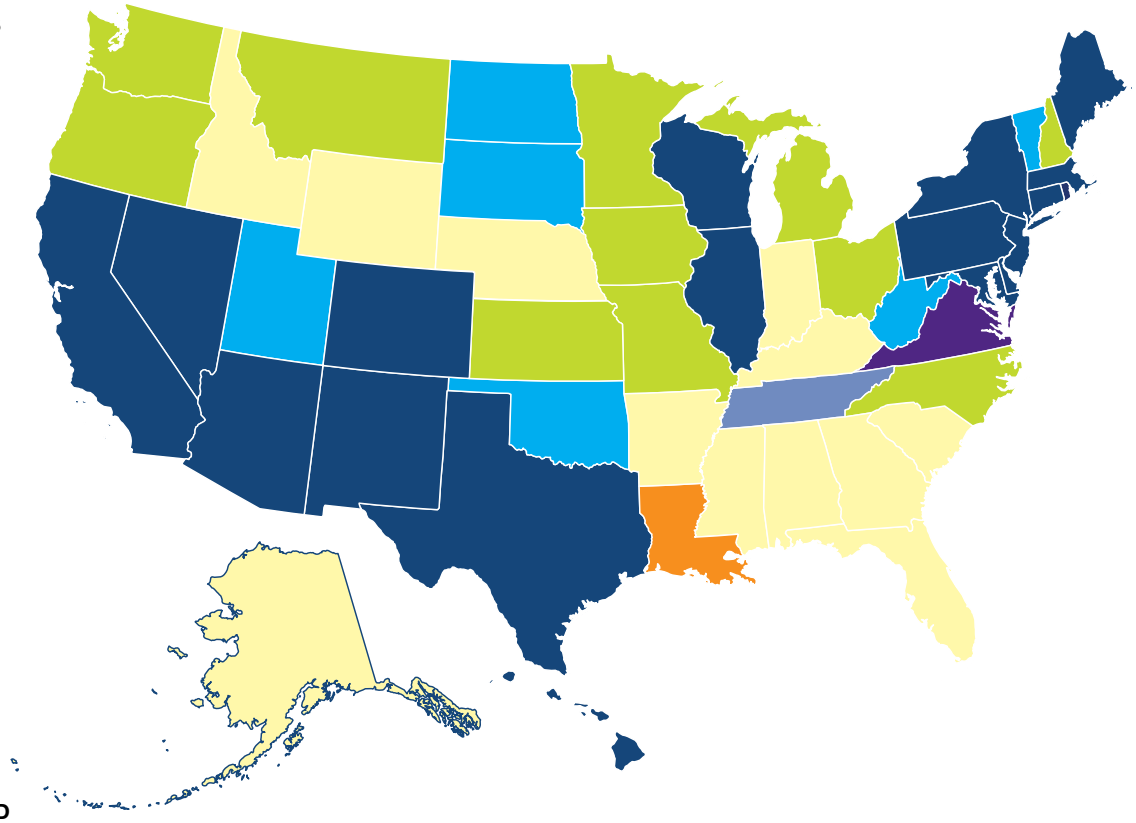


TIP

Why "invest" in wind component manufacturing? Because for many it can prove a viable market for diversification, it's good for the environment and it's a step in the right direction towards US energy independence.

Renewable Portfolio Standards (RPS) and Goals
29 states and D.C. have an RPS; 7 States and 3 Power Authorities have Goals

CHART B



LEGEND

- **RPS ACCELERATED OR STRENGTHENED RPS**
- **ACCELERATED OR STRENGTHENED RPS**
- **VOLUNTARY STATE OR UTILITY STANDARDS OR GOALS**
- **STRENGTHENED VOLUNTARY STANDARD**
- **PILOT OR STUDY**

AZ: 15% by 2025
CA: 33% by 2020
CO: 30% by 2020
10% – co-ops
CT: 27% by 2020
DC: 20% by 2020
DE: 25% by 2025
HI: 40% by 2030
IA: 105 MW;
1 GW wind goal by 2010
IL: 25% by 2025;
wind 75% of RPS
KS: 20% by 2020
LA: 350 MW by 2012-13
MA: 15% new by 2020, then 1%
annually; 2 GW wind goal by 2020
MD: 20% by 2022

ME: 30% by 2010; 10% new by 2017;
8 GW wind goal by 2030
MI: 10% MWH and
1,100 MW by 2015
MN: 25% by 2025;
30% by 2020 – Xcel
MO: 15% by 2021
MT: 15% by 2015
NC: 12.5% by 2021 – IOUs
10% by 2018 – co-ops, munis
ND: 10% by 2010
NE Public Power Districts:
10% by 2020
NH: 23.8% by 2025
NJ: 22.5% by 2020
NM: 20% by 2020 – IOUs
10% – co-ops
NV: 25% by 2025
NY: 30% by 2015

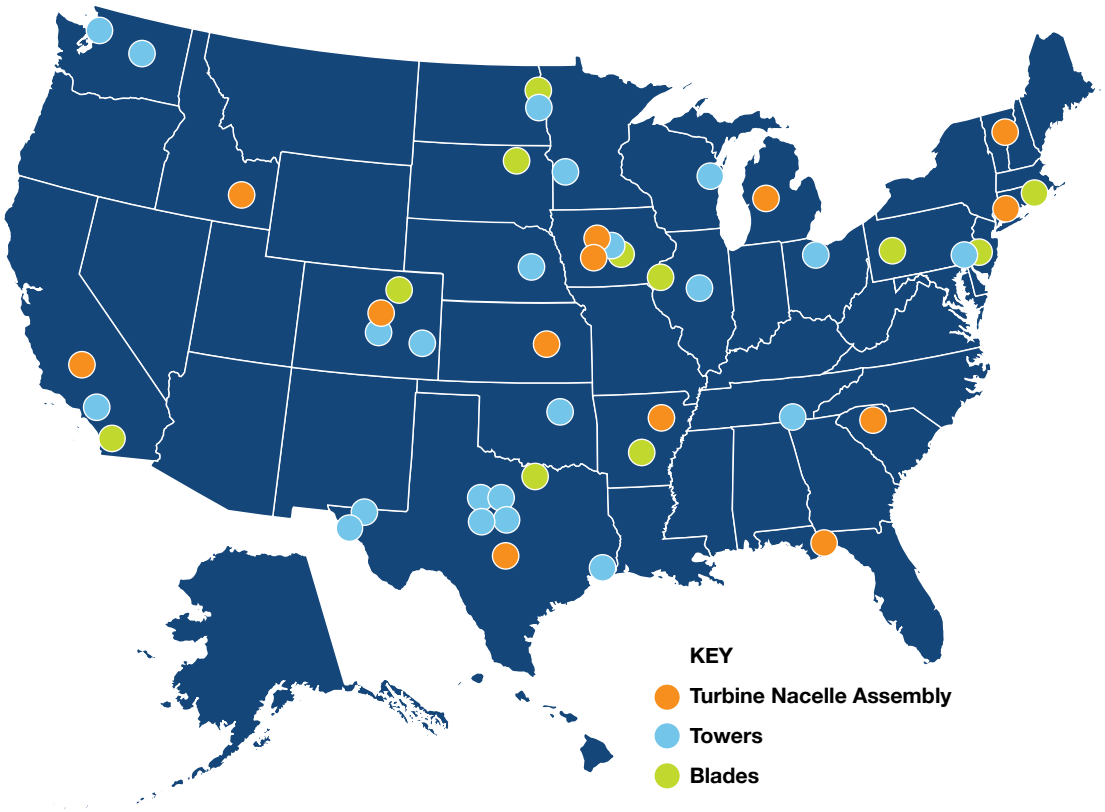
OH: 12.5% by 2025
OK: 15% by 2015
OR: 25% by 2025
5 -10% – smaller utilities
PA: 18% by 2020
RI: 16% by end 2019
SD: 10% by 2015
TX: 5,880 MW by 2015;
500 MW non-wind goal
UT: 20% by 2025
VA: 15% by 2025; goal with
production incentives
VT: 20% by 2017; all growth to
2012 from RE and EE
WA: 15% by 2020
WI: 10% by 2015
WV: 25% by 2025

Sources: (derived from data in) Lawrence Berkeley Labs, State Public Utility Commission (PUC) and legislative tracking services, Pew Center. Details, including timelines, are in the Database of State Incentives for Renewables and Energy

Wind Energy Growth in U.S.

The number of U.S. wind turbine operations has jumped from just one in 2005 — GE Energy — to nine in 2010. During this same period of time, the number of total facilities manufacturing components for the wind industry grew ten-fold, from 40 in 2005 to over 400 in 2010.

The following maps show the current installed wind power capacity in the U.S., as well as the location of the manufacturing facilities.



US WIND TURBINE OEM NACELLE ASSEMBLY BY YEAR

GE Energy	Clipper	Gamesa	DeWind	Acciona	Northern Power Systems	Nordex	Siemens	Vestas
2002 - 2010	2006 - 2010	2006 - 2010	2007- 2010	2008 - 2010	2010* *manufacturing of 2.2 MW turbine	2010	2010	2010

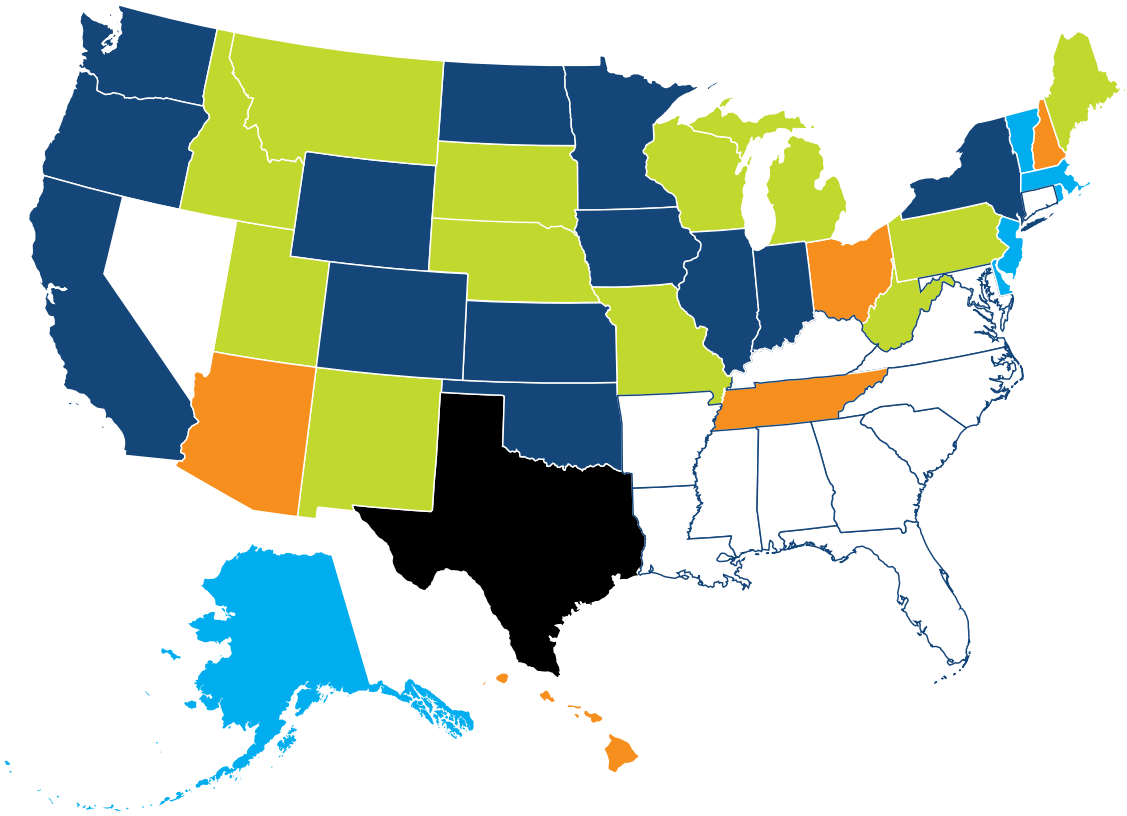
- Announced OEM Nacelle Assembly Facilities: Alstom, A-Power, Mitsubishi, Nordic

TOTAL OPERATING FACILITIES

	Online 2004	Online 2010	Announced	Total Expected Online in Coming Years
Towers	6	22	8	30
Blades	4	11	5	17
Nacelle Assembly	3	12	8	20
Total	30 - 40	Over400	40	Over 450
Manufacturing Jobs	2,500	20,000	18,000	38,000

Source: AWEA

Installed Wind Power Capacity (MW) in 2010



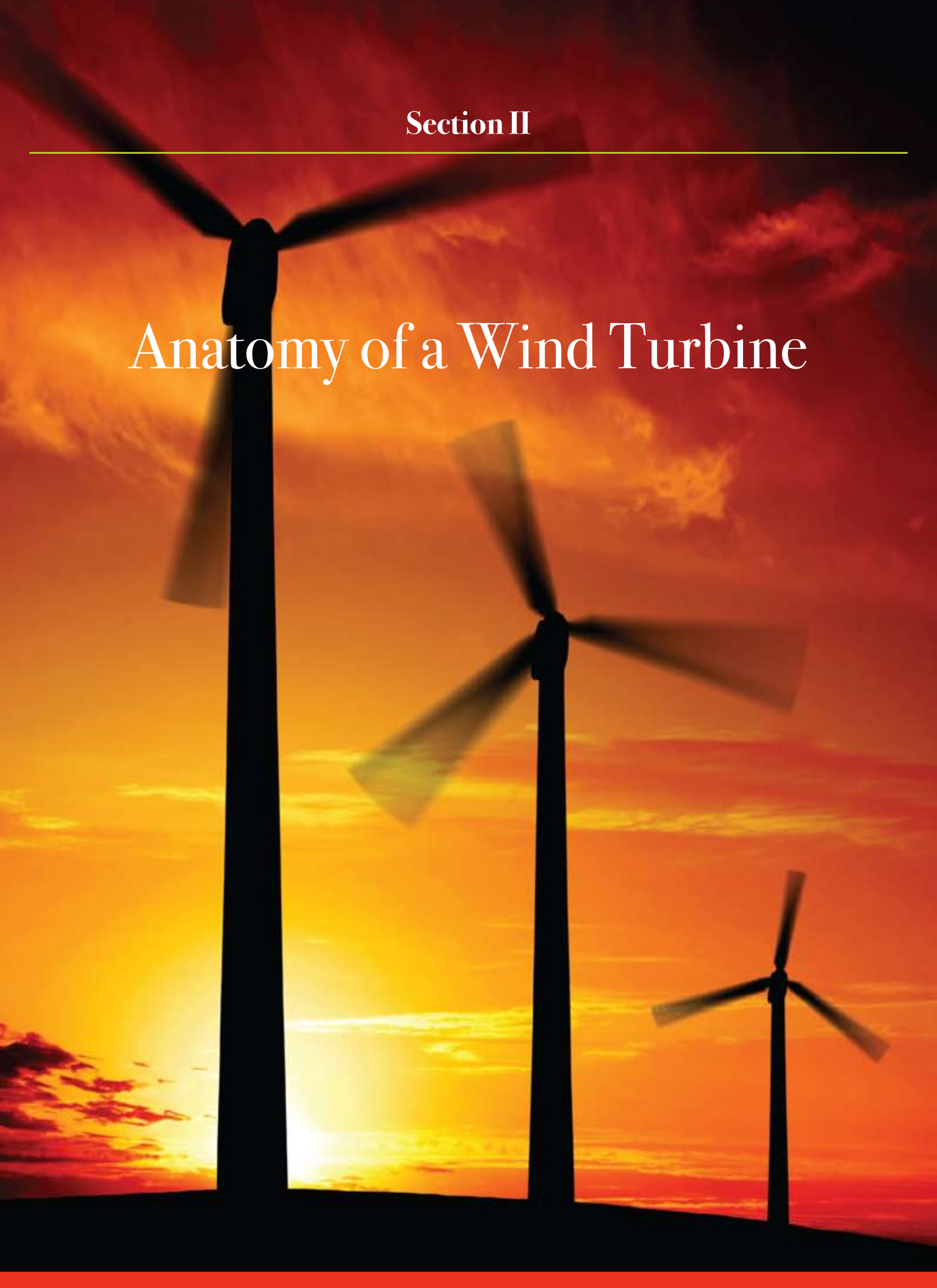
WIND POWER CAPACITY IN MEGAWATTS

■ **< 100 MW** ■ **100 TO 1,000 MW** ■ **>1,00 MW TO 10,000 MW** ■ **>10,000 MW**

AL:	10	NH:	26	OR:	2,104
AZ:	128	NJ:	8	PA:	748
CA:	3,177	NM:	700	RI:	2
CO:	1,299	NY:	1,275	SD:	709
DE:	2	MA:	18	TN:	29
HI:	63	MD:	70	TX:	10, 085
IA:	3,675	ME:	266	UT:	223
ID:	353	MI:	164	VT:	6
IL:	2,046	MN:	2,192	WA:	2,104
IN:	1,339	MO:	457	WI:	469
KS:	1,074	MT:	386	WV:	431
ND:	1,424	OH:	10	WY:	1,412
NE	213	OK:	1,482		

Section II

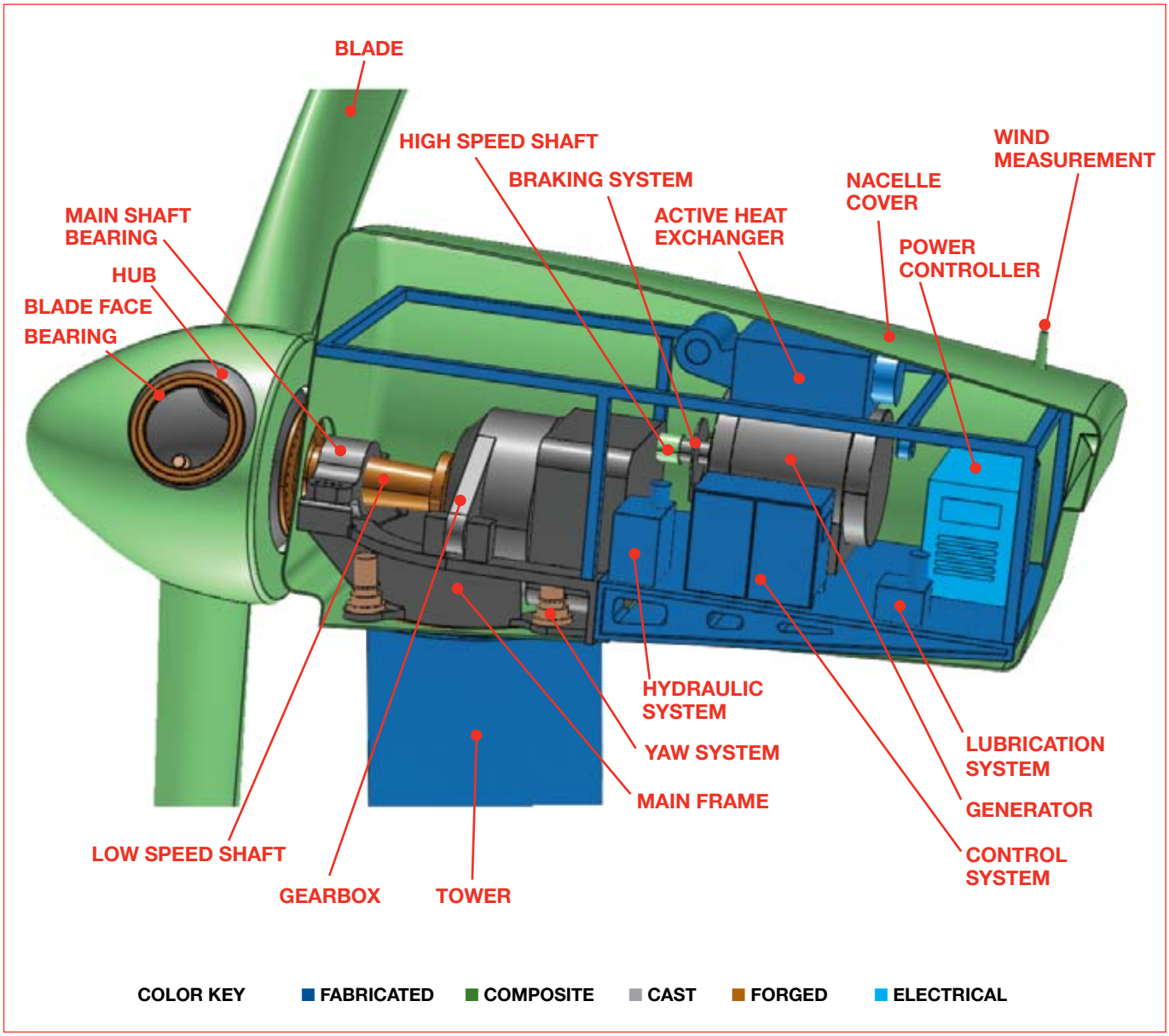
Anatomy of a Wind Turbine



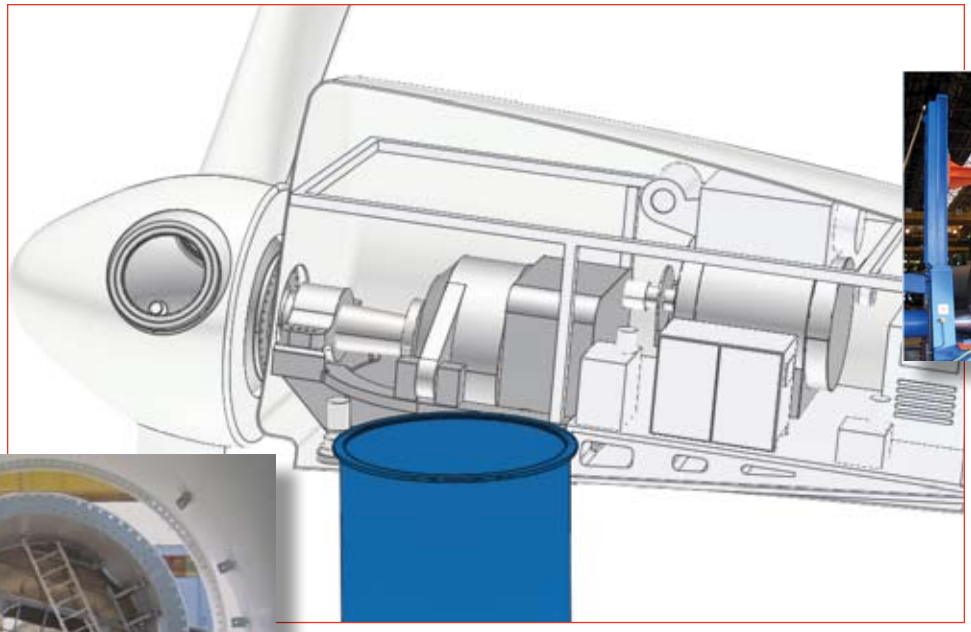
Anatomy of a Wind Turbine

A wind turbine is a collection of operating systems that transfers the energy from wind into electric energy that ultimately will be used in homes, communities, and businesses. The main operating systems include: tower, blade, rotor, drivetrain, gearbox, generator, electrical systems, nacelle, yaw & pitch, and controls.

This section reviews the construction of standard utility-scale wind turbines that are between one to three MW (Megawatt) in size. The two typical configurations for these turbines are a modular gearbox system or a direct-drive system. This section will utilize the modular gearbox system, the most common type, to explain the anatomy. This style uses a gearbox to step up the rotor speed entering the generator.



Tower



Rolled tower section

Tower internals

TOWER OVERVIEW

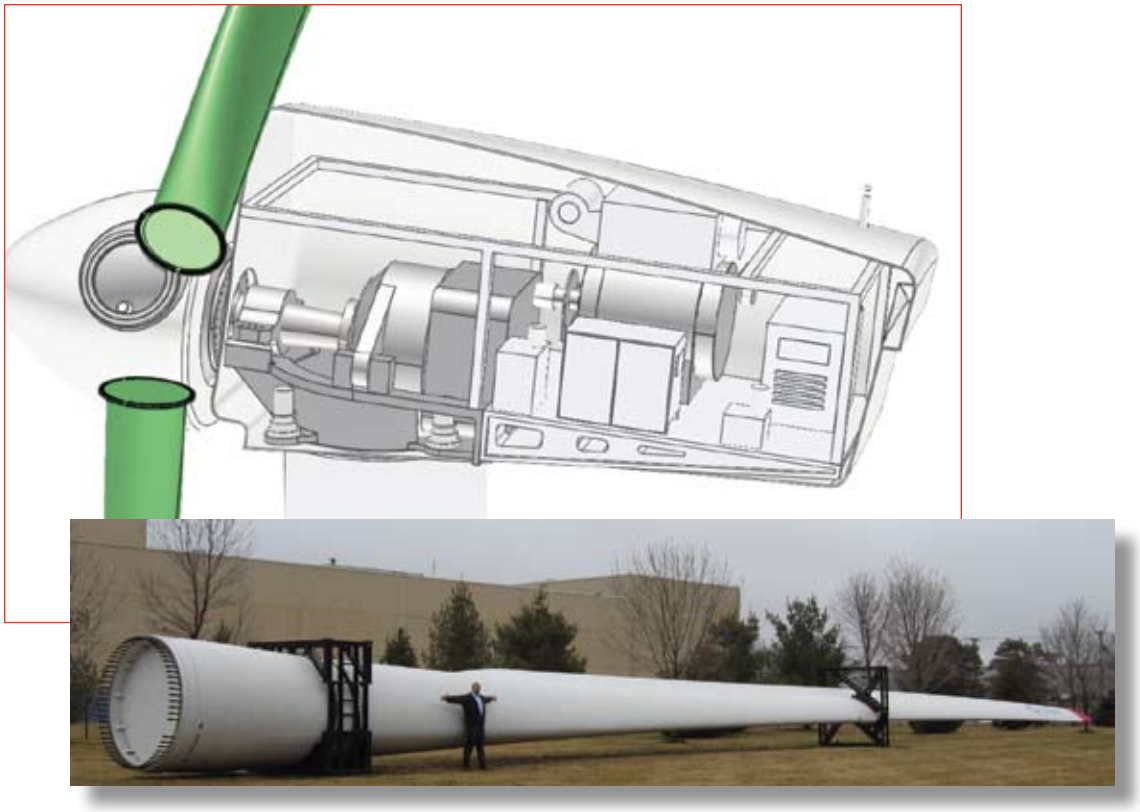
- Supports the wind turbine
- Rolled steel sheet - welded
- Attaches to concrete base and foundation
- Maximizes height for good wind
- 66% of total wind turbine weight

INTERNAL COMPONENTS

Steel Plate, Flanges, Yaw Gear, Coatings/Paint, Brackets, Door Assemblies, Hatches, Hoist, Climb Assist, Ladders, Platforms, Lighting, Cables

SUPPLIER IMPLICATIONS

- 100 - 200 tons of steel
- 50 - 120 meters in height
- Shipped in three sections or more
- Internals assembled at tower manufacturer



Blade for 2.5 MW wind turbine

BLADE OVERVIEW

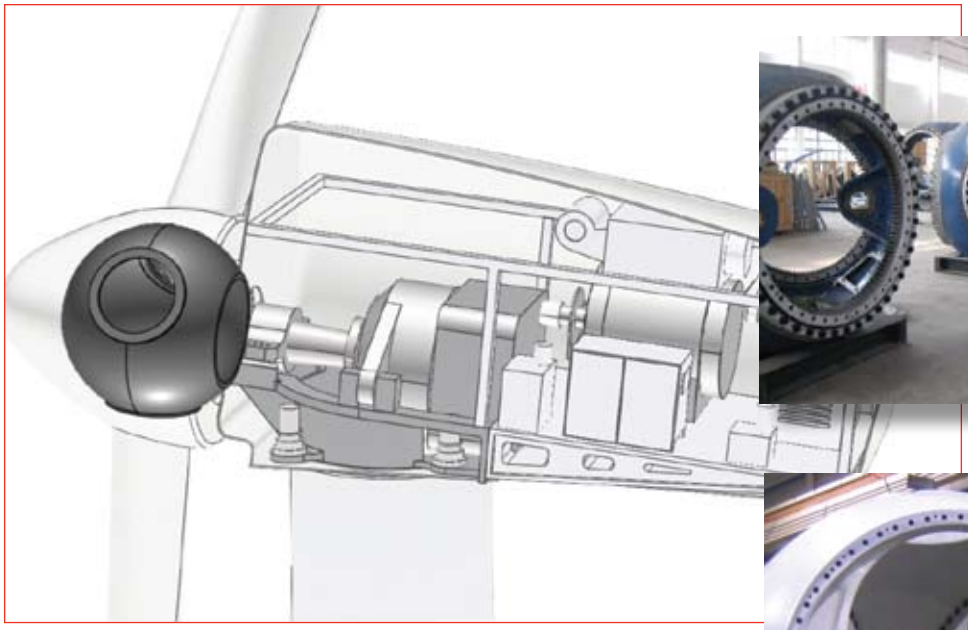
- Creates lifting force and rotational torque to generate power
- 70% to 75% fiberglass by weight with epoxy or polyester resin
- 7% of total wind turbine weight

INTERNAL COMPONENTS

Internal Core/Spar, Fiberglass, Skin Composite Laminates, Carbon Fiber, Epoxy or Polyester Resin, Root Insert, Fasteners, Barrel Nut, Protective Painting/Coating, Lightning Protection, De-Icing System

SUPPLIER IMPLICATIONS

- 6-10 tons each
- 30 - 55 meters in length
- Vacuum resin infusion and pre-preg molding (most are two pieces, some are one piece)
- Core parts integrated into final blade assembly
- Hull with core materials
- Spar caps
- Spars with sandwich
- Root section
- Bolt holes



Hub with pitch system

Cast, machined, and coated hub

ROTOR HUB OVERVIEW

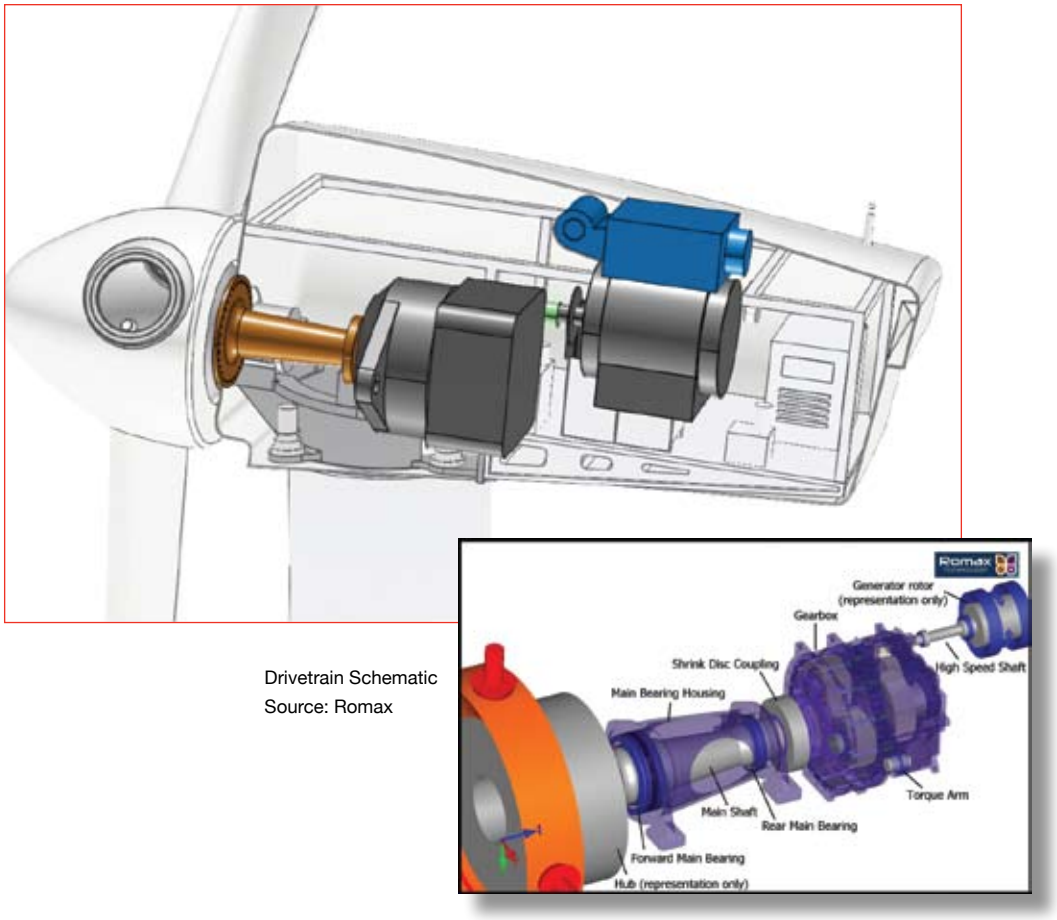
- Extract the power of the wind and convert it to rotary motion
- Hub connects the blades to the main shaft

INTERNAL COMPONENTS

Hub , Nose Cone, Pitch Brake (Disc, Calipers, Pads, Hoses, Seals, Housing), Bearings, Lubrication System

SUPPLIER IMPLICATIONS

- One of the largest components at 7 - 20 tons
- Material is typically cast ductile iron
- Tight casting and machining specifications



Drivetrain Schematic
Source: Romax

DRIVE TRAIN OVERVIEW

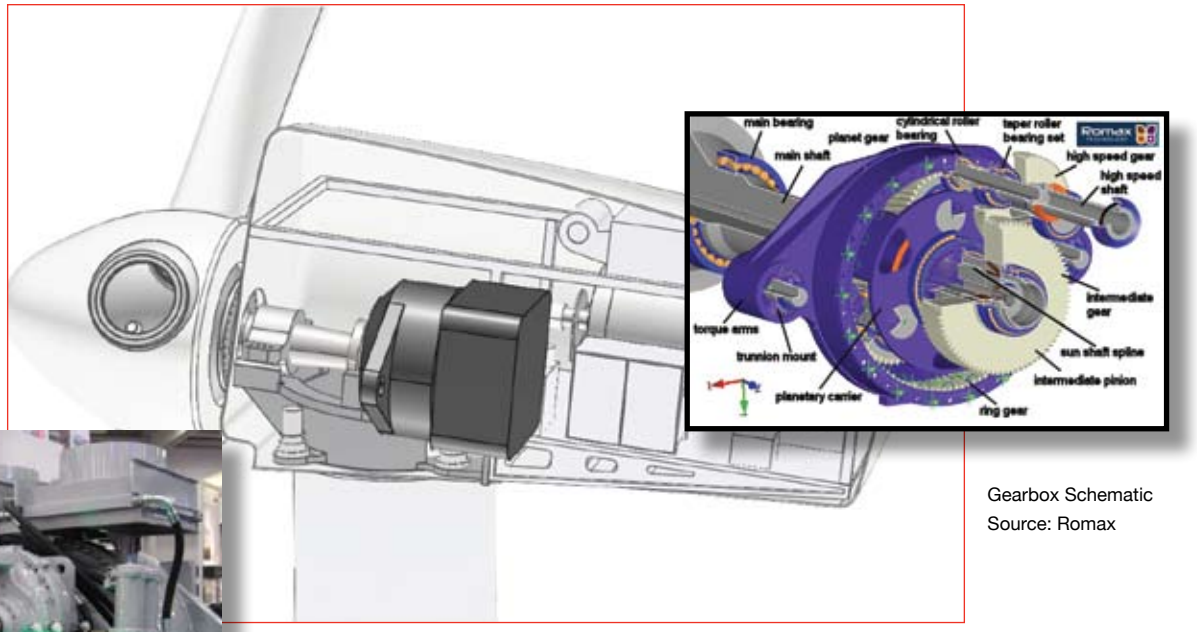
- Consists of all the rotating components: rotor, main shaft, couplings, gearbox, brakes, and generator
- 10 -20 rpm low speed side to 1200 – 2000 rpm high speed side

INTERNAL COMPONENTS

- Main Shaft, Rotor Lockout, Bearing, Seal, Lubrication, Compression Coupling, Rotor Lock, Connector Plate, Slip Ring Assembly, Transmission Shaft, High Speed Shaft, High Speed Coupling
- Brake System (Disc, Calipers, Pads, Hoses, Seals, Housings)

SUPPLIER IMPLICATIONS

- Main shaft is forged steel, machined and ground at 15- 25 tons weight
- Machined steel couplings, bolted, keyed,some with rubber



Gearbox Schematic
Source: Romax

Gearbox

TIP

Gearbox Manufacturing occurs at 3 US locations: Winergy, GE, Clipper
3 more locations in process: ZF, Moventas, Bosch

Two more plants are beginning construction

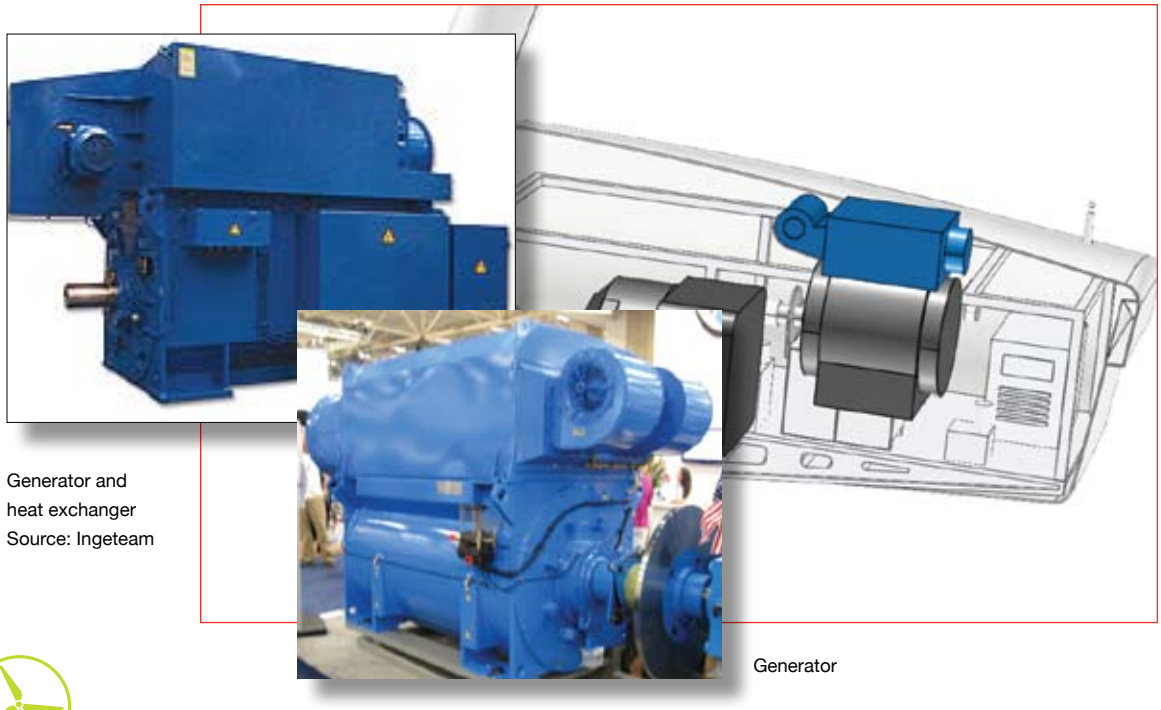
There is a growing market to maintain and repair the 20,000 turbines in operation today

GEARBOX OVERVIEW

- 10 - 20 rpm to 1500-1800 rpm on high speed shaft
- One of the heaviest and most expensive components of a wind turbine
- Normally planetary or parallel-shaft gearboxes
- Not used on direct-drive wind turbines

INTERNAL COMPONENTS

Housing, Planetary Gears (ring gear, sun gear, planet gear, carrier gear), Hollow Shafts Bearings (planet bearing, carrier bearing, shaft bearing), Hoses, Torque Arm Systems, Lubrication System, Cooling System, Hoses, Sensors (temperature, particulate)



Generator and
heat exchanger
Source: Ingeteam

Generator

TIP

Most generators have been imported

Generators represent a growing industry potential investment opportunity

Northern Power builds their own

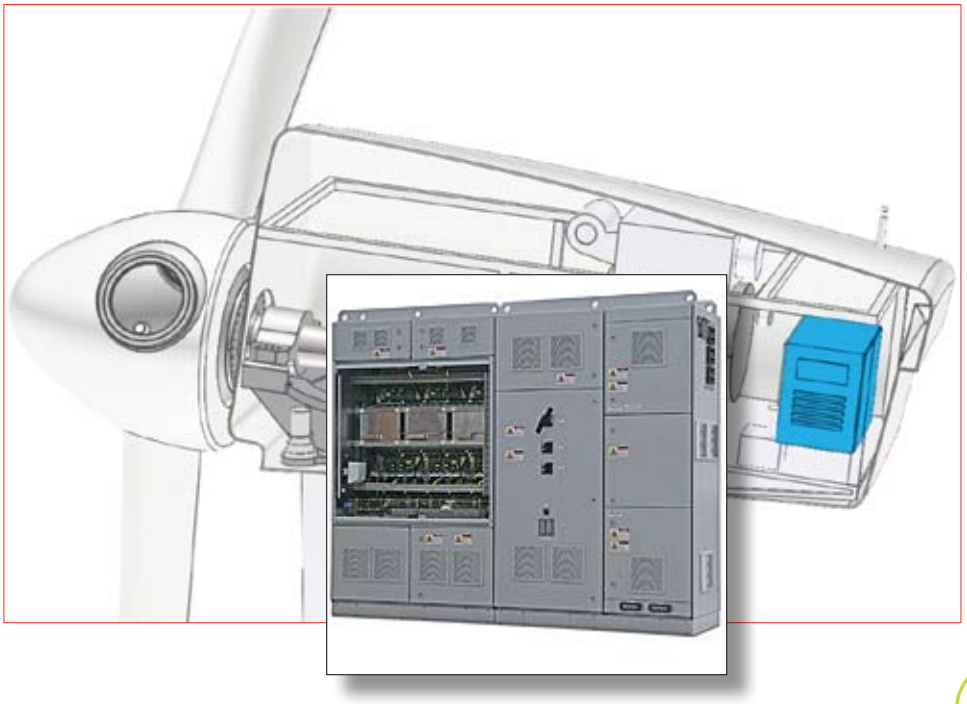
Ingeteam from Spain is building an assembly plant in Wisconsin

GENERATOR OVERVIEW

- Converts mechanical energy into electric power
- 3 types are synchronous, asynchronous, • double fed induction generator
- Most common is DFIG (Double Fed • Induction Generator)
- PMG (Permanent Magnet Generator) most commonly used on direct-drive turbines and are growing in popularity

INTERNAL COMPONENTS

Housing, Windings (stator & rotor), Lamination, Rotor Magnets, Commutator and Brushes, Bearings (rotor front bearing, rotor rear bearing, autolube system), Encoder, Shaft, Slip Rings (slip ring and brush), Exciter, Couplings, Generator Temperature Sensor, Coils, Cooling System (Radiator, Hoses, Filters, Cooling Fan, Pump, Pump Motor, Reservoir, Heat Exchanger)



Power converter
Source: Ingeteam

TIP

Most opportunities are manufacturing to the Tier 2 & 3 components

ELECTRICAL OVERVIEW

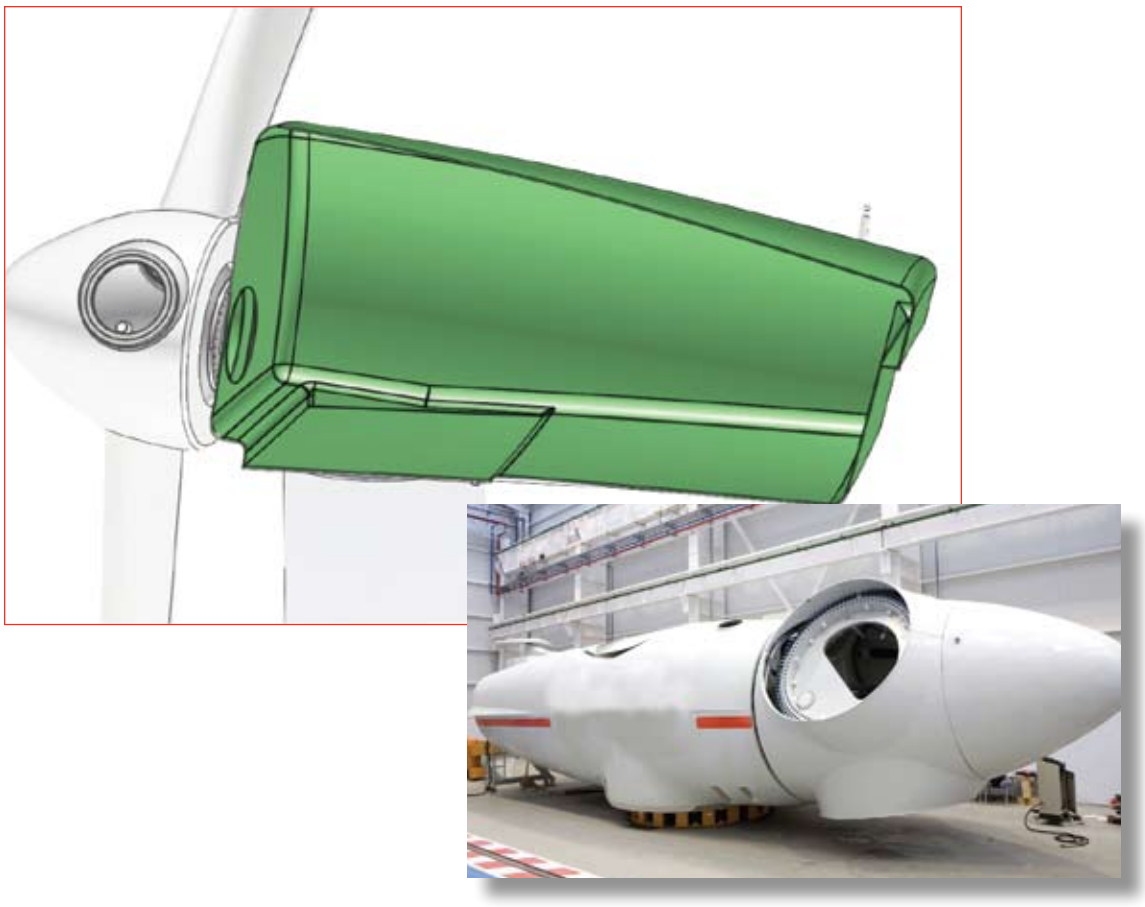
- Power converters change electric power from one form to another; DC to AC or AC to DC, or one voltage to another
- Inverters convert DC to AC
- Switchgear connects or disconnects wind power plants from the grid
- Transformer adjusts the voltage

HIGHER FREQUENCY REPLACEMENT PARTS ON OPERATING TURBINES

- Electrical System parts
- Electronic Control parts
- Sensors

INTERNAL COMPONENTS

Power Converter , Converter with IGBT Module (on the rotor side), DC Intermediate Circuit, Power Inverter, (on grid side), Power Factor Correction System (capacitors, harmonics, filter contractor), Soft Starter, Motor Contactor, Wiring and Connections (main contactor), Main Disconnect, Fuse Main Circuit Breaker, Relay, Cabinet Heater, Power Supply, Grounding System, Main Transformer (pad mounted or nacelle mounted)



Nacelle housing

TIP

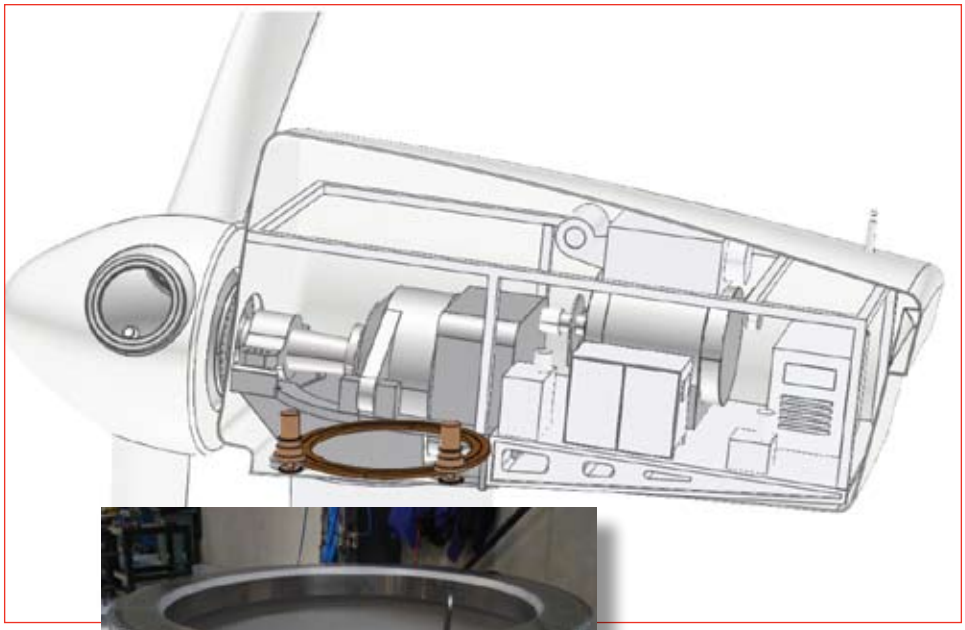
These housings are built as subassembly containing many components and shipped to assembly plant for final assembly

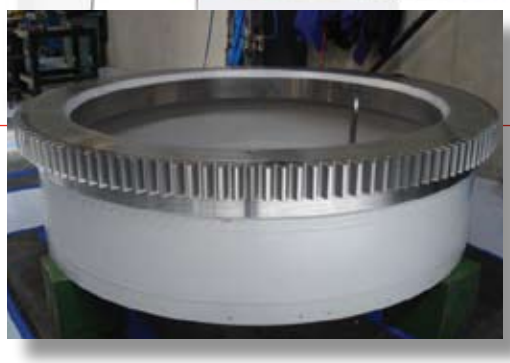
NACELLE HOUSING OVERVIEW

- Is the housing for all major components of a wind turbine
- Provides weather protection
- Normally made from lightweight materials such as fiberglass around a steel frame

INTERNAL COMPONENTS

Fiberglass Shell with Structural Steel Frame, Brackets, Exit Hatch and Latches, Wiring, Lightening Rod, Landing Pad, Ducting





Bull gear–
3 to 4 meter diameter

TIP

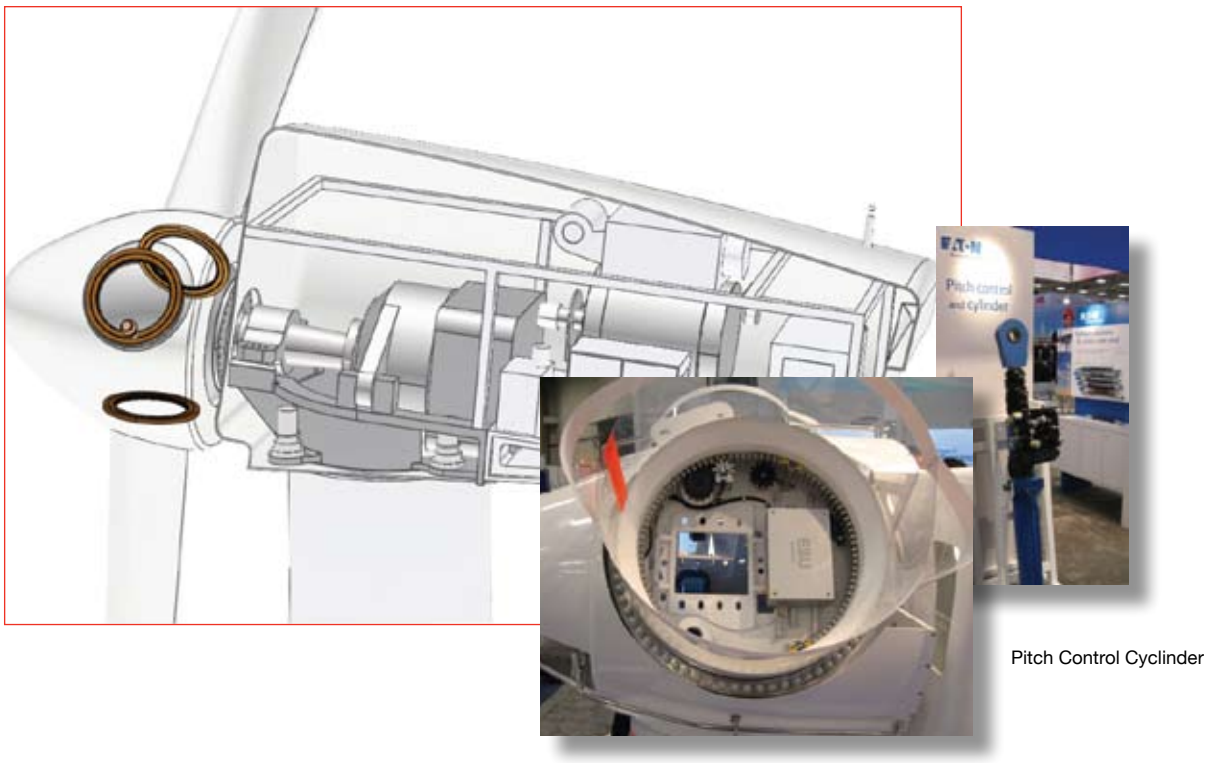
Have been mostly imported and represents a good manufacturing opportunity for US companies

YAW SYSTEM OVERVIEW

- Orients the wind turbine in line with the wind direction
- 3 or 4 motors used to rotate
- Includes a parking brake system

INTERNAL COMPONENTS

Brake, Calipers, Housing, Pads, Seals, Hoses, Electric or Hydraulic Drive, Reducer Gearbox, Lubrication System, Fan, Pinion gear, Polymer Slide Pads/Discs, Encoder



Pitch Control Cyclinder

View of Pitch System

TIP

If you supply components for electrical, hydraulic or mechanical systems, you could have an opportunity in this part of a wind turbine

PITCH SYSTEM OVERVIEW

- Feathers the blades to best capture the energy from the wind
- Used to stall the rotor to help slow down the turbine
- Geared slew ring with electric or hydraulic driver
- Each blade controlled separately

INTERNAL COMPONENTS

ELECTRIC PITCH SYSTEM

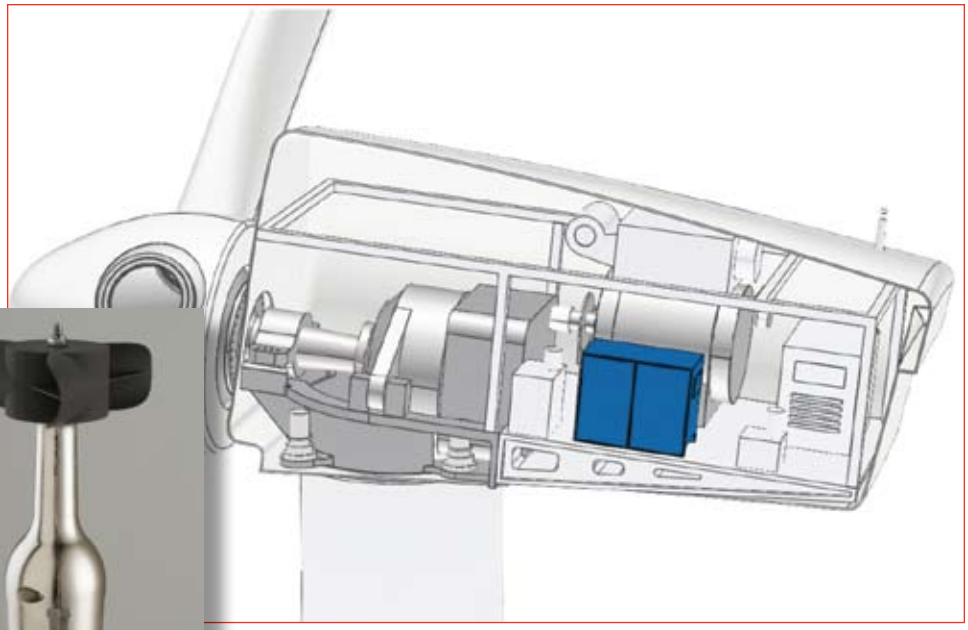
Motor, Cooling Fan, Motor Brake, Pitch Gear, Gear Reducer, Limit Switch , Battery, Battery Charger, Seals, Auto-Lube System, Rotary Electric Drive (pinion, power electronics/drive, cabling, contactor/circuit breaker fuse, encoder, power supply, heater, misc. electrical)

HYDRAULIC PITCH SYSTEM

Linear Hydraulic Drive, Accumulator, Pump & Pump Motor, Proportional Valve, Position Sensor, Hoses/Fittings, Spherical Bushing, Cylinder, Linkage, Position Controller, Limit Switch

MECHANICAL PITCH SYSTEM

Bearings and Lubricants, Motors, Gears, Pitch Cylinder Linkage



Wind sensor
Source: NRG

TIP

If you supply sensors, controllers, power amplifiers, actuators or related components today, you could have an opportunity in wind today

CONTROL SYSTEM OVERVIEW

- Balances and optimizes machine operation and power production
- Maximizes fatigue life
- Maximize energy production
- Provide means to monitor

INTERNAL COMPONENTS

SENSORS
Speed, Position, Flow, Temperature, Current, Voltage

CONTROLLERS
Mechanical Mechanisms, Electrical Circuits, Computers

POWER AMPLIFIERS
Switches, Electric Amplifiers, Hydraulic Pumps and Valves

ACTUATORS
Motors, Pistons, Magnets, Solenoids

INTELLIGENCE
Computers, Microprocessors

Section III

Doing Business with OEMs

Doing Business with OEMs

Supply Chain Opportunities

Wind energy OEMs, for the most part, don't manufacture the components/products required to build a wind turbine. These companies are primarily engaged in designing the turbine, outsourcing parts, assembly, testing and shipping.

OEMs generally purchase manufactured components in two ways. The most common method is by hiring an Integrator company, which procures and assembles components directly from Tier 2 & 3 suppliers – OEMs purchase about 90% of turbine components though Integrators.

OEMs only purchase about 10% of components directly – manufactured by Tier 1 suppliers.
The total number of parts purchased directly by OEM's for each turbine is estimated to total between 800 and 1000 – out of the 8,000 components in a turbine.

Following are the types of components that are purchased directly as well as through intergrations.
Please note that each of these categories includes a number of sub-systems.

TOWER:
- Towers
- Ladders
- Lifts

ROTOR:
- Hub
- Nose Cone
- Blades
  - Composites
  - Blade Core
- Pitch Mechanisms
- Drives
- Brakes
- Rotary Union

NACELLE:
- Nacelle Cover
- Nacelle Base
- Heat Exchanger
- Controllers
- Generator
- Power Electronics
- Lubricants
- Filtration
- Insulation
- Gearbox
- Pump
- Drivetrain
- Ceramics
- Shaft

FOUNDATION:
- Rebar
- Concrete
- Casings

OTHER:
- Transformers
- Bolts/Fasteners
- Wire
- Paints and Coatings
- Lighting
- Lightning Protection
- Steelworking/Machining
- Communication Devices
- Control and Condition Monitoring Equipment
- Electrical Interface and Connections
- Batteries
- Bearings
- Brakes

Tier One Direct Purchase

DIRECT PURCHASE - TIER ONE							
Foundry	Electrical & Electronics	Hydraulics	Composites	Misc.	Forge	Machine Shop	Fabricator
Bases	Bus Bars	Accumulator	Insulators	Packaging	Main Shafts	Bases	Brackets
Housings	Cables, Wires,	Ducting	Spinner Covers	Plastic Components	Shrink Discs	Housings	Plates
Hubs	Cabinets	Filters		Rubber Components	Yaw Gears	Hubs	Rear Frames
	Controls	Heat Exchangers		Signage	Large Fasteners	Main Shafts	Structural Supports
	Electronic Components	Hoses		Transportation & Logistics Frames	Retainers	Seal Labyrinths	
	Harnesses	Lube Systems					
	Heating Elements	Motors					
	Instrument-ation	Pumps					
	Lighting	Rotary Unions					
	Motors	Seals					
	Sensors	Valves					
	Software						

The Role of Integrators: OEMs' Other Customers

Main Integrators Used By Wind Turbine OEMs and Their Tier 2, 3, & 4 Suppliers

These tiers of suppliers supplies the following general types of components: castings, forgings, fasteners, rods, tubing, hoses, steel plate, copper plate, wiring, wiring harnesses, cable, lubricants, cooling fluids, coatings, rubber isolation mounts, seals, gears, and retainers.

Other components include:

- **BRAKES:** calipers, discs, hoses, housings, pads, seals
- **BEARINGS:** lubricants, rolling elements, steel, seals
- **GENERATORS AND TRANSFORMERS:** brushes. coils, bearings, cooling systems, couplings, housings, laminates, shafts, windings, controls
- **GEARING AND DRIVES:** actuators, bearings, brakes, cooling systems, drive systems, gears, housings, lube systems, pitch drive, UPS, shafts
- **TOWERS:** coatings, doors, electric cabling, elevators, flanges, hoists, ladders, lighting, plate, platforms
- **BLADES:** fiberglass, resins, coatings, core, mesh, protective film, roots, substrates, studs, barrel nuts
- **NACELLE STRUCTURE:** brackets, crane system, ducting, fiberglass shell, framing, harnesses, insulation, lighting, polymer enclosure, power distribution

TIP

In addition to OEM parts, you may also want to investigate supplying service parts

Tier One Integrator

The following is an example of a tier one integrator within the tower supply chain. The tower manufacturer is a focused fabricator who forms, welds, and assembles a complete tower. They are responsible for integrating components from the following suppliers:

Product	Supplier
Steel plate	Steel mill
Forged flanges	Forgers
Tower top	Fabricators
Door frames	Fabricators
Platforms	Fabricators
Ladders	Fabricators
Fasteners	Forgers
Electrical components	Extruders, molders, assemblers
Coatings	Coaters

Other Main System Integrators: Blades, Bearings, Brake Systems, Generator, Transformer, Gearing & Drives, Towers, Nacelle Housing

TIP

A majority of the components found in a wind turbine are produced by tier two, three & four suppliers, not the wind turbine manufacturer. To find your customer, contact the integrator who provides a sub-system for the turbine.

In addition to selling parts directly to an OEM or through an integrator, there are other opportunities for manufacturers to participate in the wind energy market.

This includes supplying parts for maintenance, repair and operations of wind farms. The frequency of repair ranges from 1 out of 2 turbines per year on electrical components to 1 out of 10 on larger gearboxes, generators and blades. The goal is to minimize downtime which ranges from 1 day for electrical components and up to 6 days for gearboxes, generators and blades.

It's also important to recognize that currently there are about 14,000 turbines out of warranty and some additional 5,000 wind turbines go out of warranty each year. Some of the types of services/products that are needed for wind farm operations are listed below.

Other 2nd and 3rd tier opportunities exist for suppliers of parts in wind farm construction. These include construction site electrical components, logistics and erection fixtures, anchoring systems, fasteners, cabling, transformers, lighting, substation equipment and O&M structures. In these situations the contracting company would generally be the developer of the wind farm not the turbine OEM or Integrator.

O&M SERVICES AND PRODUCTS NEEDED:

MAINTENANCE SERVICES:
- Warranty and Out-of Warranty
- Uptower Upkeep (PM)
- Cleaning

CONSTRUCTION SITE:
- Fixtures
- Embed Rings
- Rebar
- Anchor Rods
- Fasteners
- Electrical Cabling
- Transformers
- Tower Wiring
- Lighting
- Substation Equipment
- O&M Building

OFF-SITE SUPPORT:
- Generators
- Gearboxes
- Blades
- Accompanying Repair

MAINTENANCE AND REPAIR PARTS:
- Electrical System Parts
- Electrical Control
- Sensors
- Hydraulic System
- Yaw System
- Rotor Hub
- Mechanical Brake
- Rotor Blades
- Gearbox
- Generator
- Support and Housing
- Drivetrain

Section IV

Meeting OEM Requirements

Meeting OEM Requirements

Wind turbine OEMs are very conservative in their supplier qualification process and have extremely demanding quality requirements. They require consistent and zero defect quality.

When screening prospective suppliers, OEMs look for clear evidence of that core competency. Many require ISO 9001 to begin qualification process and conduct rigorous audits above and beyond to ISO standards prior to placing the first order. Because of these high quality standards, it may take up 18 months from the first contact until receipt of the initial production order.

Driving the need for these high quality standards revolves around the extremely high cost of repair.

Wind turbines are designed for a 20+ year lifespan, operating in harsh environmental conditions usually in remote locations and with the most sensitive components being 300' up in the air. The cost of repairing a nacelle – which must be dismantled on the ground – easily runs upwards of $250K and repair estimates often cost 10 times that of original manufacturing.

TIP

Wind turbine engineering often takes years and requires formal design certification. After designs are certified, changes are rarely permitted. As a result, component production for wind turbine parts is almost always contract manufacturing.

OEM–Supplier builds to print

O&M– Supplier repairs or replaces part.

What is Expected From a New Supplier

Wind Turbine OEMs are Conservative and have Heavy Qualification Requirements

OEMs have very specific expectations when considering a new supplier.

These include:

CONSISTENT QUALITY
- ISO 9001 or Compliant

PRODUCTION CAPABILITIES
- High Mix - Low Volume
- Job Shop < Wind > Auto
- Available Capacity
- Right -Sized
- Expandable

COST COMPETITIVE
- Off-shore Price Points
- Logistic Advantages
- World-Class Operation

RELIABILITY OF DELIVERY
- Equipment Redundancy
- Vendor Redundancy
- Demonstrated Results
- Liquidated Damages

DRIVING FACTORS IN THE WIND INDUSTRY:

- The technical difficulty of the application
- The challenges of performing maintenance
- The high cost of repair

Comparison of Automobile Gearboxes vs. Wind Turbines Gearboxes

	Auto	Wind Turbine
Production per week	4,000 – 6,000 units	4 – 6 units
Typical operation	1 - 2 hours/day	20 – 24 hours/day
Design life	7 – 10 years	20 – 25 years
Where maintenance is performed	Network of garages/ dealers	90 meters in the air in a remote location
Machinery replacement	Performed at ground level by hand & portable equipment	Often requires crane and special transport
Cost of major mechanical repair	$3,000 - $5,000	$300,000 - $500,000

Market Entry Tips

FIND THE BEST FIT

- Original Equipment, Best Tier
- Repair and Maintenance

INVEST IN ROBUST OPERATIONS

- Quality Management Systems
- Multiple processes
- Ultra responsiveness

MARKET YOUR COMPANY

- Identify the buyers
- Differentiate yourself
- Get to the buyers!

TAKE A RUTHLESS APPROACH TO COST REDUCTION

- Focus on LEAN operations
- Think world class

REMEMBER OEM MANUFACTURING REQUIREMENTS

- Capital equipment
- Long-term planning
- Hyper-competitiveness

KEEP IN MIND CHANNEL OPTIONS

- Start at a lower tier
- Team with a partner
- Try component repair

What Successful Companies Have Done

MAKE SMART INVESTMENTS

- Begin at a Lower Tier
- Grow One Customer at a Time

PLAN FOR NEEDED INVESTMENTS

- Process Improvement
- Quality Systems
- Capital

DEVELOP MARKETING STRATEGY

- Identify Target Customers
- Create a Winning WIND “Pitch”
- Launch Cost-Effective Sales Effort

Wind Turbine OEM and Tier One Suppliers in the United States*

OEM COMPANY	US HEADQUARTERS	STATE	WEBSITE
Acciona Energy	West Branch	IA	www.acciona-na.com
American Tower Co.	Shelby	OH	www.amertower.com
Ameron	Rancho Cucamonga	CA	www.ameronwindtowers.com
Broadwind Energy	Naperville	IL	www.bwen.com
Clipper Windpower	Cedar Rapids	IA	www.clipperwind.com
Danotek	Canton	MI	www.danotekmotion.com
DMI Industries	Fargo	ND	www.dmiindustries.com
DMSE/Dewind	Round Rock	TX	www.dewindco.com/eng
Dragon Wind	Lamar	CO	www.modernusa.com/dragonproducts/dragonwind
Fuhrlaender	Bristol	RI	www.fuhrlaender.de/index_en.php
Gamesa	Langhorne	PA	www.gamesacorp.com/en
GE Energy	Atlanta	GA	www.gepower.com
Goldwind	Chicago	IL	www.goldwindglobal.com
Katana Summit	Columbus	NE	www.katana-summit.com
LM Wind Power	Grand Forks	ND	www.lmwindpower.com
Mitsubishi	Newport Beach	CA	www.mpshq.com
Molded Fiber Glass	Ashtabula	OH	www.moldedfiberglass.com
Nordex	Chicago	IL	www.nordex-online.com/en
Nordic Windpower	Berkley	CA	www.nordicwindpower.com
Northern Power Systems	Barre	VT	www.northernpower.com
REpower	Denver	CO	www.repower.de/index.php?id=347&L=1
SIAG Aerisyn	Chattanooga	TN	www.siag.de
Siemens Wind Power	Orlando	FL	www.energy.siemens.com/entry/energy/us
SMI & Hydraulics Inc.	Porter	MN	www.smihyd.com
Suzlon	Chicago	IL	www.suzlon.com
TBailey	Anacortes	WA	www.tbailey.com
Thomas & Betts Corp.	Memphis	TN	www.tnb.com
TowerTech	Oklahoma City	OK	www.towertechinc.com
TPI Composites	Scottsdale	AZ	www.tpicomposites.com
Trinity Structural Towers	Dallas	TX	www.trinitytowers.com
Upwind Solutions	Medford	OR	www.upwindsolutions.com
Vestas	Windsor	CO	www.vestas.com/en

* Only OEMs with utility-scale installations in 2009 are included on this list

For additional information on Supplier Handbooks, contact:

GLWN™ - Global Wind Network

www.glwn.org

4855 West 130th Street, Suite 1, Cleveland, Ohio 44135-5137

mesammon@glwn.org

AWEA - American Wind Energy Association

www.awea.org

1501 M Street NW, Suite 1000, Washington, DC 20005

manufacturing@awea.org

BGAF - BlueGreen Alliance Foundation

www.bgafoundation.org/cemc

2828 University Ave. SE, Suite 200, Minneapolis, MN 55414

lindan@bluegreenalliance.org