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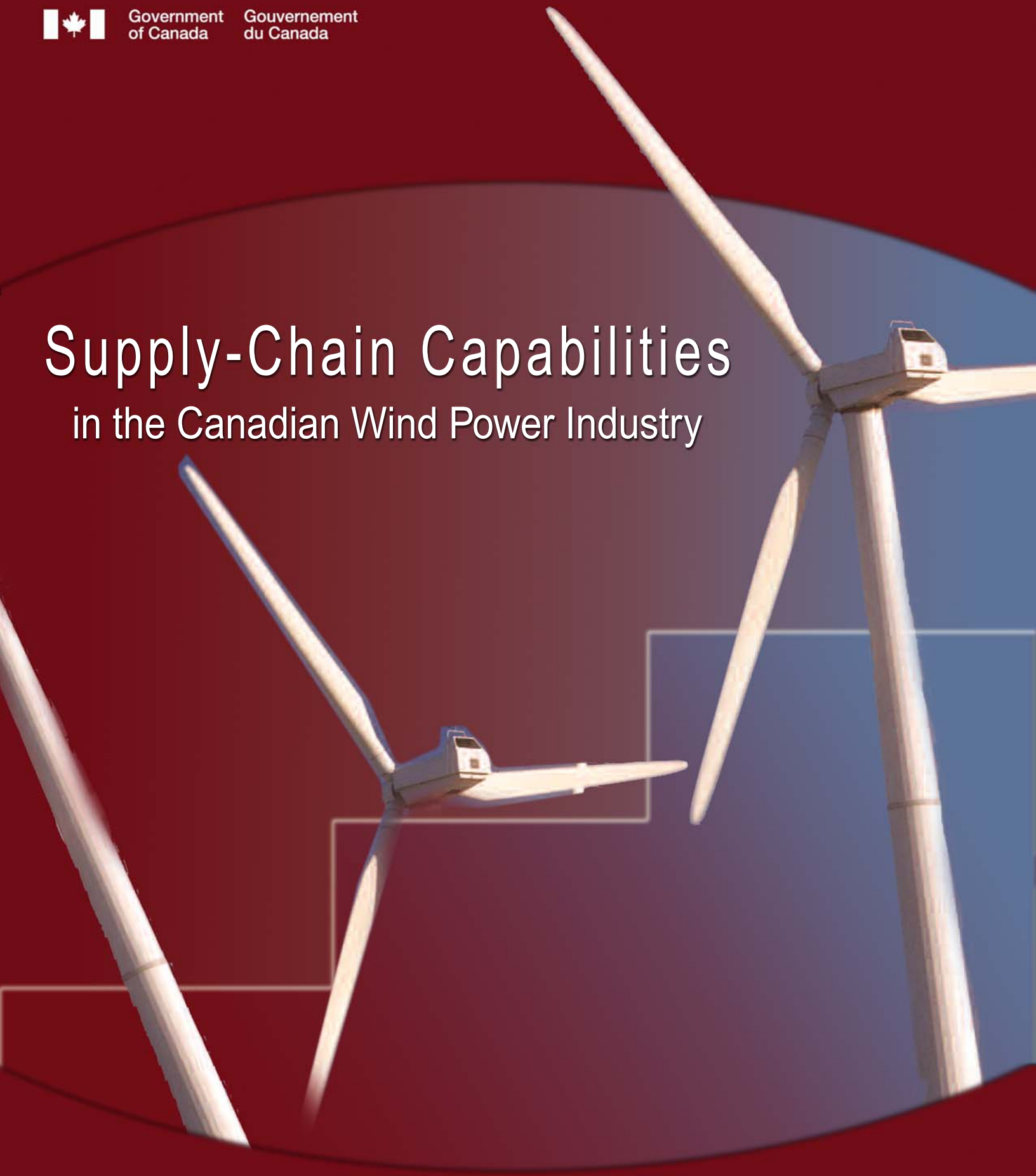
Supply-Chain Capabilities

in the Canadian Wind Power Industry



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Contents

Acronyms and Abbreviations

AEC	Architectural Energy Corporation
AWEA	American Wind Energy Association
AWTS	Atlantic Wind Test Site
CanWEA	Canadian Wind Energy Association
DFIG	Double-fed induction generator
IRAP	Industrial Research Assistance Program
kW	Kilowatt
KWh	Kilowatt hour
MW	Megawatt
NRCan	Natural Resources Canada
OEM	Original equipment manufacturer
PD	Project developer
PEI	Prince Edward Island
PERRL	Pilot Emission Removal, Reduction and Learning Initiative
PTC	Production tax credit
RFP	Request for Proposal
RPS	Renewable Portfolio Standard
THM	Total head mass
WPPI	Wind Power Production Incentive
WTG	Wind turbine generator

1.0 Executive Summary

In large grid-connected wind farms, the wind turbine generator (WTG) represents up to 70 percent of the total capital investment, making it the most important element in the wind energy industry. The value of the cumulative global WTG market over the next five years is approximately US$38 billion, according to Danish BTM Consult ApS. This lucrative opportunity has attracted major global companies such as GE, Shell, Siemens and lately Allianz to the wind energy business.

Modern WTG technologies originated in Denmark and have improved steadily over the past 20 years, making WTGs a commercially proven product. Consequently, wind energy has become very competitive compared with other conventional energy sources. The current mainstream WTG products are characterized by large, variable-speed rotor blades with pitch control. Both gear-driven and direct-drive models are available in WTG drive train configurations. Technological innovation and offshore markets have led to the significant development of multi-MW WTGs, large rotor blades, advanced generators and power electronics. Large WTGs and their components industry require expertise in engineering, manufacturing, logistics, installation and maintenance as well as financial strength.

The Canadian wind energy has been developed gradually over the past three years with a total installed capacity of 439 MW to date. It is forecast that federal and provincial government initiatives currently being considered or implemented could result in a cumulative installed wind power capacity of 5600 MW by the year 2012, representing an investment of C$8.4 billion. Canada currently imports all large WTGs and components with the exception of towers, losing out on the opportunities to generate revenues, taxes and employment. However, Canada has a strong industrial base capable of manufacturing WTGs and most of the components, provided the special expertise could be acquired. The expertise in manufacturing rotor blades, towers, base frames and inverters already exists. In addition, several Canadian companies have been trying to establish a WTG assembly business through licensing or joint ventures with European WTG manufacturers.

This study analyses the supply-chain structure in the life cycle of a wind farm and identifies several potential areas where Canadian companies could provide services. In terms of WTG assembly and component manufacturing, this study identifies both the technical and financial barriers facing potential Canadian suppliers.

It is recommended that Canadian companies concentrate on manufacturing rotor blades, towers, base frames, nacelle covers and spinners, flexible drive shafts, disc brakes, vibration mounts, inverters, control cabinets, and generators. Technology transfer or joint ventures with leading European manufacturers are necessary for Canadian companies to obtain the necessary expertise and overcome the learning curves.

Canadian service companies could generate substantial business in the area of maintenance, repair, overhaul and performance upgrades of WTGs and their components (e.g. gearboxes, generators, hydraulics and rotor blades). It is highly recommended that capable Canadian companies team up with the best European service providers to obtain the required expertise.

A total of 31 foreign and domestic companies participated in interviews for the study. Their feedback provides valuable insights into the supply of WTGs and their components in the global and Canadian markets. Briefly, the interviews showed that leading global WTG manufacturers could be enticed to invest in production facilities in Canada provided there exists a sizable wind energy market supported by stable long-term government policies in favour of renewable energy. However, these leading foreign WTG suppliers will only invest and will not transfer their technologies to Canadian companies.

The potential opportunities for Canadian companies in WTG assembly and component manufacturing rely on forging partnerships with small to medium-sized European WTG and component manufacturers through licensing or joint ventures. Strong support from both federal and provincial governments is essential to nurture the success of Canadian companies. A long-term, well-funded support program is recommended to help:

- the establishment of WTG nacelle assembly and blade manufacturing facilities by the leading global WTG suppliers;
- technology transfer, prototyping and product commercialization by Canadian companies;
- the purchase of capital equipment by Canadian companies;
- training of technicians in WTG manufacturing, component manufacturing and WTG service and repair;
- R&D on a few key WTG components such as rotor blades and power electronics; and
- the upgrading of Canadian WTG testing facilities in Atlantic Wind Test Site (AWTS), Prince Edward Island.

Following the example of the successful establishment of a wind energy industry in Spain, Canada has the opportunity of capturing the benefits of the rapid growth in this sector.

With a coordinated effort by Canadian industries and governments, it is feasible for Canada to achieve annually $1.8 billion Canadian content from manufacturing, installation and service by 2012, providing 13 000 high-quality jobs in Canada.

2.0 Introduction and Background

Wind energy is a significant and powerful resource. It is safe, clean, abundant and almost limitless as a secure energy supply. The wind industry is the world's best opportunity to begin the transition to a global economy based on sustainable energy. The global wind energy industry achieved another record year in 2003 with 8344 MW of new capacity installed, equal to an investment of US$9 billion. The cumulative worldwide installed capacity reached 40 000 MW, providing about 0.5 percent of the world's electricity demand by the end of 2003. Almost 50 countries around the world now contribute to the global total, and the number of people employed by the industry is estimated to be around 100 000.

Wind power is a growing industry in Canada, with numerous industry proposals for expansion on the horizon. To date, Canada has approximately 439 MW installed capacity of wind power. There is a growing interest in understanding how an expanded industry in Canada could contribute to economic development and to opportunities across the full supply chain.

In large, grid-connected wind farms, WTGs represents about 65 to 70 percent of the total investment. The balance of the costs are for land, interconnection, foundations, road construction, installation and development-related services. According to Danish BTM Consult ApS, the value of the cumulative WTG market over the next five years is about US$38 billion. This is an indication of how important WTG manufacturing is within the whole wind energy value chain. Unfortunately, Canada at present has no large WTG manufacturers. All turbine components except towers are imported. Canada's only blade manufacturer went out of business in early 2004 due to lack of orders. All large WTGs installed in Canada were imported; thus most of the revenue, taxes and employment benefits went to foreign countries.

The objectives of this study are to identify the opportunities for maximizing the Canadian content without increasing the cost of electricity from wind and for manufacturing large WTGs, components and services. Specifically this study aims to:

- identify current and potential manufacturing capabilities in Canada;
- suggest actions to attract further investment in manufacturing; and
- identify the regional distribution of opportunities and the potential and emerging markets in Canada that are well positioned to satisfy key Canadian and U.S. markets.

The study was prepared by SYNOVA International Business Development of Milton, Ontario, for the Energy and Marine Branch, Industry Canada, to serve broad interests of Canadian stakeholders in the wind energy industry. The study is built on a previous study entitled "Manufacturing and Service Opportunities for Canadian Companies in Large Turbines" that was prepared by SYNOVA International Business Development for CANMET Energy Technology Centre (CETC), Ottawa, Energy Sector, Department of Natural Resources Canada in September 2002.

In the previous study, SYNOVA examined a total of 17 WTG components and subsystems and the status of leading international players. As a result, five components (rotor blades, towers, base frames, vibration mounts and generators) were identified for further investigation, based on the criteria of low entry barriers, bulkiness of the product and technologies that are currently available in Canada or are easily transferred. In addition, an initial action plan for Canadian government agencies, the Canadian Wind Energy Association (CanWEA) and manufacturing companies was recommended. The previous report emphasized that *timing to the market is of the essence* because this process would take place over the next two or three years. After that, it would be more difficult and expensive to enter the market. It is essential for Canadian suppliers to understand the industry, the technology and the market to develop competitive products and services on time.

Canada has one of the most abundant wind resources in the world. The federal government and several provincial jurisdictions have issued key initiatives, such as the federal Wind Power Production Incentive (WPPI) and provincial Requests for Proposals (RFPs) and Renewable Portfolio Standards (RPS) for new wind power projects to support wind energy development. However, all projects still depend on European or U.S. suppliers for the turbines and key components. There are only a few connections between developers/investors and local manufacturing industries. Canadian manufacturing companies have to rely on foreign suppliers to get work orders for limited components such as towers. Moreover, previous attempts at local turbine assembly do not provide a sustainable model unless long-term programs are implemented, as proven by the two failed operations in Québec.

Despite the difficult situation, several Canadian manufacturers are working on initiatives to manufacture turbines in Canada through technology transfer or joint ventures with European WTG suppliers. Consequently, the local component supply will be an important part of these initiatives.

This study will examine the challenges facing the Canadian manufacturing industry. It will make key recommendations for a coordinated national effort to grow the Canadian supply of key components of large WTGs and to build up a solid supply base for WTGs and sustainable turbine assembly operations in Canada.

3.0 Global Large WTG Manufacturing Industry

3.1 Technologies and Product Development of Large WTGs

Evolution of Large WTG Technology

Modern commercial wind energy started in the early 1980s following the oil crises in the 1970s. Issues of security and diversity of energy supply and long-term sustainability generated interest in renewable energy sources.

Many developments and improvements have taken place since the commercialization of WTG technology in the early 1980s. However, the basic architecture of the mainstream turbine design remains unchanged. The classic "Danish concept" of a three-bladed upwind design, gear-driven with fixed-speed operation and direct grid connection has proven both an engineering and a commercial success in large WTG innovation. Denmark can lay claim to two of the world's leading large WTG suppliers: Vestas and Bonus (Bonus was just bought by Siemens), which have dominated global markets for the past 20 years.

The three-bladed rotor typically has a separate front bearing with a low-speed shaft connected to a gearbox that provides an output speed suitable for a generator. A typical nacelle layout of the modern Danish concept turbine is shown in figure 1.

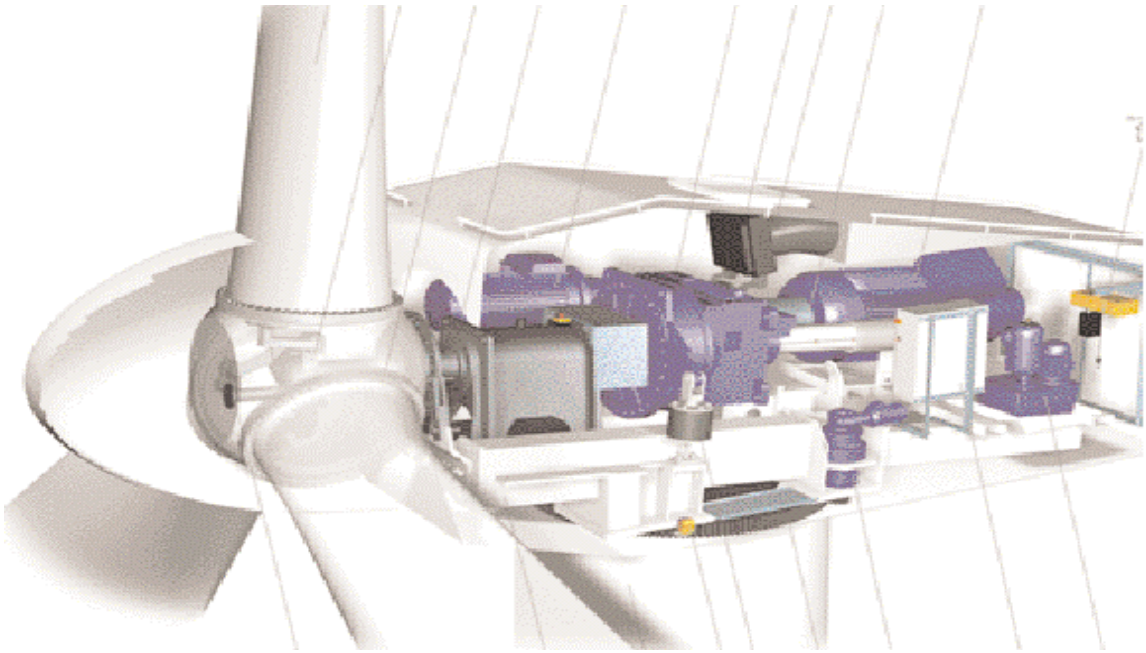


Figure 1. Nacelle layout of the modern Danish concept turbine. *Reprinted by permission of Vestas American Wind Technology, Inc.*

In the early days, the Danish three-bladed, single fixed-speed, stall-regulated turbines dominated the market at rated power levels of less than 200 kW. Blades were almost invariably manufactured from glass-polyester resin.

With the decreasing cost and technological improvements in the reliability of the power electronics, the variable-speed technology has been gaining ground because it offers better quality power output to the grid. Variable speed is therefore used more and more in large turbines, especially in the MW-class segment. Another feature commonly adopted in larger turbines (over 1 MW) is pitch regulation, which has replaced traditional stall regulation in the majority of MW-class turbines. The blade pitch is varied continuously under active control to regulate power at the higher operational wind speeds. This works effectively with variable speed, generates better quality power output than the stall regulation and reduces the loads to which the turbine is exposed.

Since 2003, attention has focused on technology around and above 1.5 MW rated output. The largest commercial turbines have the capacity of 5 MW with rotor diameters greater than 100 m. Epoxy-based systems predominate in blade manufacturing and carbon fibre spar-caps are increasingly used in large blades.

While the classic Danish concept with a gear-driven drive train is adopted by the majority of the leading global turbine suppliers and has continuously dominated the market, the direct-drive (gearless) turbines have made a significant breakthrough. With 6800 direct-drive turbines in operation, Enercon of Germany has proven that gearless turbines are as competitive as the classic Danish turbines that use a gearbox in the drive train. Table 1 shows the evolution of mainstream WTG technologies over the past 25 years:

	Early 1980s (original Danish concept)	**Early 1990s**		**Late 1990s**		**2000–2004**		
Stall regulated	√			√				
Active stall			√					
Fixed speed	√	√	√					
Limited variable speed					√			
Gearbox	√	√	√	√	√	√		
Pitch regulated		√			√	√	√	√
Variable speed				√		√	√	√
Direct drive							√	
“Multibrid”								√

Table 1. Evolution of mainstream WTG technology, 1980–2004

Design Drivers for Modern Large WTGs

Modern wind power technologies have improved steadily over the past 20 years and most of the problems with WTGs in the early days have been solved. Examples include:

- *Reliability:* In large, modern wind farms with proven medium-sized turbines, an operation availability of 98 percent is consistently achieved.
- *Noise:* Today, mechanical and aerodynamic noise has been reduced significantly in large WTGs.
- *Efficiency:* Large WTGs are highly efficient with less than 10 percent thermal loss in their transmission system. The aerodynamic efficiency has gradually risen from a 0.44 coefficient of performance to about 0.5 for the state-of-the-art technologies. The theoretical limit, known as Bets factor, is 0.59.
- *Grid impact:* Variable-speed technology and grid reinforcement have greatly improved grid stability in connection with modern wind farms.
- *Potential for major contribution to a national energy supply:* Wind energy could play a significant role in a national energy supply as proven by a 16 percent penetration level in Denmark and a 5 to 6 percent penetration level in both Germany and Spain.

The large WTG technologies have matured and are commercially proven. The world's leading turbine and component manufacturers are working on further developments of large turbines to meet new challenges in the following areas:

- special configurations for low and high wind speeds;
- grid compatibility;
- acoustic performance;
- aerodynamic performance;
- visual impact;
- weight and cost reduction;
- condition monitoring; and
- wind/energy production forecasting.

The latest developments in WTG technology are driven primarily by the emerging offshore market. These developments focus on the most effective ways to manufacture very large turbines. Specific consideration has been given to:

- low mass nacelle arrangements;
- large rotor technology and advanced composite engineering;
- design for offshore foundations, erection and maintenance;
- installation and maintenance methods; and
- grid connection of large wind farms

Technology Trends of Modern Large WTGs

Growth in WTG Size

The most significant trend in the marketplace is the continuing increase in size of commercial WTGs. The average turbine size supplied worldwide in 2003 was 1211 kW (up from 1087 kW in 2002 and 915 kW in 2001).

Units of 20 to 60 kW, with rotor diameters ranging from 20 to 40 m, appeared in the early wind farms in California of the1980s. The latest multi-MW machines now have rotor diameters over 100 m. The largest machine erected is the 4.5 MW E-112 direct-drive prototype from Enercon. REpower of Germany will be erecting a 5 MW prototype with a rotor diameter of 117 m later this year.

To date, 1.5 to 1.8 MW turbines have been the mainstream products in all major wind energy markets. The most successful products in the market place are:

- GE Energy 1.5s/sl series with more over 2500 units installed worldwide;
- Enercon's E-66 series (1.5 to 2 MW direct-drive) with over 2000 units installed; and
- REpower's MD70/77 (1.5 MW) series with over 500 units erected.

However, a rapidly growing 2 to 3 MW turbine segment is gradually taking over the 1.5 MW-class products. Approximately two dozen 2 to 3 MW turbines from the world's leading suppliers such as Vestas, NEG Micon, GE Energy, Nordex, Gamesa, Bonus, REpower and Enercon are already in series production or late stages of prototype verification. The market has evolved so rapidly that 70 percent of new orders received in 2004 — according to a leading WTG supplier — are for 2.3 MW and 2.5 MW product series. A table of new 2 to 3 MW-class turbine models is attached in Appendix 6.

The growth in machine size has been paralleled by the growth in markets and manufacturers. The German market is the largest in the world, as is the Germany WTG manufacturing industry. It is represented not only by German turbine and component suppliers such as Enercon, REpower, Nordex, DeWind, Fuhrländer, Siemens, Weier Elektromotorenwerk, and Abeking & Rasmussen Winergy (formerly Flender), but also by foreign turbine suppliers such as Vestas and GE Energy with significant manufacturing and engineering facilities in Germany.

The Spanish market has seen notable growth in recent years that has combined efforts in licensing, technology transfer and independent manufacturing (as with Vestas and Gamesa); the development of established turbine manufacturers (such as Ecotècnia and MADE); and the development of the Spanish aerospace industry (MTorres) and integrated developer/manufacturers (EHN).

Development of Variable-Speed Technologies and WTG Generators

The electric generator and power electronics are two of the most important components in modern WTGs. The technical features of the generator and the power-converting devices dictate how WTGs convert wind energy into electricity output and how well WTGs connect to grids.

The percentage of wind energy in the central grid supply is increasing in major wind power countries. Therefore, coping with grid stability demands and avoiding blackouts is becoming a big issue in wind power industry. The German electricity distribution giant — E.ON Netz GmbH — recently announced new binding grid requirements for wind operators. One of the key requirements is that in case of a major grid problem, turbines not only have to remain connected but also have to play an assisting role. This means that WTGs must have a built-in capacity to behave like small power plants. The challenge to comply with grid stability requirements has led leading world suppliers of WTGs to develop new state-of-the-art solutions, especially in generators and power electronics.

Variable-speed technology has distinct advantages over the traditional fixed-speed technology commonly seen throughout the 1990s in turbines that had rated power below 1000 kW. The advantages of variable-speed technology include the possibility for active grid support, the potential to operate WTGs and wind farms as peak power plants, and the prospect of cheaper offshore foundation structures.

To date, the double-fed induction generator (DFIG) continues to dominate the market for variable-speed gear-driven WTGs of 1.5 MW and above. This is because DFIGs provide almost all the benefits of full-range variable-speed drives except that only about one-third of the power passes through the power electronic converter. Thus the power converter with DFIG is approximately one-third the size and cost of a conventional variable-speed drive with fully rated converters. This means DFIGs have a substantial cost advantage compared with conversion of full power usage.

Lately, a few leading WTG suppliers such as GE Energy and MADE have switched to synchronous-type generators for the larger 2 MW+ turbine segment despite the increased system cost. This trend to adapt new grid stability requirements for WTGs means that WTGs must have built-in capacity to support the grids and to remain connected to the grid in case of a voltage dip. Compared with DFIGs, which have only 25 to 30 percent of the power through a frequency converter and have more problematic grid behaviours, synchronous-type generators have 100 percent power through converters and do not suffer from these “built-in” grid-related problems.

Synchronous-type generators have long been a common feature of direct-drive variable-speed WTGs. They have been marketed by Enercon (Germany), Lagerwey (Holland), Zephyros (Holland), Jeumont Industrie (France), MTorres (Spain) and the newcomer Vensys (Germany).

It is worthwhile noting that the 2 MW Z-72 direct-drive turbine from Zephyros is equipped with a 4000 volt permanent magnet generator from ABB, which offers full range of generators

and converters for both gear-driven and gearless WTGs. ABB has production facilities in Canada. In addition, the German industrial giant Siemens is also offering various generator products for the wind energy industry. In particular, Siemens has teamed with the Norwegian company Scanwind of Trondheim to erect a 3 MW variable-speed, pitch control prototype turbine with a Siemens direct-drive permanent magnet-type generator. Siemens, which has production facilities across Canada, has long been eager to supply its direct-drive generators to WTG manufacturers.

The U.S. patent for variable-speed WTG system electronics, awarded originally to Kenetech Windpower in 1993 and now owned by GE Energy, has prevented major European WTG suppliers from selling variable-speed turbines in the growing U.S. market. To circumvent the patent dispute problem, several European suppliers such as Gamesa and Fuhrländer have adapted semi-fixed–speed turbine models using Rotor Current Control (RCC)-type generators for the U.S. market. The technology originates with the German generator manufacturer Weier. Vestas further developed the same technology and renamed it OptiSlip® for the U.S. market. In the latest development, GE Energy and Enercon have settled their long-running patent dispute over the variable-speed technology through a "worldwide cross-licensing deal on a long term basis."

Rotor Blade Development

The rotor blade as well as the generator is a high-profile and high-tech component of the WTG. The design and manufacturing of rotor blades requires special knowledge and expertise in aerodynamics, advanced materials, quality control, modern manufacturing processes and testing. To date, blades with rotor diameters over 100 m are being designed manufactured and tested to meet the needs of large WTG development. LM Glasfiber of Denmark has dominated the independent blade supply market.

Due to the importance of rotor blades in the whole WTG system, several world-leading turbine manufacturers have built up their own blade manufacturing capabilities to secure the supply and to control the technologies for critical components. Vestas, NEG Micon, Enercon, Bonus, Nordex, Gamesa and GE Energy all have their own blade production facilities. In-house blade production is an important part of the vertically integrated strategy employed by these original equipment manufacturers (OEMs). This in return has caused some difficulties for independent rotor blade manufacturers such as LM and NOI; the latter company in Germany has recently become insolvent.

The majority of rotor blades are made from glass polyester or glass epoxy. Although there is some automation involved in the process, it is labour intensive with the procedures still traced back to their boat-building origins. However, new production processes are being implemented. For example, Enercon is changing to vacuum infusion moulding for production. Bonus is also manufacturing blades using glass epoxy with resin infusion technology. NEG Micon's British plant produces wood epoxy blades.

With the need for high-dimensional quality, higher specific strength, improved fatigue properties and reduction of mass for large blades, all established manufacturers have switched from polyester to epoxy-resin infusion and use epoxy-resin–based systems.

For the aerodynamics of the rotor blade, Enercon of German presented a new generation of rotor blades that have achieved an aerodynamic efficiency (Cp) of 56 percent, 6 percent above the current Cp average. Enercon claims that its new blade innovation has improved airflow around the nacelle, resulting in increased energy capture and less sensitivity to turbulence.

Hybrid Systems

Gearbox failure has long been a headache for traditional gear-drive–type WTG manufacturers. The maintenance and overhaul of the gearbox adds extra cost to wind farm operations. Direct-drive turbines save the capital cost of the gearbox, reduce drive train loss and keep the maintenance costs down. However, direct-drive generators (e.g. synchronous-type generators) are much larger. In particular, the large diameter of the generator has led to a much higher total head mass (THM) of the direct-drive turbines. The large and heavy THM in the direct-drive turbines has made it very difficult to install and transport the nacelle.

A "hybrid" configuration has a single-stage gearbox (gearing approximately 6:1) in the drive train, driving a medium-speed multi-pole generator. The goal is to avoid the complexity of a multistage gearbox and to achieve a lower system mass with a more efficient and compact nacelle arrangement than that of the direct-drive turbines.

German consulting firm Aerodyn initially developed the hybrid concept, "Multibrid." The Finnish company WinWind Oy acquired Multibrid technology for up to 1 MW in size and has supplied nine units of 1.1 MW (WWD-1) hybrid turbines since 2001. The WWD-1 turbine has a rotor diameter of 56 m and contains a single stage of planetary gearing (ratio of 5.7:1) coupled with a low speed (40 to 146 rpm) multi-pole permanent magnet generator. The company claims that the high reliability and high energy yield capability of the Multibrid technology has been a success for its 1 MW WWD-1 turbines. At present, WinWind Oy is developing a 3 MW (WWD-3) hybrid prototype with a 90 m rotor. Technically, the hybrid system is a midway solution between the power train with a high-speed generator and the power train with direct drive.

Offshore Technology

Offshore technology is being developed in Europe, mainly because of the lack of good onshore sites. Installation and service costs are substantially higher. By the end of 2003, only 529 MW of capacity was installed in the offshore wind farms, which accounts for a fraction of the world total wind power capacity. However, offshore wind energy is set to grow significantly, especially in Europe. The potential offshore market is the main driving force behind large turbine technology development.

Since the first offshore turbine (450 kW Bonus) was installed in Denmark in 1991, there have been four major turbine suppliers to the offshore market: Vestas, Bonus, NEG Micon and GE Energy. Notably, GE's 3.6 MW and 1.5 MW, Bonus's 2.3 MW, Vestas's 2 MW and 3 MW, and NEG Micon's 2 MW have been installed during the past four years. The commercially available turbines for offshore application are at 2 MW capacity and above and have a higher tip speed and built-in handling equipment (e.g. cranes) in the nacelle.

In North America, there is no shortage of excellent offshore sites, though major offshore projects will probably not start before 2010. In Canada, Lake Erie could be an excellent location for the first offshore project. With its shallow waters and densely populated shoreline, it would answer the need for clean energy. The east coast could be a second suitable site, especially because it could provide opportunities for Canadian suppliers to provide blades and towers from nearby sites.

To have both a low cost and reliable electricity supply, suppliers to offshore wind farms have to solve logistical problems involving the manufacture, transport, erection and maintenance of offshore multi-MW turbines. In commercial-scale offshore wind farms, logistics will involve integrated dockyard assembly facilities and special-purpose installation barges. For rotor blades over 50 m in length, direct access to the sea from the manufacturing plant is highly desirable. Some manufacturers provide helipads on the nacelle of the turbines to increase access for maintenance engineers.

Although offshore wind farms offer much better wind conditions and a large scale in terms of wind power capacity, the higher costs of installation and maintenance are the ultimate challenge. These higher costs will force suppliers and contractors to work on optimal designs and equipment solutions for WTG foundations, grid connections, turbine erection, reliability and maintenance.

In a feasibility study conducted by European Union Commission, a price level of €850 per kW could be achieved in a modern large-scale offshore wind farm, although an extra 10 percent of the turbine cost was added for the special safety, maintenance and access needs of offshore WTGs.

3.2 Leading Global WTG and Component Manufacturers

Large WTG Manufacturers

In 2003, the world's eight leading large WTG manufacturers supplied approximately 89 percent of the global market. At the same time, several small and medium-sized European suppliers have made progress in penetrating a few regional markets through technology transfer or joint ventures.

The WTG manufacturing industry is characterized by industry consolidation in the leading supplier group, diversified product supply by technology innovators and low-cost manufacturing in the emerging markets.

By analyzing the existing turbine and component suppliers, interested Canadian companies will find their position in future "supply-chains" for the large WTG manufacturers.

Vestas Wind Systems A/S, Denmark

The Vestas group, including former NEG Micon, is the largest wind turbine manufacturer in the world, operating in more than 40 countries on 6 continents. It had a combined market share of 32 percent in 2003 and expects to achieve revenues of €2.6 billion in 2004. The principle activities of the Vestas group are development, manufacturing, marketing, sales and maintenance of large wind turbines. Vestas is not involved in wind farm development, financing and ownership but does provide guidelines. To date, the Vestas group offers turbines with capacities ranging from 660 kW to 4.2 MW for both onshore and offshore applications. Manufacturing in Vestas group is vertically integrated with in-house production of most of the key wind turbine components and turbine assembly in Denmark, Germany, Spain, Italy, India and Scotland. In addition, Vestas announced plans to set up an assembly and blade manufacturing operation in Australia. Components purchased externally by Vestas are supplied primarily by large suppliers with a good international reputation. The company's policy is to maintain two or more suppliers for each component.

The Vestas group has been very successful in the Canadian market with turbines ranging from 660 kW to 3 MW installed in Québec, Ontario, Alberta, Saskatchewan, the Yukon and Prince Edward Island. Total capacity is approximately 290 MW. Along with the recent high growth in the wind energy sector, Canada would offer great potential for the Vestas group to establish production facilities to supply the North American market.

GE Energy, United States

With 1503 MW installed worldwide during 2003, GE Energy has climbed to second place in large wind turbine supply in less than the two years. This has been since it acquired the manufacturing assets of the former Enron Wind, with technologies and products that originated with two pioneers of wind power, Zond Systems Inc. of the United States and Tacke Windtechnik GmbH and Co. KG of Germany. To date, GE Energy manufactures turbines from 1.5 to 3.6 MW and rotor blades in the United States. In addition, GE Energy is sourcing blades in Germany (Aberking und Rasmussen), Brazil (Tecsis), United States (LM and MFG) and Denmark (LM).

It is noteworthy that the GE 1.5s/sl (1.5 MW) turbine is one of the most successful products in the wind energy industry with more than 2500 units installed worldwide since the first TW1.5 MW prototype was erected by Tacke Windtechnik GmbH eight years ago. GE Energy has to rely on its 1.5s/sl turbine for most of its business until development is completed for its GE 2.X (2.3 MW, 2.5 MW, 2.7 MW) series product and GE 3.6 MW for offshore application.

GE Energy holds the patent for variable-speed wind turbine system electronics that originated from former Kenetech Windpower. The patent has prevented most of the European variable-speed turbine manufacturers from entering the U.S. market. Enercon of Germany resolved the patent dispute with GE Energy recently. In the latest development of power electronics, GE Energy introduced "Low voltage ride-thru" (LVRT) technology to enable its new turbines to meet grid transmission standards similar to those demanded of thermal generators. GE Energy started to supply its 1.5 MW turbines to Canada this year and has won the bid to supply the first 990 MW wind energy project in Québec.

Enercon GmbH, Germany

Enercon is the third-largest wind turbine manufacturer in the world and the largest direct-drive, variable-speed turbine supplier with products from 300 kW to 4.5 MW in unit rated power. Since its founding in 1984, Enercon has developed high-tech, three-bladed, variable-speed, direct-drive turbines and has installed more than 6900 units with a cumulative capacity of over 6000 MW globally. Enercon has production facilities in Germany, Sweden, Brazil, India and Turkey with the highest percentage of in-house component manufacturing in the industry. To date, Enercon has installed three E-112 (4.5 MW) turbines, the largest wind turbines in the world.

Enercon installed one E-40 (600 kW) turbine in Alberta in 2002 and is considering developing the Canadian market in the near future.

Gamesa Eólica, Spain

Gamesa Eólica is the premier wind turbine supplier in Spain and the fourth-largest manufacturer in the world. Started as a joint venture with Vestas in the 1990s, Gamesa Eólica has developed its own extensive manufacturing, design and product development capabilities for wind turbines and rotor blades. Currently, Gamesa Eólica has 15 manufacturing facilities and offers a range of products from 660 kW to 2 MW. Apart from Spain, Gamesa Eólica has supplied turbines to the United States, Italy, France, Japan, China and Latin America.

Gamesa Eólica is part of the Spanish Gamesa group, which also owns wind farm developer Gamesa Energia, wind turbine service provider Gamesa Servicios and aeroplane manufacturer Gamesa Aeronautica. Gamesa Eólica often works with its sister companies to deliver turnkey projects, including wind farm development and service. In 2003, Gamesa Eólica acquired another Spanish wind turbine manufacturer, MADE Energias Renovables, from Spanish utility Endesa. The combined group has a global market share of 15 percent and great growth potential because of the large wind farm project pipeline of Endesa.

On September 23, 2004, the Gamesa group announced that the company will locate its North American headquarters and East Coast development office in Philadelphia. In addition, Gamesa plans to build a turbine manufacturing facility in Pennsylvania. Gamesa has a total of

2000 MW wind energy projects under development in the United States, including a recently signed 600 MW contract in Pennsylvania.

Bonus Energy A/S, Denmark (just bought by Siemens)

Bonus Energy is one of the wind turbine pioneers from Denmark. Since 1979, Bonus has installed over 5500 turbines around the world. The Bonus turbines are highly reliable and efficient. The company is known for its outstanding track record, solid financial status and very conservative business strategy. Bonus manufactures its own rotor blades.

Bonus is one of the few large wind turbine manufacturers that so far have stayed with its proven two-speed technology in combination with its active-stall type (CombiStall®) output control. Bonus has recently become a dominant supplier of offshore wind farm projects in Denmark: 10 Bonus 2.3 MW turbines were installed in the Samsø project and 72 Bonus 2.2 MW in the Nysted project during 2003.

Bonus has not supplied any turbines in Canada.

REpower Systems AG, Germany

REpower was founded in 2001 by five small Germany companies: pro+pro Energiesysteme GmbH & Co. KG, Jacobs Energie GmbH, Denker & Wulf AG, BWU-Brandenburgische und Umwelttechnologien GmbH, and BWU-Anlagenfertigung-service GmbH. Its headquarters are located in Hamburg. The company employs a staff of about 490 and operates internationally through its subsidiaries or joint ventures in Greece, France, Italy, Spain, Australia, Canada and the United Kingdom. The company is one of the fastest growing turbine manufacturers with sales of €300 million in 2003, up from just €50 million in 1999.

REpower offers turbines from 600 kW to 2 MW and is planning to erect a 5 MW prototype for the offshore market this year. Its MD70/77 1.5 MW, gear-driven, variable-speed turbine is one of the most successful products in the market with over 760 units erected by REpower and its licensees around the world. The latest products are the MM70 and MM82, 2 MW turbines with high efficiency.

REpower is a vertically low integrated turbine manufacturer and sources most of the turbine components externally. In addition, REpower is in the turbine licensing business, licensing its products to companies in Germany, France, Japan and China. REpower's international development strategy is to enter a new market with a strong local partner through either a joint venture or licensing.

In Canada, REpower has a joint venture — REpower Wind Corp., a Canadian consortium in Sudbury, Ontario.

Nordex AG, Germany

Nordex AG is a publicly traded German company and one of the leaders in large wind turbine manufacturing. With 60 percent of the products for export, Nordex is an aggressive supplier to international wind energy markets. The company employs about 700 staff, has offices and subsidiaries in 17 countries, and achieved revenues of €250 million during its 2003/2004 fiscal year.

Nordex offers turbine types from the traditional stall-regulated N43/600 to one of the world largest series MW class turbine N80 (2.5 MW). The company has installed about 2475 turbines worldwide as of September 2004. Süwind, another German wind turbine manufacturer, is part of Nordex AG.

During the past two years, Nordex experienced some operational problems, including substantial loss and massive write-offs in some of its development costs, inventory and other capital expenditures. The company is implementing a major restructuring plan.

In Canada, Nordex supplied 20 units of its 1.3 MW turbines in Alberta in 2001.

Ecotècnia S.C.C.L, Spain

Ecotècnia is one of the wind energy pioneers in Spain, entering the wind energy sector in 1981. The company currently designs and manufactures wind turbines ranging from 640 kW to 1.67 MW. Ecotècnia has three production facilities in Spain with an annual capacity of 500 MW and employs about 260 people. It is also involved in the development of turnkey projects.

Ecotècnia is famous for its modular design in the drive train of wind turbines. Its turbines are designed to suit Spain's mountainous topography. It has excellent track records for its products dating back to its 225 kW turbines installed in the early 1990s. Lately, Ecotècnia has developed 1.67 MW variable-speed turbines with rotor diameters of 74 m and 80 m. Its novel modular design enables easier transport logistics in complex terrain.

In 1999, Ecotècnia became part of Mondragon Corporacion Cooperativa (MCC), which has €6 billion in revenues and employs 53 000 people around the world. Ecotècnia's main activities continue in Spain, but the company has installed turbines in Japan, India and Cuba. Ecotècnia had some business contacts with the Québec government in 2000 but decided not to enter the immature Canadian market.

Small and Medium-Sized WTG Manufacturers and Engineering Companies

Fuhrländer GmbH, Germany

Fuhrländer is a small to medium-sized wind turbine manufacturer in Germany. The company has made significant efforts to increase its share in the large German onshore market and a few overseas markets, including Japan and China, during recent years. Fuhrländer purchased the onshore wind energy activities of another Germany wind turbine manufacturer — Pfleiderer — in early 2004. It also formed a joint venture with Pfleiderer, focusing on wind turbine manufacturing and service. The combined product portfolio contains turbines with rated power of 30 kW, 100 kW, 250 kW, 800 kW, 1 MW and 1.5 MW. In addition, Fuhrländer also manufactures MD70/77 1.5 MW turbines under a license from REpower. At the present, Fuhrländer is developing a new 2.3 to 2.7 MW range prototype under a license from Wind to Energy GmbH.

In Canada, Fuhrländer has a partner, AAER Systems Inc. based in Montréal. AAER Systems Inc. has announced a plan to manufacture Fuhrländer's turbines in Quebec and supply the products to the North American market.

Lagerwey the Windmaster, Netherlands

Lagerwey is a pioneer in the direct-drive wind turbine segment with early success through its 250 kW turbine and later with its 750 kW turbine during the 1990s. The company has undergone a restructuring after running into serious financial troubles in recent years. The main product of Lagerwey is the LW 50/52/58 series 750 kW turbine with direct-drive generator, active pitch and variable-speed control.

Lagerwey was involved in a new direct-drive 2 MW turbine development with ABB and LM in recent years. The first LW72 – Zephyros 2 MW prototype has been operational since March 2002. This initiative has led to the creation of a new company Zephyros, based in Amsterdam, which focuses on developing and marketing Z-72 2 MW turbine for both onshore and offshore markets.

Lagerwey erected a LW52 turbine at Exhibition Place in Toronto in 2002 and another one in Alberta in 2003. Lagerwey has granted a license for its 750 kW turbine to Americas Wind Energy (AWE) based in Toronto.

Jeumont Industrie S.A

Jeumont Industrie developed a direct-drive 750 kW (J48/J53) turbine but only a limited number of these turbines have been erected since 1999. The French company is engaged in developing a new 1.5 to 2 MW J70/77 direct-drive turbine series with variable-speed and pitch-control technology.

In Canada, a consortium of Quebec companies bought a license for the J48 750 kW from Jeumont in 2001. The consortium assembled three J48 turbines and erected them in the Gaspé area of Quebec in 2003.

WinWind Oy, Finland

WinWind Oy is a small Finnish turbine manufacturer that acquired the rights to develop and market "Multibrid"-type wind turbines based on the technology developed by Aerodyn Energiesysteme of Germany. The company has successfully supplied nine 1 MW WWD-1 turbines and has several WWD-1 under construction for projects in Portugal, France and Finland.

WinWind Oy plans to install a 3 MW WWD-3 prototype "Multibrid" type turbine before the end of 2004.

Vensys Energiesysteme GmbH, Germany

Vensys is a small German wind turbine design and manufacturing company that developed an innovative direct-drive 1.2 MW turbine, Vensys 62, with a permanent magnet generator. One V62 prototype was erected in May 2002. However, the machine caught fire and burned down in November 2003. The prototype has since been replaced and is said to run well. In addition, Vensys is developing a larger 2 MW direct-drive turbine.

Vensys has a license agreement for the V62 with the premier local turbine manufacturer in China, Gold Wind Science & Technology Corp.

Wind to Energy (W2E) GmbH, Germany

W2E is a new wind turbine design firm founded by a group of ex-Nordex engineers in May 2003. The lattice tower builder Seeba Energiesysteme and turbine manufacturer Fuhrländer are equity partners of W2E and have financed the initial turbine development work.

W2E has developed a new variable-speed, pitch-controlled turbine series, W90, with rated power of 2.3 MW, 2.5 MW and 2.7 MW suitable for different wind regimes. W2E currently licenses its W90 to Fuhrländer GmbH and the two companies are working together to erect the first 2.5 MW prototype by the end of 2004.

World Leading Manufacturers of Wind Turbine Components

Rotor blades

LM Glasfiber A/S is the world's largest independent blade manufacturer and has supplied over 67 000 rotor blades since 1978. The company has production facilities in Denmark, Germany, Spain, United States, India, Holland and China and employs about 3100 people. LM has the industry's largest specialised blade engineering staff and manufacturing capacity, in-house mould building, process development and blade testing facilities. The company supplies blades from 13.5 m in length for 250 kW turbines up to 44.8 m for 3 MW turbines. At present, LM is developing blades of 54 m and 61.5 m in length with fiberglass and carbon-reinforced epoxy composite materials for the next generation of multi-megawatt turbines. LM's work with REpower for a 5 MW prototype turbine is a good example.

NOI Rotortechnik is a German blade manufacturer with production facilities in Germany, Holland and Scotland.

Euros GmbH is a German design and manufacturing company of rotor blades for WTGs from 600 kW to 5 MW. Euros was the licensor of the EU51 blade to Bolwell Corp. in Ontario (750 kW). These blades are used for the Lagerwey 750 kW and Zond 750 kW turbines.

Umoe Group is a Norwegian company with extensive experience in making large load-bearing structures in advanced composites. Umoe has started blade manufacturing for wind turbines and can fabricate 70 to 77 m diameter rotor blades using a vacuum injection process in glass/epoxy materials. The company delivered its first set of UM70-type blades to REpower in February 2003 and started series production in the same year.

Gearboxes

Hansen Transmission of Belgium is a world leader in the design and manufacturing of high-quality gear units for wind turbines. The company is making investments in a new production facility to meet increasing demand in the market. The German insurance company Allianz has recently purchased Hansen Transmission for €132 million. Hansen opened its new facilities in March 2004 with a capacity for 2000 MW at a cost of €101 million. Sales in 2003 were €127 million.

Metso Drives Technology of Finland is a leading global supplier of technology, systems and equipment for the wind energy industry. The company has supplied its gearboxes to many wind turbine manufacturers, including its fellow Finnish turbine manufacturer WinWind Oy for the WWD series "Multibrid" turbines.

Winergy AG (formerly Flender) is one of the world's largest power transmission manufacturers. More than 20 000 wind turbines are operating with Winergy's gearboxes. The company has a state-of-the-art assembly plant with 40 000 m^2 of manufacturing space and facilities for testing up to 8000 kW electrical units.

Generators and electronic components

Weier Elektromotrenwerk GmbH and **Winergy AG** of Germany and **Elin EGB Motoren GmbH** of Austria are the world's leading suppliers of wind turbine generators and power transmission systems.

The multinational industrial conglomerates **ABB** and **Siemens** are two major manufacturers of generators and other electronic components (transformers, substations, etc.) for the wind energy industry.

Towers, hubs and base frames

Bladt Industry A/S, DS SM A/S and **Erik Roug A/S** are three major tower manufacturers from Denmark for major Danish and German wind turbine manufacturers. **DS SM A/S** and **Erik Roug A/S** have supplied towers for Nysted and Middelgrunden offshore projects with Bonus turbines.

KGW Schweriner Maschinenbau GmbH, **Omnical Borsig Energy GmbH** and **Pfleiderer AG** are major tower manufacturers from Germany.

Valmont Wind Energy is a U.S.-based tower manufacturer, part of Valmont Industries Inc. The company has introduced an innovative tower design that includes a "self-erecting" device.

Other components

FAG OEM and Handel AG is a German supplier for bearings for main shaft, blade pitch and yaw systems in wind turbines. FAG has manufacturing facilities in Stratford, Ontario.

MITA Teknik A/S of Denmark is a leading supplier of control and monitoring systems for wind turbines.

KK Electronic A/S of Denmark is a controller manufacturer for major wind turbine manufacturers.

Manufacturas Eléctricas S.A. is a Spanish manufacturer of high- and medium-voltage equipment for wind power plants.

SKF of Sweden is the world's largest manufacturer of bearings. The company also supplies bearings used in wind turbines. SKF has a sales and service subsidiary in Canada.

Skoda Steel of the Czech Republic is one of the biggest global suppliers of main wind turbine shafts, maintaining about 30 to 40 percent of the global market share. The company manages

the complete manufacturing cycle, including steel production, ingot making, forging, finish-machining and surface treatment. Skoda Steel also supplies bedplates and hubs for wind turbines.

Windcast A/S of Denmark is one of the world's leading suppliers of advanced and high-quality casting components for wind turbines. The company was acquired by Vestas in 2003.

Svendborg Brakes of Denmark is a manufacturer of hydraulic disc brake systems, electronic brake controllers and hydraulic power packs. The company has manufacturing facilities in Denmark, Germany and Spain. Wind turbines are major applications for Svendborg Brakes' products along with equipment for the mining industry.

3.3 Supply-Chain Structures for Grid-Connected Wind Farms

The supply chain for the life cycle of a wind farm consists of the following phases:

- planning phase: duration, 1 to 3 years;
- construction phase: duration, 1 year;
- generating phase: duration. 20 to 25 years.

Appendix 2 provides the cost structure for a generic 30 MW wind farm.

Planning Phase

The planning phase of a wind farm typically is led by a project developer who performs some of the tasks himself and subcontracts the rest to consulting and engineering firms. As the project progresses to the point where a power purchase agreement can be negotiated, the project developer either sells the project or partners with a financing company.

The planning phase normally includes the following activities:

Activity	Performed by
Identify suitable site for a wind farm……	Project developer (PD)
Wind resource assessment……... – Installation/removal of met-tower with sensors and data logger (1–2 years)…… – Data retrieval…… – Preparation of long-term wind assessment (wind study using data obtained and reference data)……	PD or consultant PD or subcontractor PD PD or consultant
Preparation of feasibility study……... – Community consultation……...	PD or consultant PD

Activity	Performed by
– Obtain all costs and schedules for the construction and generating phase……..	PD or consultant
– Soil test for foundations……	Consultant
– Wind farm design…….	PD or consultant
– Infrastructure design (e.g. roads)……..	Engineering company
– Interconnection design……..	Engineering company
– Power generation permit……...	PD or consultant
– Building permit…….	PD or consultant
– Due diligence……	Engineering company
– Land survey…….	Surveyor or engineering co.
– Legal work: power purchase, interconnection, land lease, financing, supply contracts……..	Specialized law firm
– Green Tag certification and sales……..	PD, certifying agency
– EcoLogo generation and AEC certification……..	PD, certifying agency
– WPPI application and contracting…….	PD
– Environmental assessment application (provincial and federal)……..	PD or consultant
– Bird and wildlife studies……...	Biologist

Table 2. Activities and responsibilities in planning phase

Construction Phase

There are two distinct market segments for large WTGs (600 kW or more): large wind farms (10 MW or more) and small wind farms (10 MW or less).

Large Wind Farms (10 MW or more)

Power purchasers, typically large utilities and financial institutions, prefer to enter into turnkey construction agreements with one of the dominating global turbine manufacturers shown in table 3.

Manufacturers	Global market share (2003)
Vestas (Denmark)	21.7%
GE Wind (U.S.)	18%
Enercon (Germany)	14.6%
Gamesa (Spain)	11.5%
NEG Micon (Denmark)	10.2%
Bonus (Denmark)	6.6%
REpower (Germany)	3.5%
Nordex (Germany)	2.9%

Source: Bjoern Johnsen, "Wo die neuen Maerkte sind", Sun Media, issue 5, May 2004, page 4, http://www.erneuerbareenergien.de/0504/s_31-34.pdf

Table 3. Global turbine manufacturers

In 2004, Vestas and NEG Micon merged under the Vestas name. Further consolidation of the industry seems logical as larger and larger wind farms are being developed in the on- and offshore markets. These developments will restrict all but a few companies capable of strong finance, engineering and manufacturing in a global environment.

The situation in the North American market is further restricted by a patent for variable-speed turbines using inverters, which was initially filed by Kenetech and is now owned by GE Energy. So far, only Enercon has settled its patent dispute with GE Energy and is now in the position to enter the North American market.

As a result, Vestas, GE Energy and Gamesa are the leading companies bidding on large projects. However, it can be expected that Enercon will enter the North American market soon. The remaining companies will either have to settle the patent dispute with GE Energy or find technical solutions to avoid the patent disputes.

For these reasons, this study will concentrate on the four major companies supplying the MW -sized turbine that will most likely dominate the Canadian and U.S. wind energy market in the short term.

The activities and responsibilities during the construction phase of large wind farms are shown in table 4:

Activity	Performed by
Construction project management……..	Project owners
Construction of turnkey wind farm…….	WTG manufacturer
WTG supply: – Nacelle…….. – Towers, blades……..	 WTG manufacturer WTG manufacturer or subcontractor
Infrastructure, access roads, excavation, trenches for power cables, foundations…….	Local subcontractor
Transportation…….	Subcontractor
Craning……	Subcontractor
Installation and commissioning……..	WTG manufacturer
Interconnection, step-up transformer at each WTG…	WTG or electric engineering company
Collection system…… – Substation……. – Interconnection at transfer station……. – Pole line…… – Insurance……..	Electric engineering company Electric engineering company Electric engineering company Electric engineering company Arranged by WTG manufacturer

Table 4. Activities and responsibilities in construction phase of large wind farms

Small Wind Farms (10 MW or less)

This market segment is being served by a number of small to medium-sized WTG companies. It seems that the major turbine companies are concentrating their efforts on MW turbines for large wind farms while small projects such as community-based wind farms are being served by smaller companies offering turbines from 600 to 1500 kW. In Canada, the following companies have installed turbines for small wind farms:

Jeumont (France/Québec)	750 kW
Lagerwey / AWE (Holland/Ontario)	750 kW
Nordex (Germany)	1.2 MW, 1.5 MW
Turbowind (Belgium)	600 kW
Tacke (Germany)	600 kW

Additional companies are known to have an interest in the Canadian market:

Fuhrländer /AAER (Germany/Quebec)	1.5 MW
Vensys (Germany)	1.2 MW
Win Wind (Finland)	1 MW
REpower (Germany)	750 kW, 1.5 MW, 2 MW
Suzlon (India)	950 kW, 1/1.25 MW
DeWind (Germany)	950 kW

Bonus (Denmark) 1.3 MW, 2/2.3 MW

As of October 2004, a total of 439 MW of wind power capacity were installed in Canada. Broken down by province, the capacities are shown in table 5:

Province	Installed capacity (MW)
Alberta	269
Quebec	113
Saskatchewan	22
Ontario	15
PEI	14
Nova Scotia	5
Yukon	1
Total	**439**

Table 5. Installed wind capacity in Canada, by province

For small wind farms, the construction contracts are typically broken down into about five packages and contracted directly by the owner. Typically these packages would be as shown in table 6:

Activity	Performed by
Nacelle and rotor blades	WTG manufacturer
Tower, build to print	Tower manufacturer
Foundation, build to print	Construction company
Access road excavation	Construction company
Interconnection (from turbine to transfer point including substation)	Electric engineering company
Transportation and craning	Transportation and craning company
Installation and commissioning	WTG manufacturer or subcontractor
Insurance	Arranged by insurance broker

Table 6. Activities and responsibilities in construction phase of small wind farms

The turbine manufacturer is the design authority for the entire turbine from the foundation to the blades. This is similar to the aerospace industry. The manufacturers design the integrated

system and obtain a certification from national certification bodies, such as Risø in Denmark and Germanischer Lloyd in Germany.

A number of the major turbine manufacturers are vertically integrated, designing and manufacturing critical components such as rotor blades, controls and towers themselves. For other components, such as gearboxes, generators and couplings, the turbine company provides the design loads and specifications, while the detailed design and certification work is performed by the component manufacturer.

It is important for potential Canadian manufacturers to know who in the supply chain owns the design for a specific component and whether their potential customer is the turbine manufacturer, the subsystem supplier or the wind farm owner.

Generating Phase

For large wind farms, so-called "worry-free" maintenance contracts are typically awarded to the WTG manufacturers for up to five years. After this period, independent service companies specialized in blade repair, oil change, periodic maintenance and component repair will have an opportunity take over the service. These companies typically have a lower overhead cost than large WTG manufacturers and focus on WTG service only. Some owners are known to have set up their own service departments as well. Component repair for blades, generators and gearboxes provide good opportunities for Canadian companies, since lower shipping costs and shorter turnaround times are attractive to North American WTG owners. Activities and responsibilities are generally as shown in table 7:

Activity	Performed by
Operation management…….	Owner
Scheduled and unscheduled maintenance – first 2–5 years…….. – after 2–5 years…….	 WTG manufacturer WTG manufacturer or independent service companies
Main component inspection, repair, overhaul – rotor blades, gearboxes, generators……..	Original equipment manufacturer or independent service company
Upgrade to: – increase generation…….. – solve problems…….	 Engineering/service companies WTG manufacturer

Table 7. Activities and responsibilities in generating phase

4.0 Large WTG Supply and Service in Canada

4.1 Large WTG Supply

In 1995, the first large (600 kW) WTG was installed in Tiverton, Ontario, with financial support from Natural Resources Canada (NRCan). The turbine was modified for cold weather operation. Four years later, the first two wind farms were installed in Québec, featuring a total of one hundred and thirty-six 750 kW turbines. These turbines were assembled in Québec; as well, the towers were partially manufactured there. Vestas began to dominate the market in the year 2000 when it installed V47 600/660 kW turbines. So far, 235 units of the V47 have been installed in Canada. The nacelles, including blades, were imported from Denmark, while most of the towers were manufactured in Canada and the United States. For details on WTGs operating in Canada, please see Appendix 1.

The first modern megawatt-size turbines arrived in Canada in 2001. Vestas has installed a total of fifty-two V80 (1.8 MW) turbines so far. All components, including the towers, were imported from Denmark. In 2003, Vestas installed a prototype of the V90 model, a 3 MW turbine, at the Atlantic Wind Test Site in Prince Edward Island. To date, this is the largest WTG in North America. In addition to these high-profile installations, a number of European companies such as Tacke (600 kW), Lagerwey (750 kW), Nordex (Germany, 1.3 MW), Turbowind (Belgium, 600 kW), Jeumont (France, 750 kW) and Enercon (Germany, 600 kW) installed a small number of turbines in Canada.

Of all the turbines installed in Canada, only the one hundred and thirty-three NEG Micon 750 kW turbines and the three Jeumont 750 kW turbines were assembled in Canada. These assembly operations were closed down once the orders had been filled.

In Canada, the outlook for the assembly of large WTGs and their components is bright, but not assuredly so. Federal government programs such as Wind Power Production Incentive (WPPI); Pilot Emission Removal, Reduction and Learning (PERRL) initiative of Environment Canada and the Purchase of Green Power by the federal government have provided some stimulation to the wind energy market. However, this will not lead to a long-term breakthrough unless accompanied by long-term federal and provincial programs such as the extension of the WPPI and Renewable Portfolio Standards (RPS). These programs facilitate the development of a market of sufficient size to support domestic wind energy manufacturing activities.

4.2 Component Manufacturing

Component manufacturing in Canada has been limited to towers, blades and inverters. Towers were manufactured by a number of metal fabricators in Quebec, Ontario, Saskatchewan and Alberta using conventional equipment at hand.

Blades for WTGs from 25 to 1.5 MW were manufactured by Bolwell Corporation in Ontario from 1994 to 2003 using advanced resin-infusion technology. All but 2 of a total of 250 sets of blades were exported to Europe and the United States. Increased shipping costs for larger blades, exchange rate risk and most of all, the lack of a stable home market led to the closure of Bolwell Corporation operations in early 2004.

Xantrex, a Vancouver-based company, supplied inverters to GE Energy for the 1.5 MW turbines in 2003. However, GE Energy may supply its own inverters in an attempt to increase its vertical integration.

Major investment for state-of-the-art automation equipment was not justifiable due to the lack of long-term contracts. Similar conditions prevail in the United States where the Production Tax Credit typically lasted for one to two years, interspersed with being discontinued for 12–15 months. Private companies cannot and will not invest in manufacturing equipment under such conditions.

Consequently, the nacelles, rotor blades and in some cases, even the towers were imported mainly from Europe despite high shipping costs. This left just the infrastructure work such as access roads, the foundations, craning, and the interconnection work for Canadian companies.

4.3 Service Industry

At present, there is no independent wind turbine service company established in Canada. Older wind farms such as the Cowley Ridge wind farm in Alberta and the Le Nordais wind farm in Quebec are maintained by their owners, with varying degrees of success. The newer installations have been maintained by the original equipment manufacturer (OEM), Vestas in the majority of cases.

Each wind farm has to be managed and serviced by a local service team of mechanical and electrical/electronic technicians. Periodic maintenance is carried out in spring and autumn. In addition, unscheduled service such as troubleshooting, components exchange and repair have to be provided immediately after a breakdown. Specialized technicians, who move from one wind farm to another, carry out blade inspection and repair. Component overhaul is typically done off-site in specialized workshops.

The service of large WTGs has become a lucrative business in Europe. In most cases, the OEM provides turbine servicing during the first two to five years while WTGs are still under warranty. After this period, some wind farm operators opt to perform their own service or subcontract the service to independent service companies. These service companies typically have lower overheads, specialize in service only and are quite capable of providing

competitive service. In addition to companies providing scheduled and unscheduled maintenance and services, there will be opportunities for companies to perform the following:

- rotor blade inspection, repair and overhaul services (after 10 years of operation);
- main component overhaul and repair, such as gearboxes, generators and hydraulics; and
- retro-fitting of upgrades, such as oil-filtration systems, condition monitoring and performance improvements.

4.4 Recent Initiatives in Establishing a Canadian WTG Manufacturing Base

Development of the wind energy project has been very fragmented across Canada because each province and developer has different goals and strategies. There is no national strategy to support the establishment of local wind turbine manufacturing industries. In addition, there are very few connections among wind farm developers, investors, and local Canadian manufacturing industries. The only exception is the first 1000 MW Request for Proposal issued by Hydro-Québec in 2003. This RFP requires up to 60 percent local content and specifies the locations in Quebec (Gaspésie region) for turbine assembly.

Despite the roadblocks, several Canadian companies have tried to set up facilities to assemble large WTGs or to manufacture components through technology transfer (licensing) or joint ventures with European WTG suppliers. Table 8 gives a brief summary of recent Canadian initiatives:

Region	Canadian company	Technology Provider	Status
Nova Scotia	Turbowinds Canada	Turbowinds Belgium	One prototype installed (imported)
Ontario	REpower Wind Corp. and Northland Power	REpower AG, Germany 750 kW and 1.5 MW	Manufacturing in Sudbury was announced in 2003 (no manufacturing activities yet)
	Northland Power	Vensys, Germany 1.2 MW direct drive	Company plans to install one prototype in Sudbury
	Americas Wind Energy Inc.	Lagerwey, Holland 750 kW	Two turbines installed (imported); plans to set up assembly operation
Québec	GEQ (Groupement éolien québécois)	Jeumont Industries, France 750 kW/J48 direct drive	Three turbines assembled and installed in 2003; operation was closed
	AAER systems Inc.	Fuhrländer-Pleiderer AG, Germany; turbines from 600 kW to 1.5 MW	Licence agreement signed; plan for the first prototype in Quebec by 2005
	TM4 Inc. (generator manufacturer)	Own permanent magnet generator technology	In discussion with several leading WTG OEM for partnerships

Table 8. Recent initiatives of manufacturing large WTGs in Canada

With high entry barriers for large turbine manufacturing and little support from developers and investors, new entrants find it extremely difficult to compete in a Canadian market that is dominated by world leaders such as Vestas and GE Energy.

5.0 Opportunities and Barriers facing Canadian Companies

5.1 Forecast for Canadian and U.S. Wind Energy Development

Various reports—such as the 2004 BTM report from the globally recognized Danish wind energy forecaster BTM Consult ApS, and information from CanWEA—were consulted to prepare a realistic forecast. Whereas the wind energy industry has matured in Europe, and predictions can be based on long-term government legislation, the same measure cannot be used as a predictor for North America. Based on our assumptions (listed below and drawn largely from initiatives proposed or implemented by federal and provincial governments), we foresee that about 5600 MW (cumulative) of wind power capacity will be installed in Canada by the year 2012 with total investments of $8.4 billion (see tables 9 and 10).

Province	Cumulative forecasted installed capacity (MW) 12/2004	Forecast 2005–2012								Cumulative installed capacity by end of 2012
	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total
Nfld/Labrador	0	30	15	15	10	10	10	10	10	**110**
PEI	14	5	10	10	10	0	0	15	15	**79**
New Brunswick	0	10	15	15	15	15	15	15	15	**115**
Nova Scotia	10	20	10	10	10	10	10	15	15	**110**
Quebec	113	150	150	150	300	300	300	350	350	**2163**
Ontario	15	100	150	150	150	200	200	200	200	**1365**
Manitoba	0	50	75	75	75	75	75	75	100	**600**
Saskatchewan	22	18	20	20	20	20	20	25	25	**190**
Alberta	269	60	60	60	60	60	60	70	70	**769**
BC	0	0	10	15	15	15	15	20	30	**120**
Yukon	1	0	1	0	1	0	1	0	1	**5**
NWT	0	0	1	0	1	0	0	0	0	**2**
Nunavut	0	0	0	1	0	0	1	0	0	**2**
MW/Year	**444**	**443**	**517**	**521**	**667**	**705**	**722**	**795**	**831**	**5645**
MW cumulative	**444**	**887**	**1404**	**1925**	**2592**	**3297**	**4019**	**4814**	**5645**	

Table 9. Forecast for wind energy development in Canada

Forecast 2005–2012									
	2004 (cumulative)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Total revenue									
Investment Canada (millions)	$666	$665	$776	$782	$1001	$1058	$1083	$1193	$1247
Operation (millions)	$19	$45	$70	$101	$126	$155	$190	$213	$250
Exports (millions)	$50	$23	$60	$120	$180	$225	$270	$300	$300
Total revenue (millions)	**$735**	**$733**	**$906**	**$1003**	**$1307**	**$1438**	**$1543**	**$1653**	**$1797**
Employment in person-years									
Employment, manufacturing, installation	4662	4652	5429	5470	7003	7403	7581	8346	8726
Employment, operation	190	398	646	910	1173	1454	1735	2011	2293
Employment export	50	150	400	800	1200	1500	1800	2000	2000
Total employment	**4902**	**5252**	**6529**	**7280**	**9463**	**10 453**	**11 281**	**12 476**	**13 226**

Source: SYNOVA International Business Development, 2004

Table 10. Forecast revenue and employment in wind energy sector in Canada

The forecast for Canada is based on the following assumptions:

- Operation costs include scheduled/unscheduled maintenance, repair reserves, insurance, monitoring and administration, and land lease. It has been assumed that for every C$100 000 in operation costs, one person-year job will be created. The annual operating costs have been calculated using 4.25 percent of the ex-works cost of a WTG and using C$1 million per MW ex-works.
- As per the American Wind Energy Association (AWEA) data, 10.5 person-years are required for the manufacturing and installation of one MW.
- For jobs to be created for the export of components:
  - one person-year will be created for every C$150 000 in sales; and
  - 10 percent of U.S. sales will come from Canadian component export, equivalent to one person-year per MW installed in the United States.
- The installed cost is estimated at $1.5 million per MW.
- The federal and provincial governments will proceed swiftly with the implementation of the Kyoto Accord and the previously mentioned commitments to achieve emission reductions.
- Oil prices will stay above US$35 per barrel.
- The WPPI program is extended to 4000 MW at 1 cent per kilowatt hour.

- International and domestic greenhouse gas emission trading is implemented by the governments.
- All provinces, especially Ontario, Quebec and Manitoba, stand by their commitments regarding the use of renewable energy.

In contrast to our projections, the forecast for Canada from the BTM report *(World Market Update 2003)* is substantially lower, as shown in table 11. (The forecast for the United States was used to calculate the export opportunities.)

Province	Cumulative installed capacity (MW) by end of 2003	Installed capacity (MW) in 2003	Forecast 2004–2008 (including offshore)					Installed capacity (MW) between 2004-2008	Cumulative installed capacity by end of 2008
	2003	2003	2004	2005	2006	2007	2008	Sum	Accum.
Canada	351	81	150	200	200	250	250	1050	1401
United States	6361	1687	700	1200	1500	2000	2000	7400	13 761
Other Americas	193	50	100	100	200	300	300	1000	1193
MW/Year	**6905**	**1818**	**950**	**1500**	**1900**	**2550**	**2550**	**9450**	**16 355**

Source: World Market Update 2003, BTM Consult ApS

Table 11. Forecast for the Americas

Based on SYNOVA's forecast, the annual wind power installation could reach 831 MW by 2012. Assuming Canadian content of 60 percent of the WTG manufacturing and installation and 100 percent of the wind farm service and export can be achieved, the following annual benefits can be created by 2012:

Activity	Canadian content	Jobs
WTG manufacturing and installation	$748 million	8726
Operation, including maintenance and overhaul	$250 million	2300
Exports	$300 million	2000
Total	$1298 million	13 026

Table 12. Annual benefits to Canada by 2012

5.2 Technical Barriers Facing Canadian Companies

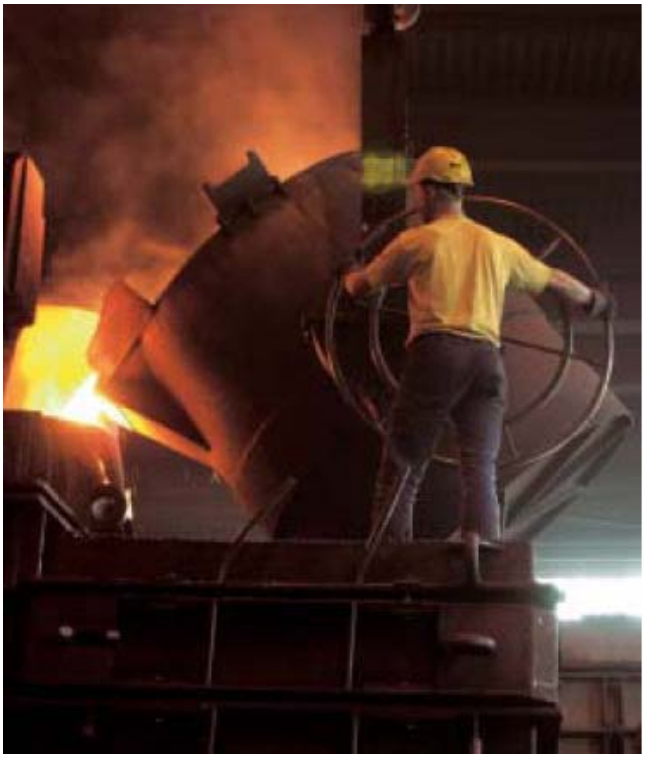
Large modern wind turbines have been developed in Europe over the last 20 years. The wind power technologies have been improved continuously and expertise in design, engineering, manufacturing, installation and operation has accumulated over the years through R&D and learning from failures and test results. The rapid growth in turbine size and in some cases lack of sufficient time allocated for testing could result in major technical problems. These problems could then in turn lead to financial difficulties for any newcomers in the wind turbine manufacturing industry.

European WTG companies, component manufacturers, research institutes, certification authorities and insurance companies' test labs have worked in close partnerships to solve many of the technical problems in wind turbine manufacturing, problems such as:

- gearbox failures;
- rotor blade failures;
- generator failures;
- power quality issues;
- corrosion problems; and
- noise.

In terms of component supply, large WTG manufacturers such as GE Energy and Vestas have established a global procurement network, sourcing rotor blades and base frames in countries as far away as Brazil and sourcing towers in Korea. Global WTG companies will consider quality issues, exchange rates, freight costs, lead time, import duties, local content requirements and capacity utilization for their own production facilities when making procurement decisions.

Vestas, for example, acquired Windcast Group A/S, the world's leading die-casting supplier, in 2003 to make sure it has the capacity and knowledge to develop and deliver high-quality die-cast components such as blade hubs and machine foundations. The takeover of Windcast is a strategic move by Vestas so that die-casting components will not become a bottleneck for the growing market. Figures 2 and 3 show examples of die-casting component manufacturing.



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Figures 2 and 3: Die-cast component manufacturing

The technical barriers facing Canadian manufacturers are characterized as:

- lack of expertise in design, engineering and testing of modern large wind turbines; Canadians have to rely on foreign suppliers for large wind turbine products;
- difficulty in finding foreign turbine technology licensors willing to transfer competitive technologies to Canada;
- lack of expertise in the design, engineering and manufacture of specific components such as gearboxes, large bearings, electronic control systems, wind turbine generators, yaw systems and hydraulic systems;
- lack of manufacturing capabilities for large die-castings and automation in metal fabrication;
- shortage of experienced engineers/technicians in wind turbine assembly and component manufacturing;
- lack of test facilities for large wind turbines and their components; and
- low productivity due to lack of automation and suitable material handling equipment.

5.3 Financial Barriers Facing Canadian Companies

Most of the potential Canadian WTG and component manufacturers whom we interviewed expressed their concern about the uncertainty of the Canadian wind energy market. Without

the certainty of a 300 to 600 MW annual production of wind power for a minimum of three years, manufacturers cannot justify investing millions of dollars. Even after the certainty has been achieved, manufacturers in Canada will face additional financial barriers.

European suppliers are extremely competitive due to their high level of automation and well-trained labour force. The difficulty facing Canadian manufacturers can best be explained using the learning curve experienced by the aerospace industry. The following is an example of the labour-intensive rotor blade manufacturing process.

It takes a crew of well-trained and experienced workers about 800 hours to complete one rotor blade for a 1.5 MW wind turbine. The prototype typically takes three times longer or 2400 hours. Using a learning curve coefficient of 86 percent for this type of work, the required hours are reduced to 86 percent of the time when the number of blades doubles (see table 13).

Number of blades	Person hours
1	2400
2	1064
4	1775
8	1527
16	1313
32	1129
64	970
128	835
>200	800

Table 13. Person hours to manufacture rotor blades

This example demonstrates the challenge that a new Canadian blade manufacturer will face in a competitive global market. In addition, foreign competitors may have already written off the costs of their equipment and do not have to include the amortization in their cost. To overcome the start-up barriers and be successful, Canadian manufacturers will require substantial financial support.

For large rotor blade manufacturing, the investment in automation, material handling equipment, training and technical assistance, qualification tests, and production facilities could cost up to C$10 million. Conventional financial institutions are not prepared to finance start-up companies in a new industry sector such as WTG manufacturing.

With the increased size of wind farms, the financial demands on turbine and component manufacturers are escalating. When large utilities and energy companies in the United States, such as FPL Energy, Shell Wind Energy and American Electric Power, invest in large-scale

wind farms, they demand that equipment suppliers back up the warranty and performances guarantees financially. Only a few leading turbine manufacturers such as GE Energy, Vestas, Gamesa, Bonus, Enercon and Mitsubishi are considered as suppliers for large projects. The same measures apply to Canada where investors, insurance companies and developers demand proven products and technologies and financial strength when selecting suppliers for large-scale wind farm projects.

For Canadian companies new to the industry, the financial barriers are difficult to overcome. It will take years of product development, prototyping, testing and certifying before a new supplier is accepted by project developers and investors. In addition, a new supplier must face severe competition from the global leaders with their proven products and economies of scale in production.

For Canadian manufacturers to compete in the market with quality products, the governments need to step in to provide financial support for the early stage of product commercialization and assist Canadian companies in overcoming the learning curve. In addition, venture capital firms need to be encouraged to invest in the manufacturing of new innovative products such as large wind turbines and their components.

5.4 Key Components and Services Recommended for Canadian Supply

The overall objective aims to maximize Canadian content in large wind turbine manufacturing to the extent that the overall cost for wind electricity is not increased. To achieve this goal, issues such as freight costs for large components, technical entry barriers and the existing strengths and weaknesses of the Canadian manufacturing base will be considered.

Component manufacturing opportunities for Canadian companies will depend primarily on the establishment of a stable domestic market for large wind turbines. Once the critical mass of 300 kW to 600 MW annual capacity has been achieved, and government support mechanisms for the manufacturing of large WTG components are in place, a substantial new industry could be established similar to the wind energy industry development in Spain. Emerging opportunities can be grouped as follows:

- *Components for the nacelle assembly:* A domestic market of 600 MW per year should allow for the establishment of two assembly operations in Canada.
- *Components for subsystems:* Subsystem suppliers, such as gearbox and generator manufacturers, will have opportunities to supply components.
- *Rotor blades and towers:* These large components are difficult and expensive to ship. The shipping cost from Europe to North America can increase the landed cost for rotor blades by as much as 20 percent. In addition, freight rates have increased drastically due to higher fuel costs and a shortage in freight capacity.

The following assumptions are used to quantify the opportunities (see tables 9 and 10):

- Canada's annual installed capacity reaches 443 MW by 2005, 667 MW by 2008 and 831 MW by 2012.
- Two major WTG manufacturers set up assembly operations in Canada within the next two years.
- Canadian governments implement policies and provide incentives for wind energy as well as for manufacturing. These policies and incentives are as effective as those in place in countries like Germany, Spain, Italy, Portugal, France and the United Kingdom.

Components and Subsystems Recommended for Manufacturing in Canada

Large WTG components with high shipping costs from Europe:

- tower manufacturing including supply of plates with gauges of 12–35 mm
- rotor blades, including supply of core material
- nacelle covers and spinners (FRP)
- main rotor shafts
- base frames and main bearing housing, machining only, since Canada no longer has the capability to supply large iron castings.

Other mechanical components:

- flexible drive shafts (technology transfer required)
- disc brakes
- vibration mounts (technology transfer required).

Quite a few Canadian metal fabricators have experience in manufacturing components for turbines installed in Canada from Vestas, NEG Micon, Nordex, Largerwey and GE Energy.

Other electrical components and assemblies:

- inverters (Xantrex of Vancouver is a leader in inverter technology for WTG)
- large batteries storage system for load sharing and back-up power supply using Vanadium Redox-Flow Battery (VRB of Vancouver has commercialized this technology and is offering it)
- control cabinets, using off-the-shelf components
- generators.

Components with High Entry Barriers

Table 14 summarizes the barriers to manufacturing certain components:

Components	Reasons
Large gearboxes	Technology does not exist any longer in Canada
Large bearings	Technology does not exist in Canada
Hydraulic systems	Volume too small to justify investment
Yaw drives	Highly competitive product; volume too small
Control systems	No expertise in Canada; market too small

Table 14. Components with high entry barriers

The above components are not recommended for manufacturing by Canadian companies unless foreign suppliers are willing to set up production facilities in Canada.

Service Opportunities

Service opportunities for WTGs will occur over time. The WTG supplier will typically obtain a service contract for the first two to five years of operation. Local service technicians will be hired and trained. After the initial period, independent companies have an opportunity to bid for service contracts. The opportunities can be grouped into the following categories:

- WTG maintenance and repair of turbines; mechanical and electrical/electronic service;
- blade maintenance, repair and overhaul;
- component overhaul and repair of gearboxes, generators and hydraulics; and
- reliability, safety and performance upgrades (requiring a specialized engineer base with the possibility of being very lucrative).

It is also highly recommended that interested Canadian companies team up with the best European service providers to transfer the expertise developed over the last 10 years.

Export opportunities may occur. However, these will be limited to special service providers, such as blade repair, component overhaul and upgrades.

5.5 Export Opportunities for Canadian Suppliers

Once a domestic market with a manufacturing base has been established, export opportunities — primarily to the United States — will develop. However, it is important to note that most

European component manufacturers will establish only one North America facility. Provided that Canada moves swiftly and proceeds with the implementation of a comprehensive support plan, a substantial export market can be developed.

Export opportunities, especially to the United States, will be developed once the domestic market has reached a sustainable critical mass and component suppliers are well established. In addition, a highly trained workforce and a high degree of automation for manufacturing will be required to become competitive.

Supply of large components will be restricted to geographic areas close to the United States, such as the Eastern seaboard for offshore projects and within 800 km of the U.S. border. One special interest will be the U.S. Midwest because of its excellent wind resource and vast areas of suitable sites for wind farms. Shipping by barge through the St. Lawrence Seaway to Saint Paul, Minnesota, may be a way of reducing freight costs from Quebec and Ontario to the U.S. Midwest.

For all other components that can be shipped in a container, the shipping cost in North America is insignificant. Competitiveness through automation and superior quality and service will be the most important issue. The North American market as a whole may support only one or two component suppliers for the same item. It is therefore of the utmost importance to "get out of the gate" before the United States implements a long-term (three-year) Production Tax Credit. The current tax credit stops by the end of 2005.

Once European companies are engaged in component manufacturing in Canada through direct investments, joint ventures or licensing, they will engage in supplying the U.S. market to fully utilize their Canadian facilities.

5.6 Potential Canadian Suppliers to Enter the Large WTG Manufacturing Industry

This study has identified a number of Canadian companies as potential suppliers to WTG assembly and component manufacturing. However, we believe that more companies will be interested in participating as they become more aware of the opportunities in manufacturing WTGs. A complete list of potential candidates is provided in Appendix 4. The potential Canadian suppliers are identified in table 15.

Activity	Potential Canadian suppliers
WTG assembly	REpower (Canada) America Wind Energy Ltd AAER Systems Inc. Irving Oil
Tower manufacturing	Hitachi (Canada) Industries Ltd. Marman Inc. Irving Oil Metal World Maxfield Inc. Algoma Steel Fabspec Tri-Voigt
Inverter manufacturing	Xantrex Technology Inc.
Blade manufacturing	Composotech Inc.
Generator manufacturing	TM4 Inc
Gearbox manufacturing	Metso Drives (Ontario)
Electric cabinet manufacturing	Powerhouse Controls
Welding equipment supply	ESAB Automation (Canada
Oil monitoring equipment manufacturing	GasTops
Couplings	Ontario Drive and Gear

Table 15. Potential Canadian suppliers

6.0 Competitive Advantages and Disadvantages for Canadian Companies

As the leading global WTG manufacturers will supply the majority of the large wind farms in North America, we have to understand their decision-making process. They will consider purchasing components only from proven suppliers at the lowest price including transportation.

Flexibility, short lead times, ISO 9000 accreditation, financial strength and proximity to the assembly operation are some of their considerations.

Loaded labour rates in Canada are substantially lower than in Denmark or Germany and comparable with the United States at the current exchange rate. However, without a high level of automation, Canadian companies will be unable to compete with well-established foreign suppliers.

To overcome the disadvantage of an inexperienced labour force and low productivity due to outdated or semi-manual equipment, Canadian suppliers have to benchmark with the European leading suppliers and focus on the following:

- understanding the price structure at the current market;
- setting targets for labour and material costs that are needed to undercut foreign competition;
- implementing quality systems required by their customers (ISO 9000, Six Sigma);
- investing in automation;
- acquiring manufacturing technologies through technology transfer or licensing;
- training.

6.1 Canadian Industrial Base to Supply Large WTGs

Canada's industrial clusters are located mainly in Montreal, Toronto and the Kitchener/ Waterloo/Cambridge/Guelph areas. Most basic capabilities for machining and processing are in place and can be adapted for the manufacturing of large WTG components.

Certain capabilities such as producing large-sized castings, bearings and gearboxes no longer exist in Canada. It may not be economically viable to re-establish them just for WTG component manufacturing. The global economy demands competitiveness and value-added advantages. This is already the case in the tower manufacturing industry, where a Canadian company imported flanges for the tower sections from Skoda, a leading flange manufacturer located in the Czech Republic.

Competition from U.S. companies can be expected once the United States has established a long-term market for WTGs. It is difficult to predict when this will take place; however, it will present the ultimate challenge.

Assuming that Canadian companies have a lead of two years to establish their capabilities, they will be in a position to pre-empt the U.S. companies and establish themselves as reliable suppliers to leading WTG manufacturers.

6.2 Turbine Component Manufacturing and Service in Canada

Component manufacturing for large WTGs is part of "heavy" industry. It requires material handling equipment and large machining centres. The most basic capabilities for turbine component processing and manufacturing (except for large castings, gearboxes and turbine generators) exist in several Canadian industrial centres. The manufacturing process for some components may require several companies to work together because one component may move through 5 to 10 specialized shops during its manufacturing process.

Some components such as the rotor blade, nacelle and spinner, the tower, and the base frame do not require a large processing and subcontractor base and therefore can be set up outside of industrial centres.

To date, a few Canadian companies have accumulated expertise in:

- tower and base frame manufacturing;
- rotor blade manufacturing;
- nacelle assembly; and
- electric inverters.

Currently, there are no independent wind turbine service companies in Canada. However, turbine service over the lifetime of a turbine (20–25 years) provides excellent opportunities for Canadian companies involved in similar service work, using the most efficient equipment such as platforms instead of cranes and acquiring "best practices" from the leading service companies in Europe.

7.0 Industry Survey Results

Questionnaires were prepared for the following wind energy industry groups:

- foreign wind turbine manufacturers;
- Canadian wind turbine manufacturers, current and potential;
- foreign wind turbine component manufacturers;
- Canadian wind turbine component manufacturers, current and potential; and
- Canadian service providers.

In addition to the companies classified above, other groups provided their input. The companies contacted responded quite positively and showed great interest in learning more about the emerging Canadian wind energy market. However, all participants want proof that there is a long-term market for products and services before investments will be made. The questionnaire can be found in Appendix 3 of this study.

7.1 Wind Turbine Manufacturers

Introduction

Of the seven foreign manufacturers, six answered the questionnaire. Currently, the only company assembling WTGs in North America is GE Energy with operations in Tehachapi, California, and Pensacola, Florida.

Hydro-Québec has recently selected two project developers to install up to 660 turbines (1.5 MW) from GE Energy from 2006 to 2012 for its first 990 MW wind energy project. In order to fulfill the local content requirements, GE Energy is committed to setting up a nacelle assembly operation and component manufacturing in the Gaspésie/Matane region of Quebec. Furthermore, Hydro-Québec is preparing a RFP for another 1000 MW. Additional assembly plants may be set up in Ontario or in Western Canada within the next one to two years in response to the current and future demands for WTGs in these regions.

Depending on the outcome of the 300 MW RFP in Ontario and subsequent RFPs and/or provincial legislation, Vestas may establish a manufacturing base in Ontario.

Another large WTG manufacturer, Enercon of Germany, has recently settled a patent dispute with GE Energy and may look seriously at Canada to assemble its turbines for the North American market. Most of the smaller European WTG manufacturers, like REpower (Germany), Ecotècnia (Spain), Fuhrländer (Germany), DeWind (Germany) and Suzlon (India), have been reluctant to enter the North American market because of a potential patent dispute with GE Wind regarding variable-speed WTG technology.

With the softening of the European market, these companies are known to be working on technical solutions to avoid the threat of patent litigation by GE Wind.

In the past, Canada had two WTG assembly operations. In 1999, one hundred and thirty-three NEG Micon 750 kW turbines were assembled, and in 2002/2003 three Jeumont 750 kW turbines were assembled in Quebec. After the orders were completed, the operations were shut down. As mentioned in the previous section, it can be expected that one or two foreign WTG manufacturers will set up assembly operations in the underdeveloped regions of Gaspésie/Matane. The longevity of these operations will depend on long-term orders.

Furthermore, there is an opportunity for a well-financed Canadian industrial conglomerate to enter into a joint venture with a European WTG company or to obtain a license. REpower, Fuhrländer / W2E and Vensys have indicated that they are prepared to enter into a joint venture or license its products.

Foreign Wind Turbine Manufacturers

Six foreign large wind turbine manufacturers answered the questionnaire. The results are summarized below:

- World leading WTG suppliers tend to invest in local assembly facilities on their own. They are more vertically integrated and do not license their technologies. Some key components such as rotor blades, control systems and generators would not be outsourced. On the other hand, they are willing to work with established international component manufacturers who are willing to relocate in Canada.
- Most small and medium-sized European suppliers are prepared to license their technologies or form joint ventures with Canadian companies in order to get quick and low-risk market access. Canadian industrial equipment manufacturers are favoured joint venture partners. In addition, small European WTG manufacturers are prepared to source most of the components locally, which is favourable to establishing Canadian component supplier base.
- The order requirement for establishing a Canadian assembly operation varies among different foreign suppliers. It ranges from 50 to 300 MW per year for a minimum of three to five years. The bigger the company, the larger the minimum required order size. Realistically, a minimum 150 MW per year over a three to five year period could attract a leading supplier to set up a local nacelle assembly plant.
- Long-term and stable federal and provincial policies to support wind energy are essential for European suppliers to set up local assemblies or joint ventures in Canada. A growing green energy and greenhouse gas emission trading market would also helpful to attract European investors.
- Ideal locations for establishing turbine assembly facilities will be places convenient for turbine (nacelle and blades) transport: places close to harbours, railways and roads with good infrastructure and easy access to a skilled labour force. Government incentives, similar to the tax credit and loan guarantees provided to the aerospace and automotive industries, are important for investments in turbine manufacturing facilities.

- Compared with the United States, Canada has advantages in terms of positive trade, a stable fiscal environment, a competitive labour force and a resemblance to the European mentality. On the other hand, the Canadian market for wind energy is much smaller than in the United States; this also holds true for the WTG supply chain in Canada. Foreign exchange risk is always a concern in supplying the United States from Canada.
- Depending on market conditions and the order(s) received from the current RFPs in Quebec and Ontario, these European suppliers could make a decision regarding a Canadian turbine assembly facility within next 6 to 12 months.

Canadian Wind Turbine Manufacturers

There is currently no wind turbine manufacturing operation in Canada. As described in Section 4, a few Canadian companies have taken the initiative in recent years to transfer turbine technologies from Europe based on licensing or joint ventures. The interviews conducted in this category aimed to identify potential opportunities for Canadian manufacturers for turbine assembly and further product development areas. This pragmatic approach is based on technology transfer (licensing or joint venture) from small and medium-sized European wind turbine manufacturers. Five Canadian companies answered the questionnaires.

- To date, three Canadian companies have entered licensing agreements with European turbine manufacturers. Two of them have erected demonstration turbines (below 1000 kW rated power) in Canada. However, none of them is in a position to compete with world leaders for large projects in the Canadian market due to small product size and/or limited financial resources.
- As a result of the limited types of MW-class turbines available for licensing from European companies in the current market place, Canadian manufacturers have very few choices. This limits the product offering to customers and makes it difficult to compete with multinational leaders in large projects. The only opportunities are small projects (less than 10 MW) or demonstration projects.
- Canadian companies are very confident about manufacturing capabilities in Canada. With the exception of a few key components (e.g. direct-drive, variable-speed generators; gearboxes and turbine control systems) Canadian companies have managed to source the majority of the components (including 750 kW rotor blades) in Canada. The advantages of sourcing in Canada are competitive manufacturing costs, reduced transportation costs and fast service to local customers.
- Canadian manufacturers support mandatory local content requirements for turbines installed in Canada in order to secure a share of large projects. At the same time, they are eager to export their products to the U.S. market.
- Among several potential government incentives to support wind energy, Canadian manufacturers focus on funding of R&D, commercialization, building/testing prototypes, investment in technology transfer and manufacturing facilities, and training and technology transfer to overcome the learning curve. Funding requests cited for the assembly of a demonstration turbine are between C$2 million and C$4 million.

- Ideally, Canadian manufacturers like to secure a large order to produce turbines in order to justify the large up-front capital investment for the manufacturing facility. However, under current market conditions, it is not possible to get an order without successful references and proven products, not to mention financial strength. Therefore, new Canadian entrants in the large turbine manufacturing business are facing the challenge of overcoming a vicious cycle.

7.2 WTG Component Manufacturers

Due to the lack of nacelle assembly operations and local content requirements in North America, European WTG component manufacturers did not see the need for production in the United States or Canada. Exceptions are limited by the LM's blade manufacturing operation in North Dakota and Winergy's gearbox overhaul and assembly in the United States. European component manufacturing companies are aware of the emerging wind energy market in the United States and Canada. They have learned from their experience in Spain that they need to produce in the region once the market reaches a certain size. Most European component manufacturers prefer to operate in Canada rather than the United States because they feel more at home in Canada. At the same time, their main focus will be on supplying the U.S. market.

Foreign WTG Component Manufacturers

Eight foreign WTG components manufacturers replied to the questionnaire. Their products include gearboxes, generators, vibration dampeners/isolation mounts, rotor blades, towers and automation equipment for towers, couplings, torque limiters and bearings.

Large components such as towers and rotor blades are preferably manufactured locally due to cost savings for transportation and the fact that these components make up a high percentage of the value of WTGs. Small components such as vibration dampeners and bearings are difficult to manufacture locally due to the lack of economies of scale to justify the investment and because they make up a relatively small percentage of the value of WTGs.

- Tower manufacturing has been subcontracted to Canadian companies in most of Canada's previous projects. However, the business is very competitive and Canadian manufacturers do not have the state-of-the-art automated equipment to be competitive in price and quality against foreign manufacturers. A tower manufacturer would need annual orders of 150 towers to invest heavily in state-of-the-art automation equipment. For example, it will cost US$5.2 million to install an automated production line (including plate cutting, roller, welding) for towers. In addition, storage of steel supply is an issue for tower manufacturing.
- Similar to tower manufacturing, the base frame, rotor hub and main bearing housing could be machined by some tower manufacturer. These are low-value-added components that are subcontracted to local machine shops or fabricators. The industry is highly competitive.
- The rotor blade is a high-value-added component in WTGs. Canada has experience in blade manufacturing. However, most of the rotor blades installed in Canada were supplied from Europe with the exception of two 750 kW Lagerwey turbines. This is because most

of the leading WTG manufacturers having their own blade manufacturing plants and do not purchase blades externally. In addition, the largest independent rotor blade manufacturer — LM Glasfiber A/S — has established a factory in North Dakota and will compete with any Canadian supplier in the future. The opportunities left to potential Canadian supplier(s) might be in the niche markets and service industry. There are 650 units of old 750 kW Zond turbines operating in the United States that need replacement blades or service. The small and medium-sized European WTG manufacturers may soon sell their products in North America and will need to purchase blades externally.

- The local content requirements included in the Hydro-Québec's 1000 MW RFP may lead to the establishment of a blade manufacturing plant in the Gaspésie/Matane region. GE Energy could ask its current supplier(s) to set up blade manufacturing facility in the region.
- It will require minimum sales of $2.8 million (15 MW) per year for a small to medium-sized European blade manufacturer to invest in a manufacturing facility in Canada. In addition, a long-term supply agreement with a leading WTG manufacturer would be a necessity. An opportunity exists with Euros GmbH of Germany. Euros has licensed its blade products to Bolwell Corporation in the past and has an interest in establishing a joint venture with Bolwell's successor Composotech Inc. in Ontario in order to supply the North American market.
- Components, such as gears, vibration dampeners, isolation mounts and bearings are supplied by specialized manufacturers that possess proprietary technologies. These manufacturers supply global markets and tend to keep production in their existing facilities unless there is a large enough foreign market and cost savings in setting up a new production facility locally. Technology transfer is not normally an option because of the control on proprietary technologies. Furthermore, a high up-front capital investment is difficult to justify due to the relatively small revenues in selling these small components in local markets. However, there are exceptions that may prompt leading WTG component manufacturers to set up production facilities to supply the North American market. For example, German coupling and torque limiter manufacturer KTR is interested in establishing an assembly and supply base in North America.
- Electrical generators, motors and transformers could be attractive components for Canadian manufacturers looking to cooperate with leading European manufacturer(s). Annual sales of $9 million over a minimum three-year period could attract a European manufacturer to set up a production facility in Canada.
- Most of the foreign manufacturers believe there is a distinct lack of long-term government incentives to support wind energy projects in the Canadian market. The market size is much smaller than that in the United States. It is difficult to make a decision to invest in a manufacturing facility in Canada. However, Europeans feel more comfortable in Canada than in the United States due to similarities in the business and cultural environment. The production tax credit in the United States has recently been extended until the end of 2005. However, this 15-month extension may be too short to initiate large-scale WTG manufacturing in the United States and could provide an opportunity for Canada to attract European investment.

- Government funding in technology transfer and training would be attractive to European manufacturers.

Canadian WTG Component Manufacturers, Current and Potential

A total of 12 Canadian companies in this sector participated in the interviews, including 6 companies interested in tower manufacturing. The interviewed companies manufacture or plan to manufacture components such as rotor blades, inverters, control panels, generators, couplings, towers, base frames and rotor hubs. Currently, there are three Canadian manufacturers supplying foreign WTG manufacturers: Xantrex Tech Inc. supplies inverters; Marmen Inc. and Hitachi (Canada) Industries Ltd. supply towers. The rest of the interviewed companies are either in the planning phase or not in operation due to lack of orders.

- The manufacturing of towers, base frames and rotor hubs is highly competitive. Automation equipment is required to be competitive but the current market uncertainties make it difficult for Canadian manufacturers to make large capital investments. Shortage of steel supply and a lack of long-term orders make it very risky to be in this business. In addition to domestic competition, Canadian manufacturers also face competition from the United States, Asia, South America and Europe.
- Most of the large foreign WTG manufacturers that are competing in the Canadian market manufacture blades in-house, which make it difficult for potential independent Canadian blade manufacturers to supply the local market. Establishing a joint venture with a leading European blade designer and manufacturer could bring potential business opportunities for both domestic and export markets for the Canadian blade manufacturer (Composotech).
- Power electronics and inverters are an integrated part of wind turbine control and operation. Xantrex is in a good position to supply the U.S. and European markets. But the company's manufacturing facilities are in the United States and Germany. It will need substantial business volumes in the Canadian market to put a manufacturing facility here.
- The expertise to design and manufacture turbine generators exists in Canada. However, Canadian companies have not formed partnerships with leading WTG manufacturers and do not have enough funding to build prototypes and conduct commercialization.
- The most common barriers facing Canadian manufacturers are lack of technical expertise, difficulty of competing with multinational suppliers and lack of stable long-term orders.
- In general, Canadian companies expect the following government initiatives to help build up a local turbine component manufacturing industry:
  - increased R&D and commercialization funding;
  - long-term incentives and supporting policies in order to create a sizable and stable domestic wind energy market;
  - support for Canadian companies in obtaining suitable technical expertise through joint venturing or licensing with the world leading WTG component manufacturers;
  - funding for technology transfer and training; and
  - legislation of minimum local content for wind energy projects.

Danish Trade Commissioner

The Danish Trade Commissioner, Mr. Tomas Bruun, showed great interest in providing his assistance to facilitate contacts with Danish wind turbine and component manufacturers. His office has compiled an initial list of Danish wind turbine component manufacturers (see Appendix 5).

Mr. Bruun offered to:

- facilitate technology transfer;
- cooperate between AWTS and the Danish government-funded R&D centre (Risø);
- assist in organizing a trade mission; and
- establish contacts between Canadian and Danish government officials.

Mr. Bruun's contact information is:

Mr. Tomas Bruun
Tel.: (514) 499-2099
Fax: (514) 499-0767
E-mail: **dtcmont@dtcmontreal.ca**
Web site: **www.eksportraadet.dk/hand/montreal**

8.0 Lessons learned from the Success of WTG Manufacturing in Spain

The Spanish wind energy industry has forged ahead with tremendous success in both development and manufacturing in recent years. It started with just 7 MW installed capacity in 1991 and grew to a cumulative installed capacity of 6420 MW by the end of 2003. Spain is second in the world in wind energy development.

Much of the success in Spain can be accredited to its strong national policy of support for the renewable energy industry. In 1994, Spain introduced the first piece of legislation stipulating that all electricity distribution companies pay a guaranteed premium price for green power, operating in a similar way to the *Electricity Feed Law* in Germany. The political and legal commitment to renewable energy was reaffirmed in 1997 by a new *Electricity Act* designed to bring the whole electricity system into harmony, with the steady opening up of the European power market to full competition. In 2003, wind energy producers in Spain were paid an average price of €0.0638 per kilowatt hour, maintaining wind energy as a relatively attractive investment.

The growth in the wind energy field has provided great opportunities for the development of the Spanish WTG manufacturing industry. A crucial impetus to develop wind energy in Spain has come from the bottom up, from regional governments keen to see factories built and local jobs created. At a provincial level, the incentive is simple: *companies that want to develop the region's wind resources must ensure that their investment puts money into the local economy and sources as much of its hardware as possible from local manufacturers.*

By 1999, Spanish companies manufactured not only complete WTGs but also components including rotor blades, generators, gearboxes, towers, wind sensors, etc. As a result, the majority of the turbines installed in Spain were manufactured locally. To date, Spain has cultivated not only the "home-made" leading turbine suppliers such as Ecotècnia and MADE, but also Gamesa Eólica. Gamesa emerged from a previous joint venture with Vestas to become the fourth-largest global WTG supplier with a global market share of 12 percent in 2003. In addition, several WTG manufacturers from Denmark and the United States have set up manufacturing facilities in Spain to participate in the Spanish market and meet the regional local content requirements. Among them are the industrial powerhouses NEG Micon, Bonus, GE Energy and rotor blade manufacturer LM Glasfiber.

An industry insider in Spain gives the following brief advice about how a nation could develop a sustainable WTG manufacturing industry: *At the minimum level, between 500 to 800 MW per manufacturer for at least five years to sustain the investment and business development.*

It will require at least two to three large WTG manufacturers to develop an adequate supply chain for the national market. A five-year national plan should represent the following total production capacity: 5 years x 2.5 suppliers x 650 MW per year per supplier = 8000 MW.

Part of the total production would be exported. An average export portion is 25 percent. Therefore, a total national installation capacity of 6000 MW for five years is necessary to attract investment and establish a sustainable local WTG manufacturing industry. This has been the case in Spain over the past several years. The Spanish success might not be copied in Canada, but this information at least gives Canadian stakeholders an indication about conditions required to build up a sustainable local manufacturing industry for wind energy.

9.0 Conclusions and Proposed Initiatives

9.1 Conclusions

Wind energy is the fastest growing source of energy in the world and is becoming a mainstream, environmentally friendly supplement in energy supply. According to the latest *Wind Force 12* report prepared by BTM for Greenpeace/EWEA, wind power can deliver by 2020:

- 12 percent of the global electricity demand (5000 TWh/year);
- 1 245 030 MW of wind power installed;
- annual business worth C$125 billion;
- cumulative CO_2 emission reduction of 10 771 million tonnes; and
- a cost level of 3.8¢ per kilowatt hour with installation costs of C$800 per kilowatt hour.

Consequently, political and industrial decision makers should take a serious look at the long-term opportunities and risks in the wind energy industry.

A dramatic growth in the North American wind energy market is expected, based on the following developments:

- extension of the U.S. Production Tax Credit (PTC) until the end of 2005;
- Hydro-Québec's award of a 990 MW wind energy contract and a potential RPF for an additional 1000 MW;
- Ontario's decision to shut down three coal-fired power plants with a combined capacity of 7557 MW by 2007, replacing it partially with renewable energy;
- Manitoba's recent commitment to install 1000 MW of renewables;
- Russia's commitment to ratify the Kyoto Protocol, triggering the need for Canada to implement measures to cap greenhouse gas emissions at 572 million tonnes a year by 2010, and requiring a reduction of emissions by 25 percent within this decade.

These developments have drastically improved the opportunities to increase the portion of wind energy in the total energy supply. The question is whether Canada will continue to import most of the wind turbines and their components or whether it wants to become a leader in manufacturing WTGs and their components.

The opportunities to create a new industry are immense. However, jobs and exports will not fall into place automatically. While the wind energy manufacturing industry has developed from small scale to globalization and industry consolidation, Canada has probably missed its chance of developing its own utility-size WTG. But the opportunity to attract major foreign turbine and component manufacturers is enormous.

Canada has a window of opportunity to implement a comprehensive plan that will fulfill its commitments under the Kyoto Protocol to reduce greenhouse gas emissions and that will, at the same time, create a new industry. Governments and industry need to work together to create a competitive Canadian WTG manufacturing industry.

The timing of the market entry is of the essence. This process must take place over the next few years or else it will be more difficult and expensive to enter the market. It is essential for Canadian suppliers to understand the industry, the technology and the market to develop competitive products and services on time.

The current market outlook gives a snapshot of the forecasted investment and employment opportunities (tables 9 and 10). Canadian industry could either easily miss this opportunity by maintaining the status quo or could capitalize on it by supplying components and services to major WTG manufacturers. The authors suggest a target could be to capture 20 percent of the North American wind energy market for Canadian companies by 2012.

9.2 Proposed Initiatives

The Canadian manufacturing industry does not possess advanced technology and expertise in manufacturing large wind turbines and their components. It is thus difficult for Canadian companies to enter the North American market without supporting frameworks from governments and technology transfer from leading European manufacturers. After examining the major subsystems and components of typical large wind turbines, it is recommended that efforts be concentrated initially on establishing a strong Canadian supplier base for the components and services listed below, based on the criteria of (1) low entry barriers; (2) bulky products (high freight costs from Europe to North America); and (3) technologies that are currently available in Canada:

Components/subsystems:
- rotor blades, nacelle covers and spinners
- towers and base frames
- vibration mounts
- generators
- inverters.

Services:
- maintenance, repair and overhaul of WTGs and their components
- logistics and craning.

Government support will be required to establish a competitive Canadian supply base for WTG assembly and components. By implementing a well-funded, three- to five-year program, Canada has the opportunity to establish a new manufacturing and service industry that will provide thousands of high-tech jobs and become a leader in North America. Government agencies, such as Industry Canada, Natural Resources Canada and Environment Canada in conjunction with CanWEA, need to coordinate their efforts to provide one set of clear guidelines for companies interested in participating in this emerging industry.

The following initiatives are recommended:

Short-term (starting immediately)

- Prepare a brochure for Canadian and European companies interested in manufacturing/ servicing large WTGs and their components. Contents of the brochure should provide essential facts such as market forecasts, tax incentives, support programs and other advantages to engage local manufacturers and service providers.
- Have Industry Canada/NRCan and CanWEA hold information sessions for interested companies are recommended. Canadian companies need to look at the entire supply chain, starting with the raw material for components such as rotor blades and towers to identify the growing opportunities. CanWEA has indicated its willingness to engage in such a process.
- Follow up on leads provided in this report. Visit these companies and actively support technology transfers, joint ventures and foreign investment.
- Prepare a study on shipping large components (blades, towers and nacelles), using the St. Lawrence Seaway, from Eastern and Central Canada, Québec and Ontario to the U.S. Midwest, where large wind farms are being developed.

Long-term (3–5 years)

Develop and implement a long-term, well-funded plan to secure the targets set out under Section 5.1 to create a competitive WTG supplier base. This plan needs to address the following:

- Ensure initiatives to create a stable Canadian wind energy market to support manufacturing activities include:
  - expanded and simplified WPPI program (minimum 4000 MW; 1¢ per kilowatt hour);
  - implementation of Renewable Portfolio Standard by the provinces;
  - legislated grid access;
  - emission caps, greenhouse gas emission trading; and
  - harmonized environmental assessment approval (at federal and provincial levels).
- Provide financial support to manufacturing start-ups through:
  - funding of technology transfers;
  - funding of commercialization, prototyping, re-certification including qualification tests;
  - tax incentives for the purchase of capital equipment;
  - training and technical assistance funding; and
  - incentives for foreign technology leaders to set up facilities in Canada.
- Fund commercialization and R&D. It is recommended that a special program be established similar to those for the automotive and aerospace industries.
- Organize trade missions to bring interested Canadian manufacturers and foreign technology leaders together. Canadian Trade Commissioners should be involved in these activities.

- Invite European technology leaders to visit Canada and meet potential partners and/or licensees.
- Support Canadian universities and colleges so they can provide special training courses for WTG installation and service technicians. A partnership with the leading training facilities in Europe is recommended. The Association of Canadian Community Colleges is starting to speak to Danish trading facilities as a result of the CanWEA conference. Initiatives like this could be expanded and supported.
- Upgrade the Atlantic Wind Test Site (AWTS) in Prince Edward Island. This facility needs to be staffed and equipped to test MW-class WTGs. A partnering arrangement with one of the leading European test centres is recommended.
- Form a subcommittee of WTG manufacturing within CanWEA.
- Introduce a simple measurement method to quantify the results of the program — such as Canadian content, exports, job creation and status of R&D initiatives — to measure the impact on the Canadian economy on an annual basis. This is part of a broader initiative that is required to collect and maintain basic economic data on the industry. CanWEA is very interested in working with Industry Canada on this.

Appendix 1: WTGs Installed in Canada by Manufacturer and Type

Status as of August 2004

Turbine type	Name plate power (kW)	No. of turbines	Total power (MW)	Year installed
Bonus (Denmark)	150	1	0.15	1993
Kenetech 33M (U.S.)	360	52	18.7	1993
Kenetech 33M (U.S.)	375	5	1.9	2000
Tacke Tw600 (Germany)	600	1	0.6	1995
NEG Micon (Denmark)	900	1	0.9	2001
NEG Micon (Denmark)	750	133	102	1998, 1999
Vestas V40 (Denmark)	600	4	2.40	1997, 1998
Vestas V47 (Denmark)	660	123	152.5	2001–2003
Vestas V80 (Denmark)	1800	53	96	2001–2004
Vestas V90 (Denmark)	3000	1	3	2003
Enercon (Germany)	600	1	0.6	2001
Nordex (Germany)	1300	20	26	2001
Turbowind (Belgium)	600	1	0.6	2002
Lagerwey (Netherlands)	750	2	1.5	2003, 2004
Jeumont (France)	750	3	2.25	2003
GE Energy (U.S.)	1500	20	30	2004
Total power			**439**	

Source: CanWEA Web site www.canwea.ca

Note: GE Wind installed the first 1.5 MW WTG during the summer of 2004.

Installed Capacity by Manufacturer (10/2004)			
	Turbine	**Capacity**	**Total Capacity**
Vestas/NEG Micon, Denmark			**354.16 MW**
1	V90	3 MW	3 MW
53	V80	1.8 MW	96 MW
231	V47	660 kW	152.46 MW
3	V44	600 kW	1.8 MW
133	NM750	750 kW	102 MW
1	NM900	900 kW	0.9 MW
Nordex Germany			
20		1.3 MW	**26 MW**
Kenetech			
52	33M	360/375 kW	**21.4 MW**
Jeumont, France			
3	J48	750 kW	**2.25 MW**
Lagerwey, Holland			
2		750 kW	**1.5 MW**
Tacke, Germany			
1	TW-600	600 kW	**0.6 MW**
Enercon, Germany			
1	E40	600 kW	**0.6 MW**
Turbowind, Belgium			
1	T600	600 kW	**0.6 MW**
GE Energy			
20	GE-1.5	1.5 MW	**30 MW**
Total			**439 MW**

Source: CanWEA. www.canwea.ca

Appendix 2: Cost Structure of a 30 MW Generic Wind Farm during 20 Years' Operation

1.0 Cost Structure

Summary		
Project preparation – 2 years	1.4%	$1 million
Construction – 1 year	61.6%	$45 million
Operation – 20 years	37.0%	$27 million
Total	**100%**	**$73 million**

1.1 Project Preparation Cost – 30 MW Wind Farm

- Wind resource assessment geology study
- Noise study
- Environmental impact assessment
- Building permission
- Wind farm design
- Interconnection design
- Due diligence

Total **$1 million**

1.2 Construction Cost – 30 MW Wind Farm

• Wind turbines ex-work		$30 million
• Foundation		$2.7 million
• Transportation		$2.4 million
• Craning		$1.5 million
• Installation & commissioning		$1 million
• Access roads		$1 million
• Electrical interconnection:		
– step-up transformer	$1 million	
– collection system	$1.3 million	
– substation at wind farm	$1.8 million	$3.7 million
– interconnection at transformer station	$0.3 million	
– pole line, 3 km	$0.6 million	
• Local construction supervision		$0.4 million
• Legal cost, financing cost, insurance		$1.1 million
• Contingency	3%	$1.2 million
Total wind farm cost		**$45 million**
Per kW		**$1500**

Breakdown of Wind Turbine Cost

A. Nacelle assembly		60%
• Rotor hub	4%	
• Blade bearings	1.5%	
• Hydraulic pitch system	2%	
• Rotor bearing with housing	2%	
• Rotor shaft	2%	
• Rotor brakes	1.5%	
• Main gearbox	12%	
• High-speed shaft (including clutch)	1%	
• Hydraulic power supply	1%	
• Nacelle base frame, load bearing	5%	
• Nacelle cover and spinner (FRP)	3%	
• Equipment and auxiliary system	2%	
• Yaw system (including yaw bearing)	4%	
• Generator and inverter	10%	
• Control system and monitoring	4%	
• Assembly of nacelle (in factory)	5%	
B. Rotor blades		16%
C. Tower		15%
D. Foundation		9%
Total		**100%**

1.3 Operation Cost – 30 MW Wind Farm

Annual recurring cost for 30 MW wind farm (ex-work price C$30 million)

Item	% of ex-work price	20 year operating cost
Maintenance contract	0.50%	$3 million
Repair reserves	2.25%	13.5 million
Insurance	0.50%	$3 million
Land lease	0.75%	$4.5 million
Monitoring and administration	0.50%	$3 million
Total operating cost	**4.50%**	**$27 million**

Appendix 3: Sample Questionnaire Used in the Study

Interview Questionnaire for
Canadian Wind Turbine Component Manufacturers, Current and Potential

Company name	_____	Employment	_____
Location	_____	Engineering	_____
Contact name	_____	Plant size	_____
Tel:	_____	Web site	_____
Main products	_____		_____

Question 1:

Are you currently manufacturing components for wind turbines?

- ☐ Yes
- ☐ No

Question 2:

What are the wind turbine components you are currently manufacturing or considering manufacturing?

- ☐ Rotor blades
- ☐ Gearbox
- ☐ Generators
- ☐ Yaw
- ☐ Base frames
- ☐ Rotor hubs and main bearing housing
- ☐ Towers
- ☐ Main shafts
- ☐ Nacelle covers and spinners
- ☐ Electrical cabinets
- ☐ Disc brakes
- ☐ Hydraulics
- ☐ Other – please specify:

Question 3:

A. Under what conditions would your company consider becoming a components manufacturer or expanding your operation?

- ☐ Getting a licence of a proven turbine component product
- ☐ Entering a joint venture with an existing turbine component manufacturer

B. Any other conditions to set up component manufacturing or expand your operation? Please specify:

_____

Question 4:

If your company manufactures or plans to manufacture components, where would your facilities be located?

☐ Ontario ☐ Atlantic Canada
☐ Quebec ☐ Western Canada

Question 5:

Which of the following wind turbine manufacturers (OEM) do you consider as potential customers?

☐ Vestas ☐ Gamesa
☐ GE Wind ☐ REpower
☐ Enercon ☐ Other – please specify _____

Question 6:

What are the pros and cons of manufacturing turbine components?

PROS	***CONS***
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.

Question 7:

A. What are the difficulties your company anticipates in terms of manufacturing wind turbine components in Canada?

☐ Lack of technical expertise
☐ Lack of investment (both private and government)

- ☐ Hard to compete with multinational suppliers
- ☐ Difficult to win customers
- ☐ Lack of sufficient long-term orders
- ☐ Others – please specify: _____

B. How do you overcome these difficulties when doing component manufacturing in Canada?

_____

Question 8:

What Government initiatives do you recommend to facilitate setting up assembly operations in Canada?

- ☐ Incentives – please specify:
  - ☐ R&D and commercialization funding, IRAP
  - ☐ Creating a market through WPPI
  - ☐ Expanding and simplifying WPPI
  - ☐ Tax incentives
  - ☐ Training and technology transfer funding
  - ☐ Organizing trade missions to find partners/licensors
  - ☐ Other: _____

- ☐ Regulations and policies – please specify:
  - ☐ Legislated minimum Canadian content
  - ☐ Legislated grid access
  - ☐ Greenhouse gas emission trading, legislated
  - ☐ Renewable Portfolio Standard
  - ☐ Other (please specify) _____

Question 9:

Other related comments:

_____

Appendix 4: List of Companies Interviewed

October 4, 2004

AAER Systems Inc.
Potential WTG manufacturer under license from Fuhrländer, Germany
Contact: Dave Gagnon, CEO

Algoma Steel, Ontario
Major steel company interested in tower manufacturing and steel plate supply
Contacts: Paul Finley, John Naccarato
(*Note:* Algoma did not respond to the questionnaire.)

August Friedberg
Manufacturer of fastener systems for WTGs and the automotive industry
Contact: Dr. Uwe Hasselmann
(*Note:* Company declined to consider manufacturing or joint venture activities in Canada at this time.)

AWE, Toronto/Lagerwey, Holland
Potential WTG manufacturer under license from Lagerwey, Holland; 750 kW direct-drive WTGs
Contact: Frank Pickersgill

Canadian Projects Ltd., Calgary, Alberta
Engineering and project management; service provider
Contact: Cal Christenson
Web site: www.canprojects.com

Centra, Ontario
Machining of large components for the aerospace industry; interested in learning more about manufacturing opportunities
Contact: Heidie

Composotech Inc, Ontario
Composite component manufacturer with interest in manufacturing blades under license from Euros, Germany
Contact: Mike Jeffrey, President

Danish Trade Commissioner, Montreal
Supporting technology transfer, assistance in organizing a trade mission, cooperation between AWTS and Risø
Contact: Tomas Bruun

Eickhoff Maschinenfabrik GmbH, Germany
Manufacturer of gearboxes and large castings for WTGs
Contact: Dr. E. Conrad
(*Note:* Eickhoff has no plans to establish a manufacturing facility in Canada at this time and is not in a position to complete the questionnaire.)

EMS GmbH, Germany
Manufacturer of vibration dampening systems; interested in setting up manufacturing in Canada
Contact: Franz Mitsch

Enercon, Germany
WTG manufacturer, 300 kW, 600 kW, 2 MW, 4.5 MW; desalination, wind/diesel, wind/hydrogen systems; number one supplier in Germany; will be attending CanWEA conference; interested in meeting in Montreal.
Contact: Michael Weidemann

ESAB, Ontario
Distributor of automation equipment for tower manufacturing; providing support to set up world-class tower manufacturing capabilities
Contact: Richard Hadley

Euros, Germany, CEO
Designer and manufacturer of rotor blades from 600 kW to 5 MW; potential licensor and joint venture partner for Composotech, Ontario
Contact: Dr. Michael Wolf

Fabspec, Quebec
Metal fabricator with interest in tower manufacturing and nacelle assembly
Contact: Yves Lecompte

Fuhrländer, Germany
Manufacturer of WTGs; in contact with AAER, Montreal, regarding a license;
30 kW, 100 kW, 250 kW, 1000/800 kW, 1.5 MW and 2.5 MW (prototype) turbines
Contact: Dr. Jahn Ross

Gamesa Eólica, Spain
Manufacturer of WTGs, 660 kW, 1.8 MW, 2 MW
Contact: Eduardo Roquero, Business Director

Gastops, Ottawa
Manufacturer of engine control systems for the aerospace industry; currently selling oil debris monitoring system for WTGs; interested in acquiring condition monitoring system
Contact: Dave Muir

Georgian Windpower
Promoter intending to develop industrial park for renewable energy on the shores of Lake Erie, Ontario
Contact: Michael Monette

GEQ, Helimax Energy, Quebec
Consortium that assembled three Jeumont turbines 750 kW; machine shop; consulting
Contact: Richard Legault

GE Canada/Energy
Manufacturer of WTGs, 900 kW, 1.5 MW, 2.3/2.5/2.7 MW, 3.6 MW
Company considering setting up assembly operations in Quebec, Ontario and Western Canada
Contacts: Simon Olivier, Montreal; Derek Lim & Soo, Marcel Armanene, Mississauga, Ontario

Hitachi Industries, Saskatchewan
Metal fabricator; currently manufacturing towers for 1.8 MW turbines
Contact: Denise Frey

Irving Oil, New Brunswick
Large industrial group; interested in tower manufacturing and turbine manufacturing under license
Contact: John Salvage

KTR, Germany
Manufacturer of couplings and torque measuring devices; potential licensor to ODG, Hamburg, Ontario
Contact: Dr. Norbert Partmann

Marmen Inc.
Metal fabricator currently manufacturing towers for MW turbines
Contact: Patrick Pellerin, President

Maxfield Inc., Alberta
Metal fabricator interested in tower manufacturing
Contact: Tony Giasson

Metal World, Newfoundland
Metal fabricator interested in tower manufacturing
Contact: Ivan Butler

Metso Drives, Ontario/Finland
Manufacturer of gearboxes and large castings for MW-size WTGs
Contact: Shannon Barber, Cambridge, Ontario
(*Note:* Shannon Barber plans to attend the CanWEA conference in Montreal in October 2004.)

Ontario Drive and Gear
Manufacturer of all-terrain vehicles, small and medium-size gears; interested in manufacturing couplings under license from KTR, Germany
Contact: Norbert Benik, Vice President

Powerhouse Controls, Ontario
Manufacturer of industrial control systems with interest in assembling control cabinets
Contact: Neil Nicholson

REpower, Germany/Canada
Manufacturer of WTGs, 600 kW, 750 kW, 1.5 MW, 2 MW, 5 MW
Contact: Theodor Peters

RJS Mechanical Inc., Oshawa, Ontario
Multiservice contractor for the installation of WTGs; participated in the installation of eight wind farms in Canada
Contact: Robert Scoffield
(*Note:* RJS did not respond to the questionnaire.)

SKF Canada, Ontario
Distributor of bearings for WTGs and supplier of condition monitoring systems
Contact: John Kupka

TM4 Inc., Boucherville, Québec
Member of Hydro-Québec; interested in manufacturing direct-drive generators
Contact: Mirvil Bruno

Tritt-Voigt, Ontario
Metal fabricator interested in manufacturing towers
Contact: Jeff Voight

Turbowinds Canada/Belgium
Manufacturer of WTGs, 600 kW
Contact: George Klass
(*Note:* Company did not respond to questionnaire.)

Vensys, Germany
Manufacturer of direct-drive WTGs, 1.2 MW; potential licensor
Contacts: Hugo Denker, Prof. F. Klinger

Vestas, Denmark
Manufacturer of WTGs, 660 kW, 1.8 MW, 3 MW
Contact: Hugh Campbell

Weier Electric, Germany
Manufacturer of generators for WTGs up to 5 MW, control cabinets
Contact: Dr. Michael Roether
(*Note:* The company is initially interested in setting up a service centre for its products in North America as a joint venture with a Canadian partner.)

Wind to Energy, Germany
Engineering company 2.5 MW WTG prototype; potential licensor
Contacts: Christoph Klewitz, Jan Ross

Xantrex Technology Inc.
Manufacturer of inverters for renewable energy including WTGs up to 1.5 MW
Contact: Bernd Kohlstruck

Appendix 5: WTG and Component Manufacturers from Denmark

BUSINESS	WEB	CONTACT
A.C Lemvigh-Müller	www.aclm.dk	Jørgen Lemvigh-Müller
A H Bolte A/S	www.ah-bolte.dk	Henrik Pander
A2Sea	www.a2sea.com	Kurt E. Thomsen
ABB A/S	www.abb.dk	Erik Koldby Nielsen
ABB A/S	www.abb.dk	Carl-Peter Andersen
ABB Vetco Gray Denmark	www.abb.com/vetcogray	Per Bak
Allerup Teknik A/S	www.allerup-teknik.dk/choose-dk.html	Jesper Skalshøj
Arvid Nilsson Danmark A/S	www.arvidnilsson.com	Peter Korremann
AVN Hydraulik A/S	www.avn.dk	Jørgen Rose
Bach Composite Industry A/S	www.bach-ci.dk	Geert Winther Skovsgaard
Baltship A/S	www.baltship.dk	Flemming Rung
Barsmark A/S	www.barsmark.com	Poul-Erik Andersen
Birk & Boe A/S	www.niras.dk	Flemming H. Jensen
Bladt Industries A/S	www.bladt.dk	Carsten Nielsen
Bonus Energy A/S	www.bonus.dk	Henning Kruse
BTM Consult ApS	www.btm.dk	Birger T. Madsen
C. Breinholt A/S	www.iat.dk/breinholt	Morten Kamp Knudsen
Center For Underleverandører	http://www.hih.dk/Default.asp?ID=14	Peter Aarø Rasmussen
C.C. Jensen A/S	www.cjc.dk	Knud Erik Hansen
COWI	www.cowi.dk	Torben Søgaard Jensen
Dafa A/S	www.dafa.dk	Klaus Østerberg
Danish Technology Center Aps	www.d-tech.dk	
Dansk Hydraulisk Institut	www.dhi.dk	Vagner Jacobsen
Dansk Metal	www.danskmetal.dk	
Dansk Overflade Teknik	www.dot.dk	
DELTA	www.delta.dk	Henrik Andersen
Densit A/S	www.densit.com	Lars Mogensen
Desitek A/S	www.desitek.dk	
DFDS Transport A/S - Project Division	www.dfds.dk	Thomas Hostrup
Diab Aps	www.diabgroup.com	
Elsam Engineering A/S	www.elsam-eng.com	Bent Jørgensen

EMD-Energi og Miljødata	www.emd.dk	Anders Barsk
ENERGI E2 A/S	www.e2.dk	Lars Woller
Energistyrelsen	www.ens.dk	Peter Schrøder
enXco A/S	www.enxco.com	
E. Søndergård	www.e-sondergaard.dk	
ESSCANO POWER A/S	www.esscano.dk	Kim Bovien
FAG Sales Europe-Denmark	www.fag.dk	
Fyns Coating ApS	www.fyns-coating.dk	Allan Osther
Fyns Kran Lifting	www.fyns-kran.com	
Gardit A/S	www.gardit.dk	Ib Johanson
Garre Transformere AS	www.garre.dk	
Greentech Energy Systems A/S	www.greentech.dk	Kaj Larsen
Hallkvist Trading Aps	www.hallkvisttrading.dk	
Hans Buch A/S	www.hansbuch.dk	
Hefa A/S	www.hefa.dk	
HEMPEL A/S	www.hempel.dk	Bjarne Lous
H.J. Hansen	www.hjhansen-genvinding.dk	
Hytor A/S	www.hytor.dk	Finn Høst
Ib Andresen Industri A/S	www.iai.dk	
Indutrans A/S	www.indutrans.dk	Per Koch
Jysk Vindkraft	www.jyskvindkraft.dk	Ole Bundgård Jensen
Jørgensen og Utoft A/S	www.jorgensen-utoft.dk	
K. P. Komponenter	www.kpkomponenter.dk	Martin Andersen
KK-Electronics A/S	www.kk-electronic.dk	Lars Sloth
Krangården	www.krangaarden.dk	
LM Glasfiber A/S	www.lm.dk	Anders D. Christensen
LMG Stål A/S	www.lmg.dk	
Mita-Teknik A/S	www.mita-teknik.com	Nils Rosted
Niebuhr Tandhjulsfabrik A/S	www.niebuhr.dk	Rasmus Niebuhr
Nordex A/S	www.nordex.com	Claus Poulsen
Nordmark-Maskinfabrik A/S	www.nordmark-maskinfabrik.dk	Ejnar Jacobsen
Norwin A/S	www.norwin.dk	Per Lading
Ocean Team Scandinavia as	www.oceanteam.dk	Jens Peder H. Thomsen
Offshore Center Danmark	www.offshorecenter.dk	Peter Blach
Oiltech AS	www.oiltech-olaer.dk	
Parker Hannifin Danmark A/S	www.parker.dk	

Poul Houman Andersen		
P.N. Erichsen A/S	www.pne.dk	Olaf Erichsen
PETER HARBO A/S	www.harbo.dk	Claus Harbo
PMC Technology A/S	www.pmctechnology.dk	
Rautaruukki Danmark	www.rautaruukki.dk	
Reichhold Danmark A/s	www.reichhold.com	
ResQ A/S	www.resq.no	Erik Jacobsen
Roug A/S	www.roug.dk	
Sandvik A/S	www.sandvik.com	
Scanvib ApS	www.scanvib.dk	
Schneider Electric A/S Danmark	www.schneider-electric.dk	
SEAS Wind Energy Centre	www.seas.dk	Svend Richman
Siemens A/S	www.siemens.com	
Silkeborg Spåntagning A/S	www.mssp.dk	
Sika Danmark A/S	www.sika.dk	Per Eskildsen
SKF Danmark A/S	www.skf.com	Inge Aasheim
Svendborg Brakes A/S	www.svendborg-brakes.dk	Lars Teil Johansen
Teknatex Aps	www.teknatex.dk	
Torben Rafn & Co A/S	www.torben-rafn.dk	
TIC Erhvervscenter Nordjylland	www.tic.dk	Johs Bruun Bindslev
Transport-teknik A/S	www.lpo.dk	
Tripod Consult Aps	www.tripod.dk	
Vestas Wind Systems A/S	www.vestas.com	Tom Pedersen
Vestergaard Marine Service	www.vms.dk	Morten Vestergaard
Viking Life-Saving Equipment A/S	www.viking-life.com	Pernille Kragh
Welcon A/S	www.welcon.dk	Jens Pedersen
Wincon West Wind A/S	www.wincon.dk	
YIT A/S	www.aalborgcomc.dk	J. Michael Hannibal
Orbital ApS	www.orbital.dk	Wolfgang W. Meyer
RISØ National Laboratory	www.risoe.dk	Flemming Rasmussen

Appendix 6: 2–3 MW Class Turbine Models from Foreign WTG Manufacturers

Make and type	Capacity (MW)	Rotor size (metres)	Status
Bonus 2 MW	2.0	76	Series product
Bonus 2.3 MW	2.3	82.4	Series product
DeWind D8	2.0	80	Series product
Enercon E66	2.0	70	Series product
Gamesa G-80	2.0	80	Series product
Gamesa G-83	2.0	83	Series product
Gamesa G-87	2.0	87	N/A
GE 2.3	2.3	94	Prototype
GE 2.5	2.5	88	Prototype
GE 2.7	2.7	84	Prototype
MADE AE-80	2.0	80	N/A
MADE AE-90	2.0	90	N/A
Mitsubishi MWT-200S	2.0	75	N/A
NEG Micon NM 80/2750	2.75	80	Series product
NEG Micon NM 92/2750	2.75	92	Series product
Nordex N80	2.5	80	Series product
Nordex N90	2.3	90	Series product
REpower MM70	2.0	70	Series product
REpower MM82	2.0	82	Series product
Suzlon	2.0	88	Prototype
ScanWind 3.0	3.0	90	Prototype
Vestas V80	2.0	80	Series product
Vestas V90	3.0	90	Series product
WinWind WWD-3	3.0	90	Prototype
Zephyros Z-72	2.0	71.2	Series product

Source: Bjoern Johnsen, “Wind Turbine Market 2004”, Sun Media, 2004 issue, page 72-76

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