Alberta Wind Energy Supply Chain Study

FINAL REPORT

Prepared for:

Canadian Wind Energy Association

September 2017

DelphiGroup

Environmental Strategies. Business Solutions.

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Prepared by:

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PREFACE

In 2017, the Delphi Group was retained by the Canadian Wind Energy Association (CanWEA) and members of its Alberta caucus to undertake research in order to profile Alberta's wind energy sector supply chain and its participants.

The purpose of the study was to gain a better understanding of Alberta's existing strengths in the wind energy sector, gaps in the local supply chain, and opportunities for growing businesses, investments, and the relevant workforce skills to support industry growth in line with the Province of Alberta's Renewable Electricity Program (REP).[1] The REP sets a target to ensure 30% of Alberta's electricity will come from renewable sources by 2030 and plans to add 5,000 megawatts (MW) of renewable energy capacity by 2030.

Secondary research for this study included a review of key industries involved in the wind energy sector supply chain, research on important industry and technology trends, an examination of other leading wind jurisdictions across North America, and a review of key occupations and skills involved in the wind energy sector.

Sector profiling work included data collection and analysis of statistical sources in order to estimate existing industry capacity in Alberta, as well as assess the potential economic impact from the projected growth of the province's wind sector to 2030 in terms of investments, employment, and gross domestic product (GDP); compiling a database of relevant companies and supporting organizations; and performing a supply chain assessment of existing strengths, weaknesses, and gaps. Extensive consultation was also undertaken through 20 interviews with industry leaders to gain additional insights and validate research assumptions. For more information on the project methodology, see Appendix A.

It is hoped that the outcomes from this project will help to inform wind energy sector stakeholders in Alberta on the current capacity that exists across the value chain, as well as the opportunities for participation in this growing industry over the coming decade that will help to diversify Alberta's energy economy and result in new investment and employment benefits province-wide.

[1] See: https://www.alberta.ca/renewable-electricity-program.aspx

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EXECUTIVE SUMMARY

Globally, the economic case for wind energy is growing and competing head-on with electricity generation from all other sources. A 2016 report from the US investment firm Lazard estimates the levelized cost of unsubsidized wind electricity in the United States at $32-$62 (USD) per megawatt hour (MWh), making it the lowest cost electricity generating option in many jurisdictions.[2] Similar cost structures are estimated for the Canadian market, although impacted somewhat by the US exchange rate and related costs of importing turbine components.

In 2016, the Government of Alberta established a Renewable Electricity Program (REP) that sets a target to ensure 30% of Alberta's electricity will come from renewable sources by 2030 and established plans to add 5,000 MW of renewable energy capacity by 2030.[3] Industry experts suggest that as much as 95% of this new capacity in Alberta could come from wind energy projects.

In line with Alberta's current policy directive, this report provides the Canadian Wind Energy Association (CanWEA), its members, and other stakeholders, with an understanding of Alberta's existing wind energy supply chain and related investment potential, including an overview of existing players, insights on current gaps and potential growth opportunities, and the economic impacts from Alberta's wind energy sector as a result of the REP.

Supply Chain Assessment

The wind energy supply chain includes more than 65 industries (at the six-digit NAICS[4] code level) and a very broad range of activities, from project development and construction, to operations and maintenance (O&M), and turbine component and equipment manufacturing. The tables below provide an overview of Alberta's current strengths and capacity, existing gaps, and potential future opportunities for local business across the wind energy supply chain.

Project Development & Construction

Strengths & Capacity	Current Gaps & Risks
• Alberta has a long history with wind project development, with approximately 40 commercial projects having been developed in the province over the last three decades. • Alberta-based companies have developed approximately 32% of Canada's total installed wind capacity of 11,205 MW as of 2016. • Geo-technical engineering firms, site permitting, land negotiation expertise, and environmental assessments (e.g., site monitoring, firms active in archeology and cultural anthropology, environmental consulting, and scientific firms active in biology) are abundant in Alberta. • Engineering, procurement, and construction (EPC) firms, as well as more specialized firms in mechanical, structural, and civil engineering, are abundant in Alberta with expertise that can be transferred to the wind industry, particularly in line with site preparation, including road construction, foundations and pads, and for the installation of towers. • Transportation / logistics and craning are well established industries in Alberta, with leading companies having head offices in the province.	• Research for this study identified no significant gaps in the project development and construction phases. • While specific expertise in the last couple of years with site development / construction and wind turbine tower erection is lacking, transferrable skills are available from the oil and gas industry with minimal retraining required. • If the oil and gas industry has a significant rebound, there are risks of shortages in terms of project development and construction expertise (e.g., with site permitting, environmental engineering, road building, industrial electricians, etc.). • Scheduling of project roll-outs in Alberta may impact on the cost and available of labour, as well as important construction related equipment such as large 'crawler' cranes, if not properly timed.

[2] Lazard, 2016. "Levelized Cost of Energy Analysis – Version 10.0".
[3] See: https://www.alberta.ca/renewable-electricity-program.aspx
[4] NAICS = North American Industry Classification System. See: http://www.statcan.gc.ca/eng/subjects/standard/naics/2017/index

Opportunity Areas:

- Environmental monitoring and site planning presents significant opportunities for local companies. Activities such as wind regime evaluation and the prospecting and location siting of towers is work that can be done by Alberta-based firms.
- Significant opportunities exist for companies involved in excavating, concrete, steel, metal fabrication / welding, electrical work, and sub-station control systems.
- Civil engineering work in areas such as road building and site preparation will be important.
- The construction and upgrading of sub-stations, transmission lines, and cabling present additional opportunities for Alberta firms as projects roll out.
- The transportation of and route planning for large turbine components and equipment present opportunities for Alberta logistics companies.

Operations & Maintenance (O&M)

Strengths & Capacity	Current Gaps & Risks
• Alberta's energy market has already experienced some diversity, with a number of project owners and utilities familiar with wind farm operations and maintenance. • Approximately 1,491 MW of installed wind capacity exists at present in Alberta from 901 turbines, with wind contributing roughly 6% of annual electricity generation to the provincial grid in 2016. • In house and/or sub-contracted operations teams are involved with regular maintenance and activities such as regular inspections, equipment lubrication, and instrumentation repair. • Considerable transferability of skills from the oil and gas sector to wind operation O&M exists as it relates to electrical expertise, as well as monitoring from Supervisory control and data acquisition (SCADA) systems. • Some Alberta companies are involved in the production of industrial resins and lubricants that have applications to wind farm O&M activities. • Site security and monitoring is an important responsibility undertaken by Alberta-based firms.	• Specialized and proprietary expertise is often needed for servicing and maintaining certain turbine components. • Nearly all large and specialized wind turbine equipment and component replacement parts (e.g., blades, nacelle components, etc.) are currently being imported to Alberta from outside of province or internationally. • Project owners / operators and Original equipment manufacturers (OEMs) bring in expertise from wherever it exists and/or move people into Alberta to do the work over the longer term as required. • A current industry trend is to consolidate remote operations services through automation and digital technology, which may impact on jobs and opportunities for Alberta-based firms.

Opportunity Areas:

- Most of the O&M services are procured locally when possible in order to ensure ongoing community support for the project. Specific areas include grid and system integration, balance-of-plant operations, security systems, and the monitoring and maintenance of electrical, SCADA, and control systems.
- As a growing critical mass of turbines are deployed in Alberta, it may make economic and operational sense to offer a broader range of support and service functions, such as operations centres and centralized warehouse and distribution centres for spare parts and equipment repair.
- With the growth of wind farms in Alberta, more wind turbine technicians and operations-focused training presents an opportunity for local post-secondary education and training institutions in order to meet demand.
- Alberta companies may be able to supply parts and equipment that have failed or need to be replaced (e.g., motors, bearings, specialized electronics, etc.), as well as materials such as lubricants for ongoing operations.

Wind Turbine Component Manufacturing

Strengths & Capacity	Current Gaps & Risks
• Expertise and capacity is best aligned in the areas of transformers / sub-station control systems, switchgear, and some electrical and power electronics. • Materials such as cabling and concrete are also available in Alberta. • Expertise and capacity does exist with respect to the fabrication of wind turbine towers, with potential transferrable capabilities from pressure vessel manufacturers in Alberta. • Off-site, pre-fabrication and modularization is another area of expertise in Alberta that may present transferrable opportunities to the wind sector.	• Alberta currently lacks the expertise and capacity to manufacture the vast majority of specialized wind turbine components, particularly as it relates to nacelles, machine heads, and hubs, as well as the related electronic components, gearboxes, and generators. • There is limited fibreglass expertise or carbon fibre material manufacturing in Alberta at present. • While some control system expertise exists in Alberta, OEMs have developed optimized supply chains for key components. • Volume is the largest challenge at present with respect to the cost and effort to set up local manufacturing plants / facilities, and for undertaking the training and technology transfer required, given already establish global supply chains. • Under Alberta's current REP 1 call for 400 MW, turbine components will almost entirely be imported by rail and/or truck from outside of province.

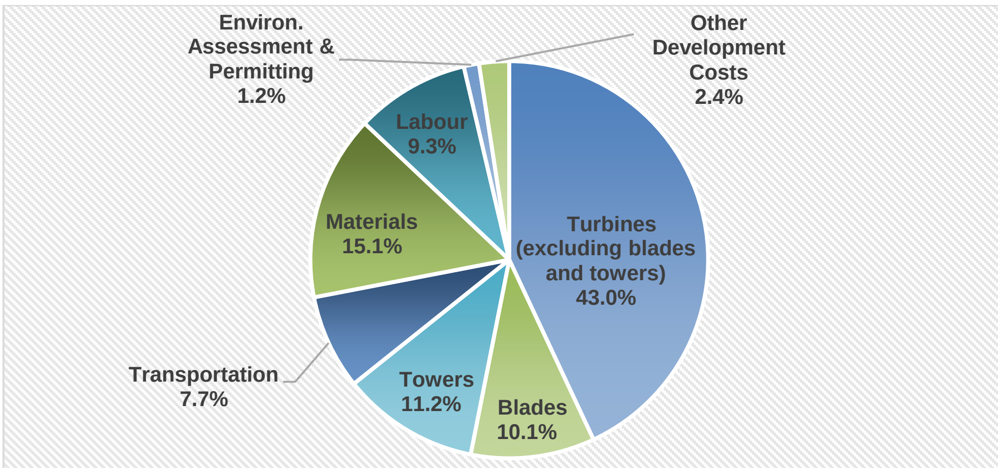
Opportunity Areas:

- Wind turbines consist of some 150 components and up to 8,000 individual parts that comprise the three main elements: the blades, the towers, and the nacelles.
- While direct expertise is currently lacking in Alberta in most areas related to turbine component manufacturing, OEMs will invest in training if the market opportunity makes economic sense.
- Some opportunities do exist for Alberta-based manufacturing of larger wind turbine components, including towers and blades (to a lesser degree), assuming a critical mass can be achieved amongst relevant OEMs and the economics favour local manufacturing over the transportation and logistics costs.
- Over the longer term, Alberta-based companies may be able to pivot to supply equipment, parts, and components, particularly in the O&M phase.
- New technologies (such as advanced manufacturing, 3-D printing, and virtual reality), could revolutionize local production and impact on the existing supply chain.

Economic Impact Assessment

The potential economic impacts of the emerging wind energy industry in Alberta were estimated in line with the province's Renewable Electricity Program (REP) policy that calls for 5,000 MW of renewable energy capacity to be added by 2030. The economic impact assessment assumed that approximately 4,500 MW (or 90%) of the added capacity by 2030 would come from utility-scale wind farms, with the balance from other renewable energy sources, such as hydro and solar photovoltaic (PV).

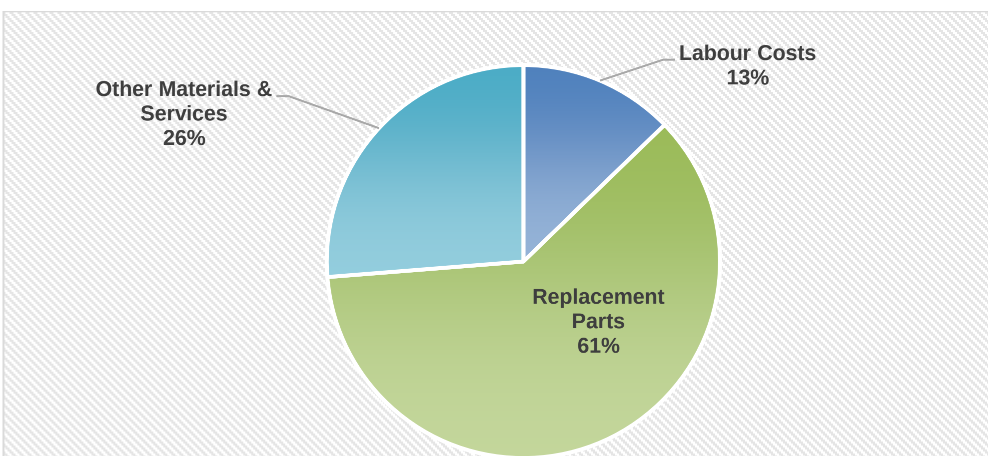
The economic impacts were estimated using the US National Renewable Energy Laboratory's (NREL) Jobs and Economic Development Impact (JEDI) model, customized with Alberta-specific economic multipliers in order to calibrate the model for the province's economy.[5] Using the localized JEDI model, the costs were estimated for project development, equipment, and construction related to 100 MW of wind farm development in Alberta. The cost breakout is illustrated in Figure ES1 below.



Source: Delphi Group and NREL JEDI Model

Figure ES1: Project development, equipment, and construction cost breakouts for a 100 MW wind farm in Alberta.

Estimates for the cost breakout related to ongoing operations and maintenance (O&M) activities over the lifetime of a wind farm is shown in Figure ES2.



Source: Delphi Group and NREL JEDI Model

Figure ES2: Project operations and maintenance cost breakouts for a 100 MW wind farm in Alberta.

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[5] See: See: http://www.nrel.gov/analysis/jedi/

Policy Scenarios & Economic Impact

Three policy scenarios were developed by Delphi, with input from CanWEA members, to help inform the economic modelling assumptions that were input into the JEDI model. The scenarios are outlined in Table ES1 below.

Table ES1: Policy scenarios related to the size and timing of wind project procurements in Alberta.

Policy Scenarios	Procurement Calls & Frequency	Policy Certainty	Impact on Alberta Manufacturing
Base Case Scenario	Approximately 1,496 MW of new wind generation capacity is procured in Alberta by 2030, based on AESO's 2014 Long-term Outlook (Main Growth forecast). However, timelines and procurement calls are unclear.	No REP exists; wind development is impacted by growth in demand for electricity, as well as Alberta's Specified Gas Emitters Regulation (SGER) policy and federal policy for the accelerated retirement of coal-fired electricity by 2030.	No manufacturing except for some O&M-related component repair and replacement activity.
REP Scenario 1	400 MW of new wind generation capacity is procured every year (2016-2028) in Alberta for a total of 4,500 MW of wind by 2028.	The provincial REP policy landscape lacks clarity around timelines for future procurement calls.	No manufacturing except for some O&M-related component repair and replacement activity.
REP Scenario 2	400 MW of new wind generation capacity is procured in 2016. 1,500 MW of new wind is announced every 3 years (in 2018, 2021, 2024), rolled out as 500 MW per year. Total of 4,500 MW of wind by 2027.	Clear provincial REP policy outlining a procurement roadmap to 2030 in partnership with AESO, with point allocations for some local content (although local content is not mandated).	Attracts wind tower manufacturing and some blade manufacturing in Alberta, as well as some components for O&M repair and replacement.

Source: Delphi Group

Total impacts from the development of 4,500 MW of wind energy in Alberta by 2030 is estimated to result in approximately $8.27 billion in installed project costs, as well as $1.37 billion in annual operational expenses (see Table ES2). By comparison, the Base Case scenario that results in 1,496 MW of wind power capacity being added in Alberta by 2030 is estimated to result in only $2.74 billion in installed project costs and $418 million in annual operational expenses.

Table ES2: Total cumulative economic impacts from the installation of 4,500 MW of wind power in Alberta under the two REP policy scenarios versus the Base Case scenario.

Total Impacts	Base Case	REP Scenario 1	REP Scenario 2
MW of Wind Power Installed by 2030	**1,496**	**4,500**	**4,500**
Installed Project Cost	**$2,724,639,315**	**$8,274,983,345**	**$8,274,983,345**
Local Spending (Project Development – Alberta)	$837,959,855	$2,682,043,826	$3,602,613,311
Total Annual Operational Expenses	**$418,130,842**	**$1,371,988,895**	**$1,372,019,945**
Direct Operating and Maintenance Costs	$42,257,535	$140,587,870	$140,587,870
Local Spending (O&M – Alberta)	$41,109,909	$136,579,475	$136,579,475
Property Taxes	$7,787,340	$25,542,000	$25,542,000
Land Lease Payments	$4,115,930	$13,506,750	$13,537,800

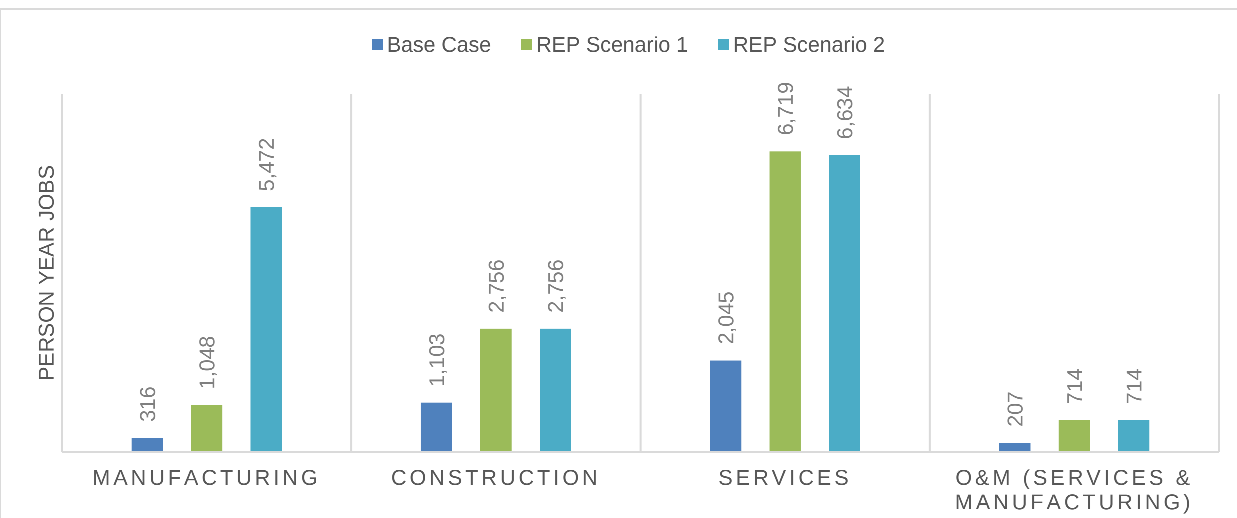
Source: Delphi Group and NREL JEDI Model

Local spending in Alberta related to project development and construction under REP Scenario 1 is estimated at $2.68 billion and $3.60 billion under REP Scenario 2 (the difference coming largely as a result of increased local manufacturing under REP Scenario 2). Direct O&M costs are estimated at approximately $140.6 million, with property taxes and land lease payments to Alberta land owners estimated at $25.5 million and $13.5 million respectively.

The impact on direct employment under the three scenarios is shown in Figure ES3, broken out by manufacturing, construction, services, and O&M activities.[6] Under the Base Case Scenario, approximately 3,464 direct person years of employment are generated during project development and construction phases, along with an additional 207 full-time equivalent jobs during the O&M phase.

By comparison, REP Scenario 1 generates approximately 10,520 direct person years of employment during the project development and construction phases for the 4,500 MW of wind farm development in Alberta, which are almost entirely realized in province. In addition, approximately 714 full-time equivalent jobs result from the O&M phase, split between jobs in services (396 jobs in total) and manufacturing (317 jobs in total). Under REP Scenario 2, approximately 14,862 direct person years of employment are generated during the project development and construction phases, with an equivalent amount of job creation in the O&M phase.

Employment impacts are similar under the two REP scenarios in terms of construction and services, where services show slightly higher employment in REP Scenario 1 due to more imported equipment requiring more transportation and logistics services. The major difference between the REP scenarios is expressed in the manufacturing portion of the supply chain, where REP Scenario 2 produces approximately 4,400 more jobs in manufacturing, particularly related to tower and blade production, as well as some minor turbine components and sub-station / transformer equipment manufacturing.



Source: Delphi Group and NREL JEDI Model

Figure ES3: Impact on direct employment from the development of 4,500 MW of wind energy in Alberta under the two REP policy scenarios versus the Base Case scenario.

[6] Services include: Professional services such as engineering, financial and consulting, wholesale and retail trade, utilities, transportation and logistics, permitting, government services, and other project development services.

It should be noted that the results presented in this report do not estimate the economic impacts from the construction of transmission and distribution infrastructure, or from the construction of related manufacturing plants as a result of increased wind sector activity. It also does not include the economic impacts from the potential export of manufactured components from Alberta to other jurisdictions. As such, it is assumed that the economic impacts are somewhat conservative.

Workforce Assessment

The province of Alberta has strong skills and a knowledge-based workforce foundation from the oil and gas industry that can be adapted and transferred to support wind energy sector development.

Alberta's technical colleges are working to get ahead of the demand for skilled workers in renewable energy with two institutions (i.e., Northern Alberta Institute of Technology and Lethbridge College) currently offering renewable energy and wind-specific programs, and two institutions with courses and programs under development (i.e., Medicine Hat College and Red Deer College).

Current capacity gaps in occupations that require more specialized knowledge and training on wind energy technology can be addressed through technical programs in Alberta, that are currently in place or under development, in order to meet the anticipated growth in wind energy projects across the province.

Supply Chain Activity	Workforce & Skills Capacity
Project Development	• Alberta has no shortage of expertise at present related to project development professions, with important universal skillsets in areas that include civil and project engineering, land acquisition, and environmental sciences. • Many relevant occupations are not wind specific, with the oil and gas industry providing a solid foundation.
Construction	• Alberta has significant workforce capacity in construction-related occupations, specifically project management professionals, industrial electricians, and trade workers / labourers whose skills could be adapted to carry out site preparation activities, as well as the final assembly and installation of wind turbines. • The installation of the wind turbines would demand trades such as cement masons to build the foundation for each turbine, as well as crane operators, welders, millwrights, electricians, and powerline technicians.
Operations & Maintenance	• Alberta has sufficient capacity in O&M related occupations which require skills that are easily transferable between renewable and non-renewable energy projects (e.g., Asset Managers). • There may be a capacity issue and subsequent skills gap for wind-specific jobs as the industry ramps up over the next few years, including with site-plant managers, wind turbine technicians, and meteorological technicians. • It is expected that demand will be met by important expertise from other parts of Canada or internationally as required.
Turbine Component Manufacturing	• Alberta's manufacturing job base is the weakest in relative terms of the four supply chain areas, with a potential shortage in terms of assemblers and fabricators, as well as with the more specialized and professional occupations, such as aerospace engineers. • Alberta does have some expertise in structural metal and platework fabrication as well as fibreglass manufacturing, and considerable strengths in industrial, design, and electrical engineering. • Assemblers and fabricators is a capacity gap that can be addressed with short-term technical training at the college level and/or with support from OEMs should the opportunity present itself.

Key Considerations

It is clear from this supply chain analysis that wind energy plays to Alberta's strengths. In many ways, wind project development is a continuation of what the province already does well and will support the continued growth and diversification of the provincial economy.

Given existing, well-established supply chains, Alberta may not receive the same economic spin-offs from a manufacturing perspective that early pioneering wind jurisdictions have seen. However, the development of wind energy projects in Alberta given the province's current situation in terms of timing will likely bring benefits in terms of access to improved turbine technology and lower overall project costs due to available global economies of scale.

In order to maximize the economic, social, and environmental benefits that will come from the adoption of more wind-powered electricity in Alberta, this report outlines three key areas for consideration: (1) Stable and supportive business environment; (2) Supporting workforce development and training; and (3) Promoting the research and innovation agenda. Details on each of these areas are outlined in the table below.

1. Stable & Supportive Business Environment

- Certainty is central to business and investment decisions; a clearly communicated, long-term procurement "roadmap" would benefit industry development.
- The structure of future procurement rounds is highly likely to impact the level and focus of economic benefits that will accrue to Alberta-based companies.
- Balancing reasonable costs for wind generated electricity with the potential for more local manufacturing should be considered in the development of future procurement rounds.
- Procurement clarity can help to avoid potential added costs of labour and equipment due to competitive market pressures.
- Streamlining permitting and regulations around transportation, particularly as it relates to working with federal and provincial governments in neighbouring provinces, will help to bring down project costs related to the import of turbine components.

2. Supporting Workforce Development & Training

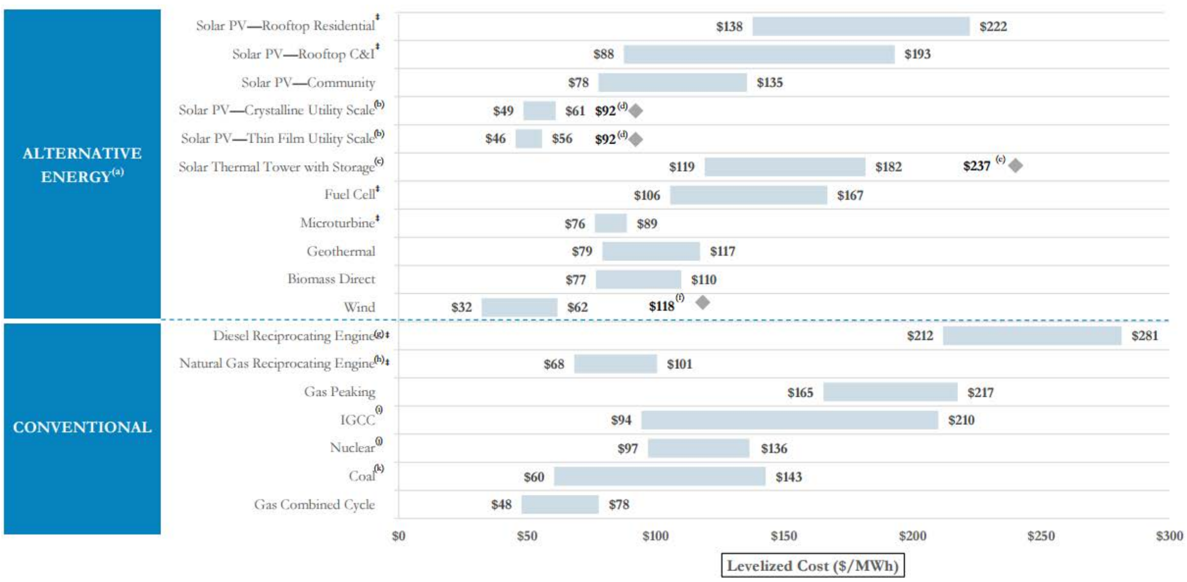
- Significant transferrable skills and occupations exist between wind and other energy sectors across all phases, including project development, construction, and operations and maintenance.
- In order to maximize employment potential from the growth of Alberta's wind sector, developing more skills in operations and maintenance will require specialized training, particularly for new job market entrants and for those living in communities near where wind farms will operate.
- Programs focused on relevant courses and continuing education for the trades will be essential to support retraining.
- Existing programs will need to continuously update courses and/or add new programming to reflect changing technology and trends.
- Government can play a key role in helping to facilitate knowledge exchange and relationships between OEMs and post-secondary education and training institutions.

3. Promoting the Research & Innovation Agenda

- Investments in innovation and R&D provide opportunities for Alberta to maximize participation of its knowledge-based workforce and potential for export over the longer-term.
- Areas for possible activation include innovation related to transportation and logistics, wind farm construction and turbine erection, smart grid and system integration, and around specific turbine component parts, such as investigating various blade materials (e.g., carbon fibre), jointed blades with different composites, tower designs, and additive manufacturing / 3-D printing.
- New digital-based technology and software solutions also show promise (e.g., virtual reality).
- An opportunity exists for the Provincial Government to work with Alberta-based innovation and funding agencies, as well as other levels of government, to create a renewable energy innovation roadmap for Alberta.

1. INTRODUCTION

In 2016, over 54,600 megawatts (MW) of new wind energy generating assets were installed world-wide, bringing the total installed global capacity to over 486,000 MW.[7] Part of the appeal of wind energy is the lack of greenhouse gas (GHG) emissions and low operating costs. Lazard in its "*Levelized Cost of Energy Analysis – Version 10.0*" estimates the levelized cost of unsubsidized wind electricity in the United States at $32-$62 (USD) per MWh, making it the lowest cost electricity generating option (see Figure 1).[8] For comparison, solar photovoltaic (PV) ranges from $46-$61 per MWh, combined cycle gas from $48-$78 per MWh, and coal from $60-$143 per MWh.



Source: Lazard, 2016

Figure 1: Comparison of unsubsidized levelized cost of energy (US $).

As such, the economic case for wind energy is growing and competing with electricity generation from all other sources. In Georgetown, Texas, for example, the local utility is now supplied by 100% renewable energy (solar PV and wind) because both solar and wind provide a fixed electricity cost lower than fossil fuel sources, helping the city avoid price volatility and the regulatory burdens arising from fossil fuel generated electricity.

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[7] Global Wind Energy Council, 2017. "Global Wind Statistics 2016", http://www.gwec.net/wp-content/uploads/vip/GWEC_PRstats2016_EN_WEB.pdf,
[8] Lazard, 2016. "Levelized Cost of Energy Analysis – Version 10.0", https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf

In Canada, electricity generation from installed wind capacity continues to grow. In 2016, an additional 702 MW of capacity was added, bringing the national total to 11,219 MW.[9] Alberta has been a pioneer in the Canadian wind electricity market. In fact, wind generation has been grid-connected in the province since the early 1980s, and the first commercial wind farm was installed in Southern Alberta at Cowley Ridge, near Pincher Creek, in 1993.

Nearly a quarter-century later, Alberta has approximately 1,491 MW of installed wind capacity from 38 projects that include 901 turbines, with wind power contributing roughly 6% of annual electricity generation to the Alberta grid in 2016. Since the first wind projects, the Alberta Electric System Operator (AESO) has also developed significant expertise incorporating the variable nature of wind generated electricity into the grid, and wind farm owners have developed the business case for ensuring profitable operations in Alberta's electricity market.

In terms of future potential, it is estimated that only 1% of Alberta's total potential wind energy resources are currently being utilized[10] and over one-third of Alberta's land base has wind energy sources suitable for wind energy production.[11] Under Alberta's Climate Leadership Plan, a renewable electricity target of 30% has been established, along with a planned phase out of coal-fired electricity by 2030. The Government of Alberta is supporting the development of 5,000 MW of new renewable energy capacity through funds derived in part from large GHG emitters. Such a strong commitment to renewables will lead to significant investment opportunities. A significant portion of the 5,000 MW of added capacity (potentially upwards of 95% according to some sources[12]) is expected to come from wind power. In fact, as of July 2017, there were a total of 53 proposed wind projects in AESO's connection project list with an equivalent of 8,036 MW. Commissioning of wind turbines will create project development and construction related jobs in Alberta, and will also present the opportunity for Alberta to participate to a greater extent in the broader wind energy value chain.

Increasing participation in Alberta in the wind energy supply chain will also lead to ripple effects across the economy, including more jobs and investment. Studies of the wind energy supply chain for other jurisdictions have identified these benefits. For example, a National Renewable Energy Laboratory (NREL) study on the impact of wind energy supply chain jobs in Texas estimated that for every 1,000 MW of installed wind capacity, the local economy could expect 2,100 full-time equivalent jobs and $260 million in economic activity during construction, followed by 240 permanent jobs and $35 million in annual economic activity during operating periods.[13]

In the United States, the wind energy industry invested over US $13.8 billion in new wind power projects in 2016, with a fleet of more than 52,000 turbines currently in operation. To support the growing wind industry, there are now more than 500 manufacturing facilities across 43 states in the US specializing in wind components such as blades, towers, and generators, as well as turbine assemblies, with the top three turbine manufacturers being GE Renewable Energy, Vestas, and Siemens (by cumulative share of the US wind turbine fleet). Growth of OEM activities in the US has driven local manufacturers to supply turbine sub-components (e.g., power transmission, electrical systems, structural products, equipment, and materials).

Some of the fastest growing states over the last five years include Texas, Iowa, Oklahoma, Kansas, North Dakota, and Colorado. However, what is interesting to note is that wind energy-related manufacturing is not always concentrated in

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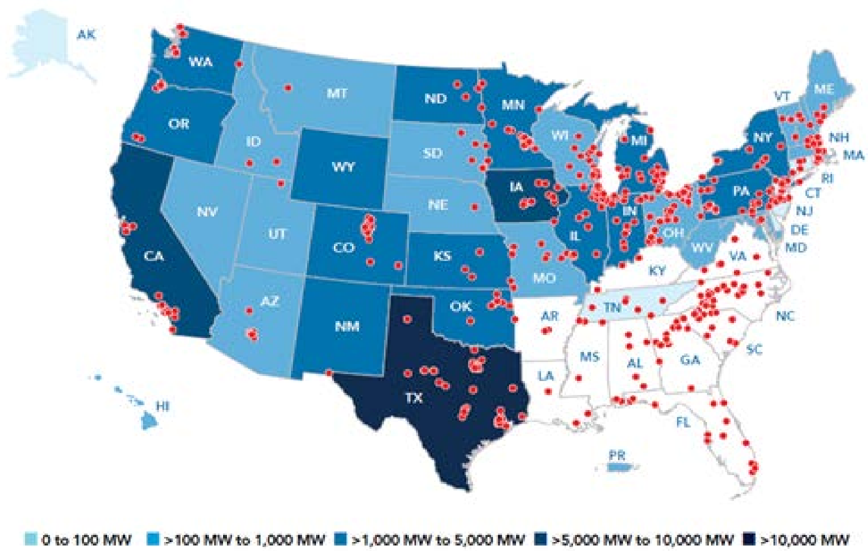
[9] Global Wind Energy Council, 2017. "Global Wind Statistics 2016", http://www.gwec.net/wp-content/uploads/vip/GWEC_PRstats2016_EN_WEB.pdf,
[10] See: https://www.pembina.org/reports/greeningthegrid-report.pdf
[11] See: http://www.alberta.ca/climate-leadership-plan.aspx
[12] From key informant interviews carried out as part of this study.
[13] NREL (2011). "Economic Development Impact of 1,00 MW of Win Energy in Texas". See: http://www.nrel.gov/docs/fy11osti/50400.pdf

the states with the greatest installed capacity. The east and southeast US, in fact, is a manufacturing hub, despite having no or few wind farms compared to other parts of the country (see Figure 2).



Source: American Wind Energy Association

Figure 2: Active wind-related manufacturing facilities in the United States at the end of 2015.

Cost of labour and existing capacity are important factors here, as are tax credits and incentives in some cases. In fact, many wind manufacturing facilities have resulted from the retooling of existing manufacturing plants in parts of the Northeast and Southeast United States for example.

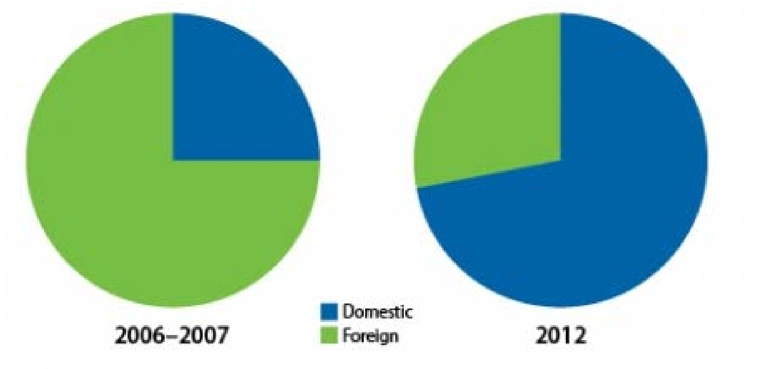
In addition, although domestic manufacturing content is strong for some wind turbine components, the US wind industry remains reliant on imports from many countries, with the level of dependence varying by component. Domestic content is highest for nacelle assembly (>85%), towers (80-85%), and blades and hubs (50-70%), but is much lower (<20%) for most components internal to the nacelle.[14]

As the wind energy sector grows in Alberta, manufacturing may present an area of new opportunity. Currently, niche manufacturing for the renewable energy value chain is limited in Alberta, with most required equipment and technology being imported into the province. However, it is often desirable from a business perspective for components to be produced closer to the installation site, particularly on the operations and maintenance (O&M) side. It is possible to reduce the need for imported content in wind energy projects as demonstrated in the United States, where in 2006-2007, the domestic content in wind turbines was approximately 25% and, by 2012, the percentage had jumped to almost 75% (see Figure 3).

That being said, Alberta comes somewhat late to the game. Many of the jurisdictions in North America considered early leaders in terms of large procurements of wind energy projects (e.g., Colorado, Iowa, Illinois, South Dakota, Texas, Ontario, and Quebec) often benefited from having manufacturing facilities set up in their state / province due to high demands for turbine components and equipment. At present, however, given existing well-established supply chains, Alberta may not receive the same economic spin-offs from a manufacturing perspective, although adding wind energy

[14] U.S. Department of Energy, 2015 Wind Technologies Market Report, p. vi. See: https://emp.lbl.gov/sites/all/files/2015-windtechreport.final_.pdf

projects relatively late will likely bring benefits in terms of access to improved turbine technology and lower overall project costs due to global economies of scale.



Source: US Department of Energy

Figure 3: Imported versus domestic content for US wind projects.

Alberta is in the midst of a once in a generation economic downturn that has seen the loss of tens of thousands of jobs in the oil and gas (O&G) sector. These lost jobs may never reappear as this sector faces changing market economics, efficiency improvements, and/or technology shifts such as automation. Jobs in different sectors are needed to absorb the highly-skilled workforce that is currently seeking employment in Alberta or is under-employed. Concurrent with the O&G downturn and job losses are diminished royalty payments to the provincial government from the natural resources sectors.

Moving Alberta forward requires diverse economic sectors that are not so heavily dependent on conventional natural resources or commodity prices for success. Such diversification could help the Alberta economy better absorb the boom-bust cycles that frequent the oil and gas industry. Organizations within the province, such as Iron and Earth, are advocating for retraining out-of-work Albertans for the next generation of jobs in the renewable energy sector value chain. This call aligns well with the large amount of renewable energy slated to be commissioned.

This study provides CanWEA, its members, and other stakeholders with an understanding of Alberta's existing wind energy supply chain and its investment potential, including an overview of existing players, insights on current gaps and potential growth opportunities, and the economic impacts from Alberta's wind energy sector as a result of the Province's Renewable Electricity Program. This report is broken out into the following chapters:

- **Chapter 2:** Results from the **supply chain analysis** which provides information and data on the current strengths, capacity, and gaps as it relates to Alberta's wind energy sector, as well as an overview of the potential growth opportunities for firms in the province.
- **Chapter 3:** Results from the **economic impact assessment** which provides an estimate of the potential economic and employment benefits of Alberta's growing wind sector across the supply chain, from project development through to construction, manufacturing, operations, and maintenance.
- **Chapter 4:** A **workforce profile** that maps key occupations relevant to the wind sector and providing data on existing workforce capacity, transferrable skills from other industries such as oil and gas, and existing education and training programs.
- **Chapter 5:** A number of top-level **recommendations** for maximizing the benefits of further developing and growing Alberta's wind energy sector and related jobs.

2. SUPPLY CHAIN ASSESSMENT

The wind energy supply chain includes more than 65 industries (at the six-digit NAICS code level) and a very broad range of activities from project development and construction, to O&M, and turbine component and equipment manufacturing.[15] This section explores existing strengths, capacity, gaps, and potential growth opportunities in Alberta across the range of related supply chain activities.

Project Development & Construction

- Project development includes a broad range of services from financial support to engineering, site surveying, and environmental consulting.
- Construction includes project management and a broad set of activities related to engineering and wind farm project construction.

Strengths & Capacity

Alberta has a long history of wind project development, with approximately 40 commercial projects having been developed in the province over the last three decades. Major project developers have included Enbridge, Suncor, TransCanada, TransAlta, EDF EN, and ENMAX. Additional smaller project developers based in Alberta include BluEarth Renewables, Northern Power, and GreenGate Power.

In addition to projects in the province, Alberta-based companies have developed approximately 32% of Canada's total installed wind capacity of 11,205 MW as of 2016 (see Table 1).

Table 1: Alberta-based companies with Canadian wind operations outside of Alberta.

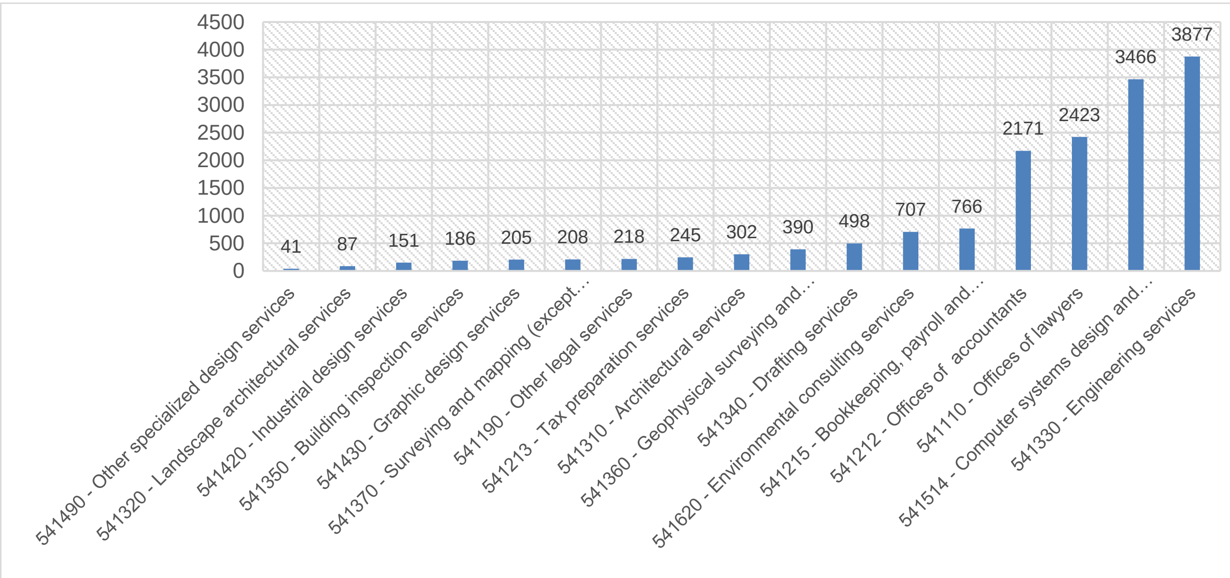
Company	Total Installed Canadian Wind Capacity outside of Alberta (MW)
AltaGas	102
BluEarth Renewables	29
Enbridge/Enbridge Income Fund	1,303
ENMAX	219
Suncor	287
TransCanada	365
TransAlta	1,329
Total	**3,634**

Source: CanWEA

[15] See Appendix E for the full list of relevant industries and existing capacity in Alberta.

Site Evaluation and Planning: Geo-technical engineering, site permitting, land negotiation, and environmental assessment (e.g., site monitoring expertise, firms active in archeology and cultural anthropology, environmental consulting, and scientific firms active in biology) firms and expertise are abundant in Alberta.

Figure 4 below illustrates the approximate number of companies with employees in Alberta active in relevant industries to upstream project development within the wind sector (at the 6-digit NAICS code level).



Source: Alberta business counts (with employees) – Statistics Canada, Q4 2016

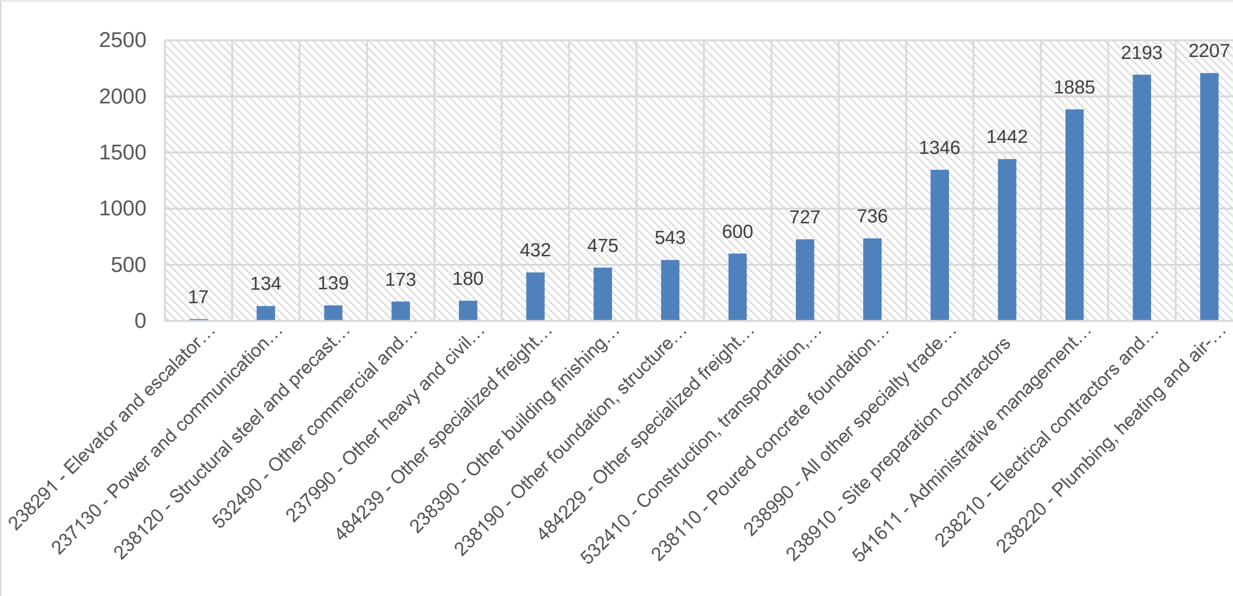
Figure 4: Alberta capacity by industry NAICS code relevant to wind project development and planning.

Engineering and Construction: Mechanical, structural, and civil engineering firms are abundant in Alberta with structural expertise that can be transferred to the wind industry, particularly in line with site preparation, including road construction, foundations and pads, and for the installation of towers.

Alberta also has significant capacity in terms of industrial project development and construction at present, including companies active in electrical, metal fabrication, and welding. In terms of construction materials, high-quality aggregate can be a scarce resource in Alberta but it does exist. Concrete companies (such as Inland Concrete), rebar, and cabling companies are relatively well-established with sufficient capacity.

Figure 5 below illustrates the approximate number of companies with employees in Alberta active in relevant industries to wind project construction (at the 6-digit NAICS code level).

Transportation and Logistics Services: Alberta has significant experience with moving large and heavy pieces of equipment (e.g., pre-fabricated buildings and equipment for the oil and gas industry), an expertise that can be leveraged for the wind sector. Alberta's heavy haul corridor, which extends from Edmonton North to Southern Alberta and into Saskatchewan, allows for equipment that is 25 feet wide, 45 feet high, and 120 feet long, weighing more than 500 tonnes.



Source: Alberta business counts (with employees) – Statistics Canada, Q4 2016

Figure 5: Alberta capacity by industry NAICS code relevant to wind project construction.

Transportation / logistics and craning are well established industries in Alberta, with leading companies having head offices in Alberta. Calgary-based Totran, for example, is involved with OEMs and rail companies, including CN and CP, to plan the transportation and logistics for the movement of most large wind project components in Western Canada (i.e., with the transport of turbine nacelles, towers, and blades to their pads at project sites).

Current Gaps

Research for this study identified no significant gaps in the project development and construction phases. While specific expertise in the last couple of years with site development / construction and wind turbine tower erection is lacking, transferrable skills are available from the oil and gas industry with minimal retraining required.[16] Expertise can also be imported from elsewhere in Canada (e.g., Ontario, Quebec, and British Columbia) as well as from the United States (e.g., Idaho, North Dakota, and Colorado).

Timing however is an important consideration. For example, if the oil and gas industry has a significant rebound, there are risks of shortages in terms of project development and construction expertise (e.g., with site permitting, environmental engineering, road building, industrial electricians, etc.). In addition, scheduling of project roll-outs in Alberta may impact on the cost and available of labour, as well as important construction related equipment such as large ‘crawler’ cranes that may have to be brought in from other global locations during turbine tower erection. This underscores the need for long-term clarity on procurement schedules and timelines for all 5,000 MW that the government will support, in order to avoid potential added costs of labour and equipment due to competitive market pressures.

[16] Based on Delphi’s workforce analysis and interviews with key informants from industry and Alberta’s post-secondary education / training institutions.

Areas of Opportunity

Site Evaluation and Planning: Environmental monitoring and site planning presents significant opportunities for local companies. Activities such as wind regime evaluation and the prospecting and location siting of towers is work that can be done by Alberta-based firms. Locally-developed software solutions such as Windographer can help with this activity for example.

Engineering and Construction: A large utility scale wind project (e.g., 200 MW project) will employ hundreds of engineering and construction workers during its pre-construction, construction, installation, and close-out phases over a 12-month cycle. Significant opportunities exist for companies involved in excavating, concrete, steel, metal fabrication / welding, electrical work, and control systems. In addition, civil engineering work in areas such as road building and site preparation will be important. For example, a 100 MW wind farm may require upwards of 50 kilometers of temporary roads depending on the project's location. The construction of sub-stations and cabling present additional immediate opportunities for Alberta firms as projects roll out. Transmission lines also may have to upgraded.

For the most part, the preference with project developers is to use local firms and suppliers for the relevant services. Project developers will often issue Request for Information (RFI) documents when developing a new project, providing opportunities for local companies to respond and get pre-qualified. Interviews for this study found that project developers appreciate when local firms are proactive in their interest to participate in wind energy development. Several interviewees indicated their interest in inviting these local suppliers to reach out in order to inform them of their capacity and expertise in specific areas of interest.

Local Alberta companies that do not have wind development experience are looking at novel financing and partnership models to gain market entry given the pressure on developers to be cost competitive with companies outside of Alberta in the first round of the REP, as well as the need to further develop wind project experience within the province. This includes up-front financing on construction requirements by the construction company. Developing a more modularized approach to building and installing infrastructure for turbines is also in line with Alberta expertise.

Transportation and Logistics: The transportation of and route planning for large turbine components and equipment present opportunities for Alberta firms, as wind projects are essentially logistics projects. However, the capital investment in equipment and trailers designed to transport wind turbine components may be a limiting factor to growth in Alberta. Companies from the US and/or Eastern Canada may provide competition to Alberta-based firms as the industry picks up.

OEMs are constantly looking at ways to improve the efficiency of their supply chains and reduce the installed cost of projects. OEMs prefer to use rail as a first priority for the movement of components and equipment at lower costs, although there has been a transition toward more trucking in recent years as components have become larger in size and struggle to get the clearance required for rail transport. For example, in the past, turbine blades were 50 meters in length with trains being configured specifically to carry these blades to distribution centres across North America. However, turbines can now have 62 and 69 metre blades where trucks are often the only transportation option.

Large wind turbine components such as blades and towers in the future may be imported to Alberta from Eastern Canada (e.g., Ontario and Quebec), through British Columbia (i.e., Port of Vancouver and Port Stewart), and/or the United States (through Washington State and Montana and/or from manufacturing facilities in states including, Oregon, North and South Dakota, Idaho, Colorado, Florida, and Texas) by CN or CP rail to rail siding sites (such as Transmark near Lethbridge) and then transported by inter-modal truck to wind project sites . Transportation companies involved in trucking and rail will need to adjust operations and related transportation equipment in order to accommodate growing volumes of wind sector components. Transportation and rail companies in Alberta are currently looking at establishing additional strategically and centrally located distribution centres in the province in order to accommodate a growing wind energy sector.

Heat Map Summary

The heat map summary below provides an overview of current capacity and future potential for participation in Alberta's project development and construction related supply chain activities.

Supply Chain Segment	Current AB Capacity	Opportunity for AB Participation	Comments / Notes
Site Evaluation	High	High	Expertise exists in site monitoring, surveying, environmental permitting work, and land negotiations, activities that are largely transferrable from the oil and gas sector (i.e., same skill sets, regulatory considerations, and government entities).
Site Preparation & Specialty Construction	High	High	Construction and engineering capacity and expertise is strong in Alberta (e.g., electrical systems and electrical cables, foundation structures and layouts, concrete re-bar, road building and civil works, etc.) for front-end development, including transferable skills from O&G and other sectors.
EPCs / Project Developers	Medium	High	Experienced EPCs exist in Alberta, although not those specialized in wind only projects. Project developers go out to local suppliers for sub-contracting on various services and materials / equipment.
Materials (e.g., concrete)	High	High	No identified gaps in terms of skills shortages in Alberta in this area. Will usually hire from the local area.
Metals (fabricators, pipe fitters, etc.)	High	High	No identified gaps in terms of skills shortages in Alberta in this area. Will usually hire from the local area.
Electrical & Control Systems	High	High	Mostly related to turbine installation, substations, and grid interconnection. Substation controls and synchronizing generation can be done in Alberta, as well as the balance of plant. However, little expertise / few opportunities exist from the turbine tower up to the nacelle components.
Transportation & Logistics Services	Medium	High	Strong logistics services in Alberta. A lot of strength in Alberta for handling large pieces of equipment / machinery (from the O&G industry).

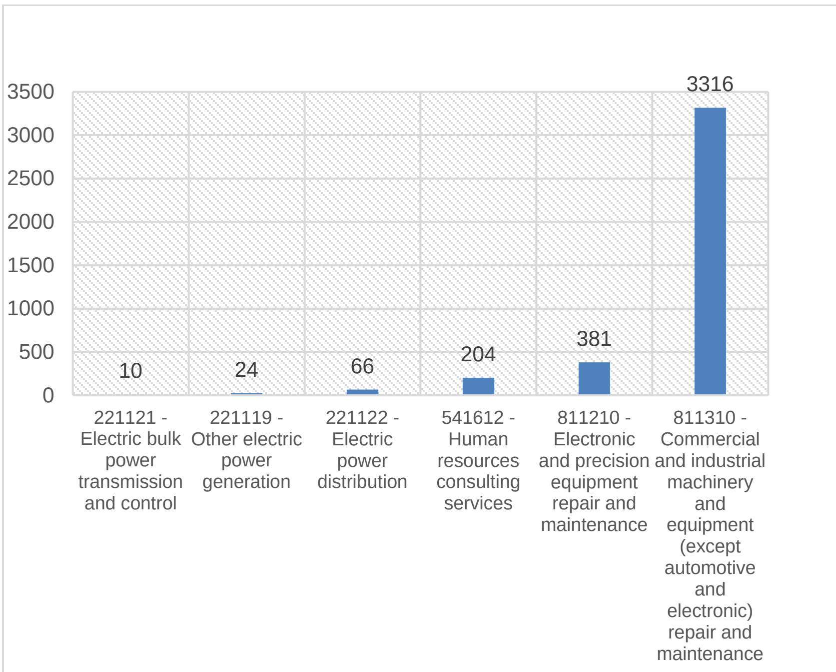
High
Medium
Low
None - Very Low

Operations & Maintenance

- Operations includes electric power generation and distribution, as well as engineering and management services.
- Maintenance includes repair and ongoing support services.

Strengths & Capacity

Figure 6 below illustrates the approximate number of companies with employees in Alberta active in relevant industries to wind project O&M activities (at the 6-digit NAICS code level).



Source: Alberta business counts (with employees) – Statistics Canada, Q4 2016

Figure 6: Alberta capacity by industry NAICS code relevant to wind project operations and maintenance.

Alberta's energy market has already experienced some diversity, with a number of project owners and utilities familiar with wind farm operations and maintenance. Companies such as ENMAX, ATCO, AltaLink, TransAlta, Enbridge, Suncor, and TransCanada are actively involved with O&M activities with existing wind farms inside and, in some cases, outside of Alberta. Site security and monitoring is another important responsibility undertaken by Alberta-based firms such as Sentinel Protection Services.

In house and/or sub-contracted operations teams are involved with regular maintenance and activities such as regular inspections, equipment lubrication, and instrumentation repair. There is also considerable transferability of skills from the oil and gas sector to wind operation O&M as it relates to electrical expertise, as well as monitoring from the Supervisory Control and Data Acquisition (SCADA) system, which needs to interface with the OEM control systems. Companies include Black & McDonald, Powell Canada, Campbell Scientific, and AWS Truepower.

Some operators and utilities have, in fact, been experimenting with wind farm technology innovation. AltaLink and TransAlta, for example, have been exploring flow battery potential on specific projects. In another case, TransAlta has been working with Tesla to develop a wind energy integration project backed up by Tesla's Powerpack storage solution.

In terms of the supply of equipment and parts for turbine component repair and maintenance, very few relevant parts are currently manufactured in Alberta. However, there are local companies involved in the production of industrial resins and lubricants that have applications to wind farm O&M, as well as suppliers such as Motion Canada that provide replacement parts with transferability to the wind industry such as bearings, hydraulics, pumps, and fittings. Some OEMs, such as Enercon, have also established service centres in Alberta for existing wind projects.

Current Gaps

While utility-scale wind farms have been operational in Alberta for nearly a quarter century, specialized and proprietary expertise is often needed for servicing and maintaining certain turbine components. For example, the control unit for a specific wind turbine is unique to the OEM and this very specialized knowledge is lacking in Alberta.

As a general rule, there is considerable expertise across Canada and North America and project owners / operators and OEMs bring in expertise from wherever it exists and/or move people into Alberta to do the work over the longer-term as required. Out-of-province expertise that has been called on for current wind-based activities in Alberta include firms such as Mortenson, One Wind, and Surespan Wind Energy Services.

In terms of turbine equipment, most large and specialized wind turbine equipment and component replacement parts (e.g., blades, nacelle components, etc.) are currently being imported to Alberta from outside of province or internationally.

Areas of Opportunity

On the services side, most of the O&M services are procured locally when possible in order to ensure ongoing community support for the project, although the opportunities vary by project on a case-by-case basis. As a growing critical mass of turbines get deployed in Alberta, it may make economic and operational sense to offer a broader range of support and service functions with spin-off opportunities within the province. As developers build a new wind project, there is usually a procurement phase for the O&M service, providing opportunities for local suppliers for example. As one example, the Blackspring Ridge project that was developed by EDF EN currently has Enbridge holding the operations contract.

Specific areas include grid and system integration, balance-of-plant operations, security systems, and the monitoring and maintenance of electrical, SCADA, and control systems. Depending on total wind project activities and the number of megawatts delivered, Alberta can expect to see a growth of operations centres, as well as centralized warehouse and distribution centres for spare parts and equipment repair. While some of the larger international firms will manage wind projects remotely from their operations head office (e.g., in Texas or Ontario), there is still a need for in-house or sub-contracted O&M expertise in Alberta for any onsite issues.

With the growth of wind farms in Alberta, more wind turbine technicians and operations-focused training presents an opportunity for local post-secondary education and training institutions in order to meet demand for this expertise. Companies look for individuals that are mechanically and technically inclined, have some experience in trades such as electrical, and are physically active and comfortable working at heights. This growing demand also presents a niche for the retraining of workers from the coal and O&G sectors.

The maintenance and repair of wind turbines is also likely to be the best opportunity for Alberta companies to participate in the manufacturing part of the supply chain. Opportunities will likely exist for local companies to supply parts and equipment that have failed or need to be replaced (e.g., motors, bearings, specialized electronics, etc.), as well as materials such as lubricants for ongoing operations. Entering the manufacturing supply chain at this phase of a project's life cycle makes more sense for the bulk of Alberta firms as it is likely an easier introduction to the technology and the industry as a whole for local companies, allowing the to be involved more closely with existing technology rather than trying to develop the latest in cutting edge turbine components and systems.

Heat Map Summary

The heat map summary below provides an overview of current capacity and future potential for participation in Alberta's project O&M related supply chain activities.

Supply Chain Segment	Current AB Capacity	Opportunity for AB Participation	Comments / Notes
Electric Power Generation & Transmission	Medium	High	Electric power generation companies running the operations of wind projects in Alberta are plentiful. The trend is to consolidate remote operations services through digital technology, which may impact on opportunities for Alberta-based firms. Smart grid and energy storage is another opportunity area.
Component Manufacturing	Low	Medium	As a critical mass of turbines gets developed in Alberta, there will be various support functions, including the repair of equipment and components. Some supply chain capacity exists already due to O&G industry, particularly around power electronics, control systems, and sub-stations.
Materials (e.g., lubricants, resins, etc.)	Low	Medium	Most of the materials / resources for maintenance are procured locally when possible. Some supply chain capacity exists already due to O&G industry.
Repair & Maintenance Services	Medium	High	As a critical mass of turbines gets developed in Alberta, there will be various support functions, warehousing, and service centres (makes economic and operational sense from a logistics standpoint).

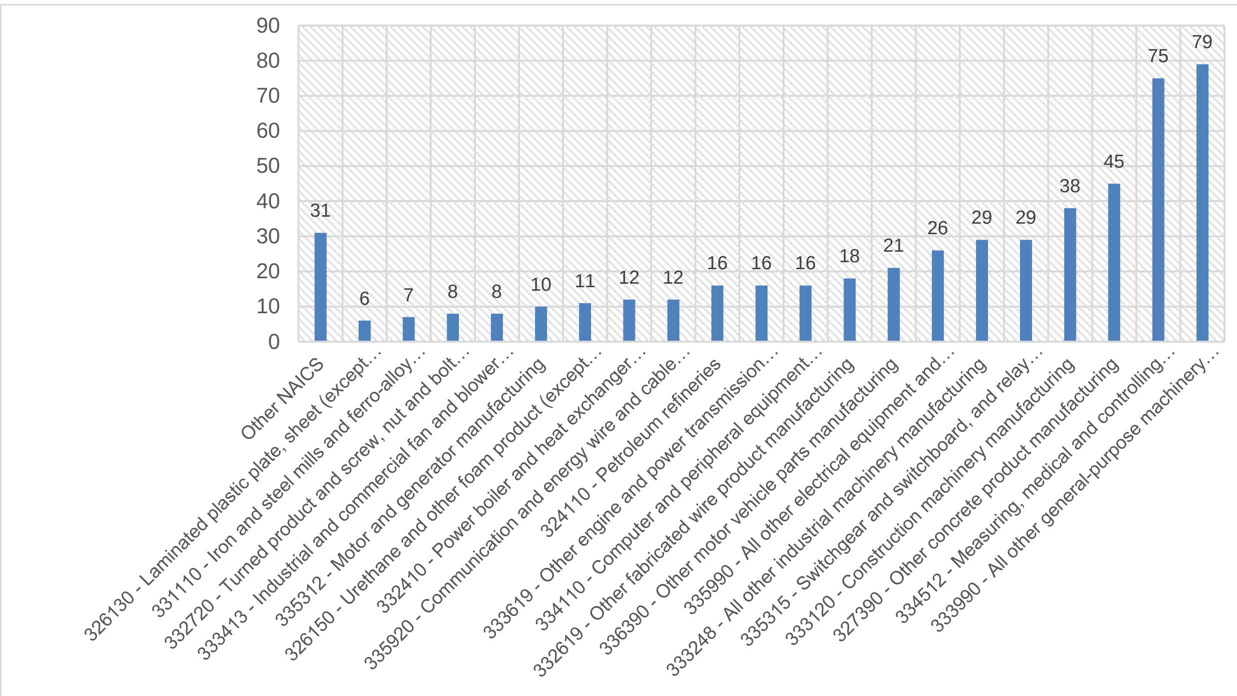
High
Medium
Low
None - Very Low

Wind Turbine Component Manufacturing

- Wind turbines consist of some 150 components and up to 8,000 individual parts that comprise the three main elements: the blades, the towers, and the nacelles.

Strengths & Capacity

Research for this study identified 37 industries (at the 6-digit NAICS code level) that are relevant to the manufacturing of wind turbines and related components. Figure 7 below illustrates the approximate number of companies with employees in Alberta active in relevant industries to wind turbine equipment and component manufacturing (at the 6-digit NAICS code level).



Source: Alberta business counts (with employees) – Statistics Canada, Q4 2016

Figure 7: Alberta capacity by industry NAICS code relevant to wind turbine component manufacturing.

Expertise and capacity is best aligned in the areas of transformers / sub-station control systems, switchgear, and some electrical and power electronics, although stiff competition with suppliers from the United States, Europe, and Asia create challenges from cost and, in some cases, performance perspectives. Materials such as cabling and concrete are also available in Alberta.

Expertise and capacity does exist in Alberta with respect to the potential for fabricating nacelle hubs, structures, and towers. For example, pressure vessel manufacturers in Alberta (such as KNM Process Equipment, Dacro Industries, and Cessco Fabrication and Engineering) have transferrable capabilities, with machinery that would be capable of taking 3-inch thick steel plating and rolling it to the required 24-foot tapered circumference in 33-meter sections that are then welded together to reach the 100+ meter tower structures.

Off-site, pre-fabrication and modularization is another area of expertise in Alberta that may present transferrable opportunities from the O&G industry to the wind sector in terms of driving down project costs, particularly as it relates to the design and construction of onsite electrical and O&M buildings for the balance-of-plant.

Current Gaps

Alberta currently lacks the expertise and capacity to manufacture the vast majority of specialized wind turbine components, particularly as it relates to nacelles, machine heads, and hubs, as well as the related electronic components, gearboxes, and generators.

The power electronics, braking, and control systems inside nacelles are proprietary in nature and vary by OEM. Many components are designed for specific wind turbine systems and are often non-interchangeable. While some control system expertise exists in Alberta, OEMs have developed optimized supply chains for key components and the first order of operation is to go with established suppliers to drive cost out of equipment through economies of scale and productivity gains.

In addition, while some transferrable infrastructure for equipment manufacturing from the oil and gas sector exists in Alberta, many of these smaller shops have been consolidated in recent months and are not set up to support wind assembly operations.

In terms of the potential for turbine blade manufacturing, some capacity currently exists with urethane product and industrial mould manufacturing; however, there is very limited fibreglass expertise or carbon fibre material manufacturing in Alberta at present.

While direct expertise is currently lacking in Alberta with respect to most areas related to turbine component manufacturing, it is fair to note that OEMs consulted for this study indicated that they will invest in training if the market opportunity makes economic sense, which in turn, depends on policy clarity, procurement predictability, and domestic market potential, as well as access to export markets given sufficient demand.

Based on the current situation in Alberta, it is expected that most wind turbine nacelle components will be imported from Ontario, Quebec, the United States, Europe, or Asia, depending on the OEM. Closer to home, Brandt Group recently purchased the former Mitsubishi-Hitachi wind turbine factory and is considering its potential for producing wind towers.[17]

Areas of Opportunity

Under Alberta's current REP 1 call for 400 MW, turbine components will almost entirely be imported by rail and/or truck from outside of province. That being said, similar to other Canadian provinces and some US states, some opportunities do exist for Alberta-based manufacturing of larger wind turbine components, including towers and blades, assuming a critical mass can be achieved amongst relevant OEMs and the economics favour local manufacturing over the transportation and logistics costs.

As an example, large procurement calls and local content requirements in Quebec over the last decade have resulted in growth of that industries manufacturing capacity and related employment, particularly in the Gaspésie region where concrete and steel tower manufacturing plants have been built, fiberglass blades are being produced, casings for power cabinets are manufactured, and some wind turbine electrical component assembly is taking place.

[17] See: http://thestarphoenix.com/business/local-business/brandt-group-plans-wind-turbine-factory-in-old-mitsubishi-hitachi-plant

While Alberta-based firms may have capacity in some areas, it is the landed cost of energy that is the ultimate determining factor for whether local suppliers may be able to access the supply chain opportunities.

Wind turbine OEMs have well-established supply chains, with the vast majority of nacelle components being imported into North America for assembly at established plants. OEMs must consider internal cost factors (such as factory loading and equipment purchasing), as well as external factors such as the latest cost of equipment, when determining the feasibility of local production. OEMs also require strong signals from government around procurement calls, in terms of both size and timelines, before they will commit to investing in manufacturing facilities.

Volume is the largest challenge at present with respect to the cost and effort to set up local manufacturing plants / facilities and for undertaking the training and technology transfer required. When developing new suppliers in the first few years, the cost equation for OEMs is usually going in the wrong direction given the lack of efficiencies from labour and production perspectives. As such, if the domestic demand for turbines and the export opportunities from Alberta to neighbouring provinces and/or other jurisdictions are not favourable, OEMs will revert back to their established supply chains.

In general, OEMs will be looking for a minimum volume of contracted turbines in order to consider nacelle manufacturing facilities. Given that this level of guaranteed direct award to a specific OEM in Alberta is unlikely, larger equipment pieces, such as towers, blades, and hub assemblies, likely present the largest opportunities for local manufacturing; particularly given the growing size of turbines as a general trend and the related rising costs for transportation and logistics.

Tower manufacturing is the most immediate opportunity given transferability from Alberta's O&G sector (e.g., pressure vessel manufacturers), the fact that OEMs prefer localized production to save on transportation costs, and the production facilities are easier to set up than for many of the other components. Steel towers support most of the OEMs, with exception of one specific model that uses concrete. However, it can take approximately one year to set up a new wind tower factory from one making pressure vessels and it can be very labour intensive. Alberta will likely compete with Saskatchewan for this investment, with the cost of rolled steel a key factor.

In addition, blades present a smaller opportunity for Alberta, particularly as blades may be outgrowing current factory capabilities potentially requiring new production facilities to be built. However, challenges for Alberta include the lack of fiberglass production expertise, strict quality standards for blade production making technology transfer more of an issue, and the costs with the development and movement of blade moulds to Alberta from other jurisdictions. At the same time, new technologies such as 3-D printing could revolutionize local production (see Figure 8).

Over the longer-term, Alberta-based companies may be able to pivot to supply equipment, parts, and components, particularly in the O&M phase.

Source: US Department of Energy

Figure 8: US Department of Energy cuts wind energy costs by 3-D printing gigantic wind blade molds in 6 feet tall sections.

The process for entering the wind component manufacturing supply chain typically involves suppliers connecting with OEMs to establish existing and potential capabilities, signing non-disclosure agreements, and undertaking equipment and technical process quality assessments. Commercial discussions (i.e., financial due diligence) and an assessment of engineering and management team capabilities are also conducted. Samples would be required in order to undertake quality checks. All in all, the process may take up to 2 years to complete.

Heat Map Summary

The heat map summary below provides an overview of current capacity and future potential for participation in Alberta's wind turbine component manufacturing supply chain.

Supply Chain Segment	Current AB Capacity	Opportunity for AB Participation	Comments / Notes
Turbine Hub / Nacelle Assemblies	None – Very Low	None – Very Low	OEMs expect to import turbine hubs and all components found within nacelle assemblies.
Gearboxes	None – Very Low	Low	Opportunities in this area relate only to ongoing maintenance / repair of turbine components, not manufacturing. Some transferable expertise from O&G exists.
Generators	None – Very Low	Low	Opportunities in this area relate only to ongoing maintenance / repair of turbine components, not manufacturing.
Power Electronics & Control Systems	Medium	Low	Opportunities in this area relate only to ongoing maintenance / repair of turbine components, not manufacturing. Some transferable expertise from O&G exists.
Towers & Main Shaft Structure	None – Very Low	Medium	Towers present a potential manufacturing opportunity in Alberta depending on policy certainty and size / timelines for the procurement calls in Alberta. Transferable expertise from O&G exists in Alberta, particularly inline with pressure vessel manufacturers.
Blades	None – Very Low	Low	Towers present a potential manufacturing opportunity in Alberta depending on policy certainty and size / timelines for the procurement calls in Alberta. Very little transferable expertise from O&G exists in Alberta, with minimal fiberglass manufacturing capacity at present.

High
Medium
Low
None - Very Low

3. ECONOMIC IMPACT ASSESSMENT

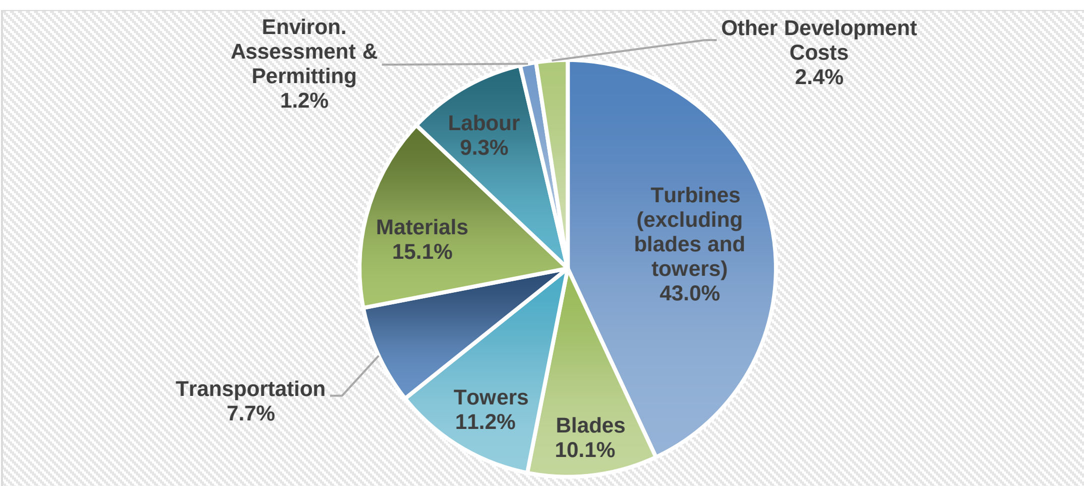
The potential economic impacts of the emerging wind energy industry in Alberta was estimated in line with the province's Renewable Electricity Program (REP) policy that calls for 5,000 MW of renewable energy capacity to be added by 2030. The economic impact assessment assumed that approximately 4,500 MW (or 90%) of the added capacity by 2030 would come from utility-scale wind farms, with the balance from other renewable energy sources, such as hydro and solar photovoltaic (PV). In addition, the economic impact from the growth of Alberta's wind energy sector in the absence of the REP was estimated as a comparison, based on AESO's load growth forecasts for electricity to 2030 prior to the current provincial government's Climate Leadership Plan.

The economic impacts were estimated using the US National Renewable Energy Laboratory's (NREL) Jobs and Economic Development Impact (JEDI) model which was first developed by NREL's WINDExchange program. The model is able to estimate the direct, indirect, and induced economic impacts of wind energy project development and operations, including related services (e.g., site preparation, construction, manufacturing, and operations and maintenance).[18]

The JEDI model was modified for the local market using Statistics Canada's Alberta-specific employment and Gross Domestic Product (GDP) multipliers in order to examine jobs, earnings, and output across three categories:

- Project development and onsite labour impacts;
- Local revenue and supply chain impacts; and
- Induced impacts.

Using the model, the costs were estimated for project development, equipment, and construction related to 100 MW of wind farm development in Alberta. These costs are illustrated in Figure 9 below and summarized in Table 2.



Source: Delphi Group and NREL JEDI Model

Figure 9: Project development, equipment, and construction cost breakouts for a 100 MW wind farm in Alberta.

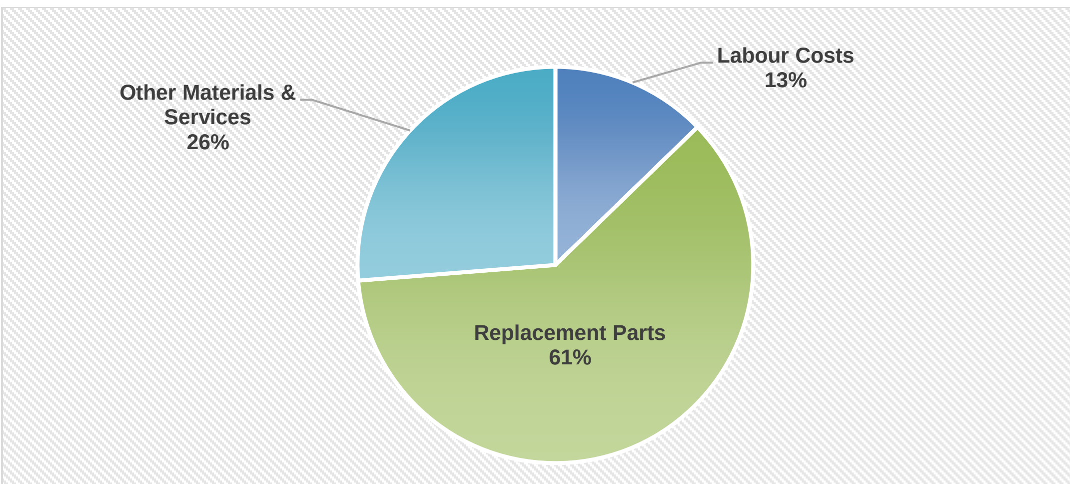
[18] See: http://www.nrel.gov/analysis/jedi/

Table 2: Project development, equipment, and construction costs for a 100 MW wind farm in Alberta.

Project Development, Equipment & Construction Costs	
Equipment Costs	$112,765,288
Turbines (excluding blades and towers)	$75,513,597
Blades	$17,678,769
Towers	$19,572,922
Transportation	$13,511,630
Materials	$26,461,158
Labour	$16,276,881
Environ. Assessment & Permitting	$2,175,717
Other Development Costs	$4,274,644
Total Costs (excluding taxes)	**$175,465,319**

Source: Delphi Group and NREL JEDI Model

Estimates for the cost breakout related to ongoing O&M activities over the lifetime of a wind farm are shown in Figure 10 and Table 3.



Source: Delphi Group and NREL JEDI Model

Figure 10: Project operations and maintenance cost breakouts for a 100 MW wind farm in Alberta.

Table 3: Project operations and maintenance costs for a 100 MW wind farm in Alberta.

Project Operations & Maintenance Costs	
Labour Costs	$398,500
Replacement Parts	$1,905,298
Other Materials & Services	$820,376
Total Costs (excluding taxes)	**$3,124,175**

Source: Delphi Group and NREL JEDI Model

Economic impacts were assessed under three "policy scenarios", with assumptions built into the JEDI model that were developed based on research and industry consultation. These policy scenarios are described in more detail below, with the results of the economic modeling presented in the section that follows. For more information on the methodology applied for the economic impact assessment, as well as more detailed breakouts on the JEDI modelled economic data for a 100 MW wind farm in Alberta, refer to Appendix A.

Policy Scenarios

Three policy scenarios were developed by Delphi, with input from CanWEA members, to help inform the economic modelling assumptions that were input into the JEDI model. The scenarios are outlined in Table 4 below.

Table 4: Policy scenarios related to the size and timing of wind project procurements in Alberta.

Policy Scenarios	Procurement Calls & Frequency	Policy Certainty	Impact on Alberta Manufacturing
Base Case Scenario	Approximately 1,496 MW of new wind generation capacity is procured in Alberta by 2030, based on AESO's 2014 Long-term Outlook (Main Growth forecast). However, timelines and procurement calls are unclear.	No REP exists; wind development is impacted by growth in demand for electricity, as well as Alberta's Specified Gas Emitters Regulation (SGER) policy and federal policy for the accelerated retirement of coal-fired electricity by 2030.	No manufacturing except for some O&M-related component repair and replacement activity.
REP Scenario 1	400 MW of new wind generation capacity is procured every year (2016-2028) in Alberta for a total of 4,500 MW of wind by 2028.	The provincial REP policy landscape lacks clarity around timelines for future procurement calls.	No manufacturing except for some O&M-related component repair and replacement activity.
REP Scenario 2	400 MW of new wind generation capacity is procured in 2016. 1,500 MW of new wind is announced every 3 years (in 2018, 2021, 2024), rolled out as 500 MW per year. Total of 4,500 MW of wind by 2027.	Clear provincial REP policy outlining a procurement roadmap to 2030 in partnership with AESO, with point allocations for some local content (although local content is not mandated).	Attracts wind tower manufacturing and some blade manufacturing in Alberta, as well as some components for O&M repair and replacement.

Source: Delphi Group

Under the REP Scenario 1, a lack of clarity around the size and frequency of future wind energy procurement calls results in very little to no manufacturing related to wind turbine components, with the exception of some repair and replacement related activity for some parts and small turbine components. It is assumed that approximately 30% of transportation and logistics costs will be paid to Alberta-based firms, reflecting the import of turbine and tower components.

Under the REP Scenario 2, a wind energy procurement roadmap to 2030 is established, outlining calls for power equal to 1,500 MW every three years, to be rolled out as 500 MW per year using a phased approach. Point allocations[19] are also assigned in order to give some priority to projects with higher local content and/or services, although local content will not be mandated. As a result, it is assumed that over the 11-year period (from 2016 to 2027), approximately 60% of all turbine towers for Alberta-based projects are produced locally, and 30% of turbine blades are manufactured in province.[20] In addition, it is assumed that approximately 5% of other turbine components (not including blades and towers) are manufactured or assembled in Alberta. Transportation and logistics costs paid to Alberta-based firms is approximately 25% of total costs given the lower need to import turbine towers and blades.

For comparison purposes, a Base Case Scenario was developed in order to examine the estimated economic impact from the growth of Alberta's wind energy sector to 2030 in the absence of the province's current Climate Leadership Plan (CLP) and the REP policy. To do so, Delphi assumed that load growth for electricity in Alberta to 2030 would be similar to forecasted demand in line with the Main Outlook in AESO's 2014 Long-term Outlook (LTO)[21], which was developed prior to the CLP policy being enacted. The Main Outlook in AESO's 2014 LTO estimated a total grid capacity of approximately 23,000 MW in 2029, which, by comparison, is slightly lower than AESO's 2017 LTO Reference Case grid capacity of 23,300 MW.[22] Under the Base Case Scenario, it is assumed that approximately 1,496 MW of new wind generating capacity would be added to Alberta's electricity grid by 2030. [23]

Under all three scenarios, it was assumed that the environmental assessment and permitting phase for wind project development in Alberta represents approximately 1.2% of total project costs. In addition, the cost for replacement parts during the O&M phase was increased by 1.5 times over the JEDI model's assumptions in order to reflect more harsh winters in Alberta.

Economic Impact Modeling Results

Total impacts from the development of 4,500 MW of wind energy in Alberta by 2030 is estimated to result in approximately $8.27 billion in installed project costs, as well as $1.37 billion in annual operational expenses (see Table 5). By comparison, the Base Case scenario that results in 1,496 MW of wind power capacity being added in Alberta by 2030 is estimated to result in $2.72 billion in installed project costs and $418 million in annual operational expenses.

Local spending in Alberta related to project development and construction under REP Scenario 1 is estimated at $2.68 billion and $3.60 billion under REP Scenario 2 (the difference coming largely as a result of increased local manufacturing under REP Scenario 2). Direct O&M costs are estimated at approximately $140.6 million, with property taxes and land lease payments to Alberta land owners estimated at $25.5 million and $13.5 million respectively.

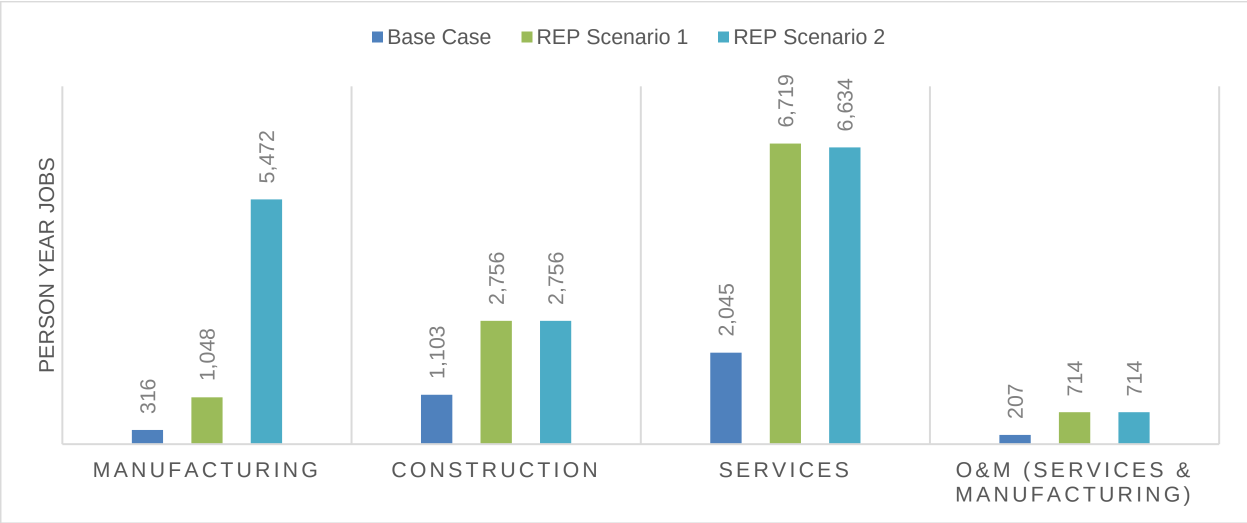
[19] Point allocations refers to awarding points for local content (products and services) that contribute to the overall scoring of wind projects in Alberta as part of AESO's procurement process.
[20] See Methodology section in Appendix A for more background on the assumptions.
[21] AESO 2014 Long-term Outlook: https://www.aeso.ca/downloads/AESO_2014_Long-term_Outlook.pdf
[22] AESO 2017 Long-term Outlook: https://www.aeso.ca/grid/forecasting/
[23] See Methodology section in Appendix A for more details on the Base Case Scenario and related assumptions.

Table 5: Total cumulative economic impacts from the installation of 4,500 MW of wind power in Alberta under the two REP policy scenarios versus the Base Case scenario.

Total Impacts	Base Case	REP Scenario 1	REP Scenario 2
MW of Wind Power Installed by 2030	1,496	4,500	4,500
Installed Project Cost	$2,724,639,315	$8,274,983,345	$8,274,983,345
Local Spending (Project Development – Alberta)	$837,959,855	$2,682,043,826	$3,602,613,311
Total Annual Operational Expenses	$418,130,842	$1,371,988,895	$1,372,019,945
Direct Operating and Maintenance Costs	$42,257,535	$140,587,870	$140,587,870
Local Spending (O&M – Alberta)	$41,109,909	$136,579,475	$136,579,475
Property Taxes	$7,787,340	$25,542,000	$25,542,000
Land Lease Payments	$4,115,930	$13,506,750	$13,537,800

Source: Delphi Group and NREL JEDI Model

The impact on direct employment under the three scenarios is shown in Figure 11, broken out by manufacturing, construction, services, and O&M activities.[24] Under the Base Case Scenario, approximately 3,464 direct person years of employment are generated during project development and construction phases, along with an additional 207 full-time equivalent jobs during the O&M phase.



Source: Delphi Group and NREL JEDI Model

Figure 11: Impact on direct employment from the development of 4,500 MW of wind energy in Alberta under the two REP policy scenarios versus the Base Case scenario.

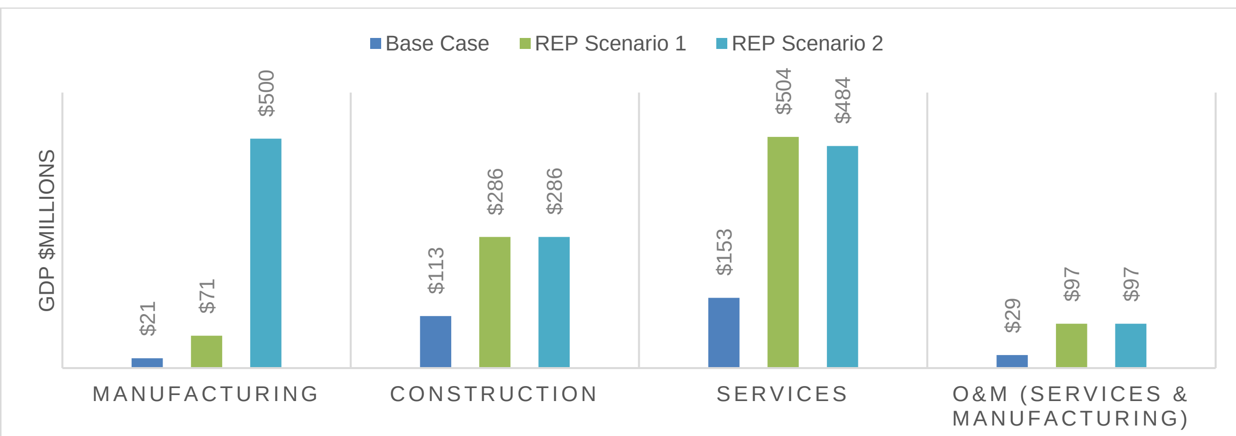
[24] Services include: Professional services such as engineering, financial and consulting, wholesale and retail trade, utilities, transportation and logistics, permitting, government services, and other project development services.

By comparison, REP Scenario 1 generates approximately 10,520 direct person years of employment during the project development and construction phases for the 4,500 MW of wind farm development in Alberta, which are almost entirely realized in province. In addition, approximately 714 full-time equivalent jobs result from the O&M phase, split between jobs in services (396 jobs in total) and manufacturing (317 jobs in total).

Under REP Scenario 2, approximately 14,862 direct person years of employment are generated during the project development and construction phases, with an equivalent amount of job creation in the O&M phase.

Employment impacts are similar under the two REP scenarios in terms of construction and services, where services show slightly higher employment in REP Scenario 1 due to more imported equipment requiring more transportation and logistics services. The major difference between the REP scenarios is expressed in the manufacturing portion of the supply chain, where REP Scenario 2 produces approximately 4,400 more jobs in manufacturing, particularly related to tower and blade production, as well as some minor turbine components and sub-station / transformer equipment manufacturing.

Figure 12 illustrates the impact on direct GDP from the development of 4,500 MW of wind projects in Alberta compared with the Base Case Scenario. Under the Base Case Scenario, approximately $287 million in direct GDP is generated during the wind project development and construction phases. By comparison, REP Scenario 1 generates approximately $860 million in direct GDP as part of the project development and construction phases while REP Scenario 2 generates approximately $1.27 billion in direct GDP.



Source: Delphi Group and NREL JEDI Model

Figure 12: Impact on direct GDP under the from the development of 4,500 MW of wind energy in Alberta under the two REP policy scenarios versus the Base Case scenario.

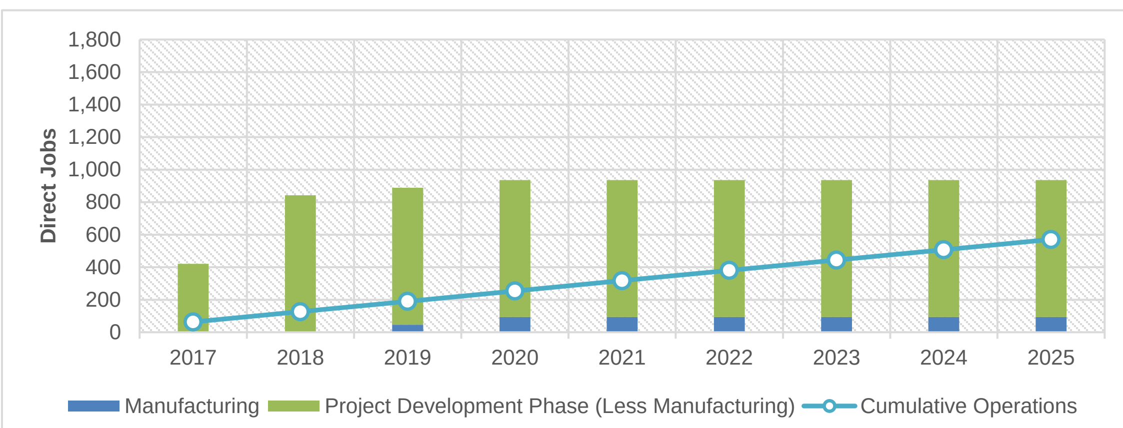
When indirect and induced impacts are considered, the total employment impact equals more than 21,350 jobs during the project development and construction phase for REP Scenario 1 and nearly 28,100 person years of employment under REP Scenario 2 (see Table 6). The O&M phase results in approximately 1,200 direct, indirect, and induced jobs. Direct, indirect, and induced GDP from the project development and construction phase equals nearly $2.4 billion for the deployment of 4,500 MW of wind projects in Alberta under REP Scenario 1 and more than $3.1 billion under REP Scenario 2.

Table 6: Direct, indirect and induced jobs and GDP in Alberta from 4,500 MW of wind energy project deployment.

During Project Development Phase	REP Scenario 1		REP Scenario 2	
	Jobs (Person Years)	**GDP** ($ millions)	**Jobs** (Person Years)	**GDP** ($ millions)
Manufacturing	1,498	128	8,382	880
Construction	9,406	1,287	9,406	1,287
Services	10,460	978	10,307	949
Total	**21,364**	**2,393**	**28,094**	**3,116**
During Operations Phase	**REP Scenario 1**		**REP Scenario 2**	
	Jobs (FTE)	**GDP** ($ millions)	**Jobs** (FTE)	**GDP** ($ millions)
Manufacturing	446	38	446	38
Services	764	122	764	122
Total	**1,210**	**160**	**1,210**	**160**

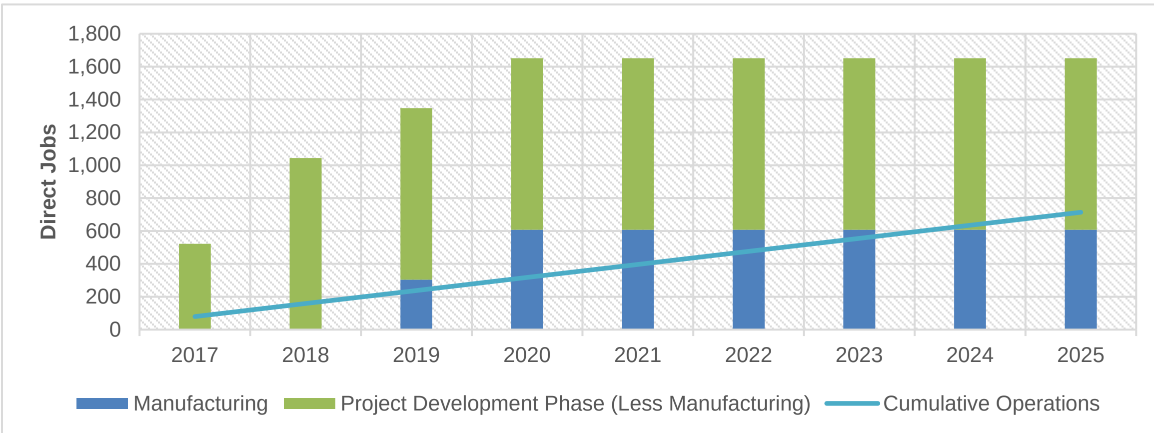
Source: Delphi Group and NREL JEDI Model

In terms of the timing and rollout of employment impacts, Figures 13 and 14 below illustrate the employment impacts related to manufacturing and project development, as well as the cumulative jobs during operations.



Source: Delphi Group and NREL JEDI Model

Figure 13: Estimated impact on direct employment from the development of 4,500 MW of wind energy in Alberta from 2017-2025 under REP Scenario 1.



Source: Delphi Group and NREL JEDI Model

Figure 14: Estimated impact on direct employment from the development of 4,500 MW of wind energy in Alberta from 2017-2025 under REP Scenario 2.

It is important to note that the results presented in this report do not estimate the economic impacts from the construction of transmission and distribution infrastructure, or from the construction of related manufacturing plants as a result of increased wind sector activity. It also does not include the economic impacts from the potential export of manufactured components from Alberta to other jurisdictions. As such, it is assumed that the economic impacts are somewhat conservative. It should also be noted that REP Scenario 2 provides protection against the cyclical nature of the industry by providing some stability to project costs through access to a more domestic supply chain that can be tailored to local demand and timelines.

4. WORKFORCE ASSESSMENT

The sections below provide an overview of the wind energy industry workforce, broken out by project development, construction, manufacturing, and O&M phases. In addition, information is provided on the education and training programs available in Alberta relevant to the wind energy sector. More detailed information and data on the Workforce and Education / Training Profiles can be found in Appendix F.

Key Wind Industry Occupations

Project Development

Alberta has no shortage of expertise at present related to project development, with important universal skillsets in areas that include civil and project engineering, land acquisition, and environmental sciences. Many of these occupations are not wind specific, with the oil and gas industry providing a solid foundation.

A potential capacity gap as it pertains to wind development exists for resource scientists and meteorologists, given they are not professions which are highly relevant to Alberta's primary energy industry (i.e., oil and gas).

Table 7: Key occupations in Project Development phase.

Job Title	NOC Code	AB Workforce[25]	Job Profile
Land Acquisition Specialist	1225	9,670	Land acquisition specialists (or Land Agents) acquire and administer land for project developers and coordinate with engineers, lawyers, scientists and community stakeholders to ensure wind projects comply with budgets, timelines, right-of-way permitting, recreation sites, and archeological sites.
Civil Engineer	2131	8,435	Civil engineers supervise the planning, design, and maintenance of wind farms, and implement environmental protection measures.
Power Systems - Transmission Engineer	2133	6,700	Transmission engineers are responsible for the safe design, construction and testing of electrical components of wind turbine designs, transmission, and distribution systems
Environmental Scientist	4161	4,055	Environmental scientists study the physical and wildlife sensitives of a project area and apply environmental regulations and policies to mitigate impacts from construction and operation of wind farms.
Project Engineer	0211	2,985	Project engineers support the project development and construction phase by integrating wind assessment studies, layout designs, and managing procurement of components and services.

[25] Total Alberta workforce estimates by NOC code are based on estimates from the 2011 Statistics Canada Census. While numbers have likely changed since that time, consultations with the Government of Alberta as part of this study suggests the deviation should not be material.

Resource Scientist	2115	200	Resource scientists study the interaction of weather, climate, and project site conditions to develop wind predications and turbine layout.
Meteorologist	2114	155	Meteorologists study the physical and chemistry dynamics and interaction of the atmosphere with land, water and climate to understand the impact on the economy and people's health and safety.

Construction

Similar to project development, Alberta has significant workforce capacity in construction-related occupations, specifically project management professionals, industrial electricians, and trade workers / labourers whose skills could be adapted to carry out site preparation activities, as well as the final assembly and installation of wind turbines. Construction workers are involved with building road access to the project site and managing traffic, operating equipment, preparing the project site and surrounding infrastructure, and assisting with assembly of turbine components. The installation of the wind turbines would demand trades such as cement masons to build the foundation for each turbine, as well as crane operators, welders, millwrights, electricians, and powerline technicians.

Table 8: Key occupations in Construction.

Job Title	NOC Code	AB Workforce [26]	Job Profile
Project Manager	0711	15,600	Project managers organize, direct and evaluate the construction of the wind plant and oversee the business development and bidding of projects.
Industrial Engineer	2141	1,900	Quality engineers work with quality control and quality assurance teams to develop processes, procedures and systems that ensure wind turbine components and processes meet quality standards and safety regulations.
Electrical Engineer	2133	6,700	Electrical engineers supervise, design, construct, and test wind turbine electrical components.
Quality Engineer	2141	1,900	Quality engineers work with quality control and quality assurance teams to develop processes, procedures and systems that ensure wind turbine components and processes meet quality standards and safety regulations.

[26] Total Alberta workforce estimates by NOC code are based on estimates from the 2011 Statistics Canada Census. While numbers have likely changed since that time, consultations with the Government of Alberta as part of this study suggests the deviation should not be material.

Trade Worker & Construction Workers	7611	21,000	Trade workers prepare and install turbines and support structures. Construction workers prepare and clean up the wind construction site, move materials and equipment, build access roads and assemble the foundation, tower, nacelle, and blades of wind turbines.

Operations & Maintenance

Alberta has sufficient capacity in operations and maintenance (O&M) related occupations which require skills that are easily transferable between renewable and non-renewable energy projects (e.g., Asset Managers). There may be a capacity issue and subsequent skills gap for wind-specific jobs as the industry ramps up over the next few years, including with Site-Plant Manager, Wind Turbine Technicians, and Meteorological Technicians, although it is expected that demand will be met by important expertise from other parts of Canada as required.

Table 9: Key occupations in Operation and Maintenance.

Job Title	NOC Code	AB Workforce [27]	Job Profile
Asset Manager	0125	1,595	Asset managers lead project financing and are responsible for developing and maintaining financial documents and records that are used by project developers.
Site-Plant Manager	0911	5,100	Site-plant managers oversee the wind plant systems and personnel by directing and coordinating operations for maintenance and repair, safety, performance, and profitability.
Environmental Science Technician	2231	5,100	The environmental science technician works with engineers, land surveyors and contractors to monitor and mitigate the wind plant's impact on species and habitats.
Wind Technician	2232	2,115	A wind technician apply their knowledge of pneumatic, electronic and microcomputers to install, inspect, maintain, operate, diagnose and fix wind turbines.
Meteorological Technician	2255	1,545	Meteorological technicians install, maintain, relocate and decommission towers and equipment used to collect the physical and chemical dynamics of the atmosphere and wind potential.

[27] Total Alberta workforce estimates by NOC code are based on estimates from the 2011 Statistics Canada Census. While numbers have likely changed since that time, consultations with the Government of Alberta as part of this study suggests the deviation should not be material.

Wind Turbine Component Manufacturing

Alberta's manufacturing job base is the weakest in relative terms of the four supply chain phases, with a potential shortage in terms of assemblers and fabricators, as well as with the more specialized and professional occupations related to aerospace engineers. Assemblers and fabricators is a capacity gap that can be addressed with short-term technical training at the college level and/or with support from OEMs should the opportunity present itself, particularly as it relates to O&M equipment and component repair and replacement activities. Aerospace engineering requires either increased enrolment at the post-secondary level or importing knowledge and skills domestically or internationally.

At the same time, Alberta does have some expertise in structural metal and platework fabrication as well as fibreglass manufacturing, and considerable strengths in industrial, design, and electrical engineering.

Table 10: Key occupations in manufacturing of wind turbine components.

Job Title	NOC Code	AB Workforce [28]	Job Profile
Welders and Related Machine Operators	7237 (AB 7265)	18,740	Welders are responsible for fusing together the steel components of the turbine for shipment to the final project site.
Structural Metal and Platework Fabricators and Fitters	7235	670	Structural metal and platework fabricators and fitters form, assemble, and fit the steel segments that comprise the steel tower of the turbine.
Fibreglass Manufacturers	9422	870	Fibreglass manufacturers are responsible for creating the fibreglass moulds to build the turbine blades.
Logistician	1215 (AB 0713)	3,200	Logisticians analyze, direct and coordinate the supply chain for all wind turbine components, from supplier to consumer.
Assembler and Fabricator	9525	255	Assemblers and fabricators are responsible for assembling parts and finished products (generators, computers, blades, towers).
Aerospace Engineer	2146	115	Aerospace engineers research, design, develop, and test the structures and systems of a wind farm from concept to production.
Electrical Engineer	2133	6,700	Electrical engineers design, construct, test, and supervise wind turbines' electrical components
Industrial Engineer	2141	1,900	Industrial engineers determine the most effective ways to eliminate wastefulness in wind turbine production processes.

[28] Total Alberta workforce estimates by NOC code are based on estimates from the 2011 Statistics Canada Census. While numbers have likely changed since that time, consultations with the Government of Alberta as part of this study suggests the deviation should not be material.

Quality Engineer	2141	1,900	Quality engineers work with quality control and quality assurance teams to develop processes, procedures and systems that ensure wind turbine components and processes meet quality standards and safety regulations.
Design Engineer	2132	7,685	Design engineers research, design, and evaluate wind turbine structure and components to ensure optimal generation of power at a low cost and reduced environmental impact.

The key takeaway from each supply chain related activity as it relates to the wind energy sector in Alberta is that the province has strong skills and a knowledge-based workforce foundation from the oil and gas that can be adapted and transferred to support wind sector development. Current capacity gaps in occupations that require more specialized knowledge and training on wind energy technology can be addressed through technical programs in Alberta that are currently in place or under development, to meet the anticipated growth in wind energy projects across the province.

Education & Training Programs

Renewable Energy Specific Training Programs

Alberta's technical colleges are working to get ahead of the demand for skilled workers in renewable energy with two institutions currently offering renewable energy and wind-specific programs, and two institutions with courses and programs under development.

The Northern Alberta Institute of Technology (NAIT) currently offers a 2-year Alternative Energy Technology program that prepares students for careers across several types of renewable energy technologies. The annual class size of the program is 24 students and provides a focus on the project development/construction and operation of renewable energy projects over the maintenance phase. Rapid changes are taking place within the program to match fast-paced technology development areas (such as micro-grids, energy storage, and digital software). While the vast majority of alumni work in Alberta, many have historically gravitated to jobs in solar, energy efficiency, mechanical engineering, or building envelope given the shortage of new wind project developments in Alberta in the last several years. Additionally, program instructors at NAIT point to the fact that wind industry show more interest in hiring those with experience in a parallel industry that they can transfer to the wind sector.

More specific to wind, Lethbridge College offers a one-year Wind Turbine Technician program with a total intake of 96 students each year. The program design is split 70:30 between O&M and project development / construction, and offers a Safety Certificate that saves companies from having to pay for safety training when hiring workers. Another feature that draws in both student and instructors to the program is its ties with the German BZEE Academy standard[29], a pioneer in wind energy training. The program is also currently looking at becoming a Certified Global Wind Organization Training Provider.[30]

[29] BZEE Academy GmbH (http://www.bzee.de/bzee/?lang=en – date accessed: May 2017).
[30] Global Wind Organization: Safety First (http://www.globalwindsafety.org/ - date accessed: May 2017).

A key area of struggle for both program providers is establishing co-op placements for their students due to the short program duration. In addition, project developers and OEMs are wary of liability risk.

In addition to the two programs outlined above, Medicine Hat College and Red Deer College are exploring renewable energy technology training programs. Medicine Hat College is focusing specifically at the development of trades (e.g., electricians) in order to provide additional training courses (i.e., continuing education), with the intention of eventually offering a certificate and diploma program similar to the program. Medicine Hat College is currently exploring ways to build synergies with nearby Lethbridge College. Finally, Red Deer College provides training and research opportunities through its Alternative Energy Innovation Lab Project and is expected to build on this over the coming years.

General Education & Training Programs

Professional occupations such as engineers, scientist, biologists, as well as trades and construction workers, are also valuable to the wind sector and require generalized education and/or training. The University of Alberta, University of Calgary, University of Lethbridge, MacEwan University, Concordia University of Edmonton, Mount Royal College, and Robertson College offer programs across engineering, science, biology, business and finance, law, and policy, all of which are relevant and necessary for a thriving wind sector.

Technical and trade schools, such as NAIT, SAIT, Red Deer College, Olds College, and Lakeland College are also well established across Alberta and offer training and apprenticeships for electricians, computer-controlled machine operators, crane and heavy equipment operators, ironworkers, parts and materials technicians who skills are easily transferable to wind project sites. Collectively Alberta's universities and technical programs also produce professors and instructors who offer experience and innovation as well as lead valuable R&D that can directly or indirectly impact technology, processes and policies that interact with the wind sector.

5. KEY CONSIDERATIONS

It is clear from this supply chain analysis that wind energy plays to Alberta's strengths. In many ways, wind project development is a continuation of what the province already does well and will support the continued growth and diversification of the provincial economy. In considering the key points outlined below, it is hoped that Alberta will be able to develop a sustainable wind industry while maximizing the economic, social, and environmental benefits that will come from the adoption of more wind-powered electricity in Alberta as part of the province's longer-term transition to a low-carbon economy.

1. Stable & Supportive Business Environment

As with any sector, certainty is central to investment decisions. The Government of Alberta's commitment to having 30% of the province's electricity coming from renewable sources by 2030 and its plans to add 5,000 MW of renewable energy capacity in that time frame has attracted a lot of interest from across Canada and internationally and is the biggest market opportunity for wind power development in the country at present. This commitment alone will result in economic benefits, as well as environmental benefits, for Alberta.

In considering future rounds of procurement, the policy scenarios and economic modelling results in this study point to a few conclusions and recommendations / suggestions. First, the structure of future procurement rounds is highly likely to impact the level and focus of economic benefits that will accrue to Alberta-based companies and, therefore, communities and governments. The difference however is evidenced mostly in manufacturing jobs and GDP impacts, with a difference of approximately 7,000 jobs and $400 million in GDP between the two REP scenarios modelled in this study.

Given this modeled impact, balancing reasonable costs for wind generated electricity with the potential for more local manufacturing should be considered in the development of future procurement rounds. Given the overall positive economic impact of wind power development, the detailed analysis of current capacities and future potential in this study points to the ability to target support for increased participation in wind power development with existing local capacity, and supporting greater workforce training investments that match the needs of the growing industry. The analysis for this study indicates targeted measures could focus on supporting tower manufacturing by existing pressure vessel manufacturers and the involvement of large construction firms in project development as examples.

To effectively maximize the investment opportunities, a clearly communicated, long-term procurement "roadmap" would benefit industry development. As modelled in REP Scenario 2 in this study, announcing large procurement plans (e.g., 1,500 MW every three years), rolled out in smaller, manageable phases may be an option for consideration. In addition, point allocation supporting local content, within the boundaries of Alberta's responsibilities arising from various trade agreements, may help to incentivize project developers and OEMs across the value chain. It is important, however, that any such incentives are balanced against any increased costs on project development and the landed cost of electricity.

Another area not fully explored in the research but noted by key informants is the opportunity to benefit from the cost and efficiency of wind power project development through streamlining permitting and regulations around transportation, particularly as it relates to working with federal and provincial governments outside of Alberta in neighbouring provinces. Issues around clearances and permits for routing are particularly an issue in British Columbia, which adds significantly to project costs. Despite the modern break bulk ports in the Metro Vancouver region and Port

Stewart, BC, Canadian ports have trouble competing because transportation and logistics costs over land to Alberta can be prohibitively expensive. Freight restrictions at Canadian ports also add cost challenges.

Finally, the Alberta Climate Leadership Plan clearly provides the thrust behind the 5,000 MW renewable energy capacity commitment. The extent to which climate goals and program implementation remain the sole policy objective for building 5,000 MW of renewable energy capacity by 2030 can impact future supply chain development in Alberta. For example, should future low carbon transition goals include a greater electrification of the economy, supported by energy storage developments, it is possible that a greater quantity of wind power be developed in the province.

Furthermore, similar to recent mechanism such as the Alberta Investor Tax Credit announced in 2016, the Government of Alberta could consider other levers it could employ, other than the procurement structure for future REP rounds, to meet economic diversification and development objectives.

2. Supporting Workforce Development & Training

Alberta has a well-established labour force of high value-added, service-oriented workers that are experienced in the energy industry. A great deal of baseline expertise exists in terms of energy system design, resource maximization, and with respect to driving cost efficiencies.

There are also significant transferrable skills and occupations relevant to the wind energy sector across all phases including project development, construction, and operations and maintenance. For example, Alberta's construction labour force has highly relevant skill sets and ample current capacity: a cubic meter of concrete is the same anywhere, building a temporary road in a field is straight forward, putting in power / distribution lines and installing a substation in a field is comparable to activities that have already been undertaken for an oil sands facility. In short, while Alberta has focused its skilled resources on oil and gas development, the existing knowledge base can be efficiently and effectively adapted to support the anticipated growth in Alberta's wind energy sector.

In fact, since the announcement of the Renewable Electricity Program in 2016, wind project development activities in Alberta have been ramping up, providing some respite to workers impacted by the downturn in the oil and gas sector in areas such as land negotiations, permitting, environmental consulting, and project management. That being said, wind sector growth in Alberta will likely never provide the level of opportunities required to absorb the 40,000 unemployed O&G workers at present so expectations must be realistic.

However, in order to maximize the employment potential from the growth of Alberta's wind sector, developing the more specialized workforce skills around operations and maintenance (e.g., wind turbine technicians) and manufacturing, should the opportunities present themselves, will require specialized training, particularly for new job market entrants, as well as retraining for those living in communities near where wind farms will operate.

There is an opportunity for government to work with industry, post-secondary institutions, and organizations such as Iron and Earth to retrain workers in communities impacted by coal plant closures for example and provide clear employment pathways into the wind sector. Programs focused on relevant courses and continuing education for the trades are helpful, such as the ones being offered by Lethbridge College and proposed by Medicine Hat College. This will take some coordination with winning project developers, as well as wind farm owners / operators, to support them in the recruitment of qualified workers and professionals.

More base funding from the Province may be required to add seats for permanent training in line with future industry growth and demand. Alberta universities, research centres, colleges, and other training institutions will need to invest in wind energy specific courses, applied research, and training / education programs in order to be able to capitalize on both the expanding market (e.g., to avoid a shortage of local qualified technicians to maintain, repair, upgrade, etc.) as well as stay abreast with the evolution of technology.

For example, trends in areas such as digitalization and remote operations of wind farms (e.g., Industrialized Internet of Things, smart grid, and ICT software), new advanced manufacturing opportunities and related skills (e.g., related to 3-D printing and the integration of virtual reality), and innovative design changes for blades and towers, are all key points of information exchange that can benefit both educators and industry.

Existing programs will need to continuously update courses and/or add new programming to reflect changing technologies and interest from the workforce for updating their skills. The Trades and Technologies Renewal and Innovation Project (TTRIP) that will see a new $65 million trades and technology building constructed at Lethbridge College, for example, will dramatically update and expand facilities for the current Wind Turbine Technician program with modern shop spaces, classrooms, offices, labs, and applied research spaces. [31] However, more support for the program specifically could help with ongoing course enhancements and equipment modernization in order to make the program truly world class.

There is also an opportunity for OEMs in Canada and wind industry leaders operating out of Alberta do more around providing training programs, which could include site tours, running safety scenarios, and training around component change-outs in order to engage potential employees and improve coherence between industry goals and graduate skill sets.

While NAIT and Lethbridge College are producing skilled workers in renewable energy sectors, a gap currently exists in terms of collaboration and communication between industry and educators with establishing a clear understanding of the skills OEMs value and which technology trends they are adopting. Communication between industry and educators would also be fundamental to developing standards and skills categorization, which is another clear gap in the training / education opportunity across all renewable energy sectors.

Government can play a key role in helping to facilitate this knowledge exchange and foster relationships between OEMs and post-secondary education and training institutions. This can be done by helping to convene the various stakeholders, supporting two-way communication between industry and relevant training bodies, and investing in joint initiatives that allow industry and academia to work more closely together around training opportunities. There are also opportunities to market the skills of graduating students outside of the province and internationally.

3. Promoting the Research & Innovation Agenda

Innovation and research and development (R&D) provide opportunities for Alberta to maximize participation from its knowledge-based workforce in the development of the local wind industry, positioning it well for the longer-term with possibilities of exporting this expertise. There is a clear link between investing in innovation and creating economic benefits when it is targeted and supported appropriately.

From a research perspective, Alberta currently has three Industrial Research Chairs focused on renewable energy technology areas, predominantly wind and solar (two at the University of Calgary and one at the University of Alberta).

[31] Learning Innovation: Lethbridge College Trades Technologies Renewal & Innovation Project (http://www.entuitive.com/project/lethbridge-college-trades-technologies-renewal-innovation-project-ttrip/ - date accessed: May 2017).

Areas for possible activation include innovation related to transportation and logistics, wind farm construction and turbine erection, smart grid and system integration, and around specific turbine component parts, such as investigating various blade materials (e.g., carbon fibre), jointed blades with different composites, tower designs, and additive manufacturing / 3-D printing.

As an example, carbon fibre manufacturing already exists for large storage tanks from the O&G industry in Alberta, which could be retooled for turbine blades. Alberta also has significant expertise and capacity in modular construction, which could be applied to towers and nacelle packages.

Automation technology could be applied to bring down the costs of tower construction and assembly (e.g., automated welders currently being used by the O&G industry for pipelines).

New digital-based technology and software solutions also show promise (e.g., the Alberta-developed Windographer software, now widely adopted by industry and recently purchased by AWS Truepower). Lethbridge College, for example, is currently experimenting with virtual reality as a training tool for students in its Wind Turbine Technician program.

Applied research to improve wind energy integration with the smart grid in Alberta, in line with energy storage solutions, could help improve grid stability and reliability. Medicine Hat College's micro-grid demonstration project allows industry to "plug-and-play" with technology in order to test new solutions and showcase effectiveness, with potential benefits for Alberta's wind sector development as well as training opportunities. In addition, a focus optimizing the O&M of wind turbines in colder climates could present new opportunities for research. As one example, current research at the University of Calgary is focused on preventing wind blade icing.

An opportunity exists for the Provincial Government to work with Alberta-based innovation and funding agencies (e.g., Alberta Innovates, Emission Reduction Alberta, AESO, research institutions, and others) and other levels of government to create a renewable energy innovation roadmap.

APPENDICES

Appendix A: Study Methodology

The Delphi Group undertook the supply chain study for CanWEA from April to July 2017. The project was broken out into three primary Research Packages, described in more detail below.

Research Package 1: Supply Chain Assessment & Database Development

Supply Chain Mapping & Trends Analysis

The Delphi project team undertook secondary research and a literature review on the approaches used by other jurisdictions in North America that have succeeded in growing a viable wind energy industry in the last five years, including Ontario, Quebec, and several US states with some of the fastest growing wind energy sectors, including Iowa, North Dakota, and Colorado.

The Delphi project team also examined in detail supply chain publications for the wind power sector using a number of key sources and multiple lines of evidence, including:

- Data drawn from reports published by CanWEA and other relevant industry and government organizations in Alberta;
- The Wind Power Renewable Energy Hand Book[32] and the Wind Energy Industry Manufacturing Supplier Handbook by AWEA.[33]
- The US Wind Energy Manufacturing and Supply Chain Competitiveness Analysis report.[34]
- Other provincial, regional, national, and international studies on the wind energy sector and related value chain; and
- Local intelligence held by industry experts and other stakeholders in Alberta and across Canada / internationally where relevant.

The Delphi project team identified the equipment, components, and service-based industries of the wind energy supply chain – including for project development and construction, operations and maintenance, and for the wind turbine manufacturing – in order to map the wind energy supply chain to the relevant, best-fit NAICS[35] codes (for primary and supporting industries / services) and Harmonized System (HS) commodity codes (for the most relevant wind turbine components) to develop a statistical framework for the collection of data. This statistical supply chain framework was further validated by confirming NAICS through various sources.

Once the full wind energy supply chain (i.e., relevant equipment, components, and services) was mapped out in adequate detail, the Delphi project team cross-referenced this information with a domestic supply chain assessment for the province of Alberta in order to identify supply chain strengths and gaps using a prepared custom tabulation of

[32] See: http://www.windpowerengineering.com/digital-issues/2016-renewable-energy-handbook/
[33] See: http://awea.files.cms-plus.com/FileDownloads/pdfs/Supplier-Handbook.pdf
[34] See: https://energy.gov/sites/prod/files/2014/09/f18/U.S.%20Wind%20Energy%20Manufacturing%20and%20Supply%20Chain%20Competitiveness%20Analysis_0.pdf
[35] NAICS = North American Industry Classification System

the business establishments in each of the relevant NAICS codes for the wind energy supply chain in Alberta.[36] The Business Registry database provides specific details of business counts by employment size groups by location at the six-digit NAICS level. Employment estimates based on these size groupings historically have been a close fit to other sources including the National Household Survey and the Labour Force Survey when aggregated and we have used this approach successfully in the past for estimating employment within renewable energy industries.

Additional information by industry code was supplemented by specific research on more niche and/or specialized products, equipment, and services across the wind energy supply chain that generally cross-cut the NAICS code structure. Delphi also worked to identify companies present in Alberta with potentially transferable capabilities / adaptabilities (based on NAICS code) although not currently active in the wind energy supply chain.

The Delphi project team also undertook a global scan of technology trends that are expected to impact on the wind energy industry and, in turn, the value chain of products and services. This assessment considered how technology trends such as the digitization of the renewable energy sector, micro-grids and energy storage, the Internet of Things, big data analytics, and potentially disruptive technologies such as 3-D printing, robotics, virtual reality, and artificial intelligence may impact on the wind energy industry and, in turn, the potential opportunities and risks for the related supply chain in Alberta.

Supply Chain Database Development

Building on existing databases, the Delphi project team worked with both publicly and privately available business directories and databases to compile a list of more than 350 relevant companies and organizations currently active across Alberta's wind energy supply chain. Particular attention was paid to Alberta-based suppliers of potential wind energy project components, equipment, and services versus out-of-province / international suppliers that may be involved in project development but not have an office or physical presence locally.

Relevant companies were identified through secondary business data, trade / membership body databases, and the research team's knowledge of key businesses and networks in Alberta. Directories include the Industry Canada Company Capabilities database, Hoover's / Dun & Bradstreet, industry association membership lists (including CanWEA and the Alberta Clean Tech Industry Alliance), and various directories either published by or linked to by government agencies (e.g., the Government of Alberta and Calgary Economic Development).

Identification of Supply Chain Gaps & Opportunities

Based on the analysis and extensive research carried out above, the Delphi project team conducted an analysis of the strengths, gaps, and opportunities associated with Alberta's wind energy supply chain. The supply chain gap analysis highlighted key observations as it relates to the Alberta's wind energy sector weaknesses in line with current local / domestic participants. Delphi's research also compiled a list of supply chain needs that are currently not being met by Alberta companies.

Delphi validated the gap and opportunities analysis through strategic and target industry outreach with the high-level data being refined and supplemented through outreach and the interview process described below. The Delphi project team then developed recommendations aimed at prioritizing opportunity areas for local company growth and potential cluster development, as well as opportunities for greater investment attraction. The identification of opportunities takes into account global industry and technology trends in the wind sector, existing supply chains for OEMs, as well as landed energy costs, in order to identify what type of investment and employment opportunities may exist for Alberta-based companies and how subject matter experts may be able to participate in this growing value chain.

[36] http://www.statcan.gc.ca/daily-quotidien/160219/dq160219e-cansim-eng.htm

Key Informant Interviews

The Delphi project team undertook a series of 20 key informant interviews with a diversity of players across the wind energy value-chain in Alberta in order to build on existing knowledge, fill-in research gaps, review the relevant industry and technology trends, and validate the supply chain analysis. Formal questionnaires for the interview process were developed by the Delphi project team with input from CanWEA. Interviews were conducted with individuals from the following groups:

- Wind energy project developers;
- Equipment and technology suppliers and OEMs;
- Firms supplying services to the wind energy supply chain (construction firms, engineering / consulting, distributors / suppliers, and transportation / logistics); and
- Government bodies, industry associations, and post-secondary institutions.

Research Package 2: Workforce & Training Program Assessment

Development of Workforce Profile

The Delphi project team generated a profile of the current wind energy sector workforce in Alberta by developing a list of occupations (based on 4-digit National Occupational Classification or NOC codes) relevant to the wind energy industry value chain (including project / site development, construction, manufacturing, operations, and other support services).

The Delphi project team collected information and data from secondary sources in order to create a workforce profile that highlights the size of the current and potential future workforce, transferable roles from conventional energy and the analogous roles in the wind energy sector, and strengths and gaps in the labour pool. Data sources to support the profile included relevant statistical information on skills capacity (by NOC code) using Statistics Canada Labour Force Survey data, from the US Bureau of Labor Statistics "Careers in Wind Energy" webpage[37], from the US Department of Energy's "Wind Career Map"[38], and from the Government of Alberta's ALIS website[39].

Mapping of Current Training Opportunities

The Delphi project team conducted secondary research to map current vocational training opportunities that exist for the wind energy sector labour force in Alberta. Institutions examined in the assessment include the University of Alberta, the University of Calgary, Lethbridge College, Lakeland College, Northern Alberta Institute of Technology (NAIT), the Southern Alberta Institute of Technology (SAIT), and other courses offered in province and/or out-of-province / online (e.g., Oak Leaf's Wind Energy Fundamentals Training course). Additional information was gathered and secondary research vetted through stakeholder interviews with key post-secondary institutions and training bodies as per the interview process outlined above.

[37] See: https://www.bls.gov/green/wind_energy/
[38] See: https://energy.gov/eere/wind/wind-career-map
[39] See: https://occinfo.alis.alberta.ca/occinfopreview/info/browse-occupations.html

Research Package 3: Economic Impact Assessment

Estimating the Economic Impact on Alberta's Wind Supply Chain from the REP

To estimate the potential economic impacts of the emerging wind energy industry in Alberta in line with the province's Renewable Electricity Program (REP) policy, the Delphi project team developed two REP policy scenarios, as well as a Base Case scenario to compare the economic impacts from growth of Alberta's wind energy sector to 2030 in the absence of the REP. A series of assumptions were developed and vetted / validated by CanWEA Project Committee members and served as inputs into the NREL's Jobs and Economic Development Impact (JEDI) model.

The JEDI model has been specifically developed in order to estimate the direct, indirect, and induced economic impacts of specialized renewable energy technologies and related services, in this case wind industry development (e.g., site preparation, construction, manufacturing, etc.).[40] JEDI shows realistic expectations of what economic impacts are achievable based on the current domestic supply chain and what level of imported services, products, and components are likely for specific jurisdictions. The Delphi project team worked with a contact at NREL in order to modify the JEDI model with Alberta-based economic multipliers published by Statistics Canada to make the model highly relevant to the Alberta market.[41]

The economic impact assessment included an examination of project design, materials and equipment manufacturing and trade, construction, and operational activities, and was used to provide an estimate the economic potential that Alberta's REP may have from two potential, realistic policy scenarios related to the procurement of wind energy projects in Alberta by 2030, including on GDP, jobs, and investments.

The economic impact assessment assumed that approximately 4,500 MW (or 90%) of the added 5,000 MW of new capacity by 2030 would come from utility-scale wind project, with the balance from other renewable energy sources, such as hydro and solar photovoltaic (PV). The two REP scenarios and the Base Case scenario are outlined in Table A1 below.

Table A1: Policy scenarios related to the size and timing of wind project procurements in Alberta.

Policy Scenarios	Procurement Calls & Frequency	Policy Certainty	Impact on Alberta Manufacturing
Base Case Scenario	Approximately 1,496 MW of new wind generation capacity is procured in Alberta by 2030, based on AESO's 2014 Long-term Outlook (Main Growth forecast). However, timelines and procurement calls are unclear.	No REP exists; wind development is impacted by growth in demand for electricity, as well as Alberta's Specified Gas Emitters Regulation (SGER) policy and federal policy for the accelerated retirement of coal-fired electricity by 2030.	No manufacturing except for some O&M-related component repair and replacement activity.
REP Scenario 1	400 MW of new wind generation capacity is procured every year (2016-2028) in Alberta for a total of 4,500 MW of wind by 2028.	The provincial REP policy landscape lacks clarity around timelines for future procurement calls.	No manufacturing except for some O&M-related component repair and replacement activity.

[40] See: http://www.nrel.gov/analysis/jedi/
[41] Sources for the Alberta-specific economic multipliers include:
- Jobs and Economic Development Economic Impact Model Wind
- Statistics Canada, Provincial Input-Output Multipliers, 2010, Catalogue no. 15F0046XDB
- Statistics Canada, Table 203-0021 Survey of household spending (SHS), household spending, Canada, regions and provinces annual (dollars)
- Statistics Canada, Labour Force Survey, Construction Union Wages Table 327-0003
- Statistics Canada, Survey of Employment, Payrolls and Hours (SEPH) various tables

REP Scenario 2	400 MW of new wind generation capacity is procured in 2016. 1,500 MW of new wind is announced every 3 years (in 2018, 2021, 2024), rolled out as 500 MW per year. Total of 4,500 MW of wind by 2027.	Clear provincial REP policy outlining a procurement roadmap to 2030 in partnership with AESO, with point allocations for some local content (although local content is not mandated).	Attracts wind tower manufacturing and some blade manufacturing in Alberta, as well as some components for O&M repair and replacement.

Under REP Scenario 1, a lack of clarity around the size and frequency of future wind energy procurement calls results in very little to no manufacturing related to wind turbine components, with the exception of some repair and replacement related activity for some parts and small turbine components. It is assumed that approximately 30% of transportation and logistics costs will be paid to Alberta-based firms, reflecting the import of turbine and tower components.

Under REP Scenario 2, a wind energy procurement roadmap to 2030 is established, outlining calls for power equal to 1,500 MW every three years, to be rolled out as 500 MW per year using a phased approach. Point allocations will also be assigned in order to give some priority to projects with higher local content and/or services, although local content will not be mandated. As a result, it is assumed that over the 11-year period (from 2016 to 2027), approximately 60% of all turbine towers for Alberta-based projects are produced locally, and 30% of turbine blades are manufactured in province.[42] In addition, it is assumed that approximately 5% of other turbine components (not including blades and towers) are manufactured or assembled in Alberta. Transportation and logistics costs paid to Alberta-based firms is approximately 25% of total costs given the lower need to import turbine towers and blades.

For comparison purposes, a Base Case Scenario was developed in order to examine the estimated economic impact from the growth of Alberta's wind energy sector to 2030 in the absence of the province's current Climate Leadership Plan (CLP) and the REP policy. To do so, Delphi assumed that load growth for electricity in Alberta to 2030 would be similar to forecasted demand in line with the Main Outlook in AESO's 2014 Long-term Outlook (LTO)[43], which was developed prior to the CLP policy being enacted. The Main Outlook in AESO's 2014 LTO estimated a total grid capacity of approximately 23,000 MW in 2029, which, by comparison, is slightly lower than AESO's 2017 LTO Reference Case grid capacity of 23,300 MW.[44]

No 2030 data is available and, therefore, values are based on the average of forecasts for 2024 and 2034, approximating the capacity in 2029. Alberta climate policy pre-CLP was taken into account as part of this scenario, including the Specific Gas Emitters Regulation (SGER) and carbon offsets available for renewable power generation.

[42] The 60% turbine tower manufacturing assumption is based on consultation with industry suggesting that, under the right policy and procurement scenario, a high likelihood of turbine tower manufacturing in Alberta could exist given existing transferrable skills and expertise and the cost considerations for transportation. Given a tower manufacturing facility can only make towers for one turbine OEM at any given time, the assumption is that a 40% of turbine towers will still be imported from outside of province.

With respect to turbine blades, it is assumed that a lower percentage (i.e., 30%) may be manufactured in Alberta under the right policy and procurement scenario given the added costs of setting up related facilities and the current lack of expertise in transferrable industries.

It should be noted that these assumption are only best estimates (that have been vetted by wind energy industry stakeholders) and are provided for the purpose of economic impact modelling as per NREL's JEDI model; as such, there is no guarantee that a policy scenario as outlined in REP Scenario 2 will result in an equal amount of manufacturing activity in Alberta. The actual percentage of local manufacturing for towers, blades, and other turbine components may in fact be higher or lower than assumed given the range of market and economic factors at play.

[43] AESO 2014 Long-term Outlook: https://www.aeso.ca/downloads/AESO_2014_Long-term_Outlook.pdf
[44] AESO 2017 Long-term Outlook: https://www.aeso.ca/grid/forecasting/

It should be noted that Alberta is developing an Output-based Allocation (OBA) system to price industrial GHG emissions in a similar way as the proposed federal output-based standard for carbon pricing. The federal standard will not apply as long as the OBA system in Alberta is equivalent to or more stringent than the federal standard (which has yet to be specified). As such, it is assumed that federal carbon pricing, as matched by the OBA, will have a negligible price impact on natural gas electricity in Alberta (possibly a slight reduction or slight increase depending on the facility) in comparison with the current SGER / OBA system.

In addition, it is assumed that Federal regulations drive coal retirements at an accelerated rate so that no coal generating capacity remains online in Alberta after 2030. Table A2 estimates the amount of new added wind generation capacity between 2017 and 2029 under this Base Case Scenario relative to other electricity generation sources.

Table A2: Estimated additional generation capacity added to Alberta's electricity grid system by 2029 in the absence of the current Renewable Electricity Program (REP).

Total Capacity 2017	16,713 MW
Total Capacity 2029	22,996 MW
Coal Retirements	6,299 MW
Added Capacity (2017-2029)	12,582 MW
Cogeneration	2,313 MW (18%)
Gas	8,478 MW (67%)
Wind	1,496 MW (12%)
Solar, Hydro, Other	295 MW (2%)

Source: Delphi Group and AESO (based on 2014 Long-term Outlook, Main Outlook Scenario)

Under all three scenarios, it was assumed that the environmental assessment and permitting phase for wind project development in Alberta represents approximately 1.2% of total project costs. In addition, the cost for replacement parts during the O&M phase was increased by 1.5 times over the JEDI model's assumptions in order to reflect more harsh winters in Alberta.

Table A3 below provides an estimate of the cost breakouts for 100 MW of wind power project development and construction in Alberta, based on the JEDI model calibrated with Statistics Canada's economic multipliers for Alberta. Table A4 provides an estimate of the related costs for 100 MW of wind project operations and maintenance (O&M) related activities in Alberta.

The Delphi project team also conducted a high-level international trade analysis of both the larger wind power components imported to Alberta, as well as other provinces such as Ontario and Quebec that have a growing wind power sector. This trade analysis helped determine both local capacity to potentially engage in the manufacture of wind power components, but also to estimate import replacement demand.

In addition, the Delphi project team considered the economic impact that might come from companies choosing to adapt their current products / services to the wind energy supply chain. This impact involves the engineering and science-based services sectors, construction, as well as various manufacturing facilities such as fiberglass manufacturing, pressure vessel manufacturers, and control systems. The multiplier impacts for these companies will grow as the wind value chain develops further.

Table A3: Project Development Cost Data for a 100 MW Wind Farm in Alberta

Construction Costs	**Cost**	**Cost Per kW**	**Percent of Total Cost**
Equipment Costs	$22,553,058	$225.53	12.3%
Turbines (excluding blades and towers)	$75,513,597	$755.14	41.1%
Blades	$17,678,769	$176.79	9.6%
Towers	$19,572,922	$195.73	10.6%
Transportation	$13,511,630	$135.12	7.3%
Equipment Total	$126,276,918	$1,262.77	68.7%
Balance of Plant			
Materials			
Construction (concrete, rebar, equip, roads and site prep)	$18,247,015	$182.47	9.9%
Transformer	$2,064,116	$20.64	1.1%
Electrical (drop cable, wire,)	$2,175,717	$21.76	1.2%
HV line extension	$3,974,310	$39.74	2.2%
Materials Subtotal	$26,461,158	$264.61	14.4%
Labour			
Foundation	$1,786,753	$17.87	1.0%
Erection	$1,517,813	$15.18	0.8%
Electrical	$2,027,585	$20.28	1.1%
Management/Supervision	$669,530	$6.70	0.4%
Misc.	$10,275,200	$102.75	5.6%
Labour Subtotal	$16,276,881	$162.77	8.9%
Development/Other Costs			
HV Sub/Interconnection			
Materials	$1,254,048	$12.54	0.7%
Labour	$384,139	$3.84	0.2%
Engineering	$1,706,445	$17.06	0.9%
Legal Services	$930,012	$9.30	0.5%
Land Easements	$0	$0.00	0.0%
Site Certificate/Permitting	$2,175,717	$21.76	1.2%
Development/Other Subtotal	$6,450,362	$64.50	3.5%
Balance of Plant Total	$49,188,401	$491.88	26.7%
Subtotal (all cost without taxes)	**$175,465,319**	**$1,754.65**	**95.4%**
Sales Tax (Material and Equipment Purchases)	**$8,423,200**	**$84.23**	**4.6%**
Total	**$183,888,519**	**$1,838.89**	**100.0%**

Table A4: Project O&M Cost Data for a 100 MW Wind Farm in Alberta

Personnel	**Cost**	**Cost Per kW**	**Percent of Total Cost**
Field Salaries	$313,141	$3.13	10.0%
Administrative	$29,690	$0.30	1.0%
Management	$55,669	$0.56	1.8%
Labour/Personnel Subtotal	$398,500	$3.99	12.8%
Materials and Services			
Vehicles	$57,178	$0.57	1.8%
Site Maintenance /Misc. Services	$22,299	$0.22	0.7%
Fees, Permits, Licenses	$11,150	$0.11	0.4%
Utilities	$44,598	$0.45	1.4%
Insurance	$428,831	$4.29	13.7%
Fuel (motor vehicle gasoline)	$22,299	$0.22	0.7%
Consumables/Tools and Misc. Supplies	$144,945	$1.45	4.6%
Replacement Parts/Equipment/ Spare Parts Inventory	$1,905,298	$19.05	61.0%
Materials and Services Subtotal	$2,636,599	$26.37	84.4%
Sales Tax (Materials & Equipment Purchases)	**$89,075**	**$0.89**	**2.9%**
Total O&M Cost	**$3,124,175**	**$31.24**	**100.0%**

Appendix B: Jurisdictional Profiles

The jurisdictional profiles below provide insights into other wind industry sector leaders in terms of their policy and supply chain development activities.

ONTARIO

WIND INDUSTRY OVERVIEW

Installed Capacity[45]	4,781 MW
Average Turbine Capacity	1.94 MW
Number of Turbines	2,465
Number of Installations	90
Industry Growth (2005[46] to 2016)	4,766 MW

SUPPLY CHAIN DEVELOPMENT

- Ontario's Feed-in Tariff (FIT) Program originally mandated local/domestic content rules (50% for projects over 10 kW). These were reduced (to 20%) in 2013 due to a WTO ruling.
- These domestic content requirements necessitated the development of a local supply chain in Ontario (e.g., steel for towers and tower formation, blades, construction, and consulting related services). Some of these companies continue to serve projects in Ontario and abroad (e.g., towers and blades).
- Despite Ontario's supply chain supporting all stages of development (from land acquisition and engineering through to manufacturing and construction), there are few to no turbine nacelle related components manufactured in Ontario.[47]
- A range of Canadian, American, European, and Asian wind energy companies (e.g., Boralex, Brookfield, Capital Power, International Power, Invenergy, NextEra Energy, Samsung Renewable Energy, and Suncor Energy) have invested in more than 100 wind farms in Ontario.[48]
- Examples of manufacturers that established operations in Ontario:
    - Siemens wind turbine blade plant in Tillsonburg.
    - General Electric wind turbine manufacturing facilities in Port Colborne, Ottawa, Windsor, and Stony Creek.
    - Wenvor Technologies Inc. wind turbine plant in Guelph.
    - Senvion PowerBlades, was located in Welland, but closed in November 2015 once all FIT orders were fulfilled
    - Bladefence located in Toronto, repairs and maintains wind turbine blades in cold climates.

[45] Canadian Wind Energy Association, Wind Markets, Ontario (http://canwea.ca/wind-energy/ontario/ - date accessed: May 2017).
[46] IEA Wind Energy Annual Report 2005, (Chapter 11: Canada), June 2006 (https://www.ieawind.org/annual_reports_PDF/2005/2005%20IEA%20Wind%20AR.indd.pdf – date accessed: May 2017).
[47] Compass Renewable Energy Consulting Inc., Wind Dividends: An Analysis of the Economic Impacts from Ontario's Wind Procurements, prepared for Canadian Wind Energy Association, November 2015 (http://canwea.ca/wp-content/uploads/2015/12/FINAL-CanWEA-Economic-Analysis-Report-Nov_25-2015_PUBLIC.pdf - date accessed: May 2017).
[48] Guy Holburn, Economic Benefits of Wind Power Development and operation in Dutton Dunwich, Ontario, prepared for Invenergy Canada LLC, January 2017 (http://www.duttondunwich.on.ca/sites/default/files/Local%2BEconomic%2BBenefits%2Bof%2BWind%2BPower%2Bin%2BDD%2B-%2B30%2BJan%2B2017.pdf - date accessed: May 2017).

WORKFORCE BENEFITS & TRAINING

- Workforce: Hundreds of jobs were created in the manufacturing facilities, thousands more were created across the supply chain (e.g., construction, local services, etc.). Estimated full time equivalent (FTE) employees grew from approximately 2,000 in 2006 to 12,000 in 2015 for construction, turbine and supply chain, and operations combined.[49]
- Training: In addition to conferences and workshops, colleges with established wind energy related programming include:
    - St. Lawrence College, Kingston
    - Niagara College Canada, Welland
    - Humber College, Toronto

POLICY

- 2006 Renewable Energy Standard Offer Program (RESOP) paid fixed rates to private wind power developers. RESOP was superseded in 2009 by FIT.
- Renewable energy projects with a capacity of 10 kW to 500 kW were incented by the FIT Program which was introduced in 2009 as part of the Green Energy and Economy Act. The price set for wind generation at the beginning of the FIT program took into account the capital investment required to get the projects up and running. The FIT Program started at 13.5 cents/kWh in 2009. In 2010, the range was 13.5 cents/kWh to 19 cents/kWh. The prices were reduced in 2012 to 11.5 cents/kWh and increased again in 2014 to 12.8 cents/kWh. Starting in 2017, the price was reduced slightly to 12.5 cents/kWh.
- IESO's Large Renewable Procurement I (LRP I) program contracted 300 MW (over 5 projects) in spring 2016. The next phase, Large Renewable Procurement II program, was suspended in fall 2016.
- In addition to these policies, in 2010, Ontario signed a Green Energy Investment Agreement (GEIA) with the Korean Consortium (including Samsung). The agreement initially committed the consortium to invest $7 billion in Ontario to develop 2,500 MW of wind and solar by 2016 and Ontario would buy $9.7 billion worth of electricity over a 20-year period. In 2013, Ontario renegotiated to buy $6 billion of electricity over 20 years, and the consortium only had to invest $5 billion to develop 1,369 MW by 2016. As part of this deal, Samsung agreed to build manufacturing plants with partners, to manufacture components for wind (blades and towers) and solar in Ontario to create approximately 900 jobs.[50] Siemens became a manufacturing partner of Samsung, with a guarantee to provide wind turbine blades for 600 MW of Samsung/Pattern wind energy projects in the province. This guaranteed demand enabled Siemens to establish a manufacturing facility in the province.[51]

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[49] Compass Renewable Energy Consulting Inc., Wind Dividends: An Analysis of the Economic Impacts from Ontario's Wind Procurements, prepared for Canadian Wind Energy Association, November 2015 (http://canwea.ca/wp-content/uploads/2015/12/FINAL-CanWEA-Economic-Analysis-Report-Nov_25-2015_PUBLIC.pdf - date accessed: May 2017).
[50] Green Energy Investment Agreement, June 2013 (http://www.ontla.on.ca/library/repository/mon/27006/323101.pdf - date accessed: May 2017).
[51] Siemens, Press Release Archive, Siemens selects Tillsonburg, Ontario as new home for Canadian wind turbine blade manufacturing facility, December 2, 2010 (http://www.siemens.ca/web/portal/en/press/Pages/Tillsonburg-Ontario-new-home-Canadian-wind-turbine-blade-manufacturing-facility.aspx - date accessed: May 2017).

QUEBEC

WIND INDUSTRY OVERVIEW

Installed Capacity[52]	3,510 MW
Average Turbine Capacity	1.87 MW
Number of Turbines	1,879
Number of Installations	45
Industry Growth (2005[53] to 2016)	3,298 MW

SUPPLY CHAIN DEVELOPMENT

- The Quebec government's wind energy tenders (for 3,500 MW to date) are tied to local content requirements.
- For example, the 2003 RFP required that the first 200 MW should have 40% local content, the next 100 MW should have 50%, and the remaining 700 MW should have 60%. The 2005 and 2010 RFPs required that 60% of the 2 GW of wind energy be sourced locally, with 10% from the Gaspésie region. The 2012 RFP to increase Quebec's wind energy capacity by 700 MW, required 30% of the turbine costs to be spent in the Gaspésie and Matane municipalities, and 60% of the overall costs to be spent in Quebec.[54]
- The Quebec local content requirement excludes certain items from the Gaspésie and Matane content totals (e.g., wind turbine warranties, transportation of turbines to site, testing and commission, O&M costs). In other words, Quebec designed the local content requirements to encourage hard capital investment in manufacturing plants.[55]
- Examples of manufacturers that established operations in Quebec:
    - LM Wind Power blade manufacturing plant
    - Composites VCI nacelle manufacturing plant
    - Marmen tower manufacturing plant
    - ENERCON tower and e-module manufacturing plant
    - Eaton electrical converter manufacturing plant
    - REpower wind turbine parts manufacturing plant

[52] Canadian Wind Energy Association, Wind Markets, Quebec (http://canwea.ca/wind-energy/quebec/ - date accessed: May 2017).
[53] IEA Wind Energy Annual Report 2005, (Chapter 11: Canada), June 2006 (https://www.ieawind.org/annual_reports_PDF/2005/2005%20IEA%20Wind%20AR.indd.pdf – date accessed: May 2017).
[54] Jan-Christoph Kuntze and Tom Moerenhout, Local Content Requirements and the Renewable Energy Industry – A Good Match?, International Centre for Trade and Sustainable Development, 2013 (http://unctad.org/meetings/en/Contribution/DITC_TED_13062013_Study_ICTSD.pdf - date accessed: May 2017).
[55] Sherry Stephenson, Addressing Local Content Requirements in a Sustainable Energy Trade Agreement, International Centre for Trade and Sustainable Development, 2013 (http://www.ictsd.org/downloads/2013/06/addressing-local-content-requirements_opt.pdf - date accessed: May 2017).

WORKFORCE BENEFITS & TRAINING

- Workforce: Hundreds of jobs were created in the manufacturing facilities, thousands more were created across the supply chain. Approximately 5,000 full time jobs were created through growth in the Quebec wind industry.[56] Close to 1,000 of these jobs are highly skilled and located in Montreal, where many Quebec, Canadian and international companies have established offices.[57]
- Training: In addition to the TechnoCentre Éolien (established in 2000) and the Quebec Wind Energy Cluster, colleges and universities with established wind energy related courses include:
  - Groupe Collegia, CEGEP de la Gaspesie et des Iles de la Madeleine
  - Université du Québec à Rimouski
  - McGill University.

POLICY

- Quebec issues energy tenders (through Hydro Quebec) for development of wind farms to a specific megawatt capacity each round. There have been 4 requests for proposals to date.
- The 2016 Energy Policy 2030 also supports wind energy development for both domestic use and export.[58]
- In addition to the policies, Quebec made tax credits available to certain activities in the wind power sector in certain regions. For example, production of wind power manufacturing of wind turbines (including any main components – tower, rotor, nacelle) in Gaspésie, Iles de la Madeleine, and La Matanie RCM in Bas Saint Laurent. As well as manufacturing activities listed under NAICS codes 31 to 33 in Gaspésie and Iles de la Madeleine. The tax credit started at 18%, calculated on the increase in total salaries in 2014, and reduced to 16% in 2015. From 2016 to 2020, the tax credit is calculated on total salaries and is 15% of eligible wages paid.[59]

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[56] Canadian Wind Energy Association, Wind Markets, Quebec (http://canwea.ca/wind-energy/quebec/ - date accessed: May 2017).
[57] Aviseo Conseil Stratégie & Économie, Estimation du nombre d'emplois de la filière éolienne dans la région de Montréal, prepared for Canadian Wind Energy Association, July 2015 (http://canwea.ca/wp-content/uploads/2014/01/Portrait-des-emplois-montr%C3%A9alais-de-la-fili%C3%A8re-%C3%A9olienne_VF29juillet2015.pdf – date accessed: May 2017).
[58] Government of Quebec, The 2030 Energy Policy: Energy in Quebec, A Source of Growth, 2016 (https://politiqueenergetique.gouv.qc.ca/wp-content/uploads/Energy-Policy-2030.pdf - date accessed: May 2017).
[59] Investissement Quebec, Tax Credit for Gaspesie and Certain Maritime Regions of Quebec, Tax Measures Department, July 2015 (http://www.investquebec.com/Documents/qc/FichesDetaillees/FTGASPESIE_en.pdf - date accessed: May 2017).

IOWA

WIND INDUSTRY OVERVIEW

Installed Capacity[60]	6,952 MW
Number of Turbines	3,965
Number of Installations	102
Industry Growth (2005[61] to 2016)	6,116 MW

SUPPLY CHAIN DEVELOPMENT

- In 2016, there were 11 active manufacturing facilities in Iowa.[62]
- Examples of manufacturers that established operations in Iowa:
  - Siemens blade manufacturer
  - TPI Composites blade manufacturer
  - Acciona wind turbine manufacturer
  - MM Composite Inc. composite components for Siemens blades
- A 2010 report on Iowa's wind energy supply chain listed 80 companies, including blade and tower manufacturers, component manufacturers, project developers, mid-scale wind services, and turbine assembly.[63]

WORKFORCE BENEFITS & TRAINING

- Workforce: There were 8,000 to 9,000 indirect and direct jobs supported by the wind industry in 2016.[64] One report states that 82% of Iowa's renewable energy jobs are in the wind sector. The demand for jobs has led to a challenge in hiring workers with advanced training. Particular challenges have included lack of experience, gaps in training and technical skills, and a small applicant pool.[65]

[60] American Wind Energy Association, Iowa Wind Energy (http://awea.files.cms-plus.com/FileDownloads/pdfs/Iowa.pdf - date accessed: May 2017).
[61] U.S. Department of Energy, Energy Efficiency and Renewable Energy, WINDExchange, Installed Wind Capacity (http://apps2.eere.energy.gov/wind/windexchange/wind_installed_capacity.asp - date accessed: May 2017).
[62] American Wind Energy Association, Iowa Wind Energy (http://awea.files.cms-plus.com/FileDownloads/pdfs/Iowa.pdf - date accessed: May 2017).
[63] Environmental Law and Policy Center, The Wind Energy Supply Chain in Iowa, November 2010 (http://elpc.org/wp-content/uploads/2010/11/IowaWindSupplyChainReportDownload.pdf - date accessed: May 2017).
[64] American Wind Energy Association, Iowa Wind Energy (http://awea.files.cms-plus.com/FileDownloads/pdfs/Iowa.pdf - date accessed: May 2017).
[65] Clean Energy Trust, Clean Jobs Midwest Survey (http://www.cleanjobsmidwest.com/story/iowa/ - date accessed: May 2017).

- Training: There are a number of colleges with established wind energy related programming in Iowa, including:[66]
    - Des Moines Area Community College
    - Eastern Iowa Community College
    - Indian Hills Community College
    - Iowa Lakes Community College
    - Iowa State University
    - Iowa Western Community College
    - Kirkwood Community College
    - University of Iowa
    - Vatterott College
    - Wester Iowa Tech Community College

POLICY

- Iowa was the first state to adopt a renewable portfolio standard (clean energy standard) in 1983 that required the major utilities to own or contract a certain amount of megawatts of renewable energy. The standard was met in 1999, and renewable energy capacity has continued to grow. The standard gave an initial push to the wind industry.[67]
- In addition to Iowa's policies, there was a stable federal tax policy that helped with scaling up, lowering costs, and driving investment in the wind sector – the Production Tax Credit initially provided a 2.3 cent/kWh tax credit, but is now being phased out.[68]
- There are also state level financial incentives available in Iowa, such as the state production tax credit of 1.5 cents/kWh for wind production up to 363 MW capacity.[69]

[66] U.S. Department of Energy, Energy Efficiency and Renewable Energy, WINDExchange, Wind Energy Education and Training Programs (http://apps2.eere.energy.gov/wind/windexchange/schools/education/education_training.asp - date accessed: May 2017).
[67] American Wind Energy Association, Iowa Wind Energy (http://awea.files.cms-plus.com/FileDownloads/pdfs/Iowa.pdf - date accessed: May 2017).
[68] Energy.gov, Renewable Electricity Production Tax Credit (https://energy.gov/savings/renewable-electricity-production-tax-credit-ptc - date accessed: May 2017).
[69] Renewable Energy Tax Credit, Chapter 476C (https://www.legis.iowa.gov/DOCS/ACO/IC/LINC/Chapter.476c.pdf - date accessed: May 2017).

NORTH DAKOTA

WIND INDUSTRY OVERVIEW

Installed Capacity[70]	2,846 MW
Number of Turbines	1,536
Number of Installations	27
Industry Growth (2005[71] to 2016)	2,748 MW

SUPPLY CHAIN DEVELOPMENT

- In 2016, there were 4 active manufacturing facilities in North Dakota.[72]
- Examples of manufacturers that established operations in North Dakota:
  - LM Wind Power (recently acquired by GE Renewable Energy) large-scale blade manufacturing facility
  - Dakota Turbines Inc. wind turbine manufacturer (uses almost exclusively parts manufactured in the upper Midwest)
  - DMI Industries, Inc. tower manufacturer.

WORKFORCE BENEFITS & TRAINING

- Workforce: There were 4,000 to 5,000 indirect and direct jobs supported by the wind industry in 2016.[73]
- Training: There are two colleges with established wind energy related programming in North Dakota:[74]
  - Lake Region State College
  - Bismark State College

[70] American Wind Energy Association, North Dakota Wind Energy (http://awea.files.cms-plus.com/FileDownloads/pdfs/North%20Dakota.pdf - date accessed: May 2017).
[71] U.S. Department of Energy, Energy Efficiency and Renewable Energy, WINDExchange, Installed Wind Capacity (http://apps2.eere.energy.gov/wind/windexchange/wind_installed_capacity.asp - date accessed: May 2017).
[72] American Wind Energy Association, North Dakota Wind Energy (http://awea.files.cms-plus.com/FileDownloads/pdfs/North%20Dakota.pdf - date accessed: May 2017).
[73] Ibid.
[74] U.S. Department of Energy, Energy Efficiency and Renewable Energy, WINDExchange, Wind Energy Education and Training Programs (http://apps2.eere.energy.gov/wind/windexchange/schools/education/education_training.asp - date accessed: May 2017).

POLICY

- North Dakota set a non-binding Renewable Portfolio Goal in 2007 with a voluntary target that by 2015, 10% of all retail electricity sold in the state would be from renewable sources.[75]
- In 2007, a Comprehensive State Energy Policy was released that recommended increasing installed wind capacity to 5 GW by 2020.[76]
- In addition to the federal tax incentives, North Dakota has several state level incentives, such as the Renewable Energy Property Tax Exemption[77] or the sales and use tax exemption on materials and equipment used in wind project development.[78] Wind easements are also allowed in North Dakota to ensure adequate exposure of a wind system to wind.[79]

[75] American Wind Energy Association, North Dakota Wind Energy (http://awea.files.cms-plus.com/FileDownloads/pdfs/North%20Dakota.pdf - date accessed: May 2017).
[76] The Pew Charitable Trusts, Clean Economy Rising: Wind Energy propels North Dakota forward, October 2014 (http://www.pewtrusts.org/~/media/assets/2014/10/clean_energy_north_dakota_web.pdf - date accessed: May 2017).
[77] DSIRE database, Renewable Energy Property Tax Exemption (http://programs.dsireusa.org/system/program/detail/160 - date accessed: May 2017).
[78] Office of State Tax Commissioner, North Dakota Tax Incentives for Business, 2014 (https://www.nd.gov/tax/data/upfiles/media/business-incentives_2.pdf?20170526132211 – date accessed: May 2017).
[79] DSIRE database, Wind Easements (http://programs.dsireusa.org/system/program/detail/3981 - date accessed: May 2017).

COLORADO

WIND INDUSTRY OVERVIEW

Installed Capacity[80]	3,026 MW
Number of Turbines	1,913
Number of Installations	25
Industry Growth (2005[81] to 2016)	2,795 MW

SUPPLY CHAIN DEVELOPMENT

- In 2016, there were at least 15 active manufacturing facilities in Colorado.[82]
- Policy and leadership in renewable energy have played a big role in wind industry development in Colorado. For example, Vestas is said to have located multiple manufacturing facilities (towers, blades, and nacelles) in the state because of this. They also sited their new tower plant in 2013 based on: the area's existing manufacturing workforce, access to transportation hubs, state and local incentives, and a streamlined permitting process. Similarly, RES Americas has indicated that it was Colorado's leadership in developing renewable energy resources that helped prompt the headquarters move from Texas to Colorado.[83]
- Examples of manufacturers that established operations in Colorado:
  - Vestas wind turbine nacelle facility, tower facility, and two blade facilities
  - PMC Technology supplies hydraulic components to Vestas; Walker Component Group supplies cable and electronic assemblies to Vestas
  - Siemens Energy Inc.
  - General Electric
  - SGB USA
- The investments from large manufacturers has led to local growth within the rest of the supply chain (e.g., to supply components to the large manufacturers).

WORKFORCE BENEFITS & TRAINING

- Workforce: There were 6,000 to 7,000 indirect and direct jobs supported by the wind industry in 2016.[84]
- Training: Colorado is a hub of research, development, and education facilities related to the wind sector. For instance, NREL is based in Golden, Colorado and has a dedicated team studying wind energy production. NREL and some training institutes (e.g., Aims Community College) have partnered with local industry.

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[80] American Wind Energy Association, Colorado Wind Energy (http://awea.files.cms-plus.com/FileDownloads/pdfs/Colorado.pdf - date accessed: May 2017).
[81] U.S. Department of Energy, Energy Efficiency and Renewable Energy, WINDExchange, Installed Wind Capacity (http://apps2.eere.energy.gov/wind/windexchange/wind_installed_capacity.asp - date accessed: May 2017).
[82] American Wind Energy Association, Colorado Wind Energy (http://awea.files.cms-plus.com/FileDownloads/pdfs/Colorado.pdf - date accessed: May 2017).
[83] E2 Environmental Entrepreneurs, Winds of Change: The economic impact of Colorado's wind industry – and how to keep it growing, 2015 (http://cleanenergyworksforus.org/wp-content/uploads/2015/06/CO-Wind-Report_final_pages_LR.pdf - date accessed: May 2017).
[84] American Wind Energy Association, Colorado Wind Energy (http://awea.files.cms-plus.com/FileDownloads/pdfs/Colorado.pdf - date accessed: May 2017).

- There are a number of institutes, colleges, and universities with established wind energy related programming in Colorado, including:[85,86]
    - Ecotech Institute
    - Aims Community College
    - Arapahoe Community College
    - Red Rocks
    - Colorado Mountain College
    - NREL (in Golden, CO) – research and development
    - National Wind Technology Center (NWTC)
    - Center for Research and Education in Wind – job training collaboration between the University of Colorado, the Colorado School of Mines, and Colorado State University
    - Renewable and Sustainable Energy Institute at University of Colorado
    - Colorado Wind Application Center
    - Front Range Community College
    - Northeaster Junior College
    - Redstone College
    - University of Denver, Sturm College of Lay
    - Wind Energy Applications Training Symposium

POLICY

- Colorado set a Renewable Portfolio Standard (RPS) in 2004 that requires investor-owned utilities to provide 30% of their 2020 electricity through renewable energy, large cooperatives (>100,000 customers) to provide 20%, and small cooperatives (<100,000 customers) and municipalities to provide 10%. Wind energy has historically been the renewable resource of choice to meet RPS requirements in Colorado.[87]
- The RFS will be met by 2020 and electricity suppliers expect wind growth to slow after this, unless another policy is implemented that supports wind development.[88]
- Other state policies that have led to wind energy development include enabling landowners, municipalities, and cooperatives to directly benefit through lease payments, taxes (e.g., Renewable Energy Property Tax Assessment), and credits (e.g., EZ Investment Tax Credit Refund for Renewable Energy Projects),[89] as well as enabling utilities to buy more wind power than required because it is cheaper than natural gas.[90]

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[85] U.S. Department of Energy, Energy Efficiency and Renewable Energy, WINDExchange, Wind Energy Education and Training Programs (http://apps2.eere.energy.gov/wind/windexchange/schools/education/education_training.asp - date accessed: May 2017).
[86] E2 Environmental Entrepreneurs, Winds of Change: The economic impact of Colorado's wind industry – and how to keep it growing, 2015 (http://cleanenergyworksforus.org/wp-content/uploads/2015/06/CO-Wind-Report_final_pages_LR.pdf - date accessed: May 2017).
[87] American Wind Energy Association, Colorado Wind Energy (http://awea.files.cms-plus.com/FileDownloads/pdfs/Colorado.pdf - date accessed: May 2017).
[88] E2 Environmental Entrepreneurs, Winds of Change: The economic impact of Colorado's wind industry – and how to keep it growing, 2015 (http://cleanenergyworksforus.org/wp-content/uploads/2015/06/CO-Wind-Report_final_pages_LR.pdf - date accessed: May 2017).
[89] DSIRE database, Colorado (http://programs.dsireusa.org/system/program?fromSir=0&state=CO – date accessed: May 2017).
[90] E2 Environmental Entrepreneurs, Winds of Change: The economic impact of Colorado's wind industry – and how to keep it growing, 2015 (http://cleanenergyworksforus.org/wp-content/uploads/2015/06/CO-Wind-Report_final_pages_LR.pdf - date accessed: May 2017).

Appendix C: Wind Sector Technology Trends

The points below provide a high-level overview of some of the recent and projected future technology trends that may be relevant to consider inline with Alberta's wind energy sector development.

Recent Technology Trends

1. **Increasing nameplate capacity** (180% increase between 1998/99 and 2015) – average of newly installed turbines are now 2 MW (mostly since 2011).
2. **Increasing hub height of turbines** (47% increase between 1998/99 and 2015) – 80 m towers dominate the overall market; towers 90 m and taller started to penetrate the market in 2011.
3. **Increasing rotor diameter** (113% increase between 1998/99 and 2015) – especially significant in the past ~6 years, with 0 turbines of >100 m installed in 2008, 47% newly installed turbines at least 100 m in diameter by 2012, and 86% by 2015; rotor diameters >110 m started the market in 2012 with 20% of newly installed turbines >110 m in 2015.
4. **Growing size of turbine –** will impact transportation in terms of roads, logistics, and machinery needed to accommodate larger tower components and blades.
5. **Lower specific-power turbines –** boosts capacity factors, runs closer to or at its rated capacity more often; used in low and high wind speed sites (used to be only designed this way for low wind speed sites).
6. **Shift in IEC Class turbines** (which consider multiple site characteristics, e.g., wind speed, gusts, turbulence, etc.) – Class 3 (lower wind speed turbines) now dominate the market (which as stated above have become increasing lower in specific-power).[91]
7. **Operating in cold climates –** OEMs are developing techniques to improve turbine efficiency and profitability in colder temperatures.

Advanced & Future Technologies Relevant to Onshore Wind

Additive manufacturing (3-D printing)

- Turbine blade mould manufacturing; expected to lower costs and enable innovative blade design – currently under testing.[92]
- Vestas and GE Renewables have used 3-D printing for a number of years for fast prototyping. Currently, U.S. DOE's Office of Energy Efficiency and Renewable Energy Advanced Manufacturing Office and Wind Energy Technologies Office, with Oak Ridge and Sandia National Labs and TPI Composites, are using 3-D printing to produce scaled-down turbine blades.
- Research is being done identifying every single part of a turbine that could be suitable for 3-D printing. Including using 3-D printing to makes parts of a hybrid blade.
- Another key aspect of 3-D printing is being able to print blades, components, etc. on demand close to where they are needed – being able to produce and distribute spare parts locally could reduce cost and downtime.
- Size, speed and costs of 3-D printers are current constraints.[93]
- Could have negative impacts on jobs as more can be done with fewer workers across a range of industries.

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[91] https://energy.gov/sites/prod/files/2016/08/f33/2015-Wind-Technologies-Market-Report-08162016.pdf
[92] https://energy.gov/sites/prod/files/2016/08/f33/3-D-printed-blade-mold-fact-sheet-08032016.pdf
[93] http://www.windpowermonthly.com/article/1421837/additive-manufacturing-will-gamechanger

Plant-level digital controls

- Actively monitor flow field, anticipate wind changes, and modify the flow through redirection, which increases performance and mitigates unwanted dynamics and interactions[94])
- Smart wind farm control (e.g., for wake control); Advanced turbine controls (e.g., using big data, LiDAR, etc.).[95]

Industrialized internet of things (IIoT)

- Connecting the digital world of the internet with conventional processes and services, with a focus on digitalization, communication, data management, industrial analytics and interoperability. For example, integrating wind farm operation with electricity markets; integrating condition monitoring, wind and weather, technician-service schedules, "virtual" power stations, and electricity markets.
- Advantages include optimizing service schedules; control over individual turbines and their components; adapting asset output to optimize earnings in the electricity markets; running wind farms within microgrids; integrating with industrial manufacturing processes; playing a role in the power-to-gas and power-to-heat sectors.
- Globally IIoT is referred to as different names, e.g., Industry 4.0 (Germany), Usine du Futur (France), Smart Industry (Netherlands), Produktion 2030 (Sweden), Industrial Strategy (UK).[96]

Larger Multi-MW turbines (>2 MW)

- 4 MW plus onshore direct-drive turbines – Enercon EP4 (models E-126 and E-141) with capacities of 4.2 MW each and 30-year operating lives, rotor diameters of 127m and 141m respectively, and specific power ratings of 332 W/m2 and 269 W/m2 respectively. There are a few competitors including Lagerwey 4.5 MW L136 (136 m rotor, specific power 310 W/m2), and Vestas 4 MW V117 (specific power 372 W/m2)[97])
- 3 MW plus – OEMs include Vestas, GE, Gamesa, Energycon, Siemens, Nordex, Senvion, and Envision with rotor diameters ranging from 115.7m to 137m, hub heights ranging from 80m to 166m.[98]

Lighter, longer blades

- Longer blades and new materials[99])
- Examples: Enercon segmented blade for 4.2MW E-141 EP4 – low wind, full composite slender blade; LM Wind Power 69.3P/B69 blade for Siemens SWT-3.15-142 – for low wind, hybrid carbon, less than 17 tonnes; Gamesa G132-3.3MW – 65.4m fibre glass reinforced blade, 16.5 tonnes.[100]

Sweep twist adaptive rotor (STAR) blade

- Gently curved tip to take maximum advantage of all wind speeds.[101]

Higher towers

- Large diameter steel tower (LDST) - steel wide-based towers with either two longitudinal segmented bottom sections supplemented by three or more "standard" road-transportable tubular steel sections, or tower designs completely built from segments.
- Hybrid or full concrete towers.[102]

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[94] https://energy.gov/eere/wind/atmosphere-electrons; https://a2e.energy.gov/
[95] https://www.slideshare.net/sandiaecis/ken-lee-trends-in-blade-technology-and-changing-rd-needs
[96] http://www.windpowermonthly.com/article/1416808/ramping-intelligence-interconnectivity
[97] http://www.windpowermonthly.com/article/1428420/exclusive-enercon-raises-bar
[98] http://www.windpowermonthly.com/article/1419302/turbines-year-onshore-turbines-3mw-plus
[99] http://www.sunwindenergy.com/wind-energy/longer-blades-new-materials-core-trends
[100] http://www.windpowermonthly.com/article/1419306/turbines-year-rotor-blades
[101] https://energy.gov/eere/next-generation-wind-technology
[102] http://www.windpowermonthly.com/article/1416811/windtech-tower-technology-reaches-new-heights

Energy Storage

- When energy storage becomes cost effective, wind could be a capacity facility and be eligible for a capacity contract, as well as for auxiliary services.

Virtual Reality

- Projects can be built without setting foot on site. It allows client to truly visualize the project, see the architects vision, and make modifications without spending on samples or trials. In terms of integration, the owner, engineer, and contractor can be involved at the same time and optimize the design, look for opportunities, etc. Overall it reduces risk and gives the client high value project plans, e.g. could be in the 10% range of cost saving for project.

Appendix D: Wind Energy Supply Chain Product & Service Areas

Project Development & Construction

Concrete
- Aggregate
- Concrete Contractor
- Concrete Forms and Accessories
- Concrete Pumping
- Grouting
- Ready Mix Supplier
- Reinforcement Steel Erector
- Reinforcement Steel Supplier

Engineering & Consulting Services
- Architects /Engineers
- Civil Architects /Engineers
- Electrical Architects /Engineers
- Environmental Engineers & Consultants
- Foundation Architects / Engineers

Electrical
- Electrical Distribution Products
- Electrical Cable
- Fibre Optic Cable
- Transformer
- Transformer Pad
- Wind Tower Wiring
- Lighting - FAA Obstruction
- Sub-station Components
- Transmission Installation
- Electrical Testing & Equipment
- Controls & Commissioning
- Cable Installation
- Electrical Wiring
- Lighting
- Welding Supplies
- Pumps
- Motors
- Compressors
- Weld Wire

Equipment Rental
- General Rental
- Impact Hammers
- Diggers
- Trenchers
- Earth Movers
- Heavy Haul Trucks
- Cranes
- Portable Sanitary Units
- Portable Generators
- Welding Equipment

Logistics Services
- Material Handling Equipment
- Other Logistics Services
- Packaging
- Project Cargo Services
- Rail Services
- Third Party Logistics
- Transport Equipment
- Trucking

Metals
- Fasteners
- Fencing
- Foundation Anchor Bolts
- Foundation Embed Rings
- Metal Fabricators
- Steel Conduit
- Steel Pipe and Fittings
- Structural Steel Erector
- Structural Steel Supplier

Other Services & Materials
- Food & Water
- Fuel
- Hotels & Restaurants
- Insulation
- Legal
- Financial
- Marketing
- Paint
- Plastic Pipe & Fittings

Site Construction
- Anchors
- Building Cranes
- Caissons
- Civil Contractors
- Drilling Contractors
- Earth Work
- Erosion & Sediment Control
- Excavation Contractors
- Foundation Contractors
- Foundation Testing
- Geopiers
- Pile Driving Contractors

Specialty Construction
- Building Construction Contractors
- Electrical Contractor
- Environmental Contractor
- HVAC Contractor
- Inspection Contractor
- Meteorological Tower Installation
- Plumbing Contractors
- Pre-engineered Building Contractors
- Wind Turbine Installation

Operations & Maintenance

Industry O&M
- Blades
- Gearboxes
- Generators
- Towers
- Turbines Commercial
- Turbines Residential
- Turbines Utility

Component Manufacturers
- Composites & Polymers
- Electrical & Electronics
- Fabricators
- Forgers
- Foundries
- Hydraulics
- Machine Shops

Materials
- Chemicals
- Lubricants
- Metals
- Resins
- Substrates
- Thermoforms
- Thermosets

Manufacturing Services
- Metal Coatings
- Epoxy / Paint Coatings
- Forming
- Grinding
- Heat treatment
- Inspection & testing
- Repair
- Stress Relieving
- Assembly
- Distribution Mgrs. Reps

Turbine Ancillary Equipment
- Fire Protection
- Material Handling
- Meteorology
- Safety and Rescue

Process Equipment
- Composite Equipment
- Consumables
- Electrical Equipment
- Fabrication Equipment
- Facility Equipment & Supplies
- Forge Equipment
- Foundry Equipment
- Materials Handling Equipment
- Machine Tools
- Machinery Cutting Tooling
- Measurement Equipment
- Power & Hand Tools
- Test Equipment

Logistics
- Air
- Maritime
- Material Handling
- Packaging
- Railroad
- Third Party Logistics
- Trucking

Operations & Maintenance
- Towers
- Bearings
- Blades
- Gearboxes
- Generator Transformer Motor
- Hydraulics
- Cranes and Rigging
- Inspection
- Maintenance Services
- Main Shaft

Enterprise Resources
- Engineering & Design
- Expansion & Relocation
- Fin, Legal & Marketing
- Human Resources
- Operations

Innovation & Advancement
- Materials
- Processes
- Technology

Affiliated Members
- Academic
- Associations
- Government
- Individuals
- Non-Profit
- Publishers
- Trade Group

Wind Turbine Component Manufacturing

Blades
- Core
- Fasteners
- Mesh
- Protective Film
- Resin
- Root
- Substrate

Control Systems
- Circuit Boards
- Complete Systems
- Harnesses
- Instrumentation
- Sensors

Gearbox
- Bearings
- Brake System
- Cast Gearbox
- Cooling System
- Gears
- Housing and Covers
- Lube System
- Machine Gearbox
- Seals
- Shaft

Generator
- Brushes
- Coils
- Cooling System
- Coupling
- Housing
- Laminates
- PM Direct Drive Generator
- Shafts
- Sliprings
- Windings

Hub & Structures
- Bearings
- Cast Hub
- Fasteners
- Machine Hub
- Main Forward Rear Frame
- Nacelle Housing - Composite
- Nacelle HVAC
- Structural Frames - Brackets

Main Shaft
- Bearings
- Brake System
- Fasteners
- Forge Shaft
- Housing
- Machine Shaft
- Shaft
- Shrink Disc

Power Electronics & Electrical
- Cabinets
- Cable
- Circuit Boards
- Complete Systems
- Converter / Inverter
- Harnesses
- Lighting
- Motors
- Switch Boards
- Transformer

Towers
- Base
- Bearings
- Doors
- Electrical Cabling
- Electrical Hardware
- Fasteners
- Gear
- Hardware
- Hoist and Elevator
- Insulators
- Ladders
- Lighting
- Platforms
- Rings

Yaw & Pitch System
- Actuators
- Brake System
- Complete Pitch System
- Complete Yaw System
- Drive Motors
- Fasteners
- Gearbox Gears
- Hardware
- Harnesses
- Hoses
- Housing
- Pitch Bearings
- Seals
- Sensors
- UPS
- Yaw Bearing Friction
- Yaw Bearing Mechanical
- Yaw Gear

Appendix E: Existing Alberta Capacity by Industry NAICS

This appendix provides a list of the industry NAICS codes (at the 6-digit level) most relevant to the various activities found across the wind energy sector supply chain. Estimates of the number of Alberta-based companies (with and without employees) for each NAICS code are also provided, based on Alberta business counts from Statistics Canada (Q4 2016).

Project Development & Construction (41 industry codes)

1. Site Evaluation

NAICS	Without employees	Total, with employees	1- 4	5-9	10-19	20-49	50-99	100-199	200-499	500 +
541360 - Geophysical surveying and mapping services	690	390	327	22	14	16	4	3	4	0
541370 - Surveying and mapping (except geophysical) services	201	208	90	30	23	39	15	7	4	0
541620 - Environmental consulting services	1349	707	570	57	33	27	15	5	0	0
541330 - Engineering services	5852	3877	3141	236	177	193	59	42	20	9
541690 - Other scientific and technical consulting services	650	498	470	19	5	3	1	0	0	0
541611 - Administrative management and general management consulting services	5782	1885	1717	95	48	17	4	2	2	0

2. Site Preparation & Specialty Construction

NAICS	Without employees	Total, with employees	1 to 4	5 to 9	10 to 19	20-49	50-99	100-199	200-499	500 +
541420- Industrial Design Services	204	151	141	8	0	1	1	0	0	0
541490 - Other specialized design services	213	41	39	0	1	1	0	0	0	0
541690 - Other scientific and technical consulting services	5416	2691	2461	136	59	26	7	2	0	0
541611 - Administrative management and general management consulting services	5782	1885	1717	95	48	17	4	2	2	0
237210 - Land subdivision	3124	384	266	52	28	24	5	5	3	3124
238190 - Other foundation, structure and building exterior contractors	772	543	378	99	36	22	4	3	1	0
238299 - All other building equipment contractors	612	346	204	50	49	32	8	2	1	0
238390 - Other building finishing contractors	1248	475	344	71	32	23	4	1	0	1248
238910 - Site preparation contractors	1656	1442	831	226	163	143	36	31	8	4
238990 - All other specialty trade contractors	3158	1346	911	206	104	78	22	18	7	0

333120 - Construction machinery manufacturing	34	38	19	5	2	6	2	2	2	0
532410 - Construction, transportation, mining, and forestry machinery and equipment rental and leasing	1318	727	331	120	113	125	21	7	10	0
532490 - Other commercial and industrial machinery and equipment rental and leasing	397	173	102	20	23	24	3	0	0	1

3. EPCs / Project Developers

NAICS	Without employees	Total, with employees	1-4	5-9	10-19	20-49	50-99	100-199	200-499	500 +
541330 - Engineering services	5852	3877	3141	236	177	193	59	42	20	9
237130 - Power and communication line and related structures construction	87	134	53	17	23	22	6	7	3	87
237990 - Other heavy and civil engineering construction	242	180	85	23	23	22	12	8	6	1

4. Materials

NAICS	Without employees	Total, with employees	1-4	5-9	10-19	20-49	50-99	100-199	200-499	500 +
238110 - Poured concrete foundation and structure contractors	503	736	334	237	74	66	19	5	1	0
327310 - Cement manufacturing	6	4	1	1	0	0	0	2	0	0
327390 - Other concrete product manufacturing	28	45	11	10	9	6	8	1	0	0

5. Metals

NAICS	Without employees	Total, with employees	1-4	5-9	10-19	20-49	50-99	100-199	200-499	500 +
238120 - Structural steel and precast concrete contractors	97	139	46	40	18	22	8	1	3	1
238220 - Plumbing, heating and air-conditioning contractors	1785	2207	1328	369	244	163	68	27	7	1
326130 - Laminated plastic plate, sheet, and shape manufacturing	4	6	5	1	0	0	0	0	0	0
331110 - Iron and steel mills and ferro-alloy manufacturing	6	7	1	1	2	2	0	0	1	0
331317 - Aluminum rolling, drawing, extruding and alloying	2	3	0	0	1	2	0	0	0	0
332314 - Concrete reinforcing bar manufacturing	1	13	2	1	3	4	0	3	0	0
332319 - Other plate work and fabricated structural product manufacturing	130	158	33	29	28	32	23	10	2	1
333519 - Other metalworking machinery manufacturing	66	93	46	21	17	7	1	1	0	0

6. Electrical & Controls

NAICS	Without employees	Total, with employees	1-4	5-9	10-19	20-49	50-99	100-199	200-499	500 +
238210 - Electrical contractors and other wiring installation contractors	2163	2193	1311	382	222	192	52	17	11	6
331420 - Copper rolling, drawing, extruding, and alloying	2	1	0	1	0	0	0	0	0	0
335930 - Wiring device manufacturing	2	2	0	0	0	1	1	0	0	0

7. Transportation & Logistics Services

NAICS	Without employees	Total, with employees	1-4	5-9	10-19	20-49	50-99	100-199	200-499	500 +
333920 - Material handling equipment manufacturing	20	33	13	5	7	2	6	0	0	0
484229 - Other specialized freight (except used goods) trucking, local	742	600	420	68	61	42	6	3	0	0
484239 - Other specialized freight (except used goods) trucking, long distance	526	432	280	40	32	48	13	17	1	1
482113 - Mainline freight rail transportation	6	12	2	1	0	4	2	0	1	2
488210 - Support activities for rail transportation	24	32	8	6	6	8	2	0	1	1

Operations & Maintenance (10+ industry codes)

1. Electric Power Generation and Transmission

NAICS	Without employees	Total, with employees	1-4	5-9	10-19	20-49	50-99	100-199	200-499	500 +
221119 - Other electric power generation	67	24	11	6	0	5	1	1	0	0
221121 - Electric bulk power transmission and control	6	10	3	2	0	0	0	1	2	2
221122 - Electric power distribution	56	66	10	6	3	38	0	3	3	3

2. Materials (e.g., chemicals, lubricants, resins, etc.)

NAICS	Without employees	Total, with employees	1-4	5-9	10-19	20-49	50-99	100-199	200-499	500 +
324110 - Petroleum refineries	16	16	4	2	2	0	1	1	3	3
325210 – Resin and Synthetic Rubber Manufacturing	5	11	0	1	4	1	4	1	0	0

3. Repair & Maintenance Services

NAICS	Without employees	Total, with employees	1-4	5-9	10-19	20-49	50-99	100-199	200-499	500 +
811210 - Electronic and precision equipment repair and maintenance	435	381	258	46	41	32	4	0	0	0
811310 - Commercial and industrial machinery and equipment (except automotive and electronic) repair and maintenance	3615	3316	2506	361	265	123	47	7	4	3
541330 - Engineering services	5852	3877	3141	236	177	193	59	42	20	9
541690 - Other scientific and technical consulting services	5416	2691	2461	136	59	26	7	2	0	0
541611 - Administrative management and general management consulting services	5782	1885	1717	95	48	17	4	2	2	0

Wind Turbine Component Manufacturing (27 industry codes)

1. Turbine Hub / Nacelle Assemblies

NAICS	Without employees	Total, with employees	1-4	5-9	10-19	20-49	50-99	100-199	200-499	500 +
332611 - Spring (heavy gauge) manufacturing	1	4	0	2	0	1	0	0	1	0
332991 - Ball and roller bearing manufacturing	0	2	0	0	0	2	0	0	0	0
333248 - All other industrial machinery manufacturing	26	29	13	5	3	7	0	1	0	0
335229 - Other major appliance manufacturing	0	1	1	0	0	0	0	0	0	0

2. Gearboxes

NAICS	Without employees	Total, with employees	1-4	5-9	10-19	20-49	50-99	100-199	200-499	500 +
333619 - Other engine and power transmission equipment manufacturing	9	16	5	5	2	2	1	0	1	0
333990 - All other general-purpose machinery manufacturing	80	79	37	19	6	14	3	0	0	0

3. Generators

NAICS	Without employees	Total, with employees	1-4	5-9	10-19	20-49	50-99	100-199	200-499	500 +
333611 - Turbine and turbine generator set unit manufacturing	5	1	1	0	0	0	0	0	0	0
333910 - Pump and compressor manufacturing	14	43	6	4	5	12	4	4	7	1
335311 - Power, distribution and specialty transformers manufacturing	3	4	1	2	1	0	0	0	0	0
335312 - Motor and generator manufacturing	8	10	5	1	0	2	2	0	0	0

4. Control Systems

NAICS	Without employees	Total, with employees	1-4	5-9	10-19	20-49	50-99	100-199	200-499	500 +
332410 - Power boiler and heat exchanger manufacturing	7	12	3	1	3	0	3	1	0	1
333413 - Industrial and commercial fan and blower and air purification equipment manufacturing	1	8	4	2	0	1	1	0	0	0
333416 - Heating equipment and commercial refrigeration equipment manufacturing	27	41	15	8	4	3	5	5	1	0
334512 - Measuring, medical and controlling devices manufacturing	44	75	24	7	18	17	3	5	1	0

5. Power Electronics

NAICS	Without employees	Total, with employees	1-4	5-9	10-19	20-49	50-99	100-199	200-499	500 +
334410 - Semiconductor and other electronic component manufacturing	15	20	7	4	2	3	3	1	0	0
335315 - Switchgear and switchboard, and relay and industrial control apparatus manufacturing	11	29	7	5	3	8	3	3	0	0
335910 - Battery manufacturing	2	3	0	0	0	2	1	0	0	0
335920 - Communication and energy wire and cable manufacturing	4	12	3	0	3	3	3	0	0	0
335990 - All other electrical equipment and component manufacturing	53	26	19	1	4	1	1	0	0	0
336390 - Other motor vehicle parts manufacturing	17	21	10	4	2	3	2	0	0	0

6. Towers & Main Shaft

NAICS	Without employees	Total, with employees	1-4	5-9	10- 19	20-49	50-99	100-199	200-499	500 +
331110 - Iron and steel mills and ferro-alloy manufacturing	6	7	1	1	2	2	0	0	1	0
332720 - Turned product and screw, nut and bolt manufacturing	3	8	1	2	2	2	0	1	0	0

7. Blades

NAICS	Without employees	Total, with employees	1-4	5-9	10-19	20-49	50-99	100-199	200-499	500 +
313320 - Fabric coating	2	0	0	0	0	0	0	0	0	0
325520 - Adhesive manufacturing	1	1	0	0	0	1	0	0	0	0
326150 - Urethane and other foam product manufacturing	3	11	2	0	2	4	2	1	0	0
333511 - Industrial mould manufacturing	9	5	2	3	0	0	0	0	0	0

Appendix F: Occupational Data & Education / Training Programs

Workforce Profile

Project Development

Job Title	NOC Code	NOC Category	Avg. Wage	AB Workforce	Job Profile
Land Acquisition Specialist	1225	Purchasing Agents and Officers	$44.12/hr	9,670	Land acquisition specialist (or Land Agent) acquire and administer land for project developers and coordinate with engineers, lawyers and scientists to ensure wind projects comply with budgets, timelines and right-of-way permits.
Attorney	4112	Lawyers and Quebec Notaries	$68.34/hr	9,200	Attorneys represent clients in the wind energy industry in contract negotiation, finance agreements, patent and intellectual property agreements, and mergers and acquisition
Civil Engineer	2131	Civil Engineers	$48.84/hr	8,435	Civil engineers supervise the planning, design, and maintenance of wind farms, and implement environmental protection measures.
Finance Manager	0111	Finance Managers	$58.60/hr	8,180	Finance managers analyze relevant data to develop preliminary project economic reporting and lead financial agreement/documents for project developers
Regulatory Expert	1122	Natural and applied science policy researchers, consultants and program officers	$53.20/hr	7,940	Regulatory experts study the policy and regulatory issues within the energy industry and apply their knowledge to develop positions and recommendations to project development teams.
Power Systems - Transmission Engineer	2133	Electrical and Electronics Engineers	$51.07/hr	6,700	Transmission engineers are responsible for the safe design, construction and testing of electrical components of wind turbine designs, transmission, and distribution systems
Power Marketer (Energy Markets)	1112	Financial and Investment Analysts	$47.54/hr	4,700	Power marketers collect, evaluate, and apply energy market data to sell power from proposed wind energy projects and lead the power purchase
Environmental Scientist	4161	Natural and Applied Science Policy Researchers, Consultants and Program Officers	$38.64/hr	4,055	Environmental scientists study the physical and wildlife sensitives of a project area and apply environmental regulations and policies to mitigate impacts from construction and operation of wind farms
Project Engineer	0211	Engineering Managers	$82.95/hr	2,985	Project engineers support the project development and construction phase by integrating wind assessment studies, layout designs, and managing procurement of components and services.
Quality Engineer	2141	Industrial and Manufacturing Engineers	$53.99/hr	1,900	Quality engineers design, implement, and coordinate between manufacturers, developers, project managers to deliver the most efficient, cost effective and high-quality products and processes that meet industry standards
Resource Scientist	2115	Other Professional Occupations in Physical Sciences	$52.85/hr	200	Resource scientists study the interaction of weather, climate, and project site conditions to develop wind predications and turbine layout.
Meteorologist	2114	Meteorologists and Climatologists	$43.08/hr	155	Meteorological technicians install, maintain, relocate and decommission towers and equipment used to collect the physical and chemical data and measure wind resource potential

Construction

Job Title	NOC Code	NOC Category	Avg. Wage	AB Workforce	Job Profile
Project Manager	0711	Construction Managers	$51.40/hr	15,600	Project managers organize, direct and evaluate the construction of the wind plant and oversee the business development and bidding of projects.
Project Engineer	0211	Engineering Managers	$82.95/hr	2,985	A project engineer supports the Project Manager during the development and construction phase of the wind project and typically becomes the construction manager.
Industrial Engineer	2141	Industrial and Manufacturing Engineers	$53.99/hr	1,900	Quality engineers work with quality control and quality assurance teams to develop processes, procedures and systems that ensure wind turbine components and processes meet quality standards and safety regulations.
Mechanical Engineer	2132	Mechanical Engineers	$54.99/hr	7,800	A mechanical engineer researches, designs, and tests the tools, machines, and mechanical devices to optimize the siting, systems, performance and cost of a wind farm
Civil Engineer	2131	Civil Engineers	$48.84/hr	8,435	Civil engineers are responsible for designing and supervising the construction of the wind plant, including testing of material quality, implementing environmental protection measures, maintenance and decommissioning.
Electrical Engineer	2133	Electrical and Electronics Engineers	$51.07/hr	6,700	Electrical engineers supervise, design, construct, and test wind turbine electrical components
Quality Engineer	2141	Industrial and Manufacturing Engineers	$53.99/hr	1,900	Quality engineers work with quality control and quality assurance teams to develop processes, procedures and systems that ensure wind turbine components and processes meet quality standards and safety regulations.
Construction Manager	0711	Construction Managers	$51.40/hr	15,600	Construction managers supervise and coordinate all wind plant construction activities, assist project managers with planning and cost estimates, and work with engineers to manage trade workers and subcontractors.
Trade Worker	7611	Construction Trades Helpers and Labourers	$25.89/hr	21,000	Trade workers prepare and install turbines and support structures
Construction Worker	7611	Construction Trades Helpers and Labourers	$25.89/hr	21,000	Construction workers prepare and clean up the wind construction site, move materials and equipment, build access roads and assemble the foundation, tower, nacelle, and blades of wind turbines.

Operations & Maintenance

Job Title	NOC Code	NOC Category	Avg. Wage	AB Workforce	Job Profile
Attorney	4112	Lawyers and Quebec Notaries	$68.34/hr	9,200	Attorneys represent clients in the wind energy industry in contract negotiation, finance agreements, patent and intellectual property agreements, and mergers and acquisition
Asset Manager	0125	Other Business Services Managers	$57.11/hr	1,595	Asset managers lead project financing and are responsible for developing and maintaining financial documents and records that are used by project developers.
Mechanical Engineer	2132	Mechanical Engineers	$54.99/hr	7,800	A Mechanical Engineer research, design, and test the tools, machines, and mechanical devices to optimize the siting, systems, performance and cost of a wind farm
Electrical Engineer	2133	Electrical and Electronics Engineers	$51.07/hr	6,700	Electrical Engineers design, construct, test, and supervise wind turbines' electrical components
Quality Engineer	2141	Industrial and Manufacturing Engineers	$53.99/hr	1,900	Quality Engineers work with quality control and quality assurance teams to develop processes, procedures and systems that ensure wind turbine components and processes meet quality standards and safety regulations.
Site-Plant Manager	0912	Manufacturing Managers	$50.57/hr	2,580	Site-plant managers oversee the wind plant systems and personnel by directing and coordinating operations for maintenance and repair, safety, performance, and profitability.
Environmental Science Technician	2231	Civil Engineering Technologists and Technicians	$44.55/hr	5,100	The environmental science technician works with engineers, land surveyors and contractors to monitor and mitigate the wind plant's impact on species and habitats
Wind Technician	2232	Mechanical Engineering Technologists and Technicians	$51.40/hr	2,115	A wind technician apply their knowledge of pneumatic, electronic and microcomputers to install, inspect, maintain, operate, diagnose and fix wind turbines.
Meteorological Technician	2255	Technical Operations and Geomatics and Meteorology	$43.08/hr	1,545	Meteorological Technicians install, maintain, relocate and decommission towers and equipment used to collect the physical and chemical dynamics of the atmosphere and wind resource potential

Wind Turbine Component Manufacturing

Job Title	NOC Code	NOC Category	Avg. Wage	AB Employees	Job Profile
Attorney	4112	Lawyers and Quebec Notaries	$68.34/hr	9,200	Attorneys represent clients in the wind energy industry in contract negotiation, finance agreements, patent and intellectual property agreements, and mergers and acquisition
Research Engineer	0013/ 2141	Senior Managers - Financial, Communications and Other Business Services	$82.48/hr	5,100	Research engineers work with government and coordinate manufacturing system materials to develop and assess new wind turbine technologies, components, and processes to deliver the most electricity at the lowest cost.
Aerospace Engineer	2146	Aerospace Engineers	$54.82/hr	115	Aerospace engineers research, design, develop, and test the structures and systems of a wind farm from concept to production.
Design Engineer	2132	Mechanical Engineers/Electrical and Electronics Engineers	$54.99/hr - $51.07/hr	7,685	Design engineers research, design, and evaluate wind turbine structure and components to ensure optimal generation of power at a low cost and reduced environmental impact

Sales Engineer	6221	Technical Sales Specialists - Wholesale Trade	$40.33/hr	16,900	Sales engineers sell complex technical goods and services to wind developers and ensure the product specifications, weights, and parts fit the needs of the ward farm project
Electrical Engineer	2133	Electrical and Electronics Engineers	$51.07/hr	6,700	Electrical engineers design, construct, test, and supervise wind turbines' electrical components
Engineering Manager	0211	Engineering Managers	$82.95/hr	2,985	Engineering managers oversee a team of engineers across all phases of the project who specify, design, analyze and verify the components and systems of the wind turbines
Industrial Engineer	2141	Industrial and Manufacturing Engineers	$53.99/hr	1,900	Industrial engineers determine the most effective ways to eliminate wastefulness in wind turbine production process
Quality Engineer	2141	Industrial and Manufacturing Engineers	$53.99/hr	1,900	Quality engineers work with quality control and quality assurance teams to develop processes, procedures and systems that ensure wind turbine components and processes meet quality standards and safety regulations.
Buyer	1225	Purchasing Agents and Officers	$44.12/hr	11,400	A buyer is responsible for purchasing raw materials and parts to manufacture wind turbines by evaluating suppliers, bidding on and negotiating contracts and supplier quality management systems
Logistician	1215 (AB 0713)	Supervisors, Supply Chain, Tracking and Scheduling Co-ordination Occupations	$41.95/hr	3,200	Logisticians analyze, direct and coordinate the supply chain for all wind turbine components, from supplier to consumer.
Salesperson	6221	Technical Sales Specialists - Wholesale Trade	$40.33/hr	16,900	A salesperson sells the manufactured wind turbine components to businesses and government using their technical knowledge of product features and pricing negotiation
Assembler and Fabricator	9525	Assemblers, Fabricators and Inspectors, Industrial Electrical Motors and Transformers	$20.24/hr	255	Assemblers and fabricators are responsible for assembling part and finished products (generators, computers, blades, towers)
Trade Worker	7611	Construction Trades Helpers and Labourers	$25.89/hr	21,000	Trade workers prepare and clean up the wind construction sites, move materials and equipment, and install turbines and support structures.
Transportation Worker	7511 (AB7 411)	Transport Truck Drivers	$28.75	44,500	Transportation workers, drivers as well as rail and water freight movers, are responsible for working with logisticians to deliver extremely large wind turbine components to the project site
Welders	7237 (AB 7265)	Industrial, electrical and construction trades	$37.04	18,740	Welders are responsible for fusing together the steel components of the turbine tower for shipment to the final project site.
Structural metal fabricators	7235 (AB 7263)	Industrial, electrical and construction trades	$30.55	670	Structural metal and platework fabricators and fitter form, assemble, and fit the steel segments the comprise the steel tower of the turbine.
Fibreglass manufacturer	9422 (AB 2233)	Plastics processing machine operators	$42.21	870	Fibreglass manufacturers are responsible for creating the fibreglass moulds and producing the turbine blades.

Education & Training Profiles

Project Development

Job Title	Education	Applicable Institutions in AB
Land Acquisition Specialist	Bachelors Degree - Business, Real Estate, Law, Engineering	University of Alberta, University of Calgary, University of Lethbridge
Attorney	Bachelors Degree; 3 years Law School; Bar Exam	University of Calgary, University of Alberta
Civil Engineer	Bachelors Degree - Civil Engineering	University of Alberta, University Calgary, University of Lethbridge
Finance Manager	Bachelors Degree - Business or Finance	MacEwan University, Mount Royal College, Robertson College, SAIT, NAIT, University of Alberta, University of Calgary
Regulatory Expert	Bachelors Degree - Political Science, Law, Economics, Public Policy, Public Affairs	University of Alberta, University Calgary, University of Lethbridge, MacEwan University, Athabasca University
Power Systems - Transmission Engineer	Bachelors Degree - Electrical Engineering	University of Alberta, NAIT, SAIT, University Calgary
Power Marketer (Energy Markets)	Bachelors Degree - Finance or engineering	University of Calgary, University of Alberta, NAIT, SAIT, University of Lethbridge, Athabasca University
Environmental Scientist	Bachelors Degree	University of Alberta, University Calgary, University of Lethbridge, MacEwan University, Athabasca University,
Project Engineer	Bachelors Degree - Engineering	University of Alberta, University Calgary, University of Lethbridge
Quality Engineer	Bachelors Degree - Engineering	University of Alberta, University Calgary, University of Lethbridge
Resource Scientist	Bachelors Degree - Atmospheric Science, Engineering, Math	University of Alberta, University Calgary, University of Lethbridge, MacEwan University, Concordia University of Edmonton, Red Deer College
Meteorologist	Bachelors Degree	University of Alberta, Grant MacEwan University

Construction

Job Title	Education	Applicable Institutions in AB
Project Manager	Bachelors Degree - Engineering, Construction Management, Business Management	University of Alberta, University Calgary, University of Lethbridge, NAIT
Project Engineer	Bachelors Degree - Engineering	University of Alberta, University Calgary, University of Lethbridge
Industrial Engineer	Bachelors Degree - Industrial Engineering	University of Alberta, University Calgary, University of Lethbridge
Mechanical Engineer	Bachelors Degree - Mechanical Engineering	University of Alberta, University Calgary, University of Lethbridge
Civil Engineer	Engineering Services	University of Alberta, University Calgary, University of Lethbridge
Electrical Engineer	Bachelors Degree - Electrical Engineering	University of Alberta, University Calgary, University of Lethbridge, NAIT
Quality Engineer	Bachelors Degree - Engineering	University of Alberta, University Calgary, University of Lethbridge
Construction Manager	High School Diploma with experience	N/A
Trade Worker	Apprenticeship or Technical School	NAIT, SAIT, Olds College, Lakeland College,
Construction Worker / Labourer	High School Diploma	N/A

Operations & Maintenance

Job Title	Education	Applicable Institutions in AB
Attorney	Bachelors Degree; 3 years Law School; Bar Exam	University of Calgary, University of Alberta
Asset Manager	Bachelors Degree - Business or Finance	MacEwan University, Mount Royal College, Robertson College, SAIT, NAIT, University of Alberta, University of Calgary
Mechanical Engineer	Bachelors Degree - Mechanical Engineering	University of Alberta, University Calgary, University of Lethbridge
Electrical Engineer	Bachelors Degree - Electrical Engineering	University of Alberta, University Calgary, University of Lethbridge, NAIT
Quality Engineer	Bachelors Degree - Engineering	University of Alberta, University Calgary, University of Lethbridge
Site-Plant Manager	High school diploma	N/A
Environmental Science Technician	Associates Degree	NAIT, SAIT, Lethbridge College
Wind Technician	Technical School / Bachelor Degree - Mechanical Engineering	NAIT, Lethbridge College
Meteorological Technician	High school diploma	N/A

Wind Turbine Component Manufacturing

Job Title	Education	Applicable Institutions in AB
Attorney	Bachelors Degree; 3 years Law School; Bar Exam	University of Calgary, University of Alberta
Research Engineer	Bachelors Degree	University of Alberta, University of Lethbridge, University of Calgary, The King's University, Mount Royal University
Aerospace Engineer	Bachelors Degree - Aerospace Engineering	University of Alberta, University Calgary, University of Lethbridge
Design Engineer	Bachelors Degree - Mechanical or Electrical Engineering	University of Alberta, University Calgary, University of Lethbridge
Sales Engineer	Bachelors Degree - Engineering	University of Alberta, University Calgary, University of Lethbridge
Electrical Engineer	Bachelors Degree - Electrical Engineering	University of Alberta, University Calgary, University of Lethbridge, NAIT
Engineering Manager	Bachelors Degree - Engineering	University of Alberta, University Calgary, University of Lethbridge
Industrial Engineer	Bachelors Degree - Industrial Engineering	University of Alberta, University Calgary, University of Lethbridge
Quality Engineer	Bachelors Degree - Engineering	University of Alberta, University Calgary, University of Lethbridge
Buyer	Bachelors Degree	University of Alberta, University of Lethbridge, University of Calgary, The King's University, Mount Royal University
Logistician	Associates or Bachelors Degree	University of Alberta, University of Lethbridge, University of Calgary, The King's University, Mount Royal University
Salesperson	High School Diploma	N/A
Assembler and Fabricator	High School Diploma	N/A
Trade Worker	Apprenticeship or Technical School	NAIT, SAIT,
Transportation Worker	High School Diploma	N/A
Welders	Apprenticeship or Technical School	NAIT, SAIT, Olds College, Red Deer College, Lethbridge College
Structural metal fabricators	Apprenticeship or Technical School	NAIT, SAIT, Olds College, Red Deer College, Lethbridge College
Fibreglass manufacturer	Science, IT or Engineering Technology program	NAIT

Appendix G: Alberta Wind Sector Supply Chain Participants

Below is a list of companies and organizations that are actively participating in or have the potential capacity to participate in the province's wind energy supply chain. Please note this list is not comprehensive.

Project Development & Construction

Project Developers

- ATCO Group
- Alberta Wind Energy
- BluEarth Renewables
- BowArk Energy
- Capital Power
- Dufferin Wind Power
- EDF EN Canada
- EDP Renewables
- Enbridge
- GreenGate Power
- GS E&R Canada
- GTE Power
- Joss Wind Power
- Kineticor Resource
- Kruger Energy
- Maxim Power
- NaturEner Energy Canada
- NextEra Energy Canada Development & Acquisitions
- Northern Power
- Pristine Power (Veresen)
- Rocky Mountain Power
- Samsung Renewable Energy
- Sequoia Energy
- Suncor Energy
- WPD Windmanager Canada
- TransCanada
- Wind River Power

Original Equipment Manufacturers (OEMs)

- Enercon Canada
- GE Renewable Energy
- Nordex-Acciona Windpower
- Senvion Canada
- Siemens Wind Power
- Vestas Canada

Consulting (Engineering)

- Axor Group
- AWS Truepower Canada
- Cahill Industrial
- Canadian Projects Limited Burns & McDonnell
- CIMA+
- Dillon Consulting
- DNV GL
- Prairie Sky
- RWDI Consulting Engineers & Scientists
- Rowan Williams Davies & Irwin
- The Cogent Group
- Williams Engineering Canada
- WSP Canada

Consulting (Environmental & Energy)

- AMEC Foster Wheeler
- Bantrel Power Solutions
- Current Solutions Incorporated Power Advisory LLC
- Dependable Energy Services
- Ecng Energy LP
- Energy Associates International
- Hatfield Consultants
- Hemmera
- Maskwa Environmental Consulting
- Power Grid Specialists
- Rodan Energy Solutions
- SgurrEnergy (Wood Group)
- Slingshot WEST Wind Energy Calgary
- SOLAS Energy Consulting
- Spirit Pine Energy Corporation
- Stantec
- Tundra Environmental & Geotechnical
- URICA Energy Management

Consulting (General)
- CanACRE
- Communica Public Affairs
- CRA
- EDC Associates
- IMPACT Consulting
- Sage Stone

Land Acquisition
- LandSolutions Inc.
- SCOTT Land & Lease

Steel Fabrication
- AB&S Steel
- Advent Steel Fabrication
- All Steel
- Ferrous Fabricators
- Harris Rebar
- J.P. Metal Manufacturing
- Leder Steel
- M2M Machining
- Rolark Stainless Steel
- Steelform Group
- Wilco
- West Structural

Project Construction
- Aecon
- Alteck Line Contractors
- Bantrel Constructors
- Bird Construction
- Black & McDonald
- Borea Construction
- Bossi Contruction
- CANA
- Ellis Don
- Hatch
- Iconic Power Systems
- J L T Construction
- Jacobs Canada
- Jyoti Structures Canada
- Kiewit
- Mammoet
- Montana Alberta Tie
- Mortenson
- Nexans Canada Inc Iconic Power Systems
- One Wind Services
- PowerTel
- Surespan Wind Energy Services
- Tarpon Construction Management
- Valard Construction
- Whissell Contracting
- Wajax

Equipment, Materials & Logistics
- Carte International
- Challenger Motor Freight
- Chinchaga Anchors & Pilings
- Canadian National (CN) Rail
- CP Rail
- Equipment Express
- ESI Energy Services
- Finning (Canada)
- Global Energy Services
- Grace Energy Solar & Wind Products
- Inland Concrete
- Mitsubishi Hitachi
- M2M Machining
- Metalboss Technologies
- Nanalysis
- SKF
- REV Engineering
- Totran Transportation Services
- Tundra Process Solutions
- TNT Crane & Rigging
- Ultra Energy Services
- Unified Systems Group Inc

Technology Supplier
- BH Electronics
- Canada Boosters
- Carte International
- Sustainable Energy Systems
- Pronghorn Controls

Operations & Maintenance

Project O&M
- AltaLink
- Arista Renewable Energies
- ATCO
- Black & McDonald
- Clear Stream Energy
- EDF EN Canada
- EDP Renewables
- Enbridge
- ENMAX
- IPS (Integrated Power Services)
- Mortenson
- One Wind
- Powell Industries
- Surespan Wind Energy Services
- SKF
- Suncor
- Tetra Tech EBA
- TransAlta
- TransCanada
- Windar Photonics

Equipment & Solutions
- ABB Inc.
- AWS Truepower Canada
- Babco Electric & Engineering
- BH Electronics
- Campbell Scientific
- GlobalView
- Motion Canada
- Nexans Canada
- NRGSTREAM
- Schneider Electric
- SKF
- Spartan Controls
- Subnet Solutions

Wind Turbine Component Manufacturing

Bearings
- Bailey Metal Products
- Casterland / Mcwheels
- Innovative Mechanical Solutions
- MetalBoss Technologies
- NTN Bearing Corporation of Canada
- Schaeffler Canada
- Timken Canada

Blades
- EPS Molders
- Erin Industries
- Firwin Alberta
- Kelly Packaging Service
- Krona Industries
- Loron Holdings
- Midgaard Spray Foam Systems
- North Peace Insulating Products
- PLR Insulating Co.
- Polyrose Manufacturing
- Sealed Air (Canada) Co./Cie
- Super Dolly Pad (1998)
- Sureline Mfg.
- Transfoamers Foam Insulation

Coatings
- Ar-Tech Coating
- Blue Flame Manufacturing
- Cactus Coating
- Diversified Coatings

Gearbox
- Wilson Machine Co. (now Wajax)

Generators
- Columbia Power Systems
- Diversified Coatings
- Ebera International
- Orbital Energy

Pressure Vessels
- Cessco Fabrication & Engineering
- Dacro Industries
- KNM Process Equipment

Other Ecosystem Stakeholders

Industry Associations & NGOs

- Alberta Clean Technology Industry Alliance (ACTIA)
- Alberta Direct Connect (ADC) Consumers Association
- Alberta Federation of Rural Electrification Associations
- Association of Professional Engineers & Geoscientistcs (APEG) Alberta
- Canadian Clean Power Coalition
- Canadian Wind Energy Association (CanWEA)
- Independent Power Producers Society of AB
- Industrial Power Consumers Association of Alberta
- Pembina Institute

Education & Training

- Athabasca University
- Iron & Earth
- Lakeland College
- Lethbridge College
- Medicine Hat College
- Mount Royal University
- Northern Alberta Institute of Technology (NAIT)
- Oak Leaf
- Olds College
- Red Deer College
- Southern Alberta Institute of Technology (SAIT)
- University of Alberta
- University of Calgary

Finance & Credit

- ATB Financial
- Bullfrog Power
- Canadian Power Holdings
- Capstone Infrastructure
- DBRS
- Emera Inc.
- Emergex
- Natural Energy Partners
- Morgan Stanley
- Sun Life

Government & Regulatory

- Alberta Electricity System Operator (AESO)
- Alberta Innovates
- Alberta Utilities Commission
- Calgary Economic Development
- Edmonton Economic Development
- Global Affairs Canada
- Government of Alberta
- Innovate Calgary (Kinetica Ventures)
- National Research Council (NRC) IRAP
- Natural Resources Canada
- Sustainable Development Technology Canada (SDTC)