

# Wind Technology Road Map

**Inform  
and  
Engage  
Canadians**

**Create  
Centres of  
Excellence**

**Support  
Innovative  
Demonstration  
Projects**

**Accelerate  
Development  
of Small Wind  
Technology**

**Expand the  
Role of  
Canadian  
Industry**

**Strengthen  
the Policy  
Framework**

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HERE**



*This document was prepared under the direction of the Wind Technology Roadmap Industry Steering Committee using input obtained from key wind energy industry and academic participants at three workshops held across the country between November 2008 and February 2009. The document attempts to represent the views of the roadmap participants and of the steering committee members, and does not necessarily reflect the views of the Government of Canada or of individual organizations represented, nor does this document constitute an endorsement of any commercial product or person.*

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*All dollar figures are in Canadian dollars, unless otherwise stated.*



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## Message from Co-Chair Dawn Farrell, Chief Operating Officer, TransAlta

As Industry Chair of the Wind Technology Roadmap process, I am honored to be able to present the culmination of all the hard work put in by our Steering Committee members, the various working groups, and the participants at our workshops. I particularly want to express my thanks for the work of the Federal Government who helped our industry compile this roadmap.

We know that the wind industry is growing rapidly both in Canada and around the world. We are now at a point where proactive action will allow Canada to increase and capture its full share of the massive global investment that will occur. The growth of this industry will be a key solution for Canada to address the carbon constrained energy markets of the future.

In this roadmap, you will find the key technology development and deployment issues that the wind industry needs to address in order to be a mainstream player in the Canadian electricity industry. Our Steering Committee has worked hard to identify a common vision where Canada becomes a global wind energy leader that meets more than 20% of its electricity needs through wind energy by 2025. We then highlight the key issues and needs of our industry to achieve this vision. It is our view that the strategies and initiatives outlined in the roadmap can be easily implemented with continued coordination and support between government, associations and industry players – making our vision a reality.

Members of the Steering Committee, government and our industry will be using this roadmap to direct the actions that are necessary for Canada to develop its vast wind resources. For more than 100 years, Canadians have developed similar expertise to utilize hydro, coal, gas and nuclear resources – tapping into wind is merely the next step in what has been a long process of utilizing natural resources for electricity production. This work is timely and it transforms our thinking about wind from being a marginal energy source to being a major component of our energy supply.

Wind is ready to take its position as a conventional source of electricity and this roadmap is designed to create the foundation that will secure this position.



# Message from Co-Chair Geoff Munro, Chief Scientist & Assistant Deputy Minister, Innovation and Energy Technology Sector, Natural Resources Canada

This Wind Technology Roadmap (WindTRM) is an industry-led, government-supported initiative that has developed a long-term vision for the Canadian wind energy industry and identified the major technology gaps and priorities to achieve a major increase in deployment of wind energy in Canada.

Canada's geography makes it ideally suited to capitalize on large amounts of wind energy. The benefits of increased deployment of wind energy include reductions in greenhouse gas emissions and air contaminants, reduced dependence on fossil fuels, and increased development for rural communities.

However, incorporating a large amount of wind energy requires continued innovation to improve efficiencies, ensure turbine technologies can be operated in the Canadian climate, and address grid integration challenges.

The WindTRM is an action plan designed to encourage the growth of domestic wind energy expertise and the development of wind energy technology specifically relevant to the Canadian environment. Through the collective action of industry, government and academia, Canada can realize these economic, energy, societal and environmental benefits.

I would like to thank my predecessor, Margaret McCuaig-Johnston, for initiating this WindTRM and for her strategic guidance throughout its development.



# Executive Summary:

## This Roadmap has identified a vision and the action items to achieve it

### Vision:

By 2025, Canada will be a world-leading supplier of key wind energy technologies and policy solutions. More than 20% of its electricity needs will be met by wind and sustained annual growth will create additional wealth through export.

### Action Items:

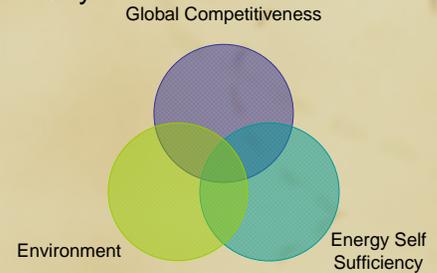
- 1. Strengthen the Policy Framework:** Commitment of public funding, including short-term incentive mechanisms, along with improvements in approval processes and long-term planning and recognition of environmental externalities through emissions markets and other market-based payments, will create a competitive environment for wind in Canada that will attract global investments, generating environmental and economic benefits for all Canadians.
- 2. Inform and Engage Canadians:** Improved communication to the public, the workforce, financiers and government officials of the real benefits and opportunities for wind energy will create an environment that motivates the broader population in Canada to commit funds, time and energy to the advancement of the wind energy industry.
- 3. Expand the Role of Canadian Industry:** Identification of key areas of need and opportunity for Canada, through mapping of the value chain, will create the information necessary to spur investment by industry and educational institutions into developing infrastructure, operations and skill sets to support the advancement of the wind energy industry in Canada.
- 4. Create Centres of Excellence:** Creation of Centres of Excellence will enable the necessary developments in tools, systems, technologies and services, so as to develop competitive niche areas for Canadian industry and drive down the cost of wind energy in Canada.
- 5. Accelerate Development of Small Wind:** Collaboration, funding and support for advancements in small wind systems will both allow Canada's individuals, small businesses and communities to have stable, secure, economical, wealth generating energy solutions, and provide leading-edge solutions for rural and remote communities around the world.
- 6. Support Innovative Demonstration Projects:** Support for innovative demonstration projects will clearly illustrate the economic and environmental feasibility of, and returns on investments in, wind energy, thereby enabling the full realization of benefits from all action areas.

# The Vision

By 2025, Canada will be a world-leading supplier of key wind energy technologies and policy solutions. More than 20% of its electricity needs will be met by wind and sustained annual growth will create additional wealth through export.

## The Destination:

By 2025, Canada will be a world leader in wind energy technology and expertise. Canadian firms will create high-value, “green” jobs. They will compete with world-leading firms by developing and exporting wind energy projects, technology and expertise. Canadian firms will help to push the envelope of technological development, particularly in areas where Canada will have a natural advantage, for example, cold climate technology, using hydro as a natural complement to wind's variability, and capitalizing on Canada's excellent coast-to-coast wind resource. Canada will continue to successfully balance its economic growth with environmental responsibility. Finally, Canadians will be able to enjoy even greater energy security through an increase in energy diversification.



## The Path Forward:

In order to seize the wind energy development, environmental and export opportunities, nearly one hundred wind energy experts from industry, academia and government have worked collaboratively to develop this WindTRM. Through a series of workshops, participants developed the vision, identified the barriers to achieving the vision, and articulated an action plan for overcoming those barriers. This document presents the key action items to which they agreed. Appendix A provides a more detailed overview of the key drivers in the wind energy market. Appendix B of this document presents a more fulsome discussion of the barriers and the action items, as well as the WindTRM development process.



Today, we are already travelling the road towards increased utilization of Canada's vast wind resource for electricity production. The need for a strong policy framework to support the continuing growth of wind energy in Canada has never been more important. This policy framework must target both utility-scale and small wind energy technology and should seek to develop a Canadian supply chain that is supported through research initiatives undertaken by Centres of Excellence and innovative demonstration projects. It must be further complemented by efforts to disseminate quality information that can engage and inform key decision-makers and the public on the opportunities associated with wind energy in Canada.

Utilization of Canada's wind resource will achieve a number of benefits, including<sup>[1]</sup>:

- The creation of a minimum of 52,000 jobs;
- \$132 billion of investment, of which a minimum of \$80 billion would be made in Canada;
- \$330 million of local tax and land lease revenues annually for communities;
- 17 megatonnes of avoided greenhouse gas emissions annually, which is nearly equal to the 2006 emissions of the province of New Brunswick, and;
- \$1.5 billion of business activity annually in the small wind sector.

[1] Source: CanWEA Wind Vision 2025 and further input from CanWEA throughout the project

## Wind Energy Industry Today

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Wind energy has become a multi-billion dollar global industry, and is continuing to experience rapid growth. The Global Wind Energy Council has predicted that the global wind market will grow by 276% to reach 332,000 MW of total installed capacity by 2013, representing an addition of 212,000 MW and over \$500 billion in investment in 5 years. This would result in wind energy accounting for around 3% of global electricity production (up from just over 1% in 2007).

Wind power could supply 6.6% of world electricity by 2020, according to a moderate projection by the Global Wind Energy Council, which represents 560,000 MW of installed capacity and more than US\$1 trillion in investment. This would also represent a savings of 825 million tonnes of CO<sub>2</sub>, which is greater than all the emissions currently produced by Canada.

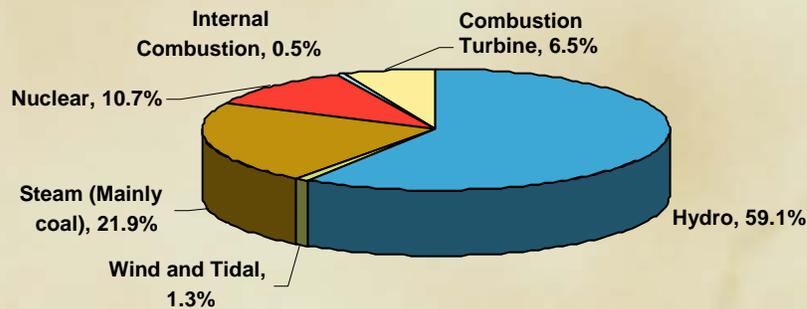
Wind energy has proven to be a major source of green jobs around the world. Globally, more than 400,000 people are employed in the wind energy sector today, which includes manufacturing, development, installation, operations and maintenance. In the United States alone, 35,000 new jobs were created in the wind energy sector in 2008. Within the European Union, wind energy has been responsible for the creation of 33 new jobs a day, every day of the week, for the last five years. The WorldWatch Institute estimates that 1.75 million new jobs will be created in the wind energy sector between now and 2020.

Approximately 27,000 MW of new capacity was installed worldwide in 2008, representing a 29% increase in the world's total installed wind power capacity compared to 2007. Worldwide investment in wind during this period was US\$50 billion.

Canada currently has approximately 2,854 MW of wind energy installed representing roughly \$6 billion of investment, and there is an additional 5,000 MW of wind energy that has been contracted or is under construction.



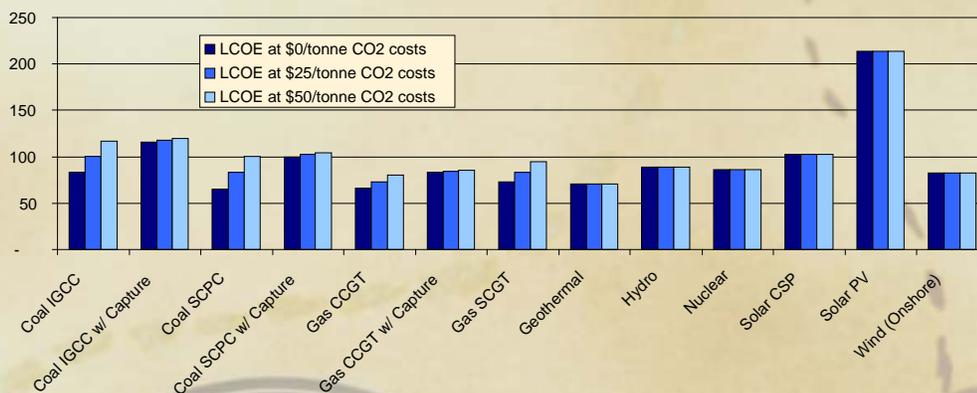
Canada's 2007 electricity generating capacity is presented in the following chart, which illustrates that wind energy is currently representing only a small share of electricity generation in Canada. As the following map illustrates, Canada has significant wind resources all across the country.



Source: Statistics Canada: no. 57-202-X

A major perceived disadvantage to wind energy has been the cost differential between electricity produced by wind, and that produced by other, more conventional methods such as gas or coal. Presently the cost of the energy in Canada does not reflect any cost related to carbon emissions. The following graph illustrates the current cost of producing electricity, and the effect that different pricing on carbon emissions would have in terms of making wind energy more competitive.

### Levelized Cost of Electricity



Source: Based on analysis by GE of 2008 data from Congressional Research Services [2]

[2] Description of Acronyms: IGCC - Integrated gasification combined cycle, SCPC - Supercritical pulverized coal, CCGT - Combined-cycle gas turbine, SCGT - Semi-closed gas turbine, CSP - Concentrating solar power

Canada enjoys a number of advantages – such as one of the world’s best wind resources, an electricity grid dominated by hydroelectricity that can facilitate the integration of large amounts of wind, ready access to the world’s largest electricity market for our electricity exports, and a quality manufacturing base that is seeking opportunities to diversify into rapidly growing industrial sectors of the 21st century – and, therefore, is in an ideal position to take advantage of the enormous investments globally that will be made in this technology. In addition to the economic opportunity presented by wind energy, greater use of wind energy can significantly improve the environmental performance and sustainability of our electricity system. To capture this opportunity, and maximize the benefits for Canada, we need to position ourselves on both a technology and policy basis.



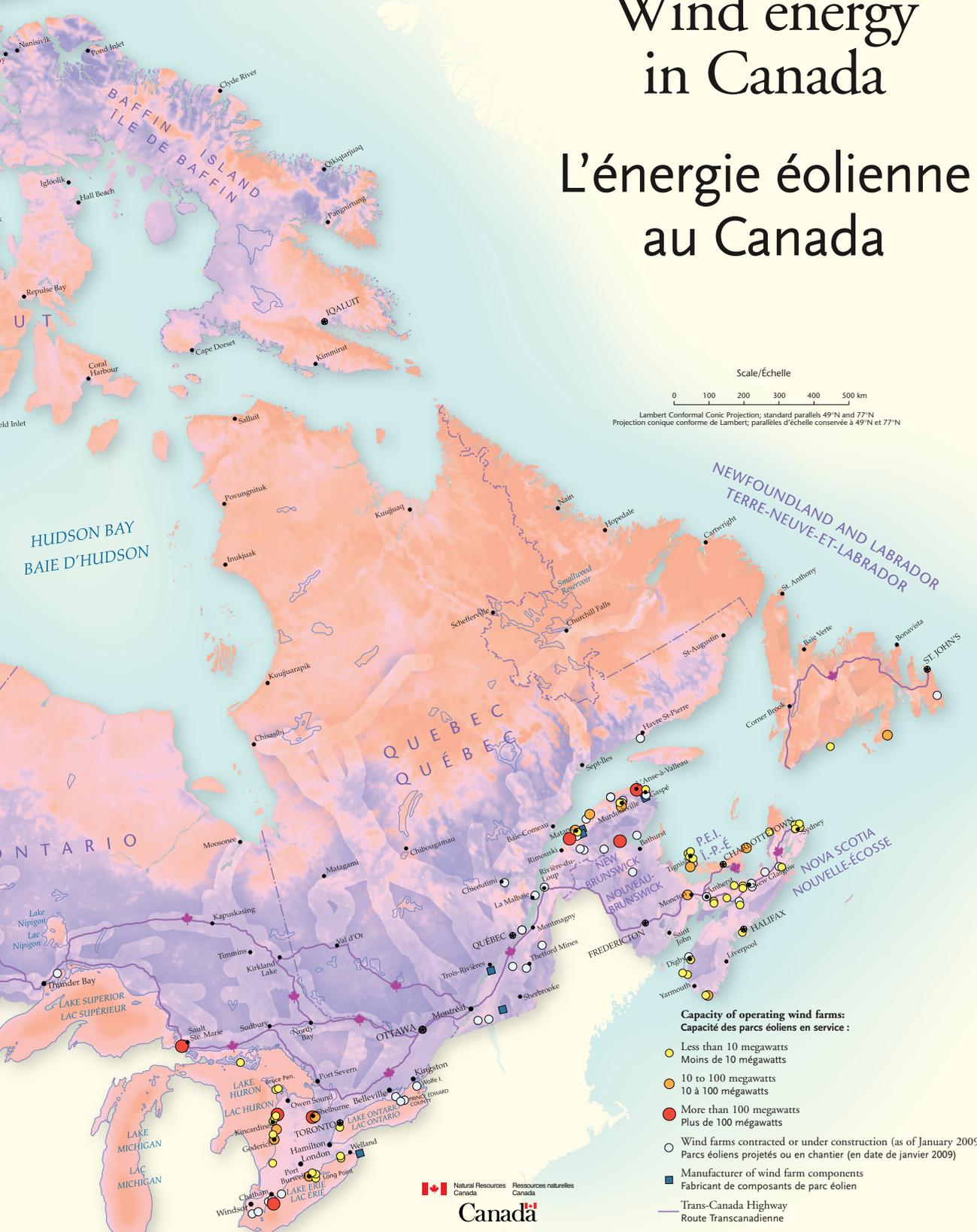
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[www.canadiangeographic.ca/wind](http://www.canadiangeographic.ca/wind)

# Wind energy in Canada

## L'énergie éolienne au Canada



Scale/Échelle

0 100 200 300 400 500 km

Lambert Conformal Conic Projection; standard parallels 49°N and 77°N  
Projection conique conforme de Lambert; parallèles d'échelle conservée à 49°N et 77°N

**Capacity of operating wind farms:  
Capacité des parcs éoliens en service :**

- Less than 10 megawatts  
Moins de 10 mégawatts
- 10 to 100 megawatts  
10 à 100 mégawatts
- More than 100 megawatts  
Plus de 100 mégawatts
- Wind farms contracted or under construction (as of January 2009)  
Parcs éoliens projetés ou en chantier (en date de janvier 2009)
- Manufacturer of wind farm components  
Fabricant de composants de parc éolien
- Trans-Canada Highway  
Route Transcanadienne

# I. Strengthen the Policy Framework

- i. Put in place temporary incentive mechanisms
- ii. Create effective procurement practices
- iii. Promote long term planning of transmission corridors
- iv. Produce regulatory roadmaps

Until the environmental attributes of wind energy are fully valued in the marketplace, it will be critical that appropriate mechanisms be put in place. This is critical, as electricity generation decisions last for 25 to 50 years. Incentive mechanisms will create a level playing field upon which the right investment decisions can be made today. Without incentive mechanisms in the short term, wind is not economical compared to other forms of fuel that currently do not pay for carbon emissions.

As the market develops and recognizes the true value of non-emitting sources such as wind, the need for such temporary incentive mechanisms will be reduced and eventually eliminated. These are seen as a short term solution that will help 'kick start' the industry. Incentive mechanisms today ensure investments in a capital stock build that is carbon neutral.

Industry will need to take the lead, in collaboration with government, in identifying improved energy resource procurement practices that best fit the Canadian situation and that also inspire investment for the next 20 years. This can be accomplished by examining the successful practices used across Canada and elsewhere in the world and adopting a process that fits the Canadian context.

Similar to other electricity technologies, one of the greatest barriers to future development is the inadequacy of the transmission system in Canada. Over the past 100 years, Canadians have invested in transmission to access our vast hydro, gas and coal resources; the decision to access Canada's vast wind resources is consistent with these past practices. The lead time to build new transmission facilities far exceeds the speed required to capitalize on the growth of wind energy. Long-term planning and permitting of new transmission capacity, that is designed to help access and integrate Canada's wind resources, will be critical for enabling future development.



Successful transmission planning will identify key areas of wind energy development as well as efficient processes to provide the transmission infrastructure required to bring this power to areas of high electricity demand. Improving the efficiency, while maintaining the effectiveness of permitting and approval processes for such infrastructure will be required if it is to be built in a timely fashion.

With best practices identified as a guideline (as described above), the establishment of clear and more efficient regulatory frameworks for permitting and approving wind energy projects will enhance clarity, reduce uncertainty, and provide a more solid base for project planning and investment.

Achieving these goals will require action on a number of fronts, as outlined in the following table. While certain parties will need to take leadership in some areas, collaboration across stakeholder groups, such as government, industry, non-government organizations (NGOs), utilities and academia, will also often be required. In some cases action will not require additional costs over the existing course of business. In other cases, investments will be necessary to achieve these goals. For example, identification of the most effective procurement practices could have a modest cost. Alternatively, temporary incentive mechanisms could require significant investments of hundreds of millions of dollars per year to enable Canada to compete for investment globally, as the market evolves to a mature stage.

Action Item	When	Who
Put in place temporary incentive mechanisms	Six months	Government
Create effective procurement practices	One year	Utilities, Industry,* NGOs, Government
Promote long term planning of transmission corridors	Long-term / Ongoing	Utilities
Define clear and efficient regulatory roadmaps	One year	Cooperation between federal and provincial governments

\*Industry refers to developers, manufacturers, service providers and all organizations involved in the wind energy industry, excluding utilities, whether privately or publicly owned.

## II. Inform and Engage Canadians

- i. Create a centralized repository of peer-reviewed studies
- ii. Provide analysis to decision-makers of costs and benefits of wind in our electricity systems
- iii. Share evidence-based information with decision-makers, media, opinion leaders and the general public
- iv. Improve and update education and training to build a sustainable (skilled) workforce

Wind energy is a relatively new contributor to Canada's energy mix, and as such, causes many stakeholders to have questions and concerns about its development and impacts. Despite this, it has been consistently demonstrated that wind energy has broad public support in Canada. In order to continue to promote evidence-based decision-making for wind energy, it is necessary to create a repository of credible and verifiable information and research that has been properly reviewed and vetted, and which is administered by an objective party. It will also be important to ensure that this information is shared with decision-makers, media, opinion leaders and the general public.

Decision-makers need to have a better understanding of the full life-cycle costs of different forms of electricity generation as well as the costs and benefits of having 20% of Canada's electricity come from wind energy in comparison with other potential electricity sector development scenarios. Such information is required to ensure well informed decision-making now and in the next decade on new infrastructure (generation and transmission) for Canada's electricity grid.

The following table identifies the key action items. In all cases, collaboration will be required across a host of stakeholders, and major initiatives are anticipated to cost several hundred thousand dollars each.

Action Item	When	Who
Create a centralized repository of peer reviewed studies	Beginning immediately	Government, industry, academia, NGOs
Provide analysis to decision-makers of cost/benefit of wind in our electricity systems	One year	Government, industry, academia, NGOs
Share evidence-based information with decision-makers, media, opinion leaders and the general public	Starting now and continuing until we reach the 20% target	NGOs, utilities, industry
Improve and update education and training to build a sustainable (skilled) workforce	Beginning immediately	Government, industry, academia, NGOs

### III. Expand the Role of Canadian Industry

- i. Map the value chain
- ii. Identify opportunities for Canadian industry
- iii. Facilitate partnerships and encourage Canadian sourcing of materials, components and services
- iv. Create an attractive climate for investment in wind energy

Canadian industry currently has very little involvement in the supply chain of large turbine manufacturing. Our limited market has historically not been sufficient in size to attract significant industry attention, except in unique circumstances such as in Quebec where procurement contracts have required local manufacturing. Despite these challenges, as described throughout this document, there is now significant opportunity for Canadian industry in the realization of the vision of this roadmap.

Mapping out the full life-cycle supply chain and identifying the opportunities that existing Canadian suppliers could fulfill will form a basis to maximize industry involvement. It is important to note that the value chain includes service organizations, software and modeling companies and providers of ancillary services, in addition to wind turbine manufacturers and component suppliers.

It will be important to facilitate partnerships between potential industry suppliers and the original equipment manufacturers (OEMs), facility owners and operators and others that will have need of the products and services that can be provided by existing industry.

We must also recognize that Canada is competing for this investment with many other jurisdictions and that it is critical for Canada to establish a competitive investment policy framework. If no action is taken, Canadian industry will miss out on a huge part of the value chain that will be created in achieving the vision.



The following table identifies the key action items in this area. Some of these initiatives, such as mapping the value chain and facilitating partnerships, are expected to cost in the range of a quarter of a million dollars each. Other activities, such as identifying opportunities for Canadian industry, are anticipated to require larger investments (in the order of approximately one million dollars each). An understanding of requisite investment levels for creating an attractive climate for investment in wind energy overall will require analysis and consideration as the market matures.

Action Item	When	Who
Map the value chain	6 months	Industry, NGOs and government
Identify opportunities for Canadian industry	One year	Industry, NGOs and government
Facilitate partnerships and encourage Canadian sourcing of materials, components and services	One year	NGOs, government and industry
Create an attractive climate for investment in wind energy	Ongoing	Government



## IV. Create Centres of Excellence

Create Centres of Excellence for:

- i. Wind Resource and Energy Yield Assessment
- ii. Advanced Operation and Transmission Planning Methodologies
- iii. Ancillary Services: Wind Integration and Wind Firming Technologies

A number of new and advanced tools and technologies will be required by the wind industry and the planners/operators of our electricity systems. The most efficient way to develop these is via joint, concerted, efforts. Such an effort can be facilitated through one or more centres of excellence or networks of centres of excellence. The major tools and technologies identified by the road mapping process include:

- Established standards for wind resource assessment, energy yield estimation and operational data reporting;
- A national wind database compiling comprehensive wind and operational data maintained for R&D and model validation/improvement purposes;
- Innovative methodologies for transmission planning including probabilistic models;
- Improved system operator tools for incorporation of wind energy into system operation including short-term forecasting, and;
- Enhanced ancillary services to help balance supply and demand with large amounts of wind penetration. This involves both wind firming technologies as well as other services and technologies to facilitate wind integration.



The following table identifies the types of Centres of Excellence that are required. It is believed that investments of \$15 to \$25 million over three years, in each of these areas, are required to make the advances that are necessary to move the industry forward towards achieving the vision.

Action Item	When	Who
<b>Wind Resource and Energy Yield Assessment</b>		
<ul style="list-style-type: none"> <li>• Develop high-quality field and laboratory data as well as long term reference data for wind</li> <li>• Develop better standards and procedures for data collection, resource assessment and operational reporting</li> <li>• Enhance model accuracy, precision and robustness for long-term planning</li> <li>• Improve short-term forecasting tools</li> </ul>	<ul style="list-style-type: none"> <li>• Data collection should start immediately (ongoing)</li> <li>• Standards could be established within 2-5 years</li> <li>• 5-10+ years required for model enhancement</li> </ul>	NGOs, research institutions, academia, industry, government
<b>Advanced Operation and Transmission Planning</b>		
<ul style="list-style-type: none"> <li>• Develop new probabilistic transmission planning tools</li> <li>• Improve operations room tools to integrate short-term wind forecasting</li> </ul>	<ul style="list-style-type: none"> <li>• Standard methodology could be established in 2 years</li> <li>• Tools could be available in 2-5 years</li> </ul>	NGOs, research institutions, academia, industry, government
<b>Ancillary Services: Wind Integration and Wind Firming Technologies</b>		
<p>Improve ancillary services to help balance supply and demand with large amounts of wind penetration. Potential solutions include: enhancements of energy storage devices; the development of interregional wind systems to take advantage of the diversity of wind production in different geographic areas; and the creation of solutions to meet generation increase/decrease requirements including demand management and more flexible energy interchanges between regions</p>	<ul style="list-style-type: none"> <li>• 2 years to scope research and produce whitepaper</li> <li>• 3+ years to quantify needs and do R&amp;D</li> <li>• 3-5 years to run a pilot project</li> </ul>	NGOs, research institutions, academia, industry, government

# V. Accelerate Development of Small Wind Technology

- i. Research technology enhancement opportunities
- ii. Improve system performance and reliability
- iii. Adopt streamlined and consistent interconnection standards
- iv. Reduce life-cycle energy costs

While there is limited policy support for the deployment of small wind energy systems in Canada, we are a world leader in the manufacture and export of small wind technologies. With more than 10 manufacturers, Canada hosts roughly 1/7<sup>th</sup> of the world's small wind turbine manufacturers. To take advantage of this opportunity, support for research and innovation for the purpose of continuous technology improvement is critical. The priority areas are:

- Research technology enhancement opportunities
- Improved reliability and performance
- Streamlined and consistent interconnection standards
- Reduction in life-cycle energy costs

The following table identifies the key action items in this area. Adopting streamlined and consistent interconnection standards is expected to cost less than one million dollars. Researching technology enhancement opportunities and reducing life-cycle energy costs are each expected to require investments in the order of five to ten million dollars.

Action Item	When	Who
Research technology enhancement opportunities	Medium term (1-5 years)	Industry, government, NGOs
Improve system performance and reliability	Medium term (1-5 years)	Industry, government, NGOs
Adopt streamlined and consistent interconnection standards	<ul style="list-style-type: none"> <li>• Short term (1-3 years) to initiate</li> <li>• Medium term (3-5 years) to engage utilities and resolve issues</li> </ul>	Industry, government, NGOs, utilities
Reduce life-cycle energy costs	Short term (1-3 years)	Industry, government, NGOs

# VI. Support Innovative Demonstration Projects

- i. Wind firming technology demonstration projects
- ii. Forecasting pilot building on Alberta and Quebec experience
- iii. Community scale wind-diesel demonstration project
- iv. Probabilistic modeling pilot

In order to gain acceptance and to enable implementation, it will be important to demonstrate several of the technologies developed through the roadmap. Research and development into wind firming will involve examining battery, capacitor, compressed air, and pumped hydro storage as well operational approaches such as hybrid operation, smart grids, demand response, and grid operation techniques. The most promising of these will need to be demonstrated in full scale.

Alberta and Quebec have completed forecasting pilot projects. Alberta and Ontario are now taking steps to offer a centralized forecasting system to the market – these types of demonstration projects across other jurisdictions can significantly advance the industry. Community-scale wind-diesel projects will need to be demonstrated as they are developed in the small wind sector. As transmission planning tools are developed, these will also need pilots or demonstrations in order to prove their acceptability to system planners and operators.

The following table identifies the key action items in this area. It is anticipated that a fund in the order of one hundred million dollars would be required to enable the investments to conduct key demonstration projects.

Action Item	When	Who
Wind ‘firming’ technology demonstration projects and/or operational approach demonstration projects	1 to 3 years	Government, industry
Forecasting pilots building on Alberta and Quebec experience	1 to 3 years	Government, industry, NGOs
Community scale wind-diesel demonstration projects	1 to 3 years	Government, industry, NGOs
Probabilistic modeling pilots to enable long-term planning	Beginning in 2 years as tools become available	Industry

## Conclusion

This document presents an exciting vision for Canadians: By 2025, Canada will be a world-leading supplier of key wind energy technologies and policy solutions, where more than 20% of its electricity needs are met by wind and sustained annual growth creates additional wealth through export.

The Wind Technology Road Map presents an action plan for realizing substantial economic and environmental gains. With the continued efforts of the participants in the community and the broader industry, academia and governments across Canada, this vision will be achieved.





For further information, visit the WindTRM website:

**[www.windtrm.gc.ca](http://www.windtrm.gc.ca)**