Renewing Futures

Technology Review

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Executive Summary

Renewable energy (RE) technologies play a crucial role in sustainable development for the world and for Canada. Plans for deploying these technologies are an essential element in the reduction of Greenhouse Gas (GHG) emissions and the management of global warming. Canada is a leader in the use of RE and the advance of policies and innovations. This report is the first publication of the Renewing Futures project from Electricity Human Resources Canada.

Growth is the dominant feature of the RE industry. Canadian investments in many RE technologies have increased ten-fold in the last decade and the list of projects continues to grow. Industrial growth on this scale brings many economic benefits including the addition of new jobs. For example, the European Union, a leader in RE development, tracks the employment impacts of industry expansion and regards this benefit as a major government policy objective.

Similar advantages can be expected in Canada. Electricity Human Resources Canada, in cooperation with the RE industry and other stakeholders, has initiated “Renewing Futures” a major, national human resources (HR) research project that will provide current and forward looking information on the impact of RE deployment on labour markets and key occupations across Canada. Renewing Futures will create a national HR strategy for renewable energy that will assist in building a skilled workforce that will meet employer needs for the next ten years. The strategy will cover training programs, regulations and government policies, certification, interprovincial mobility, retirements and retention and sector specific specializations.

Renewable energy covers a wide range of activity and this study will be focused on six technology sectors:

1. Wind
2. Solar
3. Bioenergy
4. Geothermal
5. Hydro: Large and Small
6. Marine: Tidal, Waves

Employers and the labour force working in these sectors are the primary focus of the project. It is recognized that the deployment of these technologies will depend on the development of the electricity generation, transmission and distribution systems. New installed capacity of each of the six RE technologies will be connected to the grid; adding a new supply to the existing system. Each source of RE has different properties and will impact the electric grid in different ways. For example, electricity from some RE sources is intermittent and higher shares of intermittent energy sources would require changes to the way the conventional grid is operated and managed. Storage technologies have a role here, amongst other approaches. This relationship between the RE and the existing electricity systems prompts the addition of a technology review in a seventh sector.

7. Integration and Storage

Technologies, systems and processes included in this last sector might be present in either or both of the RE and conventional energy systems. The pace of installation and the numbers and skills of the workforce will be affected by change in these systems and these impacts are a key part of the human resources analysis. Electricity Human Resources Canada has completed a labour market and human resources plan for the conventional electricity sector and findings from that work will be applied to the analysis in this study – especially in the area of large hydro which was included in the earlier work.[1] Indeed, large hydroelectric capacity is a dominant feature of Canada's RE generation and, additionally, offers the largest storage potential.

Activity in each sector spans a supply chain that stretches from research and development through system manufacturing and distribution, installation, operation and maintenance. Further these sectors are linked to energy sources other than electricity. To manage the scope of work across these areas, the Steering Committee decided that, for this project, the target employers and workforce would include activity in Canada, on the supply chain, that is connected to electricity generation. This choice includes applications of RE in combined heat and power systems but excludes systems devoted only to heat and fuel. In light of this chosen scope, references to Renewable Energy (RE) – used frequently in this report – have been be expanded to read **electricity related renewable energy (ERE)** where the more limited scope of this research applies.

This Technology Review is not an energy forecast. Findings presented here are intended to inform the labour market analysis by identifying the extent of future deployment and most likely technologies that will be installed across the sectors in each Province. This expected expansion defines the needed growth in occupations and in specialized skills and experience. Added jobs create economic benefits but may also test the limits of the skilled labour force and contribute to skills shortages.

The focus is on the technologies that are likely to be the dominant processes deployed from 2013 to 2022 and any systems that may emerge – especially those that will impact the Canadian work force. Current and future costs are reviewed here and used to translate the planned deployment of new installed capacity into investment streams that will include labour costs and content.

This Technology Review is the first publication in a series of three. The second publication is the Labour Market and Human Resources analysis and National Human Resources Development Strategy for Renewable Energy. This report analyzes future workforce expansion and skills requirements and proposes a plan for the training, certification and other HR planning dimensions that will be needed to accommodate the growth of the RE industry.

Market Assessments

Three scenarios have been developed and offer alternative projections of future deployment for RE in each Province. The scenarios are intended to reflect the range of possible outcomes and the uncertainties that are associated with projections that extend from 2013 to 2022.

Three scenarios are used in the market assessments to define upper and lower limits to labour requirements.

A. The *Utility Case* is based on a review of Provincial utility reports, energy plans and interviews with energy planners in each Province. Acting as distributors of electricity, these stakeholders, and their plans for the capacity of systems, are key decision makers. Projections of installed capacity for each ERE sector have been developed in this scenario using this source.

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[1] "Power in Motion 2011 Labour Market Information (LMI) Study" Electricity Sector Council.

B. The *Reference Case* is based on the National Energy Board (NEB) 2011 “Energy Supply and Demand Projections to 2035”. With some modification and added details this document identifies one perspective on the growth of RE installed capacity. This is not the only projection available, but it is a widely cited and detailed source that is linked to economic and industry forecasts that act as drivers. The NEB’s view of the future for RE and competing sources from the conventional industry acts as one anchor for the report.

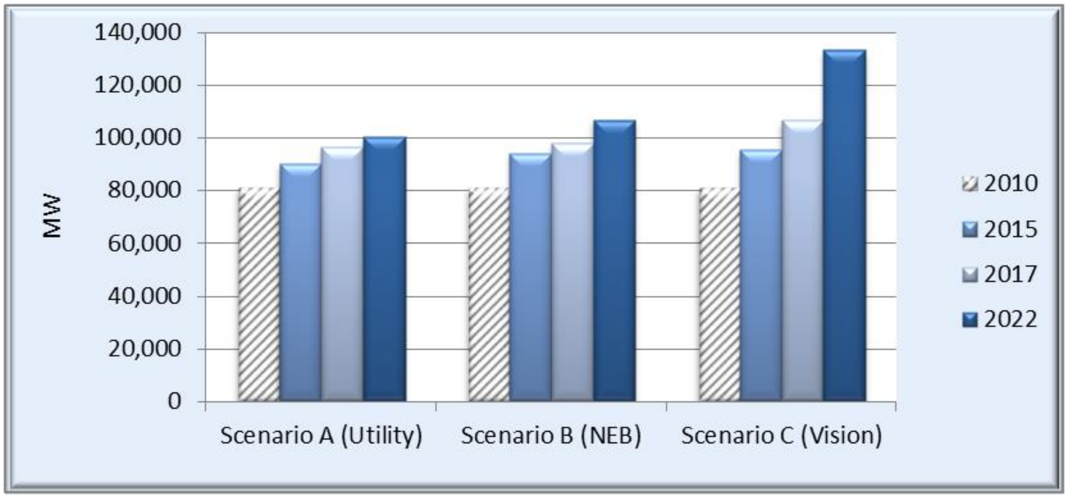
C. The *Vision Case* is based on the announced targets and published visions of the RE industry itself and the government policy statements and objectives for RE. This case is designed to test the higher limits of investment and deployment of ERE and, in turn, define the upper levels of labour requirements.

Exhibit 1 offers a visual summary of the total change in ERE systems projected in each scenario.

Exhibit 1

Three Scenarios for Renewable Energy Systems in Canada, 2010 to 2022

Projections of Installed Capacity, All ERE Sectors, in MWs, Canada



Sources: Base year: Statistics Canada catalogue 57-206, Electric Power Generating Stations
Scenario B: National Energy Board Canada’s Energy Future, November 2011
Scenarios A and C: Prism Economics

In each scenario the additions to RE systems across the ten + years run from 20% to 60%. Large hydro and wind systems dominate the additional capacity but there are notable gains for the other technologies.

Scenario A projects the more limited increases that are currently built into the plans of the large utilities and system planners. Scenario B offers an alternative that captures the view of the National Energy Board and includes an underlying projection of economic conditions and industry growth by province. Scenario C captures the vision of the industry proponents and elements of government policy for RE and sustainability in general. Each scenario is simply one possible representation of the future. It is not implied that one is more likely than the other. All three, together, have been constructed to represent the range of likely outcomes for the levels of installed capacity and the related human resource requirements.

Technology Profiles

Each Profile is summarized in the Technology Review in six parts:

- Synthesis;
- State of Maturity;
- Cost and Development Trends;
- Environmental Considerations;
- Technical and Non-technical Advantages and Challenges; and
- Emerging Trends and Related Markets.

Key findings for each technology include:

- Wind technologies will be developed on a large scale in each scenario and in all Provinces. While there are few expected changes in the systems' technologies, it is expected that the scale of deployed systems, including the turbines, rotors and other components will grow larger. This larger scale of each deployment will have important implications for the skill mix and numbers in the installing workforce. Canada has some leading manufacturers and suppliers working on smaller and mid-sized systems. Significant cost reductions are expected to help the competitive position of commercial wind installations.
- Solar technologies will also be developed on a large scale with more focused growth in Ontario. Systems will continue to be based on crystalline silicon PV cells with some potential for new approaches. Significant cost reductions in solar systems are among the largest projected for RE and are expected to strengthen the competitive position of solar systems.
- Bioenergy technologies are projected to grow in situations where systems are linked to growth in related industries and / or systems. A wide range of processes will be used and the next phase of the Renewing Futures analysis will focus on the skills and workforce that will be needed.
- There are limited opportunities for geothermal systems in Canada that focus on electricity generation but significant growth for geoexchange systems that target heating and cooling needs across the country.
- Large hydro projects are planned or underway in British Columbia, Manitoba, Quebec and Newfoundland and Labrador that will provide the major part of Canada's added ERE capacity to 2022. There are significant HR implications related to this work and to the associated demands for distribution and transmission systems. These implications were a key topic of the "Power in Motion" report, prepared by Electricity Human Resources Canada in 2010, covering the electricity industry. Research provided here will update the large hydro analysis done in the 2010 report and add details on the links to other RE technologies. Small hydro projects based on existing technologies and cost structures have significant potential in most regions; however, there are only limited examples of plans for these projects.
- Canada's potential for Tidal and Wave technologies is concentrated in British Columbia and Atlantic Canada. Many technologies are being developed and tested with demonstration sites operating in several countries. Activity in Nova Scotia is moving forward with government support and the development of tidal systems in the Bay of Fundy. Cost and

technology for in-stream tidal energy are not yet at the commercial stage and estimates of project feasibility are highly variable and depend on many factors.

Findings from the Technology Profiles will be combined with the Market Assessment projections to define the likely timing and processes to be deployed across Canada in the next step of the Renewing Futures research.

Introduction and Background

Renewable energy (RE) technologies play a crucial role in sustainable economic development for the world and for Canada. The International Energy Agency (IEA) begins the "Energy Technology Perspectives 2012" report describing renewable energy in the following manner:

> *Low-carbon electricity has system wide benefits that enable deep reductions in CO_2 emissions in the industry, transport and buildings sectors. Analysis shows how emissions per kilowatt –hour can be reduced by 80% by 2050, through deployment of low carbon technologies. Renewable energy technologies play a crucial role in developing low carbon electricity and enabling deep reductions in CO_2 emissions. The RE share of the total average world generation increases from 19% currently to 57% by 2050, a six fold increase in absolute terms. In fact low-carbon electricity is already competitive in many markets and will take an increasing share of generation in coming years.*[2]

Achieving these targets for deploying RE has important implications for labour markets. Employment created by the growth of the RE industry is recognized as a major economic benefit and is an integral part of energy strategy in the European Union. Similar advantages can be expected in Canada. Electricity Human Resources Canada (EHRC), in cooperation with the RE industry and other stakeholders, has initiated "Renewing Futures" a major, national human resources (HR) research project that will provide current and forward looking information on the impact of RE deployment on labour markets and key occupations across Canada. Renewing Futures will create a national HR strategy for electricity related renewable energy assisting in building a skilled workforce that will meet employer needs for the next ten years. The strategy will cover training programs, regulations and government policies, certification, interprovincial mobility, retirements and retention and sector specific specializations.

Growth is the central theme. Global investments and economic activity related to deploying Renewable Energy systems have grown explosively in the last decade. In Canada, for example, the National Energy Board 2011 forecast for electricity demand documents a ten-fold increase in wind generation capacity from 2005 to 2012 (from 740MW to 7025 MW)[3].

Canada's RE industry has been tracking labour conditions and HR managers see a need for planning for future jobs. For example, Industry Canada and the Canadian Wind Energy Association (CanWEA) surveyed employers in 2010 and discovered that 79% of respondents expect to expand their wind energy-related workforce over the next 2 years and 34% of those employers expect to double or more than double employment. Further, *"Fifty-five percent of respondents believed there was a shortage of experienced and skilled labour in the wind energy sector. Key fields where the shortage was identified include specialist technicians, project managers and power engineers."*[4]

These findings were repeated throughout employer interviews in the other RE Sectors and in other industries.

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[2] Taken from International Energy Agency, "Energy Technology Perspectives, 2012", executive summary, page 3.

[3] See National Energy Board, "Canada's Energy Future, Energy Supply and Demand Projections to 2035; An Energy Market Assessment November 2011" Table a.5.1.

[4] "Canadian Wind Energy Sector Profile, 2010" Industry Canada and CanWEA.

This Technology Review is the first publication in a series of research steps that will build the national HR strategy. The Technology Review sets the stage with a profile of the seven technologies and provincial market assessments that offer alternative scenarios for the deployment of RE from 2012 to 2022. Together the technology profiles and the market assessments identify for each technology and region:

- The technologies that are most likely to be used;
- The costs and investments to be incurred;
- Impacts on other industries and economic development in general; and
- Government plans and policies driving RE conditions.

These key drivers are described in this report and form the basis for the next step: a national labour market study. This will include an assessment of current conditions and alternative future scenarios describing:

- Employment growth by province and occupation;
- Skills and experience needed to meet general demands and individual sector requirements;
- Training and certification that will build and sustain the workforce; and
- Elements of workforce mobility and certification portability across sectors and provinces.

Technology profiles and market analysis prepared here reveal the nature of changes in electricity generation processes and the extent of these changes in terms of MWs of new capacity. These two dimensions will be used in the human resources analysis to assess the changing skills of the workforce and the training and certification that will best meet these changes. Six RE technology sectors have been selected:

1. Wind
2. Solar
3. Bioenergy
4. Geothermal
5. Hydro: Large and Small
6. Marine: Tidal, Waves

Employers and the Labour force working in these sectors are the primary focus of the project. It is recognized that the deployment of these technologies will depend on the development of the electricity generation, transmission and distribution systems. New installed capacity of each of the six RE technologies will be connected to the grid, adding a new supply to the existing system. Each source e of RE has different properties and will impact the electric grid in different ways. For example, electricity from some RE sources is intermittent and higher shares of intermittent energy sources would require changes to the way the conventional grid is operated and managed. Storage technologies have a role here, amongst other approaches. This relationship between the RE and the existing electricity systems prompts the addition of a technology review in a seventh sector.

7. Integration and Storage

Technologies, systems and processes included in this last sector might be present in either or both of the RE and conventional systems. The pace of installation and the numbers and skills of the workforce will be affected by change in these systems and these impacts will be part of the human resources analysis in the next report. Electricity Human Resources Canada has completed a labour market and human resources plan for the conventional sector and findings from that work will be applied in analysis in this study – especially in the area of large hydro which was included in the earlier work.[5]

The conventional electricity industry is clearly a major stakeholder in the RE future and research in this Technology Review, and in the related labour analysis and National Human Resources Strategy, will include impacts in the conventional sector. Specifically, the review of the conventional industry will cover Smart Grid and Storage Systems and Appendix A to this report introduces the issues in this area.

Activity in each sector spans a value chain that stretches from research and development through system manufacturing and distribution, installation, operation and maintenance. Further these sectors are linked to energy sources other than electricity. To manage the scope of work across these areas, the project Steering Committee agreed that the target employers and workforce would include activity in Canada, on the value chain, that is connected to electricity generation. This choice includes applications of RE in combined heat and power systems but excludes systems devoted only to heat and fuel. In light of this chosen scope, references to Renewable Energy (RE) – used frequently in this report – should be understood to mean ***electricity related renewable energy (ERE)***.

This Technology Review is not an energy forecast. Findings presented here are intended to inform the labour market analysis by identifying the extent of future deployment and most likely technologies that will be installed across the sectors in each Province. This expected expansion defines the needed growth in occupations and in specialized skills and experience. Added jobs create economic benefits but may also test the limits of the skilled labour force and contribute to skills shortages.

Three scenarios are used in the market assessments to reflect the views of different stakeholders on the future pace of installation. Scenarios are not interpreted as more or less likely but rather as alternative expectations about the future. A key role for the scenarios is to define upper and lower limits to labour requirements.

The analysis is divided into two sections: Market Assessments and Technology Profiles. Market Assessments were built up through a review of industry and government documents and interviews with provincial energy planners. Technology Profiles were built up from an extensive literature review. Detailed profiles have been prepared as background to this report and offer extensive analysis that supports the very brief summaries presented in the third section of this report[6]. While the consulting team sought to apply only the most up-to-date and authoritative sources, it is recognised that readers may have different views on the measures presented and conclusions drawn.

Together these findings will guide the projections and analysis of labour requirements by occupations, skills and experience. The next report from Renewing Futures will describe the supply / demand balances, HR management issues and training / certifications associated with this technology future.

As the report digs deeper into the details it employs a long list of technical terms and acronyms. A glossary is attached to help the reader. Findings are presented in the most concise manner possible and many details have been placed in appendices. Appendix A contains a review of Smart Grid technology. Appendix B provides detail on the methodologies applied here. Appendix C contains detailed versions of

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[5] "Power in Motion 2011 Labour Market Information (LMI) Study" Electricity Sector Council.

[6] Readers are invited to review details in the Technology Profiles in supporting documents that were created as part of the research of this report. See Appendix B for details.

the three scenarios including annual projections of the value and volume of increments to installed capacity. These projections will drive employment forecasts. Appendix D contains notes on sources and methodology and references to the detailed profiles.

Market Assessments

This section provides an assessment of the future market for renewable technologies considering current and future market potential, announced plans and high profile projects and government energy policy. Installed capacity scenarios are presented for each ERE sector for the planning horizons 2015, 2017, and 2022. These scenarios were derived in consideration of:

- Technology profiles;
- Literature and publications available from provincial utilities and / or energy departments, the National Energy Board, the Conference Board of Canada, and various renewable energy proponents; and,
- Personal communications with key informants representing electricity suppliers, government departments and renewable energy organizations.

Three scenarios are used in the market assessments to define upper and lower limits to labour requirements.

A. The **Utility Case** is based on a review of Provincial utility reports, energy plans and interviews with energy planners in each Province. Acting as distributors of electricity these stakeholders, and their plans for the capacity of systems, are key decision makers. Projections of installed capacity for each RE sector have been developed in this scenario using this source. For some Provinces utility plans did not extend to the year 2022 and, in these cases, no incremental capacity was added after 2015.

B. The **Reference Case** is based on the National Energy Board (NEB) 2011 "Energy Supply and Demand Projections to 2035". With some modification and added details this document identifies one perspective on the growth of RE installed capacity. This is not the only projection available, but it is a widely cited and detailed source that is linked to the economic and industry forecasts that act as drivers. The NEB's view of the future for RE and competing sources from the conventional industry acts as one anchor for the report.

C. The **Vision Case** is based on the announced targets and published visions of the RE industry itself and the government policy statements and objectives for RE. This case is designed to test the higher limits of investment and deployment of RE and, in turn, define the upper levels of labour requirements.

The objective of this component of the study is not to prepare definitive installed capacity projections, rather, it is to develop scenarios for planned ERE investments that span the range of likely outcomes over the next decade to inform labour force and skills needs for the RE industry.

Exhibit 2 presents the total cumulative installed capacity in each scenario (expected at the end of the year indicated) for the 10 provinces for each ERE technology for the prescribed planning horizons. Based on the technology profiles, review of utility, government and RE organization publications and reports, and key informant interviews, it is concluded that, over the next decade, there will be no development of grid-connected electricity generating installed capacity for wind offshore, solar thermal and marine wave technologies.

Exhibit 2

Renewable Energy Technology Scenarios – Canada Summary
Total Installed Capacity, MWs

Renewable Energy Sector	Base Year	Scenario A			Scenario B			Scenario C		
	2010	2015	2017	2022	2015	2017	2022	2015	2017	2022
Wind	3,962	8,253	11,295	12,804	11,714	13,138	16,379	11,095	17,953	35,852
Solar PV	281	2,428	3,062	3,150	360	560	935	1,900	2,850	7,790
Marine	20	20	20	22	34	54	104	84	84	282
Geothermal	-	-	-	-	-	2	54	-	-	190
Bio – energy	1,700	2,037	2,297	2,831	2,446	2,730	3,606	2,569	2,881	3,693
Small-Hydro	3,327	3,842	3,899	3,989	3,497	3,573	3,765	3,945	4,018	4,283
Large-Hydro	71,644	73,420	75,794	77,494	75,959	77,995	81,935	75,788	78,648	81,091
Total	**80,934**	**90,000**	**96,367**	**100,290**	**94,010**	**98,052**	**106,778**	**95,381**	**106,434**	**133,181**

Sources: Base year: Statistics Canada catalogue 57-206, *Electric Power Generating Stations*
Scenario B: National Energy Board Canada's Energy Future, November 2011
Scenarios A and C: Prism Economics

Exhibit 3 estimates the value of investment in each scenario by multiplying the change in the installed capacity in Exhibit 2 by an estimate of the cost of each addition in $2010 million per MW. The resulting measure tracks the needed investment in millions of $2010 to install the added capacity.

Exhibit 3

Renewable Energy Investment Scenarios
(Millions of $2010)

Renewable Energy Sector	Base Year Cost $M/MW	Scenario A (Utility)			Scenario B (NEB)			Scenario C		
	2010	2015	2017	2022	2015	2017	2022	2015	2017	2022
Wind	2.800	$12,015	$8,518	$4,225	$21,706	$3,987	$9,075	$19,972	$19,202	$50,117
Solar PV	5.500	$11,809	$3,487	$484	$435	$1,100	$2,063	$8,905	$5,225	$27,170
Marine	5.688	$0	$0	$11	$80	$114	$284	$364	$0	$1,126
Geothermal	4.141	$0	$0	$0	$0	$8	$215	$0	$0	$787
Bio – energy	3.750	$1,264	$975	$2,003	$2,798	$1,065	$3,285	$3,259	$1,170	$3,045
Small-Hydro	3.500	$1,803	$200	$315	$595	$266	$672	$2,163	$256	$928
Large-Hydro	3.076	$5,464	$7,303	$5,230	$13,275	$6,264	$12,121	$12,749	$8,799	$7,516
Total		**$32,353**	**$20,482**	**$12,268**	**$38,887**	**$12,804**	**$27,715**	**$47,411**	**$34,651**	**$90,688**

Sources: Base year: Statistics Canada catalogue 57-206, *Electric Power Generating Stations*
Scenario B: National Energy Board Canada's Energy Future, November 2011
Scenarios A and C: Prism Economics

The three scenarios, then, represent a range of new investment in ERE systems from 2010 to 2022 from $60 Billion in the Utility case to $166 billion in the Vision case. These investments will drive employment requirements.

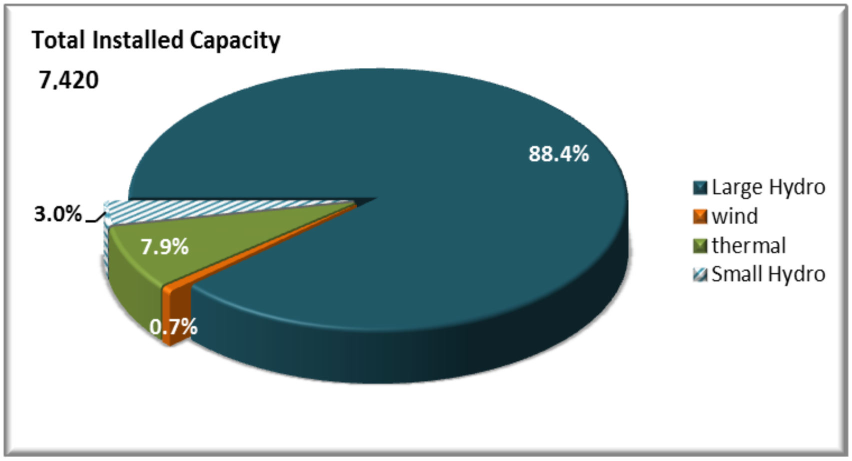
1.0 RENEWABLE ENERGY IN NEWFOUNDLAND AND LABRADOR

1.1 Current Situation

Newfoundland and Labrador Hydro is the main electricity provider with current assets including: 9 hydro plants, 1 oil-fired plant, 4 gas turbines, 25 diesel plants, and 2 wind farms. Total installed generating capacity for all classes of electrical producers was 7419 MW in 2010 with 6836 in RE. The 2010 energy generation mix is presented below.

Exhibit 4

Energy Supply Mix, Newfoundland and Labrador, 2010



Statistics Canada Table 127-0009

1.2 Markets

Current planning is based on the Muskrat Falls hydroelectric project (824 MW), sanctioned in December 2012, being connected to grid by the end of 2017. This facility will supply all the energy needs for Newfoundland (Island) and Labrador beyond 2030. (It will also supply some capacity for Nova Scotia.) This may change if mining developments in Labrador create significant additional load. The potential of Muskrat Falls moves much of Atlantic Canada closer to announced targets for RE. Accordingly there is little consideration for renewable energy development in the future.

Nalcor has built one of the first projects in the world to integrate generation from wind, hydrogen, and diesel in an isolated electricity system, located on the island of Ramea.

A summary of capital projects planned for the future include:

- **Wind:** Newfoundland and Labrador is considered a good wind resource. Consideration for additional wind development would depend on the proposed Maritime Link which would facilitate access to export markets;

- **Biomass:** There are no plans for grid interconnection of biomass facilities. But mining expansions in Labrador (VALE, IOC, Labwest, Alderon) may switch from diesel to biomass for self-generation, resulting in 50-100 MW of installed biomass capacity by 2020;
- **Small-hydro:** moratorium;
- **Large-hydro:** In the longer term the intent is to also develop a hydroelectric project at Gull Island (2250 MW); and
- **Smart Grid:** Many efficiency oriented programs are in place.

1.3 *Policies*

takeCHARGE Energy Conservation Program: Provides information, tools, and rebate programs to encourage wise energy use.

Industrial Energy Efficiency Program: Customized approach to energy savings for industrial customers. Baseline energy end-use audits assist industrial customers in identifying opportunities for capital projects, employee engagement opportunities and priority areas for electricity efficiency. The program provides funding for training and employee awareness projects to encourage innovation on conservation and efficiency.

1.4 *Scenarios*

Exhibit 5

Newfoundland and Labrador Renewable Energy Scenarios
Total Installed Capacity (MW)

Renewable Energy Sector	Base Year	Scenario A			Scenario B			Scenario C		
	2010	2015	2017	2022	2015	2017	2022	2015	2017	2022
Wind	54	54	54	54	54	79	104	88	122	198
Solar	-	-	-	-	-	-	-	-	-	-
Marine	-	-	-	-	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-	-	-	-	-
Bioenergy	-	-	50	100	-	-	-	-	50	100
Small Hydro	221	221	221	225	221	221	225	221	221	225
Large Hydro	6,561	6,561	7,385	7,385	6,561	6,561	7,385	6,561	7,385	7,385
Total	**6,836**	**6,836**	**7,710**	**7,764**	**6,836**	**6,861**	**7,714**	**6,870**	**7,778**	**7,908**

Sources: Base year: Statistics Canada catalogue 57-206*, Electric Power Generating Stations*
Scenario B: National Energy Board Canada's Energy Future, November 2011
Scenarios A and C: Prism Economics

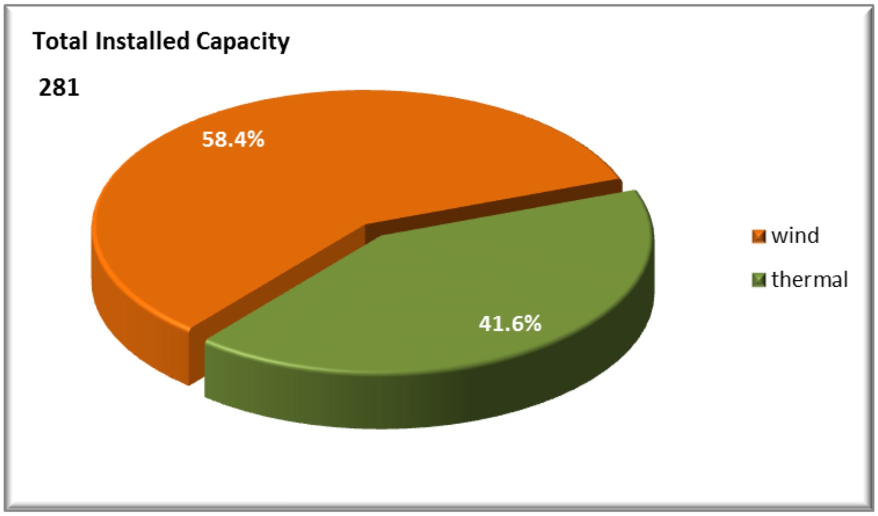
2.0 RENEWABLE ENERGY IN PRINCE EDWARD ISLAND

2.1 *Current Situation*

Maritime Electric is the main power generator with assets including: Charlottetown Thermal Generating Station and Borden Diesel Generating Station. Maritime Electric purchases up to 52 MW of wind generation from the West Cape and Eastern Kings Wind Farms. Prince Edward Island imports nearly 85 percent of its energy needs from mostly petroleum-based off-Island sources supplied via two submarine transmission cables. Total installed generating capacity for all classes of electrical producers was 269 MW in 2010. The 2010 energy generation mix is presented below.

Exhibit 6

Energy Supply Mix, Prince Edward Island, 2010



Statistics Canada Table 127-0009

2.2 *Markets*

In 2013, PEI Energy Corporation will achieve 30% wind penetration, the maximum which can be accommodated. The province does not need additional electricity capacity to serve domestic needs for the next decade. Additional wind development would only be considered for export markets. PEI has contracts to purchase Muskrat Falls energy.

A summary of capital projects planned for the future include:

- **Biomass:** PE government is installing 20 to 30 biomass boilers (0.2 MW each) over 2013-2014 for space heating (no electricity) of government buildings; and
- **Smart Grid:** Many efficiency oriented programs in place.

2.3 *Policies*

Renewable Energy Act:

Provides terms and conditions for development of renewable energy sources. Purchase price agreements, net metering systems, etc.

Energy Strategy:

Goals: Energy Mix 2018: 42% Petroleum Products; 20% Energy Efficiency; 5% Imported and Oil-fired Electricity; 3% Renewable Electricity (Wind & Biomass); 20% Biomass; 10% Liquid Biofuels.

Actions: Secure additional cable capacity to facilitate the export of commercial wind power. Provide support to WEICan and encourage research and development (R&D) opportunities for small-, medium- and large-scale wind developments. Evaluate mechanisms to facilitate the development of smaller community-based wind and other RE projects. Explore opportunities for economic development in the manufacturing, service and maintenance of small wind energy systems. Support the installation of small-scale renewable heating technologies (solar, geothermal heating systems) through grants, loans, tax and other financial incentives. Promote the use and encourage the installation of biomass heating systems in homes and businesses. Investigate the use of biomass in urban district heating systems and the potential for cogeneration facilities.

2.4 Scenarios

Exhibit 7

Prince Edward Island Renewable Energy Scenarios
Total Installed Capacity, (MW)

Renewable Energy Sector	Base Year	Scenario A			Scenario B			Scenario C		
	2010	2015	2017	2022	2015	2017	2022	2015	2017	2022
Wind	164	164	164	164	192	222	282	266	372	601
Solar	-	-	-	-	-	-	-	-	-	-
Marine	-	-	-	-	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-	-	-	-	-
Bioenergy	2	-	-	-	3	3	4	3	3	4
Small Hydro	-	-	-	-	-	-	-	-	-	-
Large Hydro	-	-	-	-	-	-	-	-	-	-
Total	**166**	**164**	**164**	**164**	**195**	**225**	**286**	**269**	**375**	**605**

Sources: Base year: Statistics Canada catalogue 57-206, *Electric Power Generating Stations*
Scenario B: National Energy Board Canada's Energy Future, November 2011
Scenarios A and C: Prism Economics

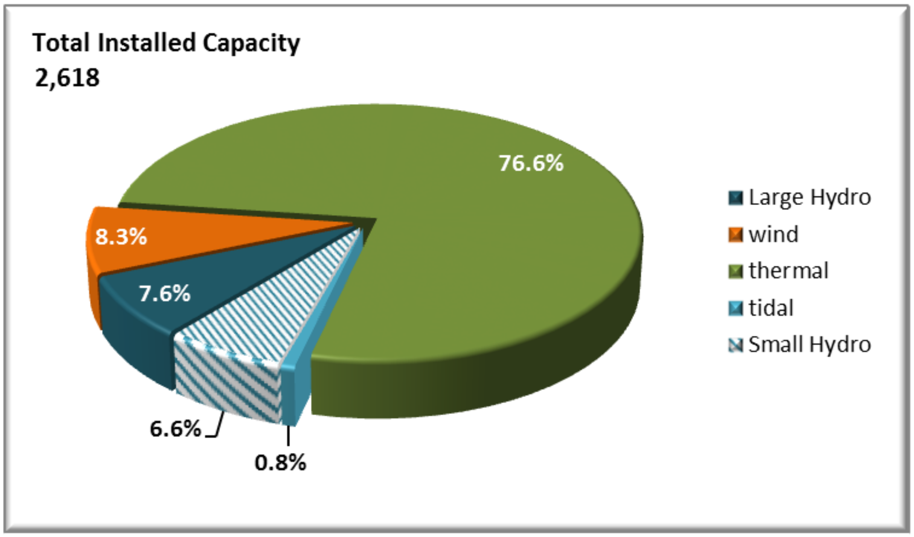
3.0 RENEWABLE ENERGY IN NOVA SCOTIA

3.1 Current Situation

Nova Scotia Power Inc. (NSPI) is the main power generator with assets including: 5 thermal; 1 tidal range and 33 hydro plants; 4 combustion turbines; 2 wind farms; and 2 additional wind turbine sites. In 2011, about 17% of generation was from renewable sources. Present contracts with Independent Power Providers (IPPs) total 229 MW (increasing to 259 MW in 2012) of wind and biomass fueled generation capacity. The province currently consumes just over 12,000 GWh of electricity per year. Total installed generating capacity for all classes of electrical producers was 2,618 MW in 2010. The 2010 energy generation mix is presented below.

Exhibit 8

Energy Supply Mix, Nova Scotia, 2010



Statistics Canada Table 127-0009

3.2 *Markets*

The Renewable Electricity Plan (REP) calls for a minimum of 600 GWh of new medium to large-scale renewable electricity, generated in equal parts by NSPI and IPPs. Most of the new renewable energy projects now under development or in operation resulted from competitive Requests for Proposals (RFPs) issued in 2007. Financing problems related to the world financial crisis stalled several of these projects.

A summary of capital projects planned for the future include:

- **Wind:** Will be 500 MW by 2017 which is considered to be maximum penetration as wind does not meet peaking requirements.
- **Solar PV:** Small pilot projects are anticipated through COMFIT.
- **Marine:** FORCE project will have a 64 MW capacity (R&D facility); considered ready for grid-connection in future. Some small projects may be possible providing electricity to the grid by 2022.
- There are also 5 approved community-based in-stream tidal projects under Nova Scotia's Renewable Electricity Regulations (COMFIT program):
  - Grand Passage (500 kW)
  - Petit Passage (500 kW)
  - Digby Gut (1.95 MW)
  - Great Bras d'Or Channel (500 kW)
  - Barra Strait (100 kW)
- **Biomass:** Some projects in very early stages. There is a significant amount of fibre that could be used for site-specific heat production (hospitals, nurseries, large institutions/industries).

- **Small-hydro:** river resources in the province are “tapped out”. The longevity of the Brooklyn (Bowater) plant (22 MW) is in question, and there are no known plans.
- **Large-hydro:** Wreck Cove facility (220 MW) has capacity, but no storage. To meet target of 40% RE by 2020 (legislated requirement), NSPI has an MOU to purchase 1 TWh/yr from Newfoundland and Labrador when Muskrat Falls (824 MW) comes on stream in 2017.
- **Smart Grid:** Enhanced net metering program in place. Many efficiency oriented programs in place.
- **Nuclear:** Moratorium.

3.3 *Policies*

Community Feed-In Tariff Program (COMFIT): Increase local ownership of small scale energy projects. Community-based power producers are to receive established price per KWh for projects producing renewable energy for a fixed period of time.

Renewable Electricity Regulations: Equity and ownership requirements for COMFIT-eligible entities, specifically including cooperatives, not-for-profits, Community Economic Development Corporations, and Aboriginal groups.

Renewable Electricity Plan: Orderly transition to new, local, renewable energy sources. Minimum of 300 GWh of large-scale renewable electricity projects from IPPs. 25% of NSPI generation is to come from renewable sources by 2015 and 40% by 2020. A further 1800 GWh per year of renewable energy needs to be harnessed by 2020. Establishes COMFIT for an expected 100 megawatts of renewable electricity projects connected to the grid. Electricity produced from co-firing biomass will play a role in meeting the 2015 target, but will undergo review for post-2015 use. To ensure sustainability, cap on new electricity generation from forest biomass at 500,000 dry tonnes (~600-700 GWh) above current uses. Co-firing biomass in thermal plants is capped at 150,000 dry tones (150 GWh). Continue to invest in tidal energy research and development; the plan establishes a COMFIT for distribution connected tidal projects. Support as much as $1.5 billion in green energy investment.

3.4 *Scenarios*

Exhibit 9

Nova Scotia Renewable Energy Scenarios

Total Installed Capacity, (MW)

Renewable Energy Sector	Base Year	Scenario A			Scenario B			Scenario C		
	2010	2015	2017	2022	2015	2017	2022	2015	2017	2022
Wind	218	315	415	415	347	377	502	511	779	1,359
Solar	-	-	-	-	-	-	-	-	-	-
Marine	20	20	20	20	34	54	104	84	84	280
Geothermal	-	-	-	-	-	-	-	-	-	-
Bioenergy	66	66	66	70	95	106	140	95	106	140
Small Hydro	174	174	174	174	198	198	198	198	198	198
Large Hydro	200	200	200	200	200	200	200	200	200	200
Total	**678**	**775**	**875**	**879**	**874**	**935**	**1,144**	**1,088**	**1,367**	**2,177**

Sources: Base year: Statistics Canada catalogue 57-206, *Electric Power Generating Stations*
Scenario B: National Energy Board Canada’s Energy Future, November 2011
Scenarios A and C: Prism Economics

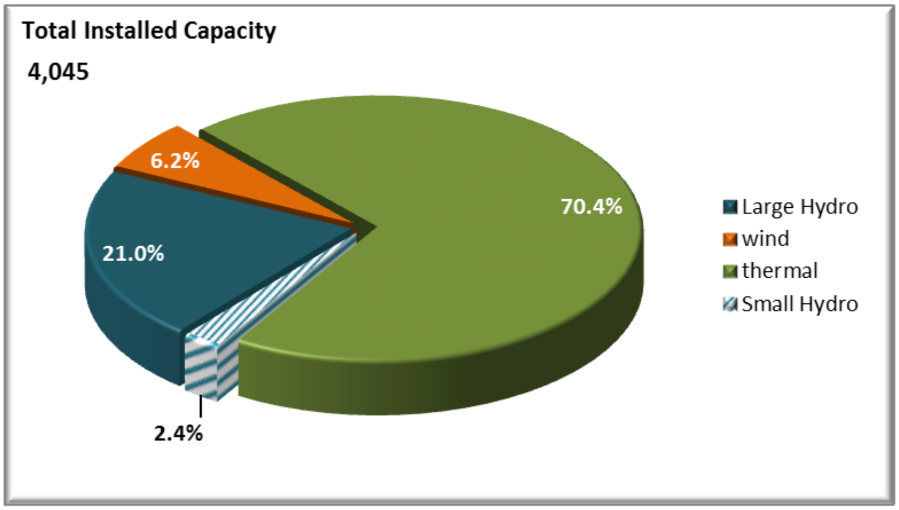
4.0 RENEWABLE ENERGY IN NEW BRUNSWICK

4.1 *Current Situation*

NB Power is the main power generator with assets including: 13 hydro, coal, oil and diesel-powered stations and 1 nuclear station. Total installed generating capacity for all classes of electrical producers was 4,045 MW in 2010 (does not include Lepreau nuclear station which only came back online in late 2012, after a lengthy refurbishment). The 2010 energy generation mix is presented below.

Exhibit 10

Energy Supply Mix, New Brunswick, 2010



Statistics Canada Table 127-0009

4.2 *Markets*

Currently 30% of electricity consumption comes from renewables: conventional hydro; wind; bio-mass. Approximately 20 % of residences use wood as total or partial heat source.

A summary of capital projects planned for the future include:

- **Wind:** Stakeholders comment that plans for new installations may be approaching an upper limit given other RE plans.
- **Biomass:** Significant amount of fibre that could be used for site-specific heat/electricity production, particularly for forestry sector.
- **Large-hydro:** Mactaquac hydro-generating station requires a decision within 20 years: refurbishment is estimated to cost $4 billion; decommissioning at $2 billion. NB Power is considering retrofit / upgrade of several existing hydro plants; a recent project at Edmundston doubled plant capacity.
- **Smart Grid:** Significant investment in collaboration with Siemens was announced in 2012. Many efficiency oriented programs already in place.
- **Nuclear:** Point Lepreau nuclear station was recently (November 2012) returned to full capacity providing about 35% of the provincial electricity supply.

4.3 *Policies*

Energy Blueprint: Procure 75% of electricity from stable, clean, renewable or emission-free sources by 2020.

Electricity from Renewable Resources Regulation: Purchase additional 10% of sales from new renewable sources by 2016. Add 300 MW of wind immediately.

Large Industrial Renewable Energy Purchase Program: Purchase renewable based electricity from qualifying large industrial customers at a set price. As of March 31, 2012, NB Power had not executed any agreements; however, when these agreements do come into force energy purchases will be retro-active to January 1, 2012.

4.4 *Scenarios*

Exhibit 11

New Brunswick Renewable Energy Scenarios
Total Installed Capacity, (MW)

Renewable Energy Sector	Base Year	Scenario A			Scenario B			Scenario C		
	2010	2015	2017	2022	2015	2017	2022	2015	2017	2022
Wind	249	294	294	314	393	408	478	477	667	1,106
Solar	-	-	-	-	-	-	-	-	-	-
Marine	-	-	-	2	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-	-	-	-	-
Bioenergy	110	110	125	125	158	176	233	158	176	233
Small Hydro	96	96	101	101	96	99	99	96	101	101
Large Hydro	851	851	851	851	851	943	943	851	943	943
Total	**1,306**	**1,351**	**1,371**	**1,393**	**1,498**	**1,626**	**1,753**	**1,582**	**1,887**	**2,383**

Sources: Base year: Statistics Canada catalogue 57-206*, Electric Power Generating Stations*
Scenario B: National Energy Board Canada's Energy Future, November 2011
Scenarios A and C: Prism Economics

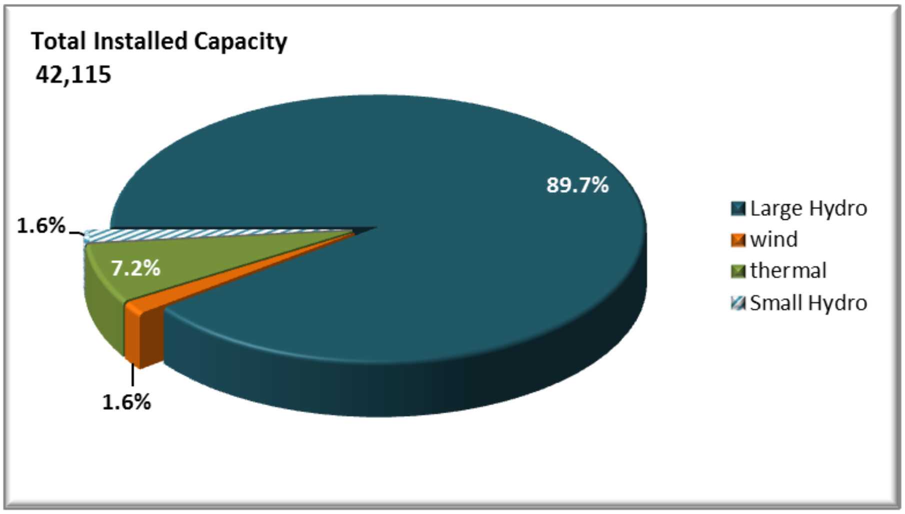
5.0 RENEWABLE ENERGY IN QUEBEC

5.1 *Current Situation*

Hydro-Québec is the main power generator with present assets including 60 hydroelectric generating stations (of which 38 are run-of-river), 27 thermal generating stations. One hydroelectric generating station and 24 of the 27 thermal power plants serve off-grid systems. These off grid systems include very large private systems serving mining and small diesel generating units. In addition, Hydro-Québec has access to almost all the output from Churchill Falls generating station (5,428 MW) under a contract with Churchill Falls (Labrador) Corporation Limited that will remain in effect until 2041. It purchases all the output from 12 wind farms and three small hydropower plants operated by Independent Power Providers (IPPs). Net export sales were $1.2 billion; 26.8 TWh in 2011. In 2011, electricity demand totaled 170.0 TWh. Total installed generating capacity for all classes of electrical producers was 42,115 MW in 2010. The 2010 energy generation mix is presented below.

Exhibit 12

Energy Supply Mix, Quebec



Statistics Canada Table 127-0009

5.2 *Markets*

In 2020, electricity demand is expected to reach 183.5 TWh. The average annual growth rate will decrease to about 0.7%, reflecting moderate population growth as well as energy efficiency initiatives. A summary of capital projects planned for the future include:

- **Wind:** Projects totaling 3,500 MW are operational or in development, and a call for tenders for 500 MW is underway that will target the capacity and operation at 4,000 MW by 2015.

- **Biomass:** Significant amount of fibre that could be used for site-specific heat/electricity production, particularly for forestry sector.
- **Small-hydro:** There are few known plans, but the province has an abundance of rivers that offer significant potential. A power purchase program targeting small hydro (50 MW or less) was launched in 2009: 5 of the 13 projects (totaling 149.7 MW) are under contract, and a series of project were cancelled in early 2013. The Quebec "Plan du Nord" will develop mining and other resource investments in Northern Quebec and related infrastructure plans include: several potential sites for development of small and medium-sized hydropower plants, or hydrokinetic turbines.
- **Large-hydro:** The intent is to develop hydropower potential to ensure that the power system will have the capacity and flexibility needed to integrate wind power. Complete Chute-Allard (62 MW) and Rapides-des-Coeurs (76 MW) developments, and continuing the Eastmain-1-A/Sarcelle/Rupert project. The latter project, which represents output of more than 8.5 TWh, was launched in 2007 by Société d'énergie de la Baie James. Its main components are Eastmain 1-A powerhouse (768 MW), Sarcelle powerhouse (150 MW), and Rupert diversion. The Romaine hydropower complex ($6.5-billion) comprises four generating stations with a total installed capacity of 1,550 MW and annual output of 8 TWh. Three units at Sarcelle powerhouse ($5 billion) came on stream in 2012.
- **Smart Grid:** Energy efficiency initiatives: energy conservation measures and programs tailored to residential customers, commercial and institutional markets, small and medium industrial customers, and large-power customers. Energy efficiency goal is to achieve 8 TWh in energy savings by 2013, and 11 TWh by 2015.
- **Nuclear:** The refurbishment of Gentilly-2 (675 MW) nuclear generating station will not proceed due to cost (about $1.9 billion).

5.3 *Policies*

Sustainable Development Action Plan (2009–2013): Work with Aboriginal and other communities to establish agreements and partnerships related to the projects. Consider wind power a logical complement to output. Continue developing hydropower potential. Increase output by close to 10 TWh and capacity by 1,056 MW by completing projects already in progress. Increase the capacity of existing hydroelectric generating stations. Hydro Quebec's research institute, IREQ, supports work on integrating wind capacity and is working with private companies to add to the fleet of electric cars and related charging stations in the Province.

Strategic Plan (2009-2013)[7]: Hydro-Québec is counting on new technologies to remain on the leading edge of its industry, improve customer services and further enhance its performance. Objective 1: Increase hydroelectric generating capacity. Objective 2: Step up exports to Ontario, New England and New York. Objective 3: Further enhance the division's performance.

Plan Nord: 3,500 MW of renewable energy to be added, by 2035, to the capacity already called for in the energy strategy. Boost development of renewable energies.

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[7] http://www.hydroquebec.com/sustainable-development/index.html

5.4 *Scenarios*

Exhibit 13

Quebec Renewable Energy Scenarios*
Total Installed Capacity, (MW)

Renewable Energy Sector	Base Year	Scenario A			Scenario B			Scenario C		
	2010	2015	2017	2022	2015	2017	2022	2015	2017	2022
Wind	658	1,626	3,138	3,138	3,724	4,498	5,748	2,637	4,665	9,051
Solar	-	-	-	-	-	-	-	-	-	-
Marine	-	-	-	-	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-	-	-	-	-
Bioenergy	304	398	398	398	437	488	644	437	488	644
Small Hydro	653	749	749	749	669	676	693	749	749	749
Large Hydro	37,786	38,842	40,392	40,392	39,732	40,039	40,829	39,732	40,039	40,829
Total	**39,401**	**41,615**	**44,677**	**44,677**	**44,562**	**45,701**	**47,914**	**43,555**	**45,941**	**51,273**

* ***Note that Utility planners and other sources did not provide forecasts for new capacity from 2017 to 2022 for Scenario A***

Sources: Base year: Statistics Canada catalogue 57-206, *Electric Power Generating Stations*
Scenario B: National Energy Board Canada's Energy Future, November 2011
Scenarios A and C: Prism Economics

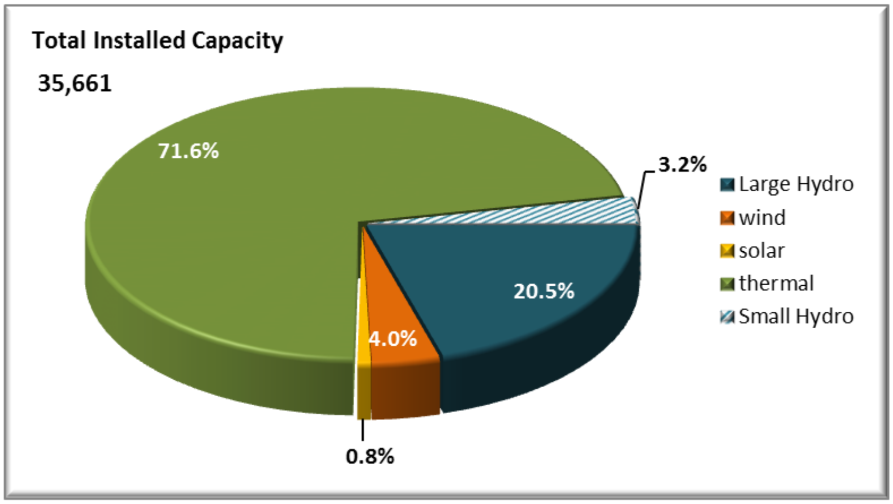
6.0 RENEWABLE ENERGY IN ONTARIO

6.1 *Current Situation*

The Independent Electricity System Operator (IESO) manages Ontario's power system connecting generators, transmitters, retailers, industries and businesses that use electricity in large quantities and local distribution companies that deliver power to residential markets. Ontario has a diverse supply mix that is in the process of incorporating increasing amounts of renewable forms of energy. Total installed generating capacity for all classes of electrical producers was 35,487 MW in 2010. The 2010 energy generation mix is presented below.

Exhibit 14

Energy Supply Mix, Ontario



Statistics Canada Table 127-0009

6.2 *Markets*

Ontario's electricity sector is going through a process of renewal – with the replacement of aging infrastructure and the transition to a more sustainable energy supply mix. The Ontario Power Authority (OPA) plans to add about 7100 MW of ERE by 2015 and 1800 MW of ERE by 2030.

A summary of capital projects planned for the future include:

- **Wind:** 13 large scale wind farms in operation providing about 1500 MW. Wind projects scheduled to come in service by summer 2013 include: Summerhaven Wind Energy Centre (125 MW) - 2013-Q1; McLean's Mountain Wind Farm (60 MW) - 2013-Q1; Port Dover and Nanticoke Wind Project (105 MW) - 2013-Q1; Dufferin Wind Farm (100 MW) - 2013-Q1.
- **Smart Grid:** Ontario is a leader in smart grids – with smart meters installed in almost every home and small business.
- **Nuclear:** continue to supply about 50 per cent of electricity needs.

6.3 *Policies*

Green Energy and Green Economy Act: Foster growth of renewable energy projects and to remove barriers to and promoting opportunities for renewable energy projects and to promoting a green economy. Promote and expand energy conservation and to encourage energy efficiency.

Feed-in-Tariff Program: Encourage the development of renewable energy technology, attract investment and create new clean energy jobs. Meet goals for improving air quality and phasing out coal-fired generation by the end of 2014. Divided into two streams:

- FIT 1.0 and FIT 2.0 program - renewable energy projects greater than 10 kilowatts; open to all types of generators, including developers, community groups and even individual homeowners.
- microFIT 1.0 and microFIT 2.0 program - renewable energy projects of 10 kilowatts or less; open to homeowners, farmers and small business owners, as well as institutions, such as schools and places of worship.

Smart Grid Fund: Investing in projects that will enhance electricity system and provide economic development opportunities. Targeted financial support to demonstration and capacity-building projects that test, develop and bring to market the next generation of smart grid solutions.

Long Term Energy Plan: Ensure supply mix balances reliability, cost and environmental performance. Phase out coal-fired generation at a faster pace, modernize nuclear fleet, include more renewables, maximize hydroelectric power, and advance conservation goals. By 2014 completely eliminate coal as a generation source and increase wind, solar and bioenergy from less than one per cent of generation capacity in 2003 to almost 13 per cent. Strategic use of natural gas will complement renewable generation.

6.4 *Scenarios*

Exhibit 15

Ontario Renewable Energy Scenarios
Total Installed Capacity (MW)

Renewable Energy Sector	Base Year	Scenario A			Scenario B			Scenario C		
	2010	2015	2017	2022	2015	2017	2022	2015	2017	2022
Wind	1,437	3,791	4,822	5,085	3,914	4,314	5,314	4,327	7,443	14,552
Solar	281	2,428	3,062	3,150	360	560	935	1,900	2,850	7,790
Marine	-	-	-	-	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-	-	-	-	-
Bioenergy	280	525	525	530	402	449	593	525	525	530
Small Hydro	1,130	1,549	1,601	1,667	1,159	1,170	1,200	1,549	1,601	1,667
Large Hydro	7,297	7,682	7,682	7,682	8,406	8,833	8,903	8,406	8,833	8,903
Total	**10,425**	**15,975**	**17,692**	**18,114**	**14,241**	**15,326**	**16,945**	**16,707**	**21,252**	**33,442**

Sources: Base year: Statistics Canada catalogue 57-206, *Electric Power Generating Stations*
Scenario B: National Energy Board Canada's Energy Future, November 2011
Scenarios A and C: Prism Economics

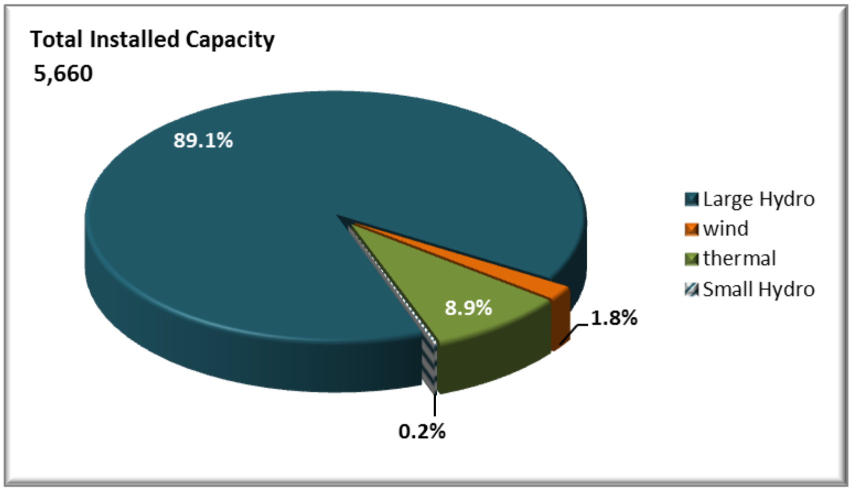
7.0 RENEWABLE ENERGY IN MANITOBA

7.1 Current Situation

Manitoba Hydro is the main power generator; present assets include: 2 thermal stations, 14 hydroelectric stations, and 4 remote diesel stations. The forecast average annual growth rate of 1.6% translates into about 80 MW / annum (after factoring in demand side management). To meet demand, Manitoba Hydro is anticipating an additional major resource just after 2020 (anticipated expenditure about $16 billion; no specifics available). $446 M over 15 years has been allocated for demand side management. Total installed generating capacity for all classes of electrical producers was 5,659 MW in 2010. The 2010 energy generation mix is presented below.

Exhibit 16

Energy Supply Mix, Manitoba



Statistics Canada Table 127-0009

7.2 Markets

A summary of capital projects planned for the future include:

- **Wind:** PPAs for wind include: St. Leon Wind Energy – 116 MW; Pattern Energy – 138 MW. Plans call for an additional 1000 MW of wind as economically viable (no specific projects).
- **Bioenergy:** Research & Development (R&D) for LT ADP (hog manure); R&D for agro/industry solid biomass waste; R&D for landfill gas at Winnipeg Brady Landfill; developing lab for biodiesel testing ($614,000 committed).
- **Small-hydro:** R&D for 4 remote sites; demo project for kenetic turbine in Winnipeg River.
- **Large-hydro:** Gull (Keeyask) 695 MW, on Nelson River (partnership with four First Nations); Conawapa 1,485 MW, on the Nelson River, planned in-service date of 2025; Pointe du Bois rehabilitation – 80 MW; Notigi – 100 MW; Gillam Island – 1,000 MW; Red Rock – 250 MW; Whitemud – 310 MW; Manasan – 265 MW; and First rapids – 200 MW.
- **Smart Grid:** Many efficiency oriented programs in place.

7.3 Policies

Green Building Policy: Ensure new, provincially funded buildings are less costly to operate and maintain, use less energy, and produce fewer greenhouse gas and other emissions than conventional buildings.

Green Energy Manufacturing Tax Credit: Refundable income tax credit = 10% of value of qualifying property produced in Manitoba and sold before 2019 for residential or commercial use in Manitoba. Qualifying property includes equipment for wind power, solar energy, geothermal energy, hydrogen fuel cells, geothermal ground source heating systems and solar thermal heating equipment.

Geothermal Energy Incentive Program: Encourage installation of geothermal systems in commercial and institutional buildings; municipal buildings; multi-unit residential buildings; mixed use, commercial/residential buildings; or single detached homes.

7.4 Scenarios

Exhibit 17

Manitoba Renewable Energy Scenarios*

Total Installed Capacity, (MW)

Renewable Energy Sector	Base Year	Scenario A			Scenario B			Scenario C		
	2010	2015	2017	2022	2015	2017	2022	2015	2017	2022
Wind	104	258	258	258	296	346	471	418	585	946
Solar	-	-	-	-	-	-	-	-	-	-
Marine	-	-	-	-	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-	-	-	-	-
Bioenergy	-	-	-	-	-	-	-	-	-	-
Small Hydro	11	11	11	11	11	11	11	11	11	11
Large Hydro	5,044	5,044	5,044	5,044	5,215	5,215	5,910	5,044	5,044	5,044
Total	**5,159**	**5,313**	**5,313**	**5,313**	**5,522**	**5,572**	**6,392**	**5,473**	**5,640**	**6,001**

* ***Note that Utility planners and other sources did not provide forecasts for new capacity from 2017 to 2022 for Scenario A***

Sources: Base year: Statistics Canada catalogue 57-206*, Electric Power Generating Stations*
Scenario B: National Energy Board Canada's Energy Future, November 2011
Scenarios A and C: Prism Economics

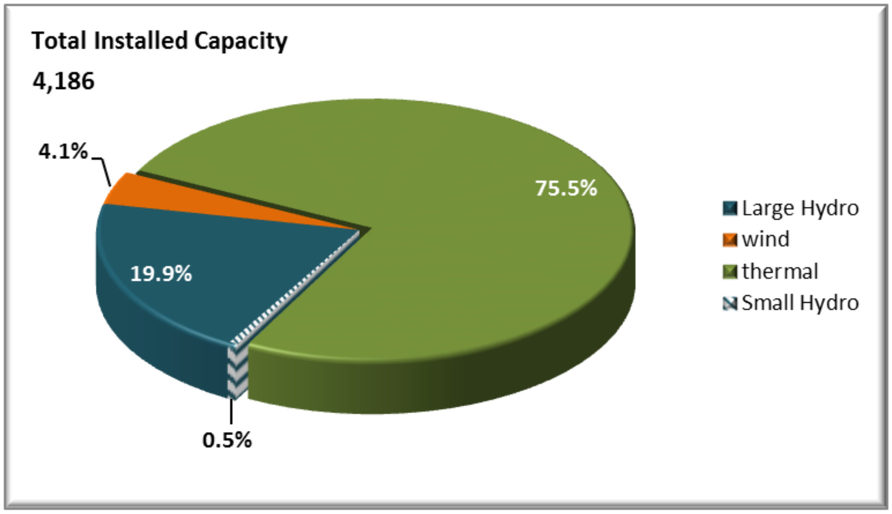
8.0 RENEWABLE ENERGY IN SASKATCHEWAN

8.1 *Current Situation*

SaskPower is the main electricity generator; assets include: three coal-fired stations, seven hydroelectric stations, six natural gas stations, and two wind facilities. Total installed generating capacity for all classes of electrical producers was 4,186 MW in 2010. The 2010 energy generation mix is presented below.

Exhibit 18

Energy Supply Mix, Saskatchewan



Statistics Canada Table 127-0009

8.2 *Markets*

Saskatchewan has a robust project pipeline providing for a mix of RE and traditional sources of power generation.

A summary of capital projects planned for the future include:

- **Wind**: Target is to achieve 370-400 MW of total wind generation by 2017; exclusively from IPPs.
- **Solar**: Installed PV array at Saskatchewan Science Centre for research purposes. No plans to develop anything further at the present time.
- **Geothermal**: DEEP Earth Energy Production Corporation: 5 MW geothermal power project in Southeast Saskatoon. Research purposes only.
- **Bioenergy**: Plan to procure additional 20 MW from IPPs for biomass, heat recovery (no timeline).
- **Small-scale hydro:** Technically attractive, but significant societal issues need to be resolved; and
- **Hydropower:** Some potential (200-250 MW each for Saskatchewan River, Churchill River and North Saskatchewan River), but significant societal issues need to be resolved. Long term plans for Pehonan – 250 MW and Elizabeth Falls – 42 MW (no timeline).

8.3 *Policies*

The Management and Reduction of Greenhouses Gases: Policy and regulatory framework for reducing GHG emissions and adapting to climate change. Target is for a 20% reduction in GHG emissions by 2020.

Action Plan Short Term: Encourage small-scale power production using renewable resources. Reduce demand through conservation and efficiency. Pursue new generation technology. Invest in carbon capture technology. Invest in smart grid technology.

Action Plan Medium Term: Reduce demand through conservation and efficiency. Partner with First Nations and IPPs. Evaluate renewable fuel power generation.

Green Options Partners Program: Streamline power purchasing for small and medium-sized "clean power" producers that sell 100 kW - 10 MW of electricity, by providing a fixed price for all power produced under contract. Offer increased stability to clean power producers as energy tariff rates are the same for peak and off-peak generation. Power rates are the same for all power production technologies and guaranteed even if program is cancelled or altered.

8.4 *Scenarios*

Exhibit 19

Saskatchewan Renewable Energy Scenarios

Total Installed Capacity, (MW)

Renewable Energy Sector	Base Year	Scenario A			Scenario B			Scenario C		
	2010	2015	2017	2022	2015	2017	2022	2015	2017	2022
Wind	171	198	373	373	406	346	471	321	562	1,084
Solar	-	-	-	-	-	-	-	-	-	-
Marine	-	-	-	-	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-	-	-	-	50
Bioenergy	-	-	25	50	-	-	-	-	25	50
Small Hydro	23	23	23	23	45	84	184	23	23	23
Large Hydro	833	833	833	833	833	833	911	833	833	833
Total	**1,027**	**1,054**	**1,254**	**1,279**	**1,284**	**1,263**	**1,566**	**1,177**	**1,443**	**2,040**

Sources: Base year: Statistics Canada catalogue 57-206, *Electric Power Generating Stations*
Scenario B: National Energy Board Canada's Energy Future, November 2011
Scenarios A and C: Prism Economics

9.0 RENEWABLE ENERGY IN ALBERTA

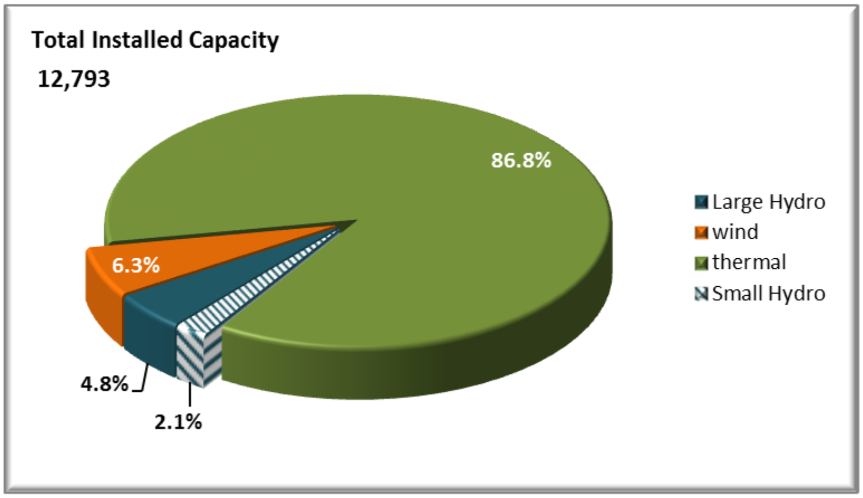
9.1 *Current Situation*

Alberta is the world's second largest exporter of natural gas and its fourth largest producer; the province supplies the United States with more than 50% of its gas imports. The province also has more than 98% of total Canadian oil reserves, which represents about 13% of global proven reserves. Coal reserves are estimated to be 33 billion tons production in 2011.

Alberta has been a net energy importer for the past ten years. Total installed generating capacity for all classes of electrical producers was 12,796 MW in 2010. The 2010 energy generation mix is presented below.

Exhibit 20

Energy Supply Mix, Alberta



Statistics Canada Table 127-0009

9.2 *Markets*

Albert's economic outlook is 2.5% annual growth to 2030 mainly driven by oilsands expansion, which translates into an energy and load demand of 3.1% annual growth till 2022. This means that 6,200 MW new generation capacity will be required by 2022 to meet growing demand and replace retiring coal capacity. Sustained low gas prices and coal legislation maintain an outlook for gas-fired combined cycle and cogeneration which will represent about 2/3 of new additions. Alberta's generation forecast is based on expectations of healthy natural gas supplies and stable long-term gas prices, as well as future climate change policy that leads to a reduced greenhouse gas cost of approximately $30/tonne in 2020.

A summary of capital projects planned for the future include:

- **Wind**: Wind capacity factor in 2011 was 33%. The expiration of the federal subsidy program for renewable power generation and no current indication of a provincial subsidy being employed will have an impact on future wind generation opportunities.
- **Geothermal**: There are no announced plans.
- **Bioenergy**: There is an intention to capitalize on 20+ million tonnes per annum of forest, agricultural and municipal residue, but there are no specific projects / timelines. There is potential for increased development of cogeneration facilities in the Northeast region.
- **Small-scale hydro:** Technically attractive, but significant societal issues need to be resolved; and
- **Hydropower:** Identified hydropower potential is Slave River – 1,500 MW, and Peace River (Dunvegan) – 100 MW, but no specific projects/timelines are set.
- A recent report from Alberta Legislature's Resource Stewardship Committee Report, "Review of the Potential for Expanded Hydroelectric Energy Production in Northern Alberta") indicates hydropower potential of up to 11,000 MW.

9.3 *Policies*

Bioenergy Producer Credit Program: Encourage development of bioenergy products including renewable fuels, electricity and heat.

Nine Point Bioenergy Plan: Stimulate bioenergy development; three programs: Bioenergy Producer Credit Program; Biorefining Commercialization and Market Development Program; Bioenergy Infrastructure Development Program.

Climate Change and Emissions Management Act: Reduce emissions of specified gases or improving Alberta’s ability to adapt to climate change, including: energy conservation and energy efficiency; demonstration and use of new technologies that emphasize reductions in specified gas emissions; through the use of alternative energy and renewable energy sources.

Alberta Energy Strategy: Energy production and consumption must ultimately take into account cumulative environmental impacts, including greenhouse gas emissions, and impacts to land, air and water. Ensure the development and deployment of new technologies that increase efficiency and reduce environmental impact. No position on nuclear. No specific investment commitment to renewable energy.

9.4 *Scenarios*

Exhibit 21

Alberta Renewable Energy Scenarios
Total Installed Capacity, (MW)

Renewable Energy Sector	Base Year	Scenario A			Scenario B			Scenario C		
	2010	2015	2017	2022	2015	2017	2022	2015	2017	2022
Wind	803	1,163	1,377	2,577	1,598	1,698	1,948	1,600	2,150	5,752
Solar	-	-	-	-	-	-	-	-	-	-
Marine	-	-	-	-	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-	-	-	-	20
Bioenergy	140	140	190	240	202	225	298	202	225	298
Small Hydro	268	268	268	268	309	309	309	309	309	309
Large Hydro	615	615	615	715	615	615	615	615	615	715
Total	**1,826**	**2,186**	**2,450**	**3,800**	**2,724**	**2,847**	**3,170**	**2,726**	**3,299**	**7,094**

Sources: Base year: Statistics Canada catalogue 57-206, *Electric Power Generating Stations*
Scenario B: National Energy Board Canada's Energy Future, November 2011
Scenarios A and C: Prism Economics

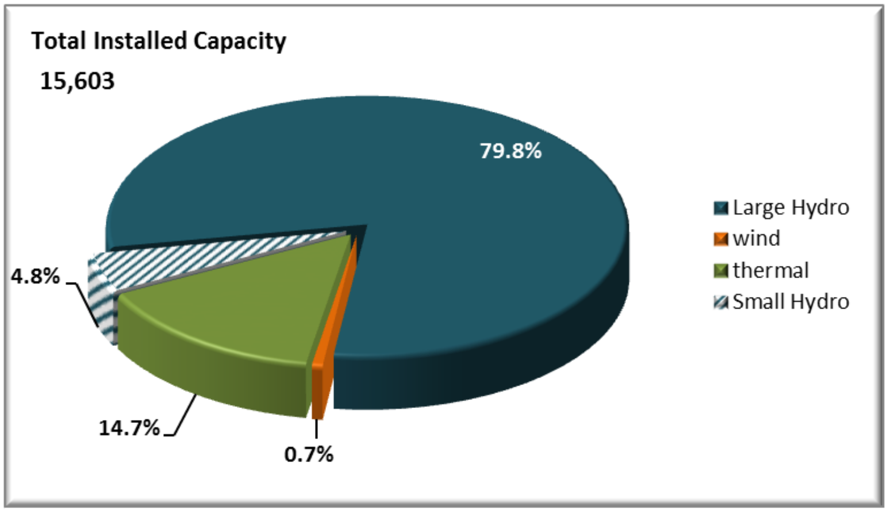
10.0 RENEWABLE ENERGY IN BRITISH COLUMBIA

10.1 *Current Situation*

BC Hydro is the main power generator serving 95 % of the population, about 1.9 million customers. Present assets include: 31 hydro plants, 3 natural gas-fired stations, and 10 diesel stations. Average residential consumption is about 11,000 kilowatt hours (kWh) per year. Capital expenditures were $1.9 billion in 2011, $400 million above prior year expenditures as BC Hydro continues to renew its aging infrastructure and expand its facilities. Total installed generating capacity for all classes of electrical producers was 15,600 MW in 2010. The 2010 energy generation mix is presented below.

Exhibit 22

Energy Supply Mix, British Columbia



Statistics Canada Table 127-0009

10.2 *Markets*

More than 70 IPPs connect to the grid, contributing approximately 20 per cent of power requirements. BC Hydro's integrated transmission system also connects to Alberta and Washington State, enabling BC Hydro to import electricity when necessary or to trade for the benefit of B.C. ratepayers. The December 2011 long-term load forecast shows that demand for energy could grow by approximately 50 per cent over the next 20 years before accounting for the savings that can be achieved by current conservation and efficiency measures.

There is considerable uncertainty related to energy requirements due to the shifting status of three major LNG plants being proposed by Malaysia's Petronas, Royal Dutch Shell PLC, and Exxon Mobil. These plants will use gas from BC and Alberta fields as a feed stock and conceivably be powered either by gas (self-generation) or by electricity from the grid. Similarly there are several major mining initiatives which may or not proceed and may or may not be grid connected. BC Hydro proposes to rely on cost-effective and readily available resources to meet customers' growing requirements.

A summary of capital projects planned for the future include:

- **Bioenergy**: Plan to procure additional 20 MW from IPPs for biomass, heat recovery (no timeline).
- **Small-scale hydro:** Technically attractive and significant resource base with significant potential for growth. There are no firm plans available to use for projections.
- **Hydropower:** BC Hydro's load resource balance shows a short-term gap in peak capacity until Revelstoke Unit 6 can be brought online in fiscal 2019 and Site C in fiscal 2021. Most of BC Hydro's future capacity planning is focused on upgrading existing facilities: Replacement of

spillway gates at Hugh Keenleyside, Cheakamus and Stave Falls; Mica Generating Station: installation of two additional 500 megawatt generating units into existing turbine bays; Gordon M. Shrum generating facility—replacement of 5 turbines (system's largest generating facility); Third dam and hydroelectric generating station on the Peace River, Site C (900 MW), is undergoing an environmental assessment. If sanctioned, this facility would supply much of the province's anticipated needs for the next decade.

- **Smart grid:** Goal is to acquire 50% of incremental resource needs through conservation by 2020. Conservation programs produced a cumulative annual energy savings of 3,424 GWh in 2012. Every home and business will have a smart meter by December 2012.

10.3 *Policies*

BC Energy Plan: Achieve electricity self-sufficiency by 2016. Ensure clean or renewable electricity generation continues to account for at least 90 per cent of total generation. No nuclear power. Establish a new Innovative Clean Energy Fund of $25 million to support development of clean energy and energy efficient technologies in electricity, alternative energy, transportation and oil and gas sectors. Implement BC Bioenergy Strategy to take advantage of abundant sources of biomass and renewable energy.

Clean Energy Act: 93% of the electricity generated within BC to be clean or renewable.
Foster development of innovative technologies that support energy conservation and efficiency and use of clean or renewable resources. Encourage use of waste heat, biogas and biomass. No nuclear power.

Innovative Clean Energy Fund: Showcase BC technologies that have a strong potential for international market demand. Support pre-commercial energy technology that is new, or commercial technologies not currently used in BC. Demonstrate commercial success for new energy technologies.

Bioenergy Strategy: Advance bioenergy development opportunities in the near mid- and long-term.

Draft Integrated Resource Plan: Increase the energy savings target to 9,800 gigawatt hours per year by 2020 (1,000 gigawatt hours more than the current plan) through conservation and efficiency programs, incentives and regulations. Explore more codes, standards and conservation options for savings beyond the annual target of 9,800 gigawatt target. Develop energy procurement options to acquire up to 2,000 gigawatt hours from clean energy producers for projects that would come into service in the 2016 — 2018 time period.

10.4 *Scenarios*

Exhibit 23

British Columbia Renewable Energy Scenarios
Total Installed Capacity (MW)

Renewable Energy Sector	Base Year	Scenario A			Scenario B			Scenario C		
	2010	2015	2017	2022	2015	2017	2022	2015	2017	2022
Wind	104	390	400	426	790	850	1,061	450	608	1,203
Solar	-	-	-	-	-	-	-	-	-	-
Marine	-	-	-	-	-	-	-	-	-	2
Geothermal	-	-	-	-	-	2	54	-	-	120
Bioenergy	798	798	918	1,318	1,149	1,283	1,694	1,149	1,283	1,694
Small Hydro	751	751	751	771	789	805	846	789	805	1,000
Large Hydro	12,457	12,792	12,792	14,392	13,546	14,756	16,239	13,546	14,756	16,239
Total	**14,110**	**14,731**	**14,861**	**16,907**	**16,274**	**17,696**	**19,894**	**15,934**	**17,452**	**20,258**

Sources: Base year: Statistics Canada catalogue 57-206, *Electric Power Generating Stations*
Scenario B: National Energy Board Canada's Energy Future, November 2011
Scenarios A and C: Prism Economics

Technology Profiles

This section describes the current state of and potential developments in six ERE technologies that are the focus of the labour market and human resources analysis later in the project. An additional section considers "enabling technologies" that are closely tied to the distribution of ERE but also have broader impacts on the electricity system as a whole. This section provides background information that links directly to the technologies that will be deployed, the timing and cost of new installations, related economic conditions and competing or complementary activity that might be impacted by new ERE investments. All of these factors will play a role in the labour market and human resources analysis that will form the next phase of this work.

Introduction and Background

Each technology is summarized in six sections. Where possible the same or equivalent measures are used in each technology, but there is no intention of comparing or assessing the relative merit of each. The descriptions present a picture of current and expected conditions that will drive RE employers in the future.

Synopsis is a short summary for each technology; noting the global and Canadian potential, key characteristics of current and future systems, the timing and nature of newly deployed systems.

State of Maturity describes the available range of technologies allocating the major contributors across an adoption cycle with three categories:

- Mature and Currently Deployed at Scale (Mass Market),
- Technologies at Market Entry, (Niche Market) and
- Future Technologies[8].

The allocation of the technologies to one of the three categories is based on the detailed research and literature review.

Costs and Development Trends: describe common cost measures available from sources that span the technologies and track past and future cost data and research. Measures include the levelized cost of energy (LCOE), installed capital costs and past and projected changes in costs. LCOE is of particular interest in the current research for the labour content during both the capital and operating phases. These measures reveal several current and expected features including:

- the variability and factors driving current (LCOE) costs,
- the range of capital costs that are associated with new installed capacity and
- the expected rate of long term cost declines that will promote future investment.

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[8] **The state of maturity** refers to the penetration level of a product/service in the market adoption cycle. Here we have divided the market adoption cycle into three phases. The "mature and currently deployed at scale" includes the technologies which are commercially available, already present in the market or are mature. However, the "technologies at market entry stage" have not seen significant utilization or deployment but are ready to be deployed and have gone through the demonstration phase. "Future technologies" are at the research and development stage and are moving towards the demonstration phase.

Data is taken from up to ten selected studies that are authoritative, based on comparable analysis and span a range in countries including Canada. These ten studies are from:

1) U.S Energy Information Administration (EIA) -- collects, analyzes, disseminates independent and impartial information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment. [9]

2) National Renewable Energy Laboratory (NREL) -- is the only federal laboratory in the U.S. dedicated to the research, development, commercialization and deployment of renewable energy and energy efficiency technologies. [10]

3) International Energy Agency (IEA) -- is an autonomous organisation which works to ensure reliable, affordable and clean energy for its 28 member countries and beyond. [11]

4) Canadian Energy Research Institute (CERI) -- is an independent, not-for-profit research establishment created through a partnership of industry, academia, and government in 1975. [12]

5) Natural Resources Canada (NRCan) -- seeks to enhance the responsible development and use of Canada's natural resources and the competitiveness of Canada's natural resources products. [13]

6) Ontario Power Authority (OPA) -- plays a unique role in Ontario's electricity sector. They coordinate province-wide conservation efforts, plan the electricity system for the long term, and contract for clean electricity resources. [14]

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[9] EIA provides a wide range of information and data products covering energy production, stocks, demand, imports, exports, and prices; and prepares analyses and special reports on topics of current interest (US EIA, 2013). For more information, visit: http://www.eia.gov/about/

[10] NREL develops renewable energy and energy efficiency technologies and practices, advances related science and engineering, and transfers knowledge and innovations to address the nation's energy and environmental goals (NREL, 2013). For more information, visit http://www.nrel.gov/about/overview.html

[11] The IEA's four main areas of focus are: energy security, economic development, environmental awareness, and engagement worldwide (IEA, 2013). For more information, visit http://www.iea.org/aboutus/

[12] CERI's mission is to provide relevant, independent, objective economic research in energy and related environmental issues. They strive to build bridges between scholarship and policy, combining the insights of scientific research, economic analysis, and practical experience. In doing so, they broaden the knowledge of young researchers in areas related to energy, the economy, and the environment while honing their expertise in a range of analytical techniques (CERI, 2013). For more information, visit http://www.ceri.ca/index.php?option=com_content&view=article&id=47&Itemid=67

[13] NR Can is an established leader in science and technology in the fields of energy, forests, and minerals and metals and use their expertise in earth sciences to build and maintain an up-to-date knowledge base of our landmass. NRCan develops policies and programs that enhance the contribution of the natural resources sector to the economy and improve the quality of life for all Canadians. They conduct innovative science in facilities across Canada to generate ideas and transfer technologies. They also represent Canada at the international level to meet the country's global commitments related to the sustainable development of natural resources (NRCan, 2013). http://www.nrcan.gc.ca/department/535

7) ARUP -- It is an independent firm of designers, planners, engineers, consultants and technical specialists offering a broad range of professional services. Its headquarters is in London, U.K. [15]

8) Mott MacDonald – is a diverse management, engineering and development consultancy delivering solutions for public and private clients world-wide. It's uniquely diverse £1 billion global consultancy works across 12 core business areas. [16]

9) Australian Academy of Technological Sciences and Engineering (ATSE) -- is made up of some of Australia's leading thinkers in technology and engineering. [17]

10) International Renewable Energy Agency (IRENA) --The International Renewable Energy Agency (IRENA) is an intergovernmental organization that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a center of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. [18]

Installed capital costs, adjusted to fit Canadian costs including labour costs and the extent of local procurement of components, are used to derive investment profiles for RE used in the Market Assessment section. Wherever possible, the focus is on the factors driving investment decisions.

Environmental Considerations describe comparable measures of GHG emission reductions and other benefits associated and impacts with each RE technology.

Technical and Non-Technical Advantages and Barriers cover qualitative factors that are not apparent in the other measures and characteristics, but will play a role in the future deployment.

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[14] They do this by working closely with their industry partners and a broad range of stakeholders across the province. Together, they are transforming Ontario's electricity system by helping to reduce energy use, maintain reliability, and establish a clean, modern and cost-effective power grid for a sustainable future (OPA, 2013). For more information, visit http://www.powerauthority.on.ca/about-us

[15] They have done extensive amount of work in the renewable energy sector (ARUP, 2012). http://www.arup.com/Home/About_us.aspx

[16] This organization has worked on multiple renewable energy projects and published credible reports on green energy (Mott MacDonald, 2012). http://www.mottmac.com/aboutmottmac/

[17] ATSE is an eclectic group, drawn from academia, government, industry and research, each with a single objective in mind – to apply technology in smart, strategic ways for the social, environmental and economic benefit. The organization has a very diverse portfolio with energy and renewable energy as one of its core competencies (ATSE, 2013).http://www.atse.org.au/atse/about/content/about/index.aspx?hkey=c7aeeb14-5044-4e54-a26d-a72261429746

[18] IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity (IRENA, 2013) http://www.irena.org/Menu/index.aspx?PriMenuID=13&mnu=Pri

Emerging Trends and Related Markets offer a final comment on new or speculative changes that are under consideration and might develop into important considerations before 2022. Comments also extend to related markets where “spin off” activity impacts the economy.

1.0 TECHNOLOGY PROFILE – WIND

Wind energy is one of the fastest-growing renewable energy sources globally and in Canada.

- Canada's technical potential for wind on both a land and offshore resource base, is estimated in the range from 358 to388 EJ with a large practical[19] potential on land between 28 and 68 EJ[20] (IIASA, 2012);
- Canada's wind resources vary from province to province and across locations, both seasonally and based on land use, land cover and topography;
- Proximity to population and / or transmission and distribution is an important consideration; and
- High quality wind resources continue to be identified for development and, as of April 30, 2013, installed capacity in Canada reached 6,568 MW (Canwea, 2013).
    - More than two-thirds of Canada's total wind power capacity is located in Alberta, Ontario and Quebec.

1.1 **Synopsis**

- Wind turbine technology has evolved rapidly over the past 20 years with the average size of individual wind turbines growing from 100 kW in the early 1980s to over 2.5 MW today;
- Canada's particular strengths include small and medium turbine manufacturing[21], hybrid power systems (wind-hydro, wind-diesel, wind-batteries) and niche technologies for remote off-grid systems;
- Factors influencing deployment include:
    - Planning constraints;
    - Wind resource;
    - Transmission location and constraints
    - Compatible land uses;
    - Site and land availability;
    - Population distribution and density;
    - Public acceptability;
    - Location and type of aviation and radar infrastructure;
    - Location of sensitive environmental areas;
    - Economies of scale are promoting the installation of many larger turbines in larger wind farms;
    - The supply of, and market for, large wind turbines (> 1.5 MW) is dominated by major international companies;
    - Costs of installation are less variable than other ERE technologies;

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[19] The practical potential for Canada is calculated from the technical potential taking into account limitations such as conflicting land use (i.e. urban area, protected areas, military exclusion zones) and remoteness - transmission access and distribution access.

[20] 1 EJ (exa joule) = 277.7 TWh or 277.7 x 10^6 MWh

[21] DFAIT indicates Canada is host to about half of the world's small wind turbine manufacturers that includes companies such as Endurance Wind Power, Hybridyne Power Systems,One world Energy, GE Canada among others : www.tardecommissioner.gc.ca

- Onshore and offshore development have many unique constraints to each, but that the single largest variable in offshore projects is the cost of transmission; and
- Life Cost Analysis (LCA) indicates that 80% of GHG emissions from wind systems occurs during construction.

1.2 State of Maturity

On-shore and off-shore wind technologies are at various stages of adoption cycle[22]. While the largest economic development is concentrated in large wind turbines and on shore installations, there is ongoing activity in smaller installations and some interest in off-shore developments:

- On-shore wind is a mature renewable technology and groups of turbines are often deployed in wind farms of many, large wind turbines;
- In many cases electricity generated from each turbine is combined and fed directly into the utility grid;
- Mid-sized turbines range from 300 kilowatts (kW) to 3.5 megawatt (MW) or higher, and
    - Added costs are related to Balance of System (BOS)[23] components;

Scale effects are important, larger wind farms, in the tens and hundreds of megawatts of installed capacity, may see better economies of scale than small wind farms or dispersed wind turbines.

- Developing larger towers, rotors and turbines will involve advanced materials and associated workforce skills in manufacturing, distribution and installation.
- On shore installations, in the 1.5 -2.5MW size range, have increased market penetration over the last decade, with an average growth rate in Canada of 40% since 2005 (CANWEA, 2013, email communication).

Small –medium turbines:

- Canada's strength is in:
    - Small to medium turbine manufacturing;
    - Expertise in large scale wind turbine tower base;
    - Frame and rotor blade manufacturing;
    - Hybrid power systems and niche technologies for remote off-grid communities; and
    - Installation in harsh climate locations, resource assessments and mapping and project development.
- Some of these technologies are currently deployed in overseas markets and at market entry stage; and
- As larger turbines, rotors and towers enter the market, the complexity of installation increases.

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[22] For Technology Descriptions, see Technology Profiles –Wind Appendix 1.

[23] **Balance of System (BOS)**: It consists of wires, switches, batteries and inverters when you are dealing with off-grid technology. Depending on your application, you will need additional equipment and materials to provide electricity at the required voltage and current. This equipment is referred to as the Balance of System (BOS) (Natural Resources Canada, 2003).

Exhibit 24

State of Maturity -- Wind

Wind Energy			
	Mature and currently deployed at scale	Technologies at market entry stage	Future technologies
On-Shore Wind	• On-Shore (1-3 MW) ❖ 1.5 MW (77m Rotor) ❖ 2.5 MW (93m Rotor) ❖ 3.0 MW ❖ 3.5 MW	• On-Shore (< 1 MW) ❖ 33-300 KW (33m Rotor) ❖ 750 KW (46m Rotor) ❖ 56-100 KW (17m Rotor)	• On-Shore (>4 MW) ❖ 4.5 MW (120-140m Rotor) ❖ 7.5 MW (150m Rotor)
Off-Shore Wind	• Off-Shore (> 2 MW) ❖ 3.6 MW (104m Rotor) ❖ 4.0 MW (110m Rotor)	• Off-Shore (5-7 MW) ❖ 5.0 MW (120^{+}m Rotor) ❖ 7.5 MW	• Off-Shore (>7 MW) ❖ 8.0 MW ❖ 9.0 MW

1.3 Cost and Development Trends

Measuring and extrapolating costs in RE systems is a very uncertain process – largely due to the relatively new technologies, the dispersed nature of the resource and variety of circumstances involved in development. Nevertheless there is an extensive literature on costs and cost trends that can be used to understand the future of wind RE deployment.

- Installation and operating costs for wind systems vary across locations, but the extended history of installation and operation allow estimates of levelized cost of energy (LCOE $/MWh)) and installed capital costs ($/KW) that fall within a narrower range than some of the newer and less mature RE technologies;
- As Exhibit #25 shows, general and on-shore wind estimates of LCOE run from $60 to $150/MWh;
- The LCOE cost of energy from wind power projects onshore have been estimated:
    - In Quebec in the range of $ 83 - $105 per MWh;
    - In Ontario costs, under Feed in Tariffs (FIT) contracts as initially $135/MWh and the new Fit price is $115/MWh;
    - and in Ontario, most projects have been commissioned under competitive bids in the Renewable Energy Supply (RES) programs, and saw prices come in around $80 – 90/MWh.
    - For offshore wind[24] was $190/MWh in 2009 (OPA, 2010a; OPA, 2010b; OPA, 2010c).
- Project characteristics described in Exhibit #26 signal the extent of cost uncertainty.

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[24] Currently, there is a moratorium in Ontario for Off Shore wind farms

Exhibit 25

Levelized Cost of Energy – Selected Studies

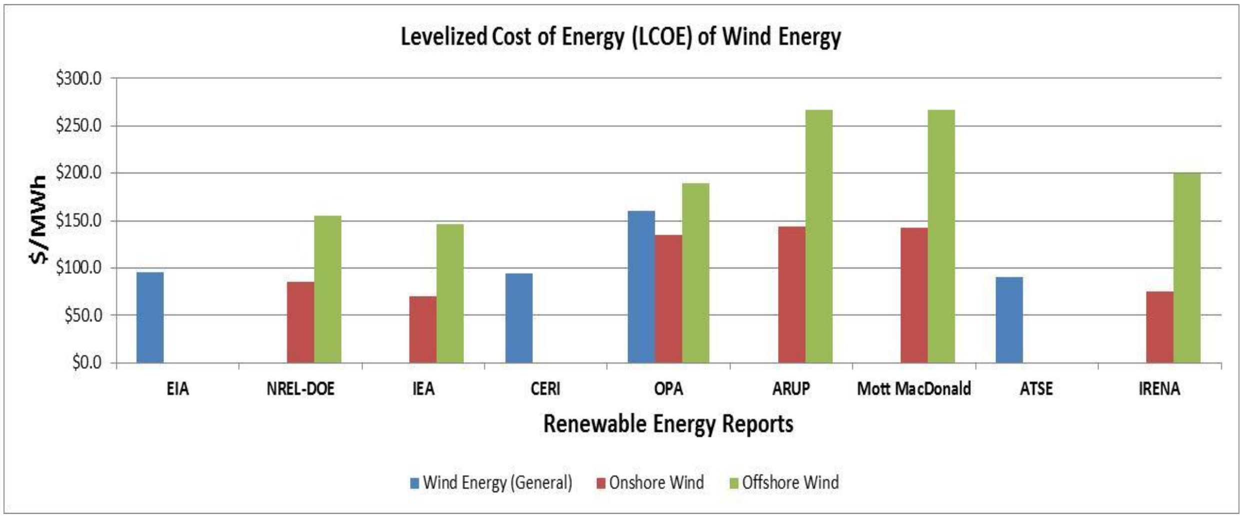

Exhibit 26

Levelized Cost of Energy, Range of Estimates – Selected Studies

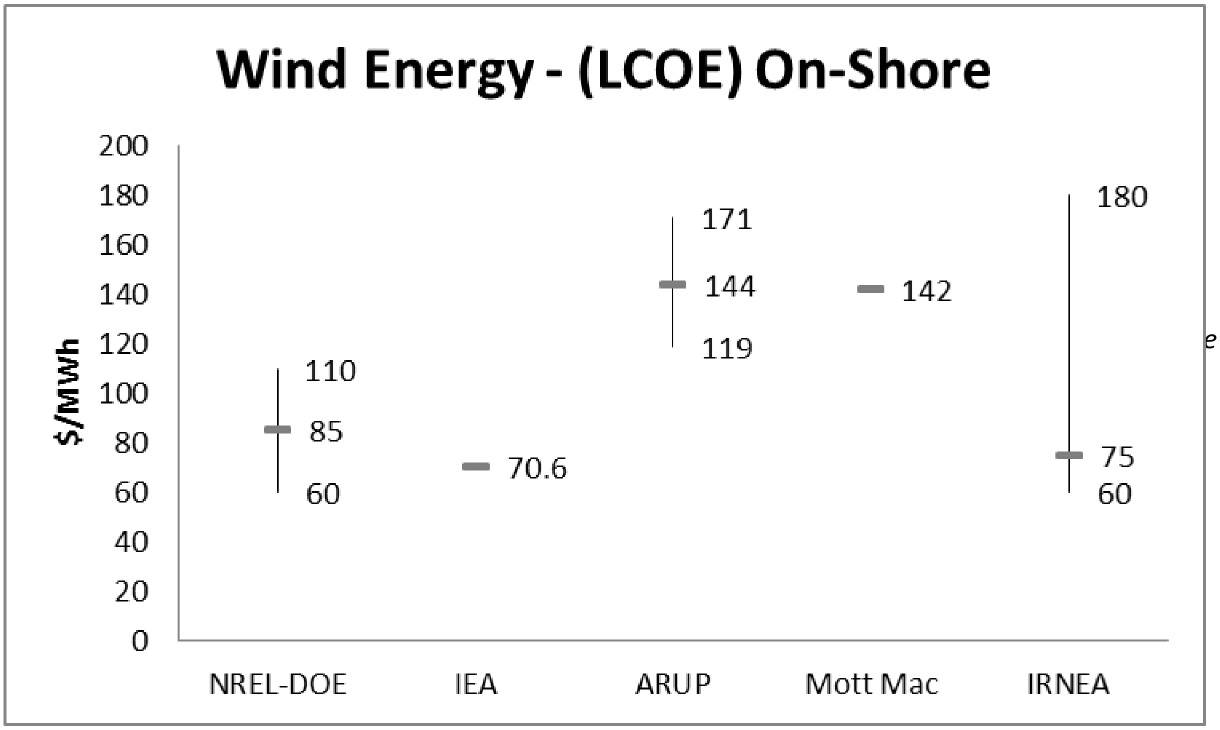

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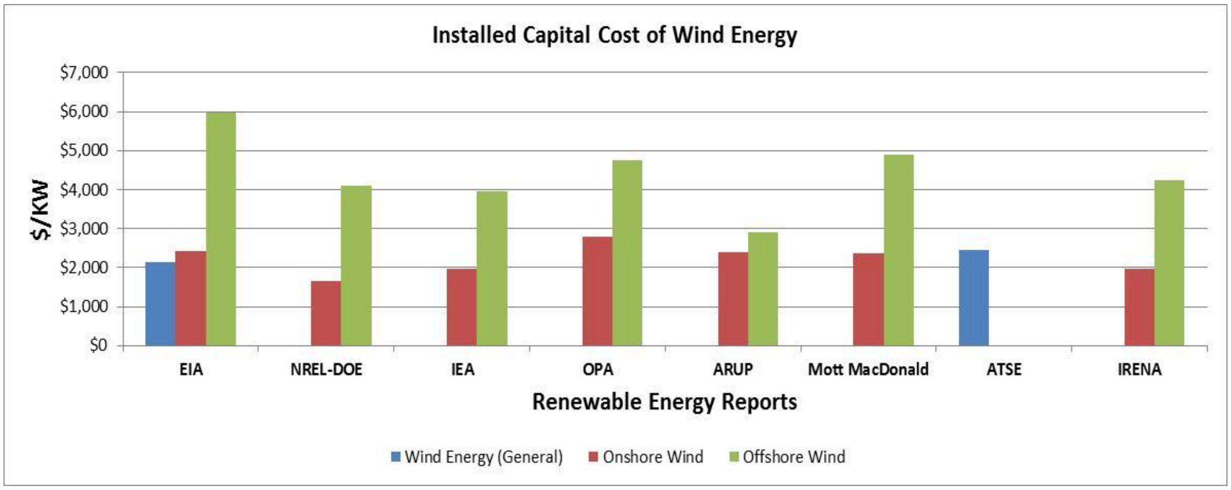
Exhibit 27

Installed Capital Costs, Selected Studies



- Total installed costs of onshore wind projects in the major OECD markets in 2011 were between $1,750 and $3,000/kW;
- Offshore wind farms are significantly more capital-intensive, with average costs of between $4,000 to $ 6,000 per kW due to:
  - grid connection from onshore to the wind farm; and
  - higher costs for equipment designed to cope with harsh marine environments (IRENA 2013).
- The installed capital cost of onshore wind facilities (weighted average price) in Ontario, not reported in the Exhibit, under FIT contracts is $2,800/kW and for offshore wind is $4,750 (OPA, 2010a; OPA, 2010b; OPA, 2010c; Scotia Capital, 2009);
- LCOE and installed costs are not the only considerations for plant-level investment decisions. More variables are involved:
  - the projected utilization rate, also referred to as the capacity factor;
  - the existing generation mix and the energy source displaced by wind energy
  - financing terms; and
  - government support such as, production tax credits, renewable portfolio standards, feed-in-tariffs, requests for proposals and Federal and Provincial tax incentives.

Expected Changes in Costs

- On-shore investment costs for wind generation are expected to decline by 23% from 2010 to 2050, and by 38% for offshore facilities (IEA, 2011);
- The scope of future cost reductions for on-shore wind (capital costs) to 2030 are in the range of 15-20% with expectations of levelized cost of energy reductions in the range of 5-10% (ATSE, 2011, ARUP, 2011); and
- Expected cost reductions are based on many changes including realizing economies of scale as turbines and wind farms grow larger.

1.4 Environmental Considerations

- Research for on-shore and off-shore wind farms[25] indicates life cycle emissions during the manufacturing construction, operation and dismantling phases result in emissions far below conventional technologies;

Exhibit 28

Wind Energy – Environmental performance

LCA Emission	On-Shore	Off-Shore
CO_2	5.6 – 9.6g/KWh	6.4 - 12.3 g/KWh
Methane (CH_4)	11.6 – 15.4 mg/KWh	10.5 - 54.4 mg/KWh

Source: (Wind Energy, 2011)

- The construction phase contributes about 80% of the emissions;
- The operational stage, including the maintenance and replacement of materials is responsible for 7%-12% of the emissions, and the end of the life of the wind farm is responsible for 3%-14% (Wind Energy, 2011); and
- Land use requirements vary and have an average value for project area requirement of about 34 +/- 24 hectares per MW equal to a capacity density of 3.0 +/- 1.7 MW/km^2 (NREL, 2009).

1.5 Technical and non-technical advantages and challenges

The principle advantage of wind RE systems is their established track record and growing scale of development.

Market and integration challenges relate to:

- Increasing utility power quality requirements;
- Long-term commitments to incentives;
- Lower capacity factors associated with lower resource quality;
- Interconnection requirements in general and variations regionally;
- Difficult transmission siting processes; and
- Risk of offshore approvals compared to land-based applications.

Some technical challenges include:

- Concerns about operating wind near grid stability limits:
    - Many modern wind turbines have grid friendly operating characteristics including – voltage control/regulation; fault ride-through capabilities; real power control, ramping and curtailment; primary frequency regulation; inertia response; short-circuit duty control[26]
- Technical limits to rotor size limit capacity factors;

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[25] Extracted from various LCA studies such as VESTAS Wind Systems, ECOINVENT, ECLIPSE (Environmental and Ecological life-cycle inventories for present and future power systems in Europe), CASES (Cost Assessment for Sustainable Energy Systems), and NEEDS (New Energy Externalities Development for Sustainability).

[26] See IEEE Special Edition (vol. 9, #6, Nov/Dec 2011).

- High tower costs and the ability to access strong wind resources aloft; and
- Turbine reliability for harsh, remote offshore environments.

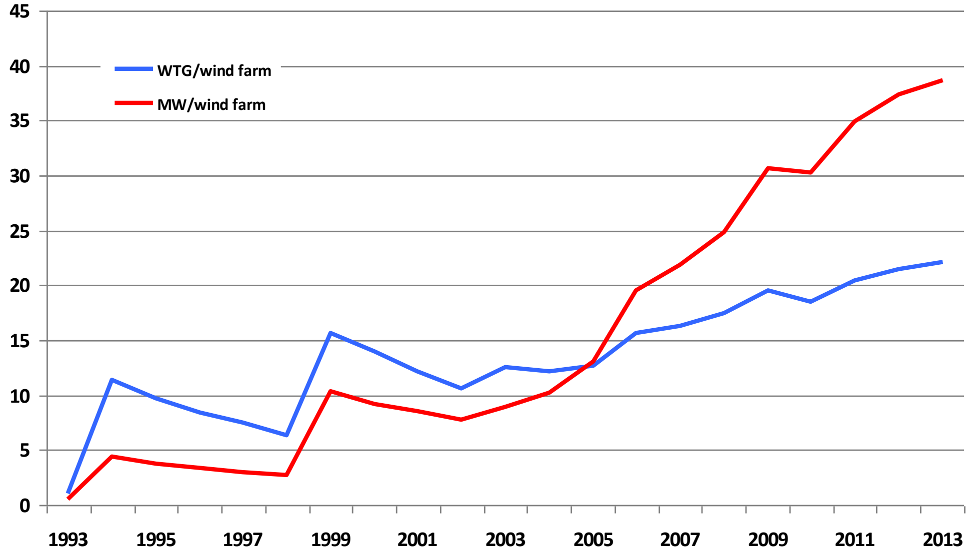
1.6 Emerging Trends and Related Markets

- US data indicates that the size of installed wind turbines continues to increase with, over a large installed base, an average of 1.79MW, with
    - More than half the turbine sizes larger than 1.5 MW and some of the larger turbine sizes at 3 MW;
    - Average hub heights and rotor diameters rising to 79.8 and 84.3 metres; and
    - For onshore wind farms, this trend towards large size is expected to continue (DOE, 2011).

- According to the Canadian data, as of March 1, 2013, there were 3,751 wind turbines in operations with a Canadian average of 1.75 MW per turbine. This compares to the average turbine size of 0.702MWin 2001, before federal programs started. The chart below shows the growth of the number of turbines and MW of installed capacity per a wind farm.

Exhibit 30

Wind Farm Installations in Canada; Turbine Size and MW size



- The European experience also confirms the trend towards large turbine sizes with average generation capacity per installed turbine at 2.2MW trending towards the 3 MW sizes;
    - Several Canadian companies develop intermediate sized turbines of 350- 850kW capacity for single turbine installation, small wind turbines (not more than 200 kW) for micro generation (IEA, 2009);
- Canada is host to about half of the world’s small wind turbine manufacturers serving the distributed resources markets (off-grid, remote communities and hybrid power systems and storage solutions);
- Chinese suppliers are expected to dominate capacity additions in the coming years.

- DOE is also suggesting that there is a risk that the overall market will not grow rapidly enough to reach a 20% wind energy penetration level by 2030 (DOE, 2011);[27] and
- Forecasts for the pace of installation vary widely;
    - While IHS EER (2011) and UBS (2011) increased their forecast of increased wind installed capacity in U.S;
    - EIA (2011), BTM (2011), Bloomberg NEF (2011), and MAKE Consulting (2011) have predicted a decline in the U.S installed MW wind capacity based on the expiration of the federal incentives (DOE, 2011).

Implications for Labour Markets and Human Resources

Significant growth in all aspects of wind power systems is expected.

Canada's installed capacity for wind generation will grow by a multiple from 2x (in the Utility scenario) to 5x (in the Vision scenario) capacity in 2016 from initial capacity of between 5,000 and 6,000 MWs in 2011 and 2012

Plans for the next four years could add 6,000 MWs;

Employers involved in this work will span a value chain from system research and design to construction, operations and maintenance.

These employers will add to the current workforce emphasizing jobs in:

- general administration;
- engineering;
- sales and marketing;
- electricians and electrical engineering technicians and technologists;
- accounting and finance;
- technical and site supervisors; and
- project management and general management.

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[27] Department of Energy (DOE). (2011). Distributed wind technology. Retrieved June 20, 2012 from http://www1.eere.energy.gov/wind/wind_dist_tech.html

2.0 TECHNOLOGY PROFILE – SOLAR

The potential for solar energy is virtually unlimited and is many times greater than global energy usage. But solar energy is variable, depending on location, time, season and other factors. The natural availability of solar energy or solar insolation[28] varies from province to province. Canada's theoretical potential for solar PV is estimated at 28,042 EJ/yr.

2.1 Synopsis

- Solar energy can be transformed into electricity through photo-voltaic (PV) or thermal systems:
    - Solar PV is the dominant technology globally and in Canada
    - Solar thermal systems are growing in the United States and have significant potential
        - Solar thermal systems are usually developed on a larger scale than PV systems
        - Several Canadian companies invest in solar thermal and some government programs exits.
- Canada's solar potential is largest in the southern Prairies – where potential is comparable to Miami Florida.
- World production and installation of solar PV systems has been growing at a 3-year compound annual growth rate (CAGR) of 66%:
    - A majority (59%) of all PV cells were produced in China and Taiwan in 2010;
    - Europe is the second largest cell producer, with 13%;
    - Japan held a 9% share of the market; and
    - North America was in fourth with 5% of PV cells produced globally in 2010 (DOE, 2011).
- The total installed Canadian PV capacity to end of 2012 was 765MW;
- Ontario accounting for most of the capacity installed during 2010-2012(NRCan, 2012);
- Conventional mono and poly silicon based solar PV is at market maturity level and will dominate the production / installation processes in Canada to 2022;
- Ontario Feed in Tariffs (FIT) provided an incentive for a number of new PV module manufacturers to establish presence in Ontario resulting in an estimated 158 MW of PV modules manufactured in Canada in 2011:
    - Provincial content rules are part of the program,
    - Ontario's policy has been challenged at the World Trade Organization and may be altered.
- The PV Supply Chain comprises of upstream development, design, equipment and component manufacturing, as well as downstream installation, operation and maintenance ; and
- The majority of these services are offered in Canada but only some of these products are made in Canada.

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[28] Solar insolation: It is a measure of solar radiation received from the sun and placed on a given surface area of the solar cell in a specific time period.

2.2 State of Maturity

- These solar power technologies are at market maturity level:
    - Crystalline silicon (c-Si) wafer-based solar photovoltaic (PV)
    - Thin film solar PV, and
    - Concentrating solar thermal power (CSP)
- Crystalline silicon PV cells represent 87% of world PV cell market sales in 2011;
- The vast majority of solar PV installed capacity is grid-connected, with the off-grid sector estimated at 2% of global capacity
- Industrially produced solar modules currently achieve efficiencies ranging from 18%–24% (DOE, 2012a);
    - Improving efficiencies is a major goal of technological development
- High temperature solar thermal energy, also referred to as concentrating solar power (CSP) technologies are not expected to play a significant role in Canada (IIASA, 2012);
- Market entry technologies like thin film silicon have the potential to change the production / installation system but these technologies are not expected to reach commercial maturity before 2022; and
- Integrated building PV is beginning to appear in the market place.
- Currently, c-Si wafer cells (1st generation) represents almost 85% of world solar PV installed capacity. This share would gradually decrease to less than 50% by 2030 in one of IEA reference scenarios.
- While to date, thin-film technologies (2nd generation) represent about 15% of world-wide solar PV installations, IEA expects that by 2030, its share would increase to about 40%.
- IEA also expects that emerging and novel solar technologies (3rd generation) would also reach market-ready status with a potential to reach about 10% of the world installed capacity by 2030.
- According to IEA, in the medium term, competitive markets for solar PV will continue to expand in off-grid and industrial applications, relying on diesel, in many countries, without incentives.

Exhibit 29

State of Technology Maturity – Solar

Solar Energy			
	Mature and Currently deployed at scale	Technologies at market entry stage	Future technologies
Solar PV	❖ Non-Wafer ❖ Mono-Silicon ❖ Poly-Silicon ❖ Wafer: Poly Based ❖ Wafer: Mono Based	❖ Amorphous Silicon (A-Si) ❖ Cadmium Telluride (CdTe) ❖ All-Black Contact ❖ Heterojunction with Intrinsic Thin layer (HIT) ❖ Buried Contact Solar Cell ❖ Ribbon ❖ Thin Film Silicon ❖ Integrated building PV	❖ Organic Polymer ❖ Low-X Concentrators ❖ Copper Indium Gallium Selenide (CIGS) ❖ Spheral ❖ Dye-Sensitized Solar Cell (DSSC)
Solar Thermal	➢ Dish-Engine Systems ➢ Solar Water Heaters	❖ Hybrid Solar Lighting ❖ Parabolic Trough	N/A

2.3 Cost and Development Trends

LCOE and Installed Costs

- There are wide variations in the estimates of LCOE and installed costs for solar PV systems;
- The ten studies reported LCOE's from 152 to 470 $/KMh;
- Installed costs from the studies range from $3410 to $6780 and clustered around $4,500.00 $/KW;
- Smaller scale and off grid solar systems have higher installed costs; and
- Utility scale based United States installed costs range between $2,000/KW and $3,600/KW and a capacity weighted average of $2,900/KW in 2012 (IRENA, 2013).

Exhibit 30

Levelized Cost of Energy – Selected Studies

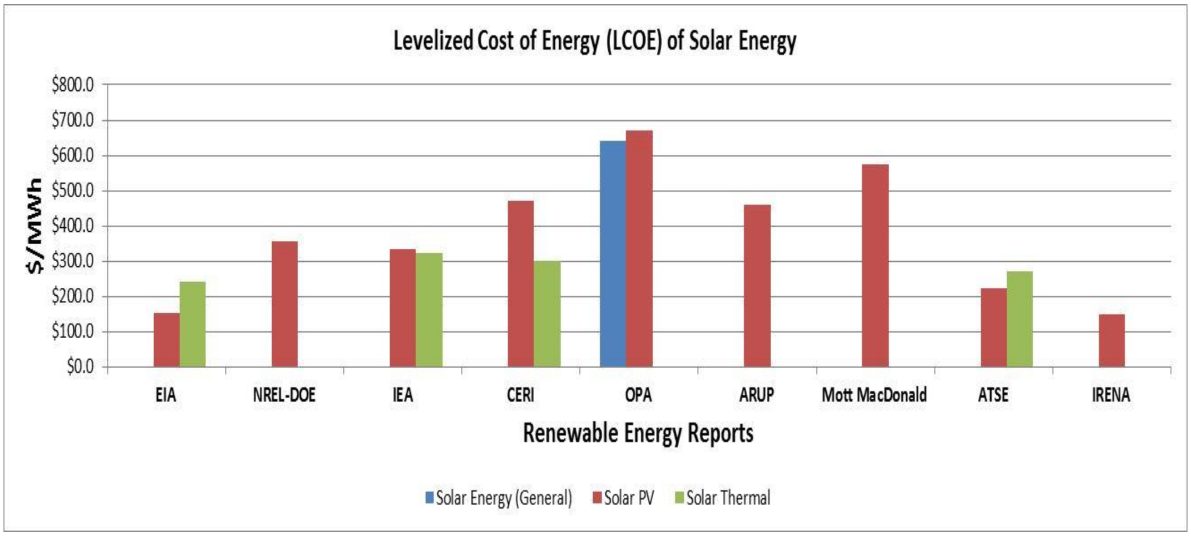
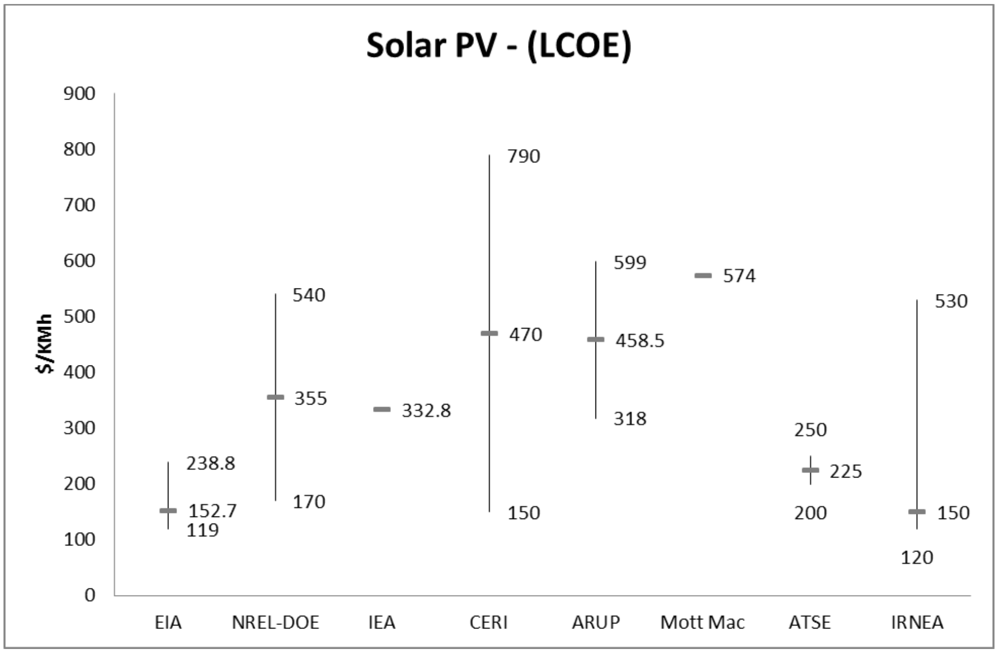
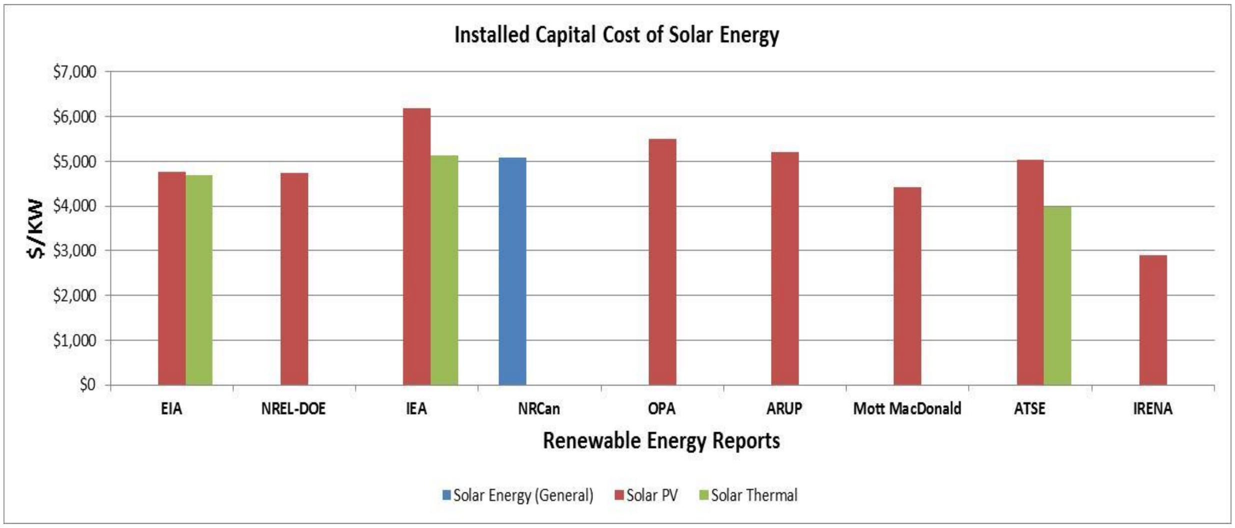


Exhibit 31

Levelized Cost of Energy, Range of Estimates – Selected Studies





Cost reductions

- Led by declining cell prices, costs are forecast to decline between 2010 and 2030 as global deployment rapidly scales up with:
    - LCOE to fall by 37%, and overall installed capital costs to decline by 51% decline by 2030
    - Costs shift from cells to Balance of System components (e.g. inverters, racks, cabling, finance)
- The projected LCOE for solar PV in the year 2020 and 2030 are in the ranges of $214 per MWh to $394 per MWh (ARUP, 2011); and
- The Mott MacDonald study (2011) in the U.K suggested that PV costs for all the main installation types are expected to see very significant cost reductions;
    - Module costs, for example, which will decline by half of current installed costs dropping to 12-18% of costs in 2040 (Mott MacDonald, 2011).

2.4 Environmental Considerations

- The Life Cycle Assessment of greenhouse gas (GHGs) emissions for solar systems are as little as 10% of the emissions from conventional systems;
- Although low in comparison to fossil fuels, there are emissions associated with solar PV through the life cycle of production to end use. For example, emissions of a 33 KW PV system are shown below (Pacca, 2006);
- Environmental and social implications of solar energy depend on the technologies used and the amount of land covered; and
- Land use conflicts, particularly affecting soils and biodiversity and landscape aesthetics are considerations that may need to be addressed in specific contexts.

Exhibit 33

Solar PV – Environmental Performance

LCA Emissions	Crystalline Silicon	Thin Films
CO_2	25 – 220 gCO_2e/KWh	15 – 90 gCO_2e/KWh
CH_4	~1 – 2 g/KWh	~1 – 2 g/KWh

Source: (NREL, 2012; Pacca et al, 2006)

2.5 *Technical and non-technical advantages and challenges*

The primary advantage of solar PV is its pervasive distribution, very significant deployment potential and ability to supply electricity at or around peak times.

The non-technical challenges include:

- The level of government policy support;
- Codes, standards, interconnection and net-metering guidelines and ease of implementation;
- Limited financing options to address high initial capital costs; and
- Limited workforce skills and training.

The technical challenges and barriers for solar PV relate to:

- High cost of solar technologies compared with conventional energy;
- Efficiency of conversion: 4% to 12% (for thin film) and under 22% (for crystalline) in the current market, and
- Performance limitations of balance of system (BOS) components such as batteries, inverters and other power conditioning equipment.

2.6 *Emerging Trends and Related Markets*

In Canada,

- About 650 companies provide solar systems and related services (e.g. sales companies, wholesalers, product manufacturers, project developers, private consultants, systems installers and industry associations),
- About 5,300 persons were employed in the solar PV sector in 2011,
- In 2011, reported revenue was over $1.2 billion, about 11% lower than in 2010.

NR Can (2012) reports:

- Ontario FIT prices have allowed for solar PV investment. Outside of Ontario, the residential rates are not sufficient to justify investment in solar PV for the majority of the population and there are few PV-specific incentive programs;
    - Markets are almost all off-grid systems.

- Total public budgets for solar PV systems in Canada were reported to be $61.8 million in 2010 and are primarily in the Ontario feed-in tariff incentive program;
- Most PV installations in Canada in 2011 were made within the grid-connected market segment; spurred primarily by Ontario's Renewable Energy Standard Offer program and Feed-in Tariff (FIT)
- The grid connected applications included 37% for residential and building integrated applications, and 62% for large ground-mounted utility scale systems equal to or less than 10 MW; and
- The Building Integrated PV market is relatively immature as compared to other forms of PV and is still at the demonstration phase in Canada.

Implications for Labour Markets and Human Resources

- Solar systems will likely be the most rapidly growing source of employment in ERE.
- Growth will be concentrated in Ontario,
- If employment growth accelerates attention will focus on:
    - Competition with other sectors for key occupations
    - Rising labour costs
    - The mobility of the skilled workforce across sectors, industries and regions
- As cell prices drop the relative costs of more labour intensive components of installation will rise including racks, cabling, inverters and substations
    - In this environment attention focuses on available skills, safety, certification, innovations in these areas.

3.0 TECHNOLOGY PROFILE – BIOENERGY

Canada' s theoretical potential for land based bioenergy (not including aquatic biomass) is estimated at 73 EJ/yr and the practical potential at 52 EJ/yr (IIASA, 2012). Biomass is the fourth largest source of Canada's electricity with a share of 2.0%. The installed capacity of bioenergy for electricity generation in Canada is 1,700 MW with largest shares in Quebec (304MW), Ontario (280 MW) and BC (798 MW) (NRCan 2010).[29] Bioenergy systems that produce only thermal energy (e.g. biofuels for heat or transportation) are not included in the scope of work of Renewing Futures.

3.1 Synopsis

Biomass is organic material such as trees, agricultural crops or residues, municipal wastes, and algae that has stored sunlight in the form of chemical energy. Bioenergy is conversion of the organic matter to electricity or heat through thermochemical processes:

- Direct combustion;
- Pyrolysis;
- Gasification;
- Liquefaction or biological processes:
    - Anaerobic digestion;
    - Aerobic composting; and
    - Fermentation.

Bioenergy systems produce both electric and thermal power with thermal capacity representing about 75% of the total. The state of bioenergy systems in use in Canada can be described as follows:

- Wood residue is the primary source of fuel with other industry and municipal waste systems providing the balance,
- Forestry and pulp and paper mills are the primary site for bioenergy systems,
- Bioenergy generating facilities are concentrated in Ontario, Quebec and British Columbia,
- There is significant potential for "purpose grown" biomass in agriculture, but industry and government policy have not exploited this opportunity (NRCan, BioCan 2010)
- Bioenergy systems produce electrical power on demand; avoiding the disadvantages of interruptible systems;
- Canada is expanding a pellet production industry preparing wood residue material for use in global bio energy systems;
- There are a wide range of alternative technologies at all stages of the adoption cycle;
- Estimates of levelized costs of energy from bioenergy related electrical systems range from $45 to $221 per KMh with wide variations around estimates depending on technologies and locations;
    - Installed costs run from just over $2000 to $7,000 with estimates concentrated around $4,000 /kW;

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[29] The NR Can, Biomass Canada study mentioned here attributes the noted totals to electricity. Much larger capacity is associated with thermal (biofules) with total national capacity at 3,360 MW. See "Canada Report on Bioenergy 2010, NR Canadian Bioenergy Association, Wood Pellet Association of Canada.NTL-IEA Bioenergy Task 40-Biotrade

- Bioenergy production from purpose grown and agricultural by-products, residues and waste have a wide range of potential positive environmental impacts; and
- There are a wide range of potential technological improvements in processes, material handling and cost reduction.

3.2 State of Maturity

There are a wide range of technologies that are now mature and deployed at scale, at entry level and in development.

Exhibit 34

State of Technology Maturity – Bioenergy/Biomass Energy

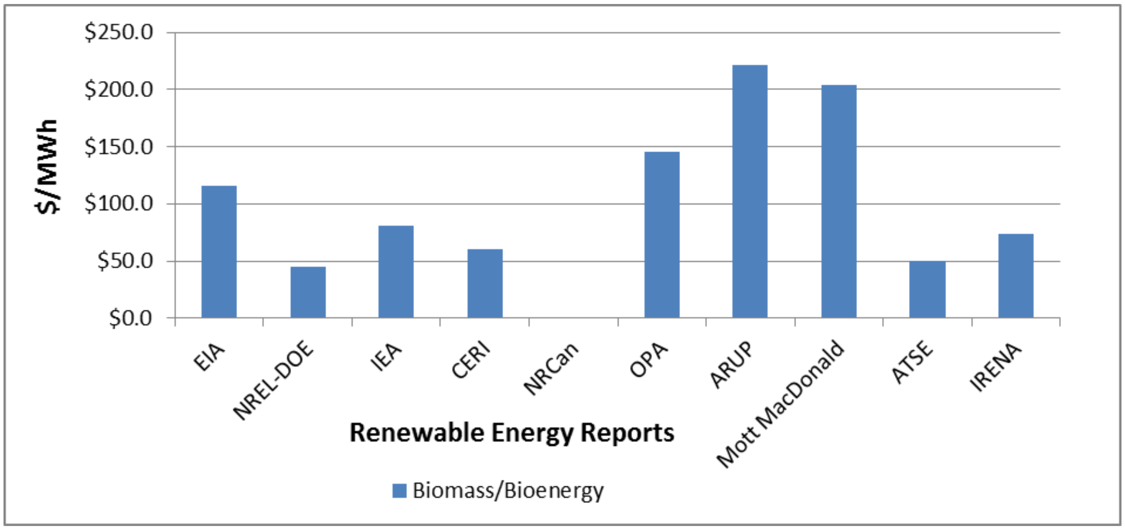
Bioenergy/Biomass Energy			
	Mature and Currently deployed at scale	**Technologies at market entry stage**	**Future technologies**
Biomass	❖ Anaerobic Digestion ❖ Stoker/FBC Steam-Electric Combustion ❖ Municipal Solid Waste (MSW) Incineration ❖ Landfill Gas (LFG) ❖ Combined Heat and Power (CHP) or Co-Generation	❖ Refuse-Derived & Process-Engineered Fuels ❖ 100% Biomass Repowering Options ❖ Pyrolysis ❖ Low-Rate Co-firing ❖ Medium-Rate Co-firing	❖ Atmospheric Biomass Gasification ❖ Torrefied Pellet Production ❖ Pressurized Gasification ❖ Integrated Biomass Gasification-Fuel Cell ❖ Biorefineries ❖ High-Rate Cofiring ❖ Hybrid Biomass-Solar/Geothermal ❖ Bio-Hydrogen
Biogas	❖ Dual-Fuel Reciprocating Engine ❖ Natural Gas Reciprocating Engine	❖ Microturbine ❖ Combustion Turbine	❖ N/A

3.3 Cost and Development Trends

- The cost for a typical biomass power plant in 2012 is estimated within a range of $20 - $280 per MWh with a weighted average cost for OECD North America at $74 per MWh (IRENA, 2013); and
- Canadian LCOE, estimated by the Ontario Power Authority ranges from $100 to $190 per MWh and is compared to international analysis in the ten studies.

Exhibit 35

Levelized Cost of Energy (LCOE) of Biomass/Bioenergy



The range of costs[30] shown in the above summary depends on the scale of operation, location and other factors. Seven of the ten studies calculated a range of estimates shown in the Exhibit #36.

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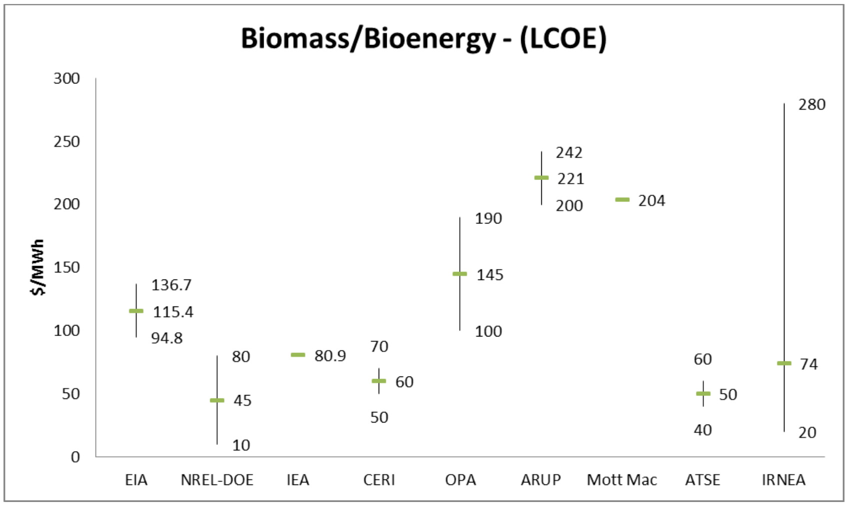
[30] The ARUP report calculated the LCOE for biomass plants <50 MW in the range of $200/MWh to $242/MWh and $239/MWh to $260/MWh for biomass plants >50 MW in the year of 2010 (ARUP, 2011). However, in the global assessment of renewable energy costs, the cost for a typical biomass power plant in 2012 is estimated within a range of $20 - $280 per MWh with a weighted average cost for OECD North America at $74 per MWh (IRENA, 2013). The International Energy Agency assessed the LCOE for solid biomass at $80.9/MWh (IEA, 2010). According to the report by Mott MacDonald, the average LCOE of various biomass technologies is $204/MWh (Mott MacDonald, 2011). The Australian Academy of Technological Sciences and Engineering (ATSE) calculated the LCOE of biomass technologies in the range of $40/MWh to $60/MWh in 2015 and $80/MWh to $100/MWh in 2040 (ATSE, 2011).

Exhibit 36

Levelized Cost of Energy, Range of Estimates – Selected Studies



The total installed costs of biomass power generation technologies vary significantly by technology and country as reflected in the study estimates of overall cost ranges shown below[31].

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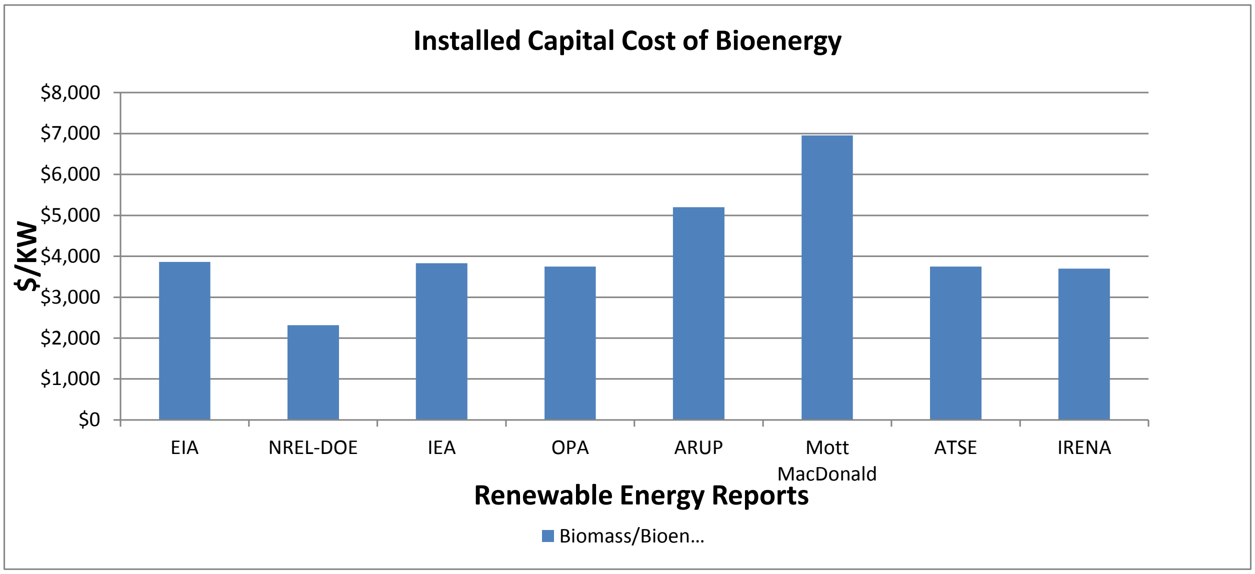
[31] For example, the total installed costs of stoker boilers was between US$ 1,880 to 4,260 per kW in 2010, while those of circulating fluidized bed boilers were between US $ 2,170 to 4,500 per kW. Capital cost estimates for gasification technologies, including fixed bed and fluidized bed solutions, are in the range of $2,140 and $5,700/ kW. Co-firing biomass at low-levels in existing thermal plants typically requires additional investments of $400 to $600/KW. The installed costs of stoker CHP and anaerobic digester are between the ranges of $3,600-$6,800/KW and $2,900-$6,600/KW respectively (IRENA, 2012; IRENA, 2013). The average installed capital cost of different biomass technologies is $6,952/KW (Mott MacDonald, 2011). The NREL-DOE estimated the installed cost of biomass within a range of $430/KW-$4,200/KW (NREL-DOE, 2011).

Exhibit 37

Installed Capital Cost of Biomass/Bioenergy



The capital cost for a sub-50 MW plant range from $4,100 / kW to $6100/ kW with a median of $5,200/ kW. This range reflects the variations in fuel type and configuration. The capital cost for an above 50 MW plant range from $3,600/ kW to $4,400/ kW with a median of $3,800/ kW. The smaller range reflects the more similar technologies and fuel that is being proposed for the larger plants (ARUP, 2011).

3.4 Environmental Considerations

Biomass energy producing plant emissions are low in comparison to traditional fossil fuels.

Exhibit 38

Biomass Energy	GHG Emissions
Electricity	95-148 Kg CO_2/MWh of electricity
CHP	27-45 Kg CO_2/MWh of CHP
Specific feedstock - Wood chips, forestry residue	10-20 Kg CO_2/MWh
Specific feedstock - SRC pellets, straw	75-100 Kg CO_2/MWh

Source: Bates 2009

Environmental impacts from bioenergy production using forest and agricultural by-products, residues and waste have significant positive environmental and social impacts as they do not:

- Create additional land use changes;
- Compete with food, feed or fibre production;

- Affect food prices; or
- Create additional demand for inputs, such as freshwater.

3.5 Technical and non-technical advantages and challenges

The principle advantages of biomass and bioenergy systems include:

- Their capacity to extract electricity from natural materials and waste streams in a complementary relationship with ongoing production and waste management processes;
- The potential for biomass fuels and pellets:
    - For export;
    - To replace or complement natural gas and coal generation, and
- Job creation and other economic benefits created in existing resource industries.

In addition to the reduction in GHG emissions, bioenergy systems:

- Return plant nutrients and portions of the carbon back to the soil;
- Help meet energy requirements;
- Reduce landfill requirements; and
- Create employment opportunities.

The non-technical challenges include:

- Managing the costs of material inputs, transportation systems, energy and labour related to:
    - Wide dispersion, low density and /or low abundance of inputs.
- Long term contracting arrangements;
- General need for incentives and programs to create market access and competitive conditions for production in Canada[32];
- High initial investment costs and undeveloped supply chains;
- Permitting procedures and emission regulations; and
- Competition between material recycling and energy recovery.

The technical challenges include:

- Process limitations: low conversion of lignocellulose in hydrolysis, tar problems related to syngas production and:
    - Co-firing limited to 5% - 10% of coal in pulverized coal based boilers.
- Problems in co-combustion in supercritical fluidized-bed boilers;
- Emission control especially in novel waste to energy processes: gasification, pyrolysis, and co-combustion; and
- Conversion technologies for high ash biomass, slagging and fouling problems.

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[32] See NRCan, BioCanada, “Canada Report on Bioenergy” page 8.

3.6 Emerging Trends and Related Markets

Biomass and bioenergy systems are unique among the RE technologies for their links to other industrial and infrastructure processes. These connections tie the trends in the sector to:

- Output growth, input costs and the profitability of industries investing in bioenergy for co-generation, heat and other related functions, e.g.
    - Statistics Canada added spending on RE in the 2010 Survey of Environmental Expenditures – a survey of industry expenditures – finding that Canadian businesses spent $455 million on capital for renewable technologies and bioenergy energy technologies accounted for over 75% of the total.

Growth in bio mass and bio energy systems is linked to:

- Industrial growth in related industries (forestry, agriculture, municipal solid waste);
- Costs and investments in managing material wastes; and
- Progress with technologies that will improve efficiencies.

Biomass and bioenergy systems are often linked directly to heating applications or to production processes earlier in the supply chain and these activities are not linked to electricity related employment.

Implications for Labour Markets and Human Resources

Additions to installed capacity for bioenergy electricity production will be linked to the prospects for:

- Existing and new sawmill and pulp and paper production; and
- New initiatives in purpose grown biomass and agricultural residues/by products
  Municipal waste and utility systems.

Given Canada's biomass resources, additional capacity is likely to be primarily driven by forestry industry growth. Contributions to capacity growth from agriculture or MSW will be more modest.

Human resources issues for the development of bioenergy systems are very different from other RE systems with:

- Operating costs related to transporting biomass to sites and other site based systems issues
- Capital and installation costs more equivalent to conventional thermal systems
- Labour market issues tied to wood industry or agricultural production

4.0 TECHNOLOGY PROFILE - GEOTHERMAL

Canada's theoretical geothermal heat potential is 3.3 million EJ with a technical potential of 52 EJ/yr heat for electricity and 12 EJ/yr heat for direct utilization. The economic potential is estimated at 0.3 EJ/yr heat for electricity. Most of Canada's potential for geothermal power generation systems is in British Columbia. Currently, utilization of geothermal in Canada is primarily direct heat (8873 TJ/yr) and no electricity (IIASA, 2012).

4.1 Synopsis

Geothermal energy technology can be divided into 'geothermal electric power plants' and 'GeoExchange™ applications'. Geo-electric power plants use medium and high temperature ground heat to produce electricity. GeoExchange™ systems use lower, shallow earth temperatures ranging from near-zero, to provide heating and cooling services to buildings and processes, generally using a network of in-ground piping and heat pumps.

- The market potential for GeoExchange™ is essentially the entire Canadian heating and cooling market, and the industry has undergone significant growth since 2006.
- Canada has extensive capability and resources in medium-temperature geothermal direct use of water heat, in addition to this GeoExchange potential.
- The geothermal industry involved in direct use of water heat is small in contrast to the GeoExchange™ industry;
- Renewing Futures analysis focuses only on geothermal energy for power generation.
- The high capacity factor (regularity of supply) of geothermal power makes geothermal energy particularly attractive as a renewable base load energy supply (NRCan - Grasby et al, 2012);
- The development of geothermal energy for power generation can take place only where suitable geological conditions occur;
    - A large number of geothermal projects are under construction or in operation in Australia, the United States, Iceland, Germany and Japan,
    - CanGEA lists nine power generation and direct use projects across Canada that are in the exploration and feasibility stages[33]
    - CanGEA tracks potential geothermal applications in every Canadian province including
        - Direct use
        - Hot sedimentary aquifers (HSA)
        - Hydrothermal (conventional)
        - Enhanced geothermal systems (EGS)
        - Off shore geothermal
        - Geo-pressured geothermal
        - Co-produced geothermal (mining and oil & gas applications)
    - No sites have been developed in Canada
- LCOE and Installed Capacity costs in other countries are comparable to costs reported for wind and solar.

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[33] See Canadian geothermal power and direct use of heat technology roadmap and implementation plan., PTAC and CanGEA, Technology information Session, February 2012.

4.2 State of Maturity

There are a wide range of geothermal technologies currently across the adoption range.

Exhibit 39

State of Technology Maturity: Geothermal

Geothermal Energy			
	Mature and Currently deployed at scale	**Technologies at market entry stage**	**Future technologies**
Geothermal power plants	❖ Dry Steam Power Plant ❖ Binary Cycle Power Plant ❖ Flash Steam Power Plant	❖ Moderate Enthalpy Binary Cycle	❖ Hybrid Solar/Geothermal Plants ❖ Hot Sedimentary Aquifer Resources ❖ Enhanced Geothermal System (EGS)/Hard Dry Rock (HDR) ❖ Geopressurized Resources
Geo-Exchange applications	• Geo-exchange Residential and commercial ground-loop heat pump combinations totalling over 120,000 systems ranging in size up to 32 million square feet (3 million m^2)	Hybrid ‘renewable heat’ systems using solar thermal or biomass inputs; wastewater system heat sinks; other	• Geo-exchange ➢ Integrated community Energy Systems, closely resembling district energy systems, with multiple inputs and outputs

Mature and currently deployed technologies in the upper left section of the diagram are the most likely systems to be installed in Canada; and

- Technologies and site development are linked to drilling activity and the potential is often tied to oil and gas technology and development.

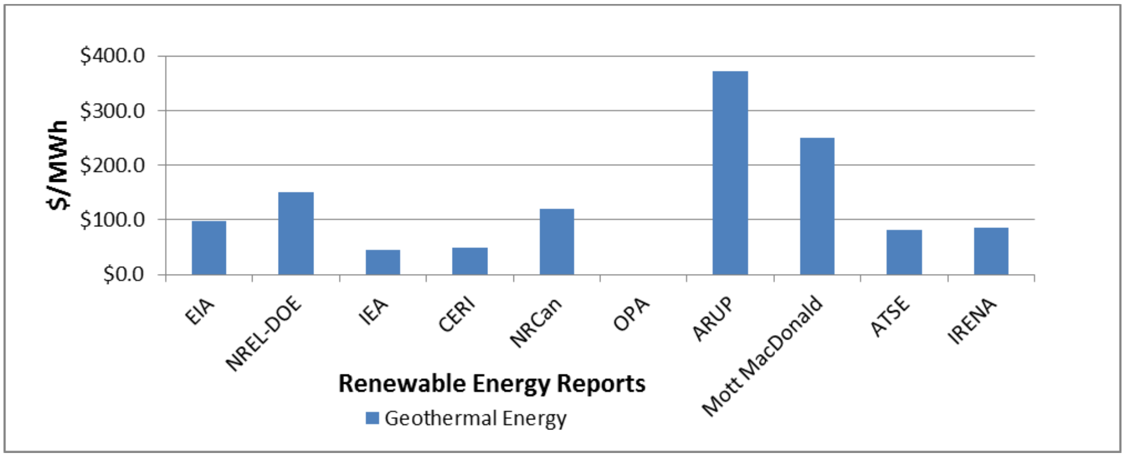
4.3 Cost and Development Trends

LCOE for geothermal applications were tracked in nine of the ten cost studies. Costs vary from $44 kWh to $372.75 /kWh;

- Costs are estimated for systems installed in 2010
- Costs are similar to biomass and to wind

Exhibit 40

Levelized Cost of Energy – Selected Studies



Cost variations in the studies are shown below and are generally wider than comparable analysis for biomass and far wider than the more established wind systems.

Exhibit 41

Levelized Cost of Energy, Range of Estimates – Selected Studies

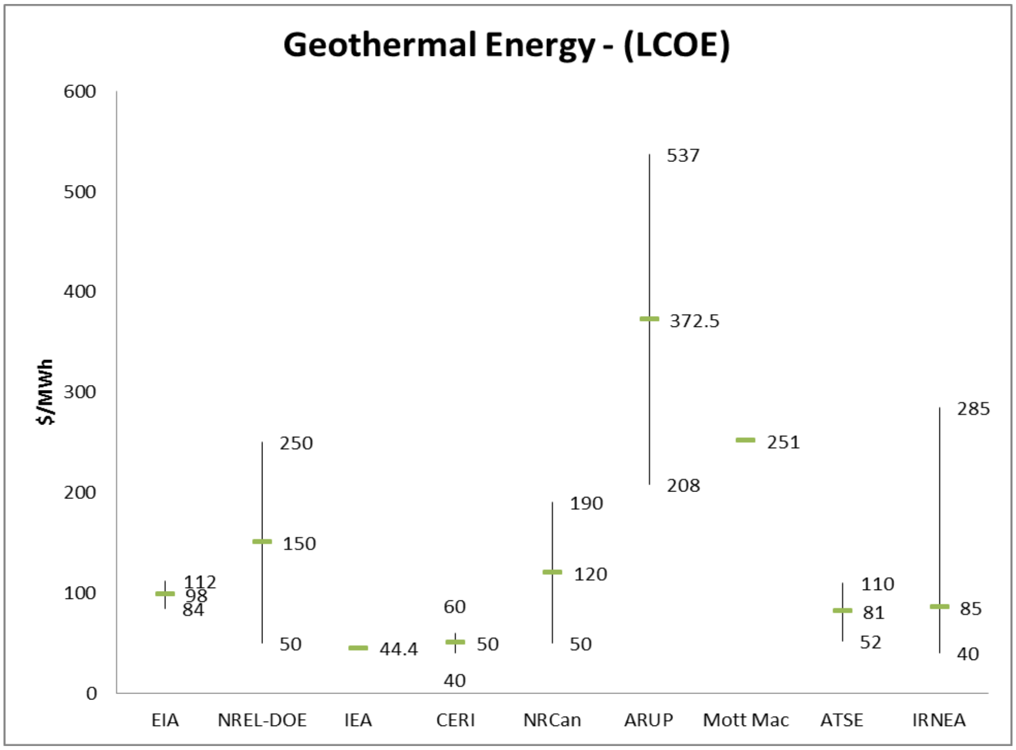
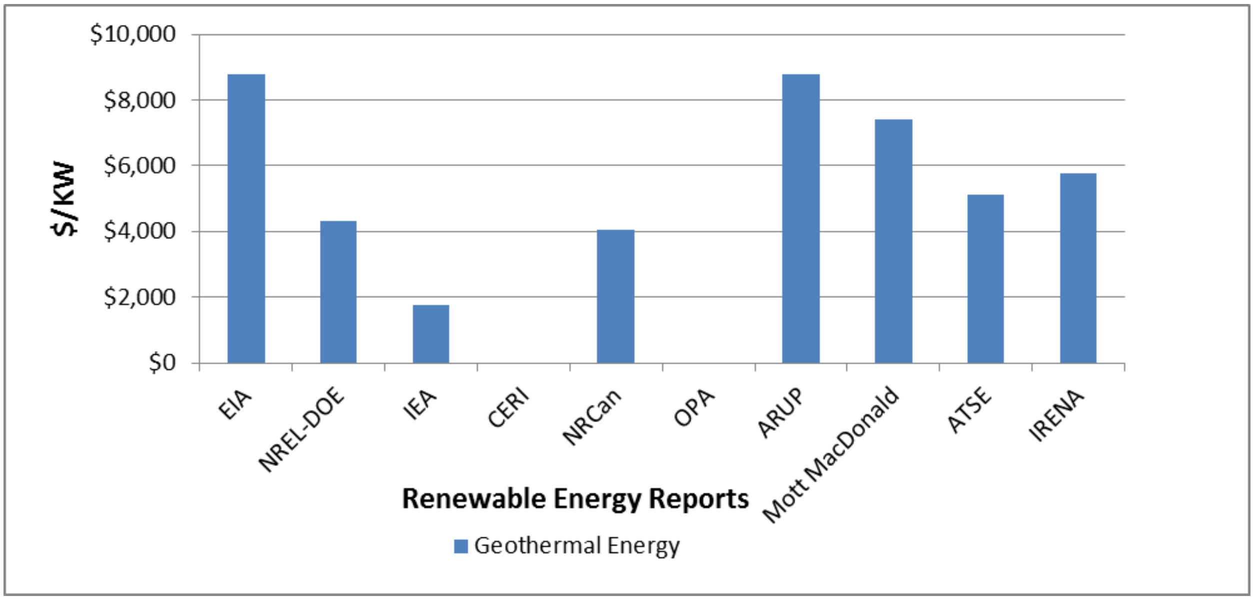


Exhibit 42

Installed Capital Costs, Selected Studies



Installed capital costs in Figure 42 are similar in level and variation to solar estimates.

4.4 Environmental Considerations

Geothermal systems have comparable records to the other RE for GHG emissions.

Exhibit 43

Gaseous emissions	Hydrothermal - flash steam, liquid dominated plant	Hydrothermal - The Geysers dry steam field	Hydrothermal - closed-loop binary plant
CO_2 (kg/MWh)	27.2	40.3	0
SO_2 (kg/MWh)	0.1588	0.000098	0
NOx (kg/MWh)	0	0.000458	0
Particulates (kg/MWh)	0	negligible	negligible

Source: Idaho National Labs (2006)

4.5 Technical and Non-technical Advantages and Challenges

The technical challenges for geothermal heating and cooling relate to

The challenges with respect to the development of geothermal power plants and their connection to the electric grid include:

- Accessing development capital;
- Stakeholders' concerns around risks and competition;
- Availability of geothermal reservoirs;
- Regulatory hurdles; and
- Economic and policy changes and their impact on feasibility.

4.6 Emerging Trends and Related Markets

Recent reports track an increase in geothermal industry growth:

- U.S. investments in geothermal energy through private investments include:
  - Public market investments including:
    - Project acquisitions; and
    - Venture capital /private equity (DOE, 2008).
- The geothermal electricity market is growing fast:
  - The European Geothermal Energy Council (EGEC) indicates a likely installed capacity of 1.5-6.0 GW in 2020, 7.0-21.0 GW by 2030 and 10-100 GW by 2050 [Bertani et al; ENER, 2011];
  - If projections are realized, 16 GW of installed capacity will be in place by 2020 [BNEF, 2011]; and
  - A global electricity capacity of 51 GW is likely in 2030 producing 380 TWh, and 150 GW producing 1,180 TWh by 2050 [Goldstein et al. 2011].

Canada has potential geothermal applications in every province.[34]

- Geothermal (conventional) potential is in British Columbia and the Yukon.
- Direct use and enhanced geothermal systems are potentially available in all provinces.
- Drilling technologies and the extensive oil and gas drilling capacity in Western Canada create significant potential for using hot water that is co-produced with oil and gas to generate electricity.
- Research and development activity related to exploration for geothermal sites and permitting and ongoing development of power sites in British Columbia, Saskatchewan and the NWT will create jobs in the future. These include:
  - Canoe Reach in B.C., Raferty Project in Sask. and the Fort Liard demonstration project in NWT.
- These projects will target electricity generation in the 1 to 3 MW range.

Implications for labour markets and human resources management

- Employment growth in geothermal power systems will be limited to research, feasibility and pilot projects with the major implications likely limited to engineering and related skills.
- There are important links between geothermal power installations and the development and operation of the mining and oil & gas industry;
- To the extent that the two industries share human resources, labour market conditions in the mining and oil & gas industry would potentially impact geothermal development and costs.
  - This will be particularly true for engineering, technical skills and trades in area related to drilling activity.

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[34] See the CanGea web site; (http://www.cangea.ca/wp-content/uploads/2013/01/CanGEA_CanadianGeothermalProjects2013.pdf p. 6).

5.0 TECHNOLOGY PROFILE – HYDRO: LARGE AND SMALL

Hydropower is the most developed and mature renewable technology globally. While large hydro systems dominate, both large and small are together the most important of the "renewables" for electrical power production worldwide. Hydropower accounts for 16% of global electricity generation and over 90% of the electricity generation from renewables. Hydroelectric power represents 60% of all electric power produced in Canada and this is the world's third largest source of hydroelectricity. Canada's hydropower maximum technical potential is 7.44 EJ (or 2066 TWh) with an economic potential at $20-80/MWh is estimated at 1.93EJ (IIASA, 2012). The Canadian Hydroelectric Association estimates current hydropower potential at 809 TWh.

The Renewing Futures initiative focuses on small hydro projects as one of the electricity related renewable energy sectors. This limited scope is intended to include the labour requirements and human resources management issues associated with many small projects and their developers. Large hydro projects are included in the overall measures of ERE but the labour market issues for this group are more similar to the circumstances of large utilities and their investments in major investment projects. As noted, large hydro makes up 60% of Canada's electric utility industry and likely dominates the labour market conditions and HR practices in the overall utility industry.[35]

- For purposes of this report, small hydropower plants are defined by an installed capacity of 1-50 MW and mini hydro power plants have a capacity between <100 KW to 1 MW (Hall et al, 2006);
- Hydropower plants can be classified in terms of their size, operating head, application and operation. There are two main types of conventional hydropower installations in Canada;
    - Reservoir: the reservoir produces electricity by using the water accumulated in a large reservoir;
    - Run-of-river uses mainly natural flow and a small head pond; and
    - One of the characteristics of hydropower installations is their volume of the live water storage;
        - Hydropower reservoirs represent the only large scale form of energy storage in electricity generation and transmission systems (grids)
        - Run-of-river projects will not hold more than several hours of water inflow; live reservoirs will hold up to several months' storage (RTA, 2010).
        - The key parameters that characterize hydropower projects are installed capacity (in MW), annual energy production (GWh) and live storage capacity (GWh). The annual energy production of a hydropower projects depends primarily on head and mean annual flow. The maximum output of hydropower facilities during peak hours is approximately equal to installed capacity.

5.1 Synthesis

- Investments of nearly $50 billion in large hydro projects are under active consideration and would add an estimated increase in generation capacity of 11,200 MW (Canadian Hydro Assoc., CIBC, 2012). Projects include:
    - Site C project on the Peace River in British Columbia (approximately 900 MW), the Waneta (435 MwW) extension and other additions in B.C.

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[35] For a more detailed discussion of labour markets and human resources management for the electric utility industry see "Power in Motion" Electricity Sector Council, 2011.

    - The Keeyask and possibly the Conawapa generating station(1168Mw) on the lower Nelson River; and
    - Gull Island and Muskrat Falls (2800 MW) on the Lower Churchill in Labrador;
        - These new projects would still only a small portion of Canada's unused hydro potential.
- Industry associations and stakeholders report several planned projects and construction on both large and small hydro in Ontario, Saskatchewan, Quebec and British Columbia

5.2 State of Maturity

The small and mini-hydro installations can be characterized by type of sites; that include low/medium/high heads and flow rate is measured in cubic feet per second (IEA, 2012). Hydro turbines can be divided into:

- Impulse turbines (Pelton & Cross-flow);
    - Uses the velocity of the water to move the runner and discharges to atmospheric pressure. An impulse turbine is generally suitable for high head, low flow applications.
- Reaction turbines, mostly for small hydro projects (Propeller, Francis, Kaplan & Kinetic).
    - Develops power from the combined action of pressure and moving water. Reaction turbines are generally used for sites with lower head and higher flows than compared with the impulse turbines (DOE, 2011).
    - Other turbine technologies include mature technologies:
        - Pelton,
        - Cross-flow,
        - Propeller,
        - Francis, and
        - Kaplan.
    - Kinetic hydro is at the R&D level (IEA, 2012).
- The hydraulic efficiency of hydropower turbines has shown a gradual increase over the years: modern equipment reaches 90% to 95% (IEA, 2012).
- NRCan mentions particular potential for new developments in very, low head turbine technology.

Exhibit 44

State of Technology Maturity – Small & Mini-Hydro

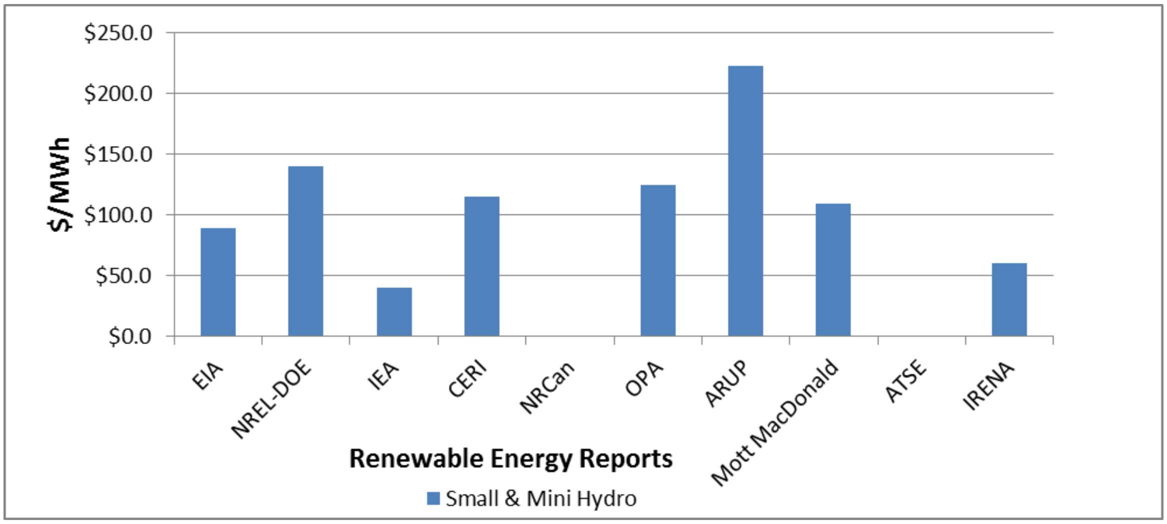
Small & Mini-Hydro			
	Mature and Currently deployed at scale	**Technologies at market entry stage**	**Future technologies**
Impulsive turbines	❖ Cross-Flow ❖ Pelton	❖ Very low head turbine	N/A
Reaction turbines	❖ Francis ❖ Propeller	N/A	❖ Hydrokinetic

5.3 Costs and Development Trends

- The cost of hydro power, large and small, varies significantly based on resource availability
- Both large and small hydro projects are characterized by high capital costs and lower operating costs;
- Where significant untapped resources remain, hydropower is still capable of providing the lowest-cost electricity of any generation type;
- Average costs for new capacity for large hydro are low and typically range between US$ 40 - 60 per MWh depending on the region (IRENA 2013);
- The cost (LCOE) for a typical small hydro power plant in 2012 is estimated within a range of $30 - $270 per MWh with a weighted average cost for OECD North America at $60 per MWh (IRENA, 2013);
- The Ontario Power Authority (OPA) evaluated the life cycle cost[36] of small and large hydroelectric between $88 per MWh to $280 per MWh and $120 per MWh to $130 per MWh respectively (OPA, 2011);
- The average LCOE evaluated by Canadian Energy Research Institute for small hydro is $115/MWh (CERI, 2006);
- Estimates of LCOE vary by plant size and cover;
    - A range of $106 per MWh to $339 per MWh for plant capacity between (0.1MW – 5MW category); and
    - $66 per MWh to $117 per MWh for the (5MW – 16MW) category (ARUP, 2011).

Exhibit 45

Levelized Cost of Energy – Selected Studies



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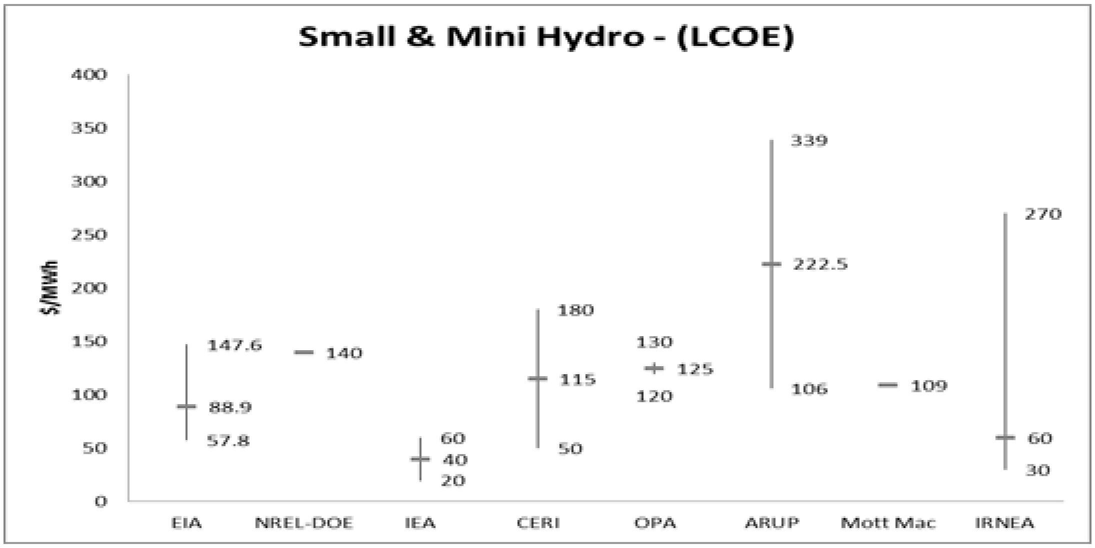
[36] Average life cycle customer cost: The whole life cycle costs that customers will incur, i.e. installation, operation, maintenance, revitalization and disposal based on the average life of the product (OUL, 2000). LCOE calculations include capital, fixed and variable operation and maintenance and transmission costs. LCOE varies with plant size, pre licensing, permitting and planning.

The range of costs is summarized in the chart below[37]:

Exhibit 46

Levelized Cost of Energy, Range of Estimates – Selected Studies



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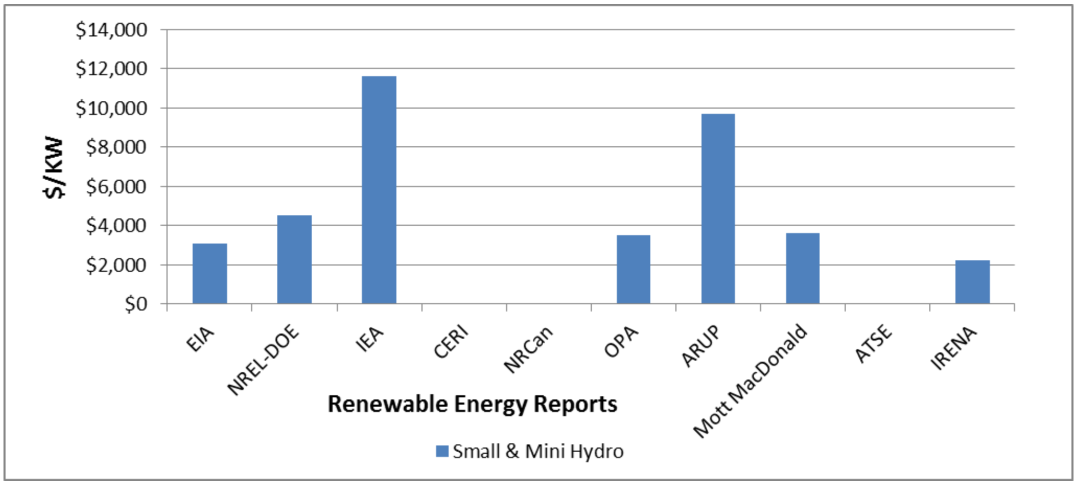
[37] For small hydro, the typical investment cost ranges from \$2,000 to \$5,000 per installed kW (OPA 2011). According to the U.S EIA, the overnight capital cost of conventional hydropower is \$3,078 per KW in the year 2011, an increase of 32% from 2010 (EIA, 2010). The IRENA (2013) reports a range of \$ 1000 - \$3500 per kW of installed capacity in contrast to an average installed capital cost of a typical hydro run-of-river plant is \$3,634/KW (Mott MacDonald, 2011). The NREL-DOE estimated the installed cost of small and mini hydro at \$4,500/KW (NREL-DOE, 2011). The total installed cost determined by International Energy Agency for small & mini hydro is \$11,600/KW (IEA, 2010).

Exhibit 47

Installed Capital Costs of Small & Mini Hydro, Selected Studies



- For hydro projects, pre-licensing and planning are an important component of the cost and variations in cost are related to the complexity of permitting for a specific site;
- Project scale is also a key factor;
- The capital cost of hydropower plant varies by size;
    - Smaller than <1 MW is within a range of $4,400 per kW to $15,000 per kW;
    - Between 1MW – 5MW range, the cost range is $3800 - 7,800 per kW; and
    - >5 MW, the cost range is between $2300 - $4,500 per kW (ARUP, 2011).

Large and small hydro technologies are mature and there are no projections of declining costs comparable to the other RE technologies:

- ATSE projected an increase of 2%-5% in the capital cost and 1%-3% increase in the LCOE for hydropower plants between the capacity of less than 1 MW – 6MW by 2030 (ATSE, 2011);
    - For the year 2020, the LCOE is assessed to be between $107 per MWh to $343 per MWh (hydro capacity of >1MW – 5MW); and
    - $66 per MWh to $118 per MWh (for capacity in the 5MW – 16MW range).

5.4 Environmental Considerations

Hydropower's (large and small) GHG emissions are low, and mainly related to the construction phase and flooding of the reservoirs. Hydropower's GHG emissions factor (4 to 18 grams CO_2 equivalent per kilowatt-hour is 36 to 167 times lower than the emissions produced by electricity generation from fossil fuels) (C2ES, 2011). See WEC (2004) life cycle emissions report for details.

The main GHGs produced in freshwater systems are CO_2 and methane (CH_4). Nitrous oxide (N_2O) may be of importance, particularly in reservoirs with large drawdown zones or in tropical areas, but no global estimate of these emissions presently exists. Results from reservoirs in boreal environments indicate a low quantity of N_2O emissions, while a recent study of tropical reservoirs does not give clear evidence of whether tropical reservoirs act as sources of N_2O to the atmosphere (Guerin et al., 2008).

Environmental and social issues surrounding hydropower development are related to reservoir creation and land use and possible effects that can range from changes in fish biodiversity to the sediment load of the river. Hydropower projects are subject to rigorous environmental assessment and review under provincial and/or provincial regulations.

Technical and Non-Technical Advantages and Challenges

The challenges include:

- Agreement with local communities including Aboriginal communities,
- Environmental mitigation measures and water rights and rights of way,
- Lack of tariffs for micro-hydro; higher costs in regards to transmission and interconnection,
- Challenges with respect to mitigation and compensation measures to improve acceptability,
- Long lead times related to project design, planning and approval process, and securing financing, and
- Access to transmission for dispersed resources.

In Canada, hydropower projects are subject to thorough consultations of local communities and First Nations and aboriginal communities are now frequently involved in the planning and implementation of projects. In some case they enter into partnership agreements with utilities.

5.5 Emerging Trends

With less than one-quarter of the world's technical hydropower potential in operation, the prospects for growth in hydro capacity are excellent. Emerging economies in Asia (led by China) and Latin America (led by Brazil) have become key markets for hydropower development, accounting for an estimated 60 % of global activity (IHA, 2011). OECD economies in North America and Europe are focusing on the modernization of existing facilities, often leading to increased capacity or generation capability, as well as new pumped storage facilities. However, outside Canada, new Greenfield capacity is being added in relatively modest quantities (IRENA, 2012).

Small hydro projects may have a bigger role outside of Canada. The European Commission's Renewable Energy Roadmap identifies small hydro power as an important ingredient in the EU's future energy mix. A 2010 report from the International Energy Agency (IEA) projected that global hydropower production might grow by nearly 75% from 2007 to 2050 under a business-as-usual scenario, but that it could grow by roughly 85% over the same period in a scenario with aggressive action to reduce GHG emissions (IEA, 2010; IRENA, 2013).

In Canada, hydropower is growing and significant investments are made or planned in all categories: large greenfield projects, refurbishments and small projects. However, there may be signs of limits to market growth for small hydro reported in the Market Assessment section. Newfoundland and Labrador has a moratorium on small hydro and there are several provinces where there are no formal plans for small hydro development. The scenarios include the plans for the major large hydro projects described above. Indeed, the "Powering the Future" report from 2010 included these projects and considered the labour market impacts.

Implications for Labour Markets and Human Resources Management

Small hydro ERE developments are known to place specific challenges for some skills and occupations:

- There is a reported shortage of power engineers and specialized civil or electrical engineers and management skilled at regulatory approvals.
- Design and installation of small hydro is more labour intensive than other RE developments and relies on:
    - Specialty concrete formwork and related skills, and
    - Project management and supervisory skills in remote locations.

6.0 TECHNOLOGY PROFILE - TIDAL AND WAVE ENERGY

Marine renewable energy resources include the kinetic energy carried by waves, currents and tides as well as the energy stored in the ocean's thermal and salinity differences (OTEC). Canada's potential tidal energy exceeds 42 GW; there have been 190 suitable sites identified, with BC having the most sites and Nunavut the greatest total potential. The Bay of Fundy, between New Brunswick and Nova Scotia, is Canada's most promising location for tidal power development. Each day, volumes of water in excess of 160 billion tons flow into the bay; more than all the world's freshwater rivers combined (University of Victoria, 2012).

6.1 Synopsis

- Advances in Tidal and Wave technologies are in the market entry and demonstration phase with a few demonstration plants;
- Cost estimates are highly variable but suggest that tidal and wave LCOE and installed costs can be comparable to other RE options;
- Canada has significant potential on the East and West Coasts. The Canadian Marine Renewable Energy Technology Road Map has set a target for Canadian industry to be involved in the installation and servicing of 2,000 MW of marine renewable energy by 2030;
- The Province of Nova Scotia is providing leadership in tidal energy development;
- Research anticipates a significant decline in costs over the next 20 to 30 years;
- While GHG emissions are minimal during operations, the proposed deployment of these technologies will generate emissions during construction and installation processes; and
- Support for Tidal and Wave technologies has promoted demonstration projects and private businesses in Atlantic Canada and British Columbia.

6.2 State of Technology Maturity

The tidal and wave energy technologies are in the R&D and demonstration stages[38]:

- Several companies are developing competing designs;
- Current and recent demonstration projects are testing the operational capabilities of the turbine designs as well as the environmental impacts (Navigant Consulting, 2007);
- The wave and tidal technologies are yet to be commercialized; and
- Investment and R&D is still required to develop commercial technology and the infrastructure to aid deployment (ARUP, 2011).

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[38] For Technology Descriptions, see Technology Profiles –Tidal and Wave Energy Appendix 6.

Exhibit 48

State of Technology Maturity - Marine

Marine (Tidal & Wave Energy)			
	Mature and Currently deployed at scale	**Technologies at market entry stage**	**Future technologies**
Marine	N/A	• Tidal Range ❖ Lagoons ❖ Wings ❖ Dams	❖ Ocean Energy Technology (OET) ❖ Ocean Thermal Energy Conversion (OTEC) Systems ❖ Tidal In-Stream Energy Conversion (TISEC) Systems ❖ Wave Energy Conversion (WEC) Systems ❖ In-Stream Hydro-Kinetic Technology

The market adoption cycle for these technologies is revolving around concept, testing, and pre-commercial phases. Tidal barrage systems have been well developed and act much like a conventional dam.

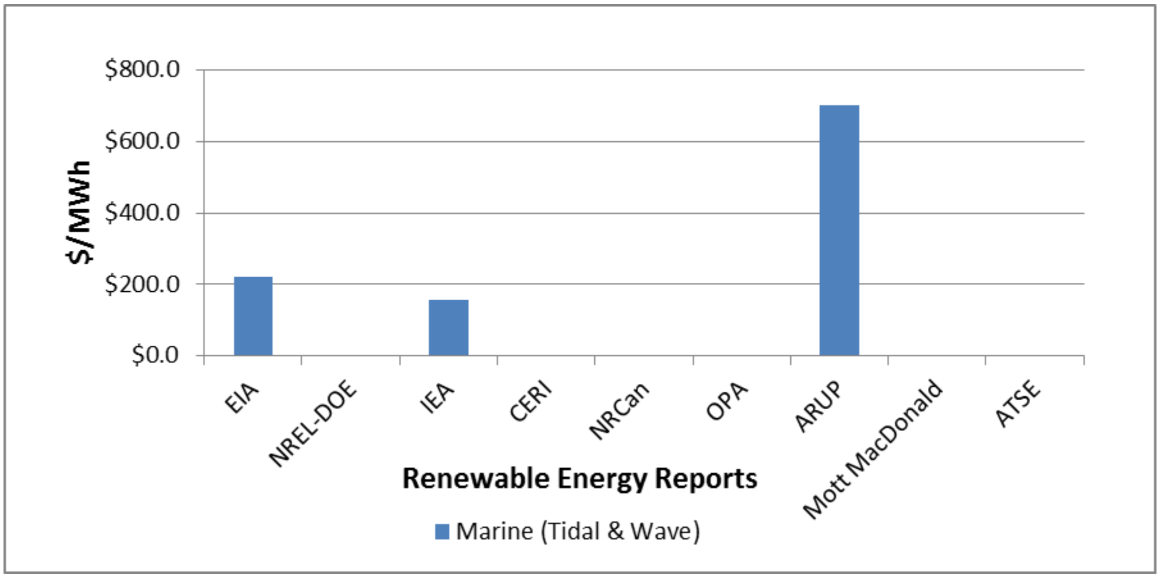
- They are currently operational in four nations:
    - Shikwa Lake Tidal Power Plant is the largest tidal barrage system with a capacity of 254 MW in South Korea (Newsworld, 2003);
    - La Rance near St. Malo in France, with a generating capacity of 240 MW on the incoming and outgoing tide;
    - Russia on the White Sea, with a capacity of 0.5 MW; and
    - Annapolis, Nova Scotia, capacity of 20 MW and an annual energy production of 50 GWh (Nova Scotia Tourism & Culture, 2002).

6.3 iii. Costs and Development Trends

Cost estimates vary widely given the range of technologies being developed and the variety of potential locations. Only three of the ten studies that have been reporting costs cover marine / tidal.

Exhibit 49

Levelized Cost of Marine Energy – Selected Studies

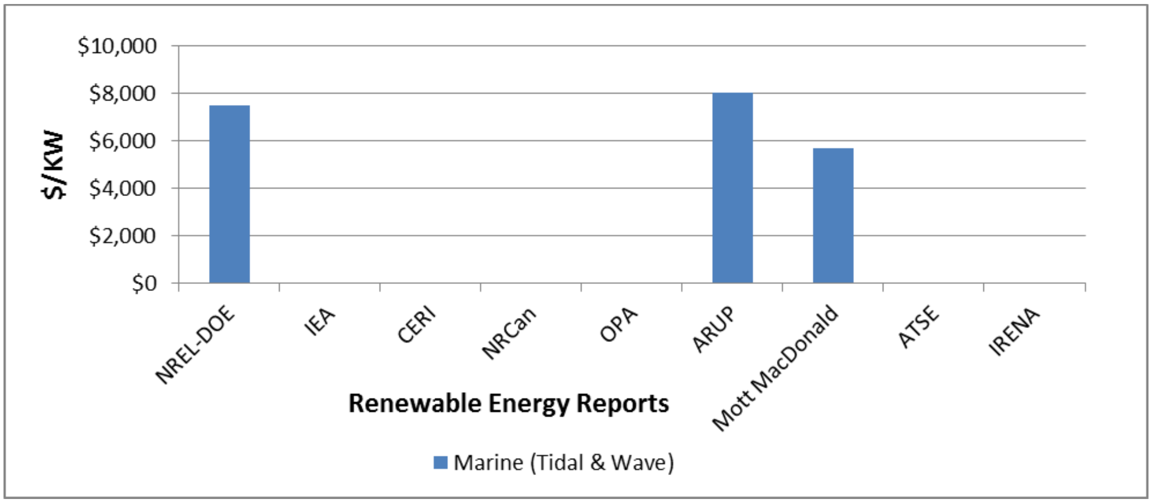


Installed Costs are highly variable and depend on various factors including:

- Turbine technology;
- Distance off shore;
- Scale of installation (MWs);
- Fixed and floating wave devices;
- Depth of system; and
- Wave versus tidal systems.

Exhibit 50

Installed Capital Costs of Marine Energy, Selected Studies



Estimates in the above graph are the mid-point of a range that spans different system options:

- Mott McDonald predicted the installed capital cost of tidal energy within a range of $2,206/KW to $6,932/KW and $1,969/KW to $6,286/KW for stream energy. Average installed costs of various tidal & wave technologies are calculated to be $5,688/KW (Mott MacDonald, 2011). The NREL-DOE estimated the installed cost of tidal and wave energy within a range of $4,500/KW-$10,510/KW (NREL-DOE, 2011); and
- The ARUP, 2011 report suggested the capital cost of deploying a prototype at a pre-demonstration stage within a range of:
    - $11,800/KW to $19,500/KW for (shallow) tidal stream devices
    - $9,600/KW to $13,500/KW for wave devices
    - $3,200/KW and $5,400/KW for tidal energy and
    - $6,600/KW to $12,900/KW for wave energy (ARUP, 2011).

The ARUP report predicted a range for LCOE of:

- $309/MWh to $413/MWh for tidal stream projects in 2020, dropping to $235/MWh to $309/MWh for tidal in 2030; and
- $328/MWh to $419/MWh for wave energy projects in the year of 2020, dropping to $205/MWh to $257/MWh for stream energy projects in 2030 (ARUP, 2011).

Mott McDonald projected the LCOE for:

- Tidal stream technology in a range of $110/MWh to $540/MWh and $100/MWh in 2030 dropping to $500/MWh in 2040;
- Wave technology in a range of $130/MWh to $670/MWh for 2030 and $110 /MWh to $600MKWh for 2040; and
- A scenario for deploying devices with 70MW of tidal capacity in the UK and 30MW elsewhere in the world anticipates an overall cost reduction of around 39% equates to a cost of energy for the leading tidal devices in 2020 of around $280/MWh–$310/MWh (Carbon Trust, 2011).

6.4 Environmental Considerations

Technologies to harness tidal and wave energy employ very different systems and these have distinct environmental impacts. In stream tidal and wave technologies are the newer, pre-commercial technologies and these are being assessed worldwide and at FORCE in Nova Scotia. Barrage / dam (tidal range technologies) have been shown to have negative environmental impacts and are not being promoted in Canada. These impacts are summarized below:

Exhibit 51

Tidal Range Technology - Environmental Performance

Severn Barrage project (University of Victoria, 2012)	CO2 emissions (kilotonne)
Manufacture + quarrying	4,741
Transport	695.5
Construction	1,500
Total	6,936.50

6.5 Technical and Non-Technical Advantages and Challenges reflect the location and the relatively new and developed nature of the systems:

- Grid connection;
- Lack of performance assessment standards;
- Long development timescales, high cost and effective technology development paths;
- Limited locations and regional limitations;
- Effects on marine life/ecosystem; and
- Lack of sector specific legislation and permitting paths

Advantages reflect the natural abundance and power of tidal and wave forces in Canada:

- Predictability of the resource timing (e.g. tidal flows);
- Many Canadian innovations and trial technologies with development potential;
- The Federal Government and the Governments of Quebec and Nova Scotia are funding research and development of tidal and wave systems including river current energy.

6.6 Emerging Trends and Related Markets

Growth of marine renewables depends on several factors including:

- Regulatory certainty,
- Reduction of risks,
- Public support / social license,
- A capable supply chain, and
- a willingness to finance;
- Technology development including:
    - Academic and industrial R&D, engineering design and prototype testing.
- Project development including:
    - R&D grants, venture capital and possibly strategic investments to support technology development companies in engineering design and prototype testing; and
- A few developers of more advanced concepts are now seeking to develop initial farms (Carbon Trust, 2006).

Canadian companies involved in tidal and water current energy conversion technologies: Blue Energy International, Clean Current Power Systems, Mavi Innovations, New Energy Corporation, Verdant Power, and Water Wall Turbines (For details see: Natural Resources Canada, 2010).

Implications for Labour Markets and Human Resources

Jobs and economic activity will be limited to engineering and project management work in the early stages of the supply chain from 2013 to 2022 including

- Research and Design:
    - Analysis and testing
    - Prototypes
    - Investment plans
- Feasibility Analysis
    - Engineering research
    - Cost analysis
    - Risk analysis
- Planning
    - Project planning
    - Permits
    - Insurance
    - Finance
    - Legal
- Design
    - Project design
    - Off shore design
    - Mechanical systems
    - Electrical systems
    - Civil and structural design
    - Control systems

Conclusions and Labour Market Implications

Findings reported in the Technology Review set out four features for each of the technologies that will be carried forward to the rest of the analysis. These include:

1. The projected additions (in MWs) to installed capacity for each sector, province, scenario and year to 2022,
2. The mature, and currently deployed at scale, technologies that will be installed,
3. Likely costs for new installed capacity and the conditions that define these costs, and
4. Labour related risks and implications in each market for human resource management.

Scenarios reveal a wide range of potential outcomes and attention focuses on the “Vision” scenario as it reflects the biggest investments in ERE and the largest increases in employment. Very few new technologies are identified in the analysis; leaving the projected new installations using established products and processes in most cases. However, some changes are apparent and will have an impact on labour requirements including the use of larger wind turbines and related structures, the potential for very low head hydro turbines and the potential for new storage and interconnection processes for local utilities. The wide range of possible costs ($ / MW) for installed capacity (with the possible exception of wind projects) imply an associated range of installation and operating conditions that will impact labour skills and costs. These variable and critical conditions imply HR management risks that must be carefully described in the next stage of the research.

The next step in the Renewing Futures process is to link the projected levels of installed capacity to estimates of employment by occupation, province and technology across the forecast horizon to 2022. These estimates will be linked, in turn, to a labour market model that tracks market conditions for the priority ERE occupations. Supply / demand balances, skill requirements, training and certifications and demographic analysis of retirements and entrants will all be linked to these findings.

These analytical findings will be complemented with the results of an employer survey that has probed the details of HR measures and management issues for the industry. Findings will provide detailed implications for issues like recruiting, training, compensation and staff retention.

At each stage of this process the analysis will remain grounded in the content of this Technology Review and follow the initial measures of market development and process installation set out for each scenario. Findings will set out a range of outcomes and HR implications that capture the risks and opportunities for Canada’s RE workforce.

Glossary

ARUP: An independent firm of designers, planners, engineers, consultants and technical specialists offering a broad range of professional services (ARUP, 2012).

ATSE: Australian Academy of Technological Sciences and Engineering

Average life cycle customer cost: The whole life cycle costs that customers will incur, i.e. installation, operation, maintenance, revitalization and disposal based on the average life of the product (OUL, 2000).

Balance of System (BOS): It consists of wires, switches, batteries and inverters when you are dealing with off-grid technology. Depending on your application, you will need additional equipment and materials to provide electricity at the required voltage and current. This equipment is referred to as the Balance of System (BOS) (Natural Resources Canada, 2003).

Binary cycle technologies: It refers to one of the kinds of geothermal electric power generating system which pass moderately hot geothermal water by a secondary fluid with a much lower boiling point than water. This causes the secondary fluid to flash to vapour, which then drives the turbines (hot water fields) (Grasby et al, 2012).

Compressed Air Energy Storage (CAES): It is a commercially available, utility scale, bulk electricity storage technology that uses high-pressure air as a storage medium. Large-scale, airtight storage volumes can be developed in geologic formations such as underground salt domes and saline aquifers. In conventional “diabatic” CAES, stored compressed air is released through a modified gas turbine, requiring the use of natural gas, making CAES a hybrid storage/generation technology. CAES is typically considered to have the lowest capital cost of any bulk electricity storage technology (Parfomak, 2012)

CAGR: Compound Annual Growth Rate

CHP: Combined Heat and Power (a.k.a. Co-generation)

Crystalline silicon: Crystalline silicon cells are made of silicon atoms connected to one another to form a crystal lattice. This lattice comprises the solid material that forms the photovoltaic (PV) cell's semiconductors (DOE, 2011).

- **Mono-silicon**: It is made up by a single crystal of silicon.
- **Poly-silicon**: It is produced by multiple crystals of silicon.

Dispatchable Generation & Non-Dispatchable Generation: The dispatchable generating technologies are the ones that can be controlled by the system operator and can be turned on and off based primarily on their economic attractiveness at every point in time both to supply energy and to supply network reliability services (e.g. frequency regulation, spinning reserves). Examples include: CCGT, coal, nuclear. On the other hand non-dispatchable (a.k.a. Intermittent) generating technologies cannot be controlled or economically dispatched by system operators based on traditional economic criteria. Examples include: wind, solar etc. (Joskow, 2010).

DOE: Department of Energy

EGS: Enhance Geothermal System

EIA: Energy Information Administration

Enthalpy hydrothermal resources: It refers to the geothermal resources beneath the Earth’s surface. The temperature of these resources ranges between 50^{0}C to 250^{0}C plus.

EJ: Exajoule

Feed-In Tariffs: It allows homeowners, business owners and private developers to generate renewable energy and sell it to the province at a guaranteed price for a fixed contract term. It helps to accelerate the investment in renewable energy (Ministry of Energy, 2013).

Flash Steam plants: They pull deep, high-pressure hot water into lower-pressure tanks and use the resulting flashed steam to drive turbines (wet stream fields) in a geothermal electric power generating system (Grasby et al, 2012).

HDR: Hard Dry Rock

Hydrolysis: A chemical reaction in which water is added to a substance usually salt resulting into the split of a compound.

IEA: International Energy Agency

IHS EER: It refers to the HIS Emerging Energy Research institute. They offer advice, and support to the global renewable power industry (IHS EER, 2013).

INSEAD: It is the world’s leading and largest graduate business school (INSEAD, 2013).

KW: Kilowatt

KWh: Kilowatt-Hour

LCOE: Levelized cost of energy

Life Cycle Analysis: It involves cradle-to-grave analyses of production systems and provides comprehensive evaluations of all upstream and downstream energy inputs and multimedia environmental emissions. The "life-cycle analysis" impacts include the extraction of raw materials; the processing, manufacturing, and fabrication of the product; the transportation or distribution of the product to the consumer; the use of the product by the consumer; and the disposal or recovery of the product after its useful life (Srinivas, 2012).

Lignocellulose: It is a plant dry matter and used for the production of bio-ethanol.

Market Penetration: It refers to the deployment of existing product in existing market.

MW: Megawatt

MWh: Megawatt-Hour

NR Can: Natural Resources Canada

NREL: National Renewable Energy Laboratory

OPA: Ontario Power Authority

Pumped Hydro Storage (PHS): It stores energy by pumping water from a lower-level reservoir (e.g., a lake or river) to a higher-elevation reservoir via an underground tunnel. During periods of high electricity demand, the water is released to the lower reservoir to turn turbines to generate electricity, similar to the way in which conventional hydropower plants generate electricity. Many existing PHS plants store eight hours or more of energy, making them useful for load leveling, and providing firm capacity. PHS can also ramp rapidly, making it useful for load following and providing ancillary services including contingency spinning reserves and frequency regulation (Parfomak, 2012).

Smart Grid: A class of technology people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way communication technology and computer processing that has been used for decades in other industries. They are beginning to be used on electricity networks, from the power plants and wind farms all the way to the consumers of electricity in homes and businesses. They offer many benefits to utilities and consumers -- mostly seen in big improvements in energy efficiency on the electricity grid and in the energy users' homes and offices (DOE, 2012).

Solar PV: It refers to the solar photovoltaic technology. A photovoltaic (PV), or solar electric system, is made up of several photovoltaic solar cells in which are made of semi-conducting materials which produce direct current electricity when exposed to sunlight. Photovoltaic (PV) cells, or solar cells, take advantage of the photoelectric effect to produce electricity. PV cells are the building blocks of all PV systems because they are the devices that convert sunlight to electricity (DOE, 2011).

Solar Thermal: It usually refers to the solar heating systems. Solar thermal technologies provide electricity, hot water, space heating, and lighting. The solar water heating is the least expensive form of solar energy—and can even work in tandem with conventional energy sources to improve the flexibility and reliability of the electricity they produce. Solar thermal technologies employ a variety of methods to convert sunlight into useful energy (DOE, 2006)

State of Maturity: It refers to the penetration level of a product/service in the market adoption cycle.

- *Research and Development (R&D)*: The technology is in research & development phase.
- *Demonstration*: The technology is at the experimental/pilot phase.
- *Market entry*: The technology is ready to be deployed in the market
- *Matured*: The technology is matured and about to enter in the aging phase

Thin film solar cells: It is created by placing a single or multiple thin layers of photovoltaic material on a substrate.

UBS: An investment bank which provides clients with expert advice, innovative solutions, outstanding execution and comprehensive access to the world's capital markets (UBS, 2013).

Appendix A

Technology Profile – Integration and Storage

This technology profile addresses the links between the electricity related renewable energy sectors discussed above and the conventional electricity industry. These links and the technologies that are changing them are a critical part of the deployment of RE systems. Improvements in the infrastructure and utility systems that deliver the electricity to customers are needed for RE systems to continue to grow. The conventional systems themselves require large investments to refurbish existing generating and transmission systems as well as expanding capacity. These changes have been unfolding on a very large scale since the mid-2000s and large investments will continue past 2022. There are important labour market issues that are directly related to these changes and these matters, in turn, link to the expansion and the labour issues of the RE sectors.

Integration of the ERE systems to the grid and to customers is about the ability of the grid to cope with the intermittency and variability of some renewable energy sources. Integration can be divided into three parts. First, *connection* refers to joining power generated by the ERE facility to the grid. Second, *smart grid* technology refers to the broader capacity of the utility, system managers and users to manage the short term and long term patterns of generation and consumption and to improve the efficiency of the entire system. Third, *storage* refers to the capacity of either the RE provider or the utility to store electricity and to balance the availability of supply from the generation system to the demands of the grid and customers.

Separate employment implications are apparent for each of these three parts and for the RE providers and utilities and system managers. Labour market impacts and human resource management implications in each of these situations will be a part of the next report. This section presents technology profiles for each part.

A.1 Connection

The first step in the connection of a RE power system to the grid is at the substation where each new RE generation system connects to the local electricity distributor. Work involved in making this connection is directly related to adding new ERE capacity and falls within the scope of the Renewing Futures study. The technology review and the stakeholder interview process have identified both traditional substation systems and new, prefabricated equipment at this point. Further, the employers and workforce engaged to perform this work are likely electrical subcontractors, power line specialists and / or employees of the local electrical distributor. The extent to which prefabricated, automated substations and related technologies are available at this point in the integration will have an impact on the more highly skilled and qualified workforce needed.

The extent of growing demand for new ERE capacity and the related requirements to install collector substations will combine with one clear and widespread labour market issue in the conventional utility industry. Shortages of power line technicians, and related occupations, have been reported in most provinces and extensive investments in training and certification have been needed to upgrade skills and address these needs. The primary cause for these labour requirements is the extensive need to refurbish and replace aging distribution and transmission systems. While these needs are already very large, they are now further complicated by the added demands for including new Smart Grid related technologies, including monitors, storage, feeder systems and other additions. This work is needed to both improve the efficiency of the existing grid and to allow the addition of new distributed generation from RE systems.

These integration issues will form a part of the labour markets and human resources analysis in the next report.

A.2 Smart Grid

A smart grid is a modern electric system that uses communications, sensors, automation and computers to improve the flexibility, security, reliability, efficiency, and safety of the electricity system. It offers consumers increased choice by facilitating opportunities to control their electricity use and respond to electricity price changes by adjusting their consumption. A smart grid includes diverse and dispersed energy resources and accommodates electric vehicle charging. It facilitates connection and integrated operation. Smart Grid technology spans the electricity system bringing production, delivery and consumption closer together to improve the overall system operation for the benefit of consumers and the environment (IESO, 2009).

A.2.1 State of Technology Maturity

Analysis of human resources in the Renewing Futures research will refer to Smart Grid technologies where they are directly related to RE systems. Much of the focus on Smart Grid systems, at the present time, is on electricity consumers and the advantages of smart metering to manage use. These user oriented technologies are currently mature and being deployed by utilities across Canada. The application of Smart Grid technologies by distributors and their relationship to RE connections is not so well defined or advanced. But this is the primary point of interest for Renewing Futures and these advances are at an earlier stage of deployment or at the market entry stage.

The IEA (2010) has identified five smart grid-specific drivers:

- Demand increase;
- Penetration of electric vehicles (EVs) and plug-in hybrid vehicles (PHEVs);
- Deployment of variable renewable energy sources;
- Peak load increase; and
- Ageing infrastructure.

Smart grid technologies offer affordable and sustainable improvements to adapt to these drivers. Smart grids:

- Enable informed participation by customers;
- Accommodate all generation and storage options (including variable renewable energy);
- Enable new products, services and markets (for example demand response);
- Provide the power quality for a range of needs;
- Optimise asset utilisation and operating efficiency; and
- Provide timely feedback for outage management during disturbances and weather related natural disasters.

Smart Grids assist system stakeholders and empower:

- Allow customers to adjust demand in response to price information and load control through smart meters, real time feedback devices for in home displays and time-of-use rates for energy conservation;
- Enable utility practices, distribution grid management including automation for fault detection, isolation and restoration of the Feeder/Distribution system, and Substation Automation and control systems to enable increased use of renewable energy sources effective integration of customer based micro generation to the distribution network; and
- Adaptive infrastructure to accommodate use of innovative and energy saving technologies and system control application such as smart mobile charging infrastructure to support electric vehicles and storage technologies.

A smart grid has the analytic infrastructure, processes and trained individuals necessary to integrate and act on information in the very short time frames required by the electricity system. It is characterized by clear standards, security protection and open architecture that allows for continued innovation through the development and deployment of new technologies and applications by multiple suppliers (IESO 2011)

The IEA Smart Grid Technology Roadmap (April 2011) provides a complete description of smart grid technology and policy. The roadmap stresses the need for more regional analysis of electricity systems. The importance of storage is highlighted in the study on prospects for large-scale storage in decarbonised power grids (IEA, 2009b) and modelled load shifting using electric vehicles in a smart grid environment (IEA, 2010b).

A.3 Energy Storage

Energy storage systems improve the ability of renewable energy resources to provide power when required.

- Energy storage can capture surplus generation during low demand periods and shift output to meet peak demand;
- Energy storage and ancillary services requirements on the grid vary considerably;
- The technical capability of the storage system's discharge time determines whether it is appropriate for large scale or small scale applications; and
- For large scale intermittent renewable generation, the storage requirements are in the MWh scale and for small scale distributed renewable resources, the storage systems are in the order of 1 to 100kWh.

With increasing penetration of solar and wind generation on the grid, cost-effective storage becomes an important technology for managing variability of output.

A good use of storage for electricity end-users is to mitigate power quality or reliability problems which affect sensitive equipment. Storage devices can thus play a key role in enabling a larger share of renewable generation to be incorporated into the grid by allowing a greater degree of flexibility to the system operator in balancing load and supply.

A.3.1 State of Technology Maturity

The energy storage technologies are at several stages of adoption cycle[39]. The choice of the ideal storage technology to be used depends on a number of factors. These are, among others, the amount of energy or power to be stored, the time for which this stored energy is required to be retained or to be released, spacing and environmental constraints, cost, and the exact location of the network on which the storage is required (Hadjipaschalis et al, 2009).

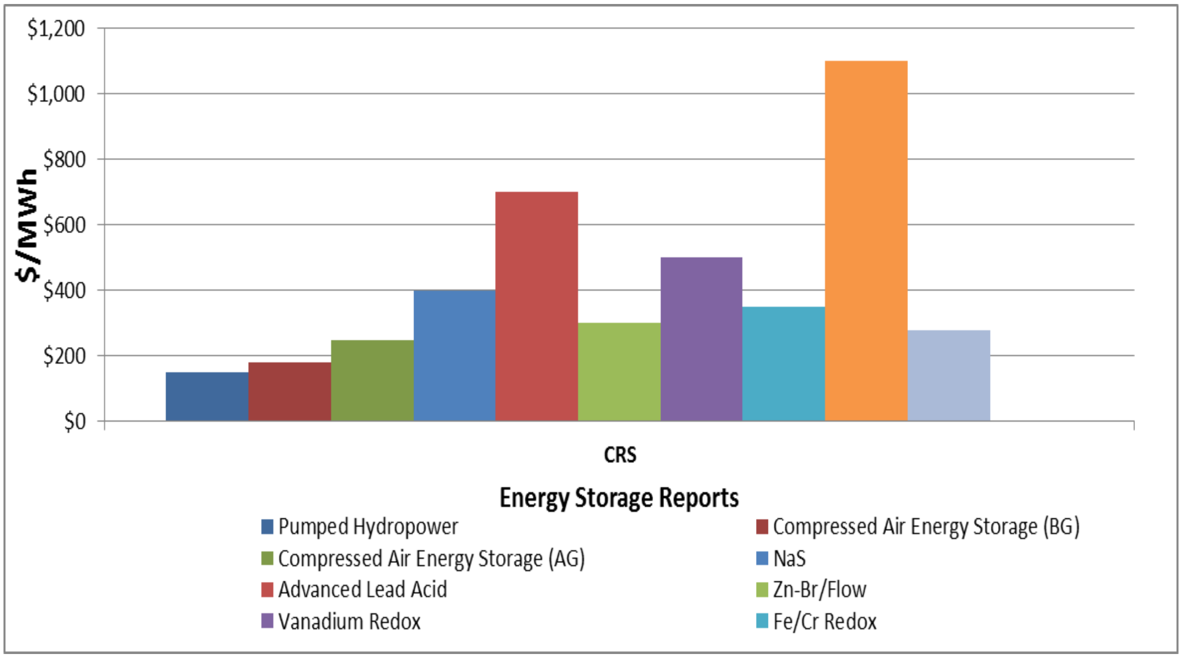
Energy storage technologies for electric applications have achieved various levels of technical and economic maturity in the marketplace. A low level of deployment of grid storage technologies is due to high capital costs and the existing market structures in the electric sector that tend to undervalue the many services that electricity storage can provide (Parfomak, 2012).

A.3.2 Costs

The LCOE for various energy storage technologies are shown in the chart below:

Exhibit 3

Levelized Cost of Energy (LCOE) of Energy Storage Technologies



Source: Parfomak (2012)

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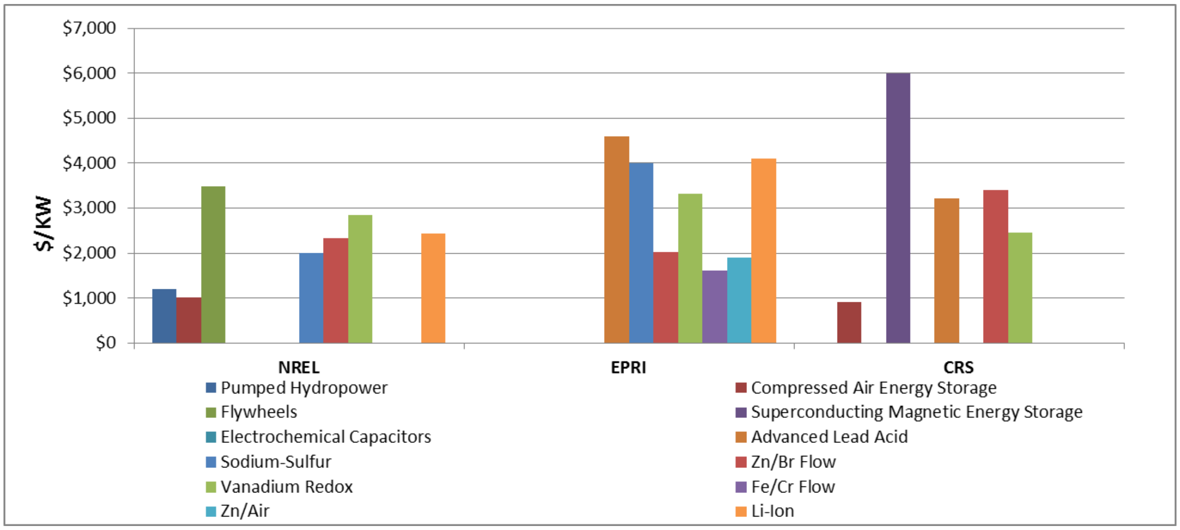
[39] For Technology Descriptions, see Technology Profiles –Energy Storage Appendix 7.

Exhibit 4

Installed Capital Cost of Energy Storage Technologies



Source: Parfomak (2012), NREL (2011)

The component cost of a conventional Compressed Air Energy Storage (CAES) system deployed in a salt cavern is estimated to be $774/KW whereas the capital cost of a conventional CAES is within a range of $600/KW to $1,200/KW (Parfomak, 2012). However, the installed capital cost of a pumped hydro is estimated to be around $1,190/KW (NREL, 2011).

Cost projections for flywheels for 120 MW/5 MWh frequency regulation plant is evaluated to be around $3,490/KW (NREL, 2011). In contrast, the capital cost of Superconducting Magnetic Energy Storage (SMES) is around $6,000/KW for 30 second of energy storage (Parfomak, 2012). The cost per unit power of electrochemical capacitors is appraised within a range of $25KW - $50/KW (Parfomak, 2012).

A.3.3 Environmental Considerations

The impacts of energy storage are a function of two components. First is the localized impact due to development and direct use of the individual energy storage technologies. These vary significantly given the large differences in technology types. The second is associated with the upstream source of electricity, and the increased generation typically required due to inefficiencies in the storage process. The environmental impact is mainly related to the land use, water use, and life cycle GHG emissions (Augustine et al, 2012).

The net/life cycle GHG emissions of pumped hydro storage, compressed air energy storage (CAES), lead acid and vanadium redox batteries in regards to construction phase are shown below: Emissions for energy stored in Flywheels, Superconducting Magnetic Energy Storage (SMES), and Electrochemical Capacitors is not included because these technologies are not widely deployed and there is a lack of data (Denhom, P & Kulcinski, 2003).

Exhibit 52

Smart Grid and Energy Storage - Environmental Performance

Net/life cycle GHG emissions	CO_2 equiv./MWhe
Pumped hydro storage	15.7
Compressed air energy storage (CAES)	17.2
Lead acid	288
Vanadium redox batteries	256

A.3.4 Technical and non-technical challenges

For **pumped hydro storage** considerations include capital cost:

- Long permitting and construction times, Environmental regulations (effect on water quality and ecosystem) and potential impacts on flooded land area.

For **compressed air energy storage (CAES)** considerations include:

- Poor energy density (Grid Application);
- High initial cost (Electric transportation);
- Land use (Grid Application);
- Limited performance (Electric transportation);
- Short cycle life (Grid Application);
- Scarcity of raw materials (Electric transportation); and
- Raw material-Range of toxicity (Grid Application).

For **flywheels** are: Safety risks from hazardous failure modes and high energy losses

For **superconducting magnetic energy storage (SMES)**: High capital costs, lower energy densities, material constraints (Scarcity of Niobium)

For **electrochemical capacitors** challenges include: Low energy density, hazardous material in electrolytes, high manufacturing cost

A.3.5 Emerging Trends

Pumped storage is well established and its availability is dependent on geography. In U.S, currently, the largest application for storage is distributed storage, primarily in the form of thermal storage used for reducing thermal heating or cooling loads. Renewable energy applications constitute the second largest storage application in terms of installed capacity, primarily due to pumped hydro and CAES systems. The remaining applications and technologies currently constitute less than 10 percent of the installed capacity (KEMA, 2012).

The largest growth in energy storage in the near term is expected to be in other distributed storage, ancillary services, and renewable integration applications. The growth in community energy storage (CES) and transmission is expected to be gradual, though the potential for the overall (CES) market is quite large.

The pumped hydro is not expected to grow significantly over the next five years although its share of the total market is quite large.

Battery technologies and thermal storage are expected to be the strongest growth areas in the near term (KEMA, 2012).

Appendix B

Three Scenarios for RE Deployment: Details

Recognizing prevailing uncertainties related to difficult economic conditions, declining electricity intensity (unit energy consumed per $ of gross domestic product (GDP)), the impact of conservation programs and technologies, cost structures, consumer acceptance, and policy frameworks, three scenarios have been developed, as described in the Exhibit 53 below.

Exhibit 53

Scenario	Description
A Reference Scenario	This scenario is based on the forecasts of the National Energy Board *Canada's Energy Future: Energy Supply and Demand Projections to 2035*, November 2011. The methodologies employed for each RE technology were as follows: • Wind energy figures were derived from Table A5.1: Capacity by Plant Type, Reference Case, NEB, 2011. • Solar PV energy figures were developed from Table A5.1 and unpublished NEB data which provides national cumulative capacity installations. These were allocated to Ontario as that province accounts for almost all of the historic grid-connected installations and is the only utility with planned solar PV installations in the next decade. • Marine energy figures were developed from Table A5.1 and unpublished NEB data which provides national cumulative capacity installations. These data were corrected to account for the tidal range plant (20MW) in Nova Scotia, which was included as a 4 MW plant. The results were allocated to Nova Scotia as that province accounts for all of the historic installations and is the only jurisdiction currently undertaking relevant R&D. • Geothermal energy figures were developed from Table A5.1and unpublished NEB data which provides national cumulative capacity installations. The results were allocated to British Columbia as it is the only province with very high-temperature geothermal resources required to produce power (NRCan). • Bioenergy figures were developed from Table A5.1 and unpublished NEB data which provides national cumulative capacity installations. These were distributed across the provinces on the basis of the 2010 installed capacity as published by Statistics Canada in its catalogue 57-206 *Electric Power Generating Stations* (NRCan). About 70% of the existing installed capacity of about 1,700 MW is in the pulp and paper/forestry sectors; primarily for self generation, but also for sale to the grid. Most of the bioenergy future development is closely related to the fortunes of these industries (NRCan). • Hydro energy figures were developed using several approaches. Unpublished NRCan data provides information regarding small hydro (<50MW) and total hydro by province for 2010, as well as national level, small hydro installation dynamics over the period 1999-2010. Small hydro has exhibited low growth rates with overall growth of about 7% over the past decade. For the purposes of developing

	projections for this study, a growth of 1% per year was applied to the 2010 installations; increases of less than 1 MW were not considered. Large hydro projections were then determined by manipulating the values presented in Table A5.1 (NEB), (which include wave/tidal, and small hydro installations). The NEB values for 2015, 2017 and 2022, by province, were discounted for marine energy (see above) and factoring out the calculated small hydro installations. In some provinces and for some periods, the NEB projections are less than 50 MW in which case this value was allocated to small hydro.
B **Utility Scenario**	This scenario reflects planned capacity installations by utilities and independent electricity providers. The scenario was constructed on the basis of utility literature (annual reports, energy blueprints, renewable energy strategies, etc.) and validated by means of personal communications with system planners and/or forecast managers in the provincial utilities and/or departments of energy (as applicable). The scenario is based on prevailing utility considerations related to: - Demand dynamics reflecting anticipated economic conditions; - Savings resulting from conservation, efficiency and smart grid technologies; - Rate structures and costs; - Investments in facility development, retirement and refurbishments; - Timelines and societal hurdles in obtaining project approvals; and, - GHG emission targets.
C **Industry Scenario**	This scenario reflects the vision of renewable energy proponents. The underlying assumptions include strong policy and regulatory support, significant cost reductions, and strong industrial and residential consumer uptake (embracing the clean-tech/green world). The scenario was developed on the basis of literature and publications as well as articulated visions proposed by renewable energy proponents and/or expected energy mix shares by renewable energy sector of future load demand as identified by the provincial utilities. The methodologies employed for each RE technology were as follows: • Wind energy figures were developed on the basis of discussions with CanWEA representatives and Wind Vision 2025. CanWea supplied national additional annual capacity installations (MW/year) for various time periods: 2010 – 2015: 1,600; 2016 – 2020: 2,600 [low], 3,600 [high]; 2021 - 2025: 2,550 [low], 3,550 [high]. Based on historic installations, the high case was applied, which resulted in installation additions for the study time horizons: 2015 – 4,800 MW; 2017 - 7,200 MW; 2022 – 17,900 MW. These national totals were then distributed and cumulated across the provinces on the basis of wind share in Utility Scenario B for each of the time horizons in question. The CanWEA Vision is 55,000 MW installed by 2025. • Solar PV energy figures were developed using the aggressive case Solar Vision 2025 forecasts (p. 26). Historically about 89% of installations have been grid-connected (NRCan, 2012). (It is expected that this ratio will decrease rapidly, as most if not all future installations will be grid-connected; by 2022, it may reach 98-99% (NRCan).For the purposes of analysis an average ratio of 95% was applied over the decade. This resulted in cumulative additions for the study time horizons: 2015 – 1900 MW; 2017, 2850 MW; 2022 – 7790MW. The 2015 calculation was adjusted to account for known data for Ontario which has 564 MW in operation and 1,420 MW under development/construction which are anticipated to be complete by 2014. These national totals were then allocated to Ontario as that province accounts for almost all of the historic grid-connected installations and none of the other utilities in other provinces have indicated any plans to install solar PV in the next decade. The

	CanSIA Vision (base case) is 12,000 MW installed by 2025. • Marine energy figures were developed on the basis of a review of relevant literature and discussions with representatives of Marine Renewables Canada. The Marine RE Technology Roadmap calls for 250 MW by 2020, but that includes river current in addition to in-stream tidal and wave. In addition to Nova Scotia R&D activity, British Columbia currently has some pilot projects on-going that should result in small capacity by 2022. • Geothermal energy figures were developed on the basis of a review of relevant literature and discussions with the Canadian Geothermal Energy Association (CanGEA). • Bioenergy is an extremely fragmented sector driven primarily by individual corporate investment intentions. Scenario C was developed by directly incorporating the greater of either Scenario A or Scenario B. • Hydro energy figures were developed on the basis of a review of relevant literature and discussions with the Canadian Hydro Association. Accurate information related to small scale hydro development is difficult to obtain. After considerable evaluation, particularly in the context of long lead times and significant capital investment, it was decided that Scenario C would essentially mirror Scenario B, for either small or large hydro.

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