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Canada 2050: Roadmap to an Energy Powerhouse

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ABSTRACT

In this chapter, we explore how the nine energy projects proposed in "Canada: Winning as a Sustainable Energy Superpower" would increase the amount of energy-related products that Canada could export, and significantly raise the proportion of renewable and non-GHG-emitting energy sources in the total energy mix. These projects would also dramatically increase the added value of the energy products that Canada uses and exports, reversing Canada's current trend presented in Chapter 2 of this book. Chapters 3 and 4 emphasize the urgency and opportunity of upgrading bitumen in Canada's strategy of moving up the value chain, while subsequent chapters identify other important energy opportunities.

The three objectives of increasing energy production, decreasing the carbon content of our energy mix and adding value prior to export are the key energy challenges that Canada faces in this century. The nine "big energy projects" proposed by the Canadian Academy of Engineering (CAE) would significantly contribute to these goals, and position Canada as a "sustainable energy powerhouse."

Introduction

Canada was created on the shoulders of "big projects" which provided the nation-building infrastructure that is the foundation of its wealth today. Massive, pioneering projects such as the Victoria Bridge, the Canadian Pacific Railway, the St. Lawrence Seaway, and the large hydroelectric complexes found in many provinces remain the foundation of much of today's economic potential. The TransCanada Microwave system, Canadian satellites, the CANDU nuclear power technology, the Alberta oil sands, the Hibernia project and many more were the result of visionary undertakings, in each case transforming Canada's opportunities for the foreseeable future. These projects were undertaken as private/public sector partnerships with governments providing leadership and sharing risks through a variety of incentives, including equity where necessary. The message here is clear: big projects, sometimes taking decades to bring to commercial fruition, often in the midst of significant controversy, are not jobs for single companies and a single set of shareholders responding to current market conditions. Nations have more control over their future than leaving themselves open to market forces: Canada is living proof of this!

Victoria Bridge, Montreal

As we look towards the future, Canadians must learn from past failures and develop their massive energy resources more strategically. Unfortunately, over the past 70 years, Canada's ability to maintain world-class leadership has diminished, as evidenced in a variety of areas. Examples include industries as diverse as piano manufacturing, television, radio, pulp and paper technology, minerals processing technology, and furniture manufacturing. For a time, its world-class aerospace industry came close to the brink, but Canadians successfully brought it back. Automobile manufacturing, and manufacturing as a whole, is still struggling in Canada, and the jury is still out on whether we will successfully continue to compete in the manufacturing arena. Energy remains an area of immense opportunity. This chapter explores how the nine big projects proposed in "Canada: Winning as a Sustainable Energy Superpower," if implemented by 2050, would transform Canada.

Canada's Current Energy Production

As one of the world's top 10 energy producers and a net energy exporter, Canada plays a key role in providing access to energy for the citizens of our planet. Canada's contribution to global energy production could be substantially increased in a sustainable manner, since Canada is endowed with a wide range of energy sources, including:

- Huge, non-renewable carbon-bearing sources of gas, oil, bitumen and coal,
- Vast uranium and thorium ores, and proven nuclear power technology,
- Massive developed and undeveloped hydroelectric power, and
- Large renewable energy resources from its vast agricultural and forestry residues.

Diverse energy sources, including renewable and non-GHG-emitting, are currently being produced in Canada as shown in Table 1. Table 2 details the current energy generation from biomass resources. This highly significant energy endowment is the basis for suggesting that Canada could ultimately become a sustainable energy superpower. This section quantifies Canada's present energy production in all key categories.

Table 1
Canada's Current Energy Production

Energy Source		Current Production (Industry Units)	Current Production in Million Barrels per Day Fuel Oil Equivalent (M BPD foe)
Conventional Oil		1.58 M BPD	1.58
Oil Sands		2.08 M BPD	2.08
Natural Gas	Conventional Natural Gas	2.19 Trillion Cubic Feet per Year	1.03
	Coal Bed Methane	0.256 Trillion Cubic Feet per Year	0.12
	Tight/Shale Gas	2.263 Trillion Cubic Feet per Year	1.07
Coal		71.17 Million Tonnes	0.70
Nuclear Energy		106,839 GWh 14,320 MW	0.19
Hydroelectric Power Generation		366,096 GWh 76,922 MW	0.68
Solar, Wind, Tidal, Bioenergy	Solar	9,937 GWh 2,456 MW	0.01
	Wind	12,571 GWh 6,637 MW	0.04
	Bioenergy (see Table 2)	217 Pj	0.10
Total			7.60

Table 2
Estimates of Annual Energy Generation from Biomass in Canada[1]

Energy Source	Current Annual Production (Industry Units)	Current Annual Production (in Pj)
Electricity generation from forestry biomass	9,829 GWh	35.38
Heat generation from forestry biomass	21,448 GWh	77.21
Bio-ethanol production	1600 Million Litres	33.79
Bio-diesel production	250 Million Litres	8.93
Wood pellets export	3 Million Tonnes	60.0
Electricity generation from Municipal Solid Waste	81 GWh	0.29
Heat generation from Municipal Solid Waste	469 GWh	1.69
Total – Pj		217.30
Total – million barrels per day fuel oil equivalent (M BPD foe)		0.10

[1] Estimates prepared by the Energy Pathways Task Force

Photo courtesy of Tourism Sarnia-Lambton

Conventional Oil

The first significant discovery of conventional oil was in Oil Springs, Ontario in 1865. Before the village was formed, the indigenous people already knew about the gum beds and used the sticky oil to waterproof their canoes[2]. The place, originally called Black Creek, became the site of North America's first commercial oil well when asphalt producer James Miller Williams set out to dig a water well in 1858 and found free oil instead. Williams' discovery triggered North America's first oil rush and the village's name was changed to Oil Springs that same year. Within a few years, Oil Springs was a bustling town with four thousand residents and, in its peak days, boasted paved roads, horse-drawn buses and street lamps. This led to a world-wide reputation for the drillers and engineers involved. However, the reserves proved to be limited. Today, production continues at a low level using the original equipment, preserving the historical significance of the site.

A huge oil discovery occurred in Leduc, Alberta in 1947[3]. This provided the geological key to Alberta's prolific conventional oil reserves and resulted in a boom in petroleum exploration and development across Western Canada. The discovery transformed the Alberta economy; oil and gas supplanted farming as the primary industry, and resulted in the province becoming one of the richest in the country. Nationally, the discovery allowed Canada to become self-sufficient within a decade and ultimately a major exporter of oil. Canada's current conventional oil production is 1.58 million barrels per day (M BPD).

Oil Sands

Oil sands represent a very different story. The existence of the heavy and viscous bitumen was known by native people and explorers for many decades prior to 1900. The oil sands areas were subjected to extensive survey and early experimentation over many decades. The Alberta government decided to build and test a demonstration bitumen recovery plant at Bitumount Alberta in 1947[4]. Although the recovery process was shown to be commercially viable, large-scale commercial production did not occur until 1967 by Suncor, and a few years later by Syncrude. Production is currently 2.08 M BPD and is likely to at least double by 2030. New production will come from both new mining projects and also a major expansion in in-situ production from the deeply buried deposits representing close to 90% of the total resource. Environmental issues may slow down the pace of production but advances are being made in site restoration and in the development of new processes with less environmental impact. Reducing greenhouse gas emissions will be a continuing challenge. It is believed that there are close to 2 trillion barrels in Alberta's various bituminous deposits.

Natural Gas

The energy equivalent of Canada's current natural gas production of 4.7 trillion cubic feet per year (including conventional natural gas, coal bed methane and tight/shale gas) is higher than that of either conventional oil or oil sands production , equivalent to to 2.22 M BPD foe[5]. Although conventional production appears to have peaked and decreased somewhat, the picture has recently changed with new production expected from coal bed methane, tight gas and shale gas. The emergence of advanced fracturing technology has opened major new gas deposits in both the US and Canada. The major issue for Canada will be the loss of US

[2] http://en.wikipedia.org/wiki/Oil_Springs,_Ontario

[3] http://en.wikipedia.org/wiki/Leduc_No._1

[4] http://en.wikipedia.org/wiki/Bitumount

[5] foe – Fuel Oil Equivalent – an index used by the energy industry to compare the size of various energy sources

markets, and the need to shift direction to liquefied natural gas for international markets. Canada will not be running out of natural gas for the foreseeable future. However, environmental concerns in the public arena over the use of fracturing technology will need to be addressed.

Coal

Canada has more energy in coal than oil and gas combined. Coal combustion is used primarily for the production of electricity in both the US and Canada. The level of carbon dioxide produced per unit of energy is much higher from coal combustion than other fossil fuels and the pressure from environmental groups to shift from coal to gas is increasing. However, coal gasification is a technological solution which reduces the greenhouse gas penalty of coal combustion. Coal gasification has the unique ability to simultaneously produce electrical power, hydrogen and high-value chemical and pharmaceutical products. Gasification also has the ability to handle diverse feedstocks, to capture, store, utilize (i.e., for other value-added processes) or sequester carbon dioxide, and to capture sulphur and trace metals. Global coal use will increase dramatically over the next century, and coal gasification demonstration projects should be undertaken based on Canada's low rank coals, utilizing the latest international technology developments and meeting rigorous environmental targets. Current production levels are 71 million tonnes per year, or 0.70 M BPD foe.

Nuclear Energy

Canada is blessed with massive supplies of the raw material for nuclear power, uranium and thorium, and has led the development of nuclear power from natural uranium. Canadian nuclear power technology development has been dominated by a few publicly owned companies and a single reactor technology. In recent years the industry's landscape has changed, with a number of new private sector players, with new reactor technologies emerging. Maximizing the future benefits to Canada from opportunities in the nuclear industry may well depend on growing synergies among a set of applied technology clusters (e.g., energy supply, medical diagnosis/treatment, food safety/sterilization, uranium mining, advanced materials) and the science and technology networks that support them.

Nuclear power can be used as a source of heat for a variety of industrial processes, either as stand-alone heat sources or in combination with electricity production, thereby contributing to the reduction of GHG emissions. A specific opportunity is that of applying nuclear energy to in-situ bitumen recovery from Alberta's oil sands, a process that currently uses fossil fuel as a heat source. This would strengthen Canada's position on greenhouse gas abatement by reducing the carbon footprint of the oil sands industry, thereby facilitating further growth.

The amount of nuclear energy that Canada produces is modest at the present time, amounting to approximately 0.19 M BPD foe. However, in view of its vast uranium and thorium deposits, it is essentially unlimited.

Hydroelectric Power Generation

With 73,000 MW of installed hydroelectric generating capacity, producing 366,096 GWh of electrical energy annually (or 0.68 M BPD foe), Canada is a leader in the development and application of advanced hydroelectric power generation and transmission technology. The untapped power in Canada's hydraulic systems, amounting to more than 163,000 MW, is more than double the current installed capacity. Priority areas for development can be found in nearly every province.

The lack of a national power grid results in uneven energy costs across the country and stranded power reserves, not to mention the loss of potential north-south trade opportunities.

A prerequisite for moving ahead with major new hydroelectric projects is the establishment of a Canada-wide high-capacity transmission network, with three objectives:

1. Link new hydroelectric projects to areas of consumption.
2. Interconnect existing provincial networks.
3. Replace thermal power plants at the end of their useful life to reduce Canada's GHG footprint.
4. Seize the opportunity to become North America's premier low-cost provider of low-carbon electricity

Solar, Wind, Tidal and Bioenergy

The current production of energy from solar and wind in Canada is negligible in comparison to other energy sources, and is expected to increase slowly over the next few decades, responding to favorable regional situations and the evolution of more effective technologies and their associated costs. The situation with bioenergy is more promising due to Canada's huge land mass, and agricultural and forestry biomass residues. Current energy produced from biomass amounts to roughly half the energy that Canada derives from nuclear power. As the second largest country in the world and the home to approximately 10% of global forests, Canada can dramatically increase sustainable bioenergy production, following the pathway successfully adoped by Europe.

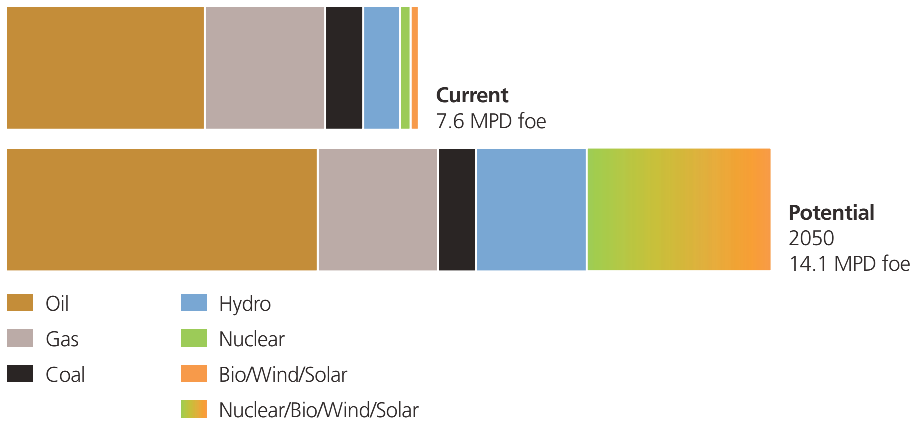
Implementing the CAE "Nine Big Projects"

The previous section provided an overview of Canada's impressive energy endowment. Let us now explore how production from these energy sources could be increased, reducing the carbon content of our overall energy mix and achieving a higher level of value-added upgrading.

The energy resources highlighted in beige in Table 1, contain carbon. The other resources can be considered either low carbon, or carbon neutral. At present, production from the carbon-containing energy sources in Canada represents 86% of the total energy production. The relative contributions of the various energy categories are shown in the top chart in Figure 1.

Considering the potential of Canada's energy resources discussed above, the nine big projects described in "Canada: Winning as a Sustainable Energy Superpower" promise to:

Figure 1
Changes in Energy Productions by Big Projects



- Increase Canada's total energy production, providing greater access to energy for global citizens,
- Enhance the contribution of renewable and non-GHG-emitting energy sources in the total energy mix, contributing to the adaptation to climate change,
- Increase the value of our energy exports by more extensive upgrading, and
- Create long-lasting wealth and energy-related high quality jobs for current and future Canadian generations, positioning Canada as an energy powerhouse.

This section attempts to quantify the benefits associated with implementing the proposed big projects.

Canada's total energy production would significantly increase from its current level of 7.6 M BPD foe if all nine big projects proposed by the Canadian Academy of Engineering (CAE) Energy Pathways Task Force are implemented. A number of different scenarios can be envisaged depending on the actual size and capacity of any one project. As an example of what could be done, the following scenario aims to nearly double Canada's energy production, significantly reduce carbon content, and increase the value of our exports. This scenario is described below, and summarized in Table 3.

Conventional Oil

It is not expected that there will be major new conventional oil discoveries in Alberta. However the extension of the life of existing fields, and the continued development of Atlantic Canada's offshore petroleum industry, should make it likely that the current production level of 1.58 million barrels per day can be maintained for the first half of this century.

Oil Sands

Energy production from Canada's oil sands, one of the largest non-conventional oil resources in the world, is expected to double over the next one to two decades to 4.16 M BPD. The economic impact of doubling oil sands production will be significant for Alberta and for the rest of the country. If a significant portion of the bitumen in this increased production is upgraded inside Canada, an expected $68 billion per year in added value will result (discussed further in Chapters 3 and 4). Our country would become the global centre of excellence for oil sands exploration, development and value-added upgrading.

Table 3
Future Scenario: Implementation of the Nine CAE "Big Projects" by 2050

Energy Source		Current Production (M BPD foe)	Potential Production Mid-century (M BPD foe)	Comments on Change
Conventional Oil		1.58	1.58	Modest new discoveries likely to maintain production level.
Oil Sands		2.08	4.16	Likely to double over next two decades. Hard to predict long term limit.
Natural Gas	Conventional Natural Gas	1.03	2.22	Current markets shrinking, but production could be maintained by developing new markets with LNG exports.
	Coal Bed Methane	0.12		
	Tight/Shale Gas	1.07		
Coal		0.70	0.70	Gasification technology could help retain markets and maintain production.
Nuclear Energy		0.19	1.90	Ample uranium resource for ten-fold or more increase.
Hydroelectric Power Generation		0.68	2.04	Could triple if major sources harnessed.
Solar, Wind, Tidal, Bioenergy	Solar	0.01	1.5	Not expected to be major player in Canada in this half century.
	Wind	0.04		Moderate increase expected, especially if economic storage technology develops.
	Bioenergy	0.10		Agricultural and forestry residues could enable a ten-fold increase.
Total		7.60	14.10	

Natural Gas

Due to the dramatic increase in shale gas production in the United States, it is expected that the export of natural gas from Canada to the US will decrease. However, if the currently planned liquefied natural gas (LNG) big projects to supply Asian markets occur, led by BC, Canada's export of natural gas will likely be maintained at current levels. Investments to build LNG infrastructure will create jobs and the process of liquefaction will increase the value-add of this resource.

Coal

Gasification is considered to be a cleaner process for upgrading coal, one of the largest energy resources in Canada, and for biomass. Investments in technology development and the implementation of advanced gasification technologies for coal and biomass feedstock are recommended. If the coal industry develops new clean technology via the gasification processes, the new technology will be applied as current coal combustion plants reach the end of their expected life span. If this occurs, current production levels and associated jobs can be maintained.

Nuclear Energy

If nuclear energy is used to provide heat energy for the recovery of in-situ bitumen from the oil sands, one of the nine proposed big projects, this would significantly reduce the release of carbon dioxide. This could be accomplished with the application of small modular nuclear reactors, now under development.

Another major nuclear application is the concept of large nuclear generating sites (often termed "nuclear farms") supplying electricity to a national high voltage grid. This would enable the export of low-GHG power to the United States and also could feed both electricity and process steam to adjacent industrial parks comprising energy-intensive industries. This potential contribution to a national grid is described in Chapter 6, and that of nuclear generating sites producing both electricity and steam is described in Chapter 9.

For illustration purposes, a ten -fold increase in nuclear energy generation from Canada's current relatively low level production would represent the energy equivalent of 1.9 M BPD foe. This would certainly be a stretch goal but would represent the energy content only slightly above the current production of conventional oil.

Hydroelectric Power Generation

A three-fold increase in hydroelectric power generation would represent the energy equivalent of 2.04 M BPD foe. In addition to job creation and investment from new hydroelectric power plants, Canada could regain its global expert status in the hydroelectric sector.

Solar, Wind, Tidal and Bioenergy

Bioenergy, still in its infancy, currently produces 0.10 M BPD foe, dwarfing the total from both solar and wind. Biomass resources from Canada's agricultural and forestry sectors could enable a ten-fold increase in Canada's renewable energy production to an energy level equivalent to 1.5 M BPD foe. This would also be a stretch goal, with the energy content equivalent to the current production of conventional oil. Bioenergy would also likely be produced in combination with bio-chemicals and other bio-products. This project could lead to the development of an entirely new industry.

Scenario Summary

The changes in total energy production and the increases in the relative contributions of renewable and non-GHG-emitting energy sources are illustrated in the lower chart of Figure 1.

If all nine big projects are implemented, total energy production would increase by 85%, and the amount of carbon containing sources in our energy mix would decrease from 86% to 61%. All of the proposed additional energy production would be produced at a significantly higher value-added level compared to current production. Additionally, these big projects will create jobs and wealth for Canadians, and position Canada as a sustainable energy powerhouse.

An Alternative Scenario – None of the Nine Big Projects are Implemented

Failure to implement the proposed nine big projects will have significant negative impacts on the current status of Canada as a major energy producer, not to mention its internal social and economic conditions.

- If the oil sands "big project" is not undertaken, the majority of the increase in oil sands production will be upgraded in United States refineries, and the expected $68 billion dollar per year value-added will be captured by those refineries.
- If the currently planned liquefied natural gas (LNG) big projects to supply Asian markets do not occur, Canada's export of natural gas to the United States will likely decrease by 50%, driven by the recent dramatic increases in the US natural gas resources.
- If the coal industry does not develop new clean technology via gasification processes, the use of coal as a power source will continue to diminish as existing power plants reach the end of their lives. In the absence of the development of appropriate coal gasification technology, a 50% decrease in coal production over the next forty years is likely, primarily due to the closure of coal-fired power plants.
- If nuclear heat energy is not applied to the recovery of bitumen from the deeply buried oil sands, the release of carbon dioxide will continue to grow, reflecting the increased bitumen production. If no new nuclear electricity generation capacity is developed, none of the expected benefits arising from the production of additional non-GHG-emitting energy, and the expansion of the nuclear industry will materialize.
- If a national power grid is not established, Canada will not capture the opportunity of being a major exporter of low-GHG electrical power to the continent.
- If no new hydroelectric power generation capacity is developed, none of the expected benefits arising from the production of additional non-GHG-emitting energy, and the expansion of the hydroelectric power industry, will materialize.
- If Canada's bioenergy potential remains undeveloped, none of the expected benefits arising from access to additional GHG-neutral energy, and the emergence of new bio-energy and bio-chemical industries will materialize.

In summary, if none of the big projects are undertaken during the next forty years, Canada will miss the opportunity of being the global energy powerhouse that it presently promises to become. This threat is real, since the US and other countries are exploring both conventional and unconventional energy resources at an unprecedented pace. The negative impacts of not implementing these big projects on GDP and jobs/wealth creation will be substantial, a loss of yearly economic activity on the order of $100 billion dollars, while the impact of doing nothing will not substantially improve the proportion of non-GHG-emitting energy!

The Pathway Forward

Each of the nine big projects described here will contribute in its own way to transition Canada to a sustainable energy powerhouse. The private sector alone is not able to effectively implement these nine nation-building projects. Government must provide a nurturing environment, through vision, leadership, incentives, supportive regulations, and public education programs. Most of the projects will require public-private partnerships, undertaken by the private sector with appropriate risk-sharing incentives. In the past, Canada has proven that it can implement such nation-building projects. With the appropriate government leadership, Canada's energy sector is prepared to seize the opportunities to transform Canada into a world-leading sustainable energy powerhouse.

Biography

Richard J. Marceau, PEng, FCAE, Vice President (Research), Memorial University: Dr. Richard J. Marceau is the Vice-President (Research) at Memorial University and President of the Canadian Academy of Engineering (2012-2014). He has served as Provost and Vice-President Academic at the University of Ontario Institute of Technology (2005-2013), Dean of the Faculty of Engineering at the Université de Sherbrooke (2001-2004), and Chair of Electrical and Computer Engineering at École Polytechnique de Montréal (2008-2001). Prior to his academic career, he practiced engineering for twelve years, first at MONENCO, then at Hydro-Québec. An active member of his community, he has been invited to participate on numerous committees and board, including as President of the Parkwood Foundation (2009-2013), a National Historic Site and former home of the founder of General Motors of Canada, R.S. McLaughlin. He is a registered Professional Engineer in the Provinces of Newfoundland and Labrador, Ontario and Québec.

C. W. (Clem) Bowman: Dr. C. W. (Clem) Bowman has worked in the energy industry for the past 50 years, in various research, management and executive capacities, including vice-president Esso Petroleum Canada, founding chairman Alberta Oil Sands Technology and Research Authority (AOSTRA), president of the Alberta Research Council, and Presidents of the Canadian Society for Chemical Engineering and Chemical Institute of Canada. Bowman's career contribution to energy technology development led to the 2008 Global Energy International Prize, awarded by Russian President Dmitry Medvedev. In 2010, the University of Western Ontario established the Bowman Centre at their Sarnia-Lambton campus to expand energy technology development. Included in a list of award and recognition was induction into the Canadian Petroleum Hall of Fame in 2013 and granting of an honorary degree by the University of Ontario Institute of Technology in 2013.