Canada's Oil Sands:

Strategic Decisions to Make Canada an Energy Superpower

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Systems methodologies are employed to investigate strategic decision problems regarding the development of the oil sands in Canada. Many countries believe energy to be one of their most important national security factors in today's competitive global era. Canada is no exception. Energy is an issue in Canadians' growing concerns related to the conflicting priorities of its economy, environment, and society. Various studies have tried to map out Canada's establishment as an energy superpower. In particular, the massive resources in Canada must be considered as competitive advantages, and oil sands (tar sands) constitute one of the most crucial elements in terms of non-renewable energy. This thesis describes Canada's oil sands – their characteristics, cost and market analysis, as well as social, economic, and environmental impacts – in order to clarify conflicts that have arisen in recent years. In addition, the importance, potential, and constraints of the oil sands are examined as leading drivers to the country becoming an energy superpower and are compared with the Canadian Academy of Engineering (CAE)'s studies and recommendations. Multiple-criteria decision analyses based on the ProGrid methodology are carried out at different levels to clarify the structure and current position of Canada's energy system. An Evaluation Matrix, including multiple criteria, is built, and language ladders with different weights are established to allow various groups of experts to evaluate available options. Based on their evaluations, the strong and weak points of the oil sands are analyzed. At a more detailed level, alternative solutions for water quantity and quality problems in Canada's oil sands are prioritized with respect to specific criteria, using the ProGrid methodology. The strategic issues in Canada's oil sands are addressed at different levels, and priorities for decision-making are determined and discussed to guide Canada in becoming an energy superpower.

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Chapter 1
Introduction

1.1 Oil Sands

The oil sands (also called tar sands) are a very special and precious resource, but their exploitation arouses controversy, because of their unique characteristics. Karl Clark and Sid Blair, the pioneers in the oil sands development who discovered the way to separate oil from oil sands, started to call them ‘oil sands’ instead of ‘tar sands’ in 1951 (Finch, 2007). In general, oil sands are unconsolidated and very friable in nature, because they are mixtures mainly made up of diverse substances such as inorganic materials, bitumen, silt, clay and water. Among these, the bitumen is the indispensable element used for oil production (NEB, 2004).

Extracting bitumen from the oil sands and producing subsequently oil is not environment-friendly and economical compared to conventional oil production. Nevertheless, many stakeholders in various industries have been interested in developing the oil sands because of their massive volume and potential for oil production. More than 80 percent of the world’s oil sands are located in Canada, and this amount makes the country rank second in the world in terms of oil reserve volume, for which Saudi Arabia is ranked first (Humphries, 2008).

In the early years of oil sands work, labourers had to shovel the viscous oil sands, move them onto barges, and drag them to plants located upriver for processing. In other words, they worked in poor surroundings, and the work efficiency and economics also were unsuitable. However, recent methods for recovering bitumen from oil sands and upgrading technologies, using more complicated machinery, have given rise to increased efficiency and a variety of job opportunities, such as mechanical, geotechnical, and mine-planning engineers, pipefitters, as well as drillers, boilermakers, quality control specialists, electricians, environmental specialists, and many others. This demonstrates that the oil sands’ value is turning from “mud into gold” (Finch, 2007).

The current market related to oil sands is limited to Canada and the US. Canada produces and exports various oil products including upgraded bitumen and non-upgraded bitumen. According to the Edmonton Journal (2008), Canada exports approximately 30 percent of the non-upgraded bitumen from Alberta to the US through pipelines. Hence, a reasonable enlargement of pipeline capacity is required to satisfy estimated future demands for oil sands products such as non-upgraded bitumen and Synthetic Crude Oil (SCO).

Since the oil sands business started, related activities have brought great economic benefit to Canada in terms of Gross Domestic Product (GDP), government revenues, and employment. On the other hand, rapid growth of the oil sands industry has caused many social problems, including fast population increases, inadequate infrastructure, expensive housing, and poor service. In particular, the oil sands development has had a negative influence upon the country's environment by increasing greenhouse gas (GHG) emissions, causing water quantity and quality problems, and resulting in overconsumption of natural gas, land reclamation, and tailing ponds.

Although the oil sands have an enormous potential to give Canada a dominant position in terms of energy, Canada will suffer ecological and social problems from being an energy superpower. Therefore, a diversity of impacts need to be considered carefully and counteracted multi-dimensionally with foresight and wisdom.

1.2 Motivation for the Research

Canada has many opportunities to be an energy superpower, with an advantageous position from abundant energy resources and a knowledge-based industry. In the past, however, Canada has not taken proper advantage of its natural resources. For example, Canada was an initial leader in the forestry, mining, aeronautics, and automotive industries. However, Canada failed to fully benefit from these opportunities because of a lack of national vision and an integrated systems approach.

Fortunately, Prime Minster Stephen Harper (2006) showed his will to make the country an energy superpower, saying that Canada is an emerging energy superpower with a powerful vision. As evidence for it, he also stated that Canada is the third largest gas producer, the seventh largest oil producer, and the largest hydro-electric generator exporter and uranium supplier (Canadian Press, 2006). Moreover, Canada has the second largest oil reserves in the world , as shown in Table 2.1. In particular, he highlighted the oil sands' role as a significant national energy resource, designating the development of the oil sands as being "akin to the building of the pyramids or China's Great Wall." To clarify Canada's potential to achieve its goal of being an energy superpower, the oil sands, as one of Canada's essential energy systems, must be analyzed strategically, because it is difficult to consider the country's energy future without discussing the oil sands.

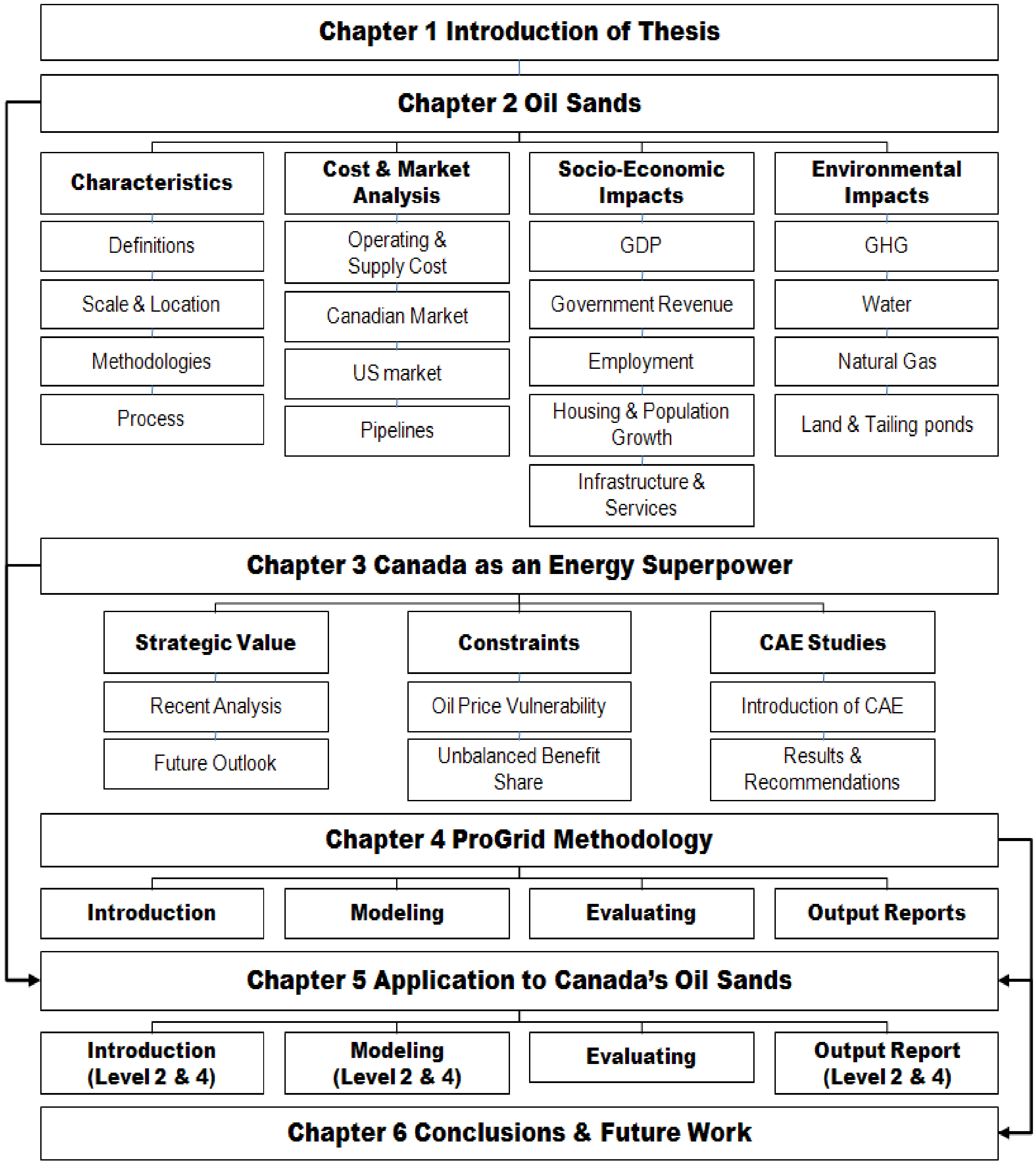
The ProGrid methodology (Bowman, 2005) is employed as a systems approach to investigate strategic decision problems regarding Canada's oil sands and their development. The methodology is a logical decision-assist tool for multiple-criteria decision analyses, and it enables decision makers to convert qualitative concepts into quantifiable measures. Hence, the ProGrid methodology is very useful in evaluating oil sands, which are intangible assets, as a national energy system.

In this thesis, the oil sands are evaluated and analyzed employing the ProGrid methodology by breaking down them into four levels and focusing on an essential element in Level 2 (the oil sands in Canada's energy system) and Level 4 (the water issues in Canada's oil sands). The results show that the oil sands can help to make the country an energy superpower. The output reports also demonstrate related strengths and weaknesses that must be considered in Canada's energy systems. Through application of the ProGrid methodology, reasonable and strategic decisions can be made to lead Canada towards an energy superpower status.

1.3 Organization of the Thesis

This thesis consists of six chapters in total, as depicted in Figure 1.1. Chapter 2 examines significant information about Canada's oil sands, such as characteristics, cost and market analysis, as well as social, economic, and environmental impacts. Chapter 3 explains the oil sands' strategic value and constraints in terms of their potential to make the country an energy superpower and compares this with the Canadian Academy of Engineering (CAE)'s studies. Chapter 4 introduces the ProGrid methodology as a decision-making tool for executing multiple-criteria decision analyses. In Chapter 5, the methodology is using as a systems approach for suggesting strategic decisions regarding Canada's oil sands and their development. The valuable information and assessment about Canada's oil sands from Chapters 2 and 3 play an important role as input data to evaluate the oil sands' value and their potential as an essential energy system to make Canada an energy superpower. Finally, Chapter 6 provides a summary of the result of this research. The findings can help stakeholders to make strategic and sound decisions. Figure 1.1 provides a schematic overview of the thesis and the flow of its ideas.

Figure 1.1. Layout of Thesis



Chapter 2
Oil Sands

This chapter introduces general information about Canada's oil sands, such as characteristics, scale, and location. Then, technologies for recovering bitumen from oil sands and processes for upgrading the bitumen are discussed. In addition, cost and market analyses are also carried out to clarify the supply and demand forces that are driving oil sands development. Finally, the related social, economic, and environmental impacts and challenges are examined to shed light on the conflicts that have arisen in recent years.

2.1 What are Oil Sands?

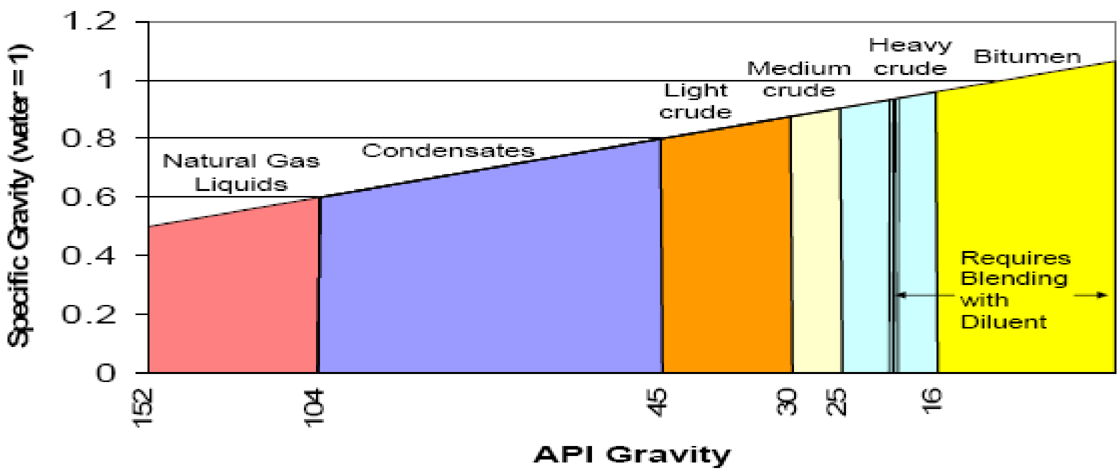
Oil sands are a unique, and very valuable energy resource, but problematic. In particular, the bitumen, one of the basic elements of oil sands, is an essential material for oil production. This section explains characteristic features of oil sands, and relevant methodologies and technologies such as extracting, upgrading, and refining.

2.1.1 Definitions

The oil sands (also called the tar sands) are viscous mixtures composed of inorganic materials, bitumen, silt, clay, and water, along with a small portion of other materials such as titanium, zirconium, tourmaline, and pyrite. Although there can be large differences of formation, a typical composition of oil sands consists of 75 to 80 percent inorganic material (90 percent of this inorganic material is quartz sand), 10 to 12 percent bitumen (bitumen saturation varies between zero and 18 percent by weight), 3 to 12 percent silt and clay, and 3 to 5 percent water. In general, the oil sands have the character of unconsolidated, crumbly, and very friable material (NEB, 2004).

Among the elements of the composition of oil sands, bitumen is an essential matter for producing crude oil. Bitumen is a viscous and heavy crude oil-based material, and it has the character of high density, viscosity, various metal concentrations, and carbon-to-hydrogen molecule count in comparison to conventional crude oils. Bitumen is also characterized by a thick, black, and tar-like substance with a density range between 970 and 1015 kg/m^3 (8 to 14° API gravity – The American Petroleum Institute's measure of gravity is a method for specifying the density of crude petroleum (Energy Type, 2009). For example, if the API gravity is greater than 10, it is lighter than water and floats on water; if less than 10, it is heavier than water and sinks.). Thus, bitumen does not flow to a well in its natural state. Figure 2.1 shows the hydrocarbon spectrum that has various crude types according to API gravity from natural gas liquids to bitumen (NEB, 2004).

Figure 2.1. Density Spectrum of Alberta Crude Types (Source: Alberta Energy, Enbridge, Alberta Energy and Utilities Board, cited in Alberta Department of Energy, “Appendix “A” – Technical Report OS#1: Markets and Pricing for Alberta Bitumen Production,” Edmonton, May 2007, p. 1.)



Bitumen is insufficient in hydrogen in terms of commercial usefulness as an oil; therefore, it must be upgraded through an injection of hydrogen or removal of some carbon in order to ensure it has an adequate level so that it can be utilized as a feedstock for conventional refineries. In addition, bitumen must be blended with a diluent that makes its density and viscosity appropriate for transport through pipelines to refineries (NEB, 2004).

2.1.2 Scale and Location of Oil Sands

Canada’s oil sands, located almost entirely in the province of Alberta, enable Canada to claim to have the second largest oil reserves in the world with the potential for over 100 years of production. According to the Oil & Gas Journal, the oil reserves in Canada are estimated at about 178 billion barrels, most of which are contained in Canada’s oil sands, as shown in Table 2.1.

Table 2.1. World Oil Reserves (Source: Based on information from the Oil & Gas Journal, January 1, 2009, posted in U.S. Energy Information Administration, July 2010)

Rank	Country	Oil (Billion Barrels)
1	Saudi Arabia	266.710
2	Canada	178.092 (173.2 :Oil Sands)
3	Iran	136.150
4	Iraq	115.000
5	Kuwait	104.000
6	Venezuela	99.377
7	United Arab Emirates	97.800
8	Russia	60.000
9	Libya	43.660
10	Nigeria	36.220
11	Kazakhstan	30.000
12	United States	21.317
13	China	16.000
...	…	…
	World Total	**1,342.21**

Most of Canada's oil sands are located in three major areas in Alberta: Athabasca, Cold Lake, and Peace River, as presented in Figures 2.2 and 2.3. The absolute size of Canada's oil sands is roughly calculated to be 140,200 square kilometers, which is an area three times larger than the size of Holland (CAPP, 2008a). It is estimated that these regions of Alberta contain approximately 1.7 trillion barrels of bitumen; proven resources consist of 173.2 billion barrels of potentially recoverable oil from oil sands in the province (U.S. Energy Information Administration, 2010).

Figure 2.2. Oil Sands Areas (Source: Energy Resources Conservation Board, "ST98-2009: Alberta's Energy Reserves 2008 and Supply/Demand Outlook 2008-2018," June 2009, p. 2-1.)

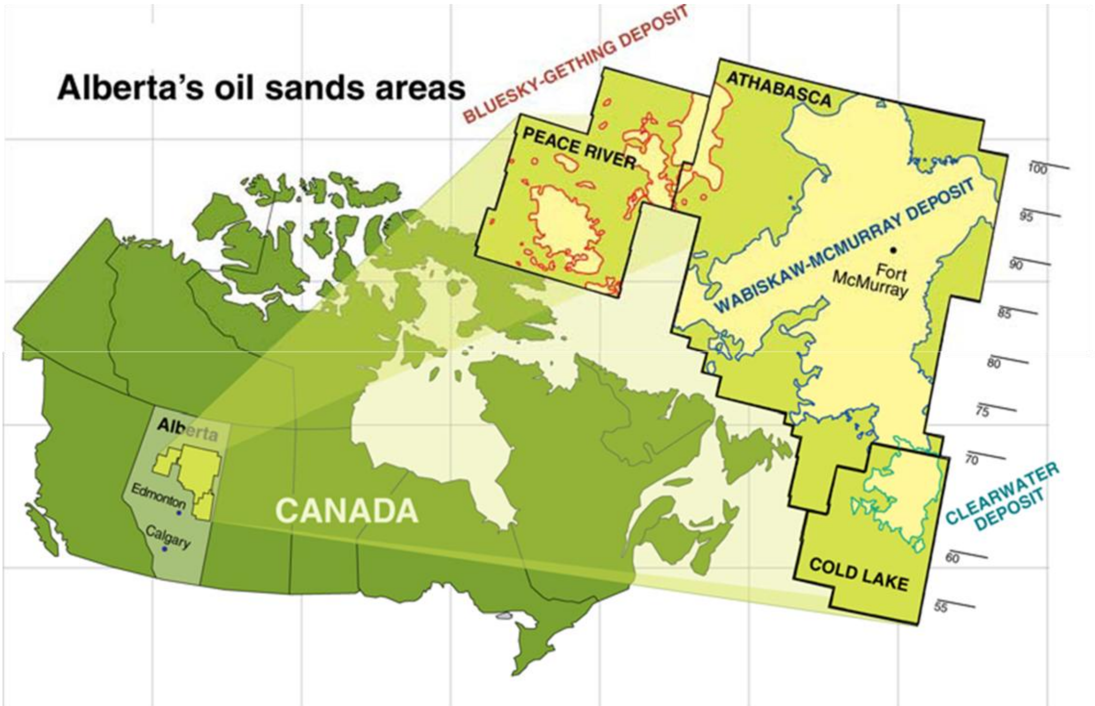
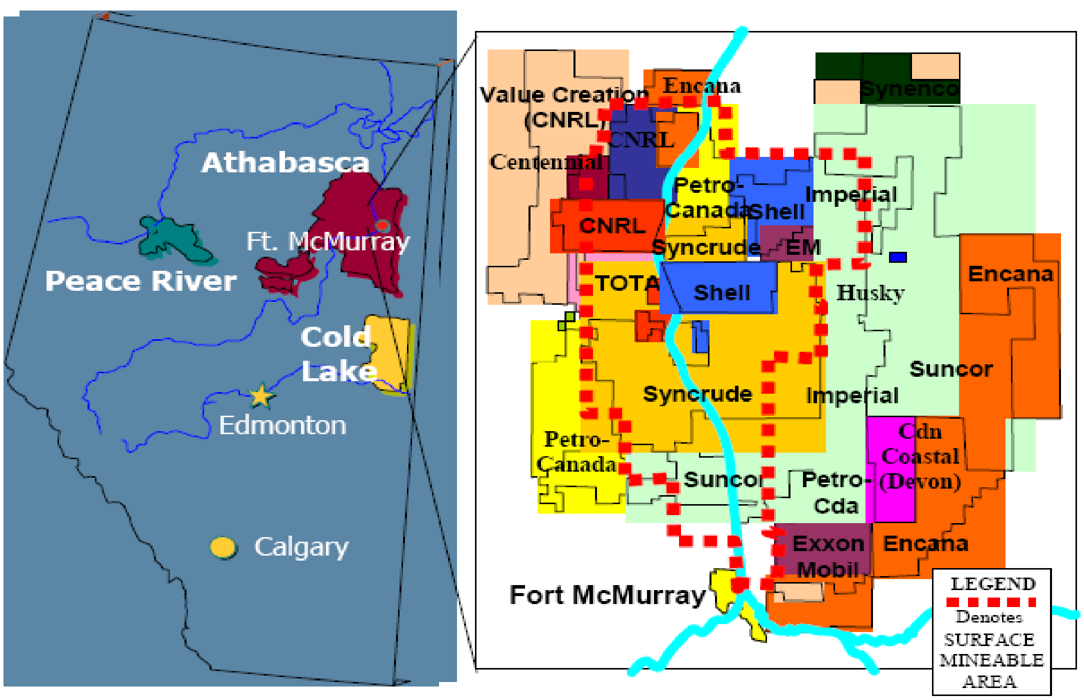


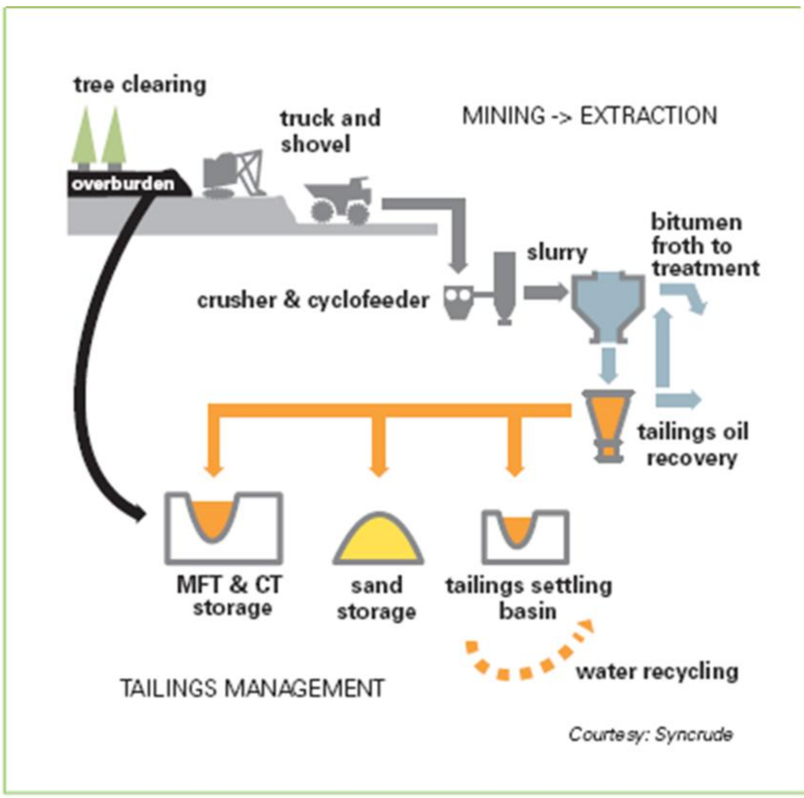
Figure 2.3. Map of Oil Sands Projects (Source: Canadian Association of Petroleum Producers, "Backgrounder: Oil Sands Economic Impacts Across Canada," April 2008, p. 1.)



2.1.3 Methodology for Recovering Bitumen in Oil Sands

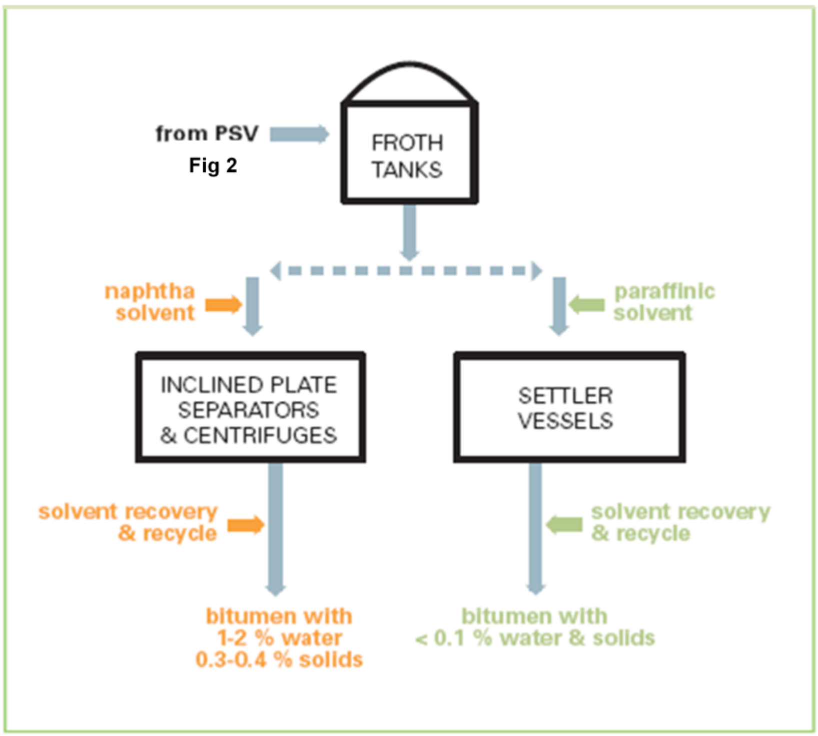
Bitumen in oil sands is recovered in two main ways: surface mining technology and in-situ technology. Oil sands within 75 meters of the surface can be mined by electric or hydraulic shovels and transported by trucks to a crusher and cyclofeeder. The oil sands are mixed with a diluent into a slurry for hydrotransport through pipelines or moved by trucks directly to an extraction facility where the bitumen is separated from the oil sands through a water-based extraction process (ACR, 2004). Figure 2.4 shows the general process of surface mining technology. Through this mining technology, around 90 percent of the bitumen can be recovered.

Figure 2.4. Major Mining Process (Source: Alberta Chamber of Resources, "Oil Sands Technology Roadmap: Unlocking the Potential," January 2004, p. 21.)



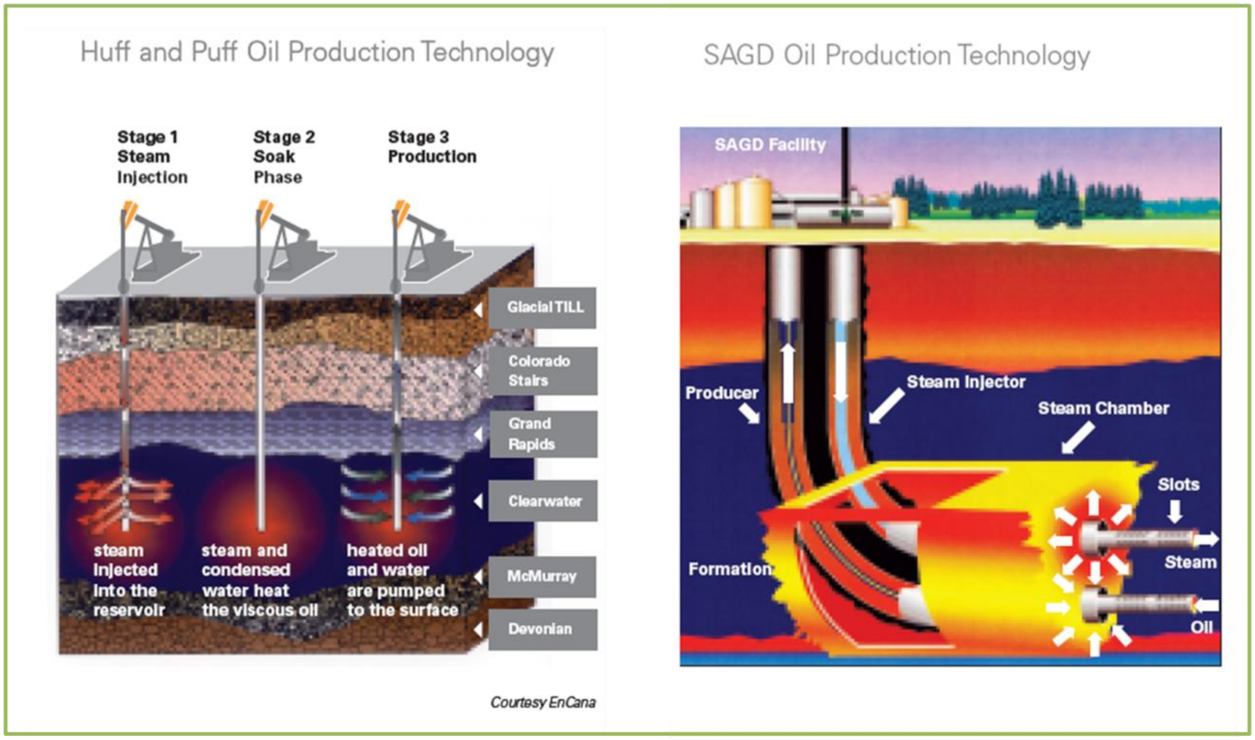
In this extraction process, warm water (75 degrees Fahrenheit) and chemicals separate the bitumen from the oil sands. Extracting the bitumen from the slurry-like oil sands involves two important steps. The first task is the separation of bitumen froth (60 percent bitumen, 30 percent water, and 10 percent fine solids) in a Primary Separation Vessel (PSV). The next step is carrying out the diluted froth treatment, which is a process to recover the bitumen and eliminate as much remaining water and as many solids as possible. In this step, two different approaches, naphtha solvent treatment and paraffinic solvent treatment, can be utilized. The naphtha solvent method uses inclined plate separators and centrifuges to get rid of residual solids and water. The newer method with paraffinic solvent utilizes other process vessels but does not require the employment of high maintenance centrifuges and generates a cleaner product (ACR, 2004). This cleaner bitumen has an appropriate quality for pipeline transport and can be blended more easily with refinery feedstock. Depending on whether or not bitumen passes through an upgrading system, the oil is sold in various forms such as raw bitumen, light crude oil, and Synthetic Crude Oil (SCO) (Humphries, 2008). Figure 2.5 illustrates a major extraction process for separating bitumen from the oil sands.

Figure 2.5. Main Extraction Process (Source: Alberta Chamber of Resources, "Oil Sands Technology Roadmap: Unlocking the Potential," January 2004, p. 23.)



The other technology, in-situ thermal recovery, can be divided into various types such as Cyclic Steam Stimulator (CSS) and Steam-Assisted Gravity Drainage (SAGD), as displayed in Figure 2.6. These two methods work best for the deposits where the oil sands are deeply buried. For in-situ recovery, wells are drilled, then steam is injected into the oil sands reservoir to heat the bitumen. After the viscosity of the bitumen becomes low and it moves like conventional oil, the heated oil and water are pumped to the ground. The Cyclic Steam Stimulator (CSS), also called a "Huff and Puff", is the most widely used in-situ technology, but only 20 to 25 percent of the natural bitumen is estimated to be recoverable. On the other hand, the Steam-Assisted Gravity Drainage (SAGD) has an advantage in terms of recoverability. The Steam-Assisted Gravity Drainage technology, a relatively new method, results in a maximum of 60 percent of the original bitumen being recoverable. Along with its recoverability, the Steam-Assisted Gravity Drainage method is more efficient in terms of a lower steam-to-oil ratio (SOR) and therefore requires less natural gas (NEB, 2004).

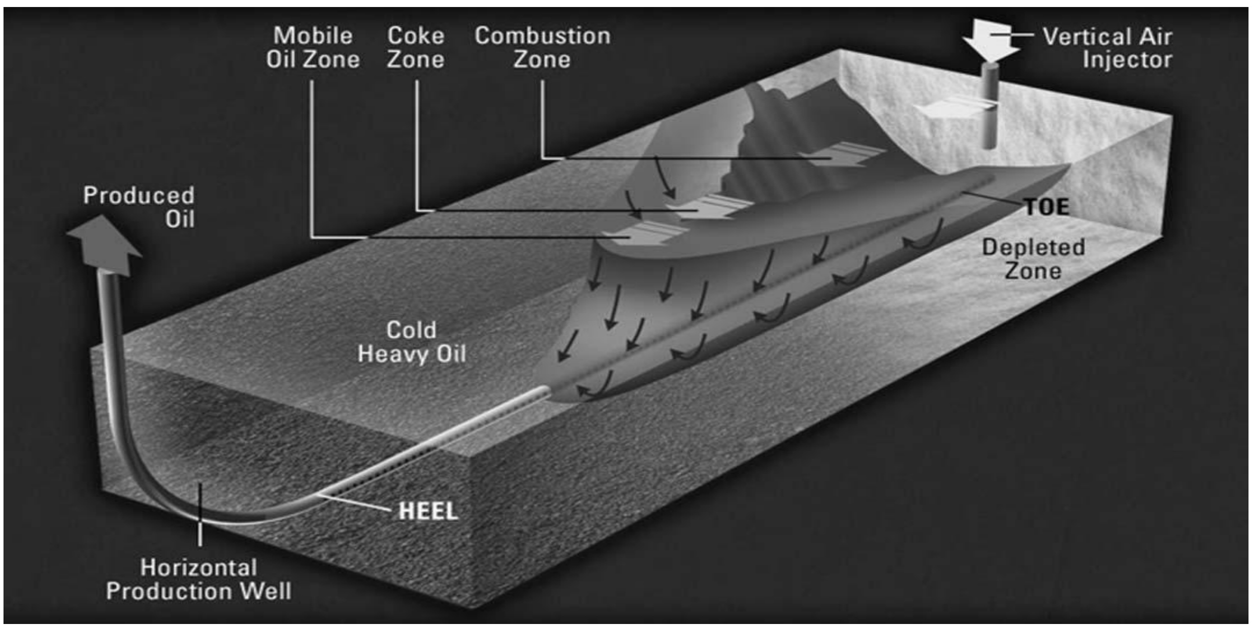
Figure 2.6. In-situ Recovery (Source: Alberta Chamber of Resources, "Oil Sands Technology Roadmap: Unlocking the Potential," January 2004, p. 28.)



There are two new technologies that have the potential to improve the recovery process in terms of cost savings and conserving resources for extracting the bitumen. The first is the Vapour Extraction Process (VAPEX), which injects vapourized solvents such as propane and butane into the reservoir in order to make the bitumen move towards the production well. Through the use of vapourzied solvent instead of steam, this method can achieve its goal without water processing or recycling, and it can reduce carbon dioxide (CO_2) emissions. The effect of cost reduction in the VAPEX technology is roughly calculated to be 75 percent of the capital costs and to be 50 percent of the operating costs compared to the capital and operating costs incurred with the SAGD technology. Moreover, this approach can reduce the consumption of the diluent to mobilize the bitumen.

The other recent in-situ technology is the Toe-to-Heel-Air-Injection (THAI) combustion system, as exhibited in Figure 2.7. This method for in-situ bitumen recovery injects air through a vertical well, and the mobile bitumen by air combustion is pumped through a horizontal well (NEB, 2004). The THAI approach can be a simpler, cheaper, and a more efficient substitute for the SAGD system, but the THAI process has a disadvantage in that it increases CO_2 emissions significantly per barrel of production (McKenzie-Brown, 2009).

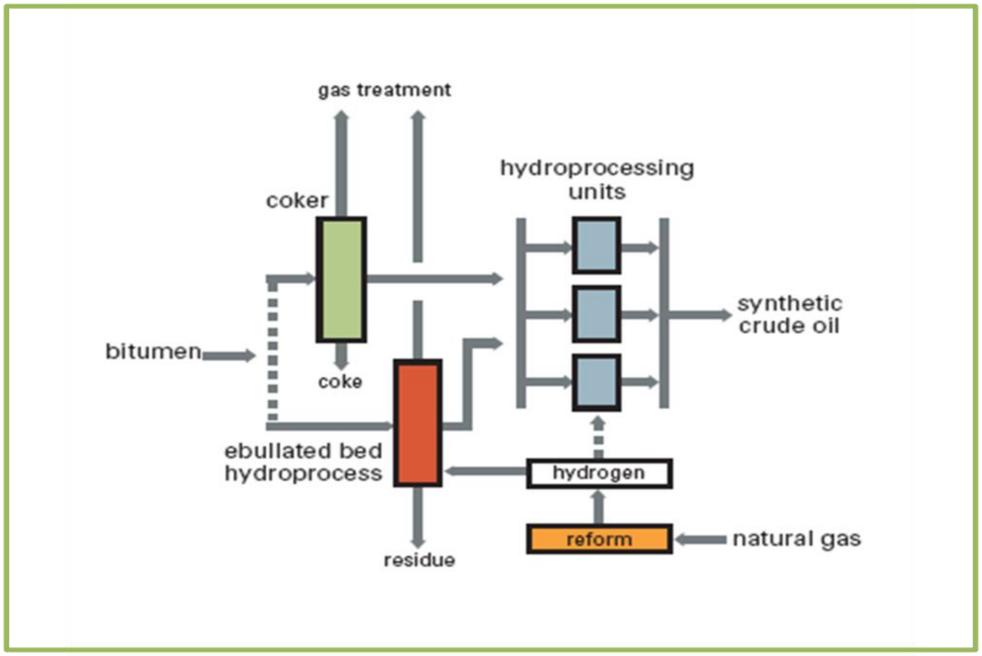
Figure 2.7. THAI Process (Source: Petroleum World, cited in National Energy Board, "Canada's Oil Sands: Opportunities and Challenges to 2015," An Energy Market Assessment, May 2004, p. 109.)



2.1.4 Oil Sands Process: Upgrading and Refining

The upgrading process for bitumen consists of two main procedures: coking to remove carbon and hydro-cracking to add hydrogen, as illustrated in Figure 2.8. Coking is a technique that "cracks" the bitumen by applying heat and catalysts, and this carbon removal method produces light oils, natural gas, and coke (a solid carbon byproduct). After the bitumen is treated in a coker, the coking operation produces a low quality product. This low quality, light oil must be transformed to a lighter gas and distillate in a refinery. Hydrocracking, used often in Canada, is also a process that cracks the oil into light oils, but does not produce coke byproducts. Natural gas is used for conversion to hydrogen in the hydrocracking technology. The output is Synthetic Crude Oil (SCO) that has zero residues, high value for market, and equivalent quality to light crude (Humphries, 2008).

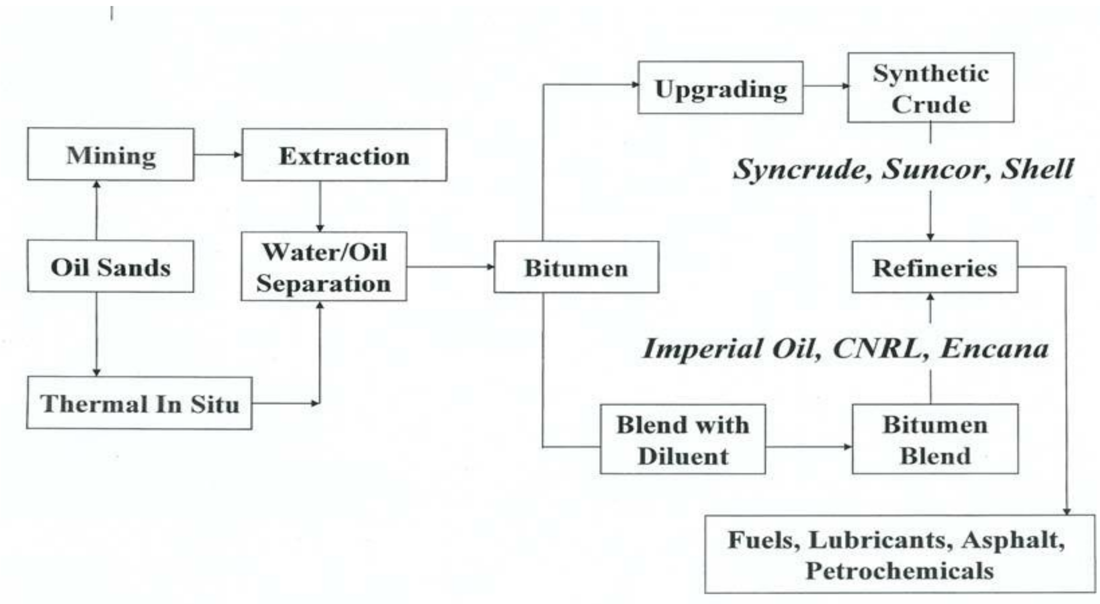
Figure 2.8. Upgrading to Synthetic Crude Oil (Source: Alberta Chamber of Resources, "Oil Sands Technology Roadmap: Unlocking the Potential," January 2004, p. 41.)



In 2008, all the crude bitumen upgraded in Alberta was estimated to be 239 million barrels (38 million m^3) of Synthetic Crude Oil, or 653,000 barrels (103,900 m^3) per day, which means about 59 percent of the raw bitumen produced in Alberta was upgraded to Synthetic Crude Oil in the province (ERCB, 2009).

According to the level of upgrading, the API gravity of the bitumen can be changed, and this change will affect the quality of crude. For example, the bitumen of 20 to 25 degrees API is used for pipeline quality crude through partial upgrading. The API level of the bitumen can also be upgraded to between 30 and 43 degrees through the full upgrade procedure resulting in a level of quality approaching that of conventional crude. An integrated mining operation contains both mining and upgrading processes, and many mining operations own an on-site upgrading facility (Humphries, 2008). For instance, Suncor operates the coking process for upgrading, while Syncrude utilizes both coking and hydrocracking, and Shell utilizes hydrocracking, as depicted in Figure 2.9.

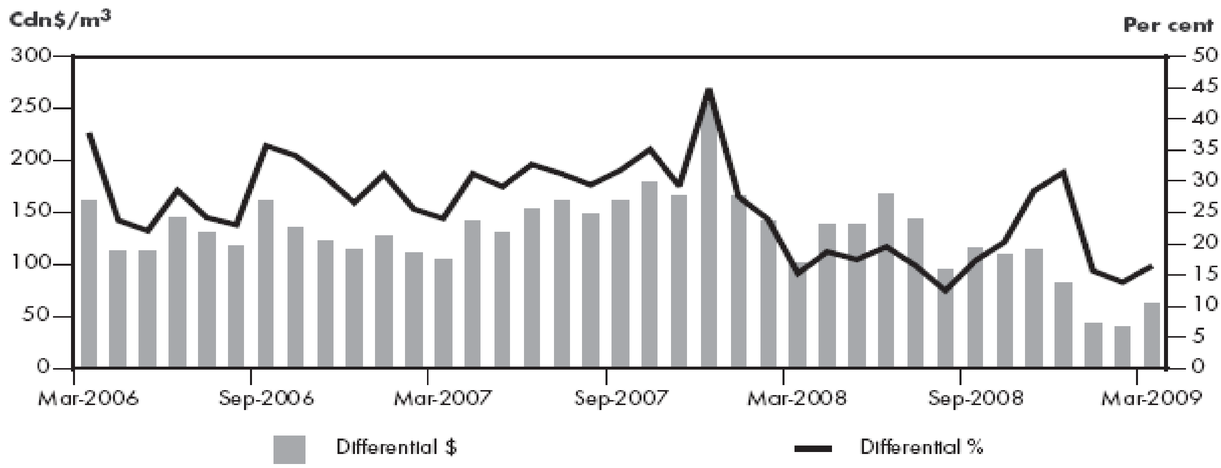
Figure 2.9. Oil Sands Processing Chain (Source: "Overview of Canada's Oil Sands," TD Securities, p. 15., cited in Humphries (2008), "North American Oil Sands: History of Development, Prospects for the Future," Congressional Research Service, p. 15.)



At present, about 60 percent of the bitumen produced in Alberta is upgraded to various products such as SCO, and the remaining 40 percent of bitumen is delivered to other provinces in Canada and states in the United States for further processing (Prebble et al., 2009). There is a major trend to integrate the upgrading process with the refinery, and this kind of integration such as the SAGD production with refinery capabilities can have an effect on cost savings for both mining and in situ producers. Therefore, whether the processing of oil sands continues successfully into the future will depend on how well the industry deals with operating costs related to upgrading and refining effectively (Humphries, 2008).

The high oil price differential between heavy oil and light oil has incited the oil sands producers to increase the capacities of upgrading facilities. For instance, when the price of heavy crude was as inexpensive as $12 per barrel in early 2006 (Humphries, 2008), the light crude oil was about $67 per barrel in the same period (TradingCharts, 2006). The price differential rate was as high as around 38 percent in March, 2006, but the rate changed to approximately 16 percent in March, 2009 (NEB, 2009), as shown in Figure 2.10.

Figure 2.10. Light/Heavy Oil Differential (Source: National Energy Board, “Canadian Pipeline: Transportation System,” Transportation Assessment, July 2009, p. 7.)



However, this volatility in oil price differential can bring about huge problems such as cost overruns from the excessive integrated mining projects or problems associated with expansion, lack of skilled workers, and engineering issues (Humphries, 2008). In other words, this price differential can play a significant role in the decision-making process including whether to build more upgraders and also influencing whether some pipelines should be expanded or new pipelines should be built. Therefore, a robust forecasting analysis associated with the price differential should be conducted in terms of cost efficiency before the integration or expansion of new facilities/infrastructure.

2.2 Cost and Market Analysis

Cost and market analysis must be considered as a core factor in order to understand the value of the oil sands and the potential market demand. In this section, the cost analysis focuses on two main cost elements, namely, operating costs and supply costs. In addition, the market is analyzed in terms of the location and capacity of refineries within Canada and the interrelationship of pipelines transporting crude oil between Canada and the United States.

2.2.1 Operating and Supply Costs

In general, operating costs can be considered as recurring expenses related to the operation. In the oil sands industry, operating costs comprise the removal of overburden, mining and hydro transport, main extraction, chemical treatment, and tailing removal. Moreover, the recovery rate, the amount of overburden, the cost of energy, the distance of transport, and infrastructure maintenance have an effect on operating costs (Humphries, 2008).

Supply costs (also called total costs) are an important factor in deciding the economic potential of the oil sands. According to the glossary of the National Energy Board (NEB), supply costs represent all costs related to resource exploitation and include the capital costs, operating costs, taxes and royalties, and a rate of Return On Investment (ROI) (NEB, 2006). In addition, supply costs are described as a range, reflecting variables such as quality of reservoir, project size, the cost of the recovery process and operating parameters (NEB, 2004).

Both operating costs and supply costs have decreased considerably since the 1970s. In that period, early supply costs were valued around C$35 per barrel (dollar value at that time). Continual process improvements have been accomplished and have resulted in substantial cost reductions. In particular, two main innovations in the production process during the 1990s played an important role in cost reductions. Firstly, trucks and power shovels with more flexibility, robustness, and efficiency replaced the draglines and bucketwheel reclaimers. Secondly, in order to transport oil sands to the processing plant, hydrotransport systems replaced conveyor belts. At present, large efforts are being implemented to maintain stable production by minimizing unexpected maintenance, which can remarkably reduce production capacity and increase operating costs (NEB, 2004).

When compared to conventional oil production, the operating costs in an oil sands project are 30 percent higher than the operating costs for conventional oil production. However, the total cost per barrel of energy from the oil sands project is less than the total cost per barrel of conventional oil production, because the royalty and tax charges from the oil sands projects are extremely low (Humphries, 2008). According to the Energy Market Assessment (NEB, 2006), US$30 to $35 per barrel for West Texas Intermediate (WTI) is needed to obtain a 10 percent Return on Investment.

Table 2.2 indicates a summary of oil sands operating costs and supply costs classified by major recovery processes. Operating costs for mining/extraction processes of bitumen were evaluated at around C$6 to C$10 per barrel (C$2003) and at between C$9 and C$12 per barrel (C$2005). Supply costs for an integrated mining/upgrading type were estimated at about C$22 to C$28 per barrel for SCO (C$2003) and at around C$36 to C$40 per barrel for SCO (C$2005). There was an operating cost increase of up to an average case of C$3 per barrel for the mining/extraction type between the NEB estimates in 2004 and 2006. There has also been a dramatic supply cost increase of up to C$13 per barrel for the integrated mining/upgrading type between the NEB estimates in 2004 and 2006.

As mentioned above, when compared to the 1970s, most of the supply costs categorized by main recovery type decreased with improvements in technologies. However, natural gas prices increased by 88 percent and capital costs also went up by 45 percent between 2003 and 2005 (Humphries, 2008). These facts brought about the general cost increases for the same period.

Operating costs for SAGD in-situ technology were estimated at around C$8 to C$14 per barrel of bitumen (C$2003) and between C$10 and C$14 per barrel in 2005 (C$2005). Supply costs for SAGD in-situ process rose from between C$11 and C$17 per barrel of bitumen (C$2003) to between C$18 and C$22 per barrel of bitumen (C$2005). Using the CSS recovery process, supply costs were evaluated higher at between C$20 and C$24 per barrel of bitumen, an increase from between C$13 and C$19 per barrel of bitumen.

Among in-situ processes, the cost increases/decreases depend heavily on the condition of the reservoir and natural gas prices. However, the oil sands industry is forecasting some cost decreases, because other new technologies such as THAI and VAPEX are more cost-effective than the conventional SAGD system (Humphries, 2008).

Table 2.2. Estimated Operating and Supply Cost by Recovery Type (C$2003 & C$2005 Per Barrel at the Plant Gate) (Source: National Energy Board, "Canada's Oil Sands: Opportunities and Challenges to 2015," May 2004 & June 2006)

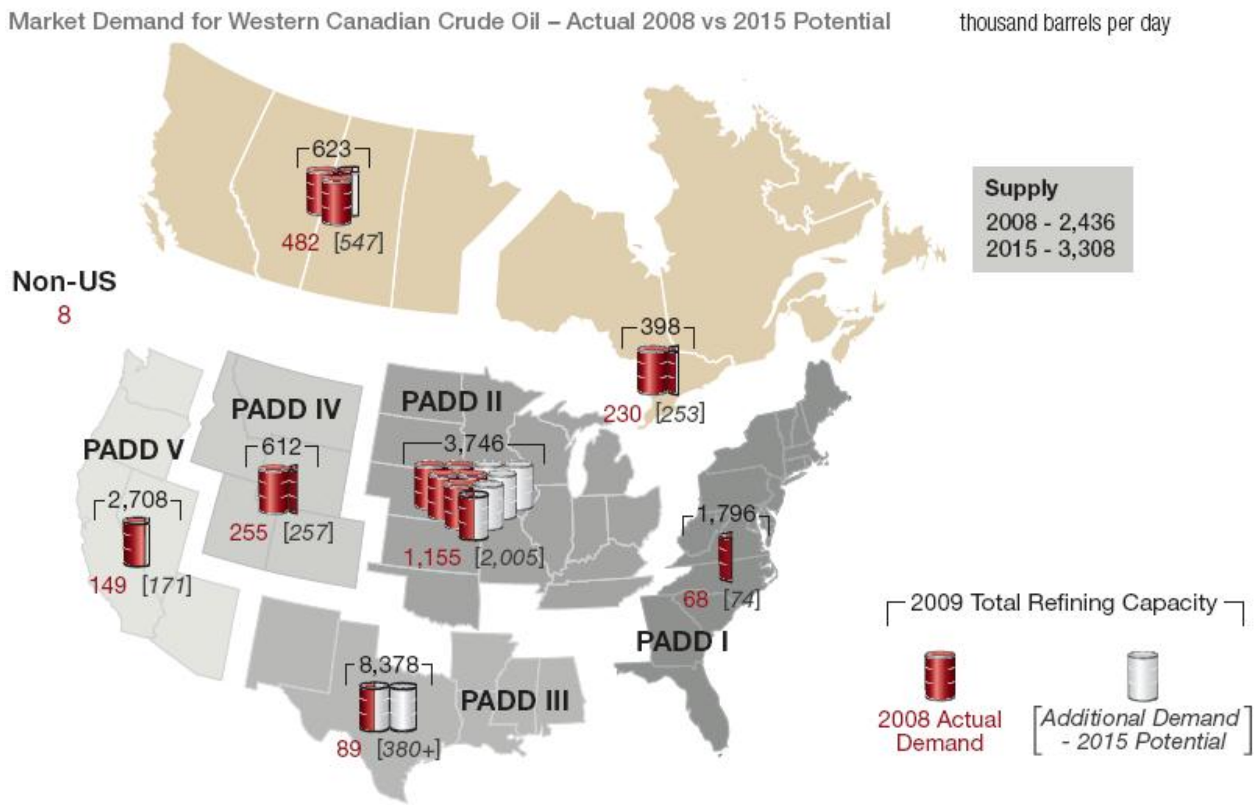
Recovery Type	Crude Type	C$2003		C$2005	
		Operating Cost	Supply Cost	Operating Cost	Supply Cost
Cold Production – Wabasca, Seal	Bitumen	4 to 7	10 to 14	6 to 9	14 to 18
Cold Heavy Oil Production with Sand (CHOPS) – Cold Lake	Bitumen	6 to 9	12 to 16	8 to 10	16 to 19
Cyclic Steam Stimulation (CSS)	Bitumen	8 to 14	13 to 19	10 to 14	20 to 24
Steam Assisted Gravity Drainage (SAGD)	Bitumen	8 to 14	11 to 17	10 to 14	18 to 22
Mining/Extraction	Bitumen	6 to 10	12 to 16	9 to 12	18 to 20
Integrated Mining/Upgrading	SCO	12 to 18	22 to 28	18 to 22	36 to 40

2.2.2 Canadian Markets

A wide range of oil price fluctuations in the past several years have been the key driver in terms of the expansion of the oil sands industry. In this respect, producers will be confronted with difficulties in deciding whether or not pipelines should be expanded to satisfy new and existing markets. Therefore, the evaluation of pipeline projects should be accompanied with an understanding of the potential market demand.

The main markets in Canada for crude oil are currently Alberta, British Columbia, Saskatchewan, and Ontario. According to the Oil & Gas Journal, Canada currently has 18 refineries (EIA, 2009). In addition, the Canadian Association of Petroleum Producers (CAPP, 2009) estimated that the total crude oil supply in refineries in Canada was approximately 2.4 million barrels per day in 2008 with supply increasing to about 3.3 million barrels per day in 2015, as depicted in Figure 2.11.

Figure 2.11. Market Demand for Western Canadian Crude Oil – Actual 2008 vs 2015 Potential (Source: Canadian Association of Petroleum Producers, "Crude Oil: Forecast, Market & Pipeline Expansions," June 2009, p. 9.)



The Energy Market Assessment from NEB in 2006 demonstrated that the refineries in Canada operated at over 90 percent of capacity, mostly to fulfill the needs of the domestic market. Furthermore, it estimated that the Canadian market does not have huge growth potential for oil sands producers because of its outdated refineries and inadequate complexity of refineries (NEB, 2006).

2.2.3 US Markets

The United States, with a refining capacity of approximately 18 million barrel per day, is Canada's largest market for crude oil exports and continues to increase crude oil supply with its refinery capabilities. In 2008, Canada became the largest crude oil exporter to the United States, surpassing Mexico and Saudi Arabia. Canada exported almost 1.9 million barrels per day and the amount of crude oil represents 19 percent of the total US imports. Of this volume, 1.7 million barrels per day were provided from Western Canada (CAPP, 2009), as shown in Figure 2.11.

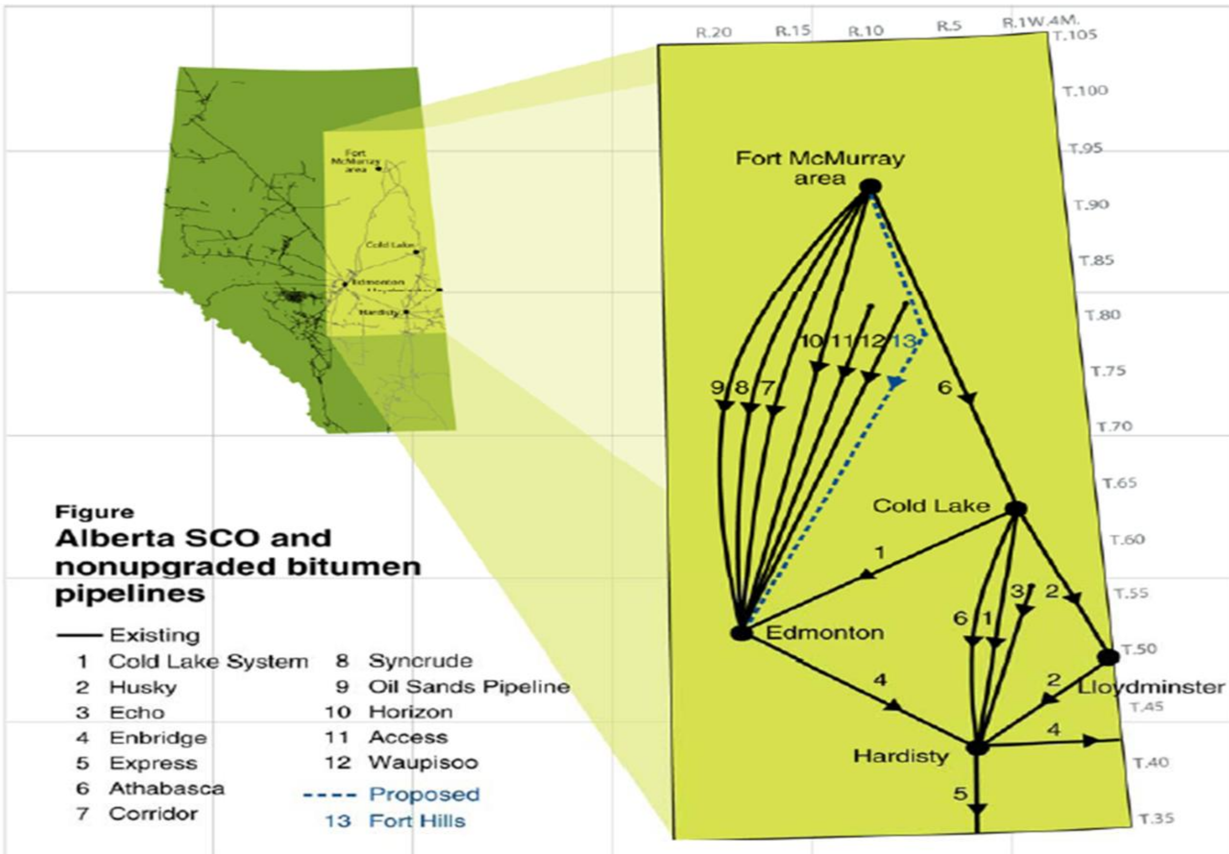
The Edmonton Journal (2008) stated that Alberta exports around 30 percent of the non-upgraded bitumen it produces to the US. According to the National Energy Board (NEB), 75 percent of Canada's nonconventional oil exported to the United States is transported to the Petroleum Administration for Defense District II (PADD, built during World War II to organize and distribute oil to five districts in the US) located in the Midwest. This area has been taking advantage of its better location to obtain larger volumes of nonconventional oil from Canada due to its refinery capacities. If Canada's oil sands production level of 5 million barrels per day in 2030 is achieved and export levels are maintained, the United States will import about 4.5 million barrel per day from Canada or around 30 percent of all US crude oil imports. US refinery capacity is expected to increase from 18 million barrels per day in 2008 to about 19.3 million barrels per day in 2030. Although there is a 1.3 million barrels per day increase, this increase will probably still be insufficient to satisfy larger volumes of oil from Canada (NEB, 2004).

2.2.4 Crude Oil Pipelines

Pipelines have been the major connection between the upstream oil producer and the downstream refiner, and they have been essential to connect the oil sands supply chain since they are the most reliable and efficient way of transporting crude oil. Most pipelines in Alberta transport Synthetic Crude Oil (SCO) and blended bitumen to two primary hub cities, Edmonton and Hardisty within Alberta, as presented in Figure 2.12. These two locations play an important role in distribution of the crude oil from Alberta to other areas of Canada and the United States (ERCB, 2009). Figure 2.12

provides the current pipelines and proposed crude pipeline project in the Athabasca and Cold Lake areas within Alberta.

Figure 2.12. Alberta SCO and Non-upgrade Bitumen Pipelines (Source: Energy Resources Conservation Board, "ST98-2009: Alberta's Energy Reserves 2008 and Supply/Demand Outlook 2008-2018," June 2009, p. 2-24.)



The Edmonton hub has over 6.5 million barrels (1 million m^3) of storage capacity for the several types of crude oil delivered from its linking pipelines (NEB, 2004). With an estimated increase in Synthetic Crude Oil and non-upgraded bitumen in the future, a reasonable expansion of pipeline capacity is vital to market the expected increased volumes of the oil sands products. Through the whole of 2008, pipeline companies made rapid progress both in finishing existing projects and in planning and implementing new projects (ERCB, 2009). Table 2.3 shows the current pipeline capacities in the Cold Lake and Athabasca regions.

Table 2.3. Alberta SCO and Non-upgraded Bitumen Pipelines (Source: ERCB, "ST98-2009: Alberta's Energy Reserves 2008 and Supply/Demand Outlook 2008-2018," June 2009, p. 2-23.)

Name	Destination	Current capacity	
		(10^3 m^3/d)	(barrel/d)
Cold Lake Area pipelines			
Cold Lake Heavy Oil Pipeline	Hardisty	30.8	194,000
Cold Lake Heavy Oil Pipeline	Edmonton	18.7	118,000
Husky Oil Pipeline	Hardisty	21.2	133,000
Husky Oil Pipeline	Lloydminster	36.0	227,000
Echo Pipeline	Hardisty	12.0	76,000
Fort McMurray Area pipelines			
Athabasca Pipeline	Hardisty	62.0	390,000
Corridor Pipeline	Edmonton	47.7	300,000
Syncrude Pipeline	Edmonton	61.8	389,000
Oil Sands Pipeline	Edmonton	23.0	145,000
Access Pipeline	Edmonton	23.8	150,000
Waupisoo Pipeline	Edmonton	55.6	350,000
Horizon Pipeline	Edmonton	39.7	250,000
		432.3	2,721,000

At present, Canada exports crude oil to its markets through three main Canadian trunklines, as depicted in Figure 2.13. Table 2.4 shows the three major Canadian pipelines, their crude types, and their estimated annual capacities.

Table 2.4. Capacity of Major Crude Oil Pipeline (Source: Canadian Association of Petroleum Producers, "Crude Oil: Forecast, Market & Pipeline Expansions," June 2009, p. 19.)

Pipeline	Crude Type	Estimated Annual Capacity (thousand b/d)
Enbridge	Light Heavy	692 1,186
Express	Light/heavy (35/65)	280
Trans Mountain	Light/heavy (80/20)	300
Total		**2,458**

The Enbridge Pipeline, originating in Edmonton, Alberta, has the longest crude oil pipeline system in the world. It transports western Canadian crude oil to the US Midwest and eastern Canada. The Kinder Morgan Express Pipeline originates at Hardisty in Alberta and transports crude to Casper, Wyoming in PADD IV, where it links to the Platte pipeline, which stretches over Wood River, Illinois in PADD II. The Kinder Morgan Trans Mountain (formerly Terasen) Pipeline delivers crude oil and SCO from Edmonton, Alberta, to markets and refineries in British Columbia and Puget Sound in Washington States in PADD V (ERCB, 2009).

Figure 2.13 shows the current export pipelines from Alberta to other areas in Canada and the United States. In addition, it presents new pipeline projects and the proposed expansions needed in order to deliver the increased nonupgraded bitumen and Synthetic Crude Oil production to estimated and expanded markets.

Figure 2.13. Canadian and US Crude Oil Pipelines (Source: ERCB, "ST98-2009: Alberta's Energy Reserves 2008 and Supply/Demand Outlook 2008-2018," June 2009, p. 2-26.)

Oil sands are currently transporting as diluted bitumen through two major pipelines, the Athabasca and the Corridor, to refineries in Edmonton. After arriving at refineries in Edmonton, the bitumen or Synthetic Crude Oil is delivered by one of various pipelines to the United States, as displayed in Figure 2.13. Both the Athabasca and Corridor pipelines have capacities of about 570,000 barrels per day and around 200,000 barrels per day, respectively. These pipeline capacities have been approaching their limits, but Corridor's capacity is expected to increase to approximately 610,000 barrels per day by 2010 according to some expansion projections (Humphries, 2008).

Several new pipeline projects have been proposed or implemented, and these expansions may result in more oil exports from Canada to the United States. With this increase in oil production from oil sands in Canada, the industry has to consider some challenges associated with crude oil prices, costs of projects, types of oil transportation for bitumen blend and synthetic, and capacity of pipelines (NEB, 2006).

2.3 Socio-Economic Impacts

Since the business started, oil sands activities have contributed remarkably to Canada's economy. The capital-intensive characteristics of the oil sands industry in particular brought about massive investments from the oil producers. Major impacts include Gross Domestic Product (GDP) growth, government revenues, and employment development. On the other hand, rapid developments of the oil sands industry have resulted in various social problems in Alberta, including expensive housing, fast population growth, insufficient infrastructure, and poor service.

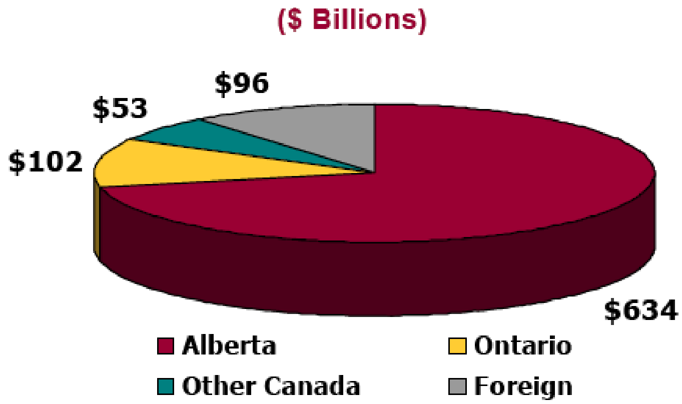
2.3.1 Gross Domestic Product (GDP)

According to the Canadian Association of Petroleum Producers (CAPP), about $8.5 billion was invested in oil sands activities in 2005, with another $8.8 billion being spent in 2006. The oil sands industry expects the annual capital expenditures to be generated in the range of about $8 billion to $12 billion. In addition, the committee announced that oil sands investment will reach $125 billion between 2006 and 2015 (Richardson, 2007).

This huge investment will exert a direct influence on Canada's Gross Domestic Product. The Canadian Energy Research Institute (CERI) has estimated that the total economic impact of oil sands activities will create a GDP benefit of $885 billion between 2000 and 2020. In addition, it has been estimated that other provinces could obtain $155 billion of the GDP profit from oil sands activities

(CAPP, 2008b). Figure 2.14 shows the GDP impact of oil sands expansion in comparison with other provinces.

Figure 2.14. GDP Impact of Oil Sands Development, 2000-2020 (Source: CAPP, "Backgrounder: Oil Sands Economic Impacts Across Canada," April 2008, p. 2.)



CERI has also estimated the overall impact of oil sands activities in terms of GDP, as shown in Table 2.5. In 2006, the total oil sands activities accounted for around three percent of Canada' GDP. Moreover, oil sands activities are expected to increase a share of Alberta's total GDP, comprising about 20 percent of its GDP by 2011 (15% in 2006) (Mourougane, 2008).

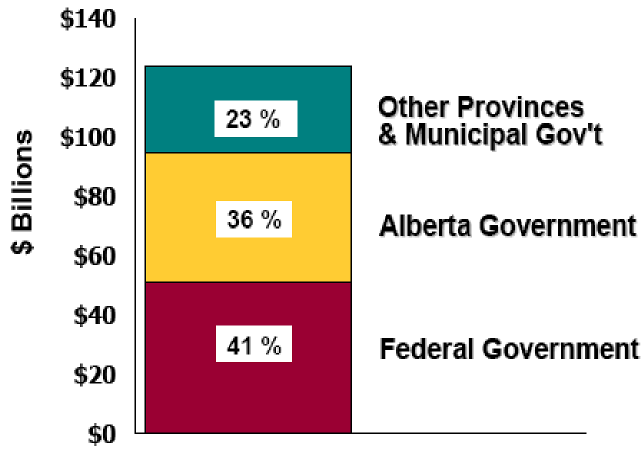
Table 2.5. Economic Impact of Oil Sands (Source: "Economic Impact of Oil Sands in the Short Term," Canadian Energy Research Institute, December 2006, cited in Mourougane (2008), "Achieving Sustainability of the Energy Sector in Canada: Economics Department Working Paper No. 618," Organisation for Economic Co-operation and Development, June 2008, p. 11.)

	2006	2011	2020	2006
	CAD billion			% of 2006 national GDP
GDP				
Total	44	69	104	3.0
Alberta	32	49	77	2.2
Rest of Canada	7	11	14	0.5
Rest of the world	5	9	13	0.3

2.3.2 Government Revenues

Various economic spin-offs from oil sands activities generate significant taxes for Alberta and other governments in Canada. CERI has estimated that total government revenues will reach $123 billion between 2000 and 2020, as presented in Figure 2.15. The revenues include corporate tax, income tax, provincial sales tax, GST, property tax, and royalties from oil sands investment and development. The government shares of revenues account for 41 percent for the Federal Government, 36 percent for the Alberta Government, and 23 percent for other provinces and municipalities combined, respectively.

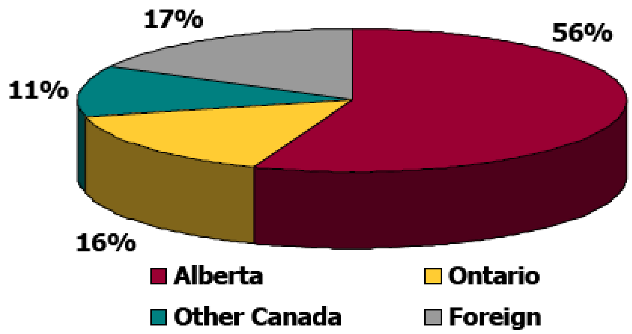
Figure 2.15. Government Share of Revenues, 2000-2020 (Source: CAPP, "Backgrounder: Oil Sands Economic Impacts Across Canada," April 2008, p. 3.)



2.3.3 Employment

CERI has estimated that oil sands activities will create roughly 6.6 million person years of work in Canada during 2000 to 2020 (Government of Alberta, 2008). The research from CERI shows that oil sands activities has resulted in significant creation of jobs within various sectors such as retail and manufacturing in other provinces and countries. In particular, as a result of oil sands development, the number of jobs created outside of the oil and gas sector will rise to be four times more than the number of jobs created within the sector. For instance, oil sands activities in Alberta have had a positive effect on employment outside of Alberta, forming 44 percent of the total employment impact, with 16 percent of the employment in Ontario, as displayed in Figure 2.16 (CAPP, 2008b).

Figure 2.16. Employment Impact of Oil Sands Development, 2000-2020 (Source: CAPP, "Backgrounder: Oil Sands Economic Impacts Across Canada," April 2008, p. 2.)



2.3.4 Housing and Population Growth

According to a recent report from the Canada Mortgage and Housing Corporation (CMHC), oil sands development has driven up Fort McMurray's housing costs to a point where they exceed the rest of Alberta's. For example, in December 2007, while the average price of a single family residence in Edmonton was $382,000, in Fort McMurray the price was almost double at $632,000. That's comparable to the average rent for a two bedroom apartment in October 2007, where in Edmonton it cost $958 while in Fort McMurray the average was more than double at $2,085.

Fort McMurray's population growth is significantly driven by the job opportunities generated through the expansion of oil sands industry. In general, as oil sands employment increases, so too does supplier employment, and the economy overall. Fort McMurray's population, which was 34,000 in early 1996, was roughly 64,000 in May, 2006, clearly in response to oil sands industry growth. If all of the planned oil sands projects go forward according to schedule, Fort McMurray's population will increase to 110,000 in the next decade and approach 130,000 by 2021 (Government of Alberta, December 2007). More than 700,000 people relocated to Alberta between 1996 and 2006, causing a $7 billion infrastructure deficit in roads, hospitals, and schools (Nikiforuk, 2008).

2.3.5 Infrastructure and Services

Alberta's high living costs, such as expensive housing, hampers private and public service sectors' recruitment efforts. Many organizations had increased workloads because they were understaffed. Positions were not filled, and funding cannot match service demands (Government of Alberta, December 2007). According to Dr. Michel Sauvé, the President of the Fort McMurray Medical Staff Association, Northern Lights Health Region encounters three times more hospital bed shortages than its provincial counterparts. Moreover, 78 doctors covered 6,000 patients, a doctor-patient ratio of 1 to 1,579 – three times lower than that of Mexico, China, Argentina, and Uzbekistan, which is a much worse ratio than in many third world countries. In addition, by 2006 more than one third of Wood Buffalo's population sought medical assistance outside the area due to the fact that it had the highest number of patients per doctor in Canada (4,500), although the World Health Organization suggests 600 as the recommended number (Nikiforuk, 2008).

School is one of society's most important institutions. However, Fort McMurray has an abnormal school/student ratio: 449 students per a school, compared with the ratio for Red Deer, Lethbridge, and Medicine Hat, 1:437, 1:414, 1:351, respectively (Radke, 2006).

Availability of major social services in a community is also a significant factor to consider in addressing growth in the oil sands areas. The homeless population in Wood Buffalo has grown by 24 percent since 2004. Table 2.6 shows that Fort McMurray, proportionally, has the largest homeless population of Alberta's main cities.

Table 2.6. Homeless Population of Five Main Alberta Cities (Source: Fort McMurray Housing Needs Count 2006, cited in Radke (2006), "Investing our Future: Responding to the Rapid Growth of Oil Sands Development," Government of Alberta, December 2006, p. 98.)

City	Population	Number of homeless	Number of homeless/65,000 population
Calgary	1,000,000 (2006)	3436	223
Edmonton	712,391 (2005)	2618	239
Red Deer	82,971 (2006)	128	100
Fort McMurray	64,441 (2006)	441	441
Grande Prairie	44,631 (2005)	179	259

A shortage of child-care facilities in oil sands regions is another social service problem. In fact, waiting lists had 200 to 250 children in Fort McMurray. Recently child-care fees in Fort McMurray were $845/child/month, much higher than Edmonton's ($589/child/month), even though subsidy rates were equal across the province (Radke, 2006). Lack of social consensus and economic participation for aboriginal people, traffic congestion, and inflation have been additional current social issues that must be addressed to sustain oil sands development.

2.4 Environmental Impacts

Some of the most serious impacts of the oil sands development are environmental. Although oil sands have a huge potential to be Canada's competitive advantage in terms of energy, Canada could also suffer serious ecological damage from being an energy superpower. Therefore, the environmental challenges related to oil sands must be carefully considered and energetically countered.

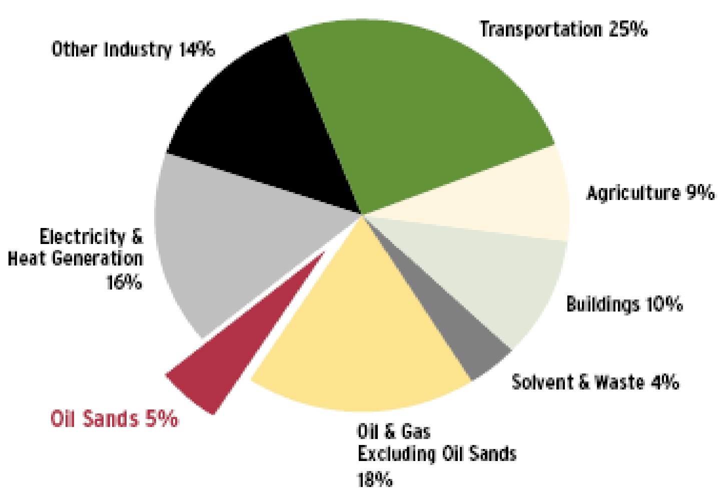
2.4.1 Greenhouse Gas Emissions (GHG) Emissions

In 2005, Canada ranked ninth in the world, contributing two percent of the world's total global greenhouse gas (GHG) emissions, as shown in Table 2.7, even though Canada has only 0.5 percent of the world's population. Within Canada, oil sands amount to five percent of the country's total GHG emissions (CAPP, 2008a), as depicted in Figure 2.17.

Table 2.7. Top-10 Countries of GHG Emission in 2005 (Unit: megaton CO_2 equivalents (megaton = million metric ton)) (Source: Based on information from the UNFCCC; IEA (fuel), EDGAR 3.2/4.0 (other) as in IEA (2007), posted in Netherlands Environmental Assessment Agency, June 2010)

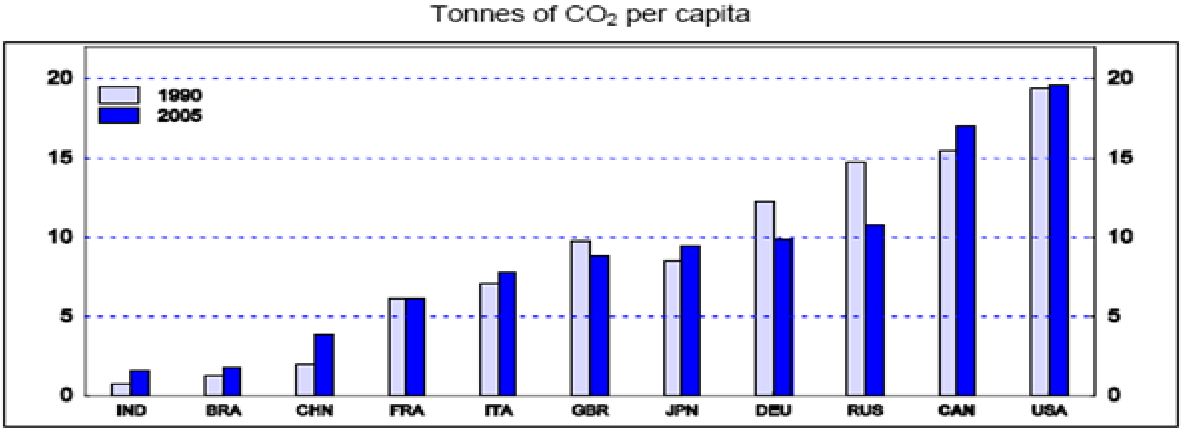
Rank	Country	Total GHG	Share in global total
1	China*	7480	17%
2	United States ®	7240	16%
3	European Union - 27 ®	5180	11%
4	Indonesia**	2870	6%
5	India	2380	5%
6	Russia ®	2130	5%
7	Brazil	1860	4%
8	Japan ®	1360	3%
9	Canada ®	750	2%
10	Mexico	680	2%

Figure 2.17. Canada's GHG Emissions by Sector (Source: Environment Canada, cited in CAPP, "Environmental Challenges and Progress in Canada's Oil Sands," April 2008, p. 4.)



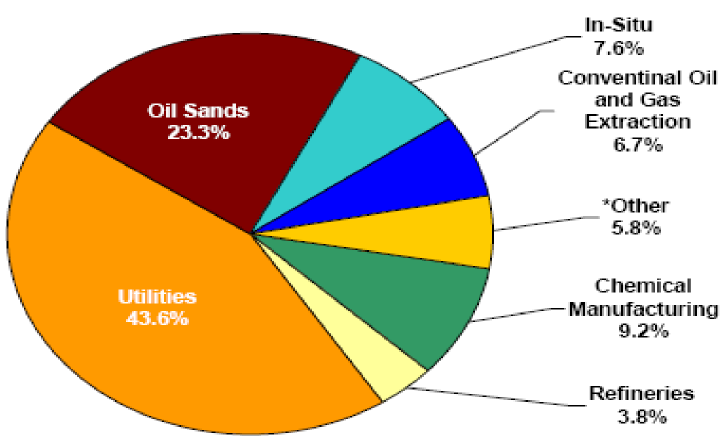
However, when the GHG emissions are compared with emissions per capita, Canada becomes one of the countries with the highest GHG levels of emissions, as shown in Figure 2.18. The Federal Government of Canada categorized the oil sand industry as a large GHG emitter (i.e., emitting more than 8,000 tonnes of CO_2 per year) in the Climate Change Plan for Canada of 2002 (NEB, 2004).

Figure 2.18. Emission per Capita (Source: International Energy Agency, CO2 Emissions from Fuel Combustion, 1971-2005, Paris, 2007 Edition, cited in Mourougane (2008), "Achieving Sustainability of the Energy Sector in Canada: Economics Department Working Paper No. 618," Organisation for Economic Co-operation and Development, Jun 2008, p. 9.)



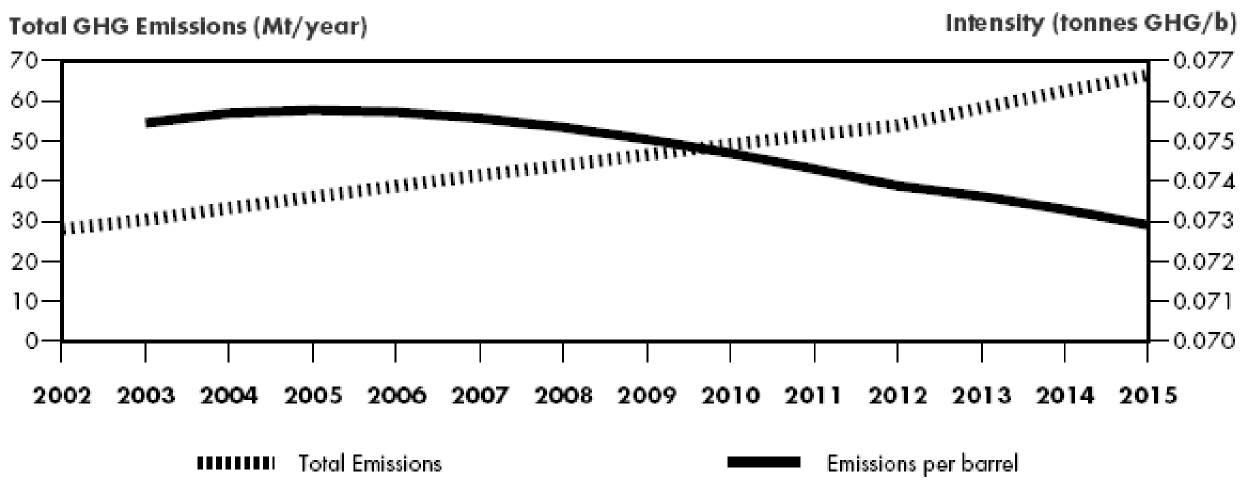
In particular, oil sands industries were ranked second in all the utilities sectors in Alberta, accounting for 23.3 percent of total Alberta's greenhouse gas (GHG) emissions (Alberta Environment, 2008), as displayed in Figure 2.19.

Figure 2.19. Alberta GHG Emissions by Industrial Sector, 2007 (Source: Alberta Environment, "Specified Gas Reporting Regulation: Alberta Environment Report on 2007 Greenhouse Gas Emissions," 2008, p. 8.)



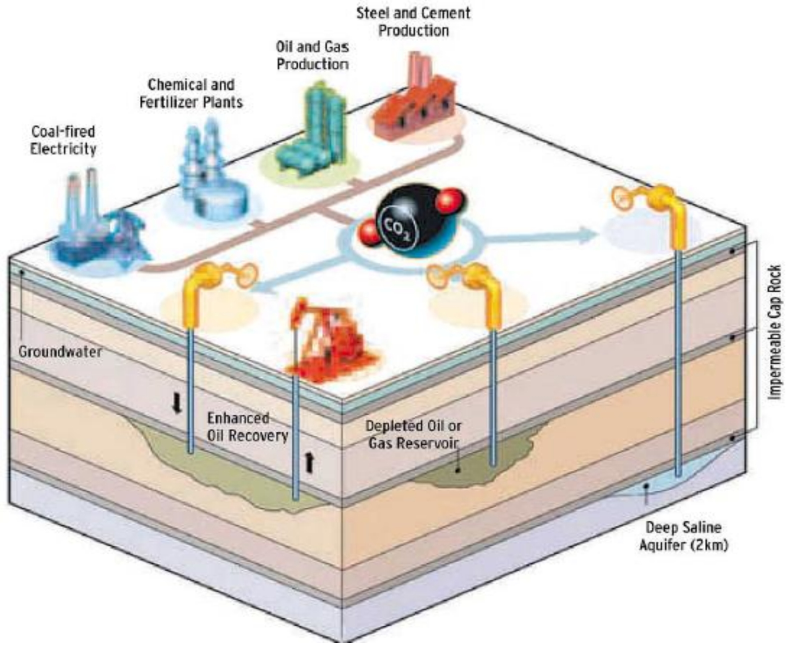
In general, oil sands industries are producing almost 40 million tonnes of GHG emissions every year. Under a business-as-usual assumption, Canada's GHG emissions will increase to 12 percent, from 756 million tonnes in 2006 to 937 million tonnes in 2020 – regardless of the fact that GHG emissions per barrel from oil sands are decreasing steadily, as depicted in Figure 2.20. In this case, the GHG emissions from oil sands are expected to increase nearly three times in 2020, to 108 million tonnes per year, and account for 44 percent of Canada's growth in emissions (Grant et al., 2009).

Figure 2.20. Projected GHG Emissions from Oil Sands (Source: Pembina Institute, cited in National Energy Board, "Canada's Oil Sands: Opportunities and Challenges to 2015: An Update," An Energy Market Assessment, June 2006, p. 39.)



As a matter of course, the oil sands industry is trying to reduce GHG emissions since their emissions have become an issue. According to the CAPP (2008a), since 1990, oil sands producers have decreased oil sand CO_2 intensity by 27 percent. At present, Carbon Capture and Storage (CCS) technology has received attention from governments, stakeholders, industry, and researchers as a core methodology to remarkably reduce GHG emissions in the future, as shown in Figure 2.21.

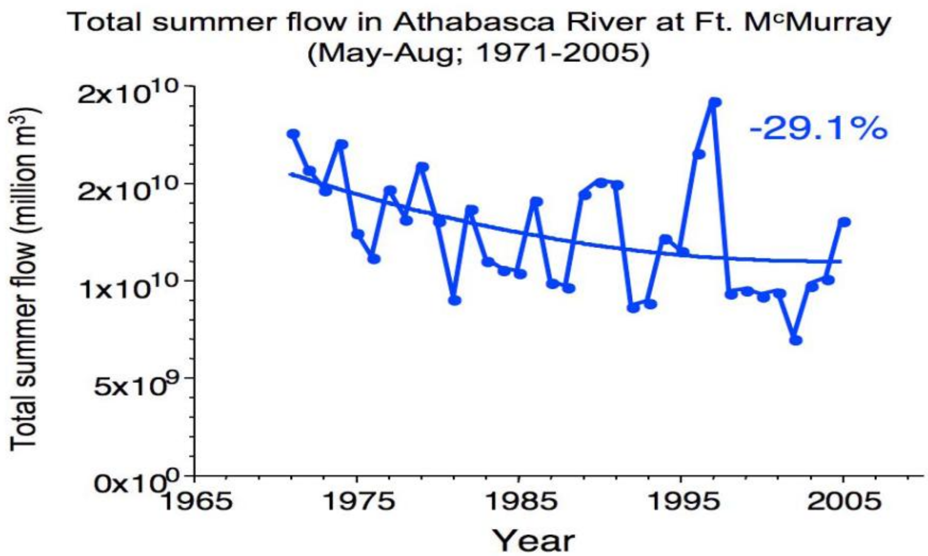
Figure 2.21. Carbon Capture and Storage (Source: Suncor 2007 Progress Report on Climate Change, cited in CAPP, "Environmental Challenges and Progress in Canada's Oil Sands," April 2008, p. 6.)



2.4.2 Water Usage and Quality

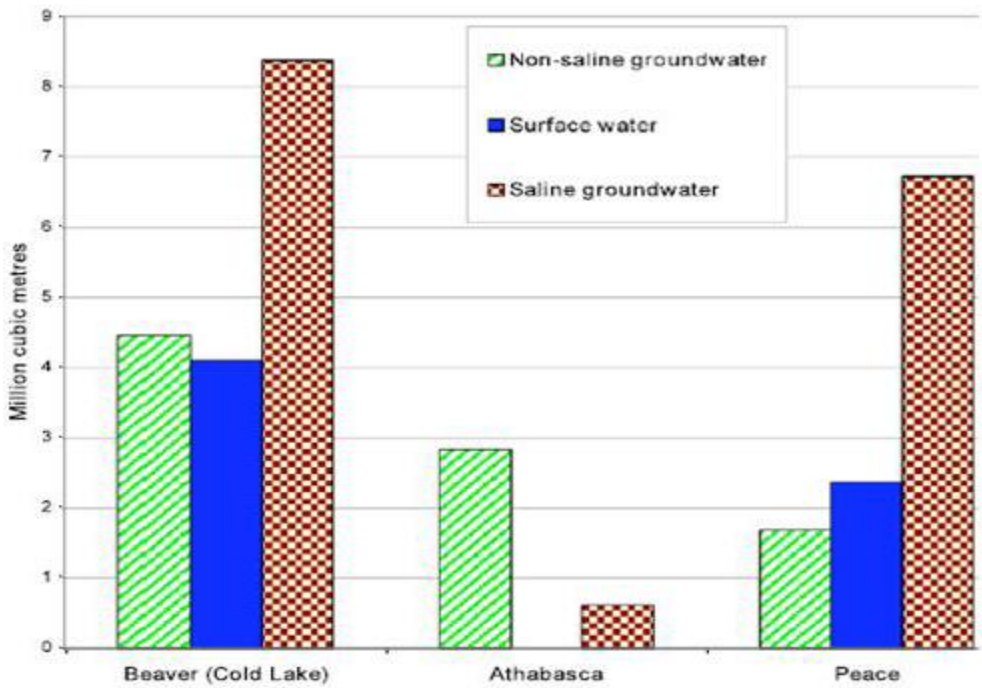
In the past century, river flows in the prairie provinces have declined. In particular, summer flows between May and August in the Athabasca River at Fort McMurray had decreased by 29 percent from 1970 to 2005, as presented in Figure 2.22. The decrease during summer flow has been less than that of any other river from the eastern slopes of Canada's Rocky Mountains, possibly because water from the Athabasca River above Fort McMurray is rarely withdrawn (Schindler et al., 2007). In addition, according to the Alberta government's 2006 report, the Athabasca River may not have enough capacity over the long term to sustain all the demand of planned mining operations and simultaneously maintain sufficient stream flows (Radke, 2006). The report also mentioned that Alberta Environment has not been successful in providing timely advice and direction with regard to water use. Moreover, the World Wildlife Fund (2006) warns that warming temperature will have a negative impact on both water quantity and quality in the area.

Figure 2.22. The Decline in Average Summer Flow in the Athabasca River (Source: Schindler et al. (2007), "Running out of Steam? Oil Sands Development and Water Use in the Athabasca River-Watershed: Science and Market based Solutions," University of Alberta, May 2007, p. 17.)



Heavy use of water in the oil sands industry is one of the most important concerns because insufficient water supply and inappropriate water disposal can have serious effects on Canada's water security. For a barrel of bitumen obtained through surface mining, about two to three barrels of water are withdrawn from the Athabasca river (Humphries, 2008) and around 85 percent of the water used in mining process is recycled (CAPP, 2008a). On the other hand, in-situ technology has greatly reduced water consumption, resulting in only 0.9 barrels of water being used per barrel (Prebble et al., 2009). Furthermore, about 90 to 95 percent of the water consumed in SAGD is recycled (Humphries, 2008). In order to minimize the new freshwater consumption, the in-situ projects utilize 50 percent of the water used from saline groundwater, as depicted in Figure 2.23. Nonetheless, the water consumption in oil sands industry is very high in comparison with the water use for conventional oil production where each barrel of conventional oil requires about 0.1 to 0.3 barrels of water consumption (Prebble et al., 2009).

Figure 2.23. Water Consumption for In Situ Method (Source: Alberta Environment, Personal Communication, November 7, 2008, cited in Prebble et al. (2009), "Carbon Copy: Preventing Oil Sands Fever in Saskatchewan," Pembina Institute, Saskatchewan Environmental Society, Canadian Parks and Wilderness Society, August 2009, p. 16.)



As of 2007, eight percent of all the surface water in Alberta is licensed for withdrawals for all purposes (Nikiforuk, 2008). The oil sands are consuming around one percent of the Athabasca's average flow, enough water to sustain a city of two million people every year (Woynillowicz et al., 2006), and its consumption from the river is forecasted to be about two percent in the future. However, the largest use – two thirds of all water consumption from the Athabasca River – is consumed for the oil sands industry (CAPP, 2008a), and less than 10 percent of the water used for oil sands industry is turned back to the Athabasca River (Richardson, 2007). As the production from oil sands in Canada is predicted to increase rapidly, water consumption is also expected to grow at an incredible rate. In short, reducing the water consumption and increasing the water return volume is a major challenge that must be resolved for the oil sands development.

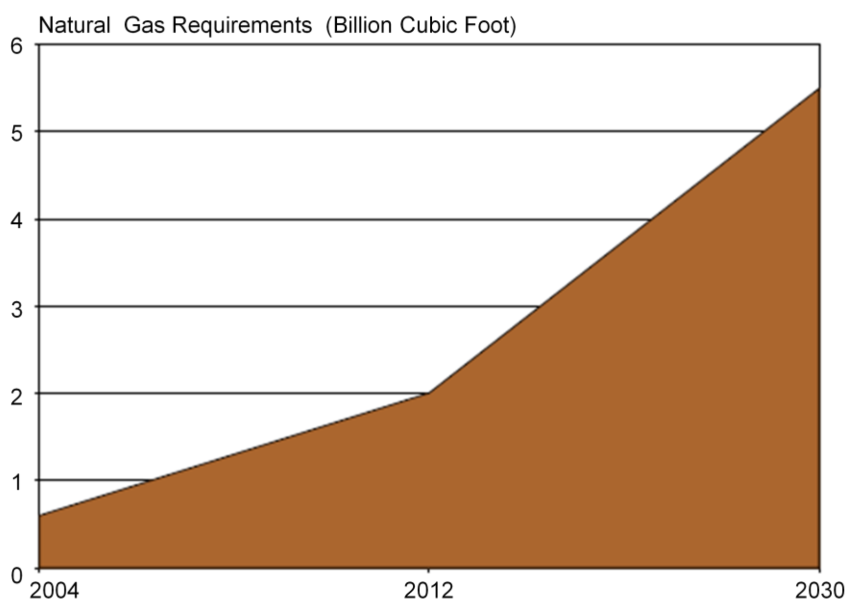
Water quality is affected not only by changes to water quantity, but also by point source or non-point source inputs (Alberta Environment, 2007). Since the mid-1990s, it is not known whether increases in oil sands mining and activity have caused any changes in polycyclic aromatic hydrocarbon (PAH) loading (Schindler et al., 2007). Moreover, Alberta has very few groundwater monitoring wells for long-term inspections, so there is no acceptable baseline data for groundwater conditions in the oil sands development area (Prebble et al., 2009).

The oil sands development has many risk factors in terms of water quantity and quality with regard to surface water, groundwater, and the health of aquatic ecosystems. Furthermore, the impacts and challenges with respect to water quantity and quality in Canada's oil sands development must be considered as a vital concern at both the provincial and national levels. In order to address these issues, managing the timing and progress of future plans is very important for government and industry to ensure the protection of Athabasca River in terms of water quantity and water quality.

2.4.3 Overconsumption of Natural Gas

Along with GHG emissions and compromised water supplies, the overconsumption of natural gas is yet another significant challenge facing the oil sands industry. In the past, Canada had abundant natural gas, a relatively cheap and clean fuel. With these benefits, the oil sands producers used natural gas as a fuel in order to extract or upgrade bitumen. However, with fast development in the oil sands industry, natural gas consumption has been significantly increased, as shown in Figure 2.24, leading to depleted supplies, reduced supplies, and increasing cost.

Figure 2.24. Increase in the Consumption of Natural Gas (Source: Woynillowicz et al. (2005), "Oil Sands Fever: The Environmental Implications of Canada's Oil Sands Rush," Pembina Institute, November 2005, p. 16.)



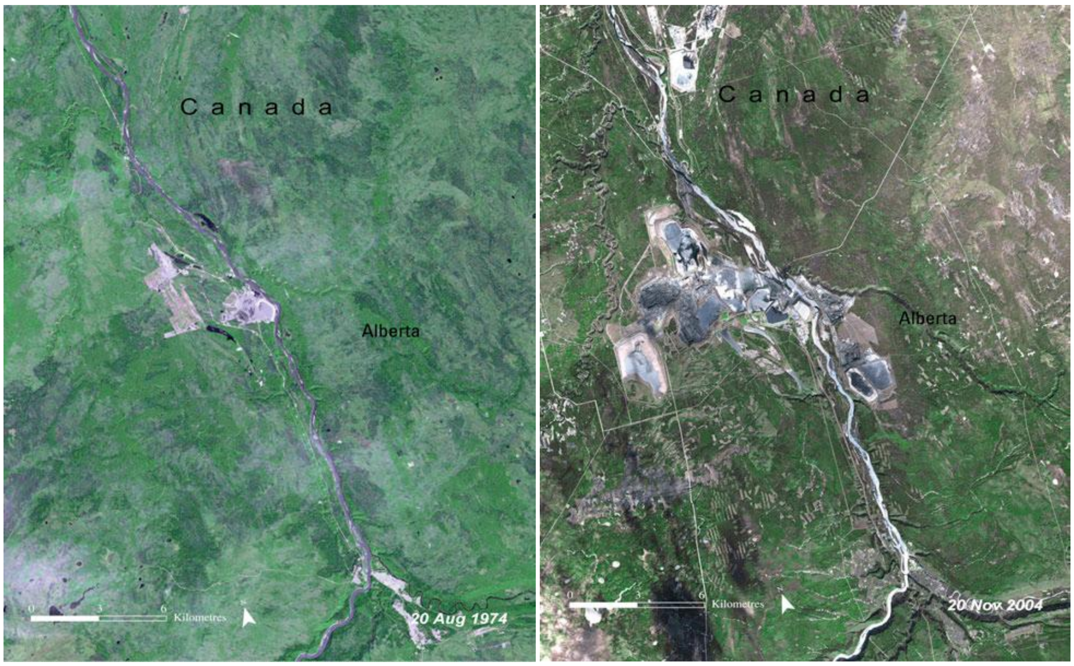
In general, the oil sands industry uses approximately 0.6 billion cubic feet of natural gas every day, enough to heat 3.2 million Canadian homes daily. In 2012, around two billion cubic feet of natural gas will be consumed per day to produce two million barrels of oil every day, enough to heat all Canadian homes for a day (Woynillowicz et al., 2005). At present, natural gas plays an important role in the operating costs of oil sands plants because of rapidly increasing and high price levels. Recent estimates show that producing a barrel of oil demands between $3.5 and $7.0 worth of natural gas. Additionally, producing a barrel of Synthetic Crude Oil (SCO) requires between 500 to 1,000 cubic feet of natural gas (Richardson, 2007).

Many studies have forecasted the production and consumption of natural gas, and the Energy Future Network is a representative non-profit organization that carries out research on broad energy issues for the Alberta Department of Energy. The organization has applied the Canadian Energy System Simulator (CanESS) from the whatif? Technologies (2010), a consulting and software company, as its analysis tool. The CanEss has been employed to run a variety of energy system scenarios based on future consumption of natural gas in Alberta and Canada. A recent whatif? simulator analysis showed that Canada will be forced to import natural gas somewhere between 2023 and 2030 (McKenzie-Brown, 2009). In summary, natural gas, seen as an environment-friendly fuel, should be utilized more efficiently because of this characteristic, and finding and adopting an alternative such as nuclear energy should be an urgent priority.

2.4.4 Land Reclamation and Tailing Ponds

Developing and operating the oil sands industry demands many environmental sacrifices. In particular, the oil sands industry can disrupt the land and the landscape and ecosystems over huge areas. The scale of disrupted land from mining operations is estimated to be as extensive as 3,500 square kilometers. Currently, around 856,000 barrels of bitumen is produced every day in the Athabasca Boreal area. From 1967 to 2006, 47,832 hectares of boreal forest in Alberta were disturbed for mining to extract bitumen through surface mining technology, only 14 percent of the surface that could be mined. As of 2006, it had been estimated that only 6,498 hectares (13.6 percent) of the disrupted region were reclaimed according to oil sands developer’s standards, with no valid reclamation guideline in place. To date, only one oil sands company has requested certification of land reclamation and has been certified by the Alberta Government. The proportion of reclaimed land is just 0.2 percent of the total land disrupted by mining (Grant et al., 2008). The in-situ method of extraction might make the degradation of the landscape appear less serious. However, in-situ operations require more infrastructure such as roads, transmission lines, and pipelines, so it can also affect both flora and fauna negatively over the long term (Richardson, 2007). Figure 2.25 shows the changes to boreal forest in Alberta.

Figure 2.25. The Change of the Boreal Forest between 1974 and 2004 (Source: Grant et al. (2008), "Fact of Fiction: Oil Sands Reclamation," Pembina Institute, December 2008, p. 7.)



Along with land reclamation, tailing ponds are also another environmental threat because tailings may percolate to groundwater, or might contaminate the surface water and the soil through leakage. After bitumen is extracted from oil sands, the remaining materials – residual sands and polluted water – are sent to settling ponds, called tailing ponds. In general, toxic tailing waste of 1.8 billion litres (1.8 million cubic meters) is produced a day. Up to now, these tailing ponds have been one of the world's largest human constructions, covering around 130 square kilometers. Considering both approved and planned projects, the total size of tailing ponds will reach 220 square kilometers, five times greater than Sylvan Lake in Alberta. The volume of tailing ponds may increase to 11,648 million cubic meters, as presented in Table 2.8 (Grant et al., 2008).

Table 2.8. Tailing Ponds for Existing and Planned Mines in the Athabasca Boreal Area (Source: Grant et al. (2008), "Fact of Fiction: Oil Sands Reclamation," Pembina Institute, December 2008, p. 39.)

Mine Project	Number of Ponds	Total Tailings Pond Volume (million m^3)	Total Tailings Pond Area (ha)
Suncor Voyageur South[202]	10	1,547	4,430
Suncor Millennium Mine	Unknown	Unknown	Unknown
Petro-Canada Fort Hills[203]	3	4,172	1,600
Syncrude Mildred Lake Mine	Unknown	Unknown	Unknown
Syncrude Aurora North Mine	Unknown	Unknown	Unknown
Syncrude Aurora South Mine	Unknown	Unknown	Unknown
Albian Sands Muskeg River Mine[204]	5	659	1,039
Albian Sands Muskeg River Mine Expansion[205]	1	520	1,316
Shell Jackpine Mine Phase 1[206]	2	516	1,600
Shell Jackpine Mine Phase 2[207]	2	1,010	2,520
Shell Pierre River Mine[208]	5	620	1,585
Imperial Oil Kearl Lake Mine[209]	1	950	2,200
CNRL Horizon Mine[210]	1	1,186	3,580
Synenco Northern Lights Mine[211]	1	173	1,180
Total Joslyn Mine[212]	3	295	1,040
Total for All Mines	**27**	**11,648**	**22,090**

Tailing ponds are contained by man-made dykes. Although the possibility of dyke failure is very low, in 1998, there was, in fact, such a disaster at Spain's Los Frailes mine (owned by the Canadian mining company, Boliden Ltd.). This accident affected three rivers, polluting 11,000 acres (around 45 square meters) of farmland, and the government of Spain had to spend over $275 million to resolve this disaster (Holroyd et al., 2009). Figure 2.26 shows the tailing pond break at Los Frailes and a Canadian tailing pond close to the Athabasca River. The potential for a similar disaster is apparent.

Figure 2.26. Spain’s Tailing Ponds Break and a Tailing Pond near the Athabasca River (Source: Holroyd et al. (2009), “The Water That Bind Us: Transboundary Implications of Oil Sands Development,” Pembina Institute, February 2009, p. 21.)

2.5 Summary

This chapter started with an introduction of a diversity of oil sands’ characteristics such as definitions, scale and location, extraction methodologies, and upgrading process to help readers understand what oil sands are. Cost and market analysis were also conducted to clarify the oil sands’ value and the potential market demand, considering operating and supply costs, the market in terms of Canada’s refinery places and capacity, and the pipelines’ role and importance within Canada and between the country and the US. Finally, the oil sands’ positive impacts on Canada’s economy and their negative impacts and challenges to society and the environment were examined to explain recent conflicts related to the oil sands. The next chapter will demonstrate the importance of Canada’s oil sands, their great potential, and the constraints on them, as a key element to lead Canada towards an energy superpower status.

Chapter 3
Canada as an Energy Superpower

Canada is standing at the crossroads of becoming an energy superpower. To achieve this status, Canada must search for a key energy source that can achieve a competitive advantage. In 2006, Prime Minister Stephen Harper, at the G8 Summit in St. Petersburg, emphasized that the development of the oil sands is "akin to the building of the pyramids or China's Great Wall." This chapter examines the importance, the potential, and the constraints of Canada's oil sands as the key driver to the country becoming an energy superpower, comparing and analyzing these considerations with the Canadian Academy of Engineering (CAE)'s studies and recommendations about Canada's energy pathways.

3.1 Strategic Value

Canada's oil sands are very important strategically to the country because of their huge quantity and the potential for development. This section presents recent analysis about Canada's recoverable oil sands deposits as a commercial oil source and future prospects for the country's oil sands with regard to the oil industry and oil production.

3.1.1 Recent Analysis

According to research of the Alberta Energy Resources Conservation Board (ERCB, 2009), there are 1.73 trillion barrels ($275 \times 10^9 m^3$) of crude bitumen in place in the oil sands. The ERCB estimated that, of the 8 percent of crude bitumen volume in place, 130 billion barrels ($20.7 \times 10^9 m^3$) is included in reservoirs where the bitumen can be extracted through surface mining. The shallow oil sands are located in the Athabasca region.

The other 92 percent of the crude bitumen volume in place, 1,601 billion barrels ($254.4 \times 10^9 m^3$), is contained in deposits where the bitumen can be extracted through in-situ technology. The reservoir includes deep oil sands, and it is located in all of the three oil sands areas: Athabasca, Cold Lake, and Peace River.

However, only 11 percent of the crude bitumen in place is recoverable as a commercial oil, so the ERCB has estimated 176.8 billion barrels ($28.1 \times 10^9 m^3$) to be the initial established reserve. In addition, the ERCB reported that approximately 4 percent of the initial established reserves had been extracted by the end of 2008, a cumulative result is 6.4 billion barrels ($1.02 \times 10^9 m^3$). Thus, at the end of 2008, 170.3 billion barrels ($27.1 \times 10^9 m^3$) remained to be extracted. The ERCB's reports on Canada's bitumen resources at year-end 2008 are given in Table 3.1.

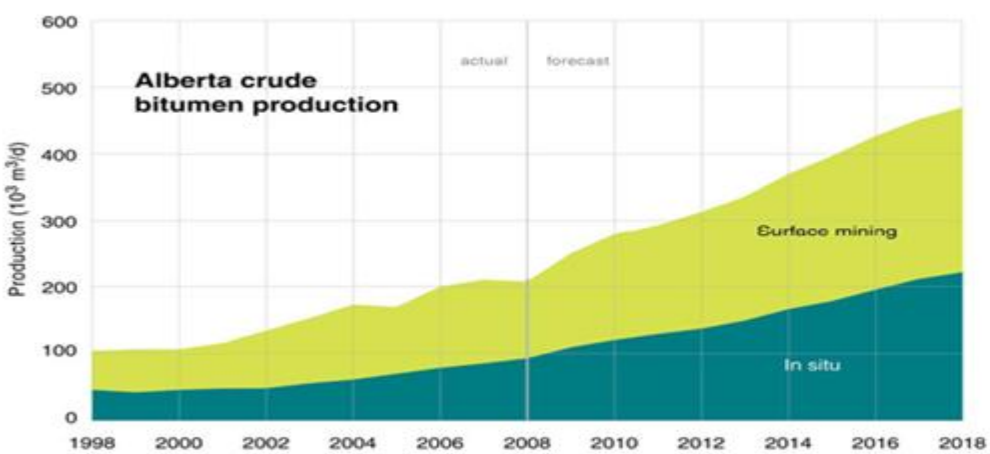
Table 3.1. Canada' Bitumen Resource (Source: National Energy Board, "Canada's Oil Sands: Opportunities and Challenges to 2015," May 2004 & June 2006)

Recovery Method	Initial Volume in Place		Initial Established Reserves		Cumulative Production		Remaining Established Reserves	
	Billion Barrels	Billion m^3	Billion Barrels	Billion m^3	Billion Barrels	Billion m^3	Billion Barrels	Billion m^3
Mineable	130	20.7	38.8	6.16	4.2	0.67	34.5	5.49
In Situ	1,601	254.4	138.1	21.94	2.2	0.35	135.8	21.58
Total	**1,731**	**275.1**	**176.8**	**28.09**	**6.4**	**1.02**	**170.3**	**27.07**

3.1.2 Future Outlook

As of 2008, Canada's oil sands' production is 1.31 million barrels per day (Government of Alberta, 2009) and is forecasted to increase to 3.0 million barrels per day by 2015 (NEB, 2006) and 4.3 million barrels per day by 2030 (Prebble et al., 2009), as illustrated in Figure 3.1. According to the Government of Alberta, as of February 2009, Canada had 91 active oil sands projects, and 43 of them are in post-payout status, defined as where the oil sands investor has earned enough revenues to recover all of the costs for the project plus a return allowance (Government of Alberta, 2009).

Figure 3.1. Alberta Crude Bitumen Production (Source: ERCB, "ST98-2009: Alberta's Energy Reserves 2008 and Supply/Demand Outlook 2008-2018," June 2009, p. 2-24.)



Based on oil production per day, Canada was the sixth largest oil producer in the world in 2008, as displayed in Table 3.2, and Canada is expected to be the third or fourth largest oil producer in the world by 2015 according to Canadian Association of Petroleum Producers (CAPP) analysis (Richardson, 2007).

Table 3.2. Oil Production by Country, 2008 (Source: BP, "BP Statistical Review of World Energy," June 2009, p. 8.)

Rank	Country	Oil (Million Barrels per day)
1	Saudi Arabia	10.85
2	Russia	9.89
3	United States	6.74
4	Iran	4.33
5	China	3.8
6	Canada	3.24
7	Mexico	3.16
8	United Arab Emirates	2.98
9	Kuwait	2.78
10	Venezuela	2.57
11	Norway	2.46
12	Iraq	2.42
...	...	...
	World Total	**81.82**

The National Energy Board stated that there are also oil sands deposits in the northwest and eastern central areas of Saskatchewan (Richardson, 2007). In particular, the oil sands in northwestern Saskatchewan are estimated to cover 27,000 square kilometres, which accounts for about five percent of the province. An estimate of the volume of the oil sands shows that there are almost 2.3 billion barrels of bitumen in Saskatchewan (Prebble et al., 2009).

In summary, the oil sands play a remarkably significant role in Canada's energy industry, with the massive volumes produced and continuous development. Many researchers from government, universities, and various organizations have been predicting the oil sands industry will grow steadily. However, some risk factors counter this positive view of Canada's future as an energy superpower.

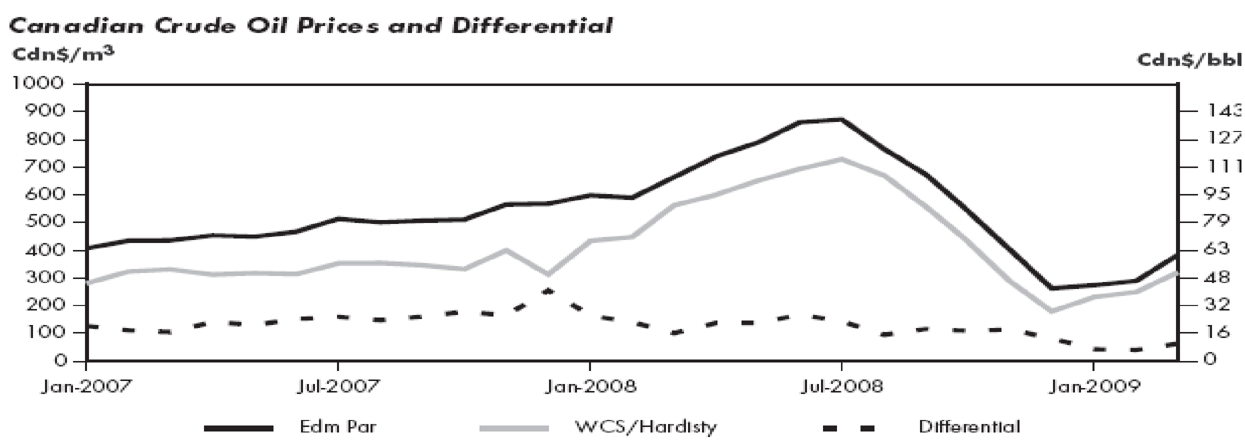
3.2 Constraints

The oil sands development has many risk factors, even though its industries have been growing continuously. In particular, because the oil sands business requires enormous capital investment, the implications of a business failure could be severe economically and socially at both a provincial and national level. This section describes some weakness of the oil sands development in terms of Canada's potential as an energy superpower.

3.2.1 Oil Price Vulnerability

When oil prices are between US$50 and $60 per barrel, the motive to develop the oil sands is huge and, in general, recompenses investors for the risks and costs associated with capital-intensive and time-consuming projects (Richardson, 2007). However, as Figure 3.2 shows, oil prices have fluctuated considerably since 2007. In particular, the oil price difference between July 2008 and December 2008 was roughly C$100, and the highest point is more than twice the price in December 2008.

Figure 3.2. Oil Price Fluctuations (Source: National Energy Board, "Canadian Pipeline: Transportation System," Transportation Assessment, July 2009, p. 7.)



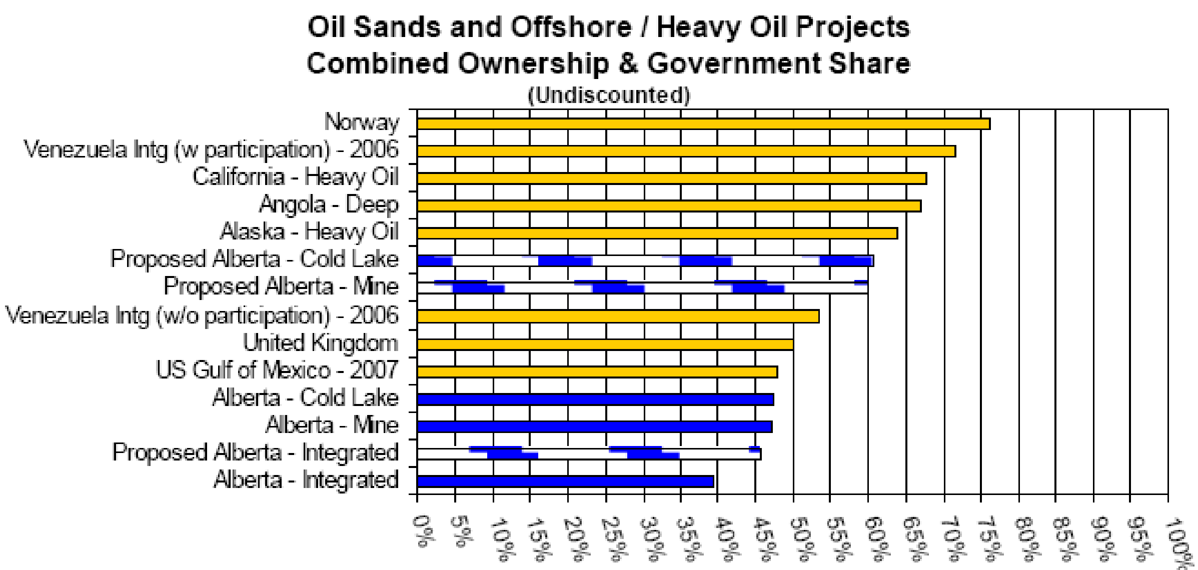
Moreover, in recent years, costs of extracting and upgrading from bitumen have been increasing significantly because of the overall rise in such costs as labour, materials, and natural gas. The National Energy Board reported that supply costs for Synthetic Crude Oil are around C$40, as exhibited in Table 2.2, and these costs are equivalent to the environmental cost such as pollution tax related to greenhouse gas emissions. In other words, if oil prices fall down the range of US$35 to US$40 per barrel, it will have an extremely negative influence upon the oil industry and the Canadian economy (Richardson, 2007). In summary, one of the weak points of oil sands development, oil price vulnerability, must be skillfully coped if Canada is to have a bright energy future.

3.2.2 Unbalanced Benefit Share: Taxes and Royalties

In 2007, the Canadian Parliament emphasized issues in how the economic benefits of the oil sand are distributed across the country. They reported that oil sands profits are not evenly distributed between Albertans and Canadians (Richardson, 2007). In addition, George Eynon, a Vice President of the Canadian Energy Research Institute, said to the Committee that "There's an economic incentive for the owners of the [oil sands] leases to monetize their assets" in Canada's current market situation.

According to the report of the Alberta Royalty Review Panel (Hunter et al., 2007), Our Fair Share, the Alberta government share of the oil sands projects accumulated through royalties was only about 40 percent of share, while the Norwegian government collected around 76 percent through royalties from the heavy oil projects, as shown in Figure 3.3.

Figure 3.3. Government Share of Oil Sands Projects Collected through Royalty (Source: ADOE 2007, cited in Hunter et al. (2007), "Our Fair Share," Alberta Royalty Review Panel, September 2007, p. 92.)



In fact, Alberta's ownership is one of the lowest total government shares in the world, and with its low profits, bringing significant benefits to both Albertans and Canadians is difficult. Thus, the royalty review panels recommended Alberta's government to modify its royalty regime for an increase in revenues going to both Albertans and Canadians.

After the report of the Alberta Royalty Review Panel, the Government of Alberta reformed the tax and royalty regime to collect more benefits from the oil sands industries, as depicted in Table 3.3.

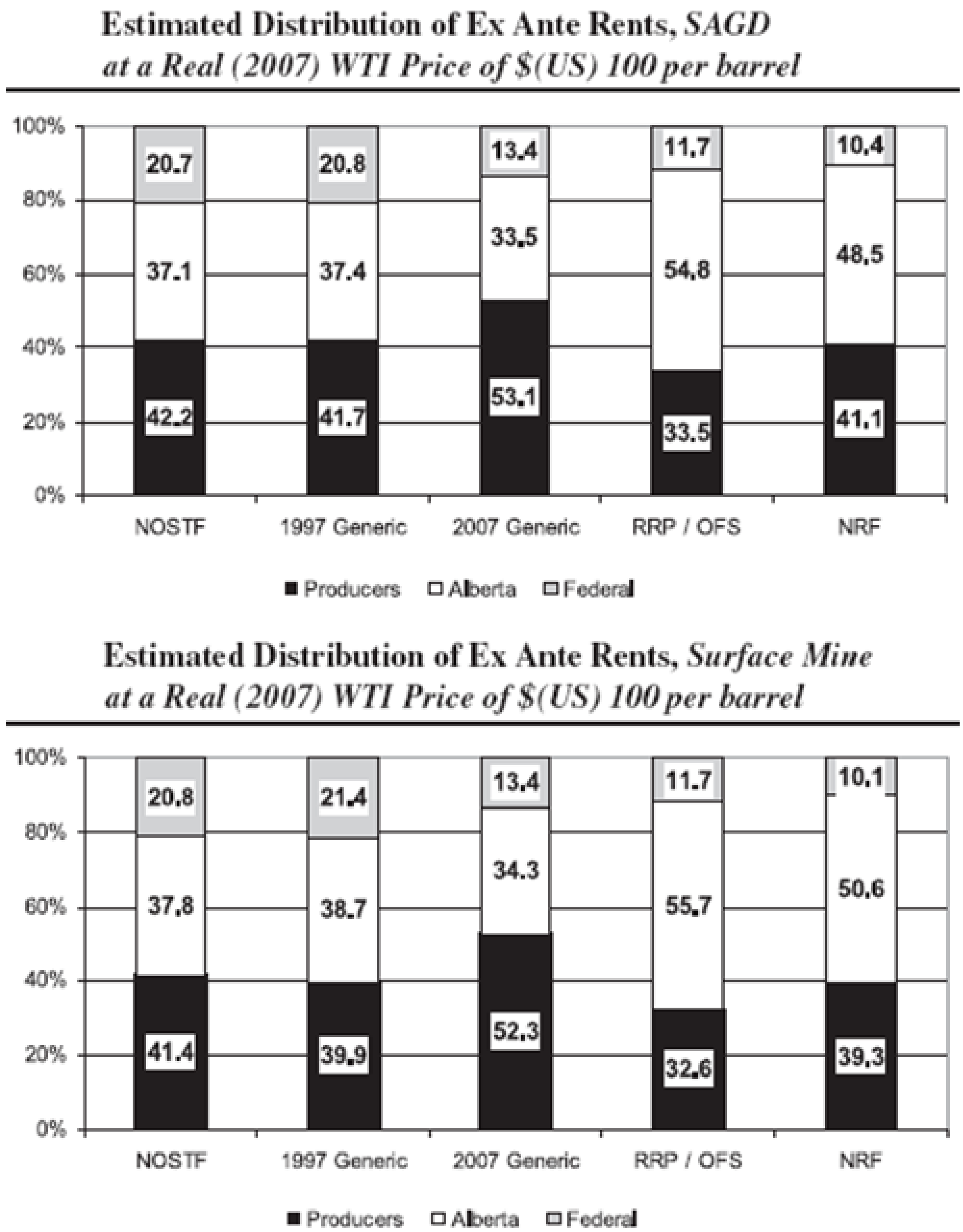
Table 3.3. Excerpts from Major Decisions by Government of Alberta (Source: Government of Alberta, "The New Royalty Framework," October 2007, p. 18)

PANEL RECOMMENDATION	GOVERNMENT DECISION	RATIONALE
Oil Sands		
14. **Base Royalty** rate to remain at 1%.	**Reject** Implement a sliding rate structure where the base rate increases from 1% when the West Texas Intermediate (WTI) price is at $55 per barrel to 9% when WTI reaches $120.	At high prices the province will receive higher revenues from oil sands development. Albertans will receive a greater share from oil sands development. Ensures all components of the royalty system are price sensitive.
15. **Increase net royalty** rate from 25% to 33%.	**Reject** Implement a sliding rate structure where the net royalty rate increases from 25% when WTI price is at $55 per barrel to 40% when WTI reaches $120.	Albertans will receive a greater share from oil sands development. Ensures all components of the royalty system are price sensitive.
16. **Implement a new Oil Sands Severance Tax:** • 0% for price less than $40/ bbl • 1% at $40/ bbl • Increase by 0.1% for each dollar per barrel increase • Maximum of 9%.	**Reject** Royalties are a right of ownership. Other jurisdictions use severance taxes to meet their revenue need because they do not own the resources. Alberta's fair share is not based on revenue needs, but ownership rights.	By introducing a price sensitive base royalty rate, Alberta can obtain more revenue upfront, especially at high prices.
17. Recognize any **environmental fees** or levies as **eligible cost** of doing business.	**Accept**	Government already allows this for costs directly related to oil sands projects.

In short, the new royalty framework changed the base royalty rate from fixed a 1% to a flexible rate, such as 1% at $55 per barrel and 9% at $120 per barrel. Moreover, the review panel reformed the net royalty rate from the range of 25 percent to 33 percent to the range of 25 percent to 40 percent, in accordance with West Texas Intermediate (WTI) prices.

In an article published in The Energy Journal, Plourde (2009) simulated the impacts of the New Royalty Framework. Figure 3.4 compares simulated results of the conventional royalty regimes and the new royalty framework.

Figure 3.4. The Simulation Results in Comparison with Royalty Regimes (Source: Plourde (2009), "Oil Sands Royalties and Taxes in Alberta: An Assessment of Key Developments Since the Mid-1990s," The Energy Journal, Vol. 30, No. 1., 2009, p. 132.)



In brief, when the WTI oil price is US$100 per barrel, in the case of SAGD, the Alberta government's share will increase to 48.5 percent through the new royalty framework from 33.5 percent according to the conventional royalty regime of 2007. However, the oil producers' share will decrease to 41.1 percent from 53.1 percent. In the case of surface mining, the Alberta government's share grows to 50.6 percent from 34.3 percent, while oil producers' share reduces to 39.3 percent from 52.3 with the same application (Plourde, 2009).

To sum up, Canada is trying to collect more money from oil sands producers, which are mostly US companies, in order to distribute more benefits to Albertans and Canadians. The updated royalty regime can be seen as one means to approach the status of an energy superpower. However, the Canadian governments' share of oil revenues is still far less than that of a country like Norway which collects a 76 percent share of revenues. Therefore, Canada must continue its efforts to collect further royalties from oil sands industries, and thereby bring the country one step closer to its goal of becoming an energy superpower. Remember that without a reasonable distribution of benefits to Canadians, it is difficult for Canada to attain the status of an energy superpower.

3.3 Canadian Academy of Engineering Studies

The Canadian Academy of Engineering (CAE) has been dealing with the engineering aspect of various national issues. In recent years, the CAE has concentrated on Canada's energy system and vision to make the country a sustainable energy superpower. This section introduces the CAE's studies and describes the results and recommendations for promoting national energy goals.

3.3.1 Introduction to the CAE

The CAE was established in 1987 and has been involved with Canada's significant engineering concerns as an independent, self-governing, and not-for-profit national organization, comprising many outstanding engineers. Members of the Academy have benefited to Canada and its corporate' gain, providing strategic science and engineering advice. More than 300 active fellows and 90 emeritus supporters of the CAE cooperate with diverse national engineering organizations: the Canadian Engineering Leadership Forum (CELF), the Canadian Federation of Engineering Students (CFES), Engineers Canada, the Engineering Institute of Canada (EIC), the Association of Canadian Engineering Companies (ACEC) and the National Council of Deans of Engineering and Applied Sciences (NCDEAS), and Canadian academies: the Council of Canadian Academies (CCA), the Royal Society of Canada (RSC), the Canadian Academy of Health Science (CAHS), and the International Council of Academies of Engineering and Technological Science (CAETS) (Bowman et al., 2007).

The CAE's duties are as follows:

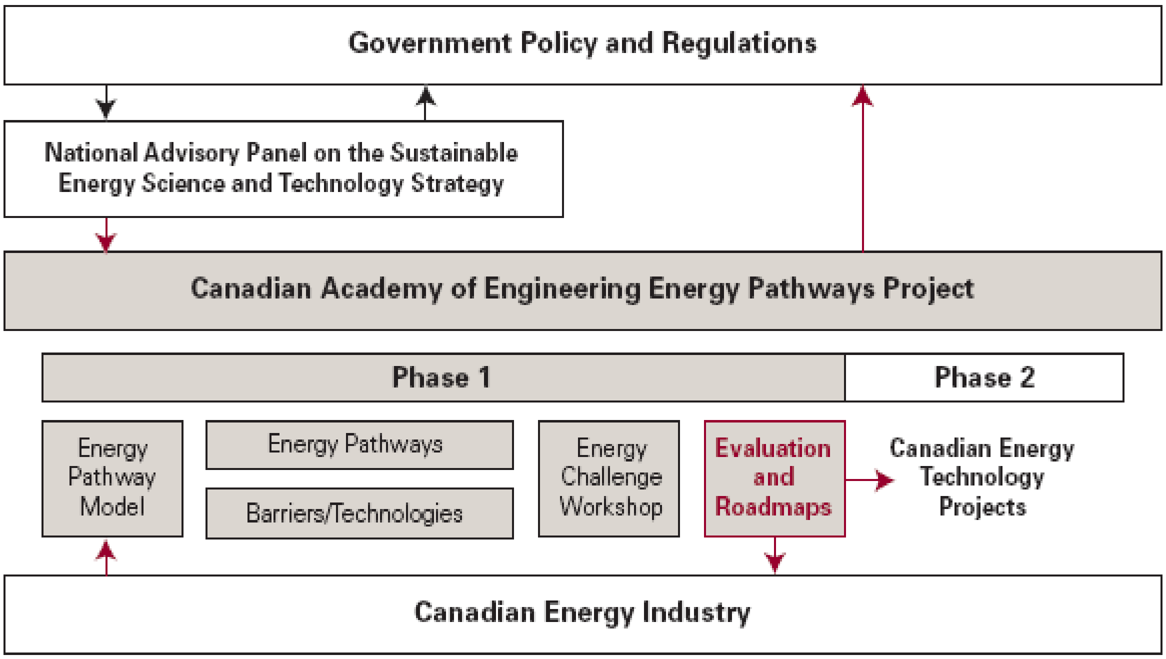
- enlightening and inspiring engineers about their role in society
- having the courage of its opinions about engineering issues in Canada and internationally without hesitation
- strengthening industrial competitiveness in Canada and beyond; conserving the environment
- informing and felicitating excellent engineering contributions towards Canada's economy
- counselling in various engineering areas such as research, training, development, and innovation
- cooperating with diverse engineering organizations, societies, and academies in Canada and beyond

Using its engineering viewpoint, the CAE has been seeking for the design specifications to make Canada an energy superpower. Clem Bowman and Bob Griesbach (2007) provide 27 energy pathways in the Energy Pathways Task Force Phase 1 – Final Report, tracing the major energy sources' routes. Over 100 energy experts participated in evaluating a diversity of potential technologies to accomplish environmental, economic, and efficient goals, using a rational decision-assist tool, the ProGrid methodology, for multiple-criteria decision analyses.

3.3.2 Developments and Recommendations

Figure 3.5 describes the CAE's position between stakeholders such as the government and the energy industry. The focus for the CAE is to help governments establishing their strategies and policies and to assist industries by providing options to satisfy their economic goals within environmental regulations.

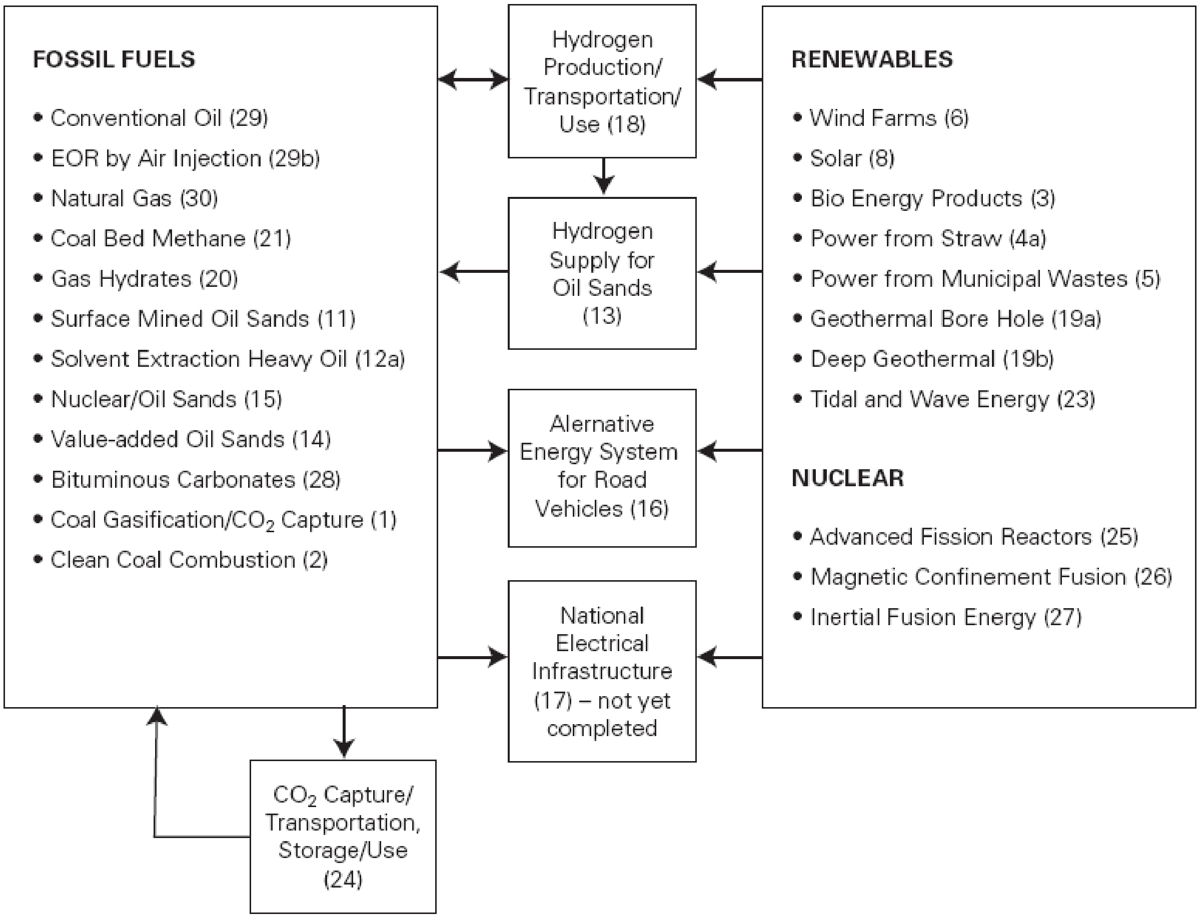
Figure 3.5. Model for Energy Pathways Project Process (Source: Bowman et al. (2007), "Energy Pathways Task Force: Phase 1 – Final Report," Canadian Academy of Engineering, August 2007, p. 8.)



In this figure, an Energy Pathways Model's development is the starting point for this process, and the validity of feasible or potential energy pathways is verified. An energy workshop then helps stakeholders to add various key inputs, leading to the evaluation results and roadmaps. Through this process, practicable and potential Canadian Energy Technology Projects are defined for Canada's energy vision.

During the CAE's data collecting, the National Advisory Panel on the Sustainable Energy Science and Technology Strategy published a report, "Powerful Connections: Priorities and Directions in Energy Science and Technology in Canada" (Bruneau et al., 2006). The report recommends an integrated energy systems approach and all stakeholders' dedicated commitment to make Canada an energy world leader. The recommendations from the panels can be compared and reviewed with the energy pathways from the CAE Project. Both the National Advisory Panel on the Sustainable Energy Science and Technology Strategy and the CAE emphasize that energy should be considered as a system. Figure 3.6 illustrates the available energy pathway for Canada as a project for the above Phase 1.

Figure 3.6. 27 Energy Pathways (Source: Bowman et al. (2007), "Energy Pathways Task Force: Phase 1 – Final Report," Canadian Academy of Engineering, August 2007, p. 10.)

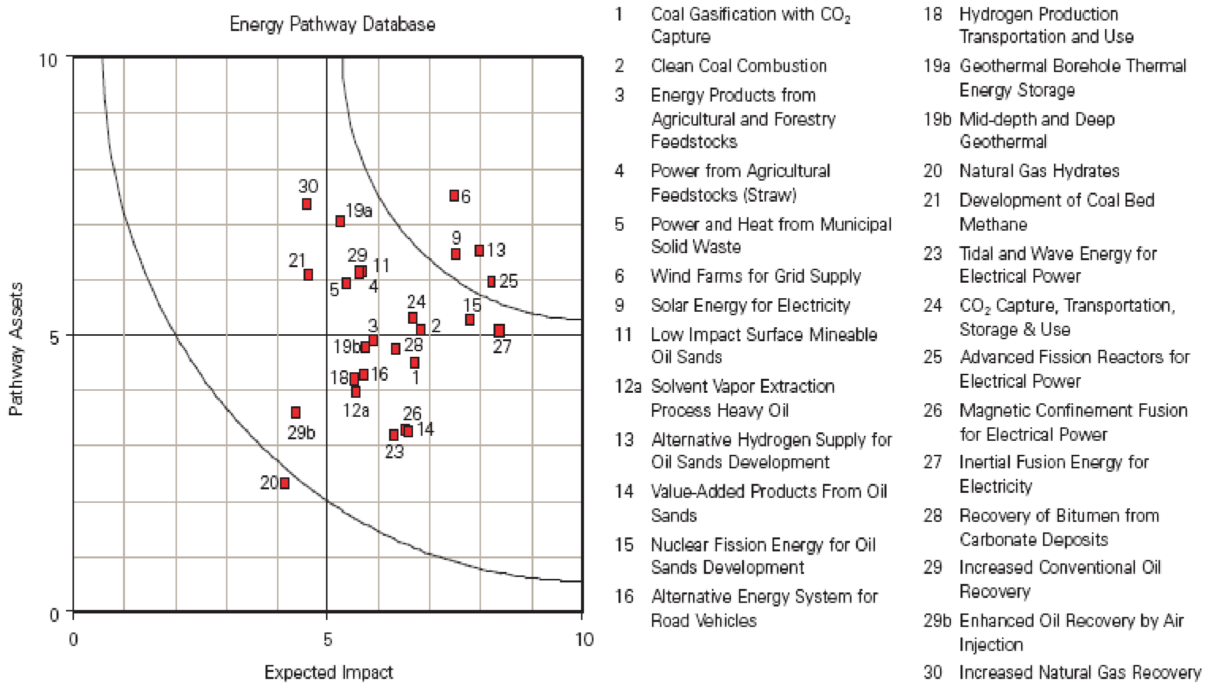


In Figure 3.6, energy pathways are comprised of three main categories of energy sources: Fossil Fuels, Renewables, and Nuclear. However, the CAE emphasizes the whole pathway from the energy sources to the end use through a conversion process and carrier. Some pathways rely on other pathways, and some, naturally, are links embedded in others. In these cases, the correlations must be ascertained.

Hydrogen and carbon dioxide are considered as significant materials, interacting with fossil fuels and renewable energy sources. In particular, this report mentions that hydrogen is an essential element for making the most of the massive oil sands resources' opportunity. Carbon dioxide is also a key factor to be addressed as a crucial contributor of greenhouse gases. Hence, technologies to utilize this gas, such as capture, store, and use, are very significant concerns.

The CAE evaluated 27 energy pathways in this project through the ProGrid methodology (Bowman et al., 2007), and the results are presented in Figure 3.7.

Figure 3.7. The Evaluation Results of the 27 Energy Pathways (Source: Bowman et al. (2007), "Energy Pathways Task Force: Phase 1 – Final Report," CAE, August 2007, p. 17.)



CAE's evaluation of the 27 pathways shows X, Y grid positions with respect to 27 energy pathways, employing the overarching objectives, such as pathway assets and expected impact, as its axes. With this representative result, the CAE compares the evaluation results of all the energy pathways and interprets them as follows:

- Four energy pathways – 6) Wind Farms for Grid Supply, 9) Solar Energy for Electricity, 13) Alternative Hydrogen Supply for Oil Sands Development, 25) Advanced Fission Reactors for Electrical Power – positioned on the upper curve, meet most of the criteria requirements, related to pathway assets and expected impact.
- The energy pathway – 20) Natural Gas Hydrates – has a weakness with regard to both pathway assets and expected impact.

After the whole evaluation, the CAE ultimately made the following four recommendations:

- Recommendation 1: Canada should undertake three National Technology Projects:

- Gasification of Fossil fuels and Biomass
- GHG Emission Reduction (carbon dioxide capture followed by transportation, long term storage, and/or use)
- Upgrades to Electrical Infrastructure (with improved access by wind and solar sources, and capacity for energy storage)

● Recommendation 2: Set up a network for bioconversion demonstration processes

● Recommendation 3: Pursue technology development on various opportunities and challenges

● Recommendation 4: Maintain abundant expertise with respect to fusion energy

At this point, we should consider the CAE's evaluation results related to oil sands development. As mentioned above, the Alternative Hydrogen Supply for Oil Sands Development is one of the top priorities. However, although other energy pathways related to oil sands development, such as Low Impact Surface Mineable Oil Sands (11) and Nuclear Fission Energy for Oil Sands Development (15), are not positioned on the most preferred pathways, those two pathways are located close to the upper curve. In other words, the CAE evaluates and considers the oil sands development as a vital energy pathway.

Very recently, Clem Bowman and Katherine Albion (2010) provided two key conclusions in a report, "Canada's Energy Progress 2007-2009," at an Energy Pathways Workshop sponsored by the CAE and University of Western Ontario Research Park in Sarnia, Ontario.

- Although Canada takes an advantageous position in the early stage of innovation, it has not been an innovative to the extent of being a profitable business.
- A systems approach is vital for the effective energy management and maximum energy technology in terms of innovation and benefits, respectively. However, Canada's current systems, such as policy and framework, have weak points when it comes to administering Canada's energy resources and processes effectively because of the difficulty in integrating as a system.

In conclusion, the CAE has been examining and looking for the various energy pathways that can lead Canada to be an energy superpower, and its analysis shows that the oil sands development is one of the essential elements to achieving Canada' national energy goals.

3.4 Summary

This chapter started by describing the strategic value of Canada's oil sands as a key driver to the country becoming an energy superpower, providing recent analysis about massive recoverable oil sands reserves and the bright future prospect of continuous growth in the oil industry. This chapter also showed oil price vulnerability as one of risk factors to investment in the oil sands industry. Moreover, an unbalanced benefit share from oil sands business was introduced as a significant element that should be overcome for the national energy goal. Finally, the Canadian Academy of Engineering's studies have examined diverse energy pathways that can guide Canada to becoming an energy superpower, and recommendations have supported that the oil sands development is one of the vital elements to achieving national energy goals.

The next chapter will introduce a practical decision-assist methodology for multiple-criteria decision analyses, converting qualitative concepts into quantifiable measures. The methodology will be very useful in evaluating Canada's oil sands as an energy system.

Chapter 4
The ProGrid Methodology

There have been many trials to evaluate societal and environmental systems with methodologies that analyze qualitative concepts objectively. For example, Analytic Hierarch Process (AHP) (Saaty, 1980) is a representative method to evaluate qualitative social issues reasonably, and people believe that this kind of approach helps stakeholders to make better decision. The ProGrid methodology was created by Dr. Bowman (2005) for similar purposes and has been used by many national and private organizations. Recently, the Canadian Academy of Engineering (CAE) where Dr. Bowman is the chairman has evaluated Canada's energy system with its energy scenario, and it has adopted the ProGrid methodology to make strategic decisions, as displayed in Figure 3.7. In particular, Canada's oil sands are a critical element of Canada's energy system, which the CAE has researched to help Canada become an energy superpower. Hence, the author chose to apply the ProGid methodology and the software in carrying out an evaluation of Canada's oil sands in order to be consistent with the research from the CAE and to compare with its results.

In this chapter, ProGrid methodology (Bowman, 2005), a means for evaluating what we cannot value explicitly, is described with respect to its characteristics, components, and development. Then, the modeling and output of ProGrid methodology is discussed in terms of evaluating intangible assets. In addition, the advantages and limitations of ProGrid methodology are examined in order to clarify the concept of helping users make sound decisions when using the methodology. Sections 4.2 and 4.3 of the following chapter draws its content principally from Dr. Bowman (2005)'s *INTANGIBLES: Exploring the Full Depth of Issues*.

4.1 Introduction

ProGrid methodology (Bowman, 2005) is a logical decision-assist tool for multiple-criteria decision analyses, and it has a capability that helps decision makers convert qualitative concepts into quantifiable measures that can be compiled and compared. Hence, the methodology is very useful in evaluating intangible assets such as the innovation capacity of a nation, the effectiveness of governance practices, and the monitoring of long-range societal goals. According to Clem Bowman's *INTANGIBLES: Exploring the Full Depth of Issues*, the value of companies is evaluated in terms of 'book value' and 'market value.' 'Book value' symbolizes the value of tangible assets such as inventory and production equipment, and it can be identified and measured without difficulty in terms of price. However, ‘market value’ is not easy to measure because it represents the value of intangible assets such as people, systems, and intellectual property. As ‘market value’ is difficult to evaluate by price, the value must to be estimated in terms of the companies’ promise. In particular, because the number of companies involved in software and information technologies has been rapidly increasing in recent years, the value of intangible assets has to be considered as a vital concern with respect to business survival. Thus, companies, government departments, and national projects have all applied ProGrid methodology to evaluate intangible assets. In detail, ProGrid methodology can be employed by

- Investors to verify and pursue winning technologies,
- Governments to provide objective and reasonable procurement practices,
- Shareholders and regulatory authorities to evaluate the effectiveness of government actions,
- Agencies to encourage national innovation schemes, and
- Nations to set up and monitor long-term societal goals.

Evaluating intangibles is similar to estimating an art work’s price at an auction. In other words, a subjective point of view could influence the evaluation, and inaccurate judgment could depreciate the true value, resulting in financial loss in terms of the owner’s investment. Therefore, the application of the ProGrid method attempts to decrease the errors and increase the accuracy of the evaluation process.

4.2 Modeling

Over the last decade, the ProGrid methodology has been developed to evaluate through modeling what cannot be measured by other means. Generally, the methodology is comprised of the following five steps:

1. Establishing the Overarching Objectives
2. Constructing an Evaluation Matrix of Multiple Criteria
3. Building metrics through Language Ladders
4. Evaluating the Intangibles
5. Marking the results on an Evaluation Grid

The first three steps are used to model intangibles; the other steps are concerned with the decision process. This section provides an explanation of the process carried out in each step.

4.2.1 Establishing the Overarching Objectives

In general, there are many conflicts in the world, which are often the result of two mindsets in apparent opposition and expressed through heightened tension and competition. Lowy and Hood (2004) explain that tension from conflicts between two opposite objectives can give rise to higher levels of success through resolution, showing around 50 examples of this tension. These conflicting objectives are described as follows: the important versus the urgent, the short term versus the long term, the offensive versus the defensive, as well as quality versus price. When the second dimension is identified and comprehended through logical reasoning, the way to understanding and utilizing intangible assets becomes more obvious. Many businesses have failed because of their one-dimensional strategy. For instance, a single-item strategy such as Henry Ford's "only-black" Model T colour finally failed when the market for Model Ts reached maturity (Alizon et al, 2009). Concentrating on quarterly results and ignoring long-term survival is also an example of a one-dimensional point of view. Unfortunately, many individuals and organizations have been trying to achieve their goal with only one-dimensional thinking, because it can be a shortcut that avoids the conflict of combining a second dimensional mode. Thus, this one-dimensional thinking, as mentioned above, can put individuals and organizations in danger. Therefore, the processes of choosing and justifying the two key overarching objectives are needed as the first step in order for stakeholders to make logical decisions, and this step plays an important role in suitably evaluating performance.

4.2.2 Constructing an Evaluation Matrix of Multiple Criteria

The Evaluation Matrix is a cornerstone for evaluating intangible assets and includes important criteria for the evaluation. In particular, creating the right criteria is one of the most critical steps in the ProGrid methodology. The process for evaluating intangible elements starts with a checklist of supporting criteria, usually based on an evaluator's own values. This methodology organizes the criteria into categories that show the real potential of objectively evaluating the intangible assets under consideration. Some criteria describe 'inputs' such as goals and resources that will be utilized; others illustrate 'output' such as the anticipated results. Other criteria represent 'enablers' such as processes and infrastructure that will allow inputs to be converted into outputs. Allocating the criteria to the appropriate columns such as inputs, enablers, and outputs in the Evaluation Matrix makes it easier to identify the importance of each criterion and performs as a framework for judging whether weak criteria can be modified or if they are fatally flawed. With this arrangement, the allocating process can be a practicable means to check performance as a guide for evaluation.

An understandable example for both the Overarching Objectives and the Evaluation Matrix is the process of moving to another house. Family members can each have their own priority, but it is not easy to satisfy all the family members' different points of view. This simple situation can bring about a conflict among family members, so a reasonable consensus on priorities, expectation, and values is required. This issue can be resolved with the ProGrid approach, demonstrated in Figure 4.1.

Figure 4.1. Moving to a New House

Establishing the Evaluation Matrix

INPUTS House	ENABLERS Connectors	OUTPUTS Environment
1. Feature	4. Price	7. Location
2. Quality	5. Resale	8. Lot
3. Upgradability	6. Maintenance	9. Neighbour-hood

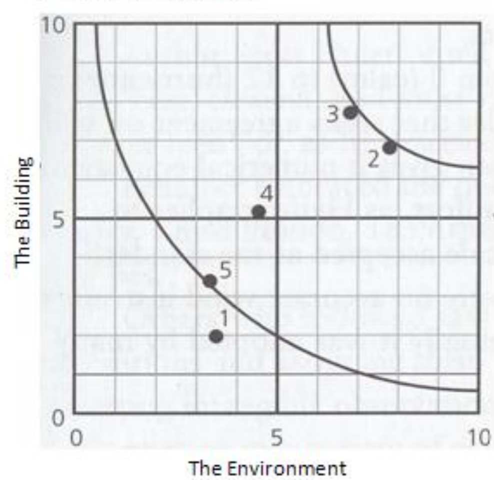
Building the Language Ladder

E.g. Feature (Four bedrooms, three bathrooms, large family room, full finished basement, two-car garage)
A. Missing more than two requirements
B. Missing one or two requirements
C. Meets requirements
D. Exceeds requirements

Establishing the Choices

House						
Criteria	#1	#2	#3	#4	#5	#6
1	A	C	D	C	B	C
2	B	C	C	B	B	B
3	A	C	C	D	B	A
4	A	C	C	B	B	C
5	C	C	C	B	B	B
6	B	C	C	A	B	A
7	A	C	C	A	B	C
8	C	C	B	C	B	C
9	B	C	C	D	B	D

Plotting the Results

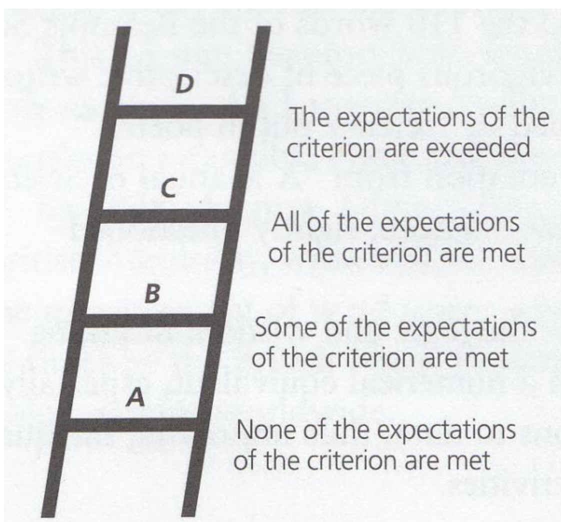


In the ProGrid methodology, the first step is establishing overarching objectives. In this example, two overarching objectives are considered: quality of the house and benefit of the environment. For the next step – constructing an Evaluation Matrix of Multiple Criteria – family members can come up with criteria through brainstorming aimed at the overarching objectives. An Evaluation Matrix includes the overarching objectives: quality of the house and benefit of the environment, and the criteria are assigned to the categorized columns, such as house, connecters, and environment, through appropriate matching, respectively. Connectors (also called Enablers) are tabulated in the middle between two overarching objectives, as illustrated in Figure 4.1.

4.2.3 Building Metrics through Language Ladders

The third step of the ProGrid methodology is the process that builds Language Ladders, as introduced simply in Figure 4.2. The concept of the Language Ladder has been in use for a long time for describing intangibles.

Figure 4.2. Generic Language Ladder (Source: Bowman (2005), *Intangibles: Exploring the Full Depth of Issues*, Grafiks Marketing & Communications, Sarnia, Ontario, 2005, p. 10.)



The Beaufort Scale, developed in 1806, is a good example of measuring an intangible – the wind itself – and is shown in Table 4.1. Captain Francis Beaufort, a top administrator in the Royal Navy, found that there were no precise expressions and no standard scales to predict winds. For instance, some people expressed a wind as ‘soft breeze,’ and other people described the same wind as a ‘smooth breeze,’ so the way winds were described could be extremely subjective. Beaufort tried to match wind speed data to numbers that could be generally understood and determined through simple observation. For Beaufort Scale reading of 0 and 1, a “calm” is paired with the description “calm; smoke rises vertically,” and a “light air” is matched with the description “direction of wind shown by smoke but not by wind vanes,” respectively. These simple descriptions can enable users to understand the state of winds clearly, and the numbers used for each new progressive level can be an objective rating for evaluating the strength of winds. With these advantages, the Beaufort Scale was designated the standard wind measurement, since no other existed at that time. Although it has been almost one hundred years since the Beaufort Scale was developed, it is still being used in many countries. Huler (2004), in Science Forum, praised the one hundred words of the Beaufort Scale as "the best, clearest, and most vigorous piece of descriptive writing I have ever seen," and he also expressed it as "science put in poetry." There have been many attempts to convert observations about various types of intangibles to numerical data, such as the Modified Mercalli Scale for measuring earthquake intensity, the Fujita Tornado Damage Scale, and the Saffier-Simpon Hurricane Scale.

Table 4.1. The Beaufort Scale (Source: Bowman (2005), *Intangibles: Exploring the Full Depth of Issues*, Grafiks Marketing & Communications, Sarnia, Ontario, 2005, p. 9.)

Beaufort Number	Name	Wind speed (mph)	Description
0	Calm	<1	calm; smoke rises vertically
1	Light air	1-3	direction of wind shown by smoke but not by wind vanes
2	Light breeze	4-7	wind felt on face; leaves rustle; ordinary vane moved by wind
3	Gentle breeze	8-12	leaves and small twigs in constant motion; wind extends light flag
4	Moderate breeze	13-18	raises dust and loose paper; small branches are moved
5	Fresh breeze	19-24	small trees in leaf begin to sway; crested wavelets form on inland waters
6	Strong breeze	25-31	large branches in motion; telegraph wires whistle; umbrellas used with difficulty
7	Near gale	32-38	whole trees in motion; inconvenience in walking against wind
8	Gale	39-46	breaks twigs off trees; generally impedes progress
9	Strong gale	47-54	slight structural damage occurs; chimney pots and slates removed
10	Storm	55-63	trees uprooted; considerable structural damage occurs
11	Violent storm	64-72	very rarely experienced; accompanied by wide-spread damage
12	Hurricane	73-136	devastation occurs

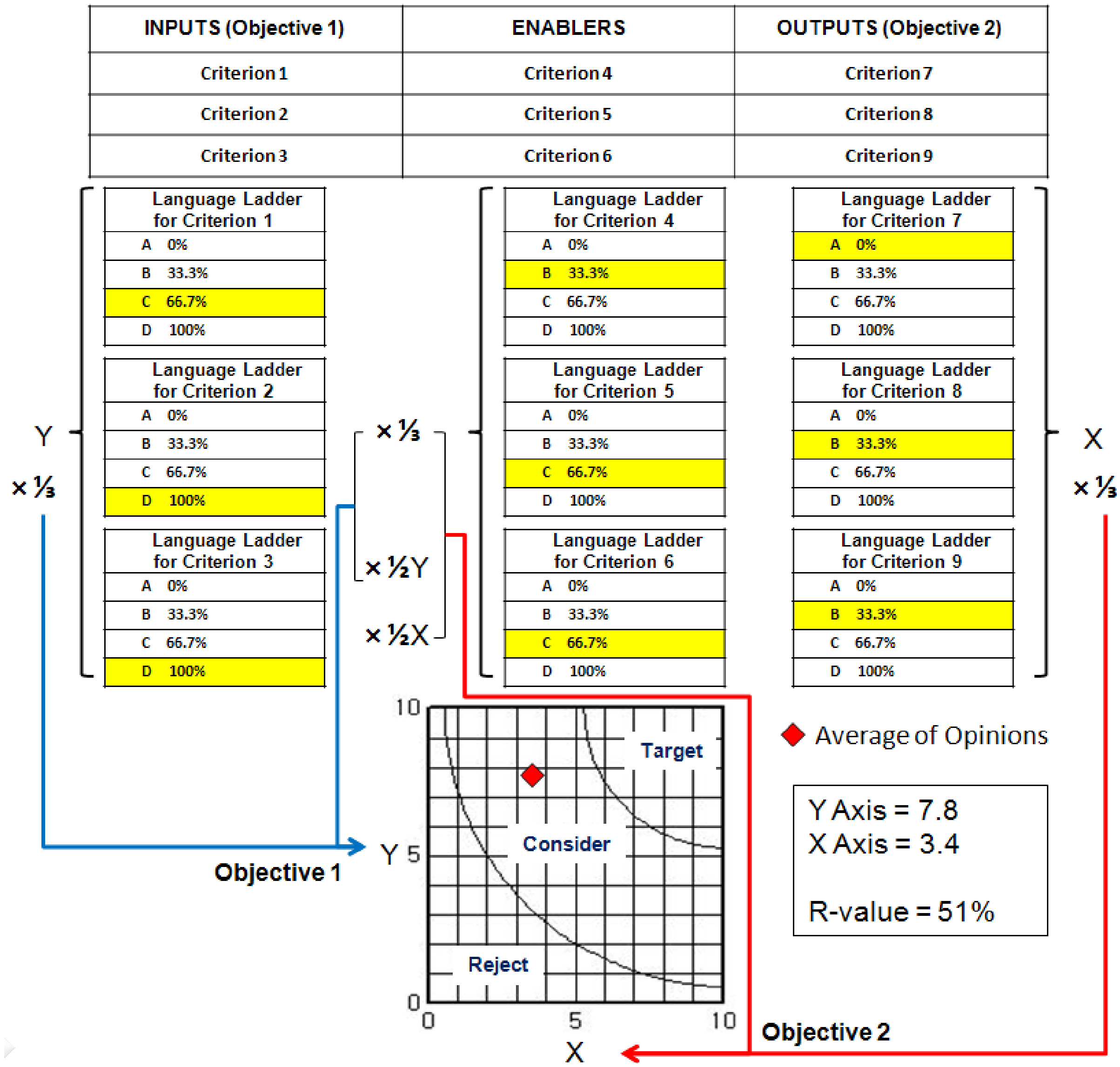
This Beaufort Scale, composed of thirteen levels, exemplifies a Language Ladder, and, once accepted, it contained the standard wording to explain and measure an intangible event. A ProGrid Language Ladder provides all evaluators with the means to describe the same thing: intensities of numerical ratings are equated with short descriptive statements. Each entry of the ladder has either a letter or number paired with a verbal definition. The entries in the scale are weighted and arranged hierarchically from weakest to strongest. Thus, for instance, a level 11 on the Beaufort Scale indicates a very severe gale, but a level 5 indicate relatively weak wind. An early stage of ProGrid applied a 10-point scale to evaluate each grade. However, a 10-step language scale was not practical because determining ratings could be very subjective among people. After extensive tests, most ProGrids use a four-step Language Ladder, preventing a middle 'safe' area. The four-step ladder starts from 'A' and advances to 'D', and each step includes short sentences made up of key words in order to help users make sound evaluations. The ladder is conceptualized as a journey, with 'A' as the starting point and 'D' as the furthest point – the ultimate distance possible from 'A'. In other words, it is an effective concept in terms of extending the scope of the ladder for achieving its goal, using the opposite of the terminology employed academically for grading.

The quality of the evaluation process through ProGrid depends on the robustness of the Evaluation Matrix and the clearness of the Language Ladder. Therefore, the words applied in each step of the Language Ladder must represent meaningful distinctions and be readily comprehensible by evaluators, thereby defining A, B, C, and D as in a dictionary.

4.2.4 Meaning of the R-values

The R-value is a percentage representing a measure of the distance of the grid point of a proposed alternative from points X = 10 and Y = 10, which are the maximum ratings. In other words, the R-value can be calculated mathematically to convert the qualitative assets into quantifiable values, using the criteria in the Evaluation Matrix and the Language Ladder steps (A, B, C, and D). The symbolic values such as A, B, C, and D can be defined as 0%, 33.3%, 66.7%, and 100%, respectively. The ratings for the criteria in the first column (input column) of the Evaluation Matrix can be assigned to the Y-axis of the grid chart, and for the third column (output column) to the X-axis, and finally for the middle column (enabler column) equally to both the X and Y-axes. Figure 4.3 presents an algorithm that shows how the ProGrid methodology works with an Evaluation Matrix and Language Ladders, and how the R-value is calculated.

Figure 4.3. Algorithm of ProGrid Methodology



The author derived the following equations for Positions X, Y, and R-value from the ProGrid software. The X and Y-axis positions of the evaluation on the grid are described as follows:

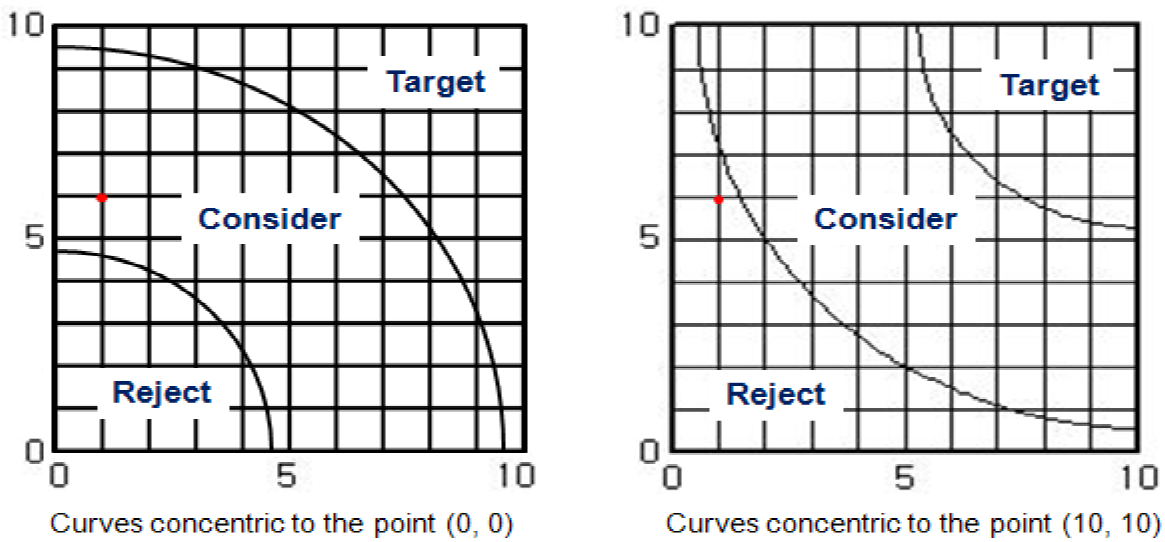
$$\text{Position X} = [(\text{Mean X progresses} \times \tfrac{1}{3}) + \{(\text{Mean enabler progresses} \times \tfrac{1}{3}) \times \tfrac{1}{2}\}] \times 2,$$

$$\text{Position Y} = [(\text{Mean Y progresses} \times \tfrac{1}{3}) + \{(\text{Mean enabler progresses} \times \tfrac{1}{3}) \times \tfrac{1}{2}\}] \times 2.$$

$$\text{Therefore, R-value (\%)} = [(\text{Mean Y values} \times \tfrac{1}{3}) + \{(\text{Mean enabler values} \times \tfrac{1}{3}) \times \tfrac{1}{2}\}] + [(\text{Mean X values} \times \tfrac{1}{3}) + \{(\text{Mean enabler values} \times \tfrac{1}{3}) \times \tfrac{1}{2}\}]$$

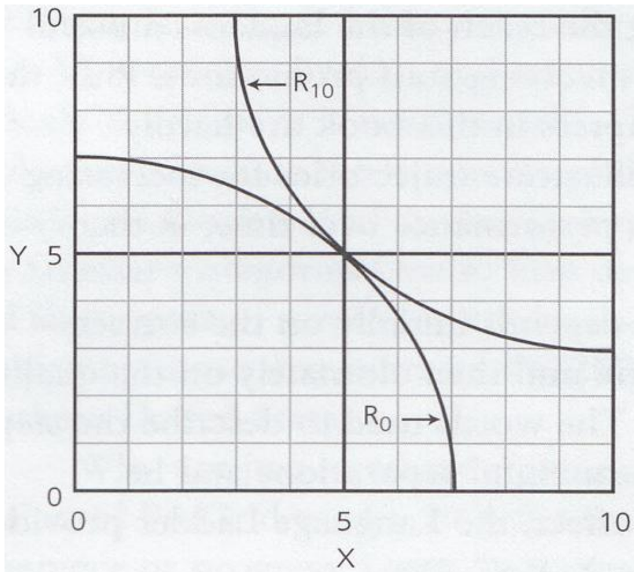
Hence, the upper curves mean an R-value of 66.7%, which, on the R-value arc, would occur when all criteria are rated ‘C’. The lower curves mean an R-value of 33.3%, being rated ‘B’. While points above the upper curves satisfy most of the criteria in the Evaluation Matrix and have potential for significant benefits, points under the lower curves do not satisfy most criteria. Therefore, three districts are labelled: Target, Consider, and Reject, as presented in Figure 4.4, and they play an important role in evaluation and decision making.

Figure 4.4. Two Approaches with Curves in Opportunity Grid



The R-value can be described such that a point (0, 0) is identical to 0%, and a grid point (10, 10) is equivalent to 100%, for both R_0 and R_{10}. R-values of 50% from both curves meet at (5, 5), showing the difference increase from the diagonal between R_0 and R_{10}, as displayed in Figure 4.5. All grid positions along an R-value arc can be rated as ‘equal’ concerning the two overarching objectives, but all points have an individual weighting of values.

Figure 4.5. Comparison between Two Approaches – R-values of 50% (Source: Bowman (2005), *Intangibles: Exploring the Full Depth of Issues*, Grafiks Marketing & Communications, Sarnia, p. 12.)



Grid travel can be described as an R-value, which can be computed by two approaches:

- R_0 – a measure of the extent from point (0, 0)
- R_{10} – a measure of the extent to point (10, 10)

Deciding the way – from the origin (0, 0) or from ultimate (10, 10) – to measure progress in the grid is important. Measuring progress from the origin point (0, 0) has features that allow any movement and any direction in the grid. Hence, the curves are designed to be concentric with the position (0, 0), using R_0 as a measure of progress, as shown on the left in Figure 4.4. This approach is suitable for evaluating events where one or two criteria from the Evaluation Matrix might mainly lie in one dimension. Evaluating individual performances in an organization to make a decision for staff promotions is an example the above, because staff members' strength can be mostly placed in one or two dimensions, and progress in that dimension should be compensated. This way does not punish staff members who contribute on only one axis. In other words, individual staff members cannot be expected to satisfy all of the performance criteria.

On the other hand, a commercial technology-intensive business can need progress on both the X and Y-axes, so measuring the extent from the ultimate (10, 10) target can be a more pertinent metric, as exhibited on the right in Figure 4.4. The difference between the above two approaches can be explained through the following example. On the left in Figure 4.4, point (1, 6) progressing from the point of origin (0, 0) – mainly weighted toward the Y-axis dimension – is expressed as a "Consider" result, however, the same point (1, 6) measuring from the ultimate point (10, 10) is indicated as a "Reject" result on the right in Figure 4.4. Therefore, according to the approach applied, results can differ, so the decision makers should consider the approach carefully.

4.3 Evaluating the Intangibles

The next step of the ProGrid methodology is to allow the various groups of experts to evaluate the intangibles with regard to the specific objectives and requirements of the organization. This process is performed by evaluators filling in the corresponding Evaluation Form made up of an Evaluation Matrix and Language Ladders based on an MS Excel file. Evaluators or reviewers generally assess the intangibles based on justifications and their expertise and fill in blanks on the form with their own ratings, such as A, B, C, and D, with reference to the Language Ladders. The evaluators can also fill in the reasons for their selections on short comment boxes provided. The results of ratings from all evaluators are gathered for discussion by a decision-making committee that consists of experts picked for their wide knowledge in the corresponding field.

4.4 Output Reports

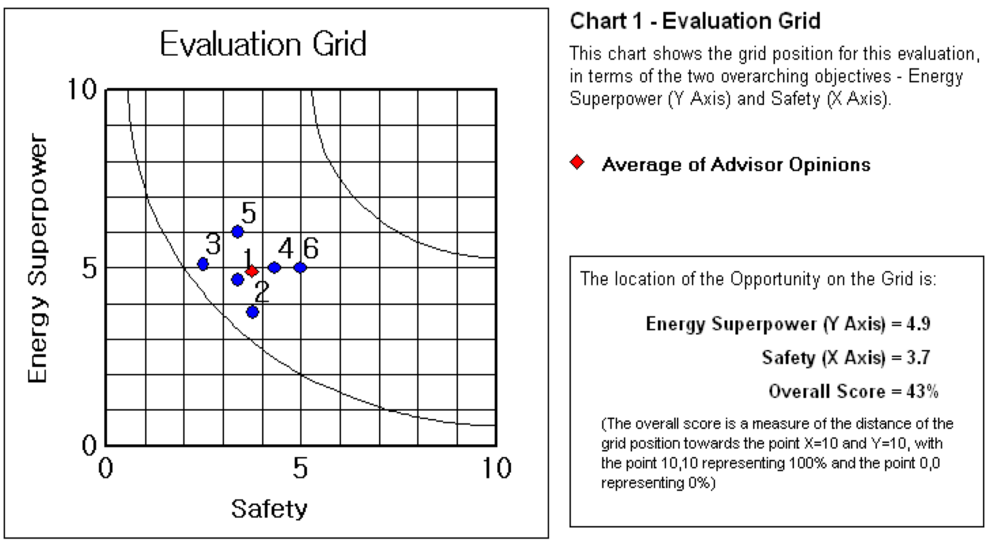
The final step of the ProGrid methodology is to establish the grid with the results from the evaluation process, employing the overarching objectives as its axes. The results are illustrated in Figure 4.6, 4.7, and 4.8, examples of the output reports. The output reports are mainly comprised of three charts: the Evaluation Grid, Evaluation Profile, and Opportunity Comparison, and one table: the Advisor Assessments, including comments. The output reports' characteristics are described below.

- All the criteria in the Evaluation Matrix are rated equally.
- The Language Ladder grades – such as A, B, C, and D – are shown as a bar scale on the Evaluation Profile.
- Ratings for the criteria in the Matrix's first and third columns, showing the elements of overarching objectives, are allocated to the Y and X axes of the Evaluation Grid chart, respectively, and the middle column, the elements of the enablers, are allocated equivalently to both the X and Y axes.
- R-value is calculated as a percentage illustrating the progress on the X and Y axes in achieving the user's goal.

4.4.1 Evaluation Grid

The Evaluation Grid provides the current grid position as evaluated by each expert and shows the evaluation average, with respect to the overarching objectives in the Evaluation Matrix. On this Evaluation Grid, the position Xs, the position Ys, and the R-value (%) from the results of experts' evaluation are simply expressed, and make it easy for users to comprehend the evaluation results, as exhibited in Figure 4.6.

Figure 4.6. Chart 1 – Evaluation Grid



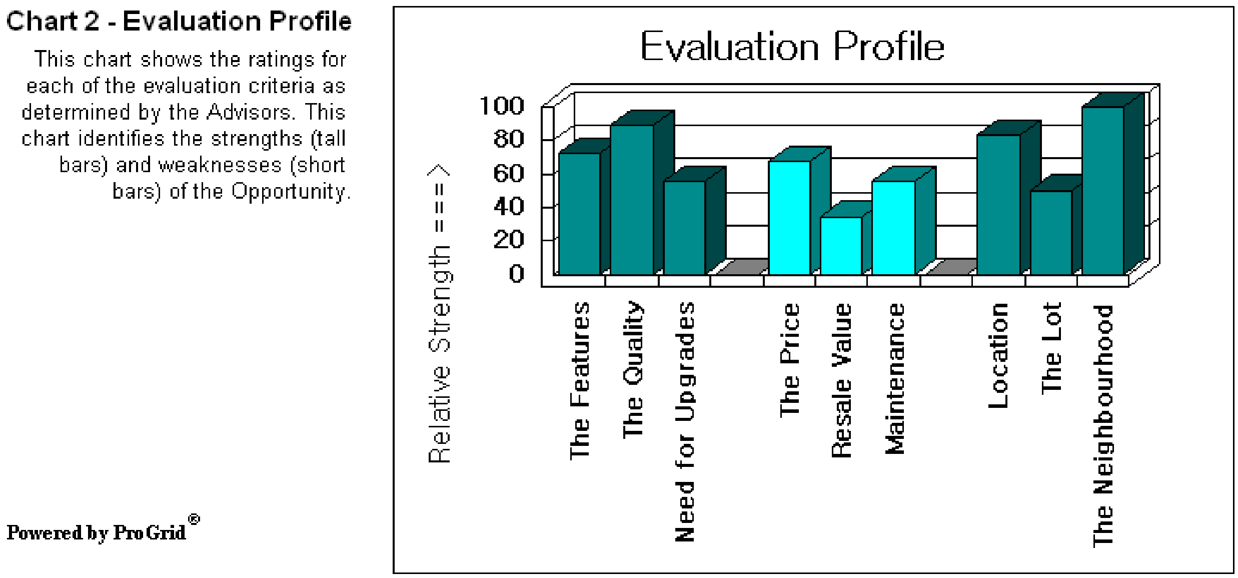
With this chart, the stakeholders can interpret the evaluation results about an alternative as follows:

- There are six evaluators participated.
- The position (3.7, 4.9) is defined as the average of evaluation results.
- The average of evaluation results is located in the area "consider."
- R-value is calculated as the 43%, illustrating the progress on the X and Y axes in achieving the user's goal.

4.4.2 Evaluation Profile

The Evaluation Profile chart shows each rating of the performance criteria and the average rating of the evaluators with respect to all the criteria in the Evaluation Matrix. Hence, it is helpful in demonstrating strengths and weaknesses of the opportunity (alternative) and for tracking progress, using the bars from the relative strength, as presented in Figure 4.7.

Figure 4.7. Chart 2 – Evaluation Profile



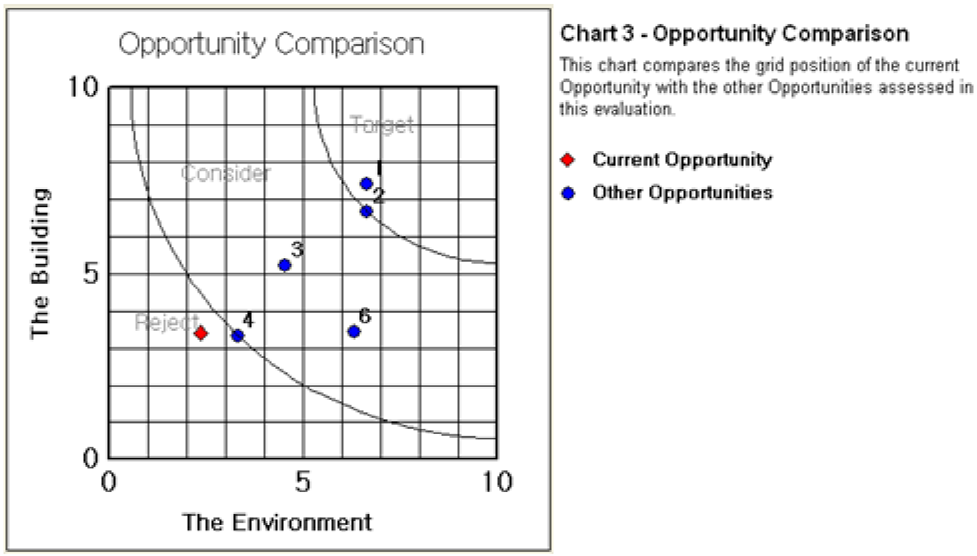
With this chart, the stakeholders can understand the evaluation results about an alternative as follows:

- There are a total of nine criteria in the Evaluation Matrix.
- The users can define all the criteria in the Evaluation Matrix.
- The users can rank the criteria in terms of relative strength.
- The ranking is as follows: neighbourhood > quality > location > feature > price > maintenance > need for upgrades > lot > resale value
- The stakeholders can interpret the alternative's strengths such as neighbourhood and quality, and weaknesses such as resale value and lot.

4.4.3 Opportunity Comparison

The Opportunity Comparison chart provides the X, Y grid positions of all the alternatives evaluated in a project, so it implements as a database. The chart shows the average rating of the evaluation results from the experts and compares the ranking of the current application (alternative) with other applications, with the overarching objectives as axes, as exhibited in Figure 4.8. Having a position lower on the chart demonstrates that there are weaknesses either in both overarching objectives or in one of them that would need to be overcome. In other words, it can prioritize alternatives according to their magnitude (R-values).

Figure 4.8. Chart 3 – Opportunity Comparison



With this chart, the stakeholders can compare the evaluation results of all the alternatives and interpret as follows:

- There are total 6 alternatives (opportunities) related to this project.
- The users can identify alternatives according to priority in terms of relative positions and the R-values based on current and other opportunities.
- Opportunity 1 and 2 are located in "Target" district, and Opportunity 3, 4, and 6 are located in "Consider" area, and finally Opportunity 5 (current opportunity) is located in "Reject" region .
- The priority is as follows : Opportunity 1 > Opportunity 2 >> Opportunity 3 > Opportunity 6 > Opportunity 4 >> Opportunity 5

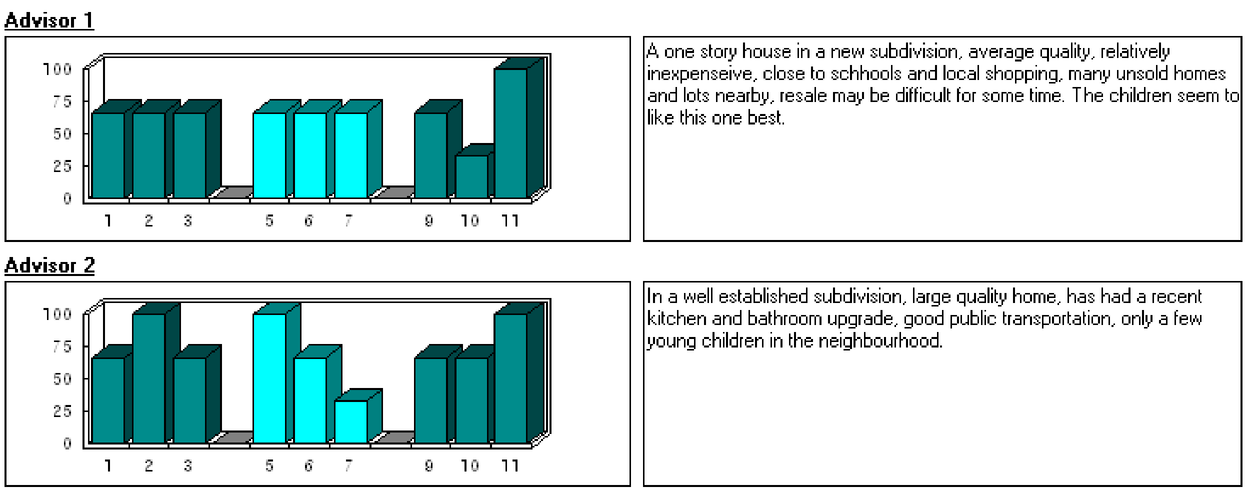
4.4.4 Advisor Assessment

The Advisor Assessment table shows each advisor's assessment about the evaluation criteria and provides an indication of the opinion diversity, as presented in Table 4.2. Hence, stakeholders can compare all the evaluation results based on each criterion from each evaluator, with their comments, as shown in Figure 4.9. This allows stakeholders to concentrate quickly on those criteria where there is the widest opinion range.

Table 4.2. Advisor Assessments

	Evaluation Criteria	1	2	3	5	6	7	9	10	11
1.	Advisor 1	C	C	C	C	C	C	C	B	D
2.	Advisor 2	C	D	C	D	C	B	C	C	D
3.	Advisor 3	C	D	C	D	B	C	D	C	D
4.	Advisor 4	D	D	B	C	A	C	D	B	D
5.	Advisor 5	C	C	B	C	B	B	D	C	D
6.	Advisor 6	C	D	C	A	A	C	C	B	D

Figure 4.9. Advisor Assessments Including Comments



With this table and chart, the stakeholders can quickly focus on all the evaluation results from each advisor and compare the results easily, and understand as follows:

- Which advisor and how evaluates the criteria.
- Why the advisor evaluate the criteria with what reasons.
- Degree of consensus among the advisors (reviewers).
- Advisors give a numerical rating through the specification of short descriptive comments.
- The comments can be as valuable to the stakeholders as the actual assessment results.

Output reports are generated for each corresponding subject of evaluation, based on the information from the evaluators. Output reports contain the following information:

1. The Opportunity Summary provided by the evaluator.
2. The Evaluation Grid showing the results of the evaluation from each evaluator, with the overarching objectives as the axes.
3. An R-value calculated as a percentage measuring the distance for the proposed opportunity.
4. The Evaluation Profile showing the average rating of the evaluators with respect to all the criteria in the Evaluation Matrix.
5. The Opportunity Comparison Grid comparing the ranking of the current application with other applications, with the overarching objectives as the axes.
6. The Advisor Assessments comparing all the evaluation results from each evaluator, with their comments.

With the above procedures and the output reports, the ProGrid provides a process to evaluate or weigh information usefully and ensures that the wisdom of all stakeholders is employed as completely as possible.

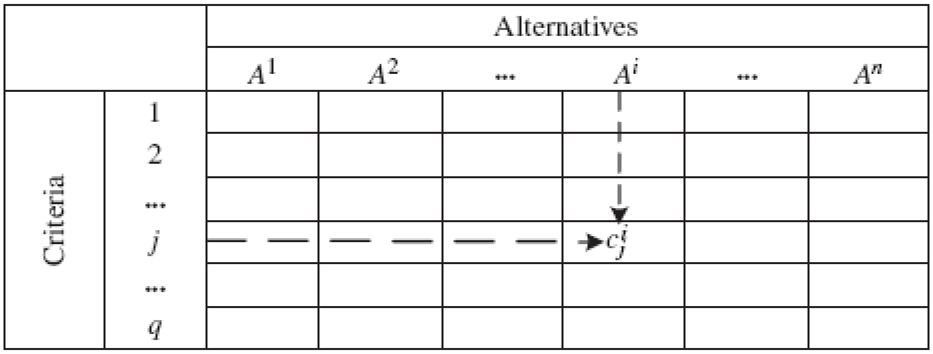
4.5 Comparison with MCDA and Benefits

The purpose of Multiple Criteria Decision Analysis (MCDA) is to help decision makers to make sound decisions through processes of sorting, ranking, and choosing alternatives with more than two criteria. The process of general MCDA has the following steps:

1. Defining an objective
2. Selecting important criteria for achieving the objective and establishing possible alternatives
3. Evaluating each alternative based on each criterion

Through this process decision makers can obtain results showing an objective number for each alternative, and can therefore determine the ranking of the alternatives according to those results (Chen et al., 2008). Figure 4.10 shows the basic concept of MCDA. In the figure, the set of alternatives is defined as $\mathbf{N} = \{ A^{\mathbf{1}}, A^{\mathbf{2}}, A^{\mathbf{3}}, \ldots, A^{\mathbf{i}}, \ldots, A^{\mathbf{n}}\}$, and the set of criteria is presented as $\mathbf{Q} = \{1, 2, 3, \ldots, j, \ldots, q\}$. The results of the alternatives based on criterion is defined as c_j^i or $c_j(A^i)$.

Figure 4.10. Basic Structure of MCDA (Source: Chen et al. (2008), "A case-based distance model for multiple criteria ABC analysis," Computers & Operations Research 35, p. 779.)



The basic concept of ProGrid methodology is the same as the general MCDA. However, the ProGrid methodology is designed to consider two opposite overarching objectives that are in conflict. The process of resolving the conflict between these objectives plays a critical role in achieving a higher level of success for drawing a rational solution. This concept of considering conflicting overarching objectives reflects the realities of societal-environmental problems. Therefore the ProGrid methodology is the appropriate method for evaluating intangible assets such as Canada's oil sands as an energy system, and this method will contribute to the making of strategic decisions.

In addition, conventional evaluation methodologies such as opinion surveys collect massive amounts of information and weed out the unnecessary data progressively. As the amounts of information increase, the work of evaluation can be very difficult and may lose any meaningful focus. Compared with conventional evaluation methods, ProGrid methodology has the following advantages:

- Comprehensive – confirms that all critical aspects have been covered
- Achieves consensus – encourages participation from all stakeholders
- Fast and reproducible – busy experts readily accept the evaluation task
- Graphical and easily comprehended
- Prioritizes values according to their magnitude
- Can be used as a corporate database
- Concentrates on key strategic issues and decisions

ProGrid methodology and the software dramatically clarifies information by reducing it to understandable charts that emphasize the issues to be addressed for each decision. In particular, the profile charts can provide significant additional information. For instance, if most of the bars are located in the middle area of the ratings, no major strengths and no serious weaknesses exist.

ProGrid also enhances the responsibility of governments to form more efficient and organized relationships with the private sector. The methodology provides an improved process for a decision environment with its openness, fairness, transparency, and accountability. The methodology helps governments to fulfill their fiscal management effectively and efficiently, with coherent scoring and weightings for each response, and dramatically reduced reviewer fatigue. The last benefit is the results can be integrated into a current government project management systems without difficulty.

On the other hand, ProGrid itself does not make decisions. Rather, the methodology organizes various information to help make sound decisions, helping stakeholders make their best situation, reviewers to take advantage of their own expertise, and decision makers to make adequate decisions. In addition, ProGrid is not a dynamic process that requires updating and review, so it needs the active participation of all stakeholders.

4.6 Summary

In this chapter, evaluating what we cannot quantitatively measure was implemented using the ProGrid methodology. This methodology is a useful decision-assist tool for carrying out multiple-criteria decision analyses, and it has the capability to convert qualitative concepts into quantifiable measures. Through the whole process from the modeling to output reports in the ProGrid methodology, decision makers can obtain reasonable suggested solutions.

The next chapter will explain how the ProGrid methodology is employed as a systems approach for strategic decisions with respect to Canada's oil sands and their development. Information regarding Canada's oil sands introduced in Chapters 2 and 3 will be used with the development of ProGrid methodology as input data. In addition, the contents will play a crucial role in evaluating the oil sands' value and their potential as a key energy system to lead Canada towards an energy superpower status.

Chapter 5

Application of the ProGrid Methodology to Canada's Oil Sands

This chapter introduces a variety of elements related to Canada's energy system as alternatives for Canada's current energy plans and analyzes the country's energy resource with various viewpoints from different levels. Comprehensive knowledge from the previous chapters plays an essential role in evaluating the value of oil sands, an element of Canada's energy system, and can help stakeholders to make strategic decisions that will lead Canada to become an energy superpower.

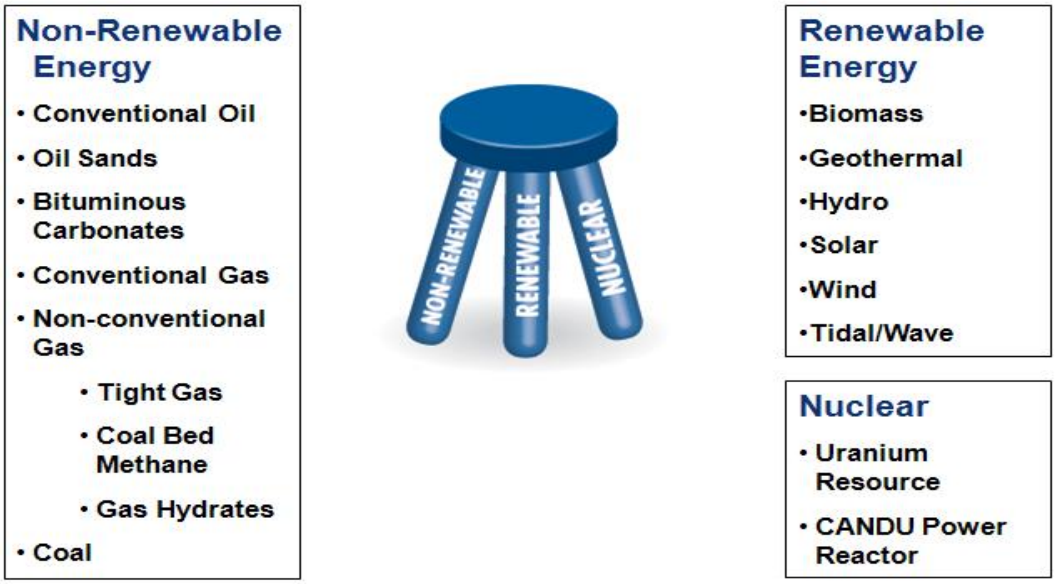
5.1 Introduction of Canada's Energy System and Application Procedure

According to Dr. Clem Bowman at the CAE workshop in Sarnia on May 18th in 2010, energy superpower status can be achieved when the following four conditions are satisfied.

- Sustainable and exportable resources
- Environmentally acceptable production
- Economically substantial value
- An integrated energy system

To accomplish the goal, first of all, Canada's energy system should be reviewed in depth and be analyzed comprehensively to identify strategic solutions. Its present energy system is composed of three major categories: Non-renewable energy, Renewable energy, and Nuclear, as shown in Figure 5.1.

Figure 5.1. Canada's Energy System (Source: Bowman (2010), "Canada – A Sustainable Energy Superpower?," Workshop, Canadian Academy of Engineering, May 2010, Sarnia, Ontario)



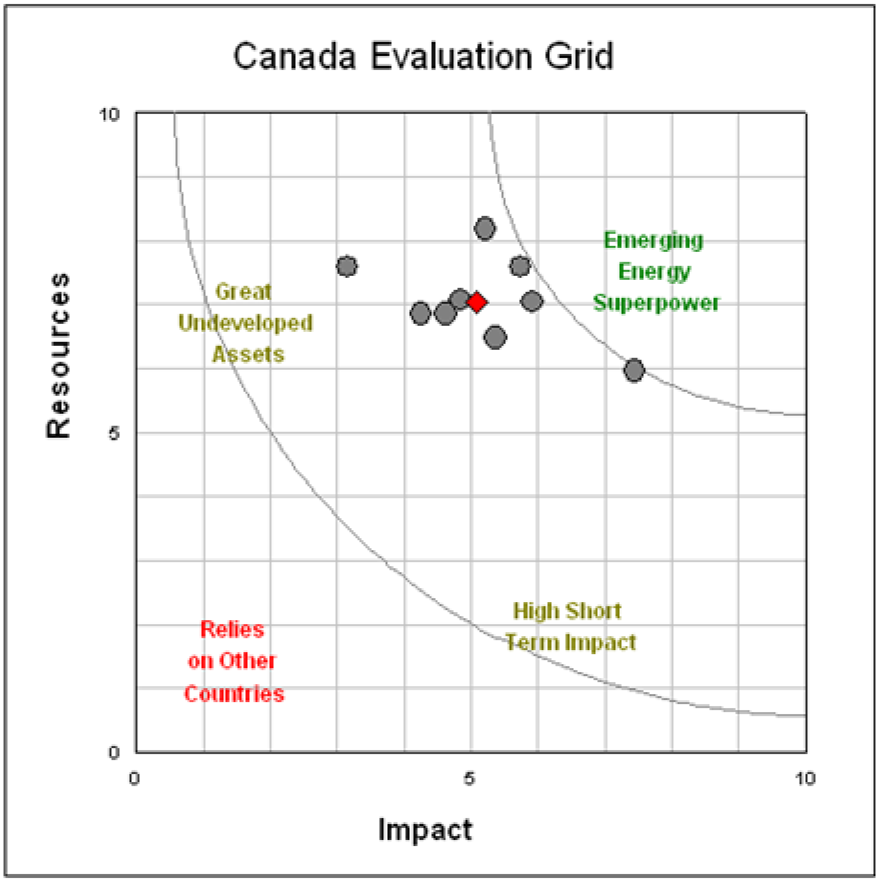
Canada's potential as an energy superpower depends on the value and role of these main three energy groups. Hence, the three together can be considered Canada's energy alternatives, so their systematic management is required, because they can lead Canada to its energy goal. At the CAE workshop, Dr. Clem Bowman evaluated the energy system to assess Canada's potential to become an energy superpower. Energy resources and their impacts are defined as the two overarching objectives, and nine key criteria are also designated through the definition of energy superpower in an Evaluation Matrix, as presented in Table 5.1. All of the key criteria in the matrix should be addressed to make Canada an energy superpower.

Table 5.1. Dr. Bowman's Evaluation Matrix (Source: Bowman (2010), "Canada – A Sustainable Energy Superpower?," Workshop, Canadian Academy of Engineering, May 2010, Sarnia, Ontario)

Energy Resources	Processes	Impact
Non-renewables	Generation Capacity	Meeting Demand
Renewable	Transport./Transmission	Economic Impact
Nuclear	Energy Systems	Quality of Life Impact

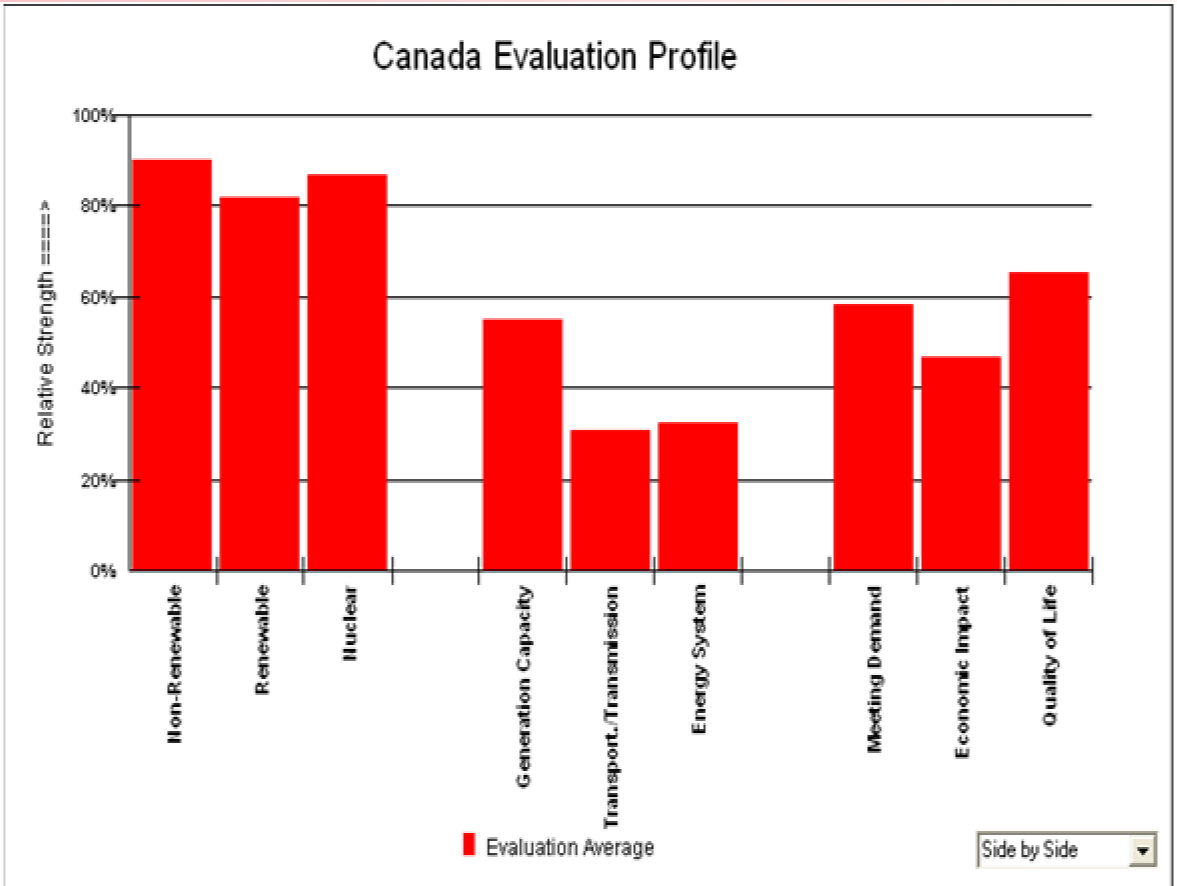
Evaluation of Canada's energy systems by various groups of experts led to the following results, as illustrated in Figure 5.2, applying the two overarching objectives as its axes.

Figure 5.2. Evaluation Result - Canada's Energy System (Source: Bowman (2010), "Canada – A Sustainable Energy Superpower?," Workshop, Canadian Academy of Engineering, May 2010, Sarnia, Ontario)



Canada's current energy system is positioned close to the level of emerging energy superpower. In other words, Canada has a high potential to emerge as a world energy leader in terms of resources and impact. Figure 5.3, the Evaluation Profile chart, also shows the criteria's strengths that should keep being developed and the criteria's weakness that should be overcome. In particular, it should be noted that non-renewable energy is positioned at the highest level, relatively, compared to the other criteria. Hence, we need to analyze non-renewable resource in detail.

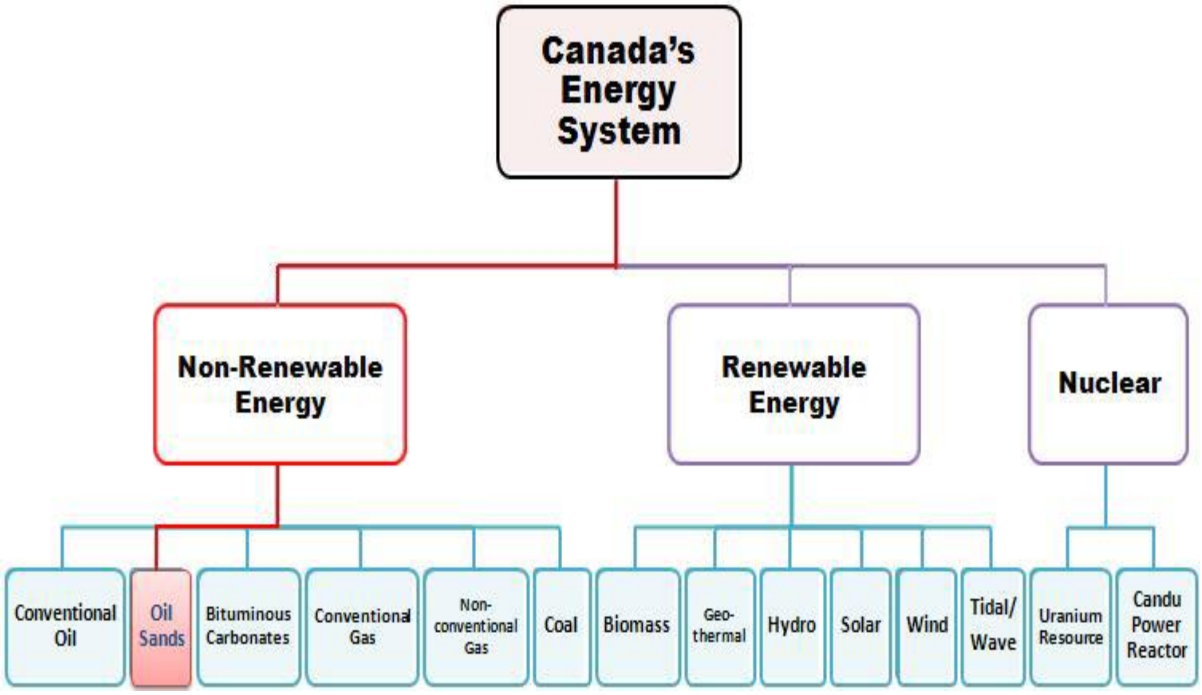
Figure 5.3. Canada's Evaluation Profile (Source: Bowman (2010), "Canada – A Sustainable Energy Superpower?," Workshop, Canadian Academy of Engineering, May 2010, Sarnia, Ontario)



As shown in Figure 5.1, non-renewable energy consists of six resources: conventional oil, oil sands, bituminous carbonates, conventional gas, non-conventional gas, and coal. These six play a key role in Canada's energy system, as seen in the highest level in the above profile chart, Figure 5.3. However, it does not show which non-renewable resource has more significance or less importance than the other non-renewable resources for Canada's energy future. Accordingly, these six resources should be evaluated with key criteria, and the result will provide the strong and weak points and also will help stakeholders to make reasonable decisions to promote Canada's vision of itself as an energy superpower.

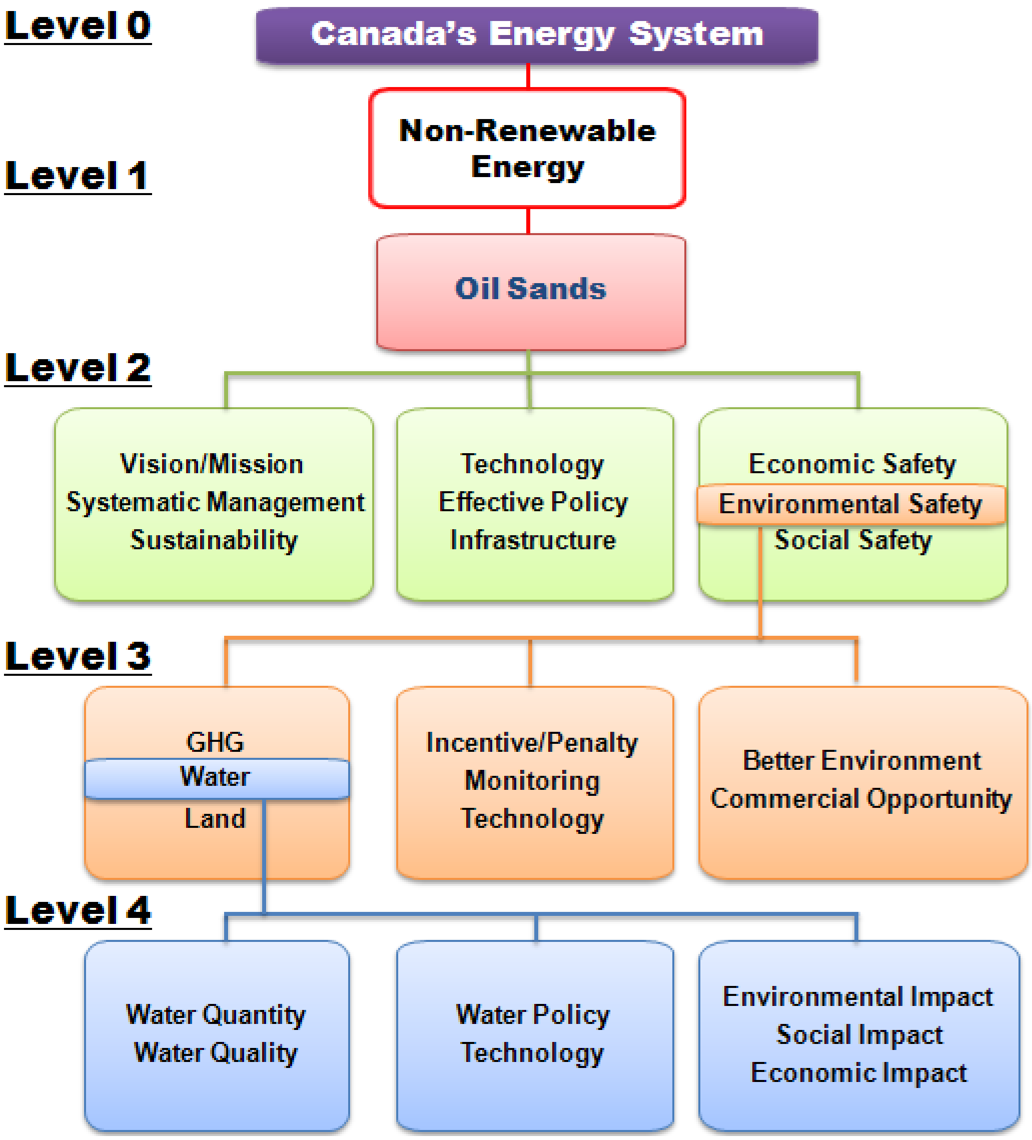
This thesis concentrates on oil sands' evaluation, as described in Figure 5.4, because the scale of study with all the non-renewable resources is too wide to research at the master's level.

Figure 5.4. Position of Oil Sands as a Energy Source



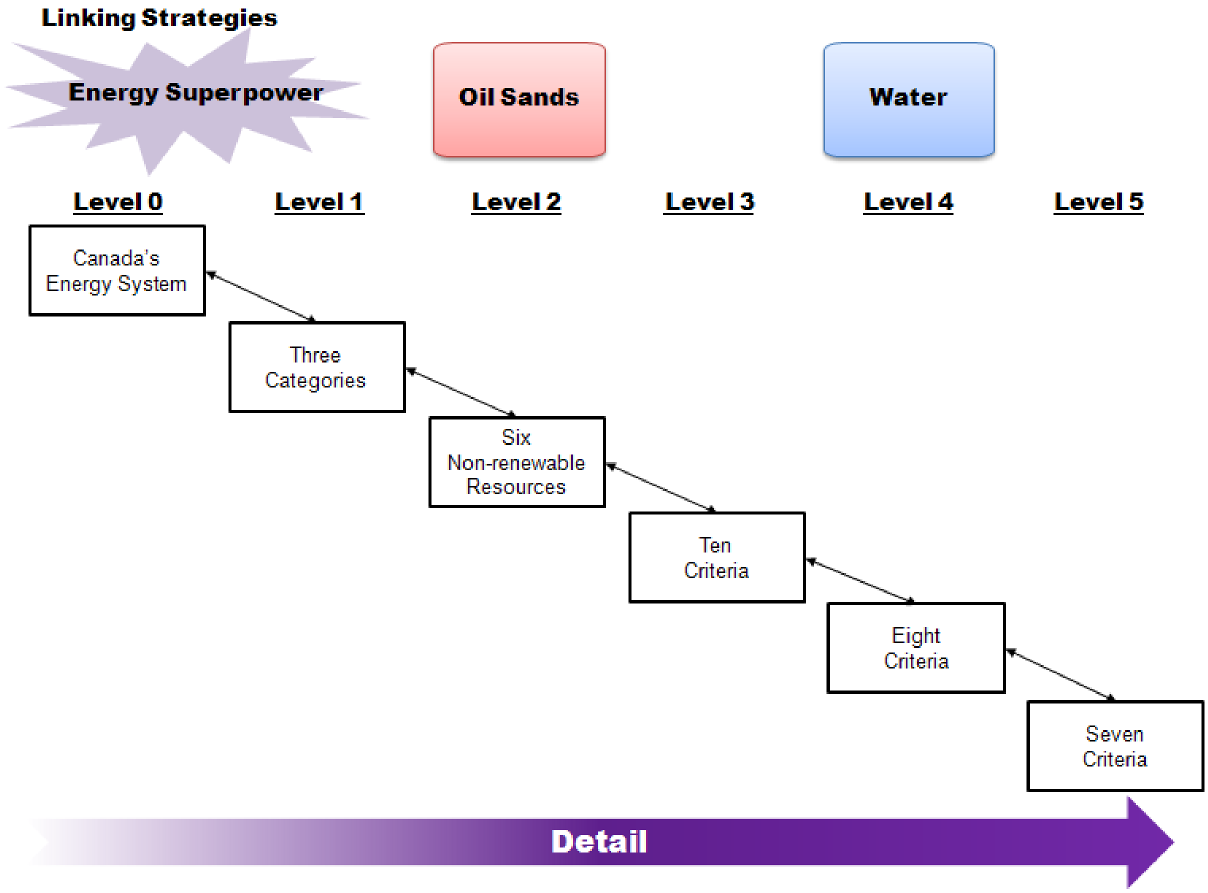
To apply the ProGrid methodology to Canada's oil sands energy resource as a decision-making tool with an integrated energy viewpoint, we need to understand that Canada's energy system is linked and stratified. Each level has its own governing structures and strategic plans, and these strategies are linked and focused on Canada's energy goal. In the same manner, the oil sands resource is linked in a complicated fashion and involves many criteria, so appropriately analyzing the oil sands resource requires the concept of Cascading Matrices with multiple-criteria based on different levels of concerns and strategies, as depicted in Figure 5.5.

Figure 5.5. Application to the Concept of Cascading Matrices



In this section, we assume that the evaluation result from Dr. Clem Bowman (2010) is performed at Level 0, taking a big picture view to assess Canada's energy system. The evaluation result represents non-renewable energy as ranking high in Canada's energy system. Hence, we can realize keenly the necessity of analysis at a more-detailed level, and the oil sands, as a source of non-renewable energy, are the starting point for this evaluation and analysis.

Figure 5.6. Focusing on Level 2 (Oil Sands) and Level 4 (Water Issues in the Oil Sands)



The oil sands can be evaluated as a Level 2 with nine criteria, and these nine criteria can be assessed individually with each different criteria at Level 3. In addition, water as an environmental indicator, one of the criteria from the environmental safety at Level 3, can be analyzed using seven criteria at Level 4. This thesis focuses on oil sands as a key energy resource with nine criteria at Level 2 and water issues in oil sands development with seven criteria at Level 4, as displayed in Figure 5.6.

5.2 Modeling (Level 2): Oil Sands as an Energy Resource

To evaluate the oil sands' value and potential as a part of Canada's energy system, the ProGrid methodology is employed to address the priorities identified as criteria in the Evaluation Matrix. Canada's oil sands as an energy resource are expressed quantitatively with R-value (%), including X and Y positions.

5.2.1 Overarching Objectives of Canada's Oil Sands

As the first step in ProGrid methodology, two overarching objectives should be selected to analyze the oil sands' current position and future based on more detailed level (Level 2). Through the deliberation generated by oil sands research, the following two overarching objectives are chosen to make Canada an energy superpower.

- Contribution to Canada becoming an energy superpower
- Economic, environmental, and social security

5.2.2 Evaluation Matrix of Multiple Criteria for Canada's Oil Sands

As the second step in ProGrid methodology, an Evaluation Matrix is established including multiple-criteria, as shown in Table 5.2. Through information and knowledge from Chapters 2 and 3, the key criteria can be considered and selected to address essential matters in Canada' oil sands.

Table 5.2. Evaluation Matrix for Canada's Oil Sands

INPUTS Contribution to the Goal	ENABLERS Connectors	OUTPUTS Security
Vision/Mission	Technology	Economic
Systematic Management	Effective Policy	Environmental
Sustainability	Infrastructure	Social

5.2.3 Language Ladder for Canada's Oil Sands

As the third step, Language Ladders are built for all the criteria in the Evaluation Matrix. Each Language Ladder for the criteria consists of key words and simple descriptions to enable users to understand the situation clearly like a dictionary. The alphabets such as A, B, C, and D are used to present the progressive standard and can perform an objective rating for evaluating the oil sands as a key driver of Canada's energy system. An instance of the Language Ladder for effective policy, one of the criteria in the matrix, is displayed in Table 5.3. All the Language Ladders regarding the multiple-criteria (nine criteria in the Evaluation Matrix) are presented in Appendix B at the end of this thesis.

Table 5.3. Language Ladder for Effective Policy

In terms of making Canada an energy superpower,	
A	an effective policy with respect to the energy resource has not been established or conducted.
B	some policies with respect to the energy resource have been established or conducted, but are not effective enough.
C	an effective policy with respect to the energy resource has been firmly established or conducted.
D	...AND the policy is utilized in many areas as a successful case of a leading policy in Canada.

5.3 Evaluating Canada's Oil Sands

Six people including Dr. Bowman and the Conflict Analysis Group at the University of Waterloo participated in evaluating the oil sands in terms of contribution, enablers, and security in the Evaluation Matrix. The author of this thesis also performed an assessment as an evaluator.

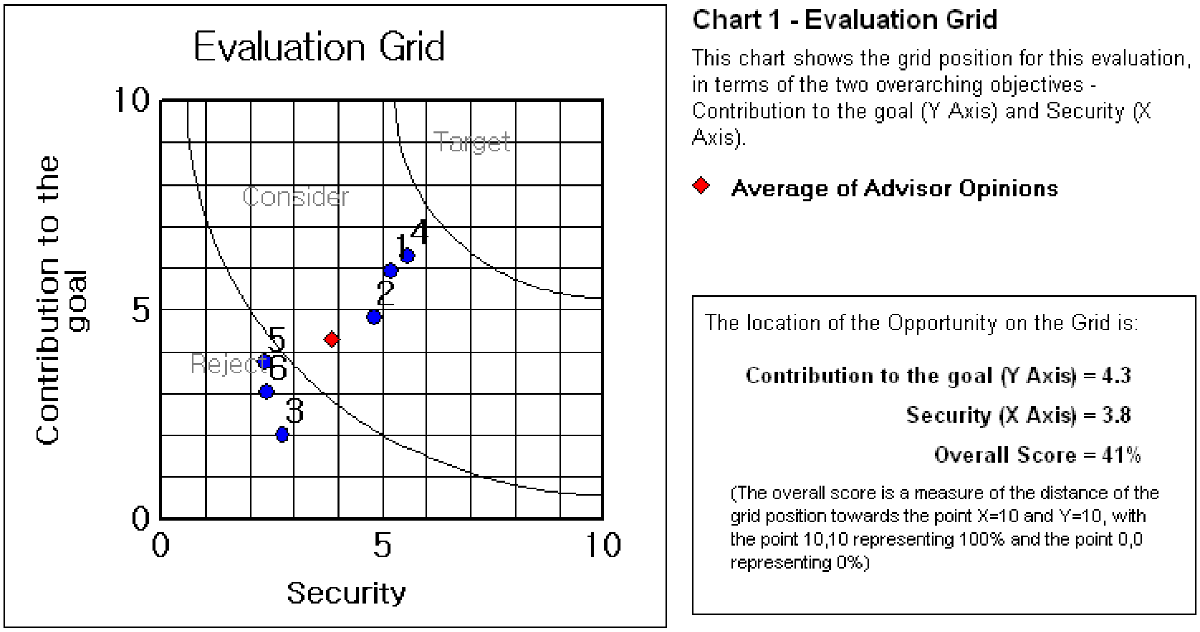
5.4 Output Reports of Canada's Oil Sands

The Evaluation Grid and Evaluation Profile are created as the output reports in this section, and these output reports present each evaluator's opinion and the average of them. To generate an Opportunity Comparison as one of the output reports, more evaluation results about other alternatives, such as conventional oil, coal, conventional gas, non-conventional gas, bituminous carbonates, are needed. However, this section focuses on only oil sands resource as an element of Level 2, so the Opportunity Comparison report is not provided at this point.

5.4.1 Evaluation Grid of Canada's Oil Sands

This Evaluation Grid is generated with each evaluator's grid position and the average of the evaluations, with regard to the contribution to Canada becoming an energy superpower and economic, environmental, and social security. The position Xs and Ys, and the R-value (%) simply represent the evaluators' results with a number of quantitative assessments. The Evaluation Grid for the oil sands is shown in Figure 5.7.

Figure 5.7. Evaluation Grid – Canada's Oil Sands



Through this Evaluation Grid chart, the stakeholders can understand the evaluation results about Canada's oil sands as follows:

- The average of the evaluators is located in the "Consider" area, but the distance for "Target" area is a bit far, which means some resolutions and actions should be implemented to lead Canada toward an energy superpower status.
- The position (3.8, 4.3) in the graph is the average of the evaluation results.
- The R-value is given as 41%, describing the current progress on the X (Security) and Y (Contribution) axes for achieving Canada's energy goal.

In summary, current oil sands resource is positioned in the "Consider" area as one of Canada's energy system. Hence, Canada's oil sands have many factors that must be considered to achieve the country's energy goal. The following chart shows stakeholders the way the oil sands can be developed for reaching Canada's energy goal.

5.4.2 Evaluation Profile of Canada's Oil Sands

The Evaluation Profile presents the average evaluators' rating regarding all the criteria in the Evaluation Matrix, as displayed in Figure 5.8.

Figure 5.8. Evaluation Profile – Canada's Oil Sands

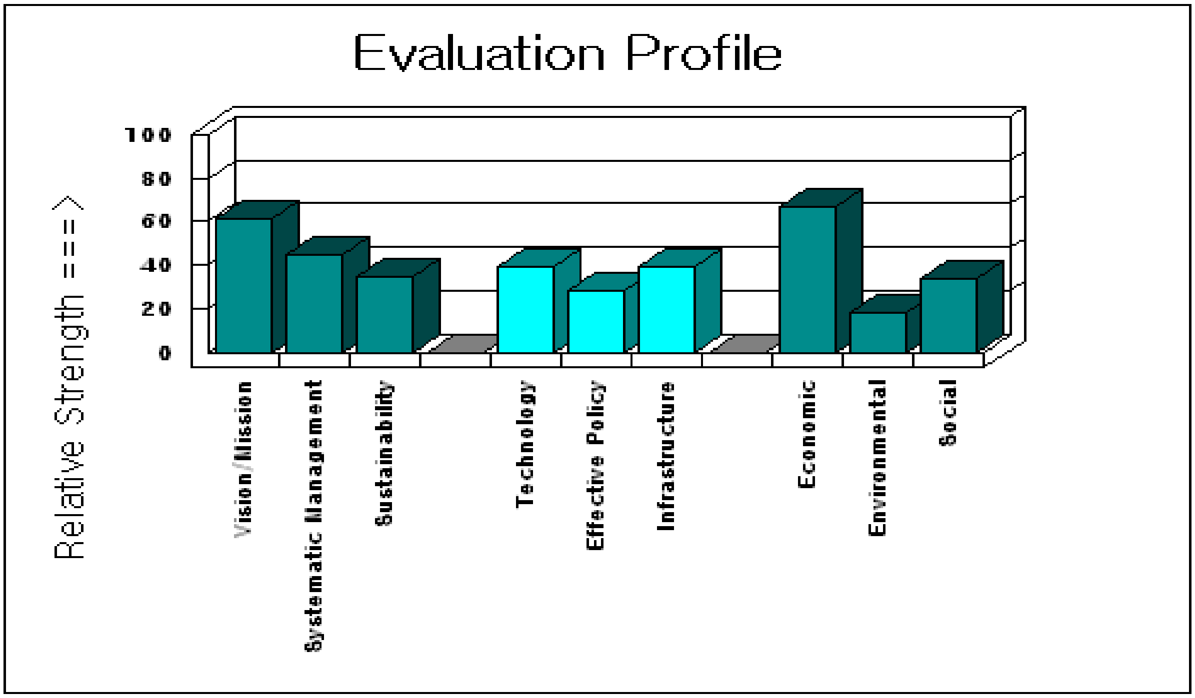


Figure 5.8 represents the relative strengths that should be developed and weaknesses that should be overcome, with regards to the criteria of the oil sands as an energy system to make Canada an energy superpower.

- The relative strength is: Economic Security > Vision/Mission > Systematic Management > Technology and Infrastructure > Sustainability and Social Security > Effective Policy > Environmental Security
- Canada's oil sands have a strong point in terms of economic security.
- Environmental security related to the oil sands must be considered and overcome as the highest priority for achieving the national energy goal.
- Effective policy, social security, and sustainability are also seriously considered and addressed for Canada's energy future.

In next section, the ProGrid methodology is employed for tackling water quantity and quality problems in Canada's oil sands at a more detailed level.

5.5 Introduction of Alternatives to Water Issues in Canada's Oil Sands

As an application at a more detailed level, this section describes various approaches for water resource allocation as alternatives to water problems in Canada's oil sands, with a focus on balancing environmental, social, and economic goals. One goal of these alternatives is to allocate water reasonably to achieve optimization of the water resource in terms of environmental, social and economic aspects, but the evaluation of alternatives is very difficult. In short, we need to find the best alternative that satisfies environmental and social goals with the least costs and negative impacts on economic goals. Through the application to the ProGrid methodology, one can see that the optimum alternatives can make a great contribution toward the oil sands resource as a key element of Canada's energy system. Schindler and Adamowicz (2007) introduced five alternatives (options) with respect to water issues in Canada's oil sands development. These alternatives (options) should be evaluated to help stakeholders make sound decisions.

5.5.1 Alternative 1: The "Status Quo"

The current water framework includes both permanent and temporary licenses related to water consumption in Alberta. A "green, yellow, red" scheme has been implemented to restrict water withdrawals according to the river flows conditions as part of the water management framework for the Athabasca River. However, the mechanisms for response to water scarcity have difficulty in applying a reasonable approach under the current policy framework: "first in time, first in right" system (the older license priority). In other words, historical property rights by date of license have priority over the value of water use. For example, if the state of the flow is judged to be in the yellow management zone (the cautionary threshold), a company that wants to obtain a license should accept the provisions for reduced water use, even though the company uses water for a higher value. In the red management zone situation, maximum withdrawal limitations such as a restriction to an annual allocation percentage over all licensed users will be implemented. In addition, users have little incentive for water use reduction under the current "command and control" approach unless there is a case of "yellow" or "red." This approach does not encourage private companies to develop and employ new technologies related to water reduction. This system has the advantage of avoiding worst-case scenarios in terms of ecology, but it does not help reducing costs related to economic activity. Hence, this approach is unfavorable for individual firms or water users and requires more costs in terms of water management compared to market based mechanisms.

5.5.2 Alternative 2: Tradable Water Rights

Tradable water rights have been implemented by various countries such as Australia, the Western United States, and Chile over 25 years. In recent times, southern Alberta has partially applied this approach to address water issues. Tradable water rights are a form of "cap and trade" system or market based mechanism to protect the water environment. This system provides a strict legal and administrative framework to transfer water from low value users to high value users. Maximum total withdrawals are limited, and trading is only possible within the limits and without negative impacts on other users or the environment. In general, this system is approved by third parties. Tradable water rights encourage stakeholders to save water through an improved technology, so the stakeholders can have benefits through selling the rights to that amount of water. Rights trading includes both temporary and permanent trades, and it has resulted in an increase of flexibility in the trading system, leading to increased trade frequency and decreased environmental costs. Water rights trading requires the capability of enforcing and monitoring trades, so it cannot take place without administrative systems and approved basin management plans. This approach has the potential to accomplish water quantity goals with the least cost, and it may provide incentive with respect to implementing water storage. Tradable water rights can be implemented with relatively low transaction costs, with approaches to address third party effects, and with transfer flexibility for both permanent old and temporary new licenses. The key issues of the Athabasca case are the way to establish the maximum amount of water withdrawal, considering the seasonal water scarcities, long-term water flow variations, and environmental issues. Water rights trading is becoming more popular in various jurisdictions. However, allocating the initial rights is difficult in the oil sands area because of its rapid economic evolvement.

5.5.3 Alternative 3: Water Charges

Water pricing policy involves set charges based on environmental and user costs with regard to water. This system can provide a standard of water resource allocation in terms of efficient water use. In addition, this approach can charge according to the type of water, such as surface water, ground water, and saline water. Water pricing policy does not directly control water consumption the way tradable water rights do, but prices encourage water demand management such as by reducing water use and adopting technology that decreases water consumption. This methodology can apply the approach of supply management based on storage structure and storage markets. Metering and reporting of water use is important to the implementation of water pricing policy. Issues related to a water pricing approach include the responsiveness of water consumption to water charges, the cost implication for companies, and the use of water revenues. Increases in water cost bring about reduced water and substituted technologies such as recycling and recirculation. However, in general, Canada's water costs for industry occupy a small portion of overall costs, and these modest water prices have little impact on overall costs. Hence, achieving a successful pricing approach requires information such as the impacts of pricing strategies and the potential for technical change. The establishment of the price levels and the use of the water revenues are also very critical issues in determining prices. The possibility for recycling, water substitution (among surface water, groundwater, and saline water), substitution of other materials, and process innovations are significant factors to evaluate the water pricing. Refunded Emissions Payments Scheme (REP) can be useful to resolve the issue of the use of the revenues from water charges. This scheme charges industry an excessive price per unit of emissions, but refunds a large portion of the revenue to the industry based on the output of the industry. The large charges can cause the industry to reduce emissions and to develop technology. However, if the amount of the charges is relatively low, the impacts are minor. This scheme is similar to a tradable permits scheme in terms of making reference to historical output levels, but it does not require many of the transaction costs compared to tradable permits schemes. This REP scheme has the potential to be an effective means of regulating the water charges in the oil sands area if it is employed suitably. The costs of monitoring and enforcements can be relatively low because water consumption and output are monitored in the oil sands region at present.

5.5.4 Alternative 4: Performance Standards and Tradable Performance Standards

Performance standards or targets can be used to encourage firms to decease water use. For instance, a target for the number of barrels of water used to produce a barrel of oil can be developed for the industrial sector at a level lower than the current industry average with disclosure on progress towards this target. The oil sands industry can voluntarily make an effort to accomplish these targets by setting technology-based standards, by supporting technology-based subsidies, and by employing differential incentive-based mechanisms. In the case of tradable performance, the desired emissions per unit output are established as a target. When a firm achieves a lower emissions intensity than this objective, the firm can sell some permits up to the target point. On the other hand, if a firm does not achieve the objective, the firm must buy permits to decease their intensity to the target. This scheme is very similar to the tradable water rights and the REP scheme. Tradable water rights require the key design with respect to the "cap" and maximum water allocation, and the approach maximizes water use efficiency within the cap. REP scheme requires the key design with regard to water charge, and the approach shows the possibility of efficient water use. However, in the tradable performance standards, the key characteristic is the target water use per unit output, and supporting regulations are required to limit water consumption to be within the cap with water charges.

5.5.5 Water Storage

In order to deal with insufficient water during winter in the Athabasca basin, a water storage approach can be one mechanism to satisfy winter flow needs with the construction of off-stream storage. This method is a feasible alternative and a practical solution to address low winter flows in the Athabasca River. However, the implementation cost has a potential to be significant. Different water charges between high flow periods and low flow periods can cause the incentive to conserve water and to shift water withdrawals as a reasonable water strategy.

5.6 Modeling (Level 4): Water Quantity and Quality Problems in the Oil Sands

In order to address the water quantity and quality problems in Canada’s oil sands, the ProGrid methodology also can be applied as a reasonable decision-assist tool with the concept of Cascading Matrices because these issues are qualitative and require an in-depth analysis based on multiple-criteria.

5.6.1 Overarching Objectives for Water Issues in Canada's Oil Sands

As mentioned before, the process of choosing the two key overarching objectives is the first step in ProGrid methodology. Through many considerations, the following two overarching objectives are selected:

- Water Security
- Balance and Impact

5.6.2 Evaluation Matrix of Multiple Criteria for the Oil Sands' Water Issues

The second step in the method is to establish multiple-criteria for the evaluation through an Evaluation Matrix, as displayed in Table 5.4. This matrix was created to include all of the key criteria that would be important in addressing water quantity and water quality problems in Canada’s oil sands.

Table 5.4. Evaluation Matrix for Water Issues

INPUTS Water Security	ENABLERS Connectors	OUTPUTS Impacts and Balance
Water Quantity	Water Policy	Environmental
Water Quality	Technology	Social
		Economic

5.6.3 Language Ladder for the Oil Sands' Water Issues

The next step is to build the Language Ladders for all the criteria. Every Language Ladder for the criteria includes short sentences composed of key words to help users make rational evaluations. The Ladders are readily comprehensible by evaluators, defining A, B, C, and D as in a dictionary. An example of the Language Ladder for Technology, one of the criteria, is illustrated in Table 5.5. All the Language Ladders regarding the multiple-criteria (seven criteria in the Evaluation Matrix) are displayed in Appendix B at the end of this thesis.

Table 5.5. Language Ladder for Technology

In Canada's oil sands, the alternative under consideration	
A	is not to merge any water-saving technologies and does not create synergy effect.
B	is partially to merge some water-saving technologies but does not create synergy effect.
C	is partially to merge some water-saving technologies and partially create synergy effect.
D	is to merge some water-saving technologies and create synergy effect.

5.7 Evaluating Water Quantity and Quality Problem in Canada' Oil Sands

Five members of the Conflict Analysis Group at the University of Waterloo participated in the evaluation process to assess the alternatives in terms of the two overarching objectives. The author of this thesis also conducted the evaluation.

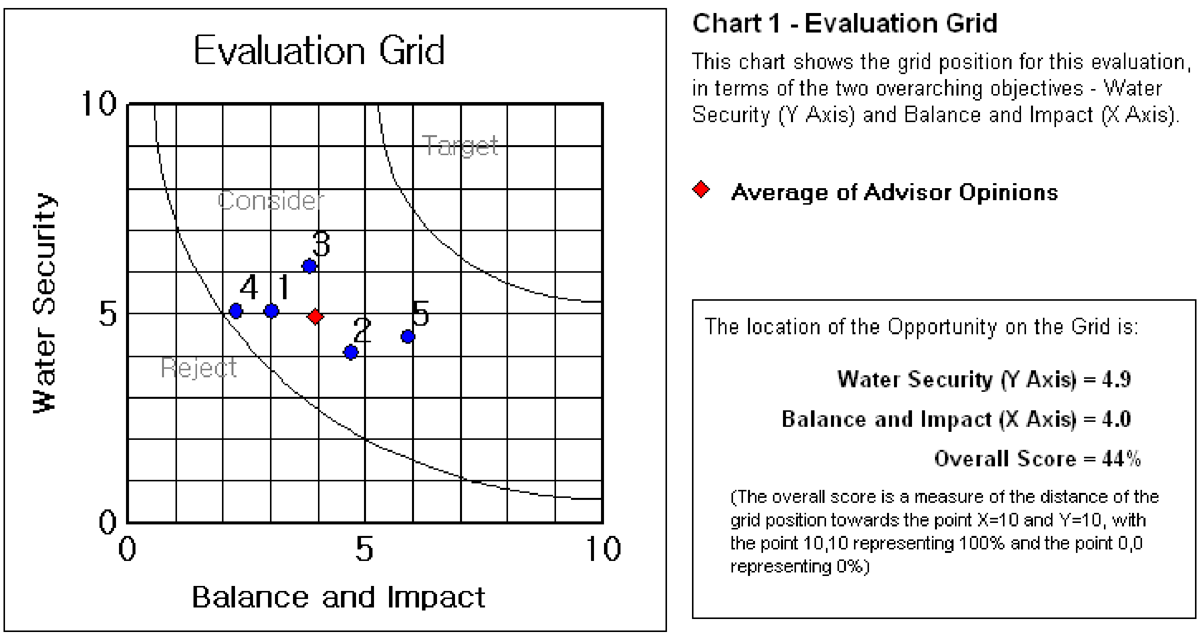
5.8 Output Reports of Canada's Oil Sands' Water Problems

All the output reports for each alternative are created in the form of the Evaluation Grid, the Evaluation Profile, and the Opportunity Comparison, presenting the results as the evaluators' opinions and their average. In particular, the Opportunity Comparison report summarizes the evaluation of all the alternatives.

5.8.1 Evaluation Grid of the "Status Quo"

According to five alternatives, five Evaluation Grids are generated with each evaluator's grid position and the average of the evaluations, with regard to the overarching objectives. In addition, the positions X and Y, and the R-value (%) from the average of the evaluation results are expressed as numbers. An Evaluation Grid of Alternative 1 (the "Status Quo"), one of the five Alternatives, is presented in Figure 5. 9.

Figure 5.9. Evaluation Grid – the "Status Quo"



Through this Evaluation Grid chart, we can interpret the evaluation results about the "Status Quo" alternative as follows:

- The average of the evaluators' opinions is positioned in the "Consider" area.
- The position (4.0, 4.9) is the average of the evaluation results.
- The R-value is given as 44%, describing the progress on the X (Balance and Impact) and Y (Water Security) axes.

In summary, the "Status Quo" is positioned in the "Consider" area, and thus, the option has many issues that must be overcome to be the optimum alternative for water issues in Canada's oil sands. The following report shows stakeholders the way the "Status Quo" can be developed for reaching the best alternative.

5.8.2 Evaluation Profile of the "Status Quo"

In the same manner as the Evaluation Grid, five Evaluation Profiles are created. They describe the average rating of the evaluators with regard to all the criteria in the Evaluation Matrix, as displayed in Figure 5.10.

Figure 5.10. Evaluation Profile – the "Status Quo"

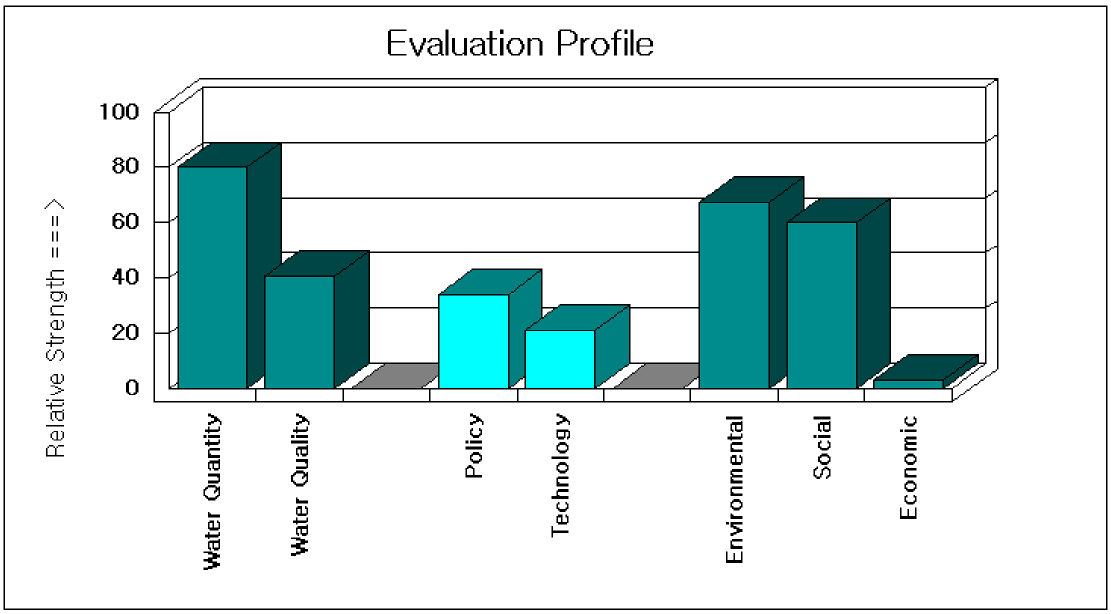


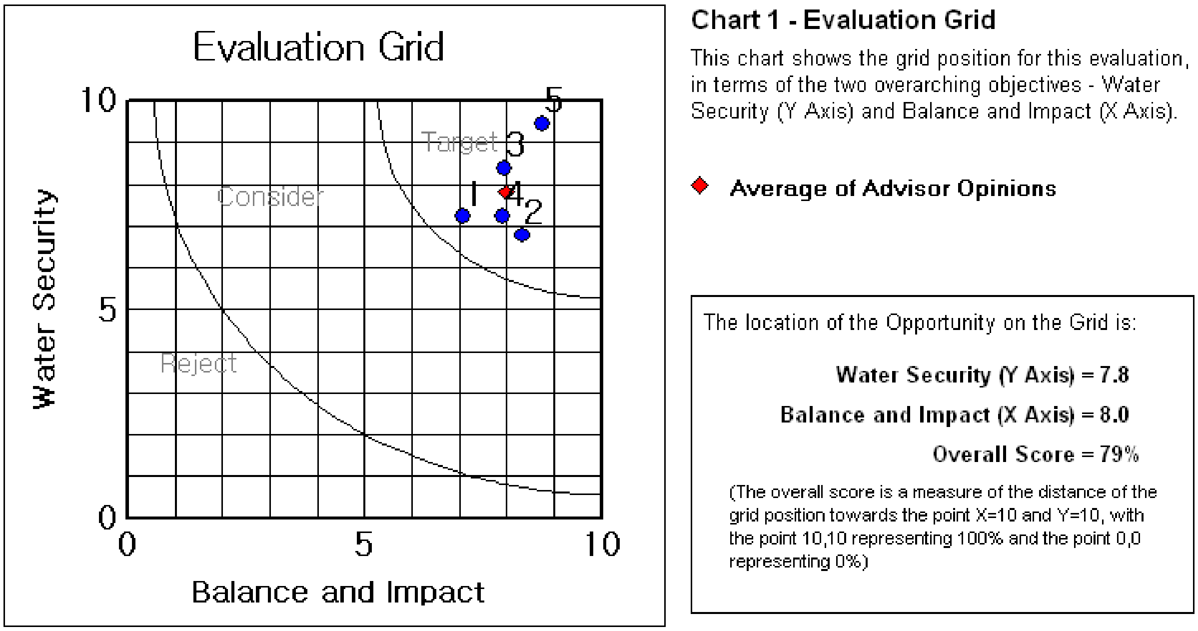
Figure 5.10 shows the criteria's relative strength and weakness with respect to the "Status Quo" alternative. The chart can be explained as follows:

- The relative strength is: Water Quantity > Environmental Impact > Social Impact > Water Quality > Policy > Technology > Economic Impact
- The "Status Quo" alternative is strong in terms of water quantity.
- The economic impact related to the water use efficiency and effectiveness must be considered as the first priority for improving the alternative.
- Technology and policy are also carefully considered for enhancing the alternative.

5.8.3 Evaluation Grid of Tradable Water Rights

Figure 5.11 shows the Evaluation Grid of Alternative 2 (Tradable Water Rights) with its positions X, Y, and the R-value (%).

Figure 5.11. Evaluation Grid – Tradable Water Rights



Using this Evaluation Grid chart, the Alternative 2 (Tradable Water Rights) can be described as follows:

- The average of the evaluators' opinions is located in the "Target" area.
- The position (8.0, 7.8) is the average evaluator opinions.
- The R-value is given as 79%, demonstrating the progress on the X and Y axes.

To summarize, the Alternative 2, tradable water rights, is positioned in the "Target" area. Hence, this option satisfies requirements of most of the criteria for water solutions related to Canada's oil sands. Even though tradable water rights are located in the target position, relative strong and weak points exist. The following Evaluation Profile chart shows stakeholders which criterion for tradable water rights can be improved upon in order to become the optimum alternative.

5.8.4 Evaluation Profile of Tradable Water Rights

Figure 5.12 provides the Evaluation Profiles of tradable water rights. As mentioned above, the chart shows the average rating of the evaluators regarding all the criteria in the Evaluation Matrix.

Figure 5.12. Evaluation Profile – Tradable Water Right

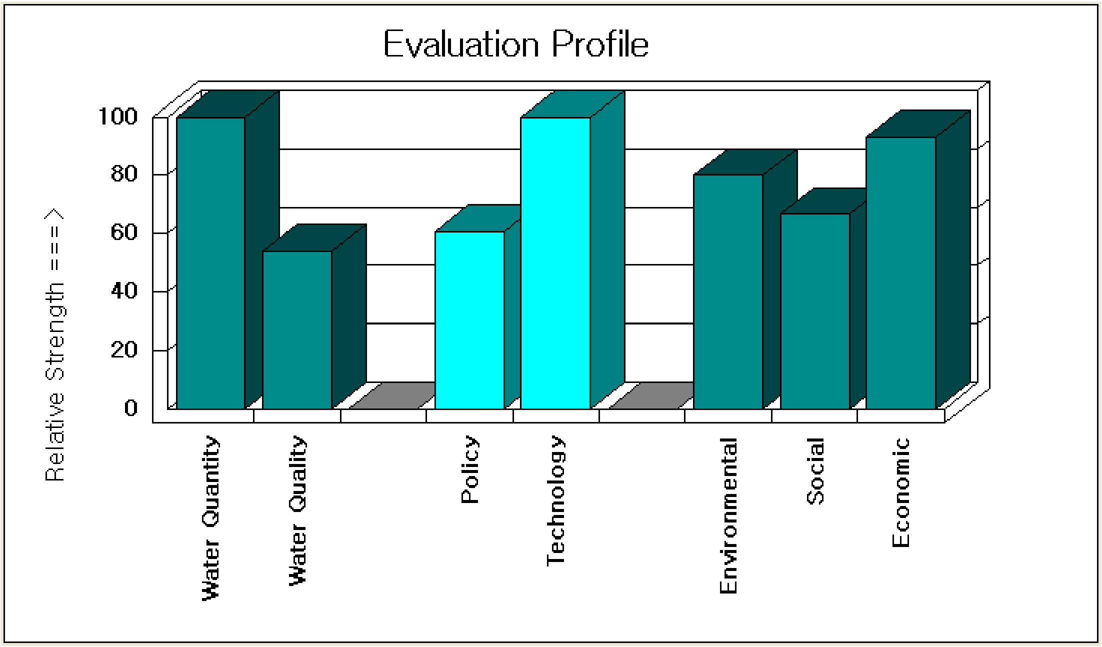


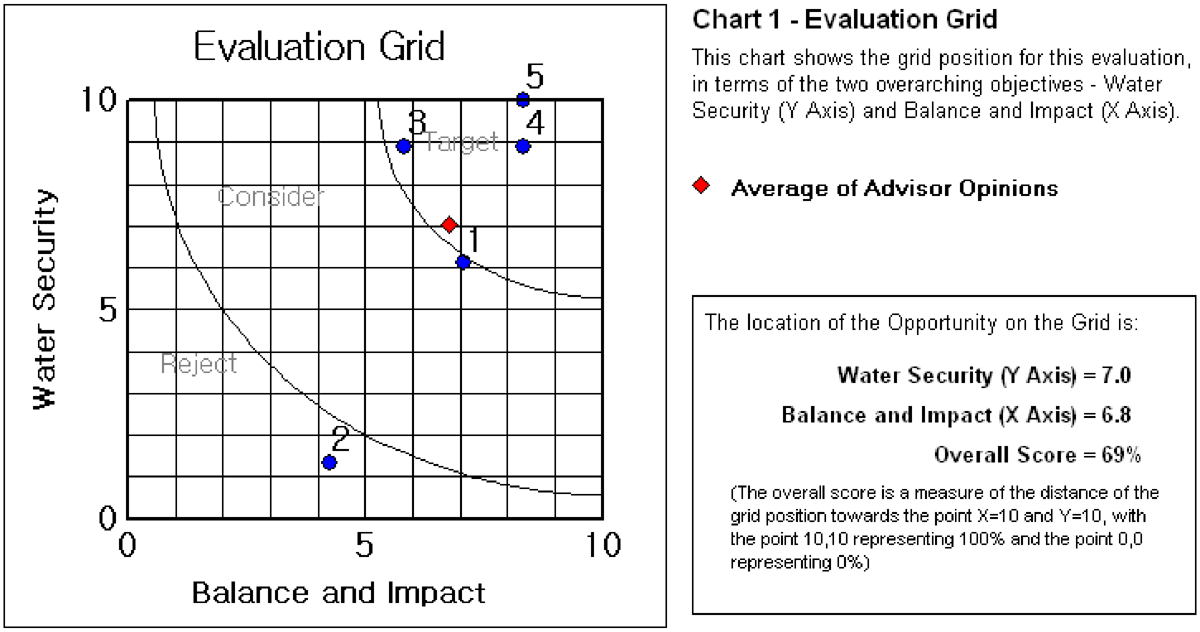
Figure 5.12 demonstrates the criteria's relative strength and weakness with respect to tradable water rights alternative. The chart can be interpreted as follows:

- The relative strength is: Water Quantity and Technology > Economic Impact > Environmental Impact > Social Impact > Policy > Water Quality
- Tradable water rights alternative has strong points in terms of water quantity and technology.
- In order to be a better alternative, tradable water rights have to consider the aspect of water quality as its first priority.
- Policy and social impact are also thoroughly considered for improving the alternative.

5.8.5 Evaluation Grid of Water Charges

Figure 5.13 presents the Evaluation Grid of Alternative 3 (Water Charges) in terms of water security and impacts, as well as the R-value (%).

Figure 5.13. Evaluation Grid – Water Charges



This Evaluation Grid chart allows us to analyze the evaluation results about water charges alternative as follows:

- The average of the evaluators' opinions is positioned in the "Target" area.
- The position (6.8, 7.0) is the average of the evaluation results.
- The R-value is given as 69%, illustrating the progress on the X (Balance and Impact) and Y (Water Security) axes.

In summary, water charges alternative is positioned in the "Target" area. Therefore, the water charges option fulfills the requirements of most of the criteria for water solutions regarding Canada's oil sands. Although water charges alternative is located in the target position, relative strong and weak points are still present. The following Evaluation Profile chart demonstrates to stakeholders which criterion for water charges alternative can be improved upon to become the best alternative.

5.8.6 Evaluation Profile of Water Charges

Figure 5.14 provides the Evaluation Profiles of water charges alternative.

Figure 5.14. Evaluation Profile – Water Charges

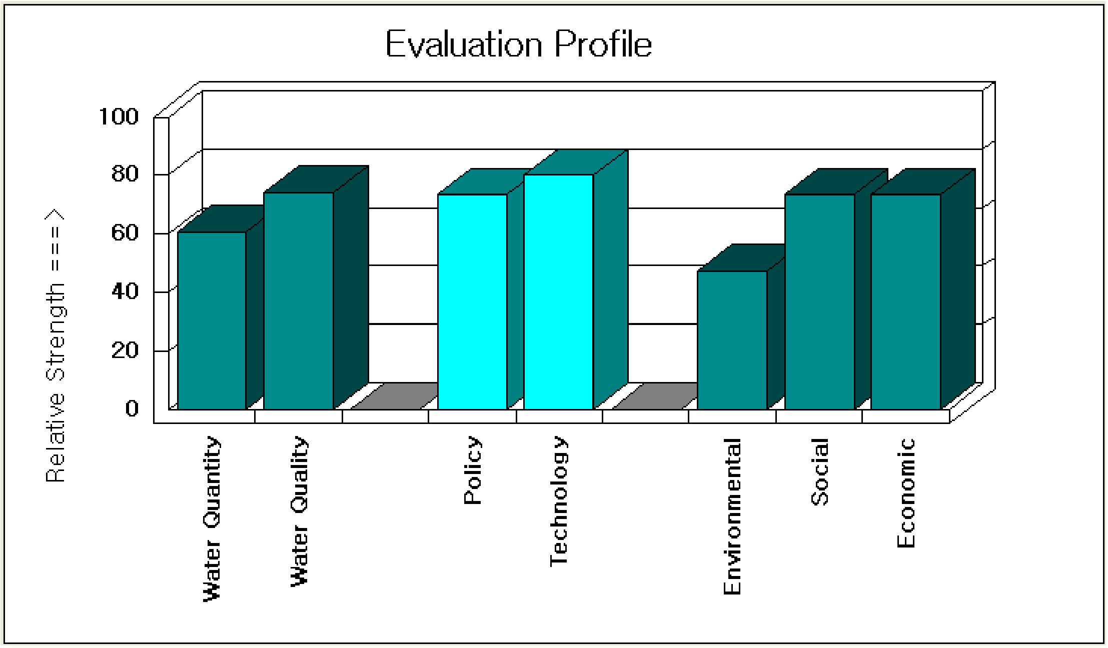


Figure 5.14 demonstrates the criteria's relative strength and weakness with respect to water charges alternative. The chart can be explained as follows:

- The relative strength is: Technology > Water Quality, Policy, Social Impact, and Economic Impact > Water Quantity > Environmental Impact
- The results of the criteria for the water charges alternative is relatively similar .
- For improving this alternative, environmental impacts must be considered as the first priority.

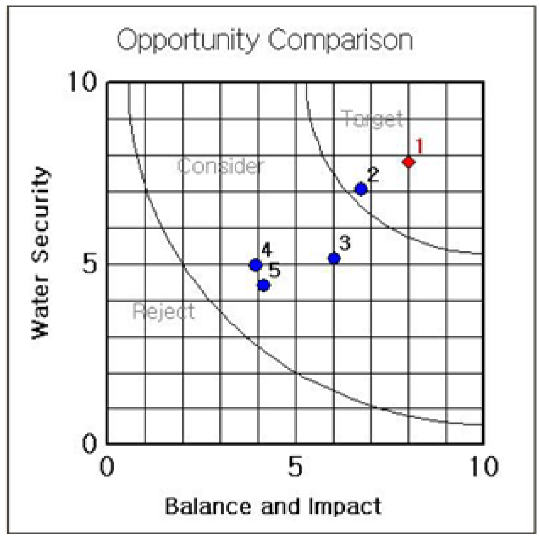
The reports of the Evaluation Grids and Evaluation Profiles with regard to these three alternatives as well as Alternative 4 (performance standards and tradable performance standards) and Alternative 5 (water storage) are provided in Appendix A at the end of this thesis.

5.8.7 Opportunity Comparison – Database Result

Figure 5.15 provides the X, Y grid positions of the five alternatives evaluated at Level 4. This grid shows the results with respect to alternatives through the evaluation process, employing the overarching objectives as its axes.

Figure 5.15. Opportunity Comparison – Five Alternatives

Ranking	Opportunity Name	X	Y	R
1.	**Tradable Water Right**	**8.0**	**7.8**	**79%**
2.	Water Charges	6.8	7.0	69%
3.	Performance Standards	6.0	5.1	56%
4.	The "Status Quo"	4.0	4.9	44%
5.	Water Storage	4.2	4.4	43%



With this representative result, the stakeholders can compare the evaluation results of all the alternatives and interpret them as follows:

- Two alternatives (Tradable Water Rights and Water Charges) are located in the "Target" district, and three alternatives (Performance Standards, the "Status Quo", Water Storage) are located in the "Consider" area.
- The priority is as follows: Tradable Water Rights (R-value: 79%) > Water Charges (69%) >> Performance Standards and Tradable Performance Standards (56%) > The "Status Quo" (44%) > Water Storage (43%)
- Each alternative has its R-value and the R-values are employed to rank the alternatives.

5.9 Summary

The main purpose of this chapter is to apply the ProGrid methodology to Canada's oil sands. The chapter started with the introduction of alternatives to Canada's energy system and described the application procedure, showing the concept of Cascading Matrices. The ProGrid methodology was used with two different levels: Level 2 for the oil sands and Level 4 for water problems in Canada's oil sands. In Level 2, the oil sands resource was considered as an energy system to make Canada an energy superpower, and the overarching objectives and the Evaluation Matrix including the criteria were established to evaluate the oil sands' value and potential. In more detailed Level 4, five alternatives were introduced to address the water quantity and quality problems in Canada's oil sands. In the same manner, two overarching objectives and the Evaluation Matrix for all the criteria were established to evaluate the alternatives for water problems in Canada's oil sands. The output reports of both oil sands and water problems in Canada's oil sands were presented in various ways such as the Evaluation Grid, Evaluation Profile, and Opportunity Comparison. These reports can help the stakeholders understand Canada's oil sands to make reasonable decisions with regard to the oil sands for Canada's energy goal.

Chapter 6
Conclusions and Future Work

This thesis examines the oil sands' characteristics, cost and market analysis, as well as economic, social, and environmental impacts. In addition, the Chapter 3 describes the importance, potential, and constraints of Canada's oil sands through recent analysis and estimation. The Canadian Academy of Engineering's studies verify the oil sands' value and potential through results from the ProGrid methodology. To analyze and address Canada's oil sands strategically, the ProGrid methodology is utilized as a practical decision-assist tool for multiple-criteria decision analyses, and the methodology allows one to convert qualitative concepts into quantifiable measures. In particular, the oil sands are examined and evaluated at two different levels – Level 2 for the oil sands and Level 4 for water problems in Canada's oil sands – using the concept of Cascading Matrices in order to demonstrate how the ProGrid methodology is employed when considering intangible social issues. The output reports from the ProGrid AdvisorSL™ software can help the stakeholders understand the value of the oil sands and make sound decisions to lead Canada an energy superpower status.

6.1 Contributions of Thesis

The major contributions of this thesis are as follows:

- The examination of Canada's oil sands through the application of the ProGrid methodology as a strategic decision-making tool represents the current position of the oil sands resource as a contributor to Canada's energy system. In addition, analyzing the output reports from the ProGrid methodology clarify the potential of the oil sands as a key driver enabling Canada to achieve status as an energy superpower.
- At Level 2 for the evaluation of Canada's oil sands, the ProGrid methodology plays a significant role in addressing many matters that have to be considered and overcome in order to achieve the country's energy goal, defining the R-value as a quantitative measure of the oil sands' current position. Moreover, rating the relative strength of the oil sands' criteria represents an important contribution to the creation of a useful decision-assist tool for carrying out multiple-criteria decision analyses.
- Through the application of the ProGrid methodology to Canada's oil sands, we can understand the oil sands' current position (R-value: 41%) and subsequently, steps to develop

the oil sands to achieve Canada's energy goals. In order to achieve these goals, the matter related to environmental security must be considered and overcome as the most important priority. In addition, the aspects related to effective policy, social security, and sustainability should be dealt with through in-depth discussion and addressed to meet Canada's energy goals.

- The application of the ProGrid methodology to water quantity and quality problems in Canada's oil sands at a more detailed level (Level 4) illustrates how alternatives can be evaluated strategically. In addition, the implementation of the ProGrid software prioritizes all the alternatives by using the R-value, and this approach interconnects with the goal of the methodology, converting qualitative intangible assets such as the effectiveness of government policy into quantifiable measures. Evaluating the options objectively is a great contributions to the ability of decision makers to make sound decisions.
- Through the application of the ProGrid methodology and evaluations, two alternatives are recommended: Tradable Water Rights (R-value: 79%) and Water Charges (R-value: 69%). These two alternatives will provide an integrated approach to achieve water security as well as the environmental, economic, and social goals in terms of water issues in Canada's oil sands. This thesis has concentrated more on water quantity. However, in terms of water quality, we can compare which alternative is better than others using the Evaluation Profile results (Water Charges > Tradable Water Right > "Status Quo" and Performance Standards > Water Storage). Therefore, the findings of this thesis will be useful for addressing water security, considering the balance and impacts on environmental, economic, and social aspects.
- The ProGrid methodology dramatically clarifies outstanding issues and information regarding the oil sands by reducing them to understandable charts that highlight the matters to be addressed. Furthermore, the methodology takes advantage of graphical presentation, thus, stakeholders can understand the comprehensive output reports quickly and easily.

6.2 Future Work

This thesis focuses on the oil sands resource as a contributor to Canada's energy system. To make Canada an energy superpower, all of Canada's energy resources are reviewed and analyzed – this process can help stakeholders in making reasonable decisions. As the first step in this process, all six resources for non-renewable energy, such as conventional oil, oil sands, bituminous carbonates, conventional gas, non-conventional gas, and coal, should be evaluated individually in terms of their current value and potential and be compared in order to prioritize resources strategically.

Canada's oil sands have complex interconnections with many criteria in terms of economic, social, and environmental aspects. In particular, conflicts related to tax and royalty charges have arisen in recent years. In order to resolve these conflicts regarding taxes and royalties, the Graph Model for Conflict Resolution (GMCR) (Fang et al., 1993) can be used for carrying out strategic studies.

In addition, the Analytic Hierarchy Process (AHP) (Saaty, 1980) can be applied to Canada's oil sands problems as a Multiple Criteria Decision Analysis (MCDA) method, because the oil sands resources can be categorized hierarchically based on economic, social, and environmental aspects. In the same manner, Analytic Network Process (ANP) (Saaty et al., 2006) can be employed to the oil sands as an energy system to evaluate reasonably and to make strategic decisions that will lead Canada to achieve the status of an energy superpower.

Appendix A

Oil Sands Output Reports for Level 2 and Level 4 using ProGrid

ProGrid
EVALUATION SOLUTIONS

AdvisorSL Opportunity Report

File Reference: Canada's Oil Sands

To analyze curmet position of Canada's oil sands as an energy system and clarify the oil sands' strengths and weaknesses that must be considered.

Opportunity Name: The Oil Sands as a Canada's energy system

Opportunity Summary:

To clarify Canada's potential to achieve its goal of being a sustainable energy superpower, the oil sands, as one of Canada's essential energy systems, must be analyzed strategically, because it is difficult to consider the country's energy future without discussing the oil sands.

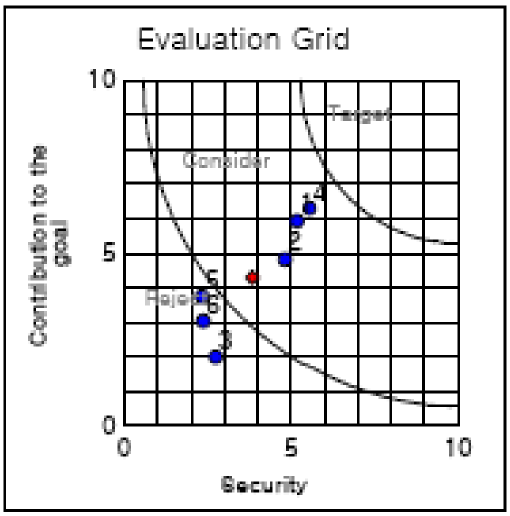


Chart 1 - Evaluation Grid

This chart shows the grid position for this evaluation, in terms of the two overarching objectives - Contribution to the goal (Y Axis) and Security (X Axis).

◆ Average of Advisor Opinions

The location of the Opportunity on the Grid is:

Contribution to the goal (Y Axis) = 4.3

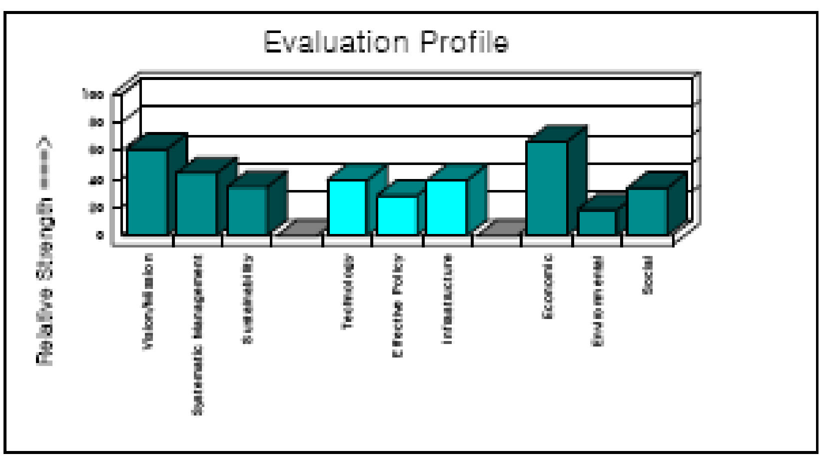
Security (X Axis) = 3.8

Overall Score = 41%

(The overall score is a measure of the distance of the grid position towards the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

Chart 2 - Evaluation Profile

This chart shows the ratings for each of the evaluation criteria as determined by the Advisors. This chart is very useful in identifying the strengths (tall bars) and weaknesses (short bars) of the Opportunity.



Powered by ProGrid

AdvisorSL Opportunity Report

File Reference: Status Quo

To find the best alternative and to prioritize the alternatives

Opportunity Name: The "Status Quo"

Opportunity Summary:

The "Status Quo" is a "first in time, first in right" system, so it has a characteristics such as older license priority. It can avoid worst scenarios in terms of ecology, but it has little incentive for water use reduction. Hence, it does not encourage the companies to develop and employ new technologies related to water reduction.

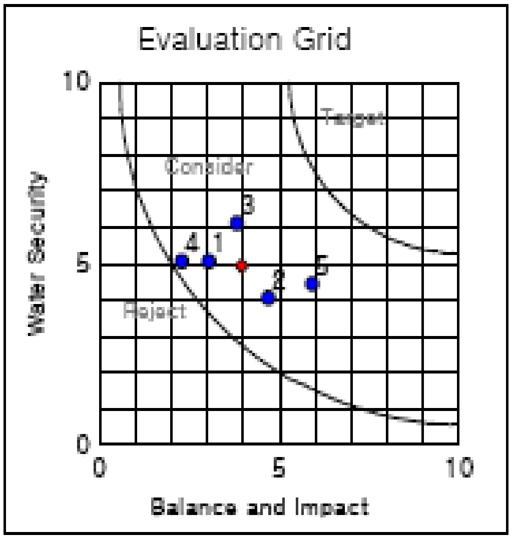


Chart 1 - Evaluation Grid

This chart shows the grid position for this evaluation, in terms of the two overarching objectives - Water Security (Y Axis) and Balance and Impact (X Axis).

Average of Advisor Opinions

The location of the Opportunity on the Grid is:

Water Security (Y Axis) = 4.9

Balance and Impact (X Axis) = 4.0

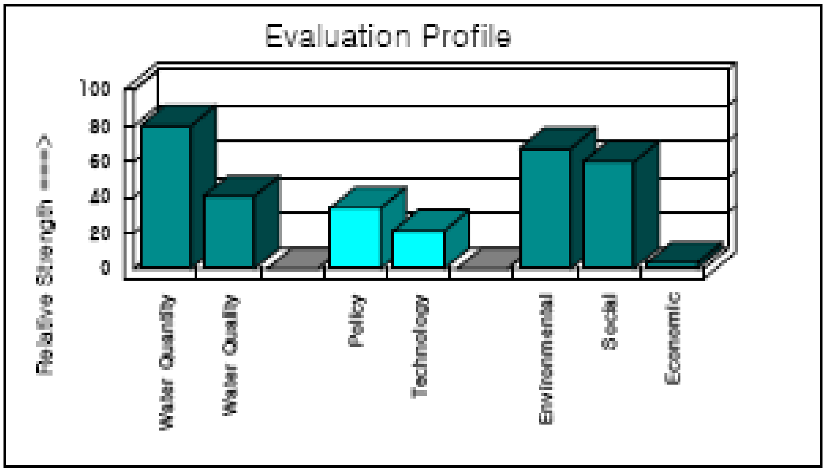
Overall Score = 44%

(The overall score is a measure of the distance of the grid position towards the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

Chart 2 - Evaluation Profile

This chart shows the ratings for each of the evaluation criteria as determined by the Advisors.

This chart is very useful in identifying the strengths (tall bars) and weaknesses (short bars) of the Opportunity.



Powered by ProGrid

AdvisorSL Opportunity Report

File Reference: Tradable Water Right

To find the best alternative and to prioritize the alternatives

Opportunity Name: Tradable Water Right

Opportunity Summary:

Tradable water rights are a form of "cap and trade" system or market based mechanism to protect water environment. This system provides a strict legal and administrative framework to make water to be transferred from low value users to high value users. Maximum total withdrawals are limited, and trading is only possible within the limits and without negative impacts on other users or environment.

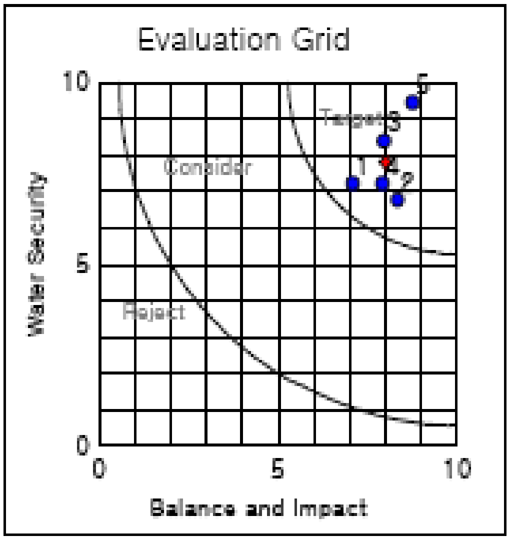


Chart 1 - Evaluation Grid

This chart shows the grid position for this evaluation, in terms of the two overarching objectives - Water Security (Y Axis) and Balance and Impact (X Axis).

Average of Advisor Opinions

The location of the Opportunity on the Grid is:

Water Security (Y Axis) = 7.8

Balance and Impact (X Axis) = 8.0

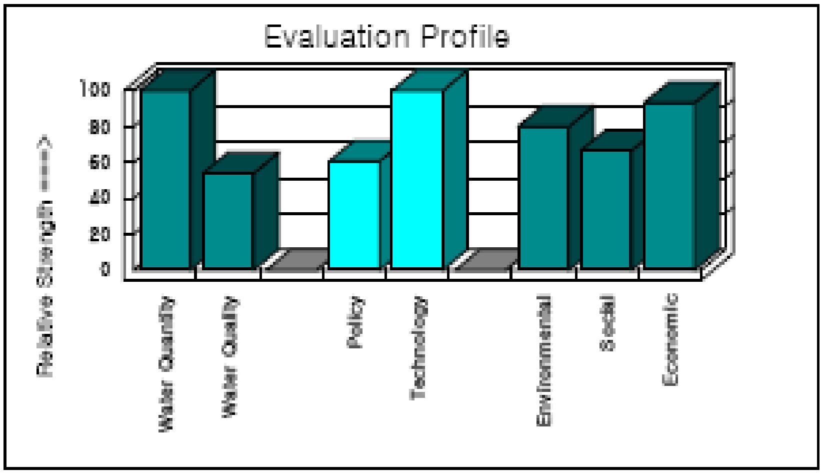
Overall Score = 79%

(The overall score is a measure of the distance of the grid position towards the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

Chart 2 - Evaluation Profile

This chart shows the ratings for each of the evaluation criteria as determined by the Advisors.

This chart is very useful in identifying the strengths (tall bars) and weaknesses (short bars) of the Opportunity.



Powered by ProGrid

AdvisorSL Opportunity Report

File Reference: Water Charges

To find the best alternative and to prioritize the alternatives

Opportunity Name: Water Charges

Opportunity Summary:

Water pricing policy is to set charges based on environmental and user costs with regard to water. This system can provide a standard of water resource allocation in terms of efficient water use. In addition, this approach can charge according to the water type of water, such as surface water, ground water, and saline water. Water pricing policy does not directly control water consumption as the way tradable water rights do, but prices encourage water demand management.

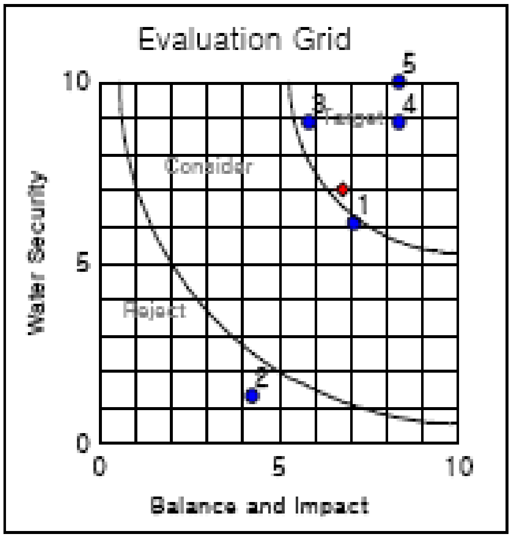


Chart 1 - Evaluation Grid

This chart shows the grid position for this evaluation, in terms of the two overarching objectives - Water Security (Y Axis) and Balance and Impact (X Axis).

Average of Advisor Opinions

The location of the Opportunity on the Grid is:

Water Security (Y Axis) = 7.0

Balance and Impact (X Axis) = 6.8

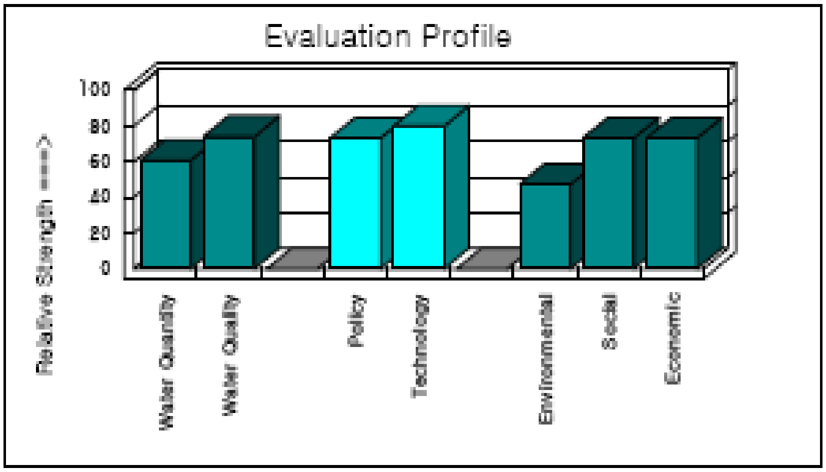
Overall Score = 69%

(The overall score is a measure of the distance of the grid position towards the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

Chart 2 - Evaluation Profile

This chart shows the ratings for each of the evaluation criteria as determined by the Advisors.

This chart is very useful in identifying the strengths (tall bars) and weaknesses (short bars) of the Opportunity.



Powered by ProGrid

AdvisorSL Opportunity Report

ProGrid
EVALUATION SOLUTIONS

File Reference: Performance Standards

To find the best alternative and to prioritize the alternatives

Opportunity Name: Performance Standards and Tradable Standards

Opportunity Summary:

Performance standards or targets can be used to encourage firms to decease water use. Oil sands industry can voluntarily make an effort to accomplish these targets by setting technology-based standards, by supporting technology-based subsidies, and by employing differential incentive-based mechanisms. The key characteristic is that the target water use per unit output, and supporting regulations are required to limit water consumption to be within a cap with water charges.

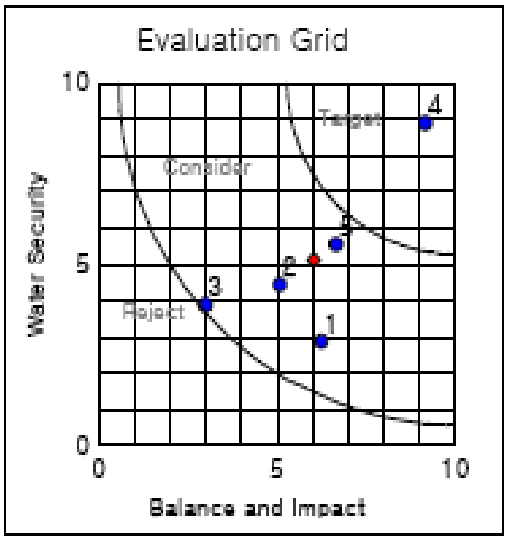


Chart 1 - Evaluation Grid

This chart shows the grid position for this evaluation, in terms of the two overarching objectives - Water Security (Y Axis) and Balance and Impact (X Axis).

Average of Advisor Opinions

The location of the Opportunity on the Grid is:

Water Security (Y Axis) = 5.1

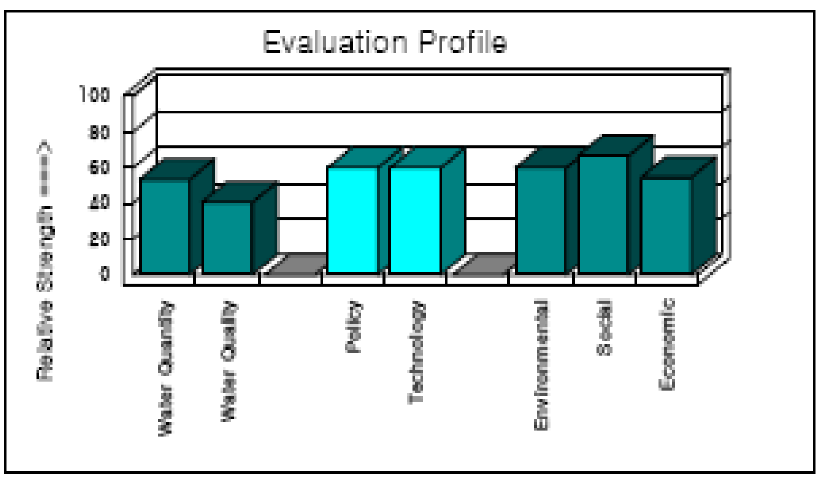
Balance and Impact (X Axis) = 6.0

Overall Score = 56%

(The overall score is a measure of the distance of the grid position towards the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

Chart 2 - Evaluation Profile

This chart shows the ratings for each of the evaluation criteria as determined by the Advisors. This chart is very useful in identifying the strengths (tall bars) and weaknesses (short bars) of the Opportunity.



Powered by ProGrid

AdvisorSL Opportunity Report

File Reference: Water Storage

To find the best alternative and to prioritize the alternatives

Opportunity Name: Water Storage - A Technology Based option

Opportunity Summary:

In order to deal with insufficient water during winter in the Athabasca basin, water storage approach can be one mechanism to satisfy winter flow needs with the construction of off-stream storage. This method is a feasible alternative and a practical solution to address low winter flows in Athabasca River. However, the implement cost has a potential to be significant.

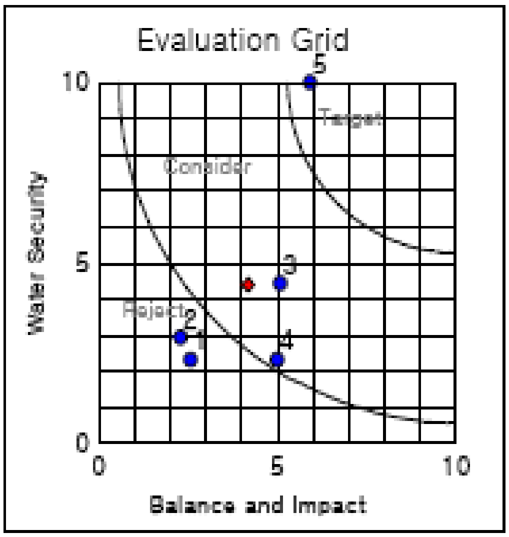


Chart 1 - Evaluation Grid

This chart shows the grid position for this evaluation, in terms of the two overarching objectives - Water Security (Y Axis) and Balance and Impact (X Axis).

◆ **Average of Advisor Opinions**

The location of the Opportunity on the Grid is:

Water Security (Y Axis) = 4.4

Balance and Impact (X Axis) = 4.2

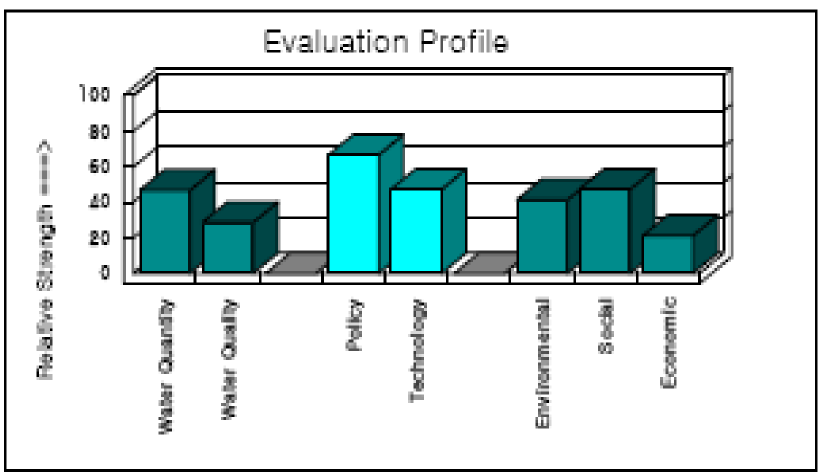
Overall Score = 43%

(The overall score is a measure of the distance of the grid position towards the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

Chart 2 - Evaluation Profile

This chart shows the ratings for each of the evaluation criteria as determined by the Advisors.

This chart is very useful in identifying the strengths (tall bars) and weaknesses (short bars) of the Opportunity.



Powered by ProGrid

Appendix B

Evaluation Forms Including Language Ladders

An Evaluation for Oil Sands as an Energy System — *ProGrid® Evaluation Form*

Evaluation Matrix™: Level 2 - Canada's Oil Sands as an Energy System

Evaluator - please insert name: [ ]

Direction: Based on your knowledge or the information provided, fill in the rating boxes with one of the A, B, C, and D.
You may write some comments in the comment boxes.

1 Input	**Vision/Mission**
	In terms of making Canada a sustainable energy superpower,
A	the energy resource's vision/mission does not coincide with the country's goal.
B	the energy resource's vision/mission partially coincides with the country's goal.
C	the energy resource's vision/mission fully coincides with the country's goal.
D	...AND will play an important role in connecting with a new energy source in the future.
Rating	Comment on criterion
2 Input	**Systematic Management**
	In terms of making Canada a sustainable energy superpower,
A	the energy resource has not been systematically managed with concrete short-term and long-term plans.
B	the energy resource has been partially managed with concrete short-term and long-term plans.
C	the energy resource has been systematically managed with concrete short-term and long-term plans.
D	...AND has the know-how about systematic management in order to apply a new source of energy in the future.
Rating	Comment on criterion
3 Input	**Sustainability**
	In terms of making Canada a sustainable energy superpower,
A	the energy resource will be exhausted in the near future or will not be renewable in any circumstance.
B	the energy resource has some volume to last for a few decades, and can be renewed or utilized in some cases.
C	the energy resource has enough volume to last for centuries and can be renewed or utilized in many cases.
D	there is no limitation to use the energy resource and it also can be renewed or utilized fully.
Rating	Comment on criterion
4 Enablers	**Technology**
	In terms of making Canada a sustainable energy superpower,
A	the energy resource's technology does not meet the requirements of an energy superpower.
B	the energy resource's technology partially meets the requirements of an energy superpower and has some potential for improvement.
C	the energy resource's technology is high enough to satisfy the requirements of an energy superpower and has great potential for improvement.
D	...AND the know-how about the energy technology can apply to other energy resources.
Rating	Comment on criterion
5 Enablers	**Effective Policy**
	In terms of making Canada a sustainable energy superpower,
A	an effective policy with respect to the energy resource has not been established or conducted.
B	some policies with respect to the energy resocurce have been established or conducted, but are not effective enough.
C	an effective policy with respect to the energy resource has been firmly established or conducted.
D	...AND the policy is utilized in many areas as a sucessful case of a leading policy in Canada.
Rating	Comment on criterion
6 Enablers	**Infrastructure**
	In terms of making Canada a sustainable energy superpower,
A	the energy resource does not have enough infrastructure to take advantage of its benefits.
B	the energy resource has some infrastructure, but the infrastructure is not enough to take advantage of its benefits.
C	the energy resource has enough infrastructure to take advantage of its benefits.
D	...AND the infrastructure provides great convenience to Canada socially and enconomically.
Rating	Comment on criterion
7 Output	**Economic Security**
	In terms of making Canada a sustainable energy superpower,
A	the energy resource's impact on the Canadian economy is very weak or is not adequate to meet the country's goal.
B	the energy resource has provided a positive impact on the Canadian economy in at least one geographic region.
C	the energy resource has provided a key impact on the Canadian economy across Canada.
D	...AND will play an important role in the country's energy goal, creating a synergy effect with other resources.
Rating	Comment on criterion

8 Output	**Environmental Security** In terms of making Canada a sustainable energy superpower,
A	the environmental impacts from the energy resource developoment have not been seriously considered.
B	the environmental impacts from the energy resource developoment have been somewhat considered, and the solution has been partially applied.
C	the environmental impacts from the energy resource developoment have been fully considered, and the solution has been systematically applied.
D	...AND the research on environmental impacts will play a signficant role in conserving Canada's environment.
Rating	Comment on criterion

9 Output	**Social Security** In terms of making Canada a sustainable energy superpower,
A	the social impacts from the energy resource developoment have not been seriously considered.
B	the social impacts from the energy resource developoment have been somewhat considered, and the solution has been partially applied.
C	the social impacts from the energy resource developoment have been fully considered, and the solution has been systematically applied.
D	...AND the research on social impacts will play a signficant role in making Canada socially stable.
Rating	Comment on criterion

Evaluator's comment about oil sands and their potential in making Canada a sustainable energy superpower

An Evaluation for Alternatives to Water Issues in Canada's Oil Sands

ProGrid® Evaluation Form

Evaluation Matrix™: Level 4 - Alternatives to Water Issues in Canada's Oil Sands

Evaluator - please insert name:

Direction: Based on your knowledge or the information provided, fill in the rating boxes with one of the A, B, C, and D. You may write some comments in the comment boxes.

1 Input **Water Quantity**

In Canada's oil sands area, the alternative

A	has significant weaknesses in terms of preserving water volume.
B	preserves the minimum water volume that people, industry, and environment require.
C	maintains stable water volume level that people, industry, and environment require, but cannot maintain long.
D	maintains stable water volume level that people, industry, and environment require for long period.
Rating	Comment on criterion

2 Input **Water Quality**

In Canada's oil sands area, the alternative

A	has significant weaknesses in terms of preserving water quality.
B	preserves the minimum water quality level that people, industry, and envionment require.
C	maintains stable water quality level that people, industry, and envionment require, but cannot maintain long.
D	maintains stable water quality level that people, industry, and envionment require for long time.
Rating	Comment on criterion

3 Enablers **Policy**

In Canada's oil sands area, the alternative

A	has significant weaknesses in terms of systematic policy.
B	is partially ready for a simple policy but not systematic.
C	is partially ready for a simple policy and partially systematic.
D	is ready for a reasonable policy and systematic.
Rating	Comment on criterion

4 Enablers **Technology**

In Canada's oil sands area, the alternative

A	is not to merge any water-saving technologies and does not create synergy effect.
B	is partially to merge some water-saving technolgies but does not create synergy effect.
C	is partially to merge some water-saving technolgies and partially create synergy effect.
D	is to merge some water-saving technologies and create synergy effect.
Rating	Comment on criterion

5 Output **Environmental Impact**

In Canada's oil sands area, the alternative

A	does not considers environmental effectiveness and does not contribute environmenta l goal.
B	partially considers environmental effectiveness but does not contribute environmental goal.
C	partially considers environmental effectiveness and partially contribute environmental goal.
D	considers environmental effectiveness and contribute environmental goal.
Rating	Comment on criterion

6 Output **Social Impact**

In Canada's oil sands area, the alternative

A	does not considers public acceptance and does not contribute social goal.
B	partially considers public acceptance but does not contribute social goal.
C	partially considers public acceptance and partially contribute social goal.
D	considers public acceptance and contribute social goal.
Rating	Comment on criterion

7 Output **Economic Impact**

In Canada's oil sands area, the alternative

A	does not considers cost effectiveness and does not contribute Canada's economy.
B	partially considers cost effectiveness but does not contribute Canada's economy.
C	partially considers cost effectiveness and partially contribute Canada's economy.
D	considers cost effectiveness and contribute Canada's economy.
Rating	Comment on criterion

Evaluator's comment about alternatives to water issues in Canada's oil sands.

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