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LOW-CARBON TECHNOLOGY DEPLOYMENT

Progress Report

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August 22, 2008

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EXECUTIVE SUMMARY

To be completed.

1. INTRODUCTION

1.1. Context and objectives

The National Round Table on the Environment and the Economy (NRTEE) was established in 1988 by the federal government of Canada with the mandate of seeking out ways in which environmental conservation and economic development could be integrated. In 2007, they produced a study entitled *Getting to 2050: Canada's Transition to a Low-Emission Future* (NTREE, 2007). This report presented a simulation of policy tools that could be used to achieve so-called 'fast and deep' reductions in greenhouse gas (GHG) emissions in the medium to long term: a 20% reduction by 2020 and a 65% reduction by 2050, relative to 2006 levels.

Following this, in July 2008, the NRTEE commissioned a study to expand on the *Getting to 2050* report entitled *A Technology Roadmap to Low Greenhouse Gas Emissions in the Canadian Economy: A Sectoral and Regional Analysis* (Nyboer, 2008). The study by Nyboer made use of the CIMS model in order to simulate the regional and sectoral effects of the NRTEE-suggested policies and to provide forecasts of the technological developments necessary in achieving the fast and deep emissions reductions.

One of the policy tools brought forth in the NRTEE study is some form of carbon emissions pricing policy (i.e. either cap and trade or a carbon tax). However, the modeling showed that certain sectors did not respond to a carbon pricing policy. It is likely that this is due to a variety of market barriers and market failures that may be preventing the penetration of new low-carbon emission technologies in these sectors. This highlighted the need for technology deployment policy to complement a carbon pricing policy.

The NRTEE has retained ÉcoRessources Consultants in order to: 1) explore the types of market barriers and market failures that may be impeding low-carbon emission technology deployment; 2) evaluate the degree to which the theoretical market penetration rates provided in the Nyboer study for certain key technologies are realistic and provide a 'ground-truthing' of the predictions found in the study; and 3) provide guidance in the development of technology deployment policy to complement carbon pricing policy.

1.2. Scope and methodology

The scope of this study will be limited to a list of specific technologies that has been provided to ÉcoRessources by the NRTEE. The technologies retained for the mandate are provided in Table 1 below:

TABLE 1- LIST OF TECHNOLOGIES TO BE ANALYSED FOR THE STUDY

Carbon Capture and Storage	**Fuel Switching to Electricity and Energy Efficiency**
Formation Carbon Dioxide from Natural Gas Processing	Residential ground source heat pump
Hydrogen Production from Oil Sands Upgrading	Commercial ground source heat pump
Ammonia Production from Chemical Products Manufacturing	Other residential and commercial heating systems
Electricity Generation from fossil fuels	Passenger Hybrid
Renewable electricity Generation	Plug-in Hybrid Vehicles
Oil Sands Upgrading	Freight Hybrid Trucks
In-situ Bitumen Extraction	**Landfill Gas Cap and Flare**
Other Carbon Capture and Storage (Cement and Lime Industry, Iron and Steel industry; Petroleum refining)	**Clean Electricity Generation**
Biofuel production	Hydro
Fuel Switching to Renewables	Wind
Passenger ethanol vehicles (inc. hybrid plug-in)	Nuclear
Passenger biodiesel vehicles	**Biofuel Production**
Freight biodiesel trucks	Cellulosic Ethanol Production

This study consists of three principal tasks:

Task 1: Identification and discussion of market barriers and market failures for low-carbon technologies: establishment of a barriers framework.

For each of the technologies identified in Table 1:

Task 2: Analysis of the accuracy of the NRTEE's forecasted market penetration rates.

Task 3: Identification of enabling conditions and policy guidance to encourage rapid and extensive low-carbon technology deployment and adoption.

A discussion the methodology used to carry out each of these tasks is provided below.

Task 1: Identification and discussion of market barriers and market failures for low-carbon technologies: establishment of a barriers framework

This task involves the establishment of a barriers framework: a list of barriers is elaborated and explained with illustrative examples. The concepts of a market barrier and of a market failure are defined and a clear distinction is made between these two terms. The objective of the creation of a barriers framework is to make use of this framework when evaluating the NRTEE-forecasted penetration rates in order to identify the specific barriers and failures that may be impeding the development and deployment of a given technology. Section 2 presents the barriers framework with a discussion of the barriers therein.

Task 2: Analysis of the accuracy of the NRTEE's market penetration rates

This task involves making use of the barriers framework defined in Task 1 to gauge the accuracy of the NRTEE-forecasted market penetration rates. For each of these selected technologies, the relevant market barriers are explored through a literature review of existing knowledge on factors that are currently inhibiting or have the potential to inhibit market penetration for these technologies. However, the principal aspect to this task is consultation with industry stakeholders. Interviews with developers, manufacturers, interest groups and other relevant stakeholders are carried out to determine the primary deployment issues "on the ground." Further, in light of the barriers identified, interviewees are asked to comment on whether they find the NRTEE's market penetration rates realistic.

A list of the stakeholders that have been contacted, as well a sample questionnaire, is given in Section 3. In Section 4, the results of Task 2 are presented for each technology.

Task 3: Identification of enabling conditions and policy for low-carbon technologies

For each technology, this task aims to identify the enabling conditions that would drive an increase in market penetration. The stakeholders that were contacted for Task 2 are also asked for their input regarding enabling conditions that could reduce or eliminate some of the identified barriers. In addition, Canadian as well as international policy experts are contacted in order to obtain additional information as to historical best practices as well as challenges and lessons learned. This analysis is then used as a basis for providing policy guidance that would aid in overcoming market barriers and market failures, in order to encourage the development and deployment of low-carbon technologies. The results of Task 3 are presented in Section 5.

2. MARKET BARRIERS AND MARKET FAILURES FOR LOW-CARBON TECHNOLOGIES – ESTABLISHMENT OF A BARRIERS FRAMEWORK

In this section we discuss some of the most common market barriers and market failures that occur in the deployment of low-carbon technologies. The market barriers and market failures discussed will form a barriers framework to be used in the following section in order to evaluate the penetration rates provided in the NRTEE technology roadmap for each technology.

At this stage it is useful to define a market barrier versus a market failure. A *market barrier* (or a barrier to entry) refers to an impediment to market access or penetration, such as public opposition or lack of infrastructure. A *market failure*, however, occurs when markets are not functioning optimally, such as in the case of a market monopoly by one or more players, or information asymmetry between market agents. Externalities, whether they are environmental or of another type, can also be the cause of a market failure, as they can lead to price distortion.

A market barrier can in some cases lead to market failure. For instance, high capital costs or financing problems can reduce the number of players in the market. For new technologies where the number of players is already low, this can lead to market imbalances or even monopolies, thus leading to market failure. Equally, market barriers can also sometimes be considered “adoption externalities” that cause market failures.

The market barriers and market failures that make up the barriers framework to be used in this study are presented below. We have made use of a number of studies in the elaboration of this barriers framework (Nilsson, 2001; Foxon, 2008; Steenberghen, 2008; Jaffe, 2005). Many market barriers and/or failures have overlapping effects, such as information and cost. In addition, as discussed above, some barriers can in fact lead to market failures. Therefore, the list given below is intended to be a general summary of the principal types of market barriers and failures that can affect new low-carbon emissions technologies. However, the synergies that exist between various barriers and failures should be kept in mind, and will be discussed in more detail for each individual technology in the analysis of Section 4.

In addition, certain barriers and failures can be considered more ‘concrete’ than others. The barriers below are therefore presented loosely in order of significance with regards to their ability to act as an obstacle to penetration of new low-carbon technologies.

Technical viability of the technology

If a new technology is not technically viable, this will prevent it from penetrating the market. The longer the proven track record of the technology, the easier it will be to obtain access to capital and financing and to find buyers. Nevertheless, even established technologies can have issues of technical unreliability that prevent their development in the market. For instance, the construction of most new nuclear power stations in Canada has run over-time and over-budget. This is now an oft-quoted concern when discussing the approval of new installation.

Technology cost

New technologies often engender relatively high costs due to limited economies of scale and learning effects. In addition, if the costs of a new technology are perceived as coming down quickly, there may be situation where perfectly rational decision making suggests waiting rather than adopting today. This can lead to significant delays of deployment, which in turn limits the learning effects and economies of scale, the two important cost drivers apart from the cost of the technology itself.

Price distortion

The full costs of the technology are not reflected in the price. These costs can include externalities, environmental or otherwise. Such price distortion can lead to the unfair economic favouring of a given technology over another. A widely discussed example of this is the lack of the inclusion of environmental externalities in the price of coal electricity generation, which makes it apparently cheaper than wind energy generation. Of course, which externalities are included in the cost of a technology can be controversial.

Price distortion can also arise due to biased calculations of cost. For instance, the use of payback periods that are overly optimistic can artificially reduce prices relative to other players in the market.

Financing and risk

Nascent and emerging technologies need capital investment in order to drive their development to the point where large-scale deployment is possible. However, the risks associated with investment in new low-carbon technologies keeps borrowing costs high and in some cases, inaccessible through conventional means. These risks are technical (is the technology proven and viable?), regulatory (does the current and future regulatory framework support the technology now and in the long-term?) and informational (does the investor know and understand enough about the technology to feel comfortable participating?). These risks are particularly problematic for access to capital or loans for the deployment of low carbon technologies in the residential or small to mid-sized commercial setting. As a result, technologies with the most emission-reducing potential are not always those that are favoured by investors. It is important to note that investment risks may be real or perceived and both can affect access to capital and lending rates.

A distinction must also be made between investments in technology *development* versus *deployment*. The capital requirements of a given technology largely depend on its stage of development. For instance, venture capital is unlikely to be necessary for coal-to-gas power plant conversions. However venture capital continues to be necessary for the development of more efficient and lower cost photovoltaic solar panels or hydrogen-powered vehicles.

This barrier can also in some cases lead to market failure, for instance if high borrowing costs renders a technology uneconomical or if a technology is economical but cannot obtain enough venture capital because it is too “new.”

Physical infrastructure

The lack of a physical infrastructure can be considered a network externality market failure. This can be a significant obstacle to the deployment of certain technologies where such an infrastructure is crucial to their adoption. This is particularly the case for the transportation and distribution of biofuels, especially first generation biofuels, since conventional petroleum fuel pipelines cannot be used for their distribution. Physical infrastructure problems also exist in the electricity sector. Transmission line infrastructures are traditionally constructed around the network of large power stations. This poses a problem for the development of renewable energy such as wind or hydro, where the ideal sites are not necessarily located near a transmission grid or consumers.

Human infrastructure

A human infrastructure is equally important. There is a need for capable and competent managerial experience and vision as well as a sufficiently large skilled workforce for the installation, operation and maintenance of the technology. Such is the case with nuclear power, in which there is a current shortage of qualified technical and managerial expertise.

Regulatory framework

An appropriate regulatory framework can also be seen as forming a part of the necessary ‘infrastructure’ for a given technology. This can be especially important to create incentives for early adopters. In the

United States, for instance, a regulatory framework involving subsidies and aggressive targets has contributed to the rapid growth of the ethanol industry. However, the comparatively slow development of renewable energy in the United States is largely attributable to its weak regulatory framework on renewables.

Equally important is the coordination of all government bodies involved such that the implementation of the policy is consistent, clear and transparent at all levels of government. Conflicting policy at different levels of government and policy procedures that are too complex can pose significant market barriers and/or failures. Finally, existing regulation in areas separate from but complementary to low-carbon technologies can inadvertently restrain their development and/or deployment.

Tradition

This barrier can arise when established players in the market guard their position and market share, making it difficult for a new technology to penetrate. In many cases, the regulatory framework surrounding the industry in question has been developed in the context of the established players, unfairly disadvantaging new entrants. This can also lead to market failure.

Information

This is an important market failure that is particularly common in emerging technologies. Information imbalances can exist between buyers and sellers, but also between research centers and developers and investors and developers. Incomplete or inaccurate information can lead to erroneous decision-making which leads to inefficient market outcomes.

For instance, this is the case in the field of solar energy where cost effective technologies such as air preheating and domestic hot water solar systems are still comparatively rarely employed, in large part due to lack of consumer understanding and awareness.

Too much access to information can also lead to market failure. In cases where a new technology can be easily copied, there may not be sufficient incentive for private investors to contribute to research and development.

Public perception

The lack of public acceptance of a given technology can be a significant barrier to its deployment. Public opposition to a technology can arise for a number of different reasons. Nuclear power has always faced varying degrees of public opposition due to concerns over safety and waste disposal. In some areas wind power has been met with local opposition due to modification of the landscape and noise.

Public acceptance is also liable to rapid change. For instance, the use of ethanol-blended gasoline was once widely encouraged as an alternative to conventional gasoline due to lower emissions upon combustion. However, public opposition to first generation ethanol as a fossil fuel alternative is beginning to mount in light of scientific studies on its full lifecycle emissions and rising food prices.

Transaction cost

Transaction costs refer to the costs incurred to obtain a good or service. This involves, for instance, the costs associated with the research for the ideal provider, negotiations with the provider, the establishment of a price and a contract, as well as policing and enforcement costs, if applicable. Prohibitively high market transaction costs can discourage efficient market decision-making.

For instance, if a consumer would like to install a wind turbine on their property, they may decide that the best model for their application is made in Germany. However, the costs associated with shipping the turbine from Germany to Canada, as well as finding and paying qualified technicians for its installation, may prevent the consumer from making the purchase.

As another example, in Toronto there is currently only one distribution site for biodiesel. Even if the market price of biodiesel was less than that of traditional diesel, if a driver is required to drive a long distance to fill up, it may render the trade uneconomical.

The *Transaction Cost* market failure is also related to the *Information* market failure. For new technologies, where public knowledge and understanding of the technology is low, the costs in time and money to obtain the necessary information to invest could prevent an investor or consumer from making an economically beneficial decision.

Principal-agent

The principal-agent problem (or agency dilemma) occurs when a party tries to motivate another party to act on its behalf. The problem may arise because of incomplete and asymmetric information between them or because they respond to different incentives. This problem is particularly frequent in the adoption of energy efficiency technologies and practices. Many energy efficiency technologies are cost-effective, yet not implemented because of this problem. For instance, it is difficult for a landlord to justify an investment in insulating a building if the tenants pay the heating bill.

Capital stock turnover

The tax rules associated with the depreciation of capital stock in a given industry can present either a barrier or an incentive. If tax rules require slow depreciation of capital stock, this can have a significant impact on the potential early profitability of technology, posing an important barrier to entry into the market. This is particularly the case for new technologies in which early revenues are low and short- to medium-term risk is higher.

2.1. Summary

Table 2 shows a summary of the barriers framework to be used in the study. As discussed above, most barriers also have the potential to be market failures. The nuances of the inter-relations between these barriers and/or failures will be evaluated in more detail for each technology in Section 4.

TABLE 2- BARRIERS FRAMEWORK

Barrier Type	Barrier and/or Failure
Technical viability of the technology	Barrier and Failure
Technology cost	Barrier
Price distortion	Failure
Financing and risk	Failure
Physical infrastructure	Barrier and failure
Human infrastructure	Barrier and failure
Regulatory framework	Barrier and failure
Tradition	Barrier and Failure
Information	Failure
Public perception	Barrier and Failure
Transaction cost	Failure
Principal-agent	Failure
Capital stock turnover	Failure

3. LIST OF STAKEHOLDERS AND THE STAKEHOLDER CONSULTATION PROCESS

In this section we provide a list of the stakeholders contacted for the study, followed by a description of the methodology used during stakeholder consultations.

3.1. List of stakeholders

To be completed.

Table 3 lists the industry stakeholders that have been contacted for interviews thus far. This table will be completed for the final report with a list of all stakeholders successfully contacted. For those stakeholders that we were unsuccessful at contacting we will also provide the reasons why, if possible (unwilling to participate, on vacation, no response, etc.). For this Progress Report, a complete list of potential stakeholders that we may attempt to contact is given in Appendix 1.

TABLE 3- STAKEHOLDERS CONTACTED FOR INTERVIEW

Industry	Name of Person/Organization	Description	Type of Organization
CCS	3 stakeholders have been contacted, to be confirmed.		
Biofuels	Pierre Sylvestre	Environment Canada Oil, Gas and Alternative Energy	Government
	Don O'Connor	$(S\&T)^2$ Consultants	Renewable fuels and transportation expert.
	Conseil Québecois du Biodiesel	Camil Lagacé Director	Industry Association. Expert in the biofuels industry.
	Canadian Bioenergy	Doug Hooper President and CEO	Biodiesel production and distribution
	Biofuel Canada	Peter Sydoruk Co-president	Design and manufacturer of biodiesel plants
	Douglas Auld	Professor of Economics Guelph University Author of CD Howe report on corn-based ethanol	Academic
	Verenium (USA)	John B. Howe VP Public Affairs	Cellulosic ethanol technology developer and producer

Industry	**Name of Person/Organization**	**Description**	**Type of Organization**
	The Biodiesel Company	Ethan Vos President	Biodiesel producer from waste oil feedstocks
Hybrid and plug-in hybrid vehicles	Pierre Sylvestre	Environment Canada Oil, Gas and Alternative Energy	Government
	National Research Council of Canada	Yaser Abu-Lebdeh *Advanced Li-ion battery technologies for Plug-in hybrid electric vehicles (PHEV)*	Government research
	Electric Mobility Canada	Al Cormier Executive Director	National non-profit industry association
	The Centre for Sustainable Transportation (University of Winnipeg)	Arne Elian, PhD (C) MBA Executive Director	Academic research
	Electric Vehicle Society	Howard Hutt Senior Electrical Vehicle Consultant	Non-profit organization for electric vehicle engineers, enthusiasts and environmentalists
	Greenfleets (British Columbia)	Jim Vanderwal Program Manager The Hybrid Experience	Non-profit organization providing info on fuel efficient technologies
	McGill University	Peter Radziszewski, McGill University *Advance power train research and development*	Academic research
Ground and Air Source Heat Pumps	Canadian GeoExchange Coalition	Denis Tanguay President and CEO	Industry Association
	Corix Utilities		Technology developer + provider
Landfill gas capture	To complete.		
Hydro	To complete.		
Wind	CanWEA	Sean Whittaker Policy Director Jean-François Nolet Policy, Quebec and Atlantic provinces	Non-profit industry association
Nuclear	To complete.		

3.2. Stakeholder consultation process

We believe the stakeholder consultation process to be central to the achievement of the objectives of the mandate. Therefore, a stakeholder consultation process was carefully developed in order to ensure that the necessary information be obtained to the greatest extent possible and that the stakeholders be sufficiently informed so as to be able to provide measured commentary.

In the first instance, stakeholders were contacted by email with a brief description of the mandate and a request for participation in an interview. Attached to the introductory email were informational “backgrounder” sheets, providing a more detailed context to the mandate as well as the relevant forecast data for the sector from the Roadmap. In these “backgrounder” sheets, stakeholders were also informed of the types of questions they would be asked. The intention of this preliminary email was to allow the stakeholder sufficient time to study the forecast data and to reflect on the questions to be asked of them.

If the stakeholder agreed to participate, an interview was conducted, most often by telephone but in some cases in person. These interviews were approximately 30 minutes in length each.

Below we provide a list of the general types of questions that we have put to the stakeholders during consultation. The discussions in the interview are of course not limited to the questions presented here.

1) What is the role of your organization in your industry? Please provide a brief overview of the work you are currently involved in.

2) Describe the current state of the market and the current state of technological development in the industry. Where do you think the industry is headed in the short, medium and long term?

3) Do you find the NRTEE forecasts realistic/feasible? Why or why not?

4) What are the principal market barriers and market failures your technology faces today and what barriers do you foresee for the future? What are the key barriers that make the NRTEE’s projected penetration rates unrealistic (if applicable)?

5) What are the enabling conditions (political, social, financial, etc.) that would enhance the deployment and market penetration of your technology?

It is important to note that at the stage of Question 4, the barriers framework outlined in Section 2 is referred to with the stakeholder in order to obtain commentary on each of the market barriers and failures identified, if they are applicable to the industry.

4. ANALYSIS OF THE ROADMAP DATA AND DISCUSSION OF BARRIERS

All parts of this section are to be developed and completed.

In this section, for each technology identified for the mandate, we seek to determine whether the forecasts presented in the NRTEE-commission Technology Roadmap (Nyboer, 2008, heretofore referred to as 'the Roadmap') are realistic. We analyze the specific market barriers or market failures that each of these technologies currently faces or may face in the future, primarily based on the results of the stakeholder consultations. The results are presented by technology type and the categories of technology type have been arranged according to how they have been presented in the Roadmap.

First, a summary of the main findings of the stakeholder consultations is presented. Then, for each technology type, a brief description of the current state of the industry is provided. This is followed by a summary of the NRTEE forecast data and then an in-depth evaluation of these forecasts and a discussion of the applicable barriers for each technology, as deduced from the stakeholder consultations.

4.1. Summary of Main Findings

For the final report, in this section we will present a summary of the principal findings from the stakeholder consultations, including a general evaluation of the Roadmap forecast data and the key barriers highlighted for each technology.

A Note Regarding the Carbon Prices Assumed in the Technology Roadmap Modeling Exercise

Before entering into a more detailed discussion of the results of the stakeholder consultations, it is worth mentioning a common commentary that was encountered during the interview process, across all sectors. Although not explicitly asked to comment on this issue, some stakeholders expressed skepticism regarding the prices per tonne for carbon assumed in the Technology Roadmap modeling exercise (namely $15 in 2010, $115 in 2015, $215 in 2020 and $300 as of 2025). They believed that in particular, a price of $300/tonne was unlikely to be achieved through a market cap-and-trade system and were skeptical of the political feasibility of imposing such a cost through a carbon tax, within the timeframe suggested by the Roadmap. Therefore in some cases, stakeholders wished it to be known that while they may have deemed the Roadmap forecast data to be realistic under the stated carbon price conditions, they nevertheless found the carbon price assumptions that the forecasts are based on to be unrealistic. This point should be kept in mind in the context of the results presented in this section.

4.2. Carbon Capture and Storage

Current state of the industry for carbon capture and storage

Summary of NRTEE forecast data

Table 4 presents the Roadmap forecast data for the penetration of the use of CCS in a wide range of industries. As can be seen in the table, it is predicted that by 2050, CCS will be almost fully applied in most GHG-intensive industries. The exceptions are heat production for biofuels manufacturing (46% penetration) and in-situ petroleum extraction (55% penetration).

TABLE 4- PENETRATION RATES FOR CCS IN VARIOUS INDUSTRIES (% OF PRIMARY PRODUCTION MAKING USE OF CCS)

	2010	2020	2030	2040	2050
Chemicals Manufacturing					
Ammonia Production	0	67	93	98	99
Process Heat Generation	0	12	38	52	66
Lime Manufacturing		11	35	68	99
Cement Manufacturing		48	59	85	99
Integrated Steel Manufacturing		8	49	81	93
Petroleum Refining		5	21	63	86
Petroleum Extraction					
Hydrogen Production		91	98	100	100
Oil Sands Upgrading		58	88	96	99
In-Situ		35	54	57	55
Natural Gas Extraction					
Formation CO_2		100	100	100	100
Combustion Emissions from Processing Plants		32	63	98	100
Biofuels Manufacturing (heat production)	2	37	45	46	46

Evaluation of forecast data and discussion of barriers

Current and potential barriers facing the CCS industry are discussed below.

Motivational Barriers

- In the absence of a financial cost for emitting CO_2, there is little reason to adopt CCS. The Canadian Federal and Albertan climate policies will incentivize CCS by creating a cost for GHG emissions; however the emissions prices may not be high enough to justify CCS investment.

In comparison to emitting GHGs into the atmosphere, CCS will always be more expensive due to the extra chemical processing, equipment, and energy needed to capture the emissions. Both the Alberta provincial government and the Canadian federal government have enacted or announced plans to implement emissions management plan frameworks. In both cases it is not clear that carbon prices will be high enough to justify CCS investment. The Federal framework is still evolving and may undergo significant changes before being finalized. The existing Canadian frameworks for limiting GHG emissions subsidize CCS investment through the technology fund or precertified investment mechanisms. Even so the uncertainty regarding the design of the programs and expected carbon prices could hinder CCS investment.

There are limited instances where CCS-like activities are practiced (Enhanced Oil Recovery (EOR), food, beverage, and chemical industries); however these alone will not drive the development of CCS due to differences in scope or scale. The large capital costs for CCS exceed the scope of most voluntary environmental compliance initiatives.

Without sufficient financial cost for emitting GHG's, companies have little incentive to mitigate their emissions. Present policies provide some incentive for developing CCS, but it is not clear whether those policies are sufficient. In the absence of convincing signals that climate policies will produce emissions costs that will justify CCS investment, the private sector cannot be expected to make significant investments in CCS.

Financial Barriers

- The financial proposition for CCS is unclear due to both technological and market factors.

From the financial perspective there is currently too much risk and uncertainty related to CCS to enable significant private sector investment. While this risk is partially attributable to policy uncertainty (see motivational barrier), there are a number of additional factors which make it difficult to quantify the financial return on a CCS project. These include both technological and market factors which affect the financial viability of CCS.

From the technological perspective there are a number of factors which affect the financial viability of CCS for all potential applications. These include both developmental and operational factors. Developmentally, since CCS is a relatively new and unproven technology there is significant uncertainty about the time and cost necessary for constructing an integrated CCS facility. Even though all components of a CCS system are expected to function well together, since such a system has not been completed before project developers need to plan for unexpected development and troubleshooting costs. Fortunately, this developmental uncertainty will decrease as engineers learn from the construction of the first CCS facilities. The difficulty is over how to encourage the initial CCS projects that are essential for providing this learning experience.

From the operational perspective the private sector is concerned about unknown maintenance costs, lower availability rates, and higher fuel costs. As an unproven technology the long run maintenance costs for the CCS infrastructure is relatively unknown. Another concern is that decision makers do not have sufficient confidence that facilities will perform as advertised once constructed. In all industries, new facilities typically exhibit lower operational availability rates until operators learn how to optimize the processes. This is especially true of tightly coupled and complex systems such as CCS. For CCS, concerns about availability are based on past experiences with the construction and development of Integrated Gasification and Combined Cycle (IGCC) power systems. Of the handful of IGCC facilities that have been constructed, many initially had low availabilities rates. The initial lower rates were commonly caused by problems with air separation units, syngas coolers, gasifiers, and other new equipment unique to IGCC facilities. The last operational concern is whether the higher energy usage for CO_2 capture compression and storage with CCS will negatively impact the economics. The uncertainty regarding operational availability drives uncertainty in terms of expected revenues from electric power and emissions offset credits. Furthermore, given uncertainty regarding the development of alternative technologies, the relative competitiveness of CCS when compared to such alternatives is also unclear. Together, these developmental and operational factors drive uncertainty over a CCS facilities technical performance. Without mechanisms for managing such risks, the private sector is likely to be less willing to invest in CCS.

The competitive environment for CCS has a large effect on the financial viability of a CCS facility. For a power facility using CCS, the profitability of the facility is dependent on conditions in the electric power and environmental emissions markets. The long lead time for CCS construction adds additional uncertainty regarding expected conditions in those markets when a facility is completed. The profitability of an operational CCS facility depends on the costs of fuels (coal, gas, oil, and alternatives), the market prices for electricity, as well as the cost of emissions allowances. And all of these factors are influenced in turn not only by the current emissions portfolio and capital stock but also the development and implementation of alternative low emitting technologies.

From the financial perspective, private entities considering CCS are faced with financial risks and uncertainties that serve as disincentives to the development of CCS. The CCS value chain remains unproven, and the market environment for future CCS projects is unclear. Of course companies frequently engage in expansion, development, and construction under uncertainty. However, the level of uncertainty for CCS is significantly greater than that in typical corporate decisions. Since this uncertainty is likely to decrease after a few initial projects, there is a strong incentive for companies to seek a free ride by avoiding CCS projects and allowing their competitors to shoulder the development risks of these initial projects. This investment disincentive discourages companies from moving forward with CCS projects. Without initiatives to manage this uncertainty and investment disincentives, further private sector development on CCS is likely to remain limited.

Regulatory Barriers

- Regulatory procedures, including licensing, permitting, and regulatory requirements for CCS, remain unclear and undeveloped. This is especially true for the Geologic Storage (GS) component of the CCS architecture.

Much like many industries, CCS facilities and operations are expected to be subject to a myriad of licensing, permitting, and regulatory requirements to ensure that their operations are conducted properly, effectively, and safely. Since CCS is still under development, however, appropriate authorities have not yet decided what regulatory requirements, if any, CCS projects will need to meet. The risk for CCS project developers is that they could proceed with project development only to find that their efforts fail to meet regulatory requirements enacted after the fact. Thus not only would a project developer be operating within an unclear regulatory environment, the developers would be exposing themselves to a significant financial risk if they need to reconfigure their facilities in the future.

This regulatory risk is especially important for the GS component of the architecture. Private sector groups could plan for GS within a geologic reservoir; however they would have no guarantee that the reservoir would meet eventual government safety requirements. Given the large infrastructure and capital costs associated with CCS, project developers have been unwilling to invest in such projects in the face of this regulatory risk. Per ton estimated CCS costs are $20-70 for capture, $6 for transportation, and $6 for storage of CO_2 emissions. Overall capital costs for electricity producing IGCC facility with CCS are estimated in excess of $1 billion. For electric power facilities with CCS, the Intergovernmental Panel on Climate Change (IPCC) estimate increased capital costs for CCS of roughly 50%. Canadian CCS requirements remain largely undefined at the federal, provincial, and local levels. And regulatory authorities have not provided sufficient guidance or guidelines regarding early projects.

- The private sector could face significant, and possibly unending, liability for any harm resulting from CCS.

While remote, the possibility exists for leakage and escape of stored emissions in ways that could harm both people and property. Traditionally, liability is used as a mechanism for ensuring companies act to limit harmful consequences of their actions. And without further action, liability for future harms would generally remain in the private sector with the entity that sequestered the emissions underground. The geologic storage of GHGs requires the isolation of such emissions from the biosphere for time periods in excess of a thousand years. Due to the long time frames and uncertainty over the level of risk, neither the private sector nor the public is well served by leaving liability with the private sector.

From the private sector's perspective, the heterogeneous nature of the subterranean environment used to store the CO_2 makes it impossible to guarantee that stored CO_2 will remain isolated indefinitely. While companies would be expected to make best faith efforts to limit any such consequences, the long time frames essentially imply that companies practicing CCS could be exposing themselves to a perpetual liability. From a financial perspective, it is understandable why companies may wish to avoid such liabilities. Accepting such perpetual liability is a large obligation that most firms would like to avoid.

It is also not clear that the public's interest is best served by making the CCS operator indefinitely liable for their operations. Few companies remain stable on the 50-100 year time frame, and companies that cease to exist could escape future liability obligations. In such cases, there would not be an entity responsible for monitoring or remediation of the geologic reservoir. The company, that injected the emissions, would thus escape liability by ceasing to exist. If companies knew they could exploit this loophole to avoid liability, they might not take appropriate measures to ensure public safety. Thus the public may not want liability to remain with an entity that is could easily escape accountability.

Based on current knowledge, there is a small but real potential for injury from CCS facilities. The public will require, and deserve, that some entity remain liable for the monitoring, upkeep, and remediation of any future problems. Efforts to absolve participants from liability would erode drivers for safety and health, yet participants may also be able to escape liability under existing laws. Accordingly, both CCS project developers and public stakeholders will require a reduction in the uncertainty and risk associated with CCS through clarification and resolution of outstanding liability issues before CCS projects can proceed further.

- There are no guidelines or protocols for CCS infrastructure.

Future deployment and coordination of a national CCS infrastructure will be inhibited by the lack of common industry guidelines, practices, and protocols. In many industries such protocols represent the distillation and aggregation of best practices based on accumulated experience. More importantly than simply encouraging best practices, these protocols reduce the overhead for constructing additional projects in the system.

As an emerging technology, the lack of common protocols is understandable as there is no historical precedent available for guidance. These protocols could be expected to evolve as the industry develops and expands. However, much like the risks faced by project developers that deploy projects before regulatory requirements are decided, early project developers face a risk of losing existing sunk costs by deploying projects that then fail to meet industry protocols. These protocols would surely evolve as the industry expands; however, some baseline set of industry standards is needed to reduce the risk for project developers.

Technical Barriers

- A wholly integrated competitive CCS system has never been demonstrated.

A full scale, commercially viable CCS has not been deployed. This serves as a barrier to CCS deployment since it increases the uncertainty and risk associated with a decision to undertake such a project. All of the key processes and components of the CCS architecture have been demonstrated separately. However, the wholly integrated system has never been used to date. For this reason, substantial uncertainty remains with respect to the ultimate cost of building a complete CCS system. This barrier will need to be overcome with technical engineering and system optimization, and successful efforts will serve to reduce the financial uncertainty associated with CCS projects.

Institutional Barriers

- Power companies lack the technical expertise and experienced personnel to construct, develop, and operate a CCS power generation facility.

Power companies and other large emitters do not have staff experienced with and knowledgeable about CCS facilities. The Canadian economy does however have significant numbers of skilled personnel with knowledge and experience with similar applications, specifically within the oil and gas extraction, processing, and handling industries as well as the chemical industries. The expectation is that the staffing, and institutional capacity will develop as the technology is deployed. It is unlikely that a model of pushing solely the institutional capacity or the physical deployment to the exclusion of the other would be sustainable.

Infrastructure Barriers

- The CO_2 transportation infrastructure is in its infancy and remains limited in scope.

A very legitimate barrier to the use of CCS is the lack of a pre-existing pipeline CO_2 transportation network. If the infrastructure were pre-deployed it would facilitate the construction of CCS capture and sequestration facilities. The existing Canadian pipeline CO_2 transportation network is relatively limited, less than 200 km. The existing network is used for EOR operations in Weyburn, Saskatchewan and Joffre, Alberta. Studies have indicated that roughly 2,000 km of CO_2 pipeline would be needed for EOR and CCS activities in Alberta. Without the pre-existing transportation capacity, construction of a CCS facility also requires the construction of the CO_2 transportation capacity, increasing capital costs. The likely development path is for the first capture facilities to be constructed at sites co-located with storage capacity or the existing transportation infrastructure. Then as CCS is adopted it will likely spur expansion of the limited existing transportation infrastructure.

- Detailed site specific knowledge of geologic sequestration capacity remains limited.

A fundamental requirement for GS of CO_2 is an appropriate reservoir for storing the CO_2. Before selecting a site for CO_2 sequestration, project developers need to conduct a detailed study and assessment to ensure that the geologic feature is capable of storing the emissions. Canadian institutions have studied potential sequestration sites at an aggregate level, but few sequestration sites have been studied in sufficient detail to enable storage of CO_2 without further study. Such site characterization is expensive and site specific, thus it is unlikely to occur in the absence of serious sequestration proposals.

Risk, Safety, and Siting Concerns

- Public acceptance of CCS is unknown.

Public awareness of CCS is incredibly low and proponents are concerned that public opposition movements, akin to those that developed in response to nuclear technology, would limit the deployment of CCS infrastructure. Arguments can be made that CCS is unlikely to face nuclear power-like resistance since the two technologies have fundamental differences. However, this is impossible to predict with sufficient confidence. The available literature on this topic is inconclusive, and the fundamental finding is that the public is not sufficiently knowledgeable regarding CCS for researchers to make reliable conclusions regarding public acceptance. The difficulty of forecasting public acceptance or opposition to CCS facilities adds to the uncertainty and risk associated with development of a CCS project.

The public cannot be expected to have significant awareness of a technology that has not been deployed. The risk, safety, and siting concerns will remain unresolved in the absence of CCS deployment. These concerns do mean that project developers should pay careful attention to public concerns and place an emphasis on proper site characterization and ensuring public safety.

- The difficulty of siting CCS facilities and reservoirs is unknown, and site specific.

Whereas infrastructure and industrial facilities typically face some local opposition to deployment, the level of resistance for CCS facilities is unknowable prior to initial deployment efforts. This uncertainty from public opposition increases the risk to project developers. Project developers can take efforts to minimize or mitigate this risk. More populated regions are more likely to face significant opposition, thus initial CCS efforts should be directed at locations where opposition is least likely.

- Accurate analysis of the risk of public injury from CCS is not possible without deployment.

Public stakeholders considering CCS deployment will want accurate analyses of the risks of harm; however such estimates are not possible without numerous trial cases. The statistical risk and likelihood of injury from CCS is not knowable in the absence of infrastructure deployment. This lack of accurate data then increases the uncertainty for project developers and the public considering CCS projects.

4.3. Fuel Switching to Renewables in Transportation and Cellulosic Ethanol Production

Current state of the industry for ethanol

Ethanol is made from a variety of high starch or sugar feedstocks (IEA, 2006). Feedstocks can be direct from sugar crops such as sugar cane (the most popular source in tropical countries) or sugar beet. Popular starch feedstocks include corn, wheat and barley as well as potatoes, and cassava. In Canada, ethanol is mainly produced from corn and wheat.

Currently, ethanol is the most common alternative fuel and is primarily made by converting starch crops into sugars, which are then converted into ethanol by fermentation. Two main methods are used to make ethanol from corn, producing different co-products (SDTC, 2006): dry milling produces dried distiller grains, high value feed products, and wet milling, resulting in gluten meal and feed, i.e. vitamin-supply feeds for animal. The choice of a method depends on the possibility of commercializing these co-products.

Ethanol is currently the most common alternative fuel used in transportation. It can be blended with gasoline in proportions varying between 5% and 85% of ethanol, the most current blends being 10% and 85%: E10 can be used in existing engines whereas E85 can be used only in flex fuel vehicles.

There are currently nine commercial scaled ethanol producing plants in Canada in operation, producing ethanol that meets Canadian standards, amounting to approximately 754 million litres per year in production, as of 2007 (Table 5).

In addition, there are several plants planned and under construction which have already obtained funding through Natural Resources Canada’s Ethanol Expansion Program (EEP) or other funds such as the Agriculture and Agri-Food Canada’s Bio-Fuels Opportunities for Producers Initiative (BOPI) program:

- GreenField Ethanol (Johnstown, ON) : 200 million litres by 2008;
- GreenField Ethanol (Hensall, ON) : 200 millions litres by 2008;
- Integrated Grain Processors Co-Operative Inc. (Brantford, ON): 150 million litres;
- Husky Energy Inc. (Minnedosa, MB) : 130 million litres by the end of 2007.

TABLE 5- ETHANOL PLANTS IN CANADA AND PRODUCTION CAPACITIES, 2007

Plant	Location	Million litres per year	Feedstock
GreenField Ethanol	Varennes, QC	120	Corn
	Total Quebec	120	
Iogen Corporation	Ottawa, ON	3	Wheat straw
GreenField Ethanol	Tiverton, ON	26	Corn
GreenField Ethanol	Chatham, ON	187	Corn
Suncor Energy Inc.	Sarnia, ON	200	Corn
	Total Ontario	416	
Husky Energy Inc.	Minnedosa, MB	10	Wheat
Husky Energy Inc.	Lloydminster, SK	130	Wheat
Pound-Maker Ethanol Ltd.	Lanigan, SK	13	Wheat
API Grain Processors/ Permolex	Red Deer, AL	40	Wheat
NorAmera BioEnergy Corp.	Weyburn, SK	25	Wheat
	Total Prairies	218	
	Total Canada	754	

Source : Compilation by EcoRessources Consultants

The Canadian government recently confirmed that they will require a minimum of 5 % renewable content in all gasoline fuel sold in Canada by 2010. Federal and provincial initiatives are seeking to promote ethanol-gasoline blends. Previously, the ethanol portion of blended gasoline benefited from an exemption of the excise tax of 10 cents per litre on gasoline. This exemption was replaced with the new program *Biofuels Opportunities for Producers Initiative* "…designed to help farmers and rural communities hire experts who can assist in developing business proposals and undertake feasibility and other studies necessary to create and expand biofuels production capacity involving significant (greater than one-third) ownership by agricultural producers" (Government of Canada, 2008). In addition, several provinces offer incentives for ethanol consumption, such as exemption on the ethanol portion of blended gasoline from road taxes, tax credits to producers or requirements on minimum renewable content in conventional fuel.

Current state of the industry for biodiesel

Biodiesel can be made from a large variety of feedstocks, depending on biomass availability and growing conditions. In addition to recycled vegetable oil (yellow grease), and rendered fat (tallow), biodiesel is also commonly made from vegetal oil: canola, sunflower, soy, palm and other less common feedstocks such as coconut, rice bran, safflower, palm kernels, jatropha and Ethiopian mustard (Hass and Foglia, 2005). In Canada, biodiesel is produced from a large variety of feedstocks including yellow grease, tallow, canola oil and fish oil while the production of soy biodiesel may also become significant in the future. Currently, biodiesel is mainly produced from yellow grease and animal fats, the most cost-effective feedstocks as well as those with the lowest environmental impacts.

For biodiesel production “fats and oils are chemically reacted with alcohol (such as methanol) in the presence of a catalyst (such as caustic soda or potassium hydroxide) to form fatty acid methyl esters. Acid treatment is sometimes used for pre-treating high fatty acid feedstocks such as recycled greases” (SDTC, 2006).

Biodiesel fuels can replace distillates (diesel and fuel oil) in all the sectors of application such as transport, residential heating, electricity production and any other industrial and agricultural use. It can be used pure or blended with diesel in proportions varying between 2% and 20%, the most current blends being 5% for regular users, while 20% blends are normally reserved to large-scale consumers. Biodiesel pilot projects have been already been developed in partnership with large-scale consumers, such as public transport providers (BioBus project) and boat excursion companies (BioMer project). The objective was to test the use of biodiesel in buses and boats for one year in order to evaluate its viability under all conditions (e.g. cold) and to measure its economic and environmental impacts. Biodiesel was mixed with diesel in concentrations of 5% and 20% and the experiment proved very successful at the technical level. Increasingly, public transport and trucking companies are considering using biodiesel for their fleets.

There are currently seven commercial-scaled biodiesel producing plants in Canada in operation, producing biodiesel that meets Canadian standards, amounting to approximately 118 million litres per year in production as of 2007 (Table 6). In addition, a 225 million litre capacity plant is under construction in the Sturgeon County in Alberta. Canadian Bioenergy will become the largest biodiesel producer and will use canola as the feedstock. There are many other micro-producers that do not meet the Canadian standards or produce at a relatively small scale.

The Canadian government recently confirmed that they will require a minimum of 2 % renewable content in all diesel fuel and heating oil sold in Canada by 2012. As for ethanol, federal and provincial initiatives are seeking to promote biodiesel-diesel blends. Previously, the biodiesel portion of blended diesel benefited an exemption of the excise tax of 4 cents per litre on diesel. This exemption was replaced with the new program *Biofuels Opportunities for Producers Initiative*. In addition, several provinces offer incentives for biodiesel consumption, such as exemption on the biodiesel portion of blended diesel from road taxes, tax refunds on biodiesel purchases, tax credits to producers or requirements on minimum renewable content in conventional fuel.

TABLE 6 - BIODIESEL PLANTS IN CANADA AND PRODUCTION CAPACITIES, 2007

Plant	Location	Million litres per year	Feedstock
Ocean Nutrition	Dartmouth, NS	3	Fish oil
S.F. Rendering	Port Williams, NS	2	Tallow
	Total Atlantic	5	
Rothsay Biodiesel	Ville Sainte-Catherine, QC	35	Tallow Yellow Grease
	Total Quebec	35	
Biox Corporation	Hamilton, ON	60	Tallow
Methes Energies	Newmarket, ON	3	Various
	Total Ontario	63	
Bifrost Bio-Blends	Arborg, MB	8	Canola
Milligan Bio-Tech	Foam Lake, SK	5	Canola Oil
	Total Prairies	13	
	Total Canada	118	

Source: Update by ÉcoRessources Consultants from Sine Nomine (2006 ; 2007)

Current state of the industry for next generation biofuels and potential future developments

An increasing interest toward lignocellulosic feedstocks will lead to the production of next generation biofuels from forestry and agricultural residues as well as municipal organic wastes. New sources of biomass include (EERE, 2007):

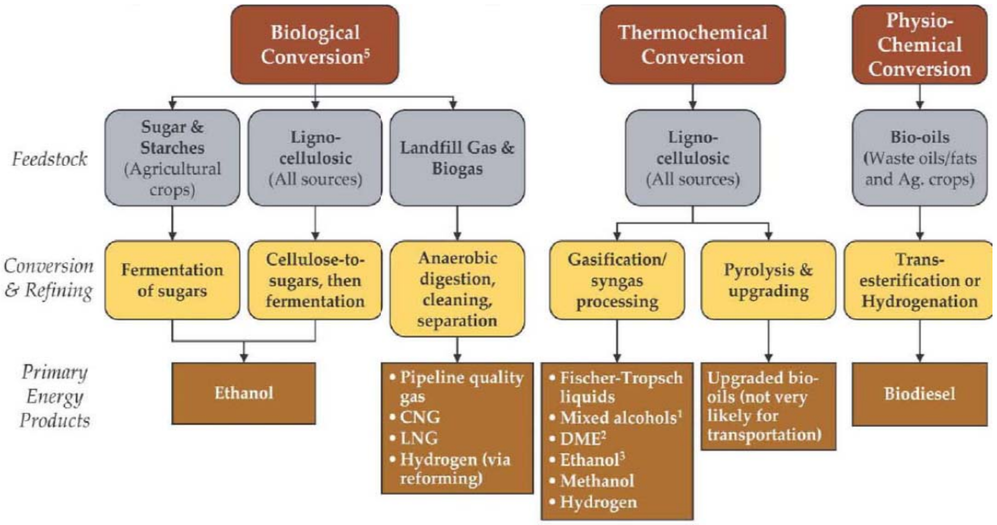
- In the short term, for small-scale applications, low- or negative-cost feedstocks such as industrial residues (black liquor from the pulp and paper industry and animal manures) could provide a good proportion of biomass.

- In the medium term, the addition of forestry and agricultural residues will provide the most important portion of biomass and significantly increase the potential for fuel and for power production.

- In the long term, dedicated cellulosic biomass crops for energy production could offer additional capacity.

Technologies to convert biomass into liquid fuels that can replace petroleum products are categorized as second or third generation technologies (EERE, 2007). The use of this type of biomass requires technologies with higher levels of complexity to convert the feedstocks into fuels. Next generation technologies liquefy or gasify solid biomass by heating it with limited or no oxygen (e.g. the Fisher-Tropsch process converts syngas to liquid fuels). The intermediate product (synthesis gas or pyrolysis oil) can be burned more efficiently and used for biomass conversion into chemicals or materials. Biodiesel production using next generation technologies produce fuels with chemical properties that are very similar to those of conventional diesel. For ethanol production, second generation technology involves enzymes capable of hydrolyzing cellulose into sugars that can afterwards be fermented. When the appropriate technology is used, be it biochemical (for certain types of biomass) or thermochemical (for a wider spectrum of biomass), cellulosic ethanol can be made from feedstocks containing cellulose such as corn stover (leaves and stalks), straw, grasses (switchgrass, miscanthus, giganteus, etc.) wood chips and sawdust. The next generation biofuel industry's growth relies heavily on the development of technologies capable of (1) converting cellulosic biomass and lignin (rather than grains or starchy/sugar-based feedstocks) into biofuel and other products (chemicals or materials) and (2) gasifying or liquefying biomass for power production or for catalytic conversion to valuable products (Figure 1). Future biorefineries would convert biomass into a variety of biofuels in addition to a variety of useful by-products (chemicals, materials, power, etc.).

FIGURE 1 – FIRST AND NEXT GENERATION TECHNOLOGIES FOR BIOMASS CONVERSION



Source: Brown, 2007

Summary of NRTEE forecast data

Tables 7, 8 and 9 present the Roadmap forecast data for the use of renewable fuels in transportation. The Roadmap predicts that by 2050, the fuel share of biofuels (ethanol and biodiesel) will have increased by 57%, that 97% of freight trucks will run on biodiesel and that plug-in hybrid vehicles will have captured 62% of the passenger vehicle market.

TABLE 7- CHANGE IN PETROLEUM FUEL SHARE (%)

Fuel Type	2020	2030	2040	2050
Petroleum products	-9	-47	-66	-68
Electricity	2	9	10	10
Biofuels (ethanol and biodiesel)	7	38	55	57

Source: Nyboer (2008).

TABLE 8- FUEL SHARE FOR BIODIESEL FREIGHT TRUCKS (%)

	2020	2030	2040	2050
Freight Trucks (Biodiesel)	20	72	96	97

Source: Nyboer (2008).

TABLE 9- PENETRATION RATES FOR PLUG-IN HYBRID ETHANOL VEHICLES (% OF TOTAL STOCK)

	2020	2030	2040	2050
Passenger plug-in hybrid ethanol	7	51	62	62

Source: Nyboer (2008).

Table 10 presents the Roadmap forecast data for the production of ethanol from ligno-cellulosic feedstocks. The Roadmap predicts that by 2050, cellulosic ethanol will make up 100% of ethanol production.

TABLE 10- CELLULOSIC ETHANOL PRODUCTION (% OF TOTAL ETHANOL PRODUCTION)

	2020	2030	2040	2050
Cellulosic Ethanol Production	91	99	100	100

Source: Nyboer (2008).

Evaluation of forecast data and discussion of barriers

The range of stakeholder opinion varied widely in the biofuels industry regarding the feasibility of the Roadmap forecast data as well as the extent of existing and potential barriers. Of the seven stakeholders contacted, two found the forecast data to be generally realistic, three found the data optimistic and two found the data very optimistic. Current and potential future barriers for the biofuels industry that were raised by stakeholders are discussed below:

Feedstock availability

This issue is one of the first that was highlighted in all of the stakeholder interviews as an important barrier. For first generation biofuels, there is competition for land use with food crop and livestock farmers and there is a limit to new land (from forest or marginal lands) available for fuel-crop farming under current regulatory conditions. With increasing demand for biofuels and commodity prices in the food industry being driven up (also partly due to high fuel prices), the costs of feedstocks are already increasing and are likely to continue.

Land use is also an issue for next generation biofuels, but less so: the feedstocks are either high-yield and require less land or they are from waste materials (agricultural and forestry waste, waste oils, etc.) and therefore require no displacement of food crops or other lands. However, for waste material feedstocks for instance, because they are the by-product of another process, their availability can be less reliable. The costs of these feedstocks are already high and as with first generation feedstocks, as demand increases, so does their cost. In addition, for waste feedstocks where collection from multiple sites may be necessary to obtain the necessary volumes, collection and transportation of these feedstocks can be an expensive and GHG-intensive process.

Most stakeholders agreed that either there will not be enough feedstock to supply demand and/or that the costs of feedstocks due to availability issues will be a significant problem. However, one stakeholder in the biodiesel industry did not believe that feedstock availability would be a problem, since technological advances would bring the costs of feedstock processing down and would permit the use of only non-land use intensive feedstocks (waste vegetable and animal oils, biomass and algae).

Fuel transportation and distribution infrastructure

Also of great importance according to the stakeholders contacted is the lack of an established and working infrastructure for the transportation and distribution of biofuels. Transportation by the existing pipeline network is problematic because biofuels act as solvents and absorb water and impurities that traditional fuels do not, thus affecting the quality of the final product. In addition, for biodiesel in particular, transportation must be done by insulated tankers and storage tanks must be heated in the winter months due to the high cloud point of the fuel (the temperature at which it begins to crystallize). For future generations of biofuels, the solvent and cold-flow properties of biofuels will be improved, allowing transportation by pipeline. In the meantime, however, alternative modes must be used, such as tanker trucks and trains. These modes are more expensive and more GHG-intensive.

The lack of an extensive and appropriate distribution network is also a significant barrier. This makes it difficult to bring the final product to the consumer. There can be high transaction costs associated with the purchase of biofuels from the point of view of the consumer if they are required to drive long distances to fill up. The high transaction costs of purchasing biofuels due to the lack of an extensive distribution network are a market failure.

The biofuels industry cannot yet invest in a dedicated pipeline and distribution system due to lack of capital and lack of sufficient volumes. This problem is a network effect market failure, yet most stakeholders emphasized that the real obstacle is the lack of an appropriate regulatory framework that requires the petroleum industry to share its existing network. This network was built and is maintained via large investments by the petroleum industry and they are understandably reluctant to allow biofuels producers to make use of their network without regulatory intervention. This lack of a regulatory framework that would allow for the most efficient transport of biofuels, thus reducing costs, is also a market failure.

State of technological advancement

Although first generation biofuel processes are already well understood and have begun development, next generation processes require more work. These next generation processes are more efficient economically, with regards to energy use and to GHG emissions. They would permit the use of residual biomass as a feedstock and would result in a product that has higher quality specifications, allows the use of a traditional transportation, storage and distribution network and that can be used in cold weather. However, more research and development is needed in order to bring next generation biofuels to commercial-scale development. Many stakeholders highlighted the need for demonstration projects in order to drive development and investment. This barrier is related to that of capital cost.

Capital cost

The economics of first generation biofuels are currently quite good. However, the capital costs for the production of next generation biofuels are currently 5-6 times higher than for first generation biofuels.

Financing and risk

State of capital markets.

Public perception

This barrier is closely related to that of feedstock availability. Public opposition has already begun against first generation biofuels due to displacement of food-crops for ethanol, the displacement of forests and other lands for biofuels, as well as the questionable GHG emission benefits of biofuel vs. fossil fuel use. This public opposition directly affects dedicated-crop biofuels such as ethanol from corn and wheat and biodiesel from soy and canola. However, this also has an indirect effect on next generation biofuels from high-yield or waste feedstocks for which land use is less of a problem and GHG benefits are higher. This is particularly the case where the public is not adequately informed of the differences between first and next generation biofuels regarding these issues. The problem of public opposition is currently a barrier, but in the case of biofuels being competitive with traditional fuels in terms of cost and quality, this could become a market failure.

4.4. Fuel Switching to Electricity and Energy Efficiency

4.4.1. Transportation

Most stakeholders in this industry (developers and industry groups in particular) commented on the Roadmap penetration rates as being realistic- but with conditions. There were two main variables that they felt were crucial to the viability of the Roadmap penetration rates: the speed of the development of battery technology and the regulatory framework surrounding plug-in vehicles. One consultant in the industry found the penetration rates to be too optimistic; he expects that it would take three generations of technical development before commercialization and that this could not be accelerated by a price on carbon. Indeed, another stakeholder stated that the transportation sector is difficult to influence by a price on carbon, stating recent increases in gas prices as being approximately equivalent to 350$/tonne CO_2.

It is also worth noting that two stakeholders expressed surprise at the lack of penetration of fully electric vehicles. They felt that some contribution to the vehicle stock by electric vehicles is to be expected. Most other stakeholders expected electric vehicles to remain a “niche” market throughout the forecast period due to higher costs and more technological developments required, with respect to both traditional vehicles and plug-in hybrids.

Current state of the industry for hybrid vehicles

A hybrid vehicle combines a combustion engine with an energy storage device, such as a battery. With most recent hybrid vehicles (e.g. Toyota Prius), the combustion engine functions with optimal effectiveness without interruption so that during the periods of low power request, it can be used to propel the vehicle simultaneously and to charge the battery. For periods of maximum power request, the engine and the battery can provide energy simultaneously. In addition, the battery can be used to recover energy during braking. However, it is not possible to recharge the battery by connection to an external source of electricity. Hybrid vehicles allow for reduced fuel consumption whilst maintaining performance. The advantages are even more significant when these vehicles are used in urban areas rather than on the highways.

Several hybrid car models are already available on the market (NRCan, 2008):

- Honda Insight: The first hybrid electric vehicle that was offered in Canada (in the 2000 model year). It is a compact two-seat car with a small and efficient engine and an aerodynamic design. The fuel consumption is about 3.9 litres/100 km in city areas and 3.2 litres /100 km on the highway.

- Honda Civic Hybrid: First offered first in Canada in the 2003 model year. It has a 1.3-litre, four-cylinder engine. The fuel consumption is about 4.9 litres/100 km in city areas and 4.6 litres /100 km on the highway.

- Toyato Prius. First offered in Canada in the 2001 model year. It has a 1.5-litre, four-cylinder engine and uses a 500-volt system. It also has a parallel hybrid configuration, called the Toyota Hybrid System, which relies on the powertrain to optimize fuel use. The battery is used during periods of low power request (below 40 km/hr) after which the engine starts to assist.

- Ford Escape Hybrid: First offered in Canada in the 2005 model year, it was the first vehicle that combine sport utility capability and the hybrid system. The fuel consumption is similar to that that of conventional compact or sub-compact vehicles.

Others vehicles are currently under development by manufacturers such as General Motors, DaimlerChrysler, Mitsubishi Motors, Nissan, Fiat Auto, Renault and Subaru.

The purchase of a hybrid vehicle can be exempted from provincial taxes in British-Colombia, f Manitoba, Ontario, Quebec and Island-of-Prince-Edouard. These provinces offer tax credits or refunds varying from 1 000 $ to 3 000 $.

Current state of the industry for plug-in hybrid vehicles

Hybrid vehicles that can be connected and recharged directly from the electricity network represent an interesting alternative. Like hybrid vehicles, they combine an energy conversion unit (e.g. a combustion engine) powered by conventional fuels with an energy storage device (e.g a battery). The difference is that the battery can be recharged by the energy conversion unit or by plugging into an electrical outlet. Consequently, these vehicles have a larger battery pack and most power can come from the stored electricity during shorter trips. The engine can be used during longer trips.

Plug-in hybrid vehicles currently only exist at the prototype stage or are produced in very small quantities. For example, Mercedes-Benz is manufacturing a limited number of plug-in hybrid vans for demonstration (EERE, 2008). They are still at the pre-commercial stage of development, but with continued research and development , they will soon be close to commercialization. Some manufacturers are currently developing plug-in models (EERE, 2008):

- General Motors develops the Chevrolet Volt, a hybrid plug-in vehicle that can run on electricity, gasoline and biofuels. The electric motor is 120-kW and the lithium-ion battery pack of 16-kWh, allow full performance on electric power only during daily trips, while the 53-kW generator and the engine combination allows driving on long distances.

- The Ford Edge is a prototype plug-in hybrid fuel cell vehicle. It contains a fuel cell, a hydrogen tank, two electric motors, and a lithium-ion battery pack. The fuel cell can power the electric motors and recharge the battery pack providing additional autonomy.

- General Motor develops the Saturn Vue Green Line Hybrid SUV that will use a modified version of their hybrid and plug-in technology, a lithium-ion battery pack, highly efficient electronics, powerful electric motors and 3.6 litres V-6 gasoline direct injection engine.

Summary of NRTEE forecast data

Table 11 presents the Roadmap forecast data for the use of electricity and energy efficiency in transportation. The data predicts that by 2050, 12% of the total stock of passenger vehicles will be hybrids and 21% will be plug-in hybrids.

TABLE 11- PENETRATION RATES FOR HYBRID AND PLUG-IN HYBRID VEHICLES (% OF TOTAL STOCK)

Vehicle type	2020	2030	2040	2050
Passenger vehicles				
Hybrid	3	6	11	12
Plug-in hybrid	6	18	21	21

Source: Nyboer (2008).

Evaluation of forecast data and discussion of barriers

Some of the key barriers to the penetration of hybrid, plug-in hybrid and plug-in hybrid ethanol vehicles, as highlighted during stakeholder interviews, are discussed below.

Technological barriers

The state of advancement in battery technology was an issue raised by all stakeholders as one of the most important barriers facing PHEVs. Electric engines operate at three times the efficiency of combustion engines; however there are a number of factors that limit their ability to be widely deployed at the moment:

- Cost

Depending on the type of battery, this can add $2000 to $20,000 to the price of the vehicle. This requires a long payback period in fuel savings. Deterioration of the battery with time means that a break-even point might never be met.

- Battery range

- Recharge time
- Safety
- Lithium supply
- Functionality under cold climate

Electric grid infrastructure

Grid load (not current barrier but potential failure). Cooperation between car and utility companies needed.

Capital cost

Capital costs still high. No range of vehicle options for consumer yet. Need low cost model, but incremental cost differential less significant for low cost range.

Fuel cost savings not always less than battery deterioration rate.

Regulatory framework

Current regulations prevent plug-ins on certain roads.

Tradition

No strong incentives yet for large automakers to rapidly develop and market plug-ins.

Information

Public not yet properly informed about the technology and its benefits.

4.4.2. Residential and Commercial

Current state of the industry for ground source heat pumps

Current state of the industry for other heating systems

Summary of NRTEE forecast data

Table 12 presents the Roadmap forecast data for the use of electric space heating and water heating systems in the residential and commercial sectors. The Roadmap predicts that by 2050, 33% of the total stock of residential heating systems will be ground source heat pump. In the commercial sector this proportion reaches 61% in 2050. Table 13 presents the Roadmap forecast data for the use of these technologies by province in 2050.

TABLE 12- PENETRATION RATES FOR HEATING SYSTEMS (% OF TOTAL STOCK)

Technology type	2020	2030	2040	2050
Residential space heating systems				
Electric Baseboards	46	51	51	51
Air Source Heat Pumps	19	31	21	13
Ground Source Heat Pumps	0	6	22	33
Residential water heating systems				
Electric Water Heating	60	83	89	93
Commercial space heating systems				
Electric Furnaces	35	42	40	36
Ground Source Heat Pumps	16	33	52	61

Source: Nyboer (2008).

TABLE 13- PENETRATION RATES FOR HEATING SYSTEMS BY PROVINCE IN 2050 (% OF TOTAL STOCK)

	Residentiel			Commercial	
	Electric Baseboards	**Air Source Heat Pumps**	**Ground Source Heat Pumps**	**Electric Furnaces**	**Ground Source Heat Pumps**
British Columbia	74	13	10	94	4
Alberta	13	10	76	32	63
Saskatchewan	44	17	38	11	87
Manitoba	79	12	9	53	47
Ontario	33	19	43	8	89
Québec	94	1	3	59	41
Atlantic	68	5	26	71	23

Source: Nyboer (2008).

Evaluation of forecast data and discussion of barriers

There is significant evidence that GSHPs have lower lifecycle costs than alternative heating and cooling systems across a wide range of climates, including relatively cold climates with low or no summer air conditioning load. In Canada, there are significant portions of the country with little or no residential air conditioning load. Those are likely the most difficult areas for GSHPs to penetrate based on the economics of current fuel and electricity prices. On the other end of the spectrum, the economics (even without carbon) are likely favourable for commercial spaces.

Assessing the reasonableness of penetration assumptions therefore likely depends less on the economics than on the existing infrastructure for deployment and other barriers discussed below.

Information Barriers

- The general public remains relatively uninformed and even unaware of GSHPs as an energy efficiency option. This has been identified by stakeholders as one of the most significant remaining barriers to deep GSHP penetration.

- There is little information related to the quality of the existing building stock. As a result, it is unclear which improvement measures provide the highest return to building owners and/or society.

- Uncertainty about the value of alternative systems:

- Location-specific levels of expertise on the drilling/installation front.

Infrastructure Barriers

The lack of appropriate infrastructure surrounding the installation of GSHPs in Canada (and in the USA) comprised of adequate training and certification of installers, verification of installations and associated norms and guidelines has been identified as a major barrier to deep penetration until recently. As a consequence in particular of inappropriate past efforts to professionally train and certify installers in significant numbers, there is likely still a shortage of qualified installers at the present time.

Financial Barriers

- Market values of homes don’t reflect life cycle costs, i.e. the investment in a GSHP does not increase the value of the structure accordingly. Today, the market value of buildings tends to not fully capture the life cycle costs of ownership (or the lease) of a building. This creates a potential barrier to investment in GSHPs, which require significant upfront investment. In particular, if the owner-tenant of a building expects to benefit from the energy and cost savings associated with the installation of a GSHP for a significantly shorter time period than the pay-back period of the GSHP investment, the owner will only have the proper incentive to invest in a GSHP if the remaining value of the GSHP can be captured through an increased property value. There is however serious doubt whether the market, at present, properly values energy-saving investments. To the extent it does not, investment in GSHP installations will be less than the economics of GSHPs suggest as being optimal.

- IRR requirements: for projects within companies make GSHP installations not attractive. The payback periods for GSHP systems under most scenarios of future fossil fuel and electricity costs are between just a few years in the most promising applications (commercial, new construction, cold winters and hot summers) to over 15 to 20 years. While carbon prices will tend to reduce the pay-back periods, it will likely still be the case that pay-back periods, especially in a commercial setting, are longer than those required by management for projects financed internally. ROIs will likely be lower in many applications than the cost of capital. As a result, to the extent that the investment in GSHP competes with alternative investments a company can make, it is likely that GSHPs will not be chosen as a high priority. This is in particular likely because GSHP and other conservation investments are likely not seen as being part of the core set of competences creating value for a company.

- Principal-agent problems in commercial/industrial structures: When buildings are not owner-occupied, lease terms tend to create disincentives for building owners to invest in conservation including GSHPs. This is because under a variety of typical lease terms building owners pass on the cost of at least some utilities to lessees. If fossil fuel as well as electricity costs are passed on, the building owner has no incentive to invest in GSHPs unless doing so increases either the value of the building or the ability to increase lease payments. As mentioned above, market values of buildings today likely don’t (fully) reflect the life cycle costs of such buildings. It is also likely that the market for commercial leases will not be differentiated enough to allow for different pricing for buildings with or without GSHPs. Consequently, it is unlikely that a building owner will be able to fully capture the benefits of making an investment in GSHPs. As a result, GSHP investment will be suboptimal.

- Access to capital: Especially some smaller companies and individual home owners may well be limited in their ability to finance the significant cost associated with the installation of a GSHP. Because the value of buildings tends not to reflect the full value of the GSHP, banks may be reluctant to lend or lend at terms that make the installation of GSHPs attractive. While still an issue, solutions seem to be emerging or at least available to address this problem. They are discussed in detail below.

Technology Barriers

- Even though GSHPs have been around for a long time, there seems to be significant innovation in the space. This may lead to waiting as the optimal decision for the individual contemplating adoption.

Differences between regions and types of installation

- Residential GSHP applications in cold regions will be less attractive than commercial applications in areas with summer air conditioning loads.

4.5. Landfill Gas Cap and Flare

Current state of the industry

Summary of NRTEE forecast data

Table 14 presents the Roadmap forecast data for the capping of landfill gas for flaring or for electricity generation.

TABLE 14- LANDFILL GAS CAP FOR FLARING OR FOR ELECTRICITY GENERATION

Data type	2020	2030	2040	2050
Landfills with flaring (%)	61	50	43	38
Landfills with electricity generation (%)	39	50	57	62

Source: Nyboer (2008).

Evaluation of forecast data and discussion of barriers

4.6. Clean Electricity Generation

Table 15 presents the Roadmap's forecasted changes in electricity generation by source as a result of the carbon pricing policy (relative to the business-as-usual-scenario). The forecast predicts an increase of 579 TWh of electricity generation in 2050 as a result of the policy. This increase is mostly from hydroelectric sources and coal and natural gas installations using CCS. Yet it also includes a decrease of 188 TWh generation from traditional coal and a decrease of 50 TWh generation from traditional natural gas.

TABLE 15- CHANGES IN ELECTRICITY GENERATION DUE TO CARBON PRICE POLICY (TWH)

	2020	2030	2040	2050
Renewable	91	187	256	304
Nuclear	25	59	80	85
Coal	5	-37	-106	-188
Natural Gas	-11	-28	-41	-50
Carbon Capture and Storage	57	183	309	429
Total Increase in Generation	167	364	498	579

Source: Nyboer, (2008)

As will be seen in the following sections for hydro, wind and nuclear specifically, despite an overall increase in electricity generation, the proportion of hydro, wind and nuclear of the total electricity mix remains stable throughout the forecast period, even by region.

4.6.1. Hydro

Current state of the industry for hydroelectricity generation

Hydroelectric power plants are considered renewable energy systems, the source of energy being the hydraulic power of the hydrologic cycle of water "evaporation-precipitation". There are abundant water resources and low-cost energy production sites in Canada. Relevant sites need appropriate river flow and a sufficient height for the water to fall such as waterfalls, rapids, canyons, deep valleys or river bends (RNCan, 2008). These sites have even a greater advantage if located close to consumers. The development of this potential has already played a significant role in the economic development of the country since the generating cost of this type of electricity has been one of the lowest in the world. Consequently, the retail prices of electricity are relatively low in Canada in comparison with many other developed countries.

Hydroelectric power plants have several components: the dam, the powerhouse that contains the mechanical and electrical equipment, and the waterways (lake or river) controlled by the dam (RNCan, 2008). The dam is use to store and release the water to activate turbines that drive the generators that produce the electricity. Small-scale plants are also developed to provide electricity in rural areas or to supply a specific residential or commercial area. It is necessary to have a sizable water flow and an adequate head of water, but to avoid building high cost facilities. Such plants can be developed at existing dams allowing minor new works and investments and reducing the cost. For example, it is possible in some cases to build only a diversion structure and to get a high drop by diverting flows at the top of a waterfall (RNCan, 2008).

There are several types of hydroelectric projects (RNCan, 2008): (1) run-of-river facilities that use low dams and produce minimal reservoir flooding, (2) partial developments, which involve an intake on a riverbank instead of a dam and can only use a portion of the available river flow, (3) developments of storage capacity to use the surplus water during low flow periods, (4) the development of hydro-thermal systems that can be used to boost low hydroelectric production, (5) pumped storage plants that moves water between two reservoirs and that are used for extra electricity generation during high demand period.

Hydropower represents the main source of electricity in Canada, about two-thirds of the total production, and most of this hydroelectricity comes from large projects. The total current installed capacity is 70 858 MW with an annual average production of 350 TWh (Industry Canada, 2008).

There are approximately 475 hydropower plants in Canada (Industry Canada, 2008). However, hydroelectricity generation is concentrated in few provinces and managed by largest electric utilities such as Hydro-Quebec, BC Hydro, Manitoba Hydro, Ontario Power Generation, Newfoundland and Labrador Hydro. In addition to these utilities, there are other producers (such as industrial companies) that own hydroelectric plants for their own use. For example, the world leader in aluminum production, Alcan, is an important producers and own plants in Quebec and British Columbia. Other producers include pulp and paper industries. In fact, the development of the hydroelectricity industry has been characterized by the increased numbers of independent producers in the past two decades.

There is still significant techno-economic potential for additional hydroelectricity production in Canada (RNCan, 2008). Indeed, new projects are already planned in Quebec, British Columbia and Manitoba. Moreover, hydroelectric power plants with important storage capacity provide an important flexibility in electricity generation that can be combined with intermittent sources such as wind power.

Summary of NRTEE forecast data

Table 16 presents the Roadmap forecast data for the use of hydro power for electricity generation. Data are presented by province. As can be seen in the table, the contribution of hydroelectricity to the electricity mix in each region remains essential stable until the end of the forecast period.

TABLE 16- ELECTRICITY GENERATION FROM HYDRO

	Total generation (TWh)				**Total generation (% of all sources)**			
	2020	**2030**	**2040**	**2050**	**2020**	**2030**	**2040**	**2050**
Canada total	505	633	759	890	58	54	53	52
Alberta and Saskatchewan	12	17	22	27	9	9	9	9
Ontario and Atlantic provinces	103	134	166	196	32	30	30	29
B.C., Manitoba and Quebec	390	483	571	668	94	92	91	91

Source: Nyboer (2008).

Evaluation of forecast data and discussion of barriers

4.6.2. Wind

Current state of the industry for electricity generation from wind power

Wind energy refers the kinetic energy that is present in moving air. Its amount depends mainly on wind speed, also on the air density determined by the air temperature, barometric pressure and altitude (Industry Canada, 2008). Wind turbines convert kinetic energy that is present in the wind into electricity. Since the most interesting sites are the windiest areas, wind turbines are generally installed height above the ground, on high towers and on open areas (mountains, see shore, etc.). The majority of wind turbines are currently located on sites with average wind speed of at least six m/s. The sites offering economical viability at short or medium terms can be classified as follow (Helimax, 2004):

- Site of exceptional quality: 9 m/s and above;
- Site of excellent quality : 8 to 9 m/s;
- Site of very good quality: 7 to 8 m/s;

There are two main types of wind turbines: wind turbines with vertical axes (the most common) and wind turbines with horizontal axe. The main components are the nacelle assembly, rotor blades, tower, and foundation. Wind turbines of various sizes exist, ranging from a few hundred watts (e.g. for residential applications) to 5 MW for large-scale production) (Hélimax, 2004).

The giant wind turbines, usually installed in wind farms, can produce hundreds of MW of electricity. The nominal output of onshore wind turbines of big size varies today from 600 kW to 2.5 MW. A 2-MW wind turbine can be used to meet the annual demand for 750 to 1000 homes. Wind turbines with nominal output of 5 MW have already been tested; they could supply power of a small city. As for small wind turbines, the market is divided into three categories: medium size wind turbines (30 kW to 300 kW), small size wind turbines (1 kW to 30 kW) and mini wind turbines (300 W to 1000 W) (CanWEA, 2008a)

The installed capacity is currently 1876 MW in Canada, with 776 MW of new capacity in 2006 (CanWEA, 2008b). There are currently 150 companies evolving in the wind power industry, including manufacturers, developers, distributors, suppliers or installers, and consulting firms (Industry Canada, 2008).

The interest in this form of energy comes from the need to develop clean energies. It has the fastest growth of all renewable energies source in Canada, with an average growth rate of 51% between 2000 and 2006 with an annual growth rate of 113% only for 2006 (CanWEA, 2008b). There are numerous projects in almost all provinces and territories, supported by initiatives at the federal and provincial levels. Moreover, in some of these provinces, such as Quebec, Manitoba and British-Colombia, large-scale hydroelectric facilities are characterized by important storage capacity, creating flexibility in electricity production, and consequently, opportunities for coupling with wind power generation, an intermittent source. Finally, coupling wind power and diesel power plants is also of particular interest in isolated regions.

Various incentives exit at the federal and the provincial level to support the development of wind energy. In 2007, the Government of Canada announced the ecoEnergy Initiative, including the Renewable Power program that promotes the development of 4,000 MW of renewable energy by 2011. Moreover, almost all provinces support the development of wind power with minimum target for renewable energy at large or wind energy specifically (CanWEA, 2008b): British Columbia (50% of clean energy), Alberta (no provincial target), Saskatchewan (300 MW by 2011), Manitoba (1000 MW by 2016), Ontario (2100 MW by 2010 and 4 600 MW by 2020), Quebec (4 000 MW by 2015), New Brunswick (400 MW by 2016), Nova Scotia (5% of clean energy by 2010 and 10% by 2013), Prince Edward Island (500 MW by 2013) and Newfoundland (80 MW).

Summary of NRTEE forecast data

Table 17 presents the Roadmap forecast data for the use of wind power for electricity generation. Data are presented by province. As can be seen in the table, the contribution of wind to the electricity mix in each region remains essential stable until the end of the forecast period.

TABLE 17- ELECTRICITY GENERATION FROM WIND

	Total generation (TWh)				**Total generation (% of all sources)**			
	2020	**2030**	**2040**	**2050**	**2020**	**2030**	**2040**	**2050**
Canada total	33	63	91	110	4	5	6	6
Alberta and Saskatchewan	6	12	17	20	4	6	7	7
Ontario and Atlantic provinces	19	35	49	60	6	8	9	9
B.C., Manitoba and Quebec	7	17	25	31	2	3	4	4

Source: Nyboer (2008).

Evaluation of forecast data and discussion of barriers

Grid Infrastructure

Resistance from utilities to integration of wind (concerns about intermittency, peak demand management). Lack of transmission lines at high wind sites- lines built with large coal or nuclear stations in mind. Very little investment in transmission grid in last 30 years- the grid is fragile and at capacity. Grid upgrade and modernization essential. Smart grids: demand load management, etc.

Manufacturing and skilled labor

90% of wind turbines in Canada are foreign-made. Skilled labor also mostly foreign. Importing turbines, parts, planners, engineers, technicians, etc. increases costs, slows down deployment. Will need 10-11,000 skilled laborers in wind industry by 2015 (conservative estimate).

Lack of sufficient manufacturing capacity to meet demand. This is a short-term barrier, as industry catches up.

Regulatory framework

Interconnection procedures and “red tape” very expensive, time-consuming and inconsistent. Not streamlined across different levels of government. Paperwork for getting a new project approved and connected a significant barrier which can in some cases lead to the project being abandoned.

Capital cost

Costs of wind have decreased significantly, but still more expensive than coal. Slight increase in costs recently due to increase in costs of copper and steel and large demand in comparison with supply but this is a small short-term effect. Stability of price of wind as energy resource better than for fossil fuels.

Price distortion

Need to “level the playing field” on costs with respect to coal by internalizing environmental costs.

Public perception

Wind not yet seen by the public (and utilities, policymakers, etc.) as being capable of supplying baseload generation.

Local opposition to new installations due to concerns over safety, noise, view, etc. This barrier is decreasing as the public is increasingly informed and more successful projects are operational. All new projects must be approved for safety + noise standards. Land lease payments to local landowners help with acceptance. Bad projects (unsafe, unprofitable, etc) hurt the industry- need regulation + standards.

4.6.3. Nuclear

Current state of the industry for electricity generation from nuclear power

Existing technologies for nuclear energy generation use uranium, and element which is abundant in nature but relatively rare in concentrated deposits. Concentrated uranium ores are only found in hard rock or sandstone and the most important deposits currently being exploited are in Australia, Kazakhstan and Canada (Cameco, 2008). Canadian uranium reserves are of high concentration and the largest uranium deposit is located in Saskatchewan. To produce energy, uranium undergoes several stages including mining and milling, refining and conversion, enrichment, fuel manufacture into fuel pellets, loading into a reactor for electricity generation, optional chemical reprocessing or residual uranium or byproduct plutonium, and disposal (Cameco, 2008).

Existing technologies for nuclear energy generation are based on uranium atom fission in a chain reaction that continues as long as uranium atoms are present in the reactor. Two main categories of nuclear reactors are currently in use worldwide: the Light Water Reactor (LWR) type represents 90% of the reactors currently in use worldwide; this category includes Boiling Water Reactors and Pressurized Water Reactor (NEA, 2005). The Pressurized Heavy Water Reactor (PHWR) type represents 5% of the reactors currently in use and 15% of the reactors under construction in the world. PHWR includes amongst others the Canada Deuterium Uranium (CANDU) reactor designed by Atomic Energy of Canada.

The Fast Breeder Reactor is a fast neutron reactor that "breeds" plutonium, i.e. it produces plutonium from uranium at greater speed than it consumes uranium. Since fission occurs at very high temperatures, it needs a liquid metal coolant such as sodium rather than water.

Many countries are investing in nuclear research and development to develop fourth generation reactors. For instance, the European pressurized water reactor, the Advanced CANDU reactor in Canada and the Generation IV nuclear systems developed within an eleven-member R&D consortium including Canada. Another type of reactor currently under development is the High Temperature Gas-Cooled Reactor. The availability of this technology on the market is planned for around 2030. Developed in the UK, there are new installations planned in several countries, such as the Pebble Bed Modular Reactor planned for construction in South Africa (OECD, 2001). These reactors use helium as the coolant rather than water. Finally, nuclear fusion is currently under development through the ITER project. Contrary to the nuclear fission reactors described above, it uses tritium produced from lithium rather than uranium. However, the availability of this technology for commercial uses is planned for 2050 (Fiore, 2006).

In 2007, 18 nuclear CANDU reactors were in operation in Canada supplying 14.6% of the total electricity (CNA, 2008). Nuclear power is concentrated in Ontario, where nuclear represents 51% of total electricity generation (81 TWh), while New Brunswick (30% of total electricity) and Quebec (3% of total electricity) have one nuclear power plant each.

Summary of NRTEE forecast data

Table 18 presents the Roadmap forecast data for the use of nuclear power for electricity generation. Data are presented by province. As can be seen in the table, the contribution of nuclear energy to the electricity mix in each region remains essential stable until the end of the forecast period.

TABLE 18- ELECTRICITY GENERATION FROM NUCLEAR SOURCES

	Total generation (TWh)				**Total generation (% of all sources)**			
	2020	**2030**	**2040**	**2050**	**2020**	**2030**	**2040**	**2050**
Canada total	124	168	204	232	14	14	14	14
Alberta and Saskatchewan	0	0	0	0	0	0	0	0
Ontario and Atlantic provinces	115	157	193	220	36	35	34	33
B.C., Manitoba and Quebec	8	10	12	12	2	2	2	2

Source: Nyboer (2008).

Evaluation of forecast data and discussion of barriers

5. IMPLICATIONS FOR POLICY

To be completed- note that the information presented in this section for the progress report is preliminary and subject to change for the final report.

In this section, we make use of the data analysis in Section 4, in addition to literature sources and experiences in other jurisdictions, in order to arrive at recommendations for policy guidance that may aid in removing or reducing some of the barriers that have been identified and discussed.

5.1. Carbon Capture and Storage

Finalize and clarify GHG reduction policies

Both the Canadian Federal and Albertan provincial government have or are implementing GHG emission reduction frameworks. Both policies are production intensity based schemes. The Albertan scheme has a target of 14% absolute emissions reductions by 2050 in comparison to 2005, whereas the federal target is 20% absolute emissions reductions in 2020 compared to 2006. The Albertan scheme took effect for emissions from July of 2007, whereas the federal program is under negotiation with the expectation that final details will be released in the Fall of 2008. The federal program should come into effect as of 2010. Both of these frameworks are likely to foster, and in some ways are dependent on, the deployment of CCS technologies. The adoption of CCS will be impacted by the credibility, stringency, enforceability, and clarity of the eventual Federal policy. The remaining uncertainty regarding federal policy design as well as the uncertainty due to policy instability resulting from leadership changes are both sources of uncertainty for CCS developers. The implementation of the Albertan and Federal GHG policies were necessary first steps to overcome the motivational barriers preventing the adoption of CCS technology. However, to fully overcome this limitation, policy makers should strive to finish their policy design as early as possible providing details to possible CCS project developers. .

Reduce financial risk for CCS developers

The developmental risks, uncertain performance, and level of capital investment for CCS projects all produce significant financial uncertainty for CCS project investors. These risks for private CCS developers are not counterbalanced by the potential rewards of CCS projects. Yet since many of these risks will decrease dramatically after the development of the first projects, there is a strong disincentive to investment to avoid this first mover disadvantage. Policy makers should implement programs to balance the risk - reward calculations of CCS projects. Policies to overcome this barrier must reduce the uncertainty, mitigate the downside risk, or enhance the upside rewards of CCS projects. There are numerous approaches discussed below for achieving these objectives.

Policies to balance the risk-reward prospects of CCS projects will need to mitigate some of the downside risks for developers, while maintaining appropriate performance incentives. It would be unwise, for instance, for policy makers to indemnify private enterprises against the risk of all cost increases since such a policy carries a moral hazard risk of encouraging such cost growth to occur. Policies should also maintain flexibility to adjust to changes in level of risk as the field develops. Thus incentives for the initial CCS demonstration projects will likely need to be more significant than incentives for subsequent projects. Policy makers may want to establish a policy to encourage the first initial projects, and then revise their incentives as additional facilities are constructed.

Policy options for balancing the CCS risk prospects must address either developmental or operational phase risk.

- Development Stage Risk
    - Partial Government Financing

With the higher initial capital cost of CCS, and the uncertainty regarding the eventual cost, CCS development could be fostered by policies ranging from fractional all the way up to complete subsidization. Under a total government finance model, the government would purchase and pay for facility development. Under such a framework the government is bearing all of the risk of project development. This is not likely to prove to be a successful model as it would be prohibitively expensive for the government and project development is generally not considered a government role or specialty. The real question is what the financial gap is between development of a traditional facility and a new CCS based facility, and whether the government can shoulder that additional incremental cost. A likely successful scenario would be for the government to aim to finance the capital cost gap between a traditional and CCS enabled facility. Providing that the project developer delivers a facility to sufficient specifications, the government then agrees to cover a fixed amount of the facility capital cost. This government cost, should be fixed and not variable based on risk, so that the project developer is incentivized to target and retire risk factors. The government portion should also include a risk premium above the expected development cost to incentivize the project developer to meet their goals most effectively. In this way, the project developer is exposed to some portion of the development risk, yet is also exposed to the upside benefits of delivering a project under budget. Such a model was proposed by the 2007 Alberta CCS stakeholder committee, where they recommended that for the initial projects the government should issue RFP's for developers to construct appropriate CCS facilities.

After initial facilities are constructed the government will want to reassess the financial gap between baseline and CCS facilities, and likely reduce the subsidized amount of the facilitiy capital cost. Eventually the government's position could change to a position of providing loan default guarantees which would lower the capital borrowing costs.

- Operational Stage Risk

The operational risk for CCS facilities is that the market for products will not be sufficient to provide an adequate financial return. For operational risk the two main government policy alternatives are to provide production based guarantees as well as loan default guarantees.

  - Production Incentives

Production subsidy guarantees provide an incentive for a facility to operate according to government requirements in order to achieve goals. Such guarantees could come in the form of either carbon sequestration subsidies or electricity price guarantees. So for a CCS power facility the government could provide contractual assurance that they can receive a certain subsidized rate for electric power that will cover the project's elevated capital and operational costs. Whereas the previous incentives mitigated capital cost overruns, such production guarantees ensure that the facility can earn an appropriate return on their capital. Since the subsidy is in the form of a guarantee, the subsidy could be structured to not occur unless market prices for the CCS facility production are insufficient to allow adequate capital cost recovery. Such rates differ from simple forward contracts since they provide a subsidized guarantee at above market rates to incentivize facility operation.

  - Loan Default Guarantees

In addition to the market risks, project owners face an operational risk that the facility will not meet minimum performance requirements. If a developed facility fails to meet minimum performance standards and is unable to meet minimum revenue requirements, the government would ensure payback of financing costs. Such an arrangement not only lowers initial borrowing costs, it protects the project developer from default if their project fails to perform. Such arrangmenets are relatively common and protect the lender from the risk of default.

The alternatives proposed work to reduce the financial barriers to CCS development. Primarily these policies seek to balance the risk-reward proposition for CCS projects by mitigating downside risk, enhancing upside opportunity, as well as reduce the uncertainty affiliated with each project.

Adopt and facilitate the development of regulations, guidelines, and protocols for CCS.

The lack of standards, guidelines, and protocols for CCS increases the uncertainty associated with CCS project proposals. The Canadian government should encourage and facilitate the adoption and development of the relevant regulations, guidelines, and industry protocols to enable the deployment of CCS. Regulatory areas in need of additional clarification are the protocols for measuring and crediting CO2 emissions reductions; as well as regulations and requirements for the long term storage rights, monitoring, and liability of storage (same cite). Regulations for the capture, transportation, and injection of CO2 are largely existing or readily crafted from existing regulations for similar activities. The federal and provincial governments have begun the process of clarifying these regulatory requirements, and resolving these outstanding issues is necessary to enable the deployment of CCS. In terms of regulations for measuring and crediting CO2 emissions reductions the government has initiated stakeholder processes to help develop appropriate protocols. As recommended by several task forces (cite) provisional requirements are necessary which would allow for the initial deployment of CCS and continued development of more permanent requirements.

A similar experience friendly approach is essential for addressing the liability issues associated with CO2 storage. As previously discussed, there are disadvantages to leaving long-term liability to either the public or private sector alone, hence proposals (cite) tend to focus on hybrid approaches where there is an initial certification process for private operations, with an eventual transfer of liability to the provincial government. The present lack of clear regulations, standards, and protocols is a firm regulatory barrier that if not resolved will prevent the deployment of CCS. Fortunately the Canadian and provincial governments have initiated efforts to reconcile these outstanding concerns. An important feature of these early regulatory frameworks is that they should provide provisional clarity to facilitate early project development yet allow for modification and learning as CCS knowledge is improved.

5.2. Fuel Switching to Renewables in Transportation and Cellulosic Ethanol Production

The following policy instruments were raised by stakeholders as possible solutions to overcoming barriers for the biofuels industry.

Mandates

By volume of fuel or by volume of CO_2. Some say mandates increase feedstock price.

Production incentives or production tax credit

USA model.

Infrastructure development

Industry regulation

Energy intensity quotas, feedstock quotas, export quotas. Getting major oil players to cooperate.

Funding for research and development

National research centre. Demonstration projects.

Rebates or tax refunds for consumers for fuel-efficient vehicles

Fiscal measures

Public information campaign

5.3. Fuel Switching to Electricity and Energy Efficiency

5.3.1. Transportation

The following policy instruments were raised by stakeholders as possible solutions to overcoming barriers in the PHEV industry.

Carbon pricing

Funding for battery research and development

Rebates/freebates or tax refund for consumers

Incentives for retrofitting existing vehicles

Disincentives for traditional vehicles

PHEV minimum production quotas for auto manufacturers

Fast and reliable inspection system to allow more PHEV's on the road

Needs to be standard country-wide; requires inter-governmental cooperation.

Public information campaign

5.3.2. Residential and Commercial

The policy approaches to address or overcome the barriers listed above are generally applicable to both residential and commercial/residential structures. In some cases, a specific policy response may be more easily adapted to address either a residential or a commercial/industrial barrier. In such cases, we note the primary focus of the policy measure below.

Building Codes

Changing building codes to require the installation of GSHPs (or ASHPs) is one way to ensure deep penetration of the technology. There are two primary ways to use building codes as a policy tool:

- The most promising approach is to require all new structures to include heating and/or cooling systems of a minimum efficiency as of some future date. If the minimum efficiency standard is chosen properly, GSHPs (or ASHPs) may be the only and natural choice. However, by not specifying a specific technology, room would be left for alternative innovations. Alternatively, the use of a specific technology such as GSHP could be prescribed. The building code should leave sufficient time for architects, design engineers, builders, installers and manufacturers to prepare for the increased demand for the set of technologies needed to comply with an updated building code. By requiring new buildings to be equipped with GSHPs or similarly efficient technologies after a specified date, deep penetration of those technologies is highly likely as the building stock turns over through the addition of new structures to the building stock. AB32 in California requires that all new residential structures be zero net energy by 2020 and all new commercial structures by 2030 . California AB32 does not prescribe the use of GSHPs and thus leaves room for innovation. Canada could adopt a similar approach or, alternatively, require specific technologies such as GSHPs to be part of new buildings.

- A more aggressive measure would be to require buildings to be brought up to a building code including either an efficiency standard or a specific technology whether or not they are new. Some communities in the United States seem to be exploring this option . For example, retrofits could be required by a certain date or whenever a building is sold or other important upgrades are being made. While this approach could practically ensure that the desired penetration level of the technology is achieved, it would likely result in compliance costs in excess of those deemed optimal.

Overcoming infrastructure barriers

Stakeholders believe that the proper framework has recently been created to overcome this barrier. There are now over 1,500 new installers certified in Canada every year, as a result of the initiatives of the Canadian Geo-Exchange Coalition. Also, verification and certification systems are now in place to provide customers with certainty regarding installation quality.

Overcoming information barriers

Several policy options exist to address/overcome existing information barriers. Some of the options include:

- Consistent and widespread information campaigns directed at explaining the benefits of GSHPs and their ability to lower overall energy costs in buildings to raise awareness of GSHPs would help overcome the current relative ignorance of GSHPs.

- A mandatory Energy Pass for all structures, needed for a sale and valid for a certain number of years. The Energy Pass would typically be the result of an energy audit, conducted by a qualified (and certified) auditor, which ensures consistency and quality of the audits. The concept of an Energy Pass exists as the German implementation of the European Energy Efficiency Directive .

- Voluntary energy audits, which are standardized, and the results of which are entered into a central database each time an audit is conducted. Conducting such a voluntary audit could be a precondition to obtaining preferential financing or rebates for certain conservation measures (including GSHPs or ASHPs) to the successful completion of an energy audit.

- Standardization and updating of existing energy audits and increased communication to encourage voluntary energy audits.

Overcome financing barriers

This can be done with a mix of rebates (freebates) and financing options that tie GSHP investments to the structure rather than the owner.

- Residential:
  - Rebates or tax credits on installation

One obvious approach to overcoming financial barriers is to offer rebates or feebates or tax credits for the installation of GSHPs. Among these, feebates may be the most attractive option: Feebates would finance the installation rebates for GSHPs out of a fossil fuel surcharge. Alternatively revenues from a carbon tax or the auction of carbon allowances under a cap and trade system could be used to finance the subsidies. The advantage of feebates in this context is that it would both lower the investment cost and increase the savings from the installation of a GSHP, thus making GSHPs economically more attractive. Ideally the rebate should be chosen at a level that just overcomes existing investment barriers, which may be related to both financial and technological barriers (see below).

  - On-bill financing by Utilities

Unless a very significant subsidy for the installation of a GSHP is offered, building owners will likely have to incur substantial residual upfront installation costs for a GSHP. The investment incentives could be significantly improved by eliminating the need for upfront cash by the building owner altogether. Private loans will eliminate the need for cash, but will not overcome the barriers associated with the trend of tenure being less than pay-back period. In other words, even if the installation of a GSHP could be entirely bank financed, the borrower would still face the risk of wanting to sell his building before the GSHP loan is fully paid back. If building values don’t properly reflect the benefit of the GSHP, there is a residual risk that the borrower will incur costs in excess of the benefits received from the GSHP during his/her ownership. To overcome this problem, the financing of a GSHP could be tied not to the owner, but to the structure itself. On-bill financing and property tax financing (discussed below) are two ways of doing so. With on-bill financing, the utility (electric or gas/oil) will finance the installation of a GSHP through a low/no interest loan. Both principal and interest if any are collected alongside the fees for electricity, gas or oil. The finance surcharge on the bill for any given structure does not go away until the loan has been paid off, irrespective of the current building owner. In other words, utility bills will be higher by the amount of the loan financing over the life of the loan. Should the building change ownership before the loan is fully repaid, the next owner will continue to pay the higher utility bill until the loan is repaid. This should however not be a disincentive for either the current or any future buyer because as long as the loan term is properly matched to the energy savings stemming from the GSHP installation, the total utility bill (loan repayment plus payment for electricity, gas or oil) can be structured as to be no higher (and possibly lower) than the utility bill prior to GSHP installation. On-bill financing exists at a small scale and is being discussed in several places in the United States . Under existing and proposed on-bill financing schemes, the utility will borrow money to finance the installation of customer-side conservation investments. To the extent it makes loans at lower rates than its owner borrowing cost, the utility receives regulatory approval to earn its approved rate of return on the preferential financing it provides.

- Other utility financing models

There is at least one utility (Corix) that currently offers GSHP installation and maintenance with a utility model, whereby the utility installs and maintains the heat pump. The utility retains ownership and charges the customer a monthly fee for financing and maintenance. The monthly fee is such that customers see net reductions in energy bills from day 1. [verify – still need to interview Corix]

- Property tax financing

This may be an attractive alternative to on-bill financing by utilities. While functioning the same way as on-bill financing, under property tax financing a government entity borrows the funds and finances the installation of GSHPs. It recovers the investment costs though increased property taxes for the duration of the financing period, after which property taxes are reduced by the amount of the financing charge. One advantage of property tax financing over on-bill financing by utilities is that public entities may be able to borrow at more attractive rates than utilities. Also, government entities may be better equipped to deal with residual default risk on the payments for the installation. Finally, governments may be better equipped to offer financing over longer terms, which may make property-tax financed projects more attractive for residential applications, where longer pay-back periods may required longer financing terms. At least one example of property tax financing is currently under development. The city of Berkeley, CA, created a Sustainable Energy Finance District in 2007 and is currently in the process of implementing a system that allows the financing of solar and conservation investments through property taxes.

- Energy Savings Performance Contracting (ESPC)

This is yet another way to reduce the need for upfront investments by building owners. Under a ESPC regime, a private party finances the installation of a GSHP in exchange for a certain percentage of the energy savings from the project until its installation costs plus a return are earned. Thereafter, the building owner benefits fully from the more efficient building. An ESPC has been used for the installation of the largest single system of GSHP in the United States at Fort Polk, Louisiana .

Overcoming technical barriers

- There is still some progress in GSHP technology. While the principle has been around for a long time, recent focus on the technology is leading to important advances in GSHP efficiency, in particular the efficiency of the ground loop. To the extent potential purchasers of GSHPs believe that the rate of progress is such that delaying the installation of a GSHP until some future date is economically advantageous and it is deemed desirable to achieve widespread deployment of GSHP with a mix of current and future technologies, the reluctance to invest in current technology needs to be overcome. One way to do this is to offer rebates for those who invest in current technologies and to commit to the rebates available for investment declining over time. The rebate structure should be such that the anticipated improvements in efficiency over time are captured in the rebate system such that early investors' rebates compensate for the expected improvements in efficiency.

- In some areas/provinces, there is still a lack of technical knowledge concerning proper drilling and installation of GSHPs, exposing adopters of the technology to significant cost and performance risk. A number of measures could be adopted to address these concerns:

    - Efficiency Performance Contracting: The installers could be required to guarantee certain efficiency and/or cost of installation

    - Insurance: Either installers could be required (or offered) insurance against sub-par performance or consumers could be provided with optional insurance against sub-optimal installation and consequently outcomes.

    - Information could be gathered on the quality of installation (total cost of installation, information on the details of the installation including geology, type of system installed, post-installation heating and cooling efficiency) and such information could be translated into a rating system for installers, available to potential purchasers of GSHPs.

Air Source Heat Pumps (ASHP)

An assessment of the penetration rates of Air Source Heat Pumps (ASHP), baseboard electric and electric water heating relies fundamentally on the belief that regional differences in the mix of power generating technologies will remain substantial throughout the forecast horizon since they rely on the assumption that either one of those technologies, although less efficient, will benefit from low electricity prices. In other words, if electricity prices are low enough, less efficient (but also less capital intensive) technologies will be advantageous relative to GSHPs. This is most true for heating/cooling applications, but also, to a lesser extent, for electric water heating. In this report we assume that electricity prices across the various provinces are as outlined in the Roadmap report. The penetration rates of electric water heaters and baseboard heating are realistic, given that both are well established technologies with relatively little upfront investment cost. ASHPs require more substantial investments, but also represent largely established technology. In that sense ASHPs represent an intermediate case. Their deployment will face many of the same barriers faced by GSHPs, although to a less severe degree, given the lower upfront investment costs. Many of the policy solutions would work equally well for ASHPs.

5.4. Landfill Gas Cap and Flare

5.5. Clean Electricity Generation

5.5.1. Hydro

5.5.2. Wind

5.5.3. Nuclear

CONCLUSIONS

To be completed.

REFERENCES

Brown, S. (2007). *California's Commitment to Advanced BiofuelsCellulosicEthanol and 2ndGeneration Biofuels. For the California Energy Commission*. Presentation at the Platts Cellulosic Ethanol and Second Generation Biofuels Conference. Chicago, October 2007.

Cameco (2008). *Uranium 101*. Information available online at http://www.cameco.com/uranium_101/#

CanWEA – Canadian Wind Energy Association (2008a). *Small Wind Energy*. Information available on line at: http://www.smallwindenergy.ca/en/Overview/SmallWindCanada.html

CanWEA – Canadian Wind Energy Association (2008b). *Canada's Current Installed Capacity*. Information available on line at: http://www.canwea.ca/farms/wind-farms_e.php

CNA – Canadian Nuclear Association (2008). *Nuclear Facts*. Information available on line at: http://www.cna.ca/english/facts.asp

EERE – Office of Energy Efficiency and Renewable Energy (2007). *The Biomass Program*. US Department of Energy. Information available online at: http://www1.eere.energy.gov/biomass/about.html

EERE – Office of Energy Efficiency and Renewable Energy (2008). Alternative fuels and advanced vehicules data center. US Department of Energy. Information available online at: http://www.eere.energy.gov/afdc/vehicles/plugin_hybrids.html

Fiore, K. (2006). *Nuclear energy and sustainability: Understanding ITER*. Energy Policy, In Press.

Foxon, T. and Pearson, P. (2008). *Overcoming Barriers to Innovation and Diffusion of Cleaner Technologies: Some Features of a Sustainable Innovation Policy Regime*. Journal of Cleaner Production, 16S1, p.S148.

Government of Canada (2008). The ecoAGRICULTURE Program. EcoACTION website: http://www.ecoaction.gc.ca/index-eng.cfm

Haas M. et T. Foglia (2005). *Alternate Feedstocks and Technologies for Biodiesel Production*, from *The Biodiesel Handbook* (Editors: G. Knothe, J. Krahl et J. Van Gerpen), AOCS Press, Illinois.

Hélimax Énergie Inc. (2004). *Étude sur l'évaluation du potentiel éolien, de son prix de revient et des retombées économiques pouvant en découler au Québec*. 71 p.

IEA- International Energy Agency (2006). *World Energy Outlook 2006*, Chapter 14: The outlook for biofuels.

Industry Canada (2008). Canadian renewable energy industry. Information available online at: http://www.ic.gc.ca/epic/site/rei-ier.nsf/en/h_nz00001e.html

Jaffe, A. B., Newell, R. G. and Stavins, R. N. (2005). *A Tale of Two Market Failures: Technology and Environmental Policy*. Ecological Economics, 54, p.164.

NEA - Nuclear Energy Agency (2005). *Projected Costs of Generating Electricity: Update 2005*. Presented to the Organisation for Economic Cooperation and Development (OECD) and International Energy Agency (IEA).

Nilsson, H. and C.-O.Wene (2001). *Best practices in technology deployment policies*. IEA Secretariat, Paper presented at the Workshop on Good Practices in Policies and Measures, Copenhagen, 13 p.

NRCan- Natural Resources Canada (2008). The Canadian Renewable Energy Network (CanREN). Information available online at: http://www.canren.gc.ca/using/index.asp#about

Nyboer, J. (2008). *A Technology Roadmap to Low Greenhouse Gas Emissions in the Canadian Economy: A Sectoral and Regional Analysis*. Draft Report. Prepared for the National Roundtable on the Environment and the Economy (NRTEE), 107 p.

OECD - Organisation for Economic Cooperation and Development (2001). *Nuclear Power in the OECD* International Energy Agency (IEA), Paris.

OEE – Office of energy efficiency (2008). Transportation for personal use: Battery-electric and hybrid vehicles. Information available online at: http://www.oee.nrcan.gc.ca/transportation/fuels/electric/electric-availability.cfm?attr=8

SDTC- Sustainable Development Technology Canada (2006) *Sustainable Development Business Case Report*: Renewable Fuel – Biofuels. Version 1, November 2006. SD Business Case.

Sine Nomine (2007) *Benchmarking Study for a Project to Determine Environmental Footprint from the Establishment of Biodiesel Corridors or Zones in at Least 3 of the 5 Regions of Canada*. Final Report – Draft Version. For Environnement Canada.

Sine Nomine (2006) *Assessment of the Biodiesel Distribution Infrastructure in Canada*. Prepared for: Natural Resources Canada.

Steenberghen, T. and Lopez, E. (2008). *Overcoming Barriers to the Implementation of Alternative Fuels for Road Transport in Europe.* Journal of Cleaner Production, 16, p.577.

Appendices

Appendix 1- Complete list of stakeholders

Table 19 to Table 30 present the current list of potential stakeholders that we will attempt to contact for the mandate. Ratings of A, B or C are given to each stakeholder according to the priority for interview. This list will certainly grow as additional references are obtained during the interview process and throughout the course of the mandate. In the final report, the final list, with consistent formatting, will be provided.

TABLE 19- CONTACTS FOR BIOFUELS

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
Canadian Renewable Fuels Association	Robin Speer	Industry Association	A
Saskatchewan Biofuels Development Council	Judie Dyck, PAg President	Industry association biofuel promoter	A
Natural Resources Canada Liquid Motor Fuels	René Pigeon	Renewable fuels expert	A
Environment Canada	Pierre Sylvestre	Government	A
MRNF Développement des hydrocarbures	Contacts : Alain Lefebvre (directeur), Georges Lê, Raynald Archambault	Government	A
CENTRE QUÉBÉCOIS DE VALORISATION DES BIOTECHNOLOGIES (CQVB)	Organisme d'aide à la recherche ayant pour rôle de stimuler et d'accélérer l'exploitation industrielle et commerciale des résultats de la recherche-développement dans les bio-industries : liaison, réseautage, soutien à l'innovation. Claude Michaud	Government	A
CIBC – Risk management	Bertrand Montel	Senior risk manager, Agriculture Credit	B
Douglas Auld	Professor of Economics Guelph University Author of CD Howe report on corn-based ethanol	Academic	B

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
Don O'Connor	(S&T) Consultants	Renewable fuels expert	B
Groupe de recherche sur les technologies et procédés de conversion Université de Sherbrooke	Esteban Chornet (Directeur)	Academia	B
Biofuel Canada		Design and manufacturer of biodiesel plants	B
NRCan CANMET	Brian Cook (Directeur général)	Government	B
MDEIE Chimie, métallurgie, plasturgie et équipements	Clément Drolet (Directeur), Martin Roberge	Government	B
AEE Transports, Industrie, Innovation technologique	Alain Daneau (Directeur)	Government	B
Renewable Fuels Association (U.S.)		U.S. Industry Association	C
BioEnergy Science Center (US Dept of Energy)	Martin Keller	Technology research on biofuels	C
Union des producteurs agricoles du Québec		Quebec industry association	C
Timothy Searchinger		Academic researcher on the impacts of biofuels on GHG emissions	C
BBI Biofuels	Stu Porter Manager, Business Development and projects	Biofuels project developer	C
Delta-T		Biofuel technology developer	C

TABLE 20- CONTACTS FOR ETHANOL

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
Greenfield Ethanol	Jean Roberge (Directeur général)	Ethanol producer and distributor Technology Developer / Industry	A
Terra Grain Fuels	Tim LaFrance	Ethanol producer	B
Northern Ethanol	Steven Reader, COO & VP Development	Ethanol producer	B
ICM		Ethanol technology developer	C

TABLE 21- CONTACTS FOR BIODIESEL

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
BIOX Corp./NRTEE Member	Tim Haig BIOX Corp/NRTEE Member	Biodiesel production	AA (to be called soon)
Environment Canada	Pierre Sylvestre Project manager, Biofuel projects	Government	A (Key player in demo projects)
CONSEIL QUÉBÉCOIS DU BIODIESEL	Camil Lagacé (directeur)	Industry Association	A
BioFleet	Terry Robert	Govt-funded non-profit organization promoting expanded use of biofuels in western provinces	A
The Biodiesel Company	Ethan Vos	Biodiesel producer	B
Canada Clean Fuels	Lucio Angelucci (President)	Biodiesel distributor	B
Canadian Bioenergy	Doug Hooper President and CEO	Biodiesel supplier (production +distribution)	B
Biodiesel Quebec		Biodiesel production	B
Renewable Energy Group		Biodiesel production and sales	C

TABLE 22- CONTACTS FOR CELLULOSIC ETHANOL

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
ENERKEM TECHNOLOGIES	Esteban Chornet (Directeur technique)	Technology Developers / Industry	AA (presently the most important player in this field in Canada)
Iogen Corp.	Jeff Passmore Sandra Kelly	Technology Developers / Industry	A
Canadian Renewable Fuels Association	Robin Speer	Industry Association	A
AgroNovita Inc.	Patrick Girouard	Cellulosic ethanol expert/consultant	A
GREENFIELD ETHANOL (ALCOOLS DE COMMERCE)	Jean Roberge (Directeur général)	Technology Developer / Industry	B
Verenium	John B. Howe VP Public Affairs	Cellulosic ethanol technology developer and producer	B
University of Dartmouth		Academic research. Technology for production of energy from cellulosic biomass; metabolic engineering; applied microbiology.	B
BioEnergy Science Center (US Dept of Energy)	Martin Keller	Technology research on cellulosic biomass	C

TABLE 23- CONTACTS FOR HYBRID AND PLUG-IN VEHICLES

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
Centre d'expérimentation des véhicules électriques du Québec (CEVEQ)	Pierre Lavallée Directeur général	Government technology research for electric and hybrid vehicles	A Hybrid and plug-in hybrid
Electric Vehicle Society	Howard Hutt	Forum for the promotion of clean transport technologies	A
International Institute for Sustainable Development (IISD)	Henry David Venema, Policies that can favor sustainable transportation by implementing PHEV	Non-profit research	A
Institut du transport avancé du Québec (ITAQ)	Pierre Tison Directeur	Private sector technology testing and research	A Hybrid and plug-in hybrid
National Research Council of Canada	Yaser Abu-Lebdeh Advanced Li-ion battery technologies for Plug-in hybrid electric vehicles (PHEV)	Government research	A Plug-in hybrid only
HYDRO-QUÉBEC Laboratoire des technologies de l'énergie	Centre de recherche spécialisé dans le développement et la mise en œuvre de nouvelles technologies énergétiques. Gaétan Lantagne, Chef du LTE	Government research	A
Transport Canada	Merrina Zhang, P. Eng. Research Coordination Officer Transportation, Technology and Innovation	Government policy	A Hybrid and plug-in hybrid
Plug-In Partners	Austan Librach	U.S. national initiative to promote PHEVs with govt, utility, environmental, business members	A Plug-in hybrid only
Transport Canada	Andre Bourbeau Manger, Environmental Analysis Sustainable Devt Division	Government policy	A Hybrid and plug-in hybrid

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
Environment Canada	Pierre Sylvestre Project manager, Biofuel projects	Government	A (Key player in demo projects)
TM4 Electrodynamic Systems	Eric Azeroual Technical Representative	Company supplying motors and drive trains for electric and hybrid vehicle manufacturers	B Hybrid and plug-in hybrid
Zenn Motor Company	Ian Clifford Chief Executive Officer		B Hybrid and plug-in hybrid
Azure Dynamics	Nigel Fitzpatrick	Hybrid technology development and production	B Hybrid and plug-in hybrid
BC Govt Alternative Energy Policy Branch (Ministry of Energy)	Jesse Maddaloni Coordinator, Community Energy Solutions	BC Government	B Hybrid and plug-in hybrid
Electric Mobility Canada	Al Cormier Executive Director:	National non-profit industry association	B Hybrid and plug-in hybrid
City of Vancouver Sustainability Group Community Vehicles Fuels and Efficiencies	Brian Beck Project Manager	Municipal govt	B
Bougie Moteur Vert Nouvelle Technologie	Bougie Moteur Vert Nouvelle Technologie Rolland Bougie Président	Technology developer	B
The Centre for Sustainable Transportation	Arne Elian, PhD (C) MBA Executive Director	Academic research	B Hybrid and plug-in hybrid

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
University of Toronto	Dr. Richard Gilbert Consultant	Academic consultant, hybrid/plug-in vehicle expert (see:	B Hybrid and plug-in hybrid
McGill University	Peter Radziszewski, McGill University Advance power train research and development	Academic research	B Hybrid and plug-in hybrid
National Research of Canada	Isobel Davidson National Research of Canada, Institute for Chemical Process and Environmental Technology Canadian government programs supporting plug-in hybrid electric vehicle development	Government research	B
Gerbrand Ceder MIT		Academic research - battery specialist	B
University of Montreal	Normand Mousseau Département de physique	Academic research - battery specialist	B
The Hybrid Experience	Jim Vanderwal GreenFleets Program Manager	Non-profit, B.C. government-funded organization providing info on fuel efficient technologies	B Hybrid and plug-in hybrid
University of Windsor	Dr. Narayan Kar Dept of Electrical Engineering University of Windsor	Academic research	C
Electric Power Research Institute (U.S.)	Mark Duvall Program Manger, Electric Transportation	R&D on electric power generation	C
U.S. National Renewable Energy Laboratory (NREL)	Tony Markel, National Renewable Energy Laboratory (NREL) Plug-in hybrid electric vehicle design options and expectations	Government research	C Plug-in hybrid only
AVESTOR / Groupe Bolloré	Entreprise qui développe et perfectionne la technologie des batteries au lithium-métal-polymère (LMP) à électrolyte solide.	Technology Developer	?

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
Véhicules Électriques et Écologiques du Québec	Lorraine Hébert Directrice Générale	Provincial industry association	?
Electrovaya	Gitanjali DasGupta, Program Manager, Electric Vehicle (representing EV OEM and battery manufacturer), Mississauga, ON	Technology developer and manufacturer for plug-in hybrid battery technology	
Pollution Probe	Bob Oliver, Transportation Programme Manager Pollution Probe, Toronto, ON	Environmental NGO	
Hydro Quebec	Serge Roy, Directeur, Systèmes énergetiques pour véhicules électriques, Hydro-Québec, Montréal	Energy provider	
Delaware Power Systems	Walter Wu, President and CEO	Batter module supplier	
CANMET Energy Technology Centre	John Marrone, Director General Nick Beck, S&T Director, Hydrogen, Fuel Cells and Transportation Energy Charles Thibodeau, Office of Energy Research and Development	Government research (Natural Resources Canada)	
Manitoba Hydro	Eric Bibeau, Manitoba Hydro Alternate Energy Industrial Chair, Department of Mechanical Engineering and Manufacturing, University of Manitoba (representing academics), Winnipeg, MB Ed Innes, Emerging Energy Technologies, Manitoba Hydro PHEV, energy efficiency, and comparison to alternatives	Academic research	

TABLE 24- CONTACTS FOR LANDFILL GAS CAP AND FLARE

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
BIOTHERMICA INTERNATIONAL INC.	Guy Drouin (Président)	Technology Developers / Industry	AA (key player)
Waste Management	Eastern Canada Kevin Cinq-Mars	Waste and environmental service provider involved with landfill gas capture	A
SOCONAG	Charles Tremblay (Directeur général)	Private sector gas and liquid flow measurement and control	A
Delphi Group	Michael Gerbis President	Environmental consultant. Conducted research project on landfill gas reduction potential to 2020	B

TABLE 25- CONTACTS FOR HYDROELECTRICITY GENERATION

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
Canadian Hydropower Association	Pierre Fortin	National Industry Association (web site lists numerous hydro engineering companies)	A
Ontario Power Generation	John Murphy Executive Vice President, Hydro	Electricity Generation Company (nuclear, coal, hydro)	A
HYDRO-QUÉBEC Institut de recherche Hydro-Québec (IREQ)	Centre de recherche spécialisé dans le développement des technologies de production et de transport (haute tension) de l'électricité et de la modélisation des réseaux.	Renewable Energy Research	A
Brookfield Power		Hydropower operator	A
LABORATOIRE APPLIQUÉ AUX MACHINES HYDRAULIQUES / Université Laval	Laboratoire de recherche rattaché à l'Université Laval dédié à l'enseignement et à la recherche sur les équipements et les machines hydrauliques (turbines hydroélectriques).	Academic technology research	B
Ontario Waterpower Association	Paul Norris, President	Ontario hydro industry association	B
BC Hydro		Public utility	B
Hydro Quebec	Energy Efficiency office	Public utility	B
Manitoba Hydro	Energy conservation office	Public utility	B
Corbu Consulting		Project management services for hydroelectric generation	C
Hatch Energy	Montreal office	Energy consulting, engineering and management company with expertise in hydroelectric development	C

TABLE 26- CONTACTS FOR WIND ENERGY

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
Canadian Wind Energy Association	Robert Hornung	Industry Association	A
HÉLIMAX ÉNERGIE	Entreprise spécialisée dans la réalisation de projets énergétiques dans le domaine de l'énergie éolienne. Contact : Richard Legault (président)	Industry (Engineering Consultant)	A
Wind Energy Institute of Canada		Technology Developer	A
UNIVERSITÉ DU QUÉBEC À RIMOUSKI / Groupe de recherche en énergie éolienne	Groupe de recherche rattaché à l'Université du Québec à Rimouski spécialisé dans l'étude des conditions d'exploitation de l'énergie éolienne et l'inventaire des vents. Jean-Louis Chaumel (Professeur-chercheur)	Academic Research	A
HYDRO-QUÉBEC Institut de recherche Hydro-Québec (IREQ)	Société publique de production, transport et distribution d'électricité impliquée dans le développement de l'énergie éolienne.	Renewable Energy Research	A
MDEIE Chimie, métallurgie, plasturgie et équipements	Clément Drolet (Directeur), Philippe Lacasse, Denys Laplante	Government	A
ÉCOLE DE TECHNOLOGIE SUPÉRIEURE / Chaire de recherche du Canada sur l'aérodynamique des éoliennes en milieu nordique	Chaire de recherche sur l'optimisation des conditions d'exploitation de l'énergie éolienne en milieu nordique spécialisée dans l'étude des phénomènes liés à l'aérodynamique des pales et la couche limite atmosphérique. Christian Masson	Academia / Research	A
GPCo INC.	Firme d'ingénieurs conseils spécialisée dans les études de faisabilité et le développement de projets de parcs éoliens : installation de tours météorologiques, analyse des données, calcul du potentiel éolien aux sites, évaluation de la production énergétique de futurs parcs éoliens. Guy Painchaud (Président)	Industry (Engineering Consultant)	B

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
HYDROMÉGA	Entreprise qui oeuvre dans le domaine de la conception, de la construction, du financement et de l'exploitation d'installations indépendantes de production d'électricité au Québec. http://www.hydromega.com/fr/home/index.html	Industry (Wind energy consultant)	B
TECHNOCENTRE ÉOLIEN GASPÉSIE-LES-ÎLES	Organisme de développement et de promotion de l'énergie éolienne. Jean Desrosiers (Directeur général)	Technology Developer	B
INSTITUT NATIONAL DE LA RECHERCHE SCIENTIFIQUE - ÉNERGIE ET MATÉRIAUX	Gaétan Lafrance (Chercheur principal)	Academic Research	B
3Ci	Robert Vincent (Président)	Technology Developer	B
AAER Energy		Wind turbine manufacturer	B
GROUPE OHMÉGA / AAT	Christian Vézina (Président)	Technology Developer / Consultant	B
TransAlta Wind		Large wind energy producer	B
Vestas Wind Technology		Wind energy technology developer, manufacturer	B
AEE Transports, Industrie, Innovation technologique	Alain Daneau (Directeur)	Government agency	B
National Renewable Energy Laboratory (US)	Bob Thresher Laboratory (US) Director, National Wind Technology Center	Academia / Technology Research Institute	B
ÉNERGIE PGE	Marc-André Normandin (Directeur)	Technology Developer	C

Name of Organization	**Contact Info / Description**	**Type of Organization**	**Priority for interview**
Corporation de gestion intégrée de la ressource éolienne Inc.			?
Coopératives regroupées en énergie renouvelable du Québec		Wind and renewable energy cooperative	?
Wind Technics		Wind turbine manufacturer and supplier	?
VRB Power Systems		Technology developer of batteries for wind power	?

TABLE 27- CONTACTS FOR NUCLEAR ENERGY

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
Canadian Nuclear Association		Industry association – very pro-nuclear	A
Canadian Coalition for Nuclear Responsibility		Not-for-profit research organization	A
Ontario Power Generation	Tom Mitchell Chief Nuclear Office	Electricity Generation Company (nuclear, coal, hydro)	A
Nuclear Energy Division Natural Resources Canada	Sylvana Guindon Director, Nuclear Energy Division (	Government policy (federal)	A
Nuclear Waste Management Organization		Government organization	A
CANDU Owners group		Not-for-profit organization in support of CANDU reactor technology	A
Canadian Nuclear Safety Commission	Environmental Assessment Division	Federal government nuclear regulator	A
David Jackson McMaster University		Nuclear energy expert and author	A
Atomic Energy of Canada Limited		Nuclear technology and services provider	B
Atomic Energy of Canada Limited Chalk River Labs		Technology developer and nuclear service provider (crown corporation)	B
Institut de genie nucléaire École Polytechnique	Daniel Rozon	Groupe de recherché universitaire	B
Coalition for Nuclear Energy		Pro-nuclear advocacy organization	B
Canadian Nuclear Society		Technical arm of the Canadian Nuclear Assn focusing on applied nuclear science and tech	B
McMaster University Nuclear Reactor	Susan Jack	Academic nuclear research	B

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
University Network of Excellence in Nuclear Engineering	Bill Garland, Professor Emeritus McMaster University	Alliance of universities, nuclear power utilities, research and regulatory agencies for the development of nuclear education and technology	B
Hydro-Québec Production	Robert Landry Directeur principal, Projets de développement et production nucléaire	Public utility	B
Canadian Nuclear Society Branch of the University of Ontario Institute of Technology	Dean George Bereznai,	Academic research	C
University of Toronto Centre for Nuclear Engineering	Brian Cox Professor Roger Newman,	Academic research	C
OECD Nuclear Energy Agency		OECD agency intergovernmental organization	C
International Atomic Energy Agency	CDN office	Intl agency related to the UN comprised of member states	C
World Nuclear University (London)		Global partnership university for international education on nuclear technology	C

TABLE 28- GENERAL CONTACTS IN RENEWABLE ENERGY

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
CANMET Renewable Energies Pgm	Natural Resources Canada	Government research	A
CANMET Energy Technology Centre-Ottawa	Natural Resources Canada	Government research	A
Renewable and Electrical Energy Division Natural Resources Canada		Government policy	A
Helios Consulting	Phil Raphals	Non-profit research group and consultant on a broad range of energy issues	A (Key advisor)
Bill Kemp	Author of Smart Power and the Renewable Energy Handbook Executive Director of SolutionsforSustainability.ca	Author, renewable energy expert	B
University of Waterloo, Green Energy Research Institute	Anthony Vannelli GERI	Academic Research	B
GPCo INC.	GPCo provides engineering consulting services to the wind, solar and other renewable energy sectors	Industry (Engineering Consultant)	B
HYDRO-QUÉBEC Institut de recherche Hydro-Québec (IREQ)		Renewable Energy Research	B
ASSOCIATION QUÉBÉCOISE DE LA PRODUCTION D'ÉNERGIE RENOUVELABLE	Claude Descoteaux Directeur General	Industry association for renewable energy producers in Quebec.	B
Centre for Energy	http://www.centreforenergy.com/	Industry Association for all energy producers	B
Kristopher Stevens	Executive Director ON Sustainable Energy Assn	Renewable energy expert	B

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
MRNF Électricité	René Paquette (Directeur général/Électricité) + Michel Guimont (Directeur général/Politiques et technologies énergétiques)	Government	B
National Renewable Energy Laboratory (US)		U.S. government research lab for a number of energy technologies	B
Energy Council of Canada	Energy Council of Canada Dr. Carmen L. Dybwad, President	Cdn national member of the World Energy Council. Respresents all representatives of Cdn energy sector	C
Canadian Electricity Association		Industry Association	C
Association de l'industrie électrique du Québec		Industry Association	C
Association québécoise pour la maîtrise de l'énergie		Information network	C
Mike Brigham	Toronto Renewable Energy Project Solar Share Initiative	Renewable energy expert	C
Paul Gipe		California wind energy consultant, expert, author	C
Consortium of Energy Efficiency		Non-profit promoter of energy efficiency in U.S. and Canada	?
Steve Lapp	St. Lawrence College Coordinator of Energy Systems Engineering Technologies	Academic researcher	?
Jose Etcheverry	ON Sustainable Energy Assn York University / Suzuki Foundation	Energy consultant and researcher	?

Name of Organization	Contact Info / Description	Type of Organization	Priority for interview
Association québécoise des consommateurs industriels d'électricité	Luc Boulanger Directeur exécutif	Industry association l'Association québécoise des consommateurs industriels d'électricité (AQCIE) représente les plus importants consommateurs d'électricité établis au Québec	?
Union des municipalités du Québec		L'Union des municipalités du Québec (UMQ) représente les municipalités de toutes tailles dans toutes les régions du Québec	
Association québécoise de lutte contre la pollution atmosphérique		NGO promoting clean air, energy efficiency and conservation	?

TABLE 29- CONTACTS FOR GROUND SOURCE PUMP HEATING SYSTEMS/GEOTHERMAL

To be completed.

Name of Organization	Contact Info/Description	Type of Organization
The Canadian GeoExchange Coalition	Ted Kantrowitz	Industry Association
Enairco		Distributor
Lysair Mécanic		Planning, distribution and installation ground source heat pump systems (residential, commercial, industrial)
Geonergy		Planning and installation
Master		Distributor
Le Groupe Thermo Stat		Planning, distribution and installation ground source heat pump systems (residential, commercial)
Geothermix		Planning, distribution and installation ground source heat pump systems (residential, commercial)

TABLE 30- CONTACTS FOR CARBON CAPTURE AND STORAGE

To be completed.

Name of Organization	Contact Info/Description
Alberta Research Council (ARC)	Bill Gunter Alberta Research Council (ARC)
Alberta Research Council	John Faltinson Integrated economic model for CO2 capture and storage
IEA GHG Weyburn-Midale Project Geological Survey of Canada	Don White Leader Prediction
University of Calgary	David Keith Geological storage of CO2 University of Calgary
Suncor Energy Inc.	Cal Coulter Integrated Carbon Dioxide Network Suncor Energy Inc.
Cdn CO2 Capture and Storage Tech Network CETC–Ottawa	Bill Reynen National Coordinator
Canadian Clean Power Coalition (Clean Coal)	Bob Stobbs
EnergyINet	Malcolm Wilson Program Director, CO2 Management
Petroleum Technology Alliance Canada	Ralf Aggarwal
Petroleum Research Centre (Saskatchewan)	Shawn Griffiths Communications Coordinator
Alberta Energy Research Institute	Alice Hedges AERI Head Office Calgary
Institute of Sustainable Energy, Environment and Economy (U of Alberta)	Mark Lowey Communications, ISEEE University of Calgary
University of Regina, CO2 Capture Research Group Paitoon Tontiwachwuthikul	Faculty of Engineering University of Regina
Energy Council of Canada	Dr. Carmen L. Dybwad, President

Name of Organization	Contact Info/Description
Association of Professional Engineers, Geologists, and Geophysicists of Alberta	
NRCan Clean Electric Power Generation	
Natural Resources Canada Office of Energy Research and Development	Graham Campbell Director General
Glencoe Resources Ltd.	Glencoe Resources CO2 capture, transport and storage project Calgary
Canadian Energy Research Institute	Costs for capture and sequestration of CO2 in western Canadian geological media (CERI) Mr. George Eynon Canadian Energy Research Institute
The Pembina Institute	Mary Griffiths Senior Policy Analyst
Petroleum Technology Research Centre (PTRC)	Carolyn Preston Executive director Weyburn-Midale CO2 Project (SK)
Environmental Services Association of Alberta (ESAA)	