PUBLIC ATTITUDES TOWARD GEOLOGICAL DISPOSAL OF CARBON DIOXIDE IN CANADA

by

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ABSTRACT

Geological disposal of carbon dioxide (GDC) is being considered for a significant role in Canada's climate change strategy, but public support for the technology is unclear. To address this knowledge gap, two focus groups and a national survey were conducted to investigate the public's perceptions of the benefits and risks of GDC, the likely determinants of public opinion, and overall support for the use of GDC in Canada.

The results showed that Canadians are slightly supportive of GDC development in Canada, perceive the technology as having a net positive impact on the environment, and believe that GDC is less risky than normal oil and gas industry operations, nuclear power, or coal-burning power plants. A majority of Canadians would likely use GDC in a climate change strategy, although it will have to be used in combination with energy efficiency and alternative energy technologies in order to retain public support.

Keywords:
Carbon Capture and Storage
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EXECUTIVE SUMMARY

Geological disposal of carbon dioxide (GDC) is being considered for a significant role in Canada's climate change strategy. The technology that will be required has been used for decades in the oil and gas industry as part of enhanced oil recovery (EOR). However, the public's likely response to GDC is unknown, and politicians may be reluctant to proceed unless they are assured that the public will accept the technology and that its implementation will be politically feasible. This research attempted to shed light on these questions by investigating the public's perceptions of the benefits and risks of GDC and the likely determinants of public opinion.

Data was collected in two phases: first through focus groups, and subsequently through a national survey. Focus groups were run with Canadians in Toronto and Edmonton in August 2004 in order to understand the likely range of attitudes and concerns about the technology, and to gather more in-depth perspectives than possible through the survey. The information obtained from the focus groups was then used to design a survey for administration to a much larger sample of Canadians. An Internet-based survey was administered in March 2005 to a representative Canadian survey sample that was recruited by a market research firm. The survey included a number of questions about climate change and GDC as well as a discrete choice experiment. It was administered to 1,967 Canadians, with the Alberta and Saskatchewan sub-sample over-weighted in order to allow for statistically significant analysis of responses from this geographic area.

The results showed that a strong majority of Canadians believe that climate change is occurring and some action should be taken to address it. However, climate change was ranked very low in importance compared to other national issues, and was the lowest ranked environmental issue. Knowledge of GDC was low, although it was higher than in the United States. The vast majority of respondents who had heard of GDC could not correctly identify what environmental problem it was meant to address.

The most important benefits of GDC were seen to be its usefulness as a bridging technology while long-term climate change solutions are developed, the potential for its use as part of carbon dioxide (CO_2)-based EOR, and its potential to reduce greenhouse gas (GHG) emissions faster and cheaper than alternatives. However, the risks were considered more important than the benefits, with the public most concerned about unknown future impacts, contamination of groundwater, the risk of a CO_2 leak, and harm to plants and animals.

Overall, respondents across Canada were slightly supportive of GDC development in Canada. They perceived the technology as having a net positive impact on the environment, and believed that GDC was less risky than normal oil and gas industry operations, nuclear power, or coal-burning power plants, all of which are extensively used in Canada. Over half of respondents would likely use GDC in a climate change strategy, while only a quarter of respondents would likely not include it. However, GDC was much less popular than energy efficiency and renewable energy alternatives, and it will have to be used in combination with these technologies in order to retain public support.

Those who opposed GDC were generally concerned about the risks, rather than fundamentally opposed to the technology, indicating that their opinions may change depending upon how GDC is managed and communicated to the public. More information about the technology; involvement of the federal government, independent experts and non-governmental organizations (NGOs) in management and monitoring; no reduction in spending on renewable energy and energy efficiency; and strong regulation and monitoring would all reduce opposition to GDC amongst the majority of those opposed. In addition, the extent to which GDC is accepted and used in other countries and the media's portrayal of GDC can shift Canadian public attitudes toward the technology.

Linear multiple regression analysis was used to identify the determinants of Canadians' support for GDC. However, the explanatory power of the models was low, likely because the technology was new to most respondents, and their opinions are not yet fully formed. While this does not diminish the validity of the opinions expressed, many of the *determinants* of the public's final opinions could not be identified. Those determinants that could be measured showed that support for GDC was proportional to respondents' perception of the seriousness of climate change; low belief in climate change led to low support for GDC, while a high importance placed on climate change corresponded with higher support for GDC.

A discrete choice experiment was included in the survey in order to understand the relative importance of various characteristics of GDC projects to the public. The most important characteristic was the managing entity; respondents in Alberta and

Saskatchewan preferred that the provincial government was the managing entity, while those in the rest of Canada favoured the federal government. Management by either level of government was strongly preferred to industry management by both samples. The experiment also showed that Canadians would prefer to see GDC used to reduce a significant fraction of the country's greenhouse gas emissions, rather than a small proportion, where the alternative is emission reductions from a climate change portfolio including energy efficiency, renewable energy, and nuclear power.

Based on the results of the focus groups and survey, a number of policy recommendations are made concerning how to develop GDC in a publicly acceptable manner. Public education about climate change is critical, as it is the key determinant of support for GDC. Public outreach about GDC should provide balanced information about how the technology works, its potential role in addressing the threat of climate change and for use in EOR, its risks and their associated probabilities (where known), and the extent to which the technology has been used historically and around the world. Proactive engagement of the media will help to avoid the dissemination of faulty or incomplete information. GDC must be strictly regulated and monitored to protect public safety and environmental quality, and the federal or provincial governments should take an active role in management of the technology, in conjunction with independent experts and NGOs. Finally, support for GDC will be higher if it is used aggressively to reduce GHG emissions, rather than targeting a small share of Canada's GHG reduction requirements, but the public does not want to see this growth come at the expense of energy efficiency and renewable energy programs.

Overall, this research showed that the public is mildly supportive of GDC, and if the technology is developed and managed in a way that addresses the public's preferences and concerns then public support could increase significantly. GDC is seen as less risky than many other commonly used energy technologies, including normal oil and gas industry operations. This should provide confidence to decision-makers that large-scale GDC development will likely be both publicly and politically acceptable.

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LIST OF ABBREVIATIONS

AB/SK – "Alberta/Saskatchewan" Sample

C – Carbon

CAN – "Rest of Canada" Sample

CBM – Coalbed Methane Recovery

CO_2 – Carbon Dioxide

DCE – Discrete Choice Experiment

DCM – Discrete Choice Model/Modelling

EOR – Enhanced Oil Recovery

GDC – Geological Disposal of Carbon Dioxide

GHG – Greenhouse Gas

H_2S – Hydrogen Sulphide

Mt – Megatonnes

NGO – Non-Governmental Organization

1. INTRODUCTION

1.1. Geological Disposal of Carbon Dioxide (GDC) Overview

The international community has recognized the threat posed by global climate change. Scientists on the Intergovernmental Panel on Climate Change have concluded that anthropogenic greenhouse gas emissions (GHGs) (predominantly carbon dioxide (CO_2)) are responsible for most of the earth's observed warming over the last 50 years (IPCC 2001). As a result, the international community has moved to reduce greenhouse gas emissions through agreements such as the Kyoto Protocol, which became international law in February 2005, and most experts recognize that emissions must be reduced by 50% to 60% or more in order to stabilize atmospheric concentrations of CO_2 (GC 2005). This can be achieved by reducing energy intensity (energy efficiency), reducing the carbon intensity of energy (switching to lower carbon fossil fuels such as natural gas or to renewable energy sources), or by disposing of or sequestering CO_2.

Many environmental groups and members of the public believe that the portfolio of actions to reduce CO_2 emissions should only include reducing energy and carbon intensity. There is significant discussion among these groups about the need to move beyond a fossil fuel-based economy (Jaccard 2005). However, fossil fuels currently provide about 80% of global primary energy (Holloway 2001), and global energy demand will continue to rise over this century, particularly in Asia, making a rapid shift away from fossil fuels a potentially difficult and costly way to reduce CO_2 emissions in the short and medium term.

There are several different options for storing or sequestering CO_2, including material, biosphere, and geosphere sinks. Material sinks include anthropogenically-created carbon sinks such as durable wood products and plastics. Biosphere sinks include the ocean, forests, and soils. Geosphere sinks include the use of CO_2 in enhanced oil recovery (EOR) and disposal of CO_2 in coal beds, depleted oil and gas reservoirs and deep saline aquifers (Gunter 1998). My focus is on the use of geosphere sinks to reduce global CO_2 emissions, because of the potential ecological risks and uncertainties surrounding ocean disposal of CO_2 (US DOE 1999). A variety of different terms are used in the literature to refer to this process. Some of these include "geological disposal of CO_2", "carbon capture and storage", "carbon sequestration", and "geological storage of CO_2". I will be using the term geological disposal of CO_2 (GDC), as research conducted in the United States shows that the public understands that the goal of this technology is technically disposal of CO_2, rather than storage of CO_2 (which implies later removal and use), and that the public gravitates toward 'disposal'-related terms when describing the technology (Palmgren 2004).

GDC involves separating a pure stream of CO_2 from the waste stream of large stationary sources (such as natural gas processing and petroleum refining plants in the near term, and electricity generating stations in the longer term), transporting the CO_2 to a disposal site (usually by pipeline) and then injecting this CO_2 deep underground into stable geological formations. As mentioned above, these formations can include depleted oil and gas wells as part of enhanced oil and gas recovery (EOR) or for pure disposal, in coalbeds as part of enhanced coalbed methane recovery (CBM), or in deep saline aquifers (porous water-filled layers of rock). The latter is the most promising alternative in the long run, as it offers technological feasibility, long-term sequestration of carbon, and enough capacity to potentially store the carbon content of all of the world's remaining exploitable fossil fuels (Williams 2002, Lamont 2003). However, EOR and CBM offer the commercial incentive of increased oil, gas, or coalbed methane recovery, and as a result some analysts believe that they will be favoured in the short run.

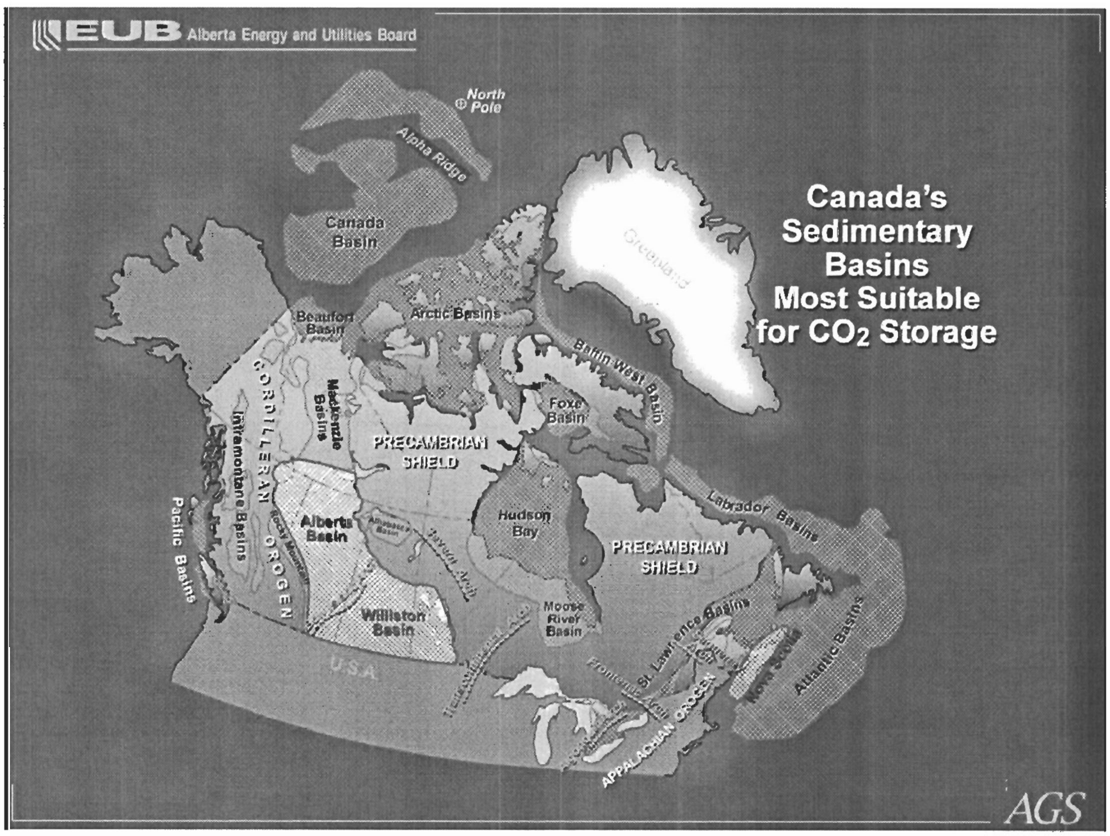
The technology required to transport and inject CO_2 has already been developed for use in other applications such as EOR and acid gas injection (AGI). EOR has been used by the oil and gas industry for decades and involves the injection of CO_2 into oil reservoirs to increase pressure and enhance oil recovery. Enhanced natural gas recovery and coal-bed methane production operate along similar lines. Canada has direct experience with EOR through the Weyburn Enhanced Oil Recovery Project in Saskatchewan, a commercial project that has been in operation since 2000 and is disposing of 1.5 million tonnes of CO_2 each year (Mt/y CO_2) (Lamont 2003, Williams 2002). The Weyburn operation has become the site of the International Energy Agency (IEA) Weyburn CO_2 Monitoring and Storage Project, and involves 20 research organizations from six countries, as well as industry, government, and academia.

The world's first commercial-scale CO_2 disposal operation was the Sleipner CO_2 Injection Project in the Norwegian sector of the North Sea, where 1 Mt/y CO_2 is stripped from natural gas produced from the Sleipner gas fields and injected into the Utsira formation saline aquifer under the North Sea each year. The CO_2 content of the natural gas must be reduced for commercial sale, and Norway's carbon tax makes geological sequestration of the CO_2 the most economically preferable disposal alternative. This project is also being carefully monitored in order to gain experience with CO_2 disposal in saline aquifers (Gale 2001). Additional experience has been gained from similar applications such as acid gas injection (AGI), natural gas storage, and underground storage of other wastes (Keith 2002b). In particular, AGI is practiced at 45 facilities in Alberta and British Columbia and has properties that make it a comparable technology to GDC (Keith 2002b, Gunter 2003). Sour gas processing requires that hydrogen sulphide (H_2S) be removed from the gas stream, and for many facilities the cheapest method is to compress the entire acid gas stream (containing CO_2 and H_2S) and inject it into a geological formation where it will be permanently sequestered. The CO_2 concentration in the acid gas stream ranges from less than 20% to over 90% (Gunter 2001).

As a signatory to the Kyoto Protocol, Canada has committed to reducing our domestic GHG emissions to 6% below 1990 levels by the 2008 – 2012 commitment period. This represents a significant challenge, as emissions have continued rising since the Kyoto Protocol was negotiated. The Canadian commitment now requires GHG reductions of approximately 270 Mt/y CO_2 equivalent – an enormous 45% reduction in GHG emissions from the business as usual scenario (GC 2005). Large-scale rollouts of nuclear power or renewable energy could be used to achieve significant emission reductions, but the option to use GDC may change the costs and political dynamics of the climate problem, and represents an especially interesting opportunity to reduce Canadian GHG emissions given Canada's high production and use of fossil fuels. Over 70% of Canada's energy comes from the combustion of fossil fuels, while less than 1% comes from non-hydro renewable energy sources such as wind and solar energy (CLA 2005). Canada has extensive remaining fossil fuel reserves (Osadetz 2002), and the economies of the western provinces in particular are heavily dependent on exploitation of these resources. As a result, Canadian governments and industry have a keen interest in GDC, as it offers the potential for continued use of fossil fuels while simultaneously addressing the threat of climate change.

In Canada the most suitable geological formations for GDC are located in the Alberta and Williston Basins in Alberta and Saskatchewan (Figure 1.1).

Figure 1.1 - Canada's Sedimentary Basins Most Suitable for CO_2 Disposal (after Bachu 2003, p. 286, courtesy of the Alberta Geological Survey)



The Alberta and Williston formations are continental sedimentary basins and are especially well suited for permanent CO_2 disposal due to geological characteristics that make fluid flow within the aquifers very low. This minimizes the risk of geological events that could cause a catastrophic leak and means that the injected CO_2 would likely remain sequestered for a long period of time (Bachu 2003). These basins feature many suitable areas for CO_2 disposal in close proximity to large point sources of CO_2 and fossil fuel reserves (Thambimuthu 2004).

The Alberta and Williston basins also offer a large CO_2 disposal capacity. Depleted oil and gas reservoirs in Canada could hold 5,000 Mt of carbon (C) (3.67 tonnes of CO_2 = 1 tonne of carbon), with Alberta accounting for 3,500 Mt C of this capacity. Coal beds could hold 4,000 to 7,800 Mt C across Canada, with a point estimate for Alberta of 5,000 Mt C. Deep saline aquifers have an estimated capacity in Alberta of 5,400 Mt C. The retention time for CO_2 disposed of in depleted oil and gas reservoirs, coal beds, and deep saline aquifers is estimated to range from hundreds of thousands to millions of years. There is far lower capacity for CO_2 disposal into depleted oil and gas reservoirs as part of EOR; Canada-wide capacity is estimated at 90 Mt C, with 60 Mt C of this capacity located in Alberta. When CO_2 is used as part of EOR the retention times are only on the scale of tens of years. However, when the CO_2 emerges from the EOR site it is then captured so that it can be re-injected (Gunter 1998). When all of these capacities are compared with Canada's required GHG emission reductions by the 2008-2012 period of 270 Mt/y CO_2 equivalent it becomes clear that the capacity offered by GDC far exceeds the highest potential requirements for CO_2 disposal in Canada in the foreseeable future.

Numerical models and evidence from natural CO_2 reservoirs suggest that CO_2 disposed of geologically will be retained for over 1,000 years – and potentially much longer (Keith 2002b, Gunter 1998). Scientists from the IEA Weyburn CO_2 Monitoring and Storage Project have modelled CO_2 migration within the disposal basin, and found that the maximum possible leakage is 0.14% of the CO_2, with the likely leakage less than 0.001% (Zhao 2004). However, while the simulated leakage rate at Weyburn is impressively low it does not indicate that all geological CO_2 disposal sites in Canada will demonstrate similarly low leakage of CO_2, particularly if there is a dramatic growth in the number of disposal sites. Leakage of CO_2 from disposal sites remains a significant concern, both because CO_2 is toxic to human, animal, and plant life at high concentrations, and since high leakage rates would negate the climatic benefit of GDC.

CO_2 becomes quite dangerous to human life if it builds up to high concentrations in confined spaces such as houses. Above a 5% concentration CO_2 causes a number of breathing problems, at 10% it causes instantaneous unconsciousness and rapid death, and above 20% CO_2 is instantaneously fatal (Holloway 1997). In cases where there has been a large rapid leak of CO_2 from a natural source the death toll has been significant: 142 people died in Dieng, Indonesia after sheets of CO_2 flowed down the Dieng volcano following its eruption; 1,700 people and all animals within 14 km were killed in Cameroon when Lake Nyos overturned, releasing a large amount of CO_2 that had built up under the lake from a slow leak; and 27 people died when a landslide in Cameroon caused the waters of Lake Monoun to overturn and release dissolved CO_2 (Sigvaldason 1989, Holloway 1997). Large leaks from a GDC site would likely result from an earthquake, volcano, fault, well blowout, pipeline rupture, or slow leak that is temporarily confined near the surface before being suddenly released. These types of leaks can be minimized by appropriate safety standards and procedures and careful site selection. Fortunately, the Williston and Alberta basins are both located on seismically stable continental crusts which make them unsusceptible to these types of natural catastrophes (Keith 2002b, Lamont 2003).

Long-term slow leakage of CO_2 from the disposal site can also be a problem, as it can harm the surrounding environment. At Mammoth Mountain, California, continuous volcanic releases of CO_2 have destroyed trees and vegetation in several areas (Farrar 1995). Gradual leaks can result from over-pressurization of the aquifer (injecting too much CO_2), small faults or cracks, geochemical complications, a blown well or an unknown release point such as a previously drilled well. These are all functions of the geological properties of the aquifer, and the risk can be reduced by research aimed at improving understanding of these geological properties. Careful inspection of storage basin areas to identify potential release points and research to determine the total storage capacity and flow patterns within each aquifer – and how CO_2 injection would change these flow patterns – will all contribute to reducing the risk of a gradual leak (Lamont 2003). Monitoring technologies also exist that will enable leaks to be detected, so that problems can be corrected.

The other problem with long-term small leaks is that the amount of CO_2 released may eventually negate the climatic benefit of disposing of it geologically, particularly as a result of the energy penalty associated with the capture and disposal of CO_2, which can be as high as 10-20%. The risk is that if CO_2 is released back to the atmosphere too quickly (i.e. when atmospheric CO_2 concentrations are still high) and releases and anthropogenic emissions exceed the capacity of sinks (such as the oceans and vegetation) to absorb it then climate change could worsen (Keith 2002b). Researchers have investigated "acceptable leakage rates", and although estimates vary, in general a 0.1% annual leakage rate is considered acceptable, while an annual leakage rate over 1% is likely to make GDC ineffective (Ha-Duong 2003, Pacala 2002, Dooley 2002, Hepple 2005).

Finally, GDC poses a number of other risks, although their associated probabilities may be small. GDC operations may harm animals and vegetation near the disposal site. In addition, the injection of supercritical CO_2 into an aquifer will result in the displacement of the waters within the formation, potentially inducing seismicity; producing ground movements that may damage manmade structures or obstruct the flow of irrigation water; mobilising toxic trace elements; or contaminating potable aquifers (Keith 2002a, Zhou 2004). Additional research will be needed in this area to determine the likelihood of these impacts, and how the risk can be minimized.

1.2. Previous Research into Public Attitudes toward GDC

Significant international research has been done in order to understand the technical feasibility of GDC. Research into the public acceptability of GDC is a newer field. GDC has associated local risks, as discussed above, and it is important to gauge the public's views as to the relative desirability of this approach for reducing CO_2 emissions.

Public acceptability is also an indicator of GDC's political and commercial feasibility, which will be required for significant expansion of the technology in Canada and around the world. To understand likely public reactions to GDC, researchers are starting to look at this issue in more depth. In 2003 the results of public opinion research in the Netherlands were published, and studies from the United Kingdom, the United States, and Japan were all published in 2004. Research to date has relied on a combination of interviews and focus groups to understand how the public thinks about GDC, and surveys of a wider audience, often involving complex statistical analysis, to draw overall conclusions. The results have shown that in most countries there is slight support for GDC, with the exception of the United States, where opinions are moderately negative. However, respondents in all countries are opposed to the disposal of CO_2 below their homes, suggesting that local opposition is likely wherever GDC projects are located.

In the Netherlands, Huijts conducted a survey of 112 people living above gas fields in Alkmaar and Bergen, where CO_2 is likely to be disposed of in the near term (Huijts 2003). Brief information about GDC, its potential risks, and the points of view of government, industry, and environmental non-governmental organizations (NGOs) was presented to respondents. The survey tested respondent knowledge about GDC, attitudes toward GDC, affect (emotions) toward GDC, and perceived risks and benefits of GDC. The results showed that most people knew little or nothing about GDC before the survey (although the proportion of the population that had at least a small amount of knowledge about GDC was higher than in other countries), and that respondents were neutral to positive about the suitability of GDC as a solution to the climate change problem, the usefulness of the technology, and the desirability of GDC outside of built areas.

However, respondents were neutral to negative concerning storage in their own neighbourhood, demonstrating what Huijts calls a NUMBY (not under my backyard) attitude. The most common emotion felt in regard to GDC was worry, and the risks and drawbacks of GDC were rated slightly higher than the benefits. Huijts concludes that it is possible that resistance to the development of GDC will arise from residents in the local area, and recommends taking actions to reduce the risks, involving environmental NGOs, making the public more aware of the benefits, and giving people an opportunity to voice their concerns.

A study by the Tyndall Centre for Climate Change Research in England followed in January 2004 (Shackley 2004). Two focus groups (10 hours each) were conducted in Manchester and York, and 212 individuals were surveyed at Manchester Airport. Participants in the focus groups had the opportunity to listen to several experts on the topic of GDC introduce the technology and debate the benefits and the risks. The survey provided increasing amounts of information about GDC to respondents. Overall, the Tyndall researchers found that the initial public reaction to GDC is uncertain or slightly negative, but shifts to slight support for the concept when more information is presented. However, this support is conditional upon an understanding of the risks of climate change, support for GHG reductions, and an understanding of the magnitude of emission reductions required. The public's largest concerns were leakage of CO_2 and that GDC development would stop or delay other actions to reduce GHGs and create a false sense of security. Support for alternative methods of reducing GHG emissions – such as renewable energy technologies, energy efficiency, and demand reduction – is higher than support for GDC, and as a result, GDC receives much higher support when it is presented as part of a portfolio of GHG reduction measures. The authors recommend that GDC be implemented as part of a portfolio of decarbonisation options and promoted as a bridging technology to other low or zero carbon energy sources.

The first American research was published in March 2004 by Palmgren *et al* at Carnegie Mellon University (Palmgren 2004). The research involved a series of face-to-face mental model interviews with 18 non-technical participants, followed by a closed-form survey that was administered to 126 individuals. Information about GDC had to be presented to respondents due to the low public familiarity with the technology. Participants in the mental model interviews were slightly supportive of GDC, but survey respondents started out slightly opposed to GDC, and became more opposed to the technology as additional information was presented. The acceptability ratings for GDC are 15 – 20% lower than those given by the Dutch sample in Huijts' work. Many of the concerns expressed were similar to those raised in the Tyndall Centre's study, including fear of health and environmental harm from sudden CO_2 leaks, and about GDC being an end-of-pipe solution that delayed necessary lifestyle changes and crowded out investment in renewable energy technologies. New concerns raised by respondents involved the upstream environmental problems associated with fossil fuel extraction, transportation, conversion, and the eventual disposal of wastes, and a fear that GDC would contaminate or destroy Artesian wells and drinking water. The authors conclude that the public is not likely to actively support GDC, and high public acceptance will require broad public understanding of the seriousness of climate change, the costs of alternatives, more scientific information about the effectiveness and safety of GDC, and open and respectful public communication.

The Massachusetts Institute of Technology followed in June 2004 with the results of its research into American public attitudes toward climate change and GDC (Curry 2004). An internet-based survey of 1,205 people was conducted, representing a general population sample of the U.S. The survey focus was on assessing attitudes toward climate change and only four questions about GDC were asked. The researchers found that climate change ranked low in importance compared with other national issues. Less than 4% of respondents had heard of GDC, and only 0.5% could correctly identify the environmental problem that it would address. When climate change-mitigation technologies were evaluated by respondents, significant support for solar energy, energy efficiency, and wind energy emerged, while GDC received little support, and was ranked second last in preference, with only iron fertilization of the oceans less favoured. When information about the relative costs of using renewable energy, nuclear power, fossil fuels, and fossil fuels with GDC was presented, support for renewable energy decreased, and support for GDC increased. The authors recommend that an open process that is seen as fair by the local community be used to address local concerns as GDC is developed.

Several studies evaluating Japanese public opinions toward GDC were published in 2004, including studies by Itaoka *et al* (Itaoka 2004), Uno *et al* (Uno 2004), and Tokushige *et al* (Tokushige 2004). Some of these studies evaluate ocean disposal of CO_2 in addition to geological disposal, as Japan is one of the leaders in research into ocean disposal. However, I will focus on the attitudes revealed about GDC.

Itaoka *et al* conducted a face-to-face survey of 1,006 adults in Tokyo and Sapporo, in which half of the sample received a limited education version with 2 pages of information about GDC, while the other half of the sample received a full education version with 8 pages of information about GDC. Explanatory factor analysis and linear multiple regression analysis were conducted on the data. The results showed that 31% of the public were familiar with CCS, which is much higher than the awareness revealed by the American studies. Respondents were slightly supportive of the concept of GDC as part of a larger climate policy portfolio, and less than 20% of the sample reported that they were fundamentally opposed to the technology. However, when asked about onshore GDC specifically, respondents were slightly opposed. Support for GDC was higher among those who received the full education version of the survey. The factor analysis and regression analysis showed that respondents' understanding of the effectiveness of GDC as a mitigation option for climate change was associated with increased support, while women and respondents with children were significantly more likely to fundamentally oppose GDC. The authors conclude that education, particularly about the effectiveness of GDC, is necessary for public acceptance.

Uno *et al* investigated public attitudes toward GDC through a survey of 60 university students and six small focus groups in Hyogo Prefecture. Participants were given educational information about GDC as well as newspaper articles about the technology in order to introduce the issue. The researchers found that concern about climate change was low among the lay public and very few people were aware of GDC. However, participants generally supported GDC development, although they were opposed to having it developed beneath their homes. Many participants thought that it was "too early to decide" about GDC, and had questions about CO_2 leakage and the impact of GDC on the local environment. Participants identified the process through which the public is involved in the development of GDC projects as important, and the authors conclude that "mutual confidence and sincere communication" with local residents about the need for GDC will be required.

Tokushige *et al* investigated risk and risk-benefit perceptions about GDC, other climate change technologies, and everyday life activities using a survey of 138 university students in Kyoto. Two components of risk – "dread risk" and "unknown risk" were measured, as was the perception of public acceptance of GDC. Overall risk perception and benefit perception were evaluated using factor analysis. Initially, only limited information was provided about each technology, so that changes in opinions after the provision of additional information could be measured. "Dread risk" perception was lower than for nuclear power, but "unknown risk" perception was higher. Receiving additional information increased public acceptance perception and benefit perception, and lowered "dread risk", but surprisingly "unknown risk" perception remained the same. The authors conclude that it will be crucial to reduce the "unknown risk" perception, perhaps through the development of monitoring technology, in order to increase public acceptance of GDC.

1.3. Research Questions and Overview and Structure of the Paper

Canada is well positioned to benefit from using GDC, has significant experience with the technology, and possesses extensive disposal capacity. Hence it stands to reason that an understanding of Canadian public attitudes toward GDC is required so that the political feasibility of this technology can be determined. As no research has yet been done on this topic my research project was designed to fill this knowledge gap. The key research questions were as follows:

1. Identify the public's state of knowledge about GDC.
2. Identify and prioritize any concerns that the public has about GDC.
3. Identify and prioritize the reasons for public support of GDC.
4. Separate and identify the opposition stemming from concern about the *risks* of GDC from *fundamental* opposition to GDC as the wrong solution to the climate change problem
5. Identify and understand some of the features that might determine the degree of public support for GDC as a GHG mitigation measure in Canada.
6. Determine how the presentation of positive (benefit-focused) media information versus negative (risk-focused) media information about GDC impacts support for the technology.
7. Determine how attitudes toward GDC differ between residents of Alberta and Saskatchewan, where most of the disposal will take place, and residents living in other areas of Canada.

The project began with research into GDC, including meetings with representatives of government, industry, academia, and environmental NGOs in order to better understand the field. Because such limited information was available about the public's likely response to GDC, the first data collection step was to run focus groups with Canadians in order to understand the likely range of attitudes about the technology and to gather more in-depth qualitative information. Focus groups were run in Edmonton and Toronto in August 2004. The information obtained from the focus groups was then used to design an internet-based survey for administration to a much larger sample of Canadians. A market research firm was hired to recruit a representative survey sample, and 1,967 Canadians completed the survey. The results were then analysed, and based on the findings, policy recommendations are made to enable government and industry to develop GDC in Canada in the most publicly acceptable manner.

The structure of the paper is as follows. Chapter 2 introduces the data collection methodology used for the focus groups and the survey. A discrete choice modelling experiment (DCE) was included in the survey, and the theory behind discrete choice modelling and the experimental design that was used are discussed. Multiple regression analysis was employed in the analysis of the survey results, and the theory and methods that were used are also presented. Chapter 3 provides an overview of the results from the focus groups and a detailed analysis of the results from the survey, including the DCE and the regression analysis. Finally, Chapter 4 presents policy recommendations and the overall conclusions from the study.

2. DATA COLLECTION AND METHODS

2.1. Focus Groups

Focus groups were held in Toronto, Ontario on August 30th, 2004, and in Edmonton, Alberta on August 31st, 2004. The Toronto focus group was held in a meeting room at Metro Hall, a municipal building in downtown Toronto, and the Edmonton focus group was held in a meeting room at the Inn on 7th, a hotel in downtown Edmonton.

Participants in the focus groups were recruited predominantly through random digit telephone dialling, in accordance with recommended industry practice. A random number generator was created in Microsoft Excel, and used to generate seven-digit potential telephone numbers. The person answering the phone was given a short introduction to the focus group, and offered $50 in compensation, dinner, and the opportunity to contribute to an important area of public policy in return for their participation. If they expressed interest in hearing more, several questions were asked in order to ascertain the participant's eligibility, ensure that a broad cross-section of society would be represented at the focus groups, and determine the participant's background knowledge about GDC. Participants were asked about their familiarity with five environmental issues, including GDC, in order to obtain this information without revealing the topic of the focus group to participants. Eligible participants were then given more information about the focus group, and received a reminder phone call the evening before. The script used for telephone recruiting is provided in Appendix A.

In general, random telephone recruitment was unsuccessful in Toronto, both because a high proportion of numbers were not in service, and because participants were very unresponsive to telephone recruitment. Only five participants were recruited from the first 294 telephone calls. As a result, the remaining Toronto participants were recruited through a convenience sample of passers-by at Metro Hall, where the focus group was to be held. Potential participants were selected in order to balance the composition of the focus group by age, gender, and ethnic diversity. The response was excellent, and within one hour eight participants had been recruited. This method is highly recommended for focus groups in the Toronto area, when funds to hire a market research agency to perform telephone recruitment are not available. Although not entirely random, efforts can be taken to obtain a representative group. Additionally, a completely random group is not necessary, as the goal of the focus groups is to determine the range and general direction of opinions that may be held by the population as a whole, and not to obtain results for statistical analysis or for extrapolation to the general population.

Random digit telephone dialling was more successful in Edmonton, where 262 telephone calls led to the recruitment of ten participants. Two additional participants were recruited directly by Alberta Environment.

Twelve participants in total were recruited in each city, with the expectation that 9-10 participants would attend each session. Actual attendance in Toronto was eleven (one male cancelled the day before), and nine in Edmonton (two female participants did not attend, and one female participant mistakenly went to the wrong location).

Both focus groups were moderated by Jacqueline Sharp. Anne-Marie Thompson (Environment Canada) assisted with the Toronto focus group and Christeen Finzel (Alberta Environment) assisted with the Edmonton focus group. The focus groups ran for two and one half hours each, from 6:30-9:00 pm. When participants arrived they signed consent forms, were given name cards, helped themselves to dinner, and then were randomly seated at the table. A digital microphone was set up in the centre of the table to record the session. The focus group started with a short survey about GDC and climate change, which the participants completed before discussion began. This was followed by an explanation about the evening and the procedures that would be followed, introductions, and a general conversation about environmental issues to warm up the group and get the participants comfortable talking with each other. The moderator then moved into questions for group discussion. Some of these questions involved handouts to participants, providing additional information to guide the discussion or asking participants to answer a question about the current topic of discussion and hand the response back to the moderator. The moderator's guide is provided in Appendix B, and the initial survey and handouts are provided in Appendix C.

2.2. National Survey

The survey was iteratively developed between December 2004 and March 2005. Results from the focus groups were used to design more targeted and accurate questions than would have been possible otherwise. The survey went through ten drafts until it was satisfactory to all of the researchers and to the funding agencies. When the text was complete the survey was programmed into a World Wide Web interface so that it could be completed online, and the results would be automatically collected and recorded.

The next step in the survey development process was field testing. Thirty-five colleagues and acquaintances of the researchers completed the survey, of which twenty-five submitted detailed comments. The initial test data was analysed, and the results of the discrete choice experiment (DCE) were modelled, in order to ensure that there were no problems with the survey. Based on the field test results, the levels of the 'Electricity Bill Increase' attribute in the DCE were changed, in order to avoid dominant choices, and a number of small changes were made to text and formatting throughout the survey in order to make it easier to understand. A copy of the final survey instrument can be found in Appendix D.

Synovate, a Canadian market research firm, was hired to provide a representative sample of Canadians to complete the survey. Synovate maintains an online panel of 70,000 Canadian households, whose members are willing to complete internet-based surveys on a variety of topics. Many market research firms maintain similar online panels. Synovate recruits members to its panel through website links, portals and online newsletters, and continually refreshes the panel to replace households that drop out or to ensure proper representation of various demographic or regional groups.

The survey sample is biased toward Canadians with internet access and some computer knowledge, and so suffers from coverage error. However, internet penetration rates have been rising, and 73% of Canadian households are now estimated to have online access

(TNS 2005), minimizing the bias introduced by online administration. All sampling methods demonstrate some drawbacks and sources of bias; telephone and mailing lists often omit large segments of the population and are especially prone to coverage error, and in-person surveys are infeasible and prohibitively expensive for national-level research (Dillman 2000). Synovate drew a sample for this study that was roughly representative of the Canadian population on gender, age, geographic region, income, and education level.

By administering the survey online, more control could be exerted over the content. The order of statements in many of the questions was randomized, in order to avoid bias toward any of the answers, and randomize any errors. Additionally, the online format prevented respondents from returning to earlier questions and changing their answers once they were given more information about GDC. The online survey was less expensive to administer than a mail or telephone survey, and hence permitted a larger sample to be surveyed. Finally, all responses to the survey were received within two weeks, and the results were automatically downloaded into a database, significantly expediting data collection and analysis and removing the possibility of data entry error.

Synovate was contracted to provide 8,500 email invitations to a representative sub-sample of its internet survey panel, which they estimated would result in 1,150 completed surveys. Incentive draw prizes totalling $1,000 were offered to respondents to improve response rates. The survey sample was to be weighted with 40% of respondents coming from Alberta and Saskatchewan (AB/SK) and 60% of respondents coming from the rest of Canada (CAN), with each of the two sub-samples designed to represent the population distribution in their respective region. In order to ensure that any errors or problems could be identified and corrected, invitation emails were first sent to only 20% of the sample population, on March 17th, 2005. Within 24 hours 305 respondents had completed the survey, and the results were again analysed to determine if the website was running smoothly and the results were as expected. On March 18th, 2005 Synovate sent out the remaining invitations. Most responses were received within the first 72 hours, but responses continued to arrive until data collection was officially ended on March 31st, 2005. The survey was extremely successful, and was completed by far more people then estimated: 775 in Alberta and Saskatchewan, and 1,197 in the rest of Canada, for a total of 1,972 completed surveys.

2.3. Discrete Choice Experiment

2.3.1. Theory

A discrete choice experiment (DCE) was included in this study in order to add an additional dimension of understanding to the research question. One of the benefits of using discrete choice modelling (DCM) is that it forces respondents to make tradeoffs and allows the utility associated with a good or service (in this case the development of GDC) to be decomposed into the utility associated with each of the different attributes of that good or service. This provides information on the *relative* importance of various attributes of GDC, and will allow me to determine which attributes of carbon storage projects are truly the most important to the public.

DCM is used to understand how individuals make choices between alternatives. These models have traditionally been used in market research, and are based on random utility theory. The decision making heuristic embodied in DCM assumes that individuals view products as bundles of characteristics, each of which has an associated importance, and that individuals choose between products by comparing their utilities, which are calculated by taking a weighted sum of the characteristics and each characteristic's associated importance (Louviere 2000). While this heuristic may bear little resemblance to the way individuals actually make choices, discrete choice models are generally successful at approximating the results of the choice process (Rivers 2003).

The utility that an individual receives from a product "j" (U_j) is comprised of a portion that the analyst can observe and measure (V_j), based on the observable characteristics, as well as a non-observable component (ε_j), as shown below in Equation 2.1:

Equation 1.1

$$U_j = V_j + \varepsilon_j$$

The measurable utility (V_j) is found by taking the weighted sum of the observable characteristics of a product and the importance that the individual places on each characteristic. When the multinomial logit model is used to analyze the results, as is the case in most applications, the non-observable component is assumed to follow a Type 1 Extreme Value (Weibull) distribution.

This study is relatively unique in that it applies the discrete choice modelling technique to choices between alternative configurations of a new environmental technology, with public good characteristics, rather than choices between products. Using the focus group results and consultations with experts, three characteristics were identified to describe GDC:

1. The entity that would manage the long-term disposal risks and have liability for GDC in Canada (Entity);
2. The share of Canadian GHG reduction targets that would be met with GDC (with the remaining share met by a combination of energy efficiency, renewable energy and nuclear power) (Share), and
3. The increase in the respondent's monthly electricity bill (ElecBill).

Each characteristic had three possible levels (further detail is provided in the section below on Experiment Design). Thus the utility function I am trying to estimate looks as follows (Equation 2.2):

Equation 1.2

$$V_j = \beta_j + \beta 1 * Entity_j + \beta 2 * Share_j + \beta 3 * ElecBill_j$$

In this case β_j is the intercept and $\beta 1$, $\beta 2$ and $\beta 3$ are coefficients that measure the importance of each characteristic to the respondents. The survey contained two independent sample populations: 1) Alberta and Saskatchewan (ABSK), and 2) the rest of Canada (CAN), so separate utility functions were estimated for each group.

2.3.2. Previous Applications of Discrete Choice Models

This research aims to evaluate the utility associated with a new and unknown technology, with government environmental policies and with a public good that may have local environmental impacts and also may be subject to broad societal opposition. DCM has previously been used to investigate each of these types of problems independently. My research is unique in that I am using DCM to investigate a problem displaying all of these characteristics in combination, which has not been undertaken in other studies.

Discrete choice modelling is often applied to the investigation of consumer reactions to new or hypothetical technologies or products, because of the ability to base the experiment on stated preferences. Discrete choice theory was initially applied almost exclusively to observed market preferences, until Louviere and Hensher determined that it could be applied to analyse data from an "appropriately designed controlled choice experiment" (Louviere 1983, p. 349). The researchers were attempting to forecast attendance at an international exposition celebrating 200 years of European settlement in Australia, and designed a stated choice experiment to compensate for the fact that no existing choice data could exist for unique or new events (Louviere 1983). Stated choice DCM research has come far since these early experiments, and in a recent study the methodology was proposed to forecast demand, price, and tradeoffs between different attributes of space tourism, another very hypothetical and unfamiliar technology (Crouch 2001).

Perhaps the most similar study to mine was one that used DCM to determine public attitudes toward, and willingness to pay for genetically modified foods (Burton 2001). Genetically modified foods are similar to carbon storage in that they are a relatively new technology, and are (debatably) a public good, albeit one where the benefits and costs may accrue to different groups. However, the two technologies are different in that the public is highly aware of genetically modified foods, as the media and interest groups became involved very early in shaping public opinions. Part of the rationale for my research is the need to determine what attitudes are likely to be, and how the media and interest groups could shape them, *before* this happens, in order to allow the government to plan an appropriate policy response and public education program. Because genetically modified foods have become so contentious, the researchers had to avoid letting the issue take on "unwarranted prominence" in the study by including many other food system attributes in each profile (Burton 2001, p. 486). I was fortunate to not have to do this; the low public awareness of GDC allowed me to focus on the technology specifically, and test a wider range of directly-relevant attributes.

One key characteristic of my research that is untraditional for a DCE is that the questions will not be entirely realistic. In reality the public will not be able to "choose" to go ahead with GDC and with what project configurations, unlike in traditional market research applications or even similar studies such as the one about genetically modified foods, where respondents actually face the experiment's choice task in the marketplace. Instead, the goal of this study is purely to obtain the importance of each attribute so that the appropriate government agencies can determine whether or not to continue with the development of carbon storage, how to develop it, and how to communicate about the technology with the public. However, this in itself is not unique; other studies have asked respondents to make choices that they can not make in the marketplace, such as about their preferred air quality levels (Haider 2002) or their preferences for the development of wind farms (Álvarez-Farizo 2002).

Despite the fact that there are no previous applications of DCM to this research question, there are a number of other DCM studies, including the ones described above, that are quite similar on one or more characteristics. These studies offered insights into specific aspects of my study development and design, which are described in more detail in the following section.

2.3.3. Experiment Design

Developing a discrete choice experiment includes six main steps: characterization of the decision problem, attribute level selection, experimental design development, questionnaire development, sample sizing and data collection, and model estimation (Adamowicz 1998). The questionnaire, sample size, and data collection methods have already been detailed, but the remaining steps will be discussed in turn.

The overall goal of this study was to understand Canadians' preferences for the development of GDC in Canada. The discrete choice experiment was included in order to determine the relative importance of different characteristics of GDC projects, in order to help policy makers and industry understand how the technology must be developed in order to retain public support.

The next step was to determine which characteristics (attributes) of GDC to test, and what levels to assign to each attribute. One consideration here was how to account for geographic heterogeneity in attitudes towards GDC. I am interested in determining how opinions about GDC vary between those living in close proximity to future developments, and Canadians who will be geographically removed from carbon storage sites. One argument says that the concerns of these two groups will be sufficiently different that separate attributes and levels will be required for each group. However, this would prevent a comparison of each group's tradeoffs. As a result, I selected attributes that would be relevant to both geographic segments, and administered a common survey to the entire survey sample. One of my main concerns when selecting the attributes to be used was ensuring that they were policy relevant, which requires that the selected attributes can be controlled by policy makers. Blamey et al (1997) emphasise that priority must be given to demand-relevant, policy-relevant and measurable attributes. Therefore, although many studies use environmental *outcomes* as attributes (Álvarez-Farizo 2002, Bergmann 2004), I will test *policies* as attributes instead. This is 1) so that the results will be relevant and actionable to government and industry; 2) because the goal of the research is to determine *how* carbon storage should be developed in Canada; and 3) because the environmental outcomes of using GDC are difficult to determine, and depend upon a number of different factors. Finally, I need to consider that too many attributes can increase the complexity of the decision situation, which increases the magnitude of the variance of the error term (Swait 1997). This will be exacerbated by the unknown topic of the study, which will already add considerable complexity to each choice situation.

Using the focus group results and consultations with experts, and considering the points above, three characteristics were identified to describe GDC. The following is how each attribute was described to respondents in the survey:

1. Share of Canadian GHG Reductions (Share): This is the amount of Canadian greenhouse gas (GHG) reduction targets that would be achieved using geological disposal of CO_2. The remaining GHG emissions would be reduced using a combination of energy efficiency, renewable energy, and nuclear power. The total amount of GHG reduction in Canada does not change – only the share reduced by geological disposal of CO_2.

2. Increase in your monthly electricity bill (ElecBill): This is the total dollar amount that your household monthly electricity bill would increase to cover the costs of achieving Canada's greenhouse gas (GHG) emission reduction targets. The average Canadian household pays about $80 per month for electricity.

3. Managed by (Entity): This is the entity that would be responsible for managing the long-term disposal risks, and that would have liability for geological disposal of CO_2 in Canada.

Each attribute had three possible levels. The Entity alternatives were the federal government, provincial government or industry; the potential Shares of Canadian GHG reduction targets that would be met using GDC were 5%, 20%, and 50%; and the potential increases in monthly Electricity bills were $5, $25, and $50. It is not as important that the actual potential figures be used as that a range of values are examined in order to evaluate the tradeoffs respondents make between the alternatives.

The next step was to design the experiment. The basic structure involves a series of questions that ask respondents to choose their preferred configuration of GDC from a number of potential options. Each configuration is made up of combinations of the different attribute levels. Traditionally, one of the alternatives is a 'base case' that represents no change from the status quo. However, in this study I elected to force a choice between alternative configurations of GDC, and follow the choice with a question asking respondents if their selection was actually acceptable to them. The reason for this decision was that all previous studies on public attitudes towards GDC have indicated that the technology is controversial, and if a high proportion of respondents selected the base case (no development of GDC in Canada), then the statistical significance of the experiment would be compromised. Additionally, forcing a choice makes it more difficult for respondents to employ strategic behaviour such as consistently choosing the base case. In the study on consumer attitudes toward genetically modified foods, the researchers encountered the problem of respondents choosing the status quo for every choice set, and failing to evaluate the attributes because of opposition to something in the question. This breaks the explicit choice modelling assumption that "observed choices are conditioned by attribute levels" (Burton 2001, p. 487). Finally, forcing an initial choice between alternative configurations may improve the quality of the data by forcing respondents to spend more time reading through the choices, since they do not have the option of simply selecting 'none of the above'.

The next step was to design the GDC configurations that respondents would be presented with. The experiment is based on three attributes which each have three possible levels. In total that means that there 81 potential configurations of GDC involving different combinations of these attributes and levels. A survey design that had respondents evaluate each of these 81 combinations would be a full factorial design. Although the statistical accuracy provided by a full factorial design is high, the number of questions required would exhaust respondents, quickly compromising the quality of their answers. As a result, most researchers use fractional factorial designs, which select a fraction of all potential combinations and group them into questions in a way that allows the main effects (main tradeoffs) between attributes to be estimated, using a much lower number of questions, but can not measure interaction effects between the attributes. As this is exploratory research, the loss of interaction effects is outweighed by the benefit of obtaining a greater number of observations for each choice task.

I elected to have respondents choose between three alternative configurations of GDC in each question, and selected a Shifted Triples 3^3 design for the fractional factorial (Bunch 1996, Chrzan 2000). Bunch *et al* evaluated a number of alternative design strategies and came to the conclusion that "For quantitative main effects models that might be linear or non-linear, the most efficient approach is 3-level Shifted Triples." (Bunch 1996, p. 34). This design method allowed each β coefficient to be estimated using only nine total choice sets (rather than the 27 choice sets contained in a full factorial design). This provided 1,972 observations for each choice (17,748 total observations), ensuring high statistical accuracy. The choice set design appears in Table 2.1.

Table 2.1 - Choice Set Design, Shifted Triples 3^3 Fractional Factorial

Choice	Alternative 1			Alternative 2			Alternative 3		
Set	Entity	Reduction	Elec Bill	Entity	Reduction	Elec Bill	Entity	Reduction	Elec Bill
1	Federal	5%	$5	Provincial	20%	$25	Industry	50%	$50
2	Federal	20%	$25	Provincial	50%	$50	Industry	5%	$5
3	Federal	50%	$50	Provincial	5%	$5	Industry	20%	$25
4	Provincial	5%	$50	Industry	20%	$5	Federal	50%	$25
5	Provincial	20%	$5	Industry	50%	$25	Federal	5%	$50
6	Provincial	50%	$25	Industry	5%	$50	Federal	20%	$5
7	Industry	5%	$25	Federal	20%	$50	Provincial	50%	$5
8	Industry	20%	$50	Federal	50%	$5	Provincial	5%	$25
9	Industry	50%	$5	Federal	5%	$25	Provincial	20%	$50

I used Limdep Version 8.0 to analyze the results of the discrete choice experiment using the conditional multinomial logit model. In order to model the two-part DCE question, the follow-up question asking whether the respondent's selected configuration would actually be acceptable to him or her was coded as a fourth "base case" alternative in each choice set. Some DCE models will include an alternative specific constant (ASC), if different alternatives correspond to different "brands". This was the case for example in recent research that used DCM to explore public preferences for hydrogen fuel cell or hybrid vehicles as compared with traditional gasoline vehicles (Eyzaguirre 2004, Mau 2005). However, my model did not require an ASC, as all four alternatives in each choice set corresponded to three generic alternative configurations of just one technology – GDC, and a base case. The lack of an ASC however required me to initially model four intercepts (only intercepts 1, 2 and 3 were entered into the model to avoid over-definition), in order to verify that there were no significant differences between the alternatives. Tables reporting the values for intercepts 1, 2, and 3, and their associated 95% confidence intervals can be found in Appendix E. The confidence intervals overlap, indicating that there is no significant difference between the intercepts. As a result, the models were re-coded with a single intercept. The observable utility function (Equation

2.2) was estimated for both the CAN and AB/SK sub-samples, and then for respondents with different socio-demographic and attitudinal characteristics within each of those sub-samples. The model results can be found in Chapter 3.

2.4. Multiple Regression Analysis

2.4.1. Theory

This study aimed to capture public attitudes toward a technology that is unfamiliar to most respondents. As a result, the opinions expressed have not been fully developed, and are best analyzed using a combination of qualitative and quantitative techniques, with the focus for the latter on descriptive statistics such as frequencies, means and confidence intervals. More complex statistical techniques such as linear multiple regression are appropriate for use on a supplementary basis to investigate whether a richer interpretation of the data is possible.

Linear multiple regression is used to identify relationships between a dependent variable that we are interested in, and a number of potential independent variables that may have an impact on the value of the dependent variable. The results are traditionally used to then make predictions about the value of the dependent variable given a new set of values for the independent variables. In this particular case we are interested in identifying whether or not respondents' attitudes and demographic characteristics have a significant impact on their support for GDC in Canada. The basic model form for a linear multiple regression is as follows (equation 2.3):

Equation 2.3

$$Y=a + b_1X_1 + b_2X_2 + b_3X_3$$

This is the equation for a multiple regression line through all of the observed data points. In this case Y = support for GDC, a = the intercept, each X is an attitudinal or demographic variable, such as belief in climate change or age, and each b is the slope, or Beta coefficient for that variable. My hypothesis was that attitudinal and demographic variables will affect ratings of support for GDC, while my null hypothesis was that there is no relationship between any of the attitudinal or demographic variables and support for GDC, for either model. Different models were estimated for the CAN and AB/SK segments.

2.4.2. Previous Applications to Public Attitudes toward GDC

Linear multiple regression has been used in several previous studies of public attitudes toward GDC. In her 2003 study Huijts used multiple regression to investigate the influence of perceived risks and benefits, affect and trust on Dutch attitudes toward GDC. Her dependent variable was attitude toward GDC, and her independent variables were constructed variables (each based on several survey questions) including perceived risks, perceived benefits, positive and negative affects, general trust, trust in environmental NGOs and trust in industry. Additional regressions looked at trust in more detail and investigated the effect of knowledge about GDC on attitudes.

Itaoka et al also used complex multiple regression and factor analysis in their 2004 study. Factor analysis identifies and describes clusters of respondents who have answered questions in a similar manner. Four factors were identified: respondent understanding of the effectiveness of GDC as a mitigation option for climate change, concern about risks and leakage, concern that GDC would allow the continued use of fossil fuels, and respondent awareness of responsibility for mitigation of CO_2 emissions. Together with socio-demographic variables, these factors were used as independent variables in a regression analysis, with public acceptance of GDC modelled as the dependent variable.

2.4.3. Multiple Linear Regression Design

In this regression, question 8 from the survey is used as the dependent variable. This question measured overall support for GDC in Canada, asking respondents "“Do you support or oppose the use of geological disposal of CO_2 in Canada?" (1 = strongly oppose, 7 = strongly support, or don't know).

The independent variables tested included:

Attitudinal Variables

- Importance of climate change relative to other national issues
- Belief in climate change
- Awareness of GDC
- Belief that the government should regulate CO_2 emission reductions
- Certainty about their level of support for GDC

Socio-demographic Characteristics

- Gender
- Age group
- Income group
- Province of residence
- Size of city that respondent lives in
- Education
- Whether or not the respondent has children 19 years of age or younger.

The first step was to enter the attitudinal and demographic variables into my data set, dummy coding them when appropriate. Next I examined the data structure of the dependent variables for both the CAN and AB/SK models, by observing the histograms to determine whether or not the dependent variables were normally distributed. Normal distribution is a requirement for parametric tests such as regression analysis. The histograms are presented in Appendix F. While neither distribution is completely normally distributed, they appear close enough to a normal distribution to proceed with the regression analysis.

I ran several ordinary least squares linear multiple regressions using SPSS. Initially the regression models were run with all of the above independent variables in order to evaluate the predictive significance of each variable. Those variables that were insignificant at the 95% level were then removed, and the models were re-run for both the CAN and AB/SK samples. The multiple regression results can be found in the Results chapter.

3. RESULTS AND ANALYSIS

3.1. Focus Group Participants

The Toronto focus group had eleven participants. The group included four men and seven women, and the average age was 31 years old. The Edmonton focus group had nine participants, including six men and three women, with an average age of 40. The following charts show the age distribution, education level, and self-assessed knowledge of GDC of the focus group participants.

Figure 3.1 - Age Distribution of Focus Group Participants

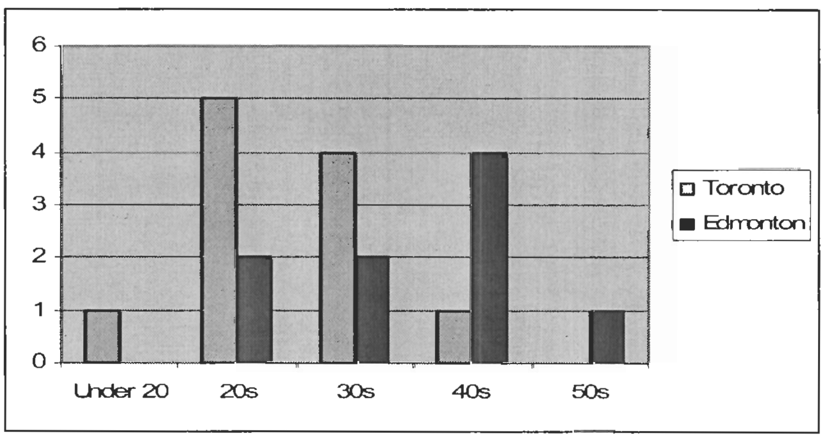


Figure 3.2 - Education Level of Focus Group Participants

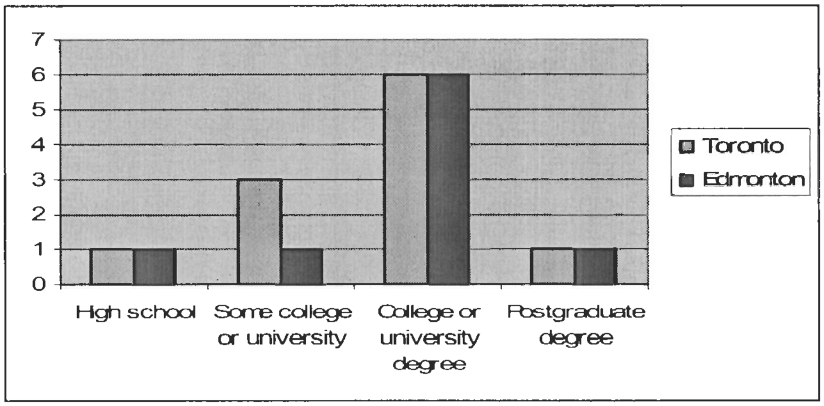
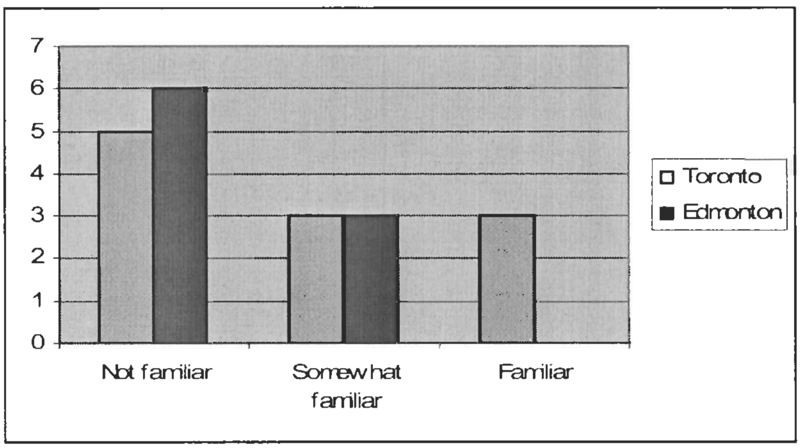


Figure 3.3 - Prior Knowledge of GDC of Focus Group Participants



Overall, the participants in both focus groups included ten men and ten women. The age range was 19 to over 50 years old, with an average age of 35. The participants were generally well educated, but there was a wide range of familiarity with environmental issues, and self-assessed familiarity with GDC was low. While the goal of focus groups is not to be totally representative of the population, these groups included a wide range of Canadians with different viewpoints, and so they were very useful in identifying the diverse opinions that Canadians may have regarding GDC.

3.2. Focus Group Results

The focus group discussions were designed to answer 12 key research questions about participants' climate change beliefs, perceptions about CO_2 and GDC, perceived benefits and risks of GDC, support for GDC both before and after receiving information about the technology, and opinions about how GDC should be developed in Canada. The results were used to guide the development of questions for the national survey. For the sake of brevity only the key results are discussed here; a thorough evaluation of the focus groups, including illustrative quotes from participants, can be found in Sharp 2005.

Participants in both Toronto and Edmonton are generally familiar with what CO_2 is, and they feel that it is somewhat dangerous to their health. However, participants seemed to perceive CO_2 as more dangerous than it actually is, and there was some confusion about what environmental problems CO_2 emissions are responsible for, with many participants believing that they cause ozone layer destruction and acid rain. As a result, public education should stress that CO_2 is only dangerous to human health in excess concentrations, and is most of concern because of its impact on the climate.

Participants in both Toronto and Edmonton strongly agreed that climate change is an important environmental problem and that GHG emissions need to be reduced in order to avoid serious climate change, with these beliefs slightly stronger in Toronto. Familiarity with GDC was low, and when presented with the term 'geological carbon dioxide storage' (the wording used in the focus groups), many focus group participants could guess what it generally referred to, but the initial connotation was negative.

Overall attitudes toward GDC were slightly negative in Toronto, and moderately negative in Edmonton. The impact of additional information on support for GDC was tested, and Toronto participants moved from neutral to slightly opposed when given more detailed information, while in Edmonton participants started off and remained somewhat opposed to the technology. Participants did not have a more positive attitude toward GDC if the CO_2 was biomass-derived, rather than fossil fuel-derived.

Participants were also asked about the perceived risk of GDC compared with both relatively accepted waste disposal technologies and nuclear waste storage. GDC was perceived to be much less risky than nuclear waste storage, much more risky than a non-hazardous waste landfill, and somewhat more risky than acid gas injection. Participants were also asked which technologies to reduce GHG emissions they would like to see used in Canada; wind and solar power and energy conservation were unsurprisingly the most favoured technologies, while GDC was the second last choice, with only nuclear power less favoured.

The greatest benefits that participants saw from GDC were the reductions in CO_2 emissions and the risk of climate change; the fact that it was a first step toward reducing GHG emissions and a positive example to other countries; and the ability to use CO_2 in EOR. Participants' greatest concerns were that storing CO_2 underground was not dealing with the underlying problem of excessive CO_2 emissions, and that energy efficiency and renewable energy should be used instead; that the CO_2 would leak, posing a safety risk and contaminating land, air, and water; and that there would be unknown negative effects in the future. A few poignant comments illustrate participants' concerns:

> "It's like kids shoving dirty clothes under the bed" – Brad, Edmonton
>
> "Nothing stays somewhere forever" – Marcia, Toronto
>
> "It gives us permission to keep going with our current lifestyle when what we need is a radical change" – Lori, Toronto

Although many respondents in both cities believed that GDC is not the right solution to the climate change problem, after discussion many were also willing to admit that people might not make all of the necessary lifestyle changes in time, leading to a role for GDC as a short-term emission reduction measure, but not as a replacement for reducing emissions at the source and making lifestyle changes.

Participants were also asked what actions could be taken to reduce their concerns about GDC. First, participants wanted more information about all aspects of GDC. They also wanted the technology to be extensively and exhaustively researched. Participants wanted to see the technology strongly regulated and possibly even run by the government, rather than industry. Participants also suggested that a separate, independent body be in charge of the technology, and manage GDC as a non-profit activity, and that expert scientists and environmental organizations take on an official watchdog capacity.

The other very important concern for most respondents is that they would have to see that long-term emission-reduction and lifestyle-changing solutions were being implemented in order to support the use of GDC in the short term. A somewhat surprising result was that support for GDC was low if it would be used to meet only 5% of Canada's Kyoto Protocol targets, but was higher if the technology was used aggressively to meet a higher proportion of Canada's GHG emission reduction target, in which case the rewards were seen as potentially balancing out the risks, cost, and effort.

Finally, participants in Edmonton had a sense that decisions about GDC were going to be made from Ontario, which made them feel helpless and defensive. Citizens in these provinces need to be involved in the decision process. A NIMBY (not in my backyard) attitude was revealed by the immense distances that Edmonton participants wanted between their homes and geological CO_2 disposal sites, which could likely be minimized if the technology is promoted by Alberta's government and industry (rather than the federal government) and if local benefits such as enhanced resource recovery are emphasized.

One of the unexpected results from the focus groups was the support for EOR. Many participants made positive comments about EOR, and it was mentioned as one of the greatest benefits of the technology. However, this opinion was not universal; a number of participants also referred to the use of CO_2 to extract additional fossil fuels as a 'vicious cycle'.

A second unexpected result was the low support for GDC among Edmonton participants. Although we expected them to express more concerns about local risks than Toronto participants, and possibly to demonstrate a NIMBY attitude, the low support for GDC was still a surprise. This is because the oil and gas industry is extremely important to Alberta's economy, and this technology holds the hope of extending the use of fossil fuels, and thus the benefits that Alberta derives from their extraction. However, this benefit was hardly mentioned by the Edmonton participants, and does not appear to have factored into their evaluation of GDC.

3.3. Survey Sample

Synovate, the market research firm hired to provide the two survey samples (CAN and AB/SK), provided a sample for each that was representative of the appropriate population on gender, age, income, and education level (with the consideration that only Canadians over 18 years of age were eligible for the survey). Of the total sample of 8,500 potential respondents provided by Synovate, 1,972 completed the survey – a 23.2% response rate. This compares very positively with Synovate's expected response rate of 13.5%, which we attributed to the interesting subject matter and the fact that the survey was advertised as university research rather than commercial market research.

The final survey samples were slightly older and more male than the populations they were drawn from. For the CAN sample the average age was 50.8 years, and 45.8% of the respondents were female. For the AB/SK sample, the average age was slightly younger at 47.7 years, and 47.9% of the respondents were female. Figures 3.4 and 3.5 show the income and education distributions for both samples.

Figure 3.4 - Income Distribution for the CAN and AB/SK Survey Samples

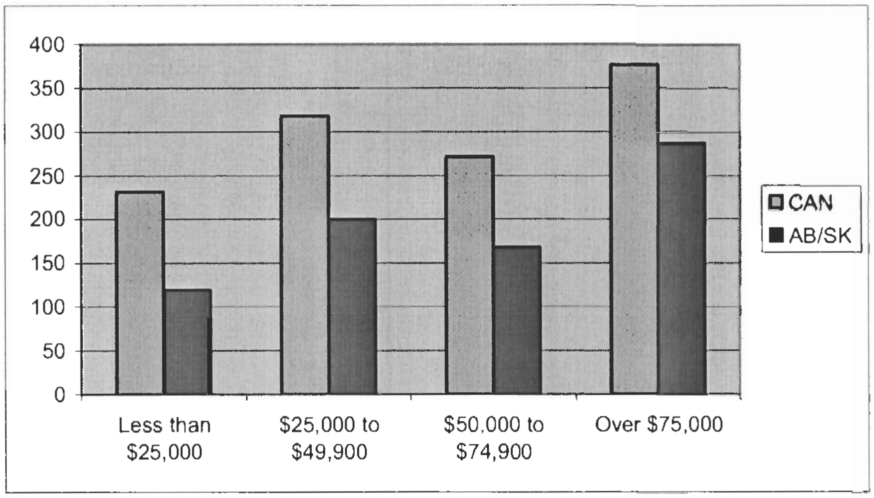
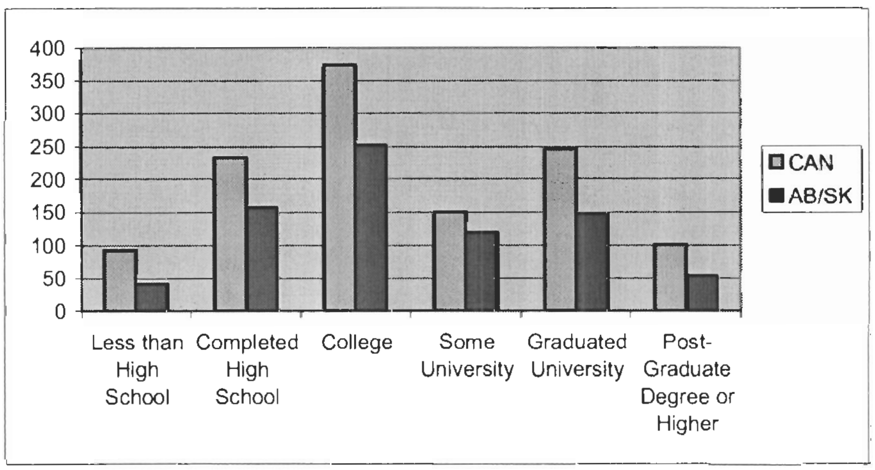


Figure 3.5 - Education Distribution for the CAN and AB/SK Survey Samples



3.4. Survey Results by Research Question

3.4.1. Summary of Results

Table 3.1 below presents a summary of the national survey results. Each research question is discussed in more detail in the following section. The full survey instrument is available in Appendix D.

Table 3.1 - Summary of National Survey Results

QUESTION	CAN	AB/SK
1. Importance of the following issues (1=low, 7=high)		
Improving Education	6.08	6.00
Improving Health Care	6.38	6.17
Increasing International Aid	4.23	4.07
Reducing Crime	6.11	6.18
Reducing Poverty	5.88	5.76
Improving the Economy	5.87	5.77
Reducing the National Debt	5.53	5.48
Reducing Taxes	5.66	5.68
Promoting Recycling	5.87	5.77
Reducing Air Pollution	6.14	5.90
Controlling Acid Rain	5.71	5.40
Reducing Water Pollution	6.20	6.08
Reducing Climate Change	5.53	5.16
Cleaning up Hazardous Waste	6.12	5.99
Saving Endangered Species	5.57	5.46
2a. % that have heard of GDC	No: 68.2 Yes: 10.5 Unsure: 21.4	No: 67.6 Yes: 15.4 Unsure: 17.1
2b. Environmental Concern that GDC Reduces (% of sample selecting each concern, multiple responses permitted)		
Respondents who only selected Climate Change	5.6	6.2
Ozone Depletion	48.8	50.8
Climate Change	47.8	50.5
Smog	43.9	40.6
Acid Rain	39.8	37.2
Water Pollution	24.8	21.5
Toxic Waste	19.2	14.5
Unsure	31.6	30.5
2c. Opinion about climate change (% of sample)		
Global warming has been established as a serious problem and immediate action is necessary	43.3	29.1
There is enough evidence that global warming is taking place and some action should be taken	36.7	39.2
We do not know enough about global warming and more research is necessary before we take action	15.6	23.3
Concern about global warming is unwarranted	3.3	7.1
No opinion	1.2	1.3

QUESTION	CAN	AB/SK
3. Government regulations should be implemented to require individuals and businesses to reduce their emissions of GHGs (1=strongly disagree, 7=strongly agree)	5.85	5.29
4. Agreement or Disagreement with the Following Statements (1=strongly disagree, 7=strongly agree)		
This technology is good because it may allow GHG emissions to be reduced more quickly and at a lower cost than other alternatives	4.63	4.53
I am concerned about potential harm to plants and animals near the disposal site or to underground organisms	5.18	5.13
I am concerned about the potential safety risks of a large CO_2 leak	5.29	5.22
This technology is good because it can be a bridging technology to achieve short-term reductions in GHG emissions while we develop long-term alternatives	5.01	4.89
This technology is good because it would allow GHG emissions to be reduced without requiring Canadians to make lifestyle changes	4.21	4.13
This technology is good because it can be used to increase oil and gas production, and reduce water use in the production process	4.66	4.82
I am concerned that there may be unknown future impacts	5.60	5.45
This technology is good because it would allow Canadians to continue to produce and use fossil fuels, without releasing GHG emissions	4.43	4.46
I am concerned about potential contamination of groundwater	5.36	5.33
I am concerned that this is the wrong way to address the climate change problem, and that we should be reducing energy use or developing renewable energy instead	4.96	4.77

QUESTION	CAN	AB/SK
5. Which technologies would you use if designing a plan to address climate change? (% of sample likely to use / not likely to use / not sure)		
Energy Efficient Appliances	92 / 2.3 / 5.7	93.3 / 2.3 / 4.4
Energy Efficient Cars	91.5 / 2.5 / 6.0	92.5 / 2.9 / 4.7
Solar Energy	91.5 / 2.9 / 5.6	91.6 / 2.7 / 5.7
Wind Energy	90.3 / 3.9 / 5.8	90.9 / 2.5 / 6.6
Hydroelectricity	84.3 / 7.9 / 7.8	82.7 / 10.3 / 7.0
Bioenergy/Biomass	72.0 / 11.7 / 16.3	71.2 / 14.6 / 14.1
Carbon Sinks	68.7 / 14.4 / 17.0	68.6 / 14.8 / 16.6
GDC	55.5 / 27.7 / 16.9	55.8 / 30.5 / 13.7
Nuclear Energy	36.2 / 52.4 / 11.4	39.5 / 48.1 / 12.4
Iron Fertilization	21.5 / 53.4 / 25.1	15.5 / 59.4 / 25.1
6. How much of a risk do you believe that each of the following technologies poses to the environment and human health? (1=very large risk, 7=no risk at all)		
Oil and gas industry operations (production and refining)	2.70	2.95
Wind turbines	6.34	6.33
GDC	3.65	3.49
Coal-burning power plants	2.26	2.63
Nuclear power	2.45	2.51
7. Overall, do you think that this technology would have a net positive or negative effect on the environment? (1=highly negative, 7=highly positive)	4.09	4.15
8. Do you support or oppose the use of GDC in Canada?(1=strongly oppose, 7=strongly support, or don't know)	4.44	4.29
9. How sure or unsure are you about your answer (1=very unsure, 7=very sure)	4.99	5.07
10. (Asked only of those who opposed the use of GDC in Canada). Agreement or disagreement with the following statements (1=strongly disagree, 7=strongly agree)		
I am concerned about the risks of GDC	5.46	5.35
I am fundamentally opposed to GDC	3.94	3.94

QUESTION	CAN	AB/SK
11. (Asked only of those who opposed the use of GDC in Canada). Which of the following would reduce your opposition to GDC? (% of sample, multiple responses could be selected)		
More information	80.3	77.0
Involvement of independent experts and NGOs	63.1	57.6
No reduction in spending on renewables and energy efficiency	62.7	61.3
Strong regulation and monitoring	61.3	62.8
More demonstration projects	46.9	43.8
Public consultation process	43.7	40.7
Knowledge that renewables and efficiency can't achieve GHG reduction targets	40.5	37.8
Decreases in Cost	33.6	30.6
12. If almost all other countries reject GDC would you support or oppose its use in Canada? (1=strongly oppose, 7=strongly support, or don't know)	3.15	3.18
13. If almost all other countries use GDC would you support or oppose its use in Canada? (1=strongly oppose, 7=strongly support, or don't know)	5.35	5.1
15. Most important characteristic of GDC projects	1. Managing entity	1. Managing entity
	2. Share of CO_2 reductions	2. Electricity bill increase
	3. Electricity bill increase	3. Share of CO_2 reductions
16. Support after reading a positive newspaper article (1=strongly oppose, 7=strongly support, or don't know)	5.22	5.03
16. Support after reading a negative newspaper article (1=strongly oppose, 7=strongly support, or don't know)	3.65	3.70

3.4.2. What are public opinions about climate change?

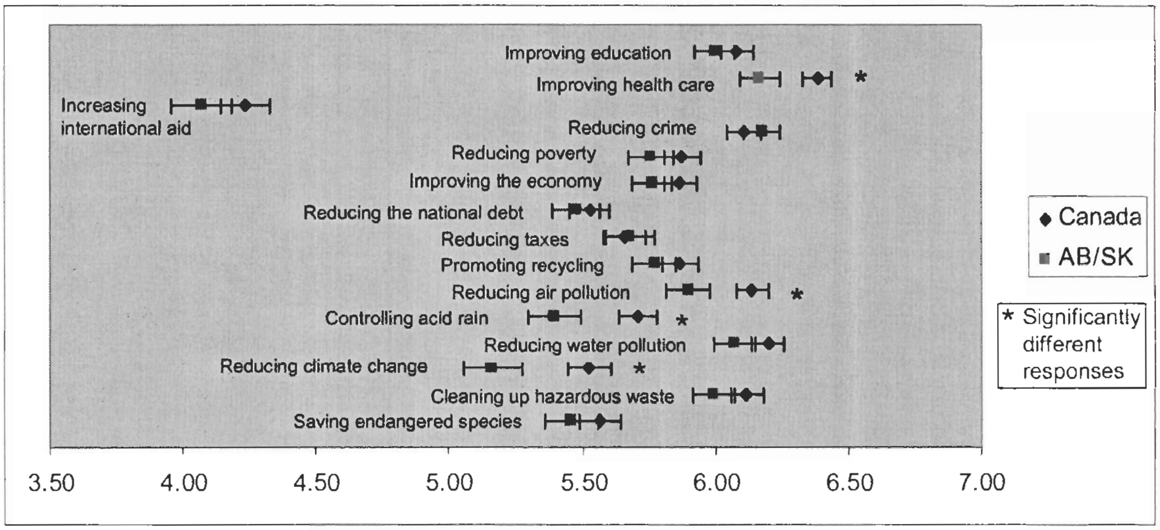
The first question in the survey provided respondents with a list of 15 national issues, of which seven were environmental issues, and asked them to rate each issue from 'not important at all' to 'extremely important'. Table 3.2 shows how both the AB/SK and

CAN sub-samples ranked the issues, while Figure 3.6 shows how the ratings varied across the issues, and indicates which issues had statistically significant differences in ratings between the two regional sub-samples.

Table 3.2 - Ranking of National Issues by Geographic Sub-Sample

	AB/SK	CAN
1	Reducing crime	Improving health care
2	Improving health care	Reducing water pollution
3	Reducing water pollution	Reducing air pollution
4	Improving education	Cleaning up hazardous waste
5	Cleaning up hazardous waste	Reducing crime
6	Reducing air pollution	Improving education
7	Promoting recycling (tie)	Reducing poverty
8	Improving the economy (tie)	Promoting recycling (tie)
9	Reducing poverty	Improving the economy (tie)
10	Reducing taxes	Controlling acid rain
11	Reducing the national debt	Reducing taxes
12	Saving endangered species	Saving endangered species
13	Controlling acid rain	Reducing the national debt (tie)
14	Reducing climate change	Reducing climate change (tie)
15	Increasing international aid	Increasing international aid

Figure 3.6 - Ratings of National Issues by Geographic Sub-Sample



Importance of Various Canadian Social Issues 1 = Not important, 7 = Extremely important
Means and 95% Confidence Intervals

Improving health care was clearly the most important issue overall, ranked first by the CAN sample, and second by the AB/SK sample. Several environmental issues were very important to both samples, such as reducing water and air pollution, cleaning up hazardous waste, and promoting recycling, while others were considered less important than most of the issues, such as saving endangered species and reducing climate change. The latter was the lowest rated environmental issues, and the second lowest rated national issue overall. Only increasing international aid was considered less important. Most issues were rated similarly by both geographic sub-samples, and only four issues had statistically significant differences in ratings: improving health care, reducing air pollution, controlling acid rain, and reducing climate change. All four of these issues were more important to the CAN sample than to the AK/SK sample.

The results are consistent with those from other Canadian surveys of national issues. An April 2005 Environics Research Group poll found that 21% of Canadians think healthcare is the most important national issue, while only 4% believe that the environment/pollution is the most important (CBC News 2005). This mirrored results from 2004 and earlier (Environics Research Group 2004). Americans were asked similar questions in recent surveys about GDC by Carnegie Mellon University and MIT. In the Carnegie Mellon study participants ranked improving education and improving healthcare as the most important issues facing the United States, while reducing climate change was ranked last of the 15 social and environmental issues (Palmgren 2004). In the MIT study terrorism and health care were the two most important issues, while the environment ranked 13th of 22 issues. Of ten environmental issues, water pollution was again considered the most important, while climate change ranked sixth (Curry 2004).

The survey also asked respondents to indicate which of a series of statements about climate change came closest to their opinion. The CAN sub-sample was more likely to believe that climate change is a serious problem requiring at least some action than the AB/SK sample, with 43.3% of the CAN sub-sample agreeing that "climate change has been established as a serious problem and immediate action is necessary", and a further 36.7% believing that "there is enough evidence that climate change is taking place and some action should be taken". Meanwhile, only 29.1% of the AB/SK sub-sample agreed with the first statement, and 39.2% agreed with the second statement. However, despite the low importance rating that climate change received compared to other national issues in the first survey question, nearly 80% of CAN respondents and nearly 70% of AB/SK respondents still thought that immediate action or some action was warranted on climate change. Most of the remainder thought that more research was necessary, and only 3.3% of the CAN sub-sample and 7.1% of the AB/SK sub-sample thought that concern about climate change was unwarranted. This question was based on a similar question in the MIT survey, so that the results could be compared to American responses. Only 17% of the American respondents agreed that climate change has been established as a serious problem and immediate action is necessary, while 36% believed that there is enough evidence that climate change is taking place and some action should be taken. Totalled, only 53% of Americans thought that immediate action or some action was warranted on climate change – a much lower percentage than in either the CAN or AB/SK sample (Curry 2004).

Respondents were also asked if they agreed or disagreed that government regulations should be implemented to require individuals and businesses to reduce their emissions of GHGs. On a 7-point scale, where 1=strongly disagree and 7=strongly agree, the CAN sub-sample mean was 5.85, and the AB/SK sub-sample mean was 5.29, signifying moderate agreement with the statement across both groups. The responses were statistically different at the 95% confidence level, indicating that the AB/SK sub-sample was slightly less supportive of the use of government regulations targeting climate change.

3.4.3. How familiar is the public with GDC?

The survey asked respondents whether they had previously heard of GDC, and to test whether those who responded affirmatively were actually familiar with the technology, a follow-up question asked respondents to indicate which environmental concerns GDC would reduce. Of the CAN sub-sample, 10.5% indicated that they had heard of GDC, 21.4% were unsure, and the remainder had not. In the AB/SK region, slightly more respondents had heard of the technology: 15.4% had heard of GDC, while 17.1% were unsure. These figures are higher than in the United States, where only 4% of respondents to the MIT survey indicated that they had heard of or read about ‘carbon capture and storage’ in the previous year (Curry 2004). Knowledge of the technology is higher in Japan, where 9% of respondents to a 2003 survey about GDC know ‘carbon capture and storage’ to a certain extent, and a further 22.2% have heard of or read about it (Itaoka 2004). GDC is best known in Europe, where 42% of respondents to a 2003 Dutch survey had at least a small amount of knowledge of ‘carbon dioxide storage’ (Huijts 2003).

However, a number of those who believe that they have heard of GDC are not actually aware what problem the technology addresses. Only 6.2% of those in the AB/SK sub-sample who had heard of GDC correctly identified only climate change as the environmental concern GDC reduced, while the figure was 5.6% for the CAN sample. While these figures were very low, they were still much higher than those obtained in the MIT survey, from which this question was adopted. Less than 0.5% of American respondents answered the question correctly, and those who indicated that they had heard of GDC were no more likely to answer correctly (Curry 2004).

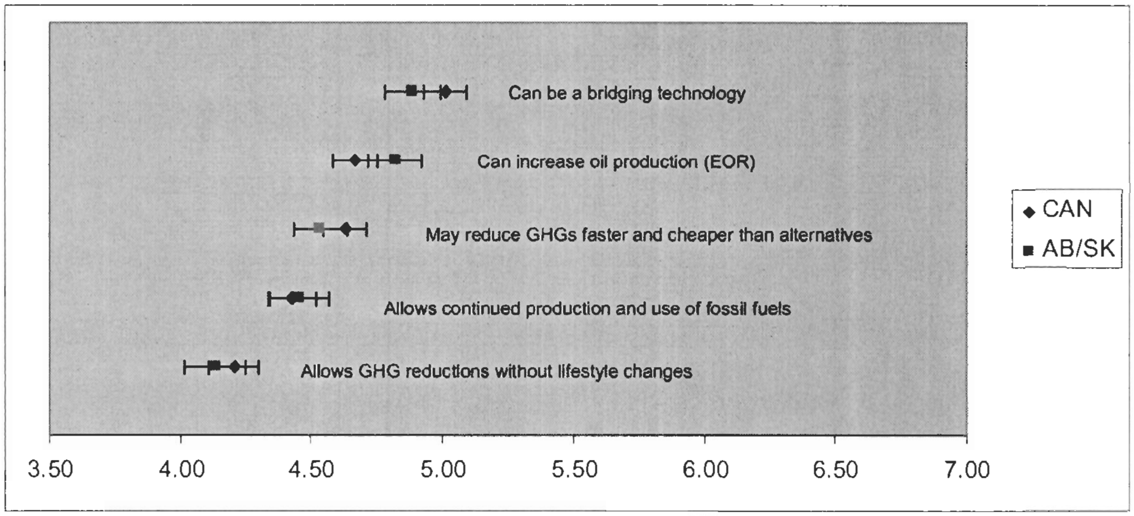
An analysis of the environmental issues that respondents who had heard of GDC thought that it would reduce shows that there was general awareness that it had to do with some sort of air pollution, rather than water pollution or toxic waste. However, echoing the confusion between climate change and ozone depletion that was revealed during the focus groups, more respondents thought that GDC would reduce ozone depletion (48.8%

of the CAN sub-sample and 50.8% of the AB/SK sub-sample) than climate change (47.8% of the CAN sub-sample and 50.5% of the AB/SK sub-sample) (respondents could select multiple issues). Other environmental concerns that received large number of votes were smog (43.9% of the CAN sub-sample and 40.6% of the AB/SK sub-sample) and acid rain (39.8% CAN and 37.2% AB/SK). Water pollution (24.8% CAN and 21.5% AB/SK and toxic waste (19.2% CAN and 14.5% AB/SK) were selected by the smallest number of respondents. 'Unsure' was the final option, and it was selected by 31.6% of the CAN sub-sample and 30.5% of the AB/SK sub-sample. The results clearly show that there is very low public awareness of GDC and its purpose, and that the name alone will not help the public to correctly determine what the technology does.

3.4.4. What do the public consider to be the greatest benefits of GDC?

Respondents were presented with ten statements (five positive and five negative) representing reasons why some people supported or opposed GDC, and were asked to indicate how strongly they agreed or disagreed with each statement on a scale of 1 to 7, where 1=strongly disagree and 7=strongly agree. Figure 3.7 shows how respondents rated the benefits.

Figure 3.7 - Ratings of the Benefits of GDC by Geographic Sub-Sample



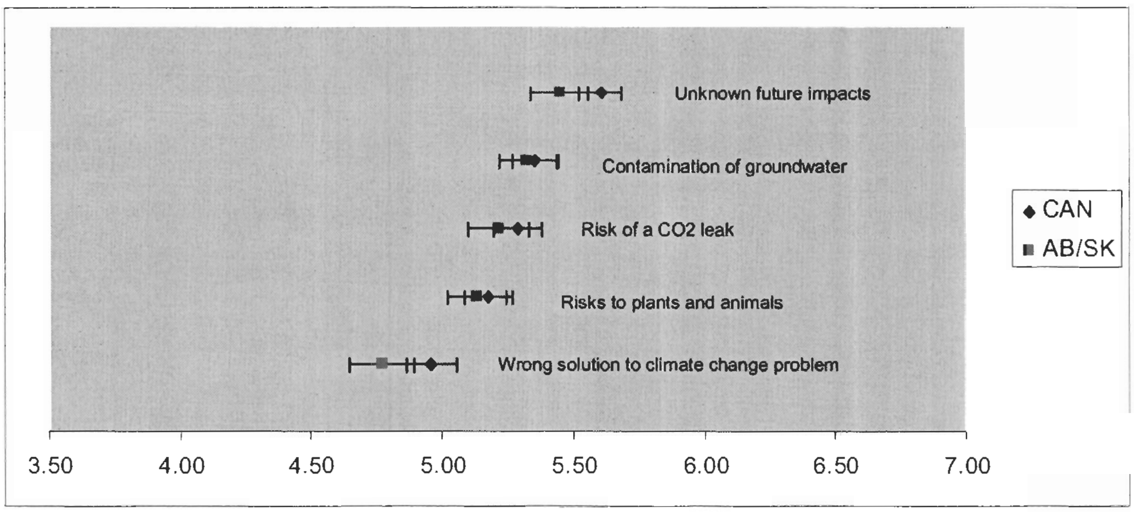
Rating of Benefits of GDC 1 = Strongly disagree, 7 = Strongly agree
Means and 95% Confidence Intervals

The public moderately agreed with the statement "one reason why this technology is good is that it can be a bridging technology to achieve short-term reductions in GHG emissions while we develop other long-term alternatives". The remainder of the benefit statements received slight agreement, although "would allow GHG emissions to be reduced without requiring Canadians to make lifestyle changes" received a nearly neutral rating. Opinions were more polarized on this statement, as some respondents believed that this was a significant benefit, while others believed it was a negative characteristic. This was reflected in the focus groups as well, where a number of participants expressed the belief that the public had a responsibility to make lifestyle changes, and shouldn't be given the option of an easy solution. The opportunity to use CO_2 in EOR continued to receive support, especially in Alberta and Saskatchewan. The ratings were not significantly different at the 95% confidence level between the CAN and AB/SK sub-samples for any of the statements.

3.4.5. What are the public's greatest concerns about GDC?

The public's ratings of the five negative statements were used to identify their greatest concerns about GDC. Figure 3.8 shows how respondents rated each of the five statements.

Figure 3.8 - Ratings of Concerns about GDC by Geographic Sub-Sample



Rating of Concerns about GDC 1 = Strongly disagree, 7 = Strongly agree
Means and 95% Confidence Intervals

Respondents were most concerned about the unknown future impacts of GDC. Almost all of the concerns were rated as moderately important. The exception was the statement "I am concerned that this is the wrong way to address the climate change problem, and believe that we should be reducing energy use or developing renewable energy instead", which only received slight agreement. This result was a surprise, because concern about this issue was very high in the focus groups. Strong agreement with this statement would likely have indicated that the public was fundamentally opposed to GDC, so this result bodes well for the political feasibility of GDC in Canada.

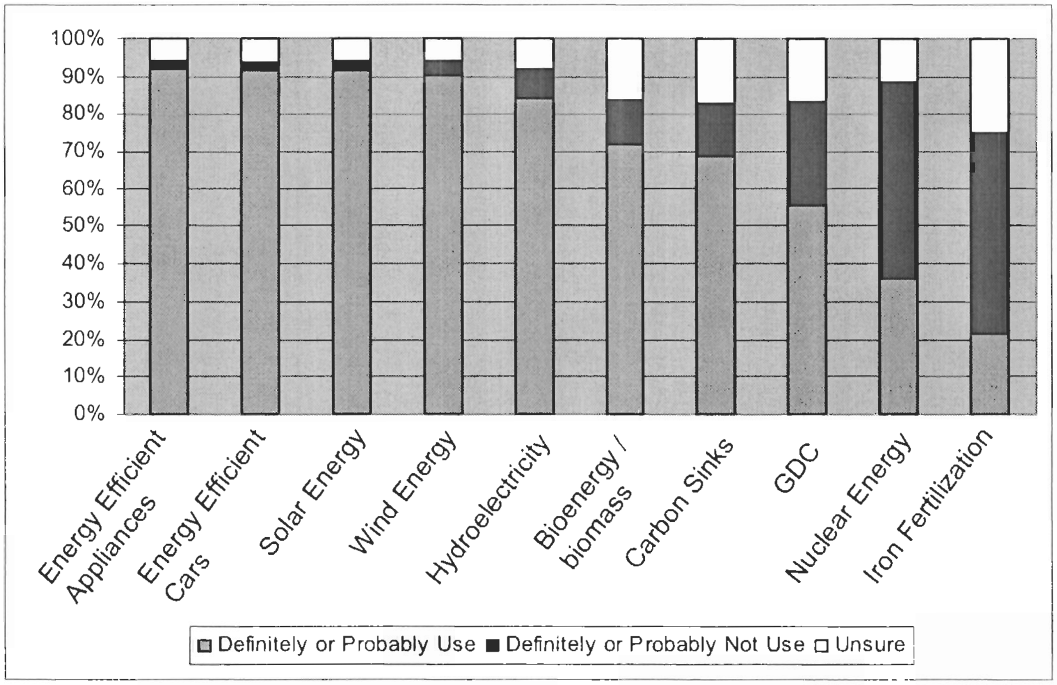
In general there was lower agreement with the benefit statements than with the risk statements – the only exception being that the "bridging technology" (and for the AB/SK sub-sample, the "EOR") positive statements received stronger agreement than the "wrong solution to the climate change problem" negative statement. This confirms that the public is more concerned with the potential risks than the potential benefits at this time.

3.4.6. Which energy and efficiency technologies would the public like to see used to reduce GHG emissions?

In order to determine the public's basic preferences among different energy and efficiency technologies, and how GDC compared to other technologies, respondents were asked which of ten technologies they would use if they were responsible for designing a plan to address climate change. For each technology respondents received a short description and indicated whether they would definitely, probably, probably not, or definitely not use it, or were not sure. Figures 3.9 and 3.10 show the results graphically for the CAN and AB/SK sub-samples respectively, and Table 3.3 presents the full numerical results. It must be stressed that the responses only provide information on the public's perceptions of the desirability of different technologies. Obviously the technologies have very different costs, efficiencies and feasibilities, and the public would likely change their preferences if full information were presented about each technology[1].

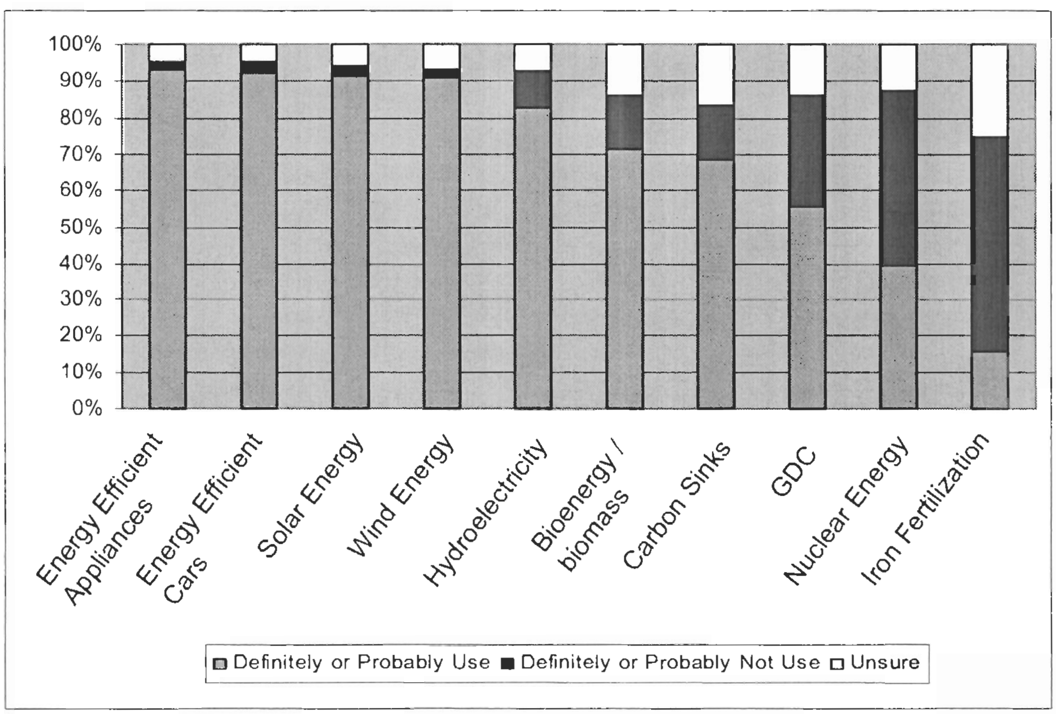
[1] Palmgren (2004) asked respondents for their willingness to pay for different energy packages that would reduce CO_2 emissions by 50%, while Curry (2004) tested the impact of providing price information on support for a variety of energy technologies.

Figure 3.9 - Perceptions of Different Energy Technologies (CAN)



Energy Technologies that Respondents Would Use in a Climate Change Strategy

Figure 3.10 - Perceptions of Different Energy Technologies (AB/SK)



Energy Technologies that Respondents Would Use in a Climate Change Strategy

Table 3.3 - Technologies that Respondents Would Use When Designing a Climate Change Strategy

Technology	Definitely or Probably Would Use (% CAN / AB/SK)	Definitely or Probably Would Not Use (% CAN / AB/SK)	Not Sure (% CAN / AB/SK)
Energy Efficient Appliances	92.0 / 93.3	2.3 / 2.3	5.7 / 4.4
Energy Efficient Cars	91.5 / 92.5	2.5 / 2.9	6.0 / 4.7
Solar Energy	91.5 / 91.6	2.9 / 2.7	5.6 / 5.7
Wind Energy	90.3 / 90.9	3.9 / 2.5	5.8 / 6.6
Hydroelectricity	84.3 / 82.7	7.9 / 10.3	7.8 / 7.0
Bioenergy/Biomass	72.0 / 71.2	11.7 / 14.6	16.3 / 14.1
Carbon Sinks	68.7 / 68.6	14.4 / 14.8	17.0 / 16.6
GDC	55.5 / 55.8	27.7 / 30.5	16.9 / 13.7
Nuclear Energy	36.2 / 39.5	52.4 / 48.1	11.4 / 12.4
Iron Fertilization	21.5 / 15.5	53.4 / 59.4	25.0 / 25.1

The results were very similar between the two geographic sub-samples, with both groups ranking the technologies identically. Energy efficiency measures were the most popular, followed by renewable energy technologies. Over half of the respondents would definitely or probably use GDC in a climate change plan, while only a little over a quarter of respondents probably or definitely would not use it, indicating good support for the technology's inclusion in Canada's climate change strategy. Nuclear energy was opposed by approximately half of the sample, and iron fertilization of the oceans was the most unpopular option by a significant margin.

This question was based on a similar question from the MIT survey, allowing the results to be compared. In the MIT survey renewable energy and energy efficiency measures were the most popular selections for a climate change plan, but the American sample favoured nuclear power (39% would definitely or probably use it in a climate change plan) over GDC. Only 29% of the American sample would definitely or probably use GDC in a climate change plan – much lower than in the Canadian sample. However, a much larger percentage of Americans than Canadians selected Not Sure for relatively unfamiliar technologies (even though the same descriptive phrases were used), and as a result, most of the use percentages are significantly lower than the Canadian figures (Curry 2004).

3.4.7. How risky does the public perceive GDC to be, in comparison with other common energy technologies?

In order to understand the perceived riskiness of GDC, respondents were asked to rate GDC and four other energy technologies on a scale of 1 to 7, where 1 is not at all risky, and 7 is extremely risky. The results are shown in Figures 3.11 and 3.12 and in Table 3.4.

Figure 3.11 - Perceived Risk of GDC Compared to Other Energy Technologies (CAN)

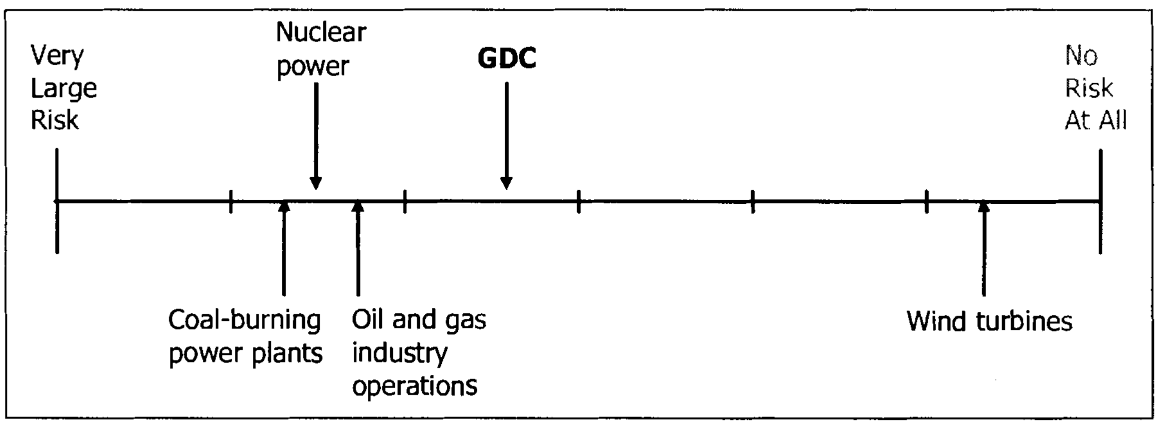


Figure 3.12 - Perceived Risk of GDC Compared to Other Energy Technologies (AB/SK)

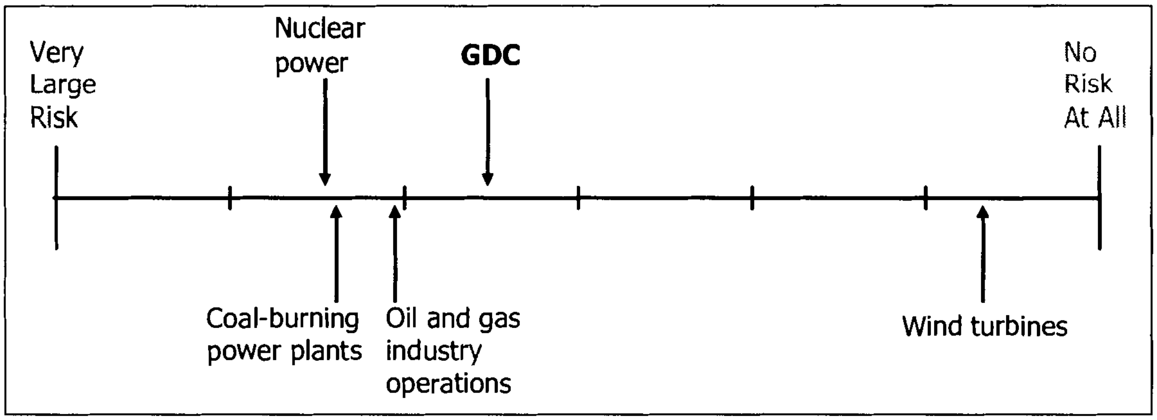


Table 3.4 - Perceived Risk of GDC Compared to Other Energy Technologies

	CAN	AB/SK	Significantly Different (95% Confidence Level)
Wind turbines	6.34	6.33	No
GDC	3.65	3.49	No
Oil and gas industry operations (production and refining)	2.70	2.95	Yes
Nuclear power	2.45	2.51	No
Coal-burning power plants	2.26	2.63	Yes

The results show that wind turbines are viewed as a nearly risk-free technology, which makes sense given the public's positive perception of wind energy (as shown in Table 3.3). What was surprising was that GDC was seen as less risky then oil and gas industry operations, nuclear power, or coal-burning power plants. The only technologies that received significantly different responses from the two geographic sub-samples were oil and gas industry operations and coal-burning power plants, both of which were ranked as less risky by those living in Alberta and Saskatchewan, where these are very common technologies. While coal-fired power plants are not always popular, either in Alberta and Saskatchewan or in the rest of Canada, they are tolerated by the public. GDC is seen as substantially less risky (with a nearly neutral risk rating) than any of these other three common technologies, indicating that it is also likely to be accepted by the public.

3.4.8. What are the public's overall attitudes toward GDC?

Several questions were asked near the conclusion of the first part of the survey to determine the public's overall attitudes toward GDC. First, respondents were asked if after considering all of the potential benefits and potential risks of GDC, they thought that the technology would have a positive or negative effect on the environment (where 1 = highly negative and 7 = highly positive). Overall, respondents thought that GDC would have a very slightly positive net impact on the environment, with a mean rating of 4.09 from the CAN sub-sample and 4.15 from the AB/SK sub-sample, although these results were not statistically different from each other.

The next question asked respondents whether they supported or opposed the use of GDC in Canada, where 1 indicated strong opposition and 7 indicated strong support. The mean ratings were 4.44 by the CAN sub-sample and 4.29 by the AB/SK sub-sample, although these results were also not statistically different from each other, and 10.6% of the CAN sub-sample and 6.6% of the AB/SK sub-sample responded that they did not know. These responses indicate that the public is slightly supportive of the use of GDC in Canada. Respondents were also asked how certain or uncertain they felt about their answer, where 1 = very uncertain and 7 = very certain. The mean responses were 4.99 for the CAN sub-sample and 5.07 for the AB/SK sub-sample (not statistically different), indicating that the public is somewhat certain of their opinion, but not completely set on it. Together, these ratings indicate that GDC has potentially high political feasibility, as the public's slight support could probably be further increased by addressing the key concerns that have been raised.

A number of other researchers have looked at the public acceptability of GDC around the world. In the Unites States, Palmgren (2004) found that survey respondents were slightly opposed to GDC, rating it 3.3 on a scale where 1 = completely oppose and 7 = completely favour. In most other countries, there was slight support for GDC. In Japan, the public is slightly supportive of promoting GDC as part of a climate change program, although they are slightly negative about the implementation of each specific type of CO_2 disposal, including both on and offshore GDC, and lake and dilution style ocean disposal (Itaoka 2004). In the United Kingdom, a survey of 212 air travelers found that 38% liked or really liked GDC, 27% were neutral, 26% didn't like it or didn't like it at all, and 8% didn't know (Shackley 2004). In the Netherlands, Huijts (2003) found that the public was neutral to a bit positive about the usefulness of GDC and its suitability as a solution to the climate change problem, and was neutral to positive concerning the desirability of GDC in general. However, people were neutral to negative about GDC below their own residential area. The results from this Canadian survey are generally slightly more positive than other public acceptability findings from around the world, particularly in comparison with the United States.

3.4.9. For those who do not support GDC, how strong is their opposition, and what actions could be taken to reduce it?

After learning what the public's level of support is for GDC, the next step is to determine why those who do not support GDC in Canada are opposed, whether or not their opinion may change in the future, and what factors could lead them to become more supportive of the technology. Therefore, respondents who indicated that they were opposed to GDC (those who ranked their support as 3 (slight opposition) or below) were asked to indicate whether they agreed or disagreed with the following two statements, where 1 = totally disagree and 7 = totally agree:

1. I am concerned about the risks of geological disposal of CO_2
2. I am *fundamentally* opposed to geological disposal of CO_2

The mean responses to the first statement were 5.46 for the CAN sub-sample and 5.35 for the AB/SK sub-sample, although these responses were not statistically different. Both groups therefore moderately agreed that they were concerned about the risks of GDC. However, the mean response by both sub-samples to the statement enquiring about fundamental opposition to GDC was 3.94, which indicates that there was very slight disagreement overall with this statement. These results show that those who do not support GDC in Canada are generally concerned about the risks, and not morally or fundamentally opposed to the technology in the manner that some people are opposed to nuclear energy. Itaoka (2004) asked a similar question in Japan and also obtained similar results; only 17.6% of those opposed to carbon capture and disposal indicated that they were fundamentally opposed, while 82.4% responded "it depends".

Given that those who are opposed to GDC in Canada generally have that opinion because they are concerned about the risks, the next step is to understand what actions could be taken that would make them more comfortable with GDC. A higher comfort level with the technology should result in decreased opposition or possibly increased support for GDC in Canada. In the survey, respondents were presented with eight actions or conditions relating to GDC that were identified in the focus groups as critical to public support for the technology, and asked which (if any) of the alternatives would reduce their opposition to GDC (multiple alternatives could be selected). The results are presented in Table 3.5.

Table 3.5 - Actions that Would Reduce Opposition to GDC (% Selecting Each Action)

	CAN	AB/SK
More information	80.3	77.0
Involvement of independent experts and NGOs	63.1	57.6
No reduction in spending on renewables and energy efficiency	62.7	61.3
Strong regulation and monitoring	61.3	62.8
More demonstration projects	46.9	43.8
Public consultation process	43.7	40.7
Knowledge that renewables and efficiency can't achieve GHG reduction targets	40.5	37.8
Decreases in Cost	33.6	30.6

The most important factor in reducing opposition to GDC is acquiring more information (through research) and disseminating it to the public. Approximately 80% of those who currently oppose GDC state that more information about the technology would reduce their opposition. Other important actions are the development of a strong regulatory and monitoring framework involving independent experts and NGOs, which would reduce the perceived risk associated with GDC, and a commitment to not develop GDC at the expense of renewable energy and energy efficiency, which are clearly the public's first choice for reducing GHG emissions in Canada. Cost is the least important factor to those who are opposed to GDC, although cost decreases would still increase support from one-third of those opposed, demonstrating that all of these actions and conditions can play an important role in increasing public support for the technology.

3.4.10. Does the public's support for GDC vary significantly based on the extent to which GDC is used in other countries?

Another factor that may influence the Canadian public's opinions about GDC is the attitude toward the technology around the world. If most countries considered GDC to be a risky technology, and its use were widely banned, we would expect Canadian attitudes to be significantly more negative. On the other hand, widespread use of GDC around the world would likely have a positive influence on Canadian attitudes, as the public would become more familiar with the technology, and a wealth of experience in the safe use of GDC would develop.

To test this theory, respondents were first asked if they would support or oppose GDC in Canada if almost all other countries in the world had rejected the technology as an unsafe option. Next respondents were asked if they would support or oppose GDC in Canada if almost all other countries in the world were using GDC and had declared it safe (on a seven point scale where 1 = strongly oppose and 7 = strongly support). As expected, when other countries had rejected GDC the Canadian attitude became one of slight opposition (3.15 in the CAN sub-sample and 3.18 in the AB/SK sub-sample, although the difference between these figures is not statistically significant). This scenario also made respondents more uncertain about their opinion: 9.2% of the CAN sub-sample and 9.6% of the AB/SK sub-sample responded "don't know". When most other countries are actively using GDC and consider it safe, the Canadian attitude improves to moderate support for the technology, with the CAN sub-sample rating it at 5.35, and the AB/SK sub-sample rating it at 5.1. This was one of the few instances where the responses were statistically different at the 95% confidence level between the geographic sub-samples, showing that the use of GDC in the rest of the world was not as important to the AB/SK sub-sample in demonstrating the safety of the technology. For this question, a smaller 6.9% of the CAN sub-sample and 6.0% of the AB/SK sub-sample responded "don't know". Compared to the initial GDC support ratings (4.44 for CAN and 4.29 for AB/SK), the new levels of support given either high or low usage of GDC in other countries are statistically quite different, indicating that dissemination of information about worldwide GDC activity will have an important impact on Canadian support for the technology.

3.4.11. Is the public's support for GDC likely to change significantly depending on how GDC is portrayed in the media?

Because GDC is still a relatively unknown technology, and because the public is not certain of their opinions, the media will play a critical role in shaping public opinion. To test the potential impact of the media's presentation of GDC on Canadian public opinions, the survey sample was split, and half of the sample was given a very positive hypothetical newspaper article at the end of the survey, while the other half was given a very negative article to read. Respondents were then asked again to indicate whether they supported or opposed the use of GDC in Canada. If the responses are significantly different from their original level of support, then we can conclude that the media's presentation of GDC will have a significant impact on Canadian public opinions toward the technology.

Respondents who received the negative article did indeed become more opposed to GDC, with those in the CAN sub-sample giving the technology a new rating of 3.65 and those in AB/SK giving it a rating of 3.70 (responses not statistically different). The impact of negative media information caused public opinion to move from slight support to slight opposition.

Respondents who received the positive article predictably became more positively disposed to GDC, increasing their ratings to 5.22 (CAN sub-sample) and 5.03 (AB/SK sub-sample) (responses not statistically different). Thus, positive media information can also cause a substantial shift in public opinion, from slight to moderate support. Both positive and negative media information resulted in opinion shifts of a similar magnitude, showing that both types of media portrayal will have an important impact on Canadian public opinions about GDC.

3.5. Discrete Choice Experiment Results

In order to further understand Canadians' preferences for the development of GDC in Canada, a discrete choice experiment was conducted as part of the survey. The goal of the experiment was to determine the relative importance of different characteristics of GDC projects, in order to help policy makers and industry prioritize the different actions that can be taken to improve public support for the technology.

The following attributes of GDC were used in the experiment:

1. The entity that would manage the long-term disposal risks and have liability for GDC in Canada (Entity);
2. The share of Canadian GHG reduction targets that would be met with GDC (with the remaining share met by a combination of energy efficiency, renewable energy and nuclear power) (Share), and
3. The increase in the respondent's monthly electricity bill (ElecBill).

Tables 3.6 and 3.7 report the model coefficients, standard errors, and monetized value of each characteristic for both the CAN and AB/SK sub-samples respectively. The CAN model had an R^2 value of 0.1512, indicating that 15.12% of the variation in the data can be explained by the model. The model's log-likelihood function value is -12,677.08. A log-likelihood value closer to zero is better, but the value increases with the sample size. As a result, it can not be evaluated on its own, and needs to be combined with the log-likelihood function value of a model with all of the coefficients set equal to zero into a likelihood ratio index (also called pseudo R^2), which can then be evaluated (Rivers 2003, Primerano 2003). The likelihood ratio index for the CAN model is 0.146, where 0 indicates that the model has no explanatory power and 1 indicates that the model can perfectly predict the data. The AB/SK model had a slightly lower R^2 value of 0.1429, indicating that 14.29% of the variation in the data can be explained by the model. The log-likelihood function value is -8,287.82 and the likelihood ratio index is 0.1414. These figures are both relatively low, indicating that respondents' choice patterns were not consistent, and there was significant random variation in the data. This is likely because GDC is a new technology, and respondents have not yet developed fully formed opinions about the technology and which characteristics will be important to them. It is also possible that respondents inferred the existence of other characteristics for each profile presented, and based some of their choice decision on this other information.

This was the first application of discrete choice modelling to understanding public attitudes toward GDC, and so the results can not be compared to other studies. However, despite the relatively low explanatory power of the model, the results are still useful. While undue weight should not be put on the exact monetary values presented below, the results do provide an indication of the relative importance of the modelled characteristics, which was my goal in experimenting with the application of discrete choice modelling to this policy question.

Table 3.6 - Discrete Choice Modelling Results (CAN)

Variable	Coefficient	S. Error	P-value	Monetized
Entity-Provincial	0.251	0.029	0.000	-$6.34
Entity-Federal	0.549	0.027	0.000	-$13.88
Share (+1%)	0.021	0.001	0.000	-$0.53
ElecBill (+$1)	-0.040	0.001	0.000	$1.00
Intercept	0.164	0.024	0.000	-$4.14

Table 3.7 - Discrete Choice Modelling Results (AB/SK)

Variable	Coefficient	S. Error	P-value	Monetized
Entity-Provincial	0.458	0.035	0.000	-$11.37
Entity-Federal	0.342	0.035	0.000	-$8.50
Share (+1%)	0.018	0.001	0.000	-$0.46
ElecBill (+$1)	-0.040	0.001	0.000	$1.00
Intercept	0.136	0.030	0.000	-$3.37

All of the coefficients are significant at the 99% significance level and have the expected signs. The characteristic 'Managing Entity' was dummy coded in the model, so Industry was chosen as the base case, and the coefficients for Entity-Provincial and Entity-Federal thus represent the difference between each of those variables and the case where Industry is the managing entity. All of the variables were standardized to the monetary attribute (increase in Electricity Bill), or *monetized* so that they could be compared. To interpret the monetized variables, recall that an increase of $1 in an individual's electricity bill is a <u>negative</u> thing (both intuitively, and by noting the negative coefficient). As a result, a negative monetized variable actually means that the specified level of that variable (for Entity), or a one-unit increase in that variable (for Share) has the same value to respondents as a *decrease* in their monthly electricity bill of the same amount.

The results show that the entity that manages GDC in Canada is the most important characteristic to both sub-samples, with the CAN sub-sample preferring to have the federal government manage GDC and the AB/SK sub-sample preferring that their provincial governments manage GDC, rather than having industry take on this role. Federal management as opposed to industry management had the same value to respondents as a $13.88 (CAN) or $8.50 (AK/SK) reduction in their monthly electricity bill. Conversely, the monetized federal coefficients could be interpreted as meaning that the public would react to industry managing GDC rather than the federal government as though their monthly electricity bill went up by $13.88 (CAN) or $8.50 (AK/SK). Provincial government management was preferred by the AB/SK sub-sample and had the same value to respondents as a $6.35 (CAN) or $11.37 (AB/SK) reduction in their monthly electricity bill, or the converse for industry management. It is notable that provincial government management is seen more favourably in Alberta and Saskatchewan, since that is where GDC will predominantly be developed, and the provincial government is likely to play an active role.

Increasing the share of Canada's GHG emission reduction targets that is met with GDC versus a combination of energy efficiency, renewable energy and nuclear power is seen as positive to both groups of respondents. Increasing the share of GDC from 0% to 50% of the target would have the same value to respondents as a $26.38 (CAN) or $22.77 (AB/SK) decrease in their monthly electricity bill. This likely results from respondents' slightly positive opinion about GDC and negative attitude toward nuclear power, and the belief that GDC needs to be used to achieve significant emission reductions in order to make the investment and the risks worthwhile.

Table 3.8 reports the 95% confidence intervals on the standardized (monetized) coefficients, which show that all of the characteristics except for the electricity bill amount and the model intercept were significantly different between the CAN and AB/SK models.

Table 3.8 - Confidence Intervals for Monetized Discrete Choice Model Results

	CAN		AB/SK		
	Upper C.I.	Lower C.I.	Upper C.I.	Lower C.I.	
Entity-Provincial	-$7.81	-$4.87	-$13.13	-$9.62	Sig. Diff.
Entity – Federal	-$15.25	-$12.51	-$10.24	-$6.76	Sig. Diff.
Share (+1%)	-$0.56	-$0.50	-$0.49	-$0.42	Sig. Diff.
ElecBill (+$1)	$0.96	$1.04	$0.95	$1.05	Not Sig. Diff.
Intercept	-$5.36	-$2.92	-$4.87	-$1.88	Not Sig. Diff.

Within each of the geographic sub-samples, separate models were run for males and females, those who support or oppose action on climate change, and those who support or oppose GDC development in Canada. The model coefficients were compared, revealing statistically significant differences between groups of respondents that had been hidden within the overall results. The only significant difference between males and females was that in both geographic sub-samples males derived more utility than females from increasing the share of emission reductions achieved through GDC. However, when the sub-samples were segmented based on climate change beliefs, more significant differences in opinion emerged. Within both the ABSK and CAN samples, increasing the share of GHG emission reduction targets met with GDC increases utility, but this utility is significantly higher for those who believe that action on climate change is needed. Those who believe that action needs to be taken to address climate change also strongly believe that industry should not be the managing entity for GDC in Canada. As for which level of government should be in charge, in Alberta and Saskatchewan climate change believers are virtually indifferent between federal or provincial government management, while in the rest of Canada, federal government management provides more than twice the utility of provincial management.

For those who do *not* believe that action is needed on climate change, the preference for government rather than industry management is much weaker. In Alberta and Saskatchewan provincial government management is the first choice, but industry is actually preferred to the federal government, which is associated with negative utility (at the 90% significance level). In the rest of Canada, federal government management is the first choice, while the provincial government management coefficient is not statistically significant.

When the geographic sub-samples are segmented based on support for GDC, similar opinions are revealed about which entity should manage GDC development in Canada. In Alberta and Saskatchewan both segments favour provincial government management, However, those who support GDC find federal management nearly as acceptable as provincial, while among those who oppose GDC the utility from federal government management is nearly as low as that for industry, but is not statistically significant. In the rest of Canada, both groups strongly favour federal government over provincial government or industry management. As would be expected, within both the ABSK and CAN sub-samples, those who support GDC receive much higher utility from the use of GDC to meet a large share of Canadian GHG reduction targets than those who do not support GDC – over three times higher in ABSK and nearly twice as high for the CAN sub-sample. Tables comparing the monetized coefficients and 95% confidence intervals for each of these segmented groups can be found in Appendix F.

A question was included in the survey after the DCE to investigate whether respondents would assign the same relative importance to each characteristic when asked to consider it on its own as they did in the experiment, where each characteristic was part of a scenario they had to evaluate.

The two geographic sub-samples ranked the three characteristics in this verification question slightly differently. The most important characteristic to both groups was the entity that managed GDC in Canada. The CAN sub-sample ranked the share of GHG reductions achieved using GDC as the second most important attribute, leaving the amount that their monthly electricity bill increased by as their last choice. The AB/SK sub-sample reversed the importance of these last two attributes, placing the electricity bill increase as the second most important attribute, and the share of GHG reductions achieved by GDC as least important. The results of this verification question compare positively with the results from the DCE. Respondents from both geographic sub-samples indeed valued the entity that managed GDC in Canada the highest. The AB/SK results from the DCE completely matched their later ranking of the importance of the characteristics, while the CAN sub-sample's results showed that in the experiment they actually valued the monthly electricity bill increase higher than the share of GHG reductions, on a per unit basis, as opposed to the opposite order in their subsequent ranking. However, the units are not directly comparable, and the monetized values are in a similar range, so the ranking question does provide good verification for the results of the DCE.

3.6. Multiple Regression Results

The preceding sections presented the results from each survey question individually. This section presents an investigation of the integrated results – how responses to some questions influence responses to others. What I am interested in is the connection between respondents' attitudes and demographic characteristics and their support for GDC, as this may provide additional insights into how support for GDC might be increased. To understand this, ordinary least squares linear multiple regression analyses were performed for both the CAN and AB/SK geographic sub-samples.

Question 8 from the survey was used as the dependent variable. This is the question that measured overall support for GDC in Canada, asking respondents "Do you support or oppose the use of geological disposal of CO2 in Canada?" (1 = strongly oppose, 7 = strongly support, or don't know).

The final model for the CAN sub-sample had four significant explanatory (independent) variables: being female, believing that climate change is not a problem, being aware of GDC, and certainty about support for GDC. All of these variables were highly significant (see Table 3.9 below). The F statistic was 10.88, with an associated significance (p-value) of 0.000, which indicates that the independent variables are jointly very significant. However, the overall explanatory power of the model was low, with an

R-squared value of 0.032, indicating that only 3.2% of the variation in the data can be explained by these independent variables. Therefore, the vast majority of factors that determined the level of support for GDC by the CAN sub-sample were not measured in the survey (or perhaps measurable at all) and could not be determined.

Table 3.9 - Multiple Linear Regression Results – CAN Sub-Sample

	Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
	B	Std. Error	Beta	t	Significance	Lower Bound	Upper Bound
(Constant)	3.631	0.198		18.313	0.000	3.242	4.020
Female	-0.278	0.120	-0.067	-2.313	0.021	-0.513	-0.042
CCNoConcern	-1.395	0.334	-0.120	-4.181	0.000	-2.049	-0.740
Aware of CCS	0.685	0.195	0.101	3.511	0.000	0.302	1.068
Q9 Certainty	0.086	0.035	0.700	2.441	0.015	0.017	0.156

Although these variables play a very small role in determining support for GDC, it is still interesting to investigate them. The results show that females and those individuals that do not believe that climate change is a problem have a lower rated support for GDC. On the other hand, being aware of GDC results in higher support, and those individuals who are more certain of their level of support for GDC are slightly more likely to support it. The converse of this is that those individuals who do not support GDC are slightly less certain about their opinion, indicating that their levels of support may change in the future as they gain more information about the technology.

The AB/SK model had seven significant explanatory variables: believing that climate change was serious and required immediate action (question (Q) 2a), believing that climate change is taking place and some action should be taken (Q 2b), believing that we don't know enough about climate change and more research is necessary before taking action (Q 2c), having an income greater than $50,000 per year, having graduated from university, and being female. Again, all of these variables were significant at the 95% or 99% confidence level (see Table 3.10 below). The F statistic was 12.96, with an associated significance level of 0.000, indicating that together all of the independent variables are jointly significant. The model is a slightly better predictor than the CAN sub-sample model, with an adjusted R-squared of 0.098, indicating that the model explains 9.8% of the variation in the data. However, this is still quite low, indicating that we have not captured the key determinants of public opinion regarding GDC.

Table 3.10 - Multiple Linear Regression Results – AB/SK Sub-Sample

	Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
	B	Std. Error	Beta	t	Significance	Lower Bound	Upper Bound
(Constant)	3.119	0.240		12.935	0.000	2.645	3.592
Q2 a	1.334	0.259	0.311	5.147	0.000	0.825	1.843
Q2 b	1.104	0.253	0.277	4.371	0.000	0.608	1.600
Q2 c	0.623	0.266	0.135	2.342	0.019	0.101	1.146
Income 50K-74.9K	0.440	0.178	0.093	2.476	0.014	0.091	0.788
Income > 75K	0.338	0.153	0.084	2.211	0.027	0.038	0.638
Graduated University	0.506	0.171	0.102	2.951	0.003	0.169	0.842
Female	-0.818	0.135	-0.210	-6.054	0.000	-1.084	-0.553

The results can be interpreted to mean that belief that climate change is a problem (Q 2a and Q 2b), or at least is worthy of future research (Q 2c) is associated with higher support for GDC. Combined with the variable CCNoConcern (Q 2d), which was significant for the CAN model, and referring to the standardized coefficients, an interesting trend is revealed whereby decreasing support for action to deal with climate change leads to decreasing support for GDC in Canada, and vice versa. Higher income levels are associated with higher support for GDC. Having an undergraduate university degree is also associated with increased support for GDC, although other levels of education did not have a significant impact, so a trend can not be identified. As with the CAN model, females were more opposed to GDC.

For both models, the residuals were examined in order to identify any problems (see Appendix G for figures). The AB/SK model's residuals were nearly perfectly normally distributed, while the CAN model's were more skewed, but not completely random. The scatter plots do not reveal any autocorrelation or heteroskedacity problems, and the collinearity diagnostics do not reveal problems of multicollinearity. Given the results, I reject the null hypothesis for both models, and conclude that attitudinal and demographic variables do affect ratings of support for GDC, although the impact is small.

Linear multiple regression was also used to understand the determinants of public opinion about GDC in other studies. In Huijts' 2003 study she performed regression analyses to understand the determinants of attitudes toward GDC. She found that perceived risks, perceived benefits, trust, positive affect, and negative affect (each of these variables was constructed from question responses) all influenced attitudes toward GDC. However, no overall model or R^2 was presented – only regression coefficients and their statistical significance, so comparisons with the current study are not possible. One of the 2004 Japanese studies (Itaoka 2004) also employed regression analysis. In that study the researchers obtained much higher explanatory power than in the current study, with R-squared values ranging from 0.355 to 0.451. One reason for this may be the higher awareness of GDC in Japan, which suggests that attitudes toward the technology may be better formed. Another reason is the researchers' use of factor analysis in the regression analysis. Use of this technique allowed for a greater proportion of respondents' opinions about GDC to be explained by attitudes identified through patterns of responses to previous questions. The most important factors were respondent understanding of the effectiveness of GDC as a mitigation option for climate change (associated with greater support for GDC), concern about risks and leakage (associated with lower support for GDC), and concern that GDC would allow continuation of current usage levels of fossil fuels (associated with lower support for GDC). As with the current study, socio-demographic variables contributed little to explaining public opinion toward GDC.

Neither of the multiple regression models developed in the current study had a high explanatory power, and the CAN model had nearly no explanatory power at all. For this reason, the multiple regression results should be viewed as preliminary and descriptive only. The low explanatory power of the models indicates that whatever factors are important determinants of public opinion about GDC were not captured by the survey questions, and most of the variability in responses is coming from other sources or is random. While this could indicate that the wrong questions were asked, it is likely that the newness and unfamiliarity of GDC mean that there is still substantial variability and randomness in people's opinions, and significant determinants of support for the technology do not yet exist. For this reason, the qualitative and quantitative findings from the individual survey questions should be looked to for the most insight into likely public attitudes toward GDC in Canada.

4. POLICY RECOMMENDATIONS AND CONCLUSIONS

4.1. Policy Recommendations

The results of this research suggest that GDC will be publicly acceptable, and therefore politically feasible as part of a balanced climate change portfolio in Canada. Over half of the respondents would definitely or probably use GDC in a climate change plan, while only a little over a quarter of respondents probably or definitely would not use it. Respondents thought that GDC would have a slightly positive net impact on the environment; considered it less risky than normal oil and gas industry operations (production and refining), nuclear power, or coal-fired power plants; and overall were slightly in support of its development in Canada. In particular, the fact that the public believes GDC to be less risky than normal oil and gas industry operations – which suffer from occasional high profile accidents and environmental problems, yet are still tolerated by the public – strongly suggests that GDC will be accepted by Canadians, and eventually may grow to be considered a standard activity associated with fossil fuel use. Despite this, the public has some key concerns about GDC, and care must be taken to protect public health and environmental quality as GDC is developed. The policy recommendations below are designed to help governments and industry address the public's questions, concerns, and preferences as GDC is developed in Canada, which would likely further increase support for the technology.

Education about Climate Change

More public education about CO_2 and climate change is needed. Although a strong majority of Canadians believe that immediate action or some action to reduce climate change is warranted, and agree that government action to reduce the threat of climate change is required, climate change still ranks very low in importance compared to other national issues – and is rated last in importance among environmental issues. There is also significant confusion about CO_2 – many people still think it is responsible for ozone layer depletion, and the public seems to perceive CO_2 as more dangerous (to their health) than it actually is. Public education should stress that CO_2 is only dangerous to human health in high concentrations, and is of most concern because of its impact on the climate.

Public awareness that climate change is a critical environmental issue is key to public support for GDC. In the multiple regression analyses, climate change beliefs were a significant determinant of support for GDC for both geographic sub-samples. As Canadians become increasingly convinced of the severity of the climate change problem, and the need for immediate action, their support for GDC is likely to increase.

Public Outreach about GDC

Public outreach about GDC should focus on several key points:

- The threat of climate change and GDC's ability to address it
- Providing more information about GDC

- GDC's risks and their associated probabilities (where known), the preventative measures that can be employed, and the remediation options that can be used in the event of a problem
- The extensive use of GDC technology historically, and around the world
- GDC's potential for use as a bridging technology
- CO_2-based EOR as a way to involve the oil and gas industry in addressing climate change and as a way to use CO_2 productively

As discussed above, the most likely supporters of GDC are those who are concerned about climate change, so an understanding of the risks of climate change as well as GDC's capability for quickly reducing CO_2 emissions may increase public support. Next, the public wants information: the dissemination of existing information, and the development of new information through continued research. Some key questions that the public has include:

- What is GDC? (in layman's terms)
- Where would GDC take place?
- How much CO_2 would be stored?
- What would be done with emissions from Eastern Canada?
- How does GDC fit in a climate change strategy (for example, GDC can't reduce CO_2 emissions from vehicles)

The public is understandably concerned about the risks of GDC, since it is a new (and to the average member of the public, unproven) technology. The greatest concerns are unknown future impacts, CO_2 leaks and groundwater contamination. When evaluating risk, the public tends to focus on the magnitude of the outcome, while ignoring or overestimating the probability of occurrence. Where research and experience has identified probabilities of negative outcomes of GDC, these should be shared with the public. As the technology is developed in Canada, government and industry must ensure that it is carefully monitored in order to avoid unanticipated negative impacts, and the public will need to be vigilant to ensure that appropriate monitoring is taking place. Information about the remediation options that exist in the unlikely event of an accident should be shared with the public, and intensive research should continue, in order to strengthen our knowledge about the use of this technology.

Most Canadians have not previously heard of GDC, so they will assume it is a new, untested technology when they first encounter it. As a result, it will be very important for government and industry to share information about the technology's safe history of use in the oil and gas industry, and its current use in both demonstration and commercial projects in Canada and worldwide. Sharing Canadian and international success stories will help to show that the technology has been successfully and safely established around the world, which the public indicated would increase their support for GDC.

GDC should also be used as much as possible as a bridging technology that will allow Canada to achieve short-term reductions in greenhouse gas emissions while other long-term alternatives are developed. The public does not want GDC to replace alternatives such as energy efficiency and renewable energy, and unless other long-term emission-reduction and lifestyle-changing solutions are implemented simultaneously, many people will not support the use of GDC in Canada.

Finally, CO_2-based EOR is viewed positively, as a way to get the oil and gas industry involved in tackling climate change, reduce water use (in some cases) by the oil and gas industry, use CO_2 in a beneficial way, and make it easier to extract oil. These benefits should be shared with the public, as should the large continued need for oil in Canada, and its importance to the Alberta and Saskatchewan economies.

Media Outreach

The survey demonstrated the potential impact the media could have on public support for GDC. Both positive and negative media information resulted in corresponding opinion shifts of similar magnitudes, indicating that both types of media portrayal of GDC will have an important impact on Canadian public opinions. Proactively providing the media with unbiased facts about GDC in Canada and worldwide before erroneous or incomplete information enters the public discourse is critical to retaining public support.

Regulation and Management

GDC in Canada it is a relatively new technology with the potential for harm to human health and the environment if it is mismanaged. Unanticipated impacts must be identified and remediated quickly. Because of these characteristics, GDC needs to be strictly regulated and managed in order to protect public health and environmental quality, and help the public feel more comfortable with the technology.

The results from the discrete choice experiment reveal that Canadians do not want industry to be the entity responsible for managing the long-term risks and retaining liability for GDC in Canada. In Alberta and Saskatchewan, where most GDC will take place, the provincial government is the preferred management entity, while in the rest of Canada respondents prefer that the federal government take over the management role. Despite the public's preference, it is not likely that the day-to-day operations of GDC in Canada will be taken over by government. Existing government policy frameworks favour a market-oriented approach to implementing GDC, suggesting it will be initiated and managed in a commercially viable manner. However, the results indicate that public support for GDC will be higher if a government entity is actively involved in monitoring and regulating GDC, ensuring risks are minimized. Focus group participants were very much in favour of involving non-governmental organizations and independent experts in the management and regulation of GDC in Canada. Having an independent organization oversee GDC in Canada may be an acceptable compromise for the public between having either government or industry take sole responsibility for managing GDC.

Additionally, it is recommended that in Alberta and Saskatchewan where GDC will be used most extensively, the public be involved in the decision process about how GDC will be managed and regulated, in order to increase their comfort, buy-in, and support for use of the technology in their provinces.

Extent of GDC in Canada

An interesting result coming out of the focus groups and the discrete choice experiment was that Canadians would prefer for GDC to be used to achieve a larger, rather than smaller share of Canada's GHG emission reductions. If the effort is made to develop GDC in Canada, focus group participants believed it to be more worthwhile to use the technology extensively than to target only a small share of total emission reductions, which could be met instead through demand management and lifestyle changes. GDC was also seen as less risky than nuclear power, which respondents do not want to see used to reduce GHG emissions in Canada. However, the public does not want the heavier reliance on GDC to reduce Canadian GHG emissions to come at the expense of energy efficiency and renewable energy projects, or public outreach programs that encourage the public to make lifestyle changes to reduce energy use (such as the One Tonne Challenge). GDC support in Canada will be highest if it is used in combination with these programs and technologies as part of a balanced climate change strategy, and is used to displace unpopular emission reduction alternatives such as nuclear power.

4.2. Suggestions for Further Research

The results showed that the public is slightly supportive of GDC development in Canada and believes that the technology is less risky than coal-fired power plants and normal oil and gas industry operations. However, medium-term applications of GDC will likely include the technology's combination with advanced coal-fired power plants to permit electricity production from coal with low CO_2 emissions. Given public attitudes toward coal-fired electricity generation, support for GDC development in this context is not certain.

This study investigated public attitudes toward GDC on a predominantly stand-alone basis. The next step, and a suggestion for future research, is an investigation of public attitudes toward energy systems based on fossil-fuel and GDC combinations, particularly in comparison with other energy system configurations, with information presented to the public on the overall cost, generation capacity, and environmental impact of each alternative.

Another necessary avenue for investigation into how the public would like to see GDC developed in Canada is an evaluation of attitudes and preferences in rural areas of Alberta and Saskatchewan where disposal sites are likely to be situated. Questions of interest include specifics about GDC development, such as how the community would like to be involved; public expectations about safety, monitoring; and regulation; and the selection of acceptable disposal locations. Focus groups and community meetings would be ideal for investigating these types of questions, as their open-ended structure is conducive to the development of new ideas. However, researchers should keep in mind that the group dynamic at these types of meetings can lead to an emphasis on public fears and the negative aspects of GDC, and make support levels appear lower than they actually are.

4.3. Conclusions

This research was the first empirical study of public attitudes toward GDC in Canada, and can be used as the basis for further investigation into the public's likely response to the development of this technology in Canada. The focus groups and subsequent national survey revealed that the public is largely unfamiliar with GDC, but will likely be slightly supportive of its development in Canada. Factors that may increase support for GDC include 1) greater public understanding of the technology, 2) a strong regulatory and management regime that has significant roles for government, independent experts and NGOs, 3) its use as part of a balanced climate change portfolio that also involves energy efficiency, renewable energy, and behavioural change components, 4) significant international experience with GDC, and 5) positive coverage by the media. The public is concerned about unknown future impacts, CO_2 leaks, and groundwater contamination, and their support will decrease if these concerns are not addressed adequately, or if industry is given full responsibility for the management and monitoring of GDC. Public support will also decrease if GDC development is perceived to come at the expense of energy efficiency and renewable energy programs, which are very popular with the public, or if the media reports negative information about GDC. Based on the findings from this research, a number of policy recommendations have been made, which can be used by the federal and provincial governments, industry, and non-governmental organizations as a guide for developing and managing GDC in Canada in a publicly acceptable manner.

Overall, the findings from this research were positive, and suggest that the public would be willing to accept the use of GDC as long as their key concerns are addressed. GDC is perceived to be less risky than normal oil and gas industry operations, which are generally accepted in Canada, despite occasional accidents and environmental problems. This should help bolster the confidence of those who may be hesitant to develop GDC on a large scale due to uncertainty about the technology's public acceptability.

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APPENDICES

Appendix A: Telephone Recruitment Guide

The Telephone Recruitment Guide as originally written was more substantial than the final version, incorporating more of an introduction to the benefits of participating in the focus group. However, the initial calling revealed that participants were only willing to listen to several seconds of introduction to the topic before they would interject that they were not interested, and so the recruitment guide was shortened significantly. This change allowed the conversations to progress significantly further, and increased the success rate.

Toronto version

Hello, my name is Jacqueline Sharp and I am a graduate student calling from Simon Fraser University. I am calling to invite you to participate in a focus group on the public's opinions about a new environmental technology that the government is considering using in Canada. This is a one-time group interview that would last about two hours, and we would pay you $50 and provide dinner. The research is being done for the public's benefit. Can I tell you a little more about this?

First of all, the session that we're trying to set up is on Monday, August 30 at 6:30 pm. Is this something that you could fit into your schedule?

First I need to ask you a few questions to make sure that you are eligible for the focus group.

1. What is your age? Are you in your 20s, 30s, 40s, 50s etc? (*if too young explain that we need people over the voting age and ask if there is anyone over 18 in the household*)

2. And in order to make sure that I have a balanced sample of participants, could you please tell me what is the highest level of education you have completed?

3. And lastly, I am going to read out five environmental issues and technologies. For each one, can you tell me if you are familiar with it, somewhat familiar with it, or not familiar with it?

    - Species extinction
    - Climate change or global warming
    - Carbon storage or carbon sequestration
    - Genetically modified foods

- Long-term storage of nuclear waste

(If not eligible (I have enough in the category), then thank them, ask if they would like to be considered as an alternate, and end call)

Thank you – you are eligible to participate in the focus group. Let me tell you a little more about this focus group. I am evaluating public attitudes towards a new environmental technology, in order to make recommendations to the government about how to develop it, and by participating you will have the chance to make sure that your opinions are represented. The focus group will only happen once and it will last for 2 hours. We won't try to sell you anything, and we won't try to sign you up for anything else. We are just interested in your opinions and views. The focus group will take place at Metro Hall on the corner of King St and John St, in Room 310 and again, it would be on Monday, August 30th. We would start at 6:30 pm and end before 9:00 pm. If I do put your name down it is very important that we have everyone show up, as we are only recruiting the number of participants that we need. Does this sound like it would work for you? (*yes: That's great! Could I get your name please?*)

Again, we'll be paying you $50, which we will give you in cash at the conclusion of the focus group. We will also be serving sandwiches, cookies, drinks, coffee and tea. The group will consist of approximately 10 other people like yourself, and we will all engage in a group discussion.

I'd like to send you an email or fax confirming your participation in this focus group along with a map and the time/date. Do you have an email address or fax number that I could send that to?

Just so you know, we will be starting right on time at 6:30 pm on August 30th, so if you get to the session after the discussion starts we may not be able to include you and we may not be able to pay you either. So it is very important that you try to get there on time at 6:30pm.

So everyone remembers, we will be calling you back the evening before the group to remind you about it. Is this the best number to get you at if we call on Sunday August 29th?

If an emergency comes up, and you are unable to attend, would you please call me and let me know at 416-560-7382? My name again is Jacqueline Sharp

Thank you very much. I look forward to seeing you on August 30th.

Answering machine:

Hi, my name is Jacqueline Sharp and I am a graduate student calling from Simon Fraser University. I'm calling to offer you the chance to be in a focus group that I am holding. This is a group interview in order to get your opinions about a new environmental technology that the government is considering using in Canada. For your participation we would pay you $50 and provide dinner. The focus group will be held on Monday, August 30th from 6:30 to 9:00 pm. I would be happy to give you some more information if you give me a call back, and I promise not to try to talk you into participating if it turns out not to interest you. You can call me back at 416-560-7382, and my name again is Jacqueline Sharp.

Appendix B: Moderator's Guide

10 (minutes) Thank you for your time today. My name is Jacqueline Sharp, and I am a researcher in the School of Resource and Environmental Management at Simon Fraser University in Burnaby, British Colombia. Has everyone reviewed the information sheet about today's focus group and signed the consent form?

We are here to learn more about your opinions about a new environmental technology that may be developed in Canada. The results will be used to help us develop a larger survey to go out to Canadians in the fall. We are interested in all the thoughts and impressions that you have as we move through the discussion, so please share everything that you are thinking. There are no right or wrong answers to the questions – your opinions are what matter. We want to hear from each of you today, so please make an effort to share your thoughts. If one of you is contributing more than the others I might ask you to let others talk a bit more, and if you haven't said much, I might ask for your opinion.

We will be recording this session, but everything you say will be treated confidentially, and only your first name will be used. I will lead the discussion with 11 questions over the course of the evening, but would like you all to engage in a free flowing discussion starting from each question.

We have a fairly full agenda today, so I'll apologize in advance if I have to cut off the discussion at any point. I don't want to be impolite, but I may have to interrupt and bring us back to the main topic if we get too far afield. Or I may have to break in and move us along to the next question so we have enough time to get through all the topics we need to discuss. If you have a cell phone or pager with you, please turn it off if at all possible, as they will be distracting to our discussion. If you do have to leave it on, please leave the room if you have to take a call and return as quickly as you can. If you need to leave for an emergency, please let us know.

Before we start, I'd like to have each of you fill in a short questionnaire (*hand out page 1*). Please make sure you fill out both sides, but don't look ahead to the other handouts. Pass it back to me when you are done.

Thank you. Now let's start by introducing ourselves – your first name only is fine, and just to start the discussion off, please also share with the group what you think is the biggest environmental problem facing Canada today?

1. 5 Now let's talk a bit about some of the questions that were on the questionnaire. What comes to mind when you hear the term carbon dioxide storage?

2. 5 What about carbon dioxide? Do you feel that it is dangerous to your health, or harmless?

3. 5-10 Now I am going to tell you a little bit about carbon dioxide storage. I will give you only basic information because I am interested in your initial reactions. Carbon dioxide is a naturally occurring gas that forms part of our atmosphere. It is also released by burning fossil fuels like coal, oil and natural gas. Geological carbon dioxide storage involves putting carbon dioxide deep underground in geological formations. (*Hand out page 2*) On this handout, please indicate whether you support or do not support the development of carbon dioxide storage in Canada? (*collect question sheets*). Now let's talk about this. What are your initial thoughts about carbon dioxide storage?

4. 15 Now I'd like to give you a bit more information about carbon dioxide storage. (*Hand out pages 3-6*) The next handout has this description written on it, so we can read it together. Carbon dioxide capture and storage involves separating carbon dioxide from gas streams that result from industrial processes like electricity production; compressing and treating the carbon dioxide as necessary; transporting the carbon dioxide; and injecting it into deep geological formations such as depleted oil and gas reservoirs and coal seams. The next page in your package, Figure 1, has a diagram to help you visualize this. In Canada, carbon dioxide storage would be developed primarily in Alberta, and in parts of BC and Saskatchewan. Figure 2 in your handout package has the suitable geological zones for carbon dioxide storage highlighted.

   I realize that there are a variety of opinions in this room regarding climate change. However, for the purposes of this focus group I need you all to assume that scientists have concluded that climate change is a real threat, and the government is committed to action, and so we will look at carbon dioxide storage in this context as one option for disposal. Most experts believe that in order to significantly reduce the risks of climate change we must reduce greenhouse gas emissions by at least 60% from current levels. By using carbon dioxide storage Canada could significantly reduce its carbon dioxide emissions while continuing to use fossil fuels. This could allow society to continue to use existing levels of fossil fuels for many decades to come. It may also allow us to achieve greater emissions reductions and faster emissions reductions than possible through energy efficiency and renewable energy developments alone, and may act as a bridging strategy to reduce emissions in the short term while longer-term solutions are further developed. Carbon storage could also enable the production of hydrogen from fossil fuels in the future with significantly reduced greenhouse gas emissions. Hydrogen produced from fossil fuels may be much cheaper than hydrogen produced from renewable energy sources or nuclear power.

   a. Now I would like you to flip the page to Question number 4. Given this additional information, please indicate whether you now support or do not support the development of carbon dioxide storage in Canada. (*Collect sheets*)
   b. Now let's discuss this. Given this additional information, what is your opinion of carbon dioxide storage?

c. The Canadian government is planning to use carbon dioxide storage to meet a small portion of Canada's greenhouse gas emission reduction targets under the Kyoto Protocol - an international agreement to reduce greenhouse gas emissions to which Canada is a signatory – what do you think about this?

5. 10 Now I am going to explain several different kinds of carbon dioxide storage that are possible in Canada. (*Hand out page 7)* Please refer to the Question 5 Background Information handout so that you can read along with me.

   There are four main types of carbon dioxide storage that are possible in Canada. The first is the one that I described earlier – compressed carbon dioxide is injected into geological formations for storage. Two other types of carbon dioxide storage use the carbon dioxide in economic processes to enhance recovery of oil and gas resources that would otherwise be left in the ground. The first is called Enhanced Oil and Gas Recovery, and it involves injecting carbon dioxide into depleting oil and gas wells, where it increases production of oil by making it less thick and sticky, and easier to extract. The second is called Enhanced Coalbed Methane Recovery, and it involves injecting carbon dioxide into deep un-mineable coal fields, where it causes more methane, which is natural gas, to flow toward wells, so that it can be extracted. In both of these second cases some of the carbon dioxide remains permanently stored underground, and the remainder is captured and re-used in the same process, and oil or natural gas production is increased. The fourth type of carbon dioxide storage is part of a process called Acid Gas Injection. Hydrogen sulphide and carbon dioxide can occur naturally underground with natural gas. When there is enough hydrogen sulphide in the natural gas it can be toxic to humans, so the combination of hydrogen sulphide and carbon dioxide, called acid gas, is removed from the natural gas during processing. One way of disposing of acid gas is to inject and store this mix of acid gas and carbon dioxide in deep geological formations underground. Carbon dioxide can make up a significant part of the acid gas stream that is stored underground, and so this can also be a significant method of carbon dioxide storage.

   a. What are your thoughts about these types of carbon storage? What is your preferred use? Least preferred use?

6. *5* Now let's talk about a different type of carbon dioxide storage. (*Hand out pages 8-9)* Please refer to the Question 6 handout so that you can read along with me. Figure 3 on your next handout may help you to visualize this.

   Carbon dioxide is released when fossil fuels such as coal and oil are burned to produce energy and electricity, and also when plants, or biomass, such as crop residues, are burned to produce energy and electricity. Plants remove carbon dioxide from the atmosphere when they grow, and then release this same carbon dioxide when they die and decompose, so that the *net* carbon dioxide released is zero. Instead of using carbon dioxide that has been separated from fossil fuels like coal or oil for carbon dioxide storage, another option is to separate and store the carbon dioxide from biomass. This process in effect results in negative overall carbon dioxide emissions, since the plants are removing carbon dioxide from the atmosphere, and then we are storing this carbon dioxide underground. Is this more or less acceptable to you than storing carbon dioxide captured from burning fossil fuels?

7. 10 Now let's have a discussion about the benefits of carbon dioxide storage. What do you feel would be the main benefits? Which are most important in your view? *(Write on flipchart)*

8. 20 Let's move on to the potential downsides of carbon dioxide storage. Do you think there may be any negative effects of doing this?

   prompting questions...

   a. What are your main concerns with carbon dioxide storage? (*write on flipchart)*
   b. What are the main risks (safety and environmental impacts) in your view?
   c. Do you feel that this is a risky technology?
   d. Who do you feel will be affected?
   e. Are you concerned about leakage of the carbon dioxide *(potential risks of leakage include health, environmental, climate impacts)*
   f. *(Edmonton) (Hand out pages 10, 12)* Figure 4 lists the potential risks of carbon storage (*read out loud*). The probability of some of these happening may be very small, and they are being studied now to determine if they are actual risks, but they are possible risks. Now take a look at Question 8 on your handout. It shows a risk continuum with nuclear waste storage at one end, and acid gas injection at the other end. Nuclear waste is produced by power plants, and is toxic to humans for thousands of years. Governments are investigating opportunities to store nuclear waste in the Canadian Shield in Canada and in Yucca Mountain in the US. Some people are concerned about this. Acid gas occurs naturally with natural gas underground, and must be stripped off during processing and stored underground throughout Alberta. When it is present in high concentrations acid gas can be toxic to humans, but injecting it underground has generally not been a concern to the public as it seen as a better alternative to flaring it or producing sulphur from it. Again, on this continuum of the perceived risk of these technologies to you, with nuclear waste storage at one end, and acid gas injection at the other end, please mark on your question sheet where would you place carbon storage? (*Collect sheets*) Now let's discuss this.
   g. *(Toronto)* Figure 4 lists the potential risks of carbon storage (*read out loud*). The probability of some of these happening may be very small, and they are being studied now to determine if they are actual risks, but they are possible risks. Now take a look at Question 8 on your handout. It shows a risk continuum with nuclear waste storage at one end, and a non-hazardous landfill at the other end. Nuclear waste is produced by power plants, and is toxic to humans for thousands of years. Governments are investigating opportunities to store nuclear waste in the Canadian Shield in

Canada and in Yucca Mountain in the US. Some people are concerned about this. New landfills must be developed in Ontario in order to dispose of the large quantities of garbage produced by households and businesses. Again, on this continuum of the perceived risk of these technologies to you, with nuclear waste storage at one end, and a non-hazardous waste landfill at the other end, please mark on your question sheet where would you place carbon dioxide storage? (*Collect sheets*) Now let's discuss this.

h. What is the closest you would feel comfortable with a carbon storage site being located from your house?
    i. Prompting: 10 km (approximately an hour and a half walk)? 20? 50? 100? 200?

9. 10 What would reduce these risks *(safety, leakage risks etc.)* in your mind?
    i. Prompting questions:
    ii. Regulation – who, how?
    iii. Public involvement? How would you like to be involved?
    iv. Monitoring – by whom, for how long?
    v. Liability for sites (in case of release etc.) – who, how long?
    vi. Specific safety procedures?
    vii. Does it make a difference to you if a federal or provincial government corporation or a private corporation runs it? Promotes it?

10. 5 *(If sustainability/moral concerns are raised)* What would reduce your general opposition to carbon storage?

11. 5 (*Hand out pages 13-14*). Please refer to Question #11 on your handout. There are a variety of different energy technologies are available to reduce greenhouse gas emissions from energy production. Some of these technologies are listed on the question sheet. Please rank these technologies from 1 to 10, where 1 is the technology that you would *most* want to see used to reduce greenhouse gas emissions, and 10 is the technology that you would *least* want to see used to reduce greenhouse gas emissions in Canada (*collect sheets, use this time to prepare final points for summary*).

12. 5 Now please refer to Question 12 on your handout? After hearing all of this information, both about the benefits and potential risks of carbon dioxide storage, please indicate on the question sheet whether or not you support the development of carbon dioxide storage in Canada? Also, please indicate what you consider to be the greatest benefit of carbon dioxide storage, and your greatest concern with carbon storage? (*Collect sheets, use this time to prepare final points for summary*)

13. 10 *(Spend 2-3 minutes summarizing the main points, key questions, and themes that came out of the focus group).* Is this an adequate summary of the main themes of our discussion tonight? *(Note any main risks and benefits that were not really brought up*

over the course of the evening). I haven't heard these benefits and concerns a lot tonight – am I correct in interpreting that that means they are not important??

14. 10 Just to remind you, the purpose of this focus group was to determine the public's attitudes towards the development of carbon dioxide storage in Canada, in order to make recommendations to the government about if and how to develop carbon dioxide storage in Canada. Have we missed anything tonight that should have been a part of this discussion? *(prompting questions...)*

    j. What additional information do you want to know about carbon dioxide storage?
    k. Do you have any other questions that you would want to have answered before you came to a stronger view?
    l. What is the most important information for the government to share with Canadians about carbon dioxide storage?

Thank you for participating in this focus group today. I appreciate your time and input. If any of you would like further information on this study, my contact information is on the information sheet that was handed out when you arrived. If anyone has any concerns about how this focus group was conducted, you can contact the Department of Research Ethics at Simon Fraser University – there is an optional comment form on the back table that you can use.

Appendix C: Handouts to Focus Group Participants

Handout 1

Initial Focus Group Questionnaire

2. Have you ever heard of carbon dioxide storage (also sometimes called carbon sequestration)? *Please circle yes or no.*

   Yes No

   a. If you answered "yes" to question 1, please indicate your support for the development of this technology in Canada. *Please circle your choice.*

Strongly opposed Somewhat opposed Neutral Somewhat support Strongly support

3. What do you think of when you hear the term "carbon dioxide storage"?

4. What comes to mind when you hear the term "carbon dioxide"?

5. Do you feel that carbon dioxide is harmful or harmless to your health? *Please circle a number on the scale below, from 1 (very harmful) to 5 (totally harmless).*

Very Harmful				Totally Harmless
1	2	3	4	5

please turn over...

6. Please indicate how much you agree or disagree with the following two statements: *Please circle a number on the scale below, from 1 (totally disagree) to 5 (totally agree).*

   a. Climate change is an important environmental problem.

Totally Disagree				Totally Agree
1	2	3	4	5

   b. Emissions of greenhouse gases (such as carbon dioxide) need to be reduced in order to avoid serious climate change.

Totally Disagree				Totally Agree
1	2	3	4	5

7. How much do you think that greenhouse gas emissions must be reduced from current levels by in order to avoid serious climate change? *Please circle your choice below.*

0%　10%　20%　30%　40%　50%　60%　70%　80%　90%　100%

Handout 2

Question # 3

Carbon dioxide is a naturally occurring gas that forms part of our atmosphere. Burning fossil fuels like coal, oil and natural gas also releases carbon dioxide. Geological carbon dioxide storage involves putting carbon dioxide deep underground in geological formations.

Please indicate your level of support for the development of carbon dioxide storage in Canada: *(Circle your response, from 1 (Strongly opposed) to 5 (Strongly support), or Don't Know).*

Strongly Opposed		Neutral		Strongly Support		
1	2	3	4	5	*or*	Don't Know

Handout 3

Question # 4 Background Information

Carbon dioxide capture and storage involves separating carbon dioxide from gas streams that result from industrial processes like electricity production; compressing and treating the carbon dioxide as necessary; transporting the carbon dioxide; and injecting it into deep geological formations such as depleted oil and gas reservoirs and coal seams (*please refer to Figure 1 on the next page*). In Canada, carbon dioxide storage would be developed primarily in Alberta, and in parts of BC and Saskatchewan. (*please refer to Figure 2).*

I realize that there are a variety of opinions in this room regarding climate change. However, for the purposes of this focus group I need you all to assume that scientists have concluded that climate change is a real threat, and the government is committed to action, and so we will look at carbon dioxide storage in this context as one option for disposal.

Most experts believe that in order to significantly reduce the risks of climate change we must reduce greenhouse gas emissions by at least 60% from current levels. By using carbon dioxide storage Canada could significantly reduce its carbon dioxide emissions while continuing to use fossil fuels. This could allow society to continue to use existing levels of fossil fuels for many decades to come. It may also allow us to achieve greater emissions reductions and faster emissions reductions than possible through energy efficiency and renewable energy developments alone, and may act as a bridging strategy to reduce emissions in the short term while longer-term solutions are further developed. Carbon storage could also enable the production of hydrogen from fossil fuels in the future with significantly reduced greenhouse gas emissions. Hydrogen produced from fossil fuels may be much cheaper than hydrogen produced from renewable energy sources or nuclear power.

Handouts 4, 5

Figure 1 – Question 4 <simple diagram showing different types of geological disposal of CO_2.>

Figure 2 – Question 4 <map of Canada showing locations of Canada's sedimentary basins most suitable for geological disposal of CO_2.>

(The figures are very large. Both are available in Microsoft PowerPoint format upon request)

Handout 6

Question # 4

Given the information you have just received about carbon dioxide storage, please indicate your level of support for the development of carbon dioxide storage in Canada: *(Circle your response, from 1 (Strongly opposed) to 5 (Strongly support), or Don't Know).*

Strongly Opposed		Neutral		Strongly Support		
1	2	3	4	5	*or*	Don't Know

Handout 7

Question #5 - Background Information

There are four main types of carbon dioxide storage that are possible in Canada. The first is the one that I described earlier – compressed carbon dioxide is injected into deep geological formations for storage.

Two other types of carbon dioxide storage use the carbon dioxide in economic processes to enhance recovery of oil and gas resources that would otherwise be left in the ground. The first is called Enhanced Oil and Gas Recovery, and it involves injecting carbon dioxide into depleting oil and gas wells, where it increases production of oil by making it less thick and sticky, and easier to extract. The second is called Enhanced Coalbed Methane Recovery, and it involves injecting carbon dioxide into deep un-mineable coalfields, where it causes more methane, which is natural gas, to flow toward wells so it can be extracted. In both of these second cases some of the carbon dioxide remains stored underground, and the remainder is captured and re-used in the same process, and oil or natural gas production is increased.

The fourth type of carbon dioxide storage is part of a process called Acid Gas Injection. Hydrogen sulphide and carbon dioxide can occur naturally underground with natural gas. When there is enough hydrogen sulphide in the natural gas it can be toxic to humans, so the combination of hydrogen sulphide and carbon dioxide, called acid gas, is removed from the natural gas during processing. One way of disposing of acid gas is to inject and store this mix of acid gas and carbon dioxide in deep geological formations underground. Carbon dioxide can make up a significant part of the acid gas stream that is stored underground, and so this can also be a significant method of carbon dioxide storage.

Handouts 8, 9

Question # 6 – Background Information

(*Please also refer to Diagram 3 on the next page*)

Carbon dioxide is released when fossil fuels such as coal and oil are burned to produce energy and electricity, and also when plants, or biomass, such as crop residues, are burned to produce energy and electricity. Plants remove carbon dioxide from the atmosphere when they grow, and then release this same carbon dioxide when they die and decompose, so that the *net* carbon dioxide released is zero.

Instead of using carbon dioxide that has been separated from fossil fuels like coal or oil for carbon dioxide storage, another option is to separate and store the carbon dioxide from biomass. This process in effect results in negative overall carbon dioxide emissions, since the plants are removing carbon dioxide from the atmosphere, and then we are storing this carbon dioxide underground.

Is this more or less acceptable to you than storing carbon dioxide captured from burning fossil fuels?

Figure 3 – Question 6 <simple diagram showing the carbon cycle with geological disposal of CO_2 from biomass.>

(Available in Microsoft PowerPoint format upon request)

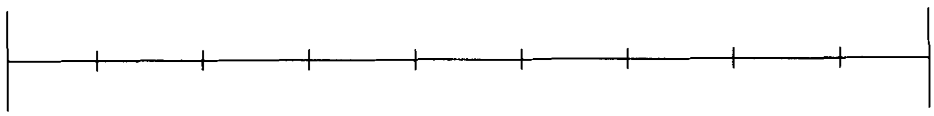
Handout 10

Question 8 – Edmonton (Toronto used 'Non-hazardous waste landfill' in place of Acid Gas Injection)

Question # 8

Risks of Various Technologies

Acid Gas Injection | Nuclear Waste Storage



Please mark an X where you would place carbon dioxide storage along this risk continuum.

Handout 11

Question # 11

A variety of energy technologies are available to reduce greenhouse gas emissions from energy production. Some of these technologies are listed below. Please rank these technologies from 1 to 10, where 1 is the technology that you would *most* want to see used to reduce greenhouse gas emissions, and 10 is the technology that you would *least* want to see used to reduce greenhouse gas emissions in Canada.

_____ Wind Power

_____ Large Hydroelectric Dams

_____ Nuclear Power

_____ Energy Efficiency and Conservation (e.g. Using more efficient appliances)

_____ Geothermal Energy (Capturing heat from below the earth's surface)

_____ Carbon Dioxide Storage

_____ Solar Power

_____ Natural Gas

_____ Small 'Run-of-the-river' Hydroelectric Dams

_____ Biomass (Burning fast-growing plants or crop residues for energy)

Handout 12

Question # 12

a) After hearing all of this information, both about the benefits and potential risks of carbon dioxide storage, please indicate whether or not you support the development of carbon dioxide storage in Canada? : *(Circle your response, from 1 (Strongly opposed) to 5 (Strongly support), or Don't Know).*

Strongly Opposed		Neutral		Strongly Support		
1	2	3	4	5	*or*	Don't Know

b) If you answered "Don't Know" above, what additional information would you need to have in order to develop an opinion about carbon dioxide storage?

c) What do you consider to be the greatest benefit of developing carbon dioxide storage in Canada?

d) What is your biggest concern with developing carbon dioxide storage in Canada?

Appendix D: Survey Instrument

Administered online at http://www.carbonsurvey.rem.sfu.ca/
User ID: ws
Password: Remmer

Welcome to our survey!

Thank you for participating in this survey. It is being conducted as part of a Masters Thesis at the Energy and Materials Research Group in the School of Resource and Environmental Management, at Simon Fraser University (Burnaby, British Columbia). Click here for our contact information.

All responses will be treated confidentially and meet the requirements of the Simon Fraser University Ethics and Privacy Policy.

We will use the results of this survey to understand the attitudes of Canadians toward a new environmental technology, and make recommendations for its development and regulation.

Your opinions and ideas are very important to us, so please answer every question.

Respondents so far have taken about 25 minutes to complete the survey.

Continuing with the survey indicates that you understand and are in agreement with our confidentiality provisions.

Please do not use the Back and Forward buttons on your browser when completing the survey.

Thank you again for your participation.

1. Below is a list of various issues. We would like to know how important you believe each issue to be. Please rate each issue from 'not important at all' to 'extremely important' *(7 point scale, order randomized)*

   a. Improving education
   b. Improving health care
   c. Increasing international aid
   d. Reducing crime
   e. Reducing poverty
   f. Improving the economy
   g. Reducing the national debt
   h. Reducing taxes
   i. Promoting recycling

j. Reducing air pollution
k. Controlling acid rain
l. Reducing water pollution
m. Reducing climate change
n. Cleaning up hazardous waste
o. Saving endangered species

2. (a) Have you ever heard of geological disposal of carbon dioxide? (Yes/No/Unsure)

2. (b) Which of the following environmental concerns do you think that geological disposal of carbon dioxide would reduce? (check all that apply):
   a. Toxic Waste
   b. Ozone Depletion
   c. Climate Change
   d. Acid Rain
   e. Smog
   f. Water Pollution
   g. Unsure

2. (c) From what you know about climate change (global warming), which of the following statements comes closest to your opinion?
   h. Climate change has been established as a serious problem and immediate action is necessary.
   i. There is enough evidence that climate change is taking place and some action should be taken.
   j. We don't know enough about climate change and more research is necessary before we take any actions.
   k. Concern about climate change is unwarranted.
   l. No opinion

3. Do you agree or disagree with the following statement? Government regulations should be implemented to require individuals and businesses to reduce their emissions of greenhouse gases (the gases that may lead to climate change)? (*7-point scale - strongly disagree to strongly agree)*

Please read the following information about climate change and a technology called geological disposal of carbon dioxide, which Canada might use to reduce the threat of climate change.

Carbon dioxide (often shortened to its chemical name CO2) *(subscript not used, to avoid potential internet browser problems)* is a clear odourless gas that is essential to life on earth – it is part of the air we breathe, and trees and plants need CO2 to grow. CO2 also traps heat around the earth (called the greenhouse effect), making the earth warm enough for humans to live. CO2 and other gases that trap heat around the earth are called greenhouse gases.

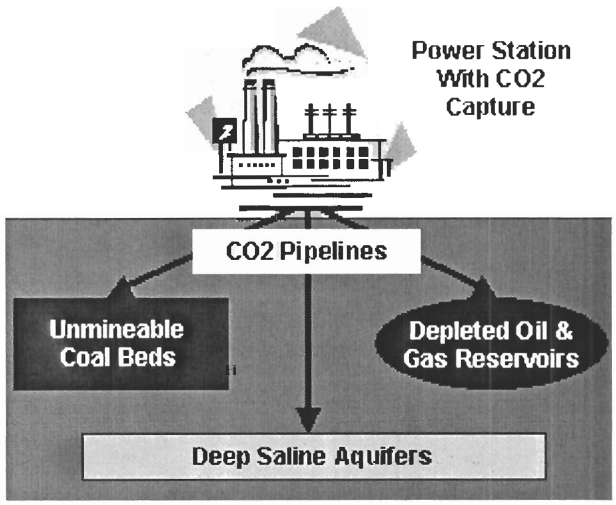
Burning fossil fuels such as coal, oil, and natural gas releases extra CO_2 into the atmosphere, which is believed to enhance the greenhouse effect and lead to climate change. Most scientists believe that the earth is already warming because of the extra greenhouse gases emitted by human activities. Climate change could have a number of serious environmental, economic, and social consequences for Canada, including:

- Warmer temperatures, which may bring more severe summer water shortages and more frequent forest fires and pest infestations
- Higher sea levels
- Significant melting of Arctic ice
- Reduced habitat for plants and animals
- Impacts on crops
- Potentially more severe and more frequent storms and extreme weather events

Because of the significant risks posed by climate change, a number of countries, including Canada, have pledged to reduce their greenhouse gas emissions. Many experts believe that in the long run emissions need to be reduced to nearly zero in order to stabilize the climate.

One way that Canada can reduce its greenhouse gas emissions is by capturing CO_2 from power plants and other large industrial plants that use fossil fuels, and disposing of the CO_2 deep underground. This is called geological disposal of CO_2. By doing this, the CO_2 is not released into the atmosphere, and does not contribute to climate change. Geological disposal of CO_2 will allow Canada to reduce greenhouse gas emissions and the threat of climate change while continuing to use fossil fuels in the near future, allowing time for our energy system to move toward alternatives as fossil fuels become scarce. This is important, since Canada currently gets over 70% of its energy from fossil fuels, while less than 1% comes from non-hydro renewable energy sources such as wind and solar energy.

Geological disposal of CO_2 works as follows: CO_2 is isolated in an energy production or industrial plant, compressed into a semi-liquid state, transported to the disposal site, and then injected through a pipeline into a safe geological reservoir. The most likely sites for geological disposal of CO_2 in Canada are in Alberta and Saskatchewan. One option is to store CO_2 in depleted oil and gas reservoirs. These reservoirs have safely stored oil and gas for thousands of years. As an added benefit, CO_2 can be used to increase reservoir pressure, allowing more oil or gas to be extracted, and in some circumstances reducing the amount of water or chemicals required in the extraction process. Another option is to store CO_2 in coal beds that are too deep to be mined. The CO_2 attaches to the coal so that it is stored there permanently, and also pushes out methane (natural gas) that was stored in the coal, so that the methane can be extracted and used. A third option is to store CO_2 in deep saline aquifers, which are very deep layers of porous rock whose holes are filled with very salty water (much saltier than the ocean). Some of the CO_2 would dissolve in the water and some would slowly react with minerals and turn to a solid, storing the CO_2 permanently. All of these geological formations are many hundreds of meters deeper underground than all but the deepest drinking water wells. Alberta's and Saskatchewan's geological formations have enough capacity to store hundreds of years of CO_2 emissions. The diagram below shows how these three types of disposal would work.



However, geological disposal of CO_2 also has potential risks. The biggest risk is that the CO_2 may leak out of one of the disposal sites. In high concentrations, CO_2 can suffocate humans and animals and kill vegetation. A slow leak from a disposal site would likely dissipate quickly, and although it might harm roots and sub-surface creatures in the area of the leak, it would be unlikely to cause harm to humans or animals. A sudden large leak in a confined or low-lying area however could be deadly to humans, animals and plants. Leaks would also release some of the CO_2 back into the atmosphere, where it would contribute to climate change. Disposal sites would be chosen carefully in order to minimize the probability of leakage, and would be located away from population centres, and test projects have not shown any measurable leakage. In addition, monitoring technology is available to detect leaks, so that any problems could be fixed. Other potential risks are that geological disposal of CO_2 may cause pressure changes underground that trigger weak earth tremors or push salt water or CO_2 into fresh water; or that CO_2 may release contaminants from rocks underground, which could then possibly move upwards. However, scientists consider these risks to be very low, and they can be minimized by careful site selection.

Geological disposal of CO_2 is possible with existing technology. CO_2 has been safely injected into depleted oil and gas reservoirs to increase production for decades in Canada and the United States, and both test and commercial-scale projects to dispose of CO_2 in all three types of geological reservoirs are underway in countries around the world, including in Canada. The main barrier to the expansion of geological disposal of CO_2 in Canada is cost. It is more expensive to capture and dispose of CO_2 than to release it into the atmosphere, so this technology will not expand significantly until regulations or financial incentives make it mandatory or profitable to reduce greenhouse gas emissions.

4. Below are some reasons why people support or oppose geological disposal of CO_2. Please indicate how much you agree or disagree with each of these statements. (*7 point scale, strongly disagree to strongly agree, order randomized*)

    a. One reason why this technology is good is that it would allow Canadians to continue to produce and use fossil fuels, without releasing greenhouse gas emissions.
    b. I am concerned that this is the wrong way to address the climate change problem, and that we should be reducing energy use or developing renewable energy instead.
    c. One reason why this technology is good is that it would allow greenhouse gas emissions to be reduced without requiring Canadians to make lifestyle changes.
    d. I am concerned about the potential safety risks of a large CO_2 leak.
    e. One reason why this technology is good is that it may allow greenhouse gas emissions to be reduced more quickly and at a lower cost than other alternatives.
    f. I am concerned about potential contamination of groundwater.
    g. One reason why this technology is good is that it can be done in conjunction with enhanced oil and gas production, increasing the amount of oil and gas produced and reducing water use in the production process.
    h. I am concerned about potential harm to plants and animals near the disposal site or to underground organisms.
    i. One reason why this technology is good is that it can be a bridging technology to achieve short-term reductions in greenhouse gas emissions while we develop other long-term alternatives.
    j. I am concerned that there may be unknown future impacts.

5. The following technologies have been proposed to address climate change. If you were responsible for designing a plan to address climate change, which of the following would you use? (*Presented in a table. For each alternative the respondent selects between definitely use, probably use, probably not use, definitely not use, and not sure. Order randomized.*)

    a. Bioenergy/Biomass: Producing energy from trees or agricultural wastes
    b. Geological Disposal of CO_2: Capturing CO_2 from power plant exhaust and disposing of it in underground reservoirs
    c. Iron fertilization of oceans: Adding iron to the ocean to increase its uptake of CO_2 from the atmosphere
    d. Carbon sinks: Using trees, vegetation, and soil to capture carbon dioxide from the atmosphere
    e. Energy efficient appliances: Producing appliances that use less energy to accomplish the same tasks
    f. Energy efficient cars: Producing cars that use less energy to drive the same distance
    g. Nuclear energy: Producing energy from a nuclear reaction

h. Solar energy: Using energy from the sun for heating or electricity production
i. Wind energy: Producing energy from the wind, traditionally by building a windmill
j. Hydroelectricity: Producing energy from falling water, traditionally by building a hydroelectric dam

6. How much of a risk do you believe that each of the following technologies poses to the environment and human health? (*7 point scale, very large risk to no risk at all, order randomized)*
    a. Nuclear power
    b. Oil and gas industry operations (production and refining)
    c. Coal-burning power plants
    d. Wind turbines
    e. Geological disposal of CO_2

7. Overall, after considering all of the potential benefits and potential risks of geological disposal of CO_2, do you think that this technology would have a positive or negative effect on the environment? (*7 point scale – highly negative to highly positive*)

8. Do you support or oppose the use of geological disposal of CO_2 in Canada? (*7 point scale – strongly oppose to strongly support, or don't know*)

9. How sure or unsure are you about your answer to Question 8? *(7 point scale – very unsure to very sure*)

10. *(If respondents answered question 8 with a rating of 3 or lower, indicating opposition to GDC).* Please indicate whether you agree or disagree with the following statements *(7-point scale – totally disagree to totally agree)*

    a. I am concerned about the risks of geological disposal of CO_2
    b. I am *fundamentally opposed* to geological disposal of CO_2

11. *(If respondents answered question 8 with a rating of 3 or lower, indicating opposition to GDC).* Which (if any) of the following would reduce your opposition to geological disposal of CO_2? (check all that apply) *(order randomized)*

    a. An inclusive public consultation process
    b. Assurance that investments in geological disposal of CO_2 would not replace investments in energy efficiency and renewable energy
    c. More demonstration projects
    d. More information about geological disposal of CO_2
    e. Decreases in the cost of the technology

f. If it is found that energy efficiency and renewable energy alone can not achieve Canada's greenhouse gas emission reduction targets at a price that Canadians are willing to pay.
g. Development of a strong regulatory and monitoring framework
h. Involvement of independent experts and environmental organizations in regulating and monitoring the industry.

12. If almost all other countries in the world had rejected geological disposal of CO_2 as an unsafe option, would you support or oppose geological disposal of CO_2 in Canada? *(7 point scale – strongly oppose to strongly support, or don't know)*

13. If almost all other countries in the world were using geological disposal of CO_2 and had declared it safe, would you support or oppose geological disposal of CO_2 in Canada? *(7 point scale – strongly oppose to strongly support, or don't know)*

Before proceeding, please read the following instructions:

You will now be asked to make a series of 9 comparisons between various ways that geological disposal of CO2 can be developed and regulated. Each comparison involves choosing between three alternative and independent configurations, based on the relative importance of each characteristic to you. Please select the configuration that you would prefer, if your choices were limited to these three.

After you select your preferred configuration from the three alternatives provided, you may feel that you do not like any of the alternatives presented. Therefore, after you have chosen your preferred configuration, you will be asked whether or not that configuration would actually be acceptable to you.

The following terms are used to describe each configuration of geological disposal of CO2:

Share of Canadian GHG Reductions: This is the amount of Canadian greenhouse gas (GHG) reduction targets that would be achieved using geological disposal of CO2. The remaining GHG emissions would be reduced using a combination of energy efficiency, renewable energy, and nuclear power. The total amount of GHG reduction in Canada does not change – only the share reduced by geological disposal of CO2.

Increase in your monthly electricity bill: This is the total dollar amount that your household monthly electricity bill would increase to cover the costs of achieving Canada's greenhouse gas (GHG) emission reduction targets. The average Canadian household pays about $80 per month for electricity.

Managed by: This is the entity that would be responsible for managing the long-term disposal risks, and that would have liability for geological disposal of CO2 in Canada.

The 9 comparisons will look very similar, but each one has important differences. Please consider each comparison independently of the others, and read each one carefully.

Choice Sets

	Alternative 1			Alternative 2			Alternative 3		
Choice Se	Entity	Reduction	Elec Bill	Entity	Reduction	Elec Bill	Entity	Reduction	Elec Bill
1	Federal	5%	$5	Provincial	20%	$25	Industry	50%	$50
2	Federal	20%	$25	Provincial	50%	$50	Industry	5%	$5
3	Federal	50%	$50	Provincial	5%	$5	Industry	20%	$25
4	Provincial	5%	$50	Industry	20%	$5	Federal	50%	$25
5	Provincial	20%	$5	Industry	50%	$25	Federal	5%	$50
6	Provincial	50%	$25	Industry	5%	$50	Federal	20%	$5
7	Industry	5%	$25	Federal	20%	$50	Provincial	50%	$5
8	Industry	20%	$50	Federal	50%	$5	Provincial	5%	$25
9	Industry	50%	$5	Federal	5%	$25	Provincial	20%	$50

14. Please rank the importance of the following characteristics of geological disposal of CO2 to you (please rate each characteristic from 'most important' to 'least important')
    a. Entity that manages the long-term disposal risks and has liability for geological disposal of CO2 in Canada
    b. Amount of Canada's greenhouse gas reduction targets met with geological disposal of CO2
    c. Increase in your monthly electricity bill

<Half of the sample received the positive newspaper article and half of the sample received the negative newspaper article>

Please read the following newspaper article:

The Canadian News

Geological Disposal of Carbon Dioxide Holds Hope for Climate Change
By Staff Reporters

As scientific evidence mounts that climate change will have severe impacts on our environment and economy, the solution may literally be beneath our feet. By capturing CO2 from power plants and storing it deep underground, geological disposal of CO2 allows us to reduce greenhouse gas (GHG) emissions with minimal impact on our economy and energy system. As an added bonus, we already know that the technology works – oil and gas companies have used it safely for thirty years to increase oil and gas production and extend the life of their wells. And there's no fear of running out of disposal space: there are ample sites available to hold all of the carbon in all of the fossil fuels on earth. This means that we could continue to use the wealth of fossil fuels around the globe while driving global emissions to the safe levels that climate scientists are calling for.

So is there a downside? Not really. There have been suggestions that the carbon dioxide could leak out, harming humans and animals, and contributing to further climate change. But this is easily avoided. An Environment Canada representative confirmed that the technology would be regulated so that disposal sites would be located outside of earthquake-prone areas, and away from communities. Extensive safety precautions can be developed, and monitoring equipment ensures that in the unlikely event of a leak, it would be detected and stopped. So far, experience at Canadian and international sites has shown that the leakage rate is virtually zero.

Geological disposal of CO2 doesn't require Canadians to make severe lifestyle changes, and it allows us to use our fossil fuel resources while making the long-term transition to renewable energy sources. This means that limited government money can be put into other areas that are priorities for Canadians, such as health care, education, and tax cuts. Geological disposal of CO2 would also protect the Canadian economy, which is heavily dependent on fossil fuels. "Climate change is the world's most serious ecological threat," says a representative of a major environmental organization. "We need geological disposal of CO2 in order to seriously tackle climate change, because even with enormous growth rates, renewable energy and energy efficiency will continue to be dwarfed by fossil fuel use throughout this century". Geological disposal of CO2 offers a ray of hope, since it allows us to reduce GHG emissions in the short and medium term at a relatively low cost, while giving us time and money to develop alternative technologies for the future.

OR

The Canadian News

Geological Disposal of Carbon Dioxide – Another 'Quick Fix' for Climate Change
By Staff Reporters

As scientific evidence grows that climate change will have severe impacts on our environment and economy, so too do the number of quick fixes that have been proposed, some of which sound as though they come straight from science fiction. The latest proposal is geological disposal of carbon dioxide (CO2). Proponents argue that CO2 should be captured from power plants and then stored deep underground. But those searching for technological fixes to the climate change problem have missed the point – our fossil-fuel based lifestyle is unsustainable and is destroying our environment, and the pollution and health impacts of fossil fuel use are having an increasingly negative effect on our economy. "Geological disposal of CO2 does not reduce our greenhouse gas (GHG) emissions at the source", says a representative of a major environmental organization. "Instead, it tries to hide the pollution, like children stuffing their dirty clothes under the bed. Even worse, every dollar that goes into developing geological disposal of CO2 means there is one dollar less to spend on renewable energy and energy efficiency – technologies that actually address the root cause of climate change".

Geological disposal of CO2 is also not as low-risk as its proponents claim. We can't expect to inject huge amounts of CO2 underground without having some of that CO2 leak back out. When that inevitably happens, our communities and Canada's beautiful natural areas will be threatened. High concentrations of CO2 can kill humans, animals, and vegetation, and natural leaks of CO2 in places like Cameroon and Indonesia have killed thousands of people. In some cases, geological disposal of CO2 could also contaminate our groundwater, mobilize toxic contaminants that were previously far underground, and even cause earthquakes. These are just the risks that we can predict – no one can know what other unintended impacts will appear in the future.

Climate change is a serious threat, and we can't afford to be wasting our money on quick fixes. There is no silver bullet – in order to reduce GHG emissions we need to reduce energy consumption and move beyond dirty fossil fuels and toward clean forms of renewable energy.

15. Overall, given everything you have read, do you support or oppose the use of geological disposal of CO_2 in Canada? *(7 point scale – strongly oppose to strongly support, or 'don't know')*

Thank you very much for participating in this study!

Appendix E: Supporting Tables – Discrete Choice Experiment

Only one intercept was included in the discrete choice model, because the initial results showed that the multiple intercepts were not significantly different. Table A.1 shows the overlapping confidence intervals for the three intercepts.

Table A.1 - Intercept Confidence Intervals for Discrete Choice Experiment

CAN				AB/SK			
	Coeff.	Standard Error	Confidence Interval (95%)		Coeff.	Standard Error	Confidence Interval (95%)
INT1	0.498	0.041	0.416 - 0.580	INT1	0.387	0.050	0.286 - 0.488
INT2	0.500	0.040	0.420 - 0.580	INT2	0.379	0.049	0.280 - 0.478
INT3	0.465	0.040	0.384 - 0.545	INT3	0.346	0.050	0.247 - 0.445
No significant difference				No significant difference			

Appendix F: Segmentation Tables – Discrete Choice Experiment

Within each of the geographic sub-samples (AB/SK and CAN) the discrete choice model coefficients were separately estimated for males and females, for those who support and oppose taking action to address climate change, and for those who support and oppose the use of GDC in Canada. The tables below show the model results and a comparison of the monetized coefficient 95% confidence intervals for each segmentation.

Table A.2 - Gender Segmentation, CAN Sub-Sample

	CAN Male				CAN Female			
Variable	Coefficient	S-Error	P-Value	Monetized	Coefficient	S-Error	P-Value	Monetized
Entity-Provincial	0.266	0.039	0.000	-$7.13	0.238	0.044	0.000	-$5.60
Entity – Federal	0.569	0.037	0.000	-$15.27	0.531	0.041	0.000	-$12.49
Share (+1%)	0.021	0.001	0.000	-$0.58	0.020	0.001	0.000	-$0.47
ElecBill (+$1)	-0.037	0.001	0.000	$1.00	-0.043	0.001	0.000	$1.00
Intercept	0.238	0.033	0.000	-$6.38	0.077	0.036	0.032	-$1.81

Table A.3 - Gender Segmentation, CAN, Comparison of 95% Confidence Intervals

	CAN Male		CAN Female		
	Lower C.I.	Upper C.I.	Lower C.I.	Upper C.I.	
Entity-Provincial	-5.0309	-9.22312	-3.55046	-7.65811	Not Sig. Diff.
Entity – Federal	-13.3054	-17.2306	-10.5715	-14.402	Not Sig. Diff.
Share (+1%)	-0.53433	-0.61862	-0.43208	-0.5151	Sig. Diff.
ElecBill (+$1)	1.054176	0.945824	1.054925	0.945075	Not Sig. Diff.
Intercept	-4.63479	-8.12901	-0.11684	-3.49637	Sig. Diff.

Table A.4 - Gender Segmentation, AB/SK Sub-Sample

	AB/SK Male				AB/SK Female			
Variable	Coefficient	S-Error	P-Value	Monetized	Coefficient	S-Error	P-Value	Monetized
Entity-Provincial	0.432	0.049	0.000	-$10.79	0.490	0.051	0.000	-$12.03
Entity – Federal	0.324	0.048	0.000	-$8.09	0.367	0.051	0.000	-$9.02
Share (+1%)	0.021	0.001	0.000	-$0.52	0.015	0.001	0.000	-$0.38
ElecBill (+$1)	-0.040	0.001	0.000	$1.00	-0.041	0.001	0.000	$1.00
Intercept	0.191	0.042	0.000	-$4.78	0.078	0.044	0.075	-$1.91

Table A.5 - Gender Segmentation, AB/SK, Comparison of 95% Confidence Intervals

	AB/SK Male		AB/SK Female		
	Lower C.I.	Upper C.I.	Lower C.I.	Upper C.I.	
Entity-Provincial	-8.3466	-13.2254	-9.51366	-14.5544	Not Sig. Diff.
Entity – Federal	-5.67143	-10.5117	-6.5186	-11.5222	Not Sig. Diff.
Share (+1%)	-0.47238	-0.57421	-0.32812	-0.43309	Sig. Diff
ElecBill (+$1)	1.065587	0.934413	1.067971	0.932029	Not Sig. Diff.
Intercept	-2.692	-6.87091	0.231617	-4.04405	Not Sig. Diff.

Table A.6 - Climate Change Belief Segmentation, CAN Sub-Sample

	CAN Oppose CC Action				CAN Support CC Action			
Variable	Coefficient	S-Error	P-Value	Monetized	Coefficient	S-Error	P-Value	Monetized
Entity-Provincial	0.015	0.067	0.827	-$0.35	0.311	0.033	0.000	-$7.92
Entity – Federal	0.242	0.064	0.000	-$5.84	0.632	0.030	0.000	-$16.08
Share (+1%)	0.016	0.001	0.000	-$0.39	0.022	0.001	0.000	-$0.56
ElecBill (+$1)	-0.041	0.002	0.000	$1.00	-0.039	0.001	0.000	$1.00
Intercept	0.253	0.056	0.000	-$6.10	0.134	0.027	0.000	-$3.41

Table A.7 - Climate Change Belief Segmentation, CAN, Comparison of 95% Confidence Intervals

	CAN CC NO		CAN CC Yes		
	Lower C.I.	Upper C.I.	Lower C.I.	Upper C.I.	
Entity-Provincial	$2.89	-$3.60	-$6.26	-$9.59	Sig. Diff.
Entity - Federal	-$2.75	-$8.93	-$14.53	-$17.63	Sig. Diff.
Share (+1%)	-$0.32	-$0.46	-$0.53	-$0.60	Sig. Diff.
ElecBill (+$1)	$1.09	$0.91	$1.04	$0.96	Not Sig. Diff.
Intercept	-$3.40	-$8.79	-$2.04	-$4.79	Not Sig. Diff.

Table A.8 - Climate Change Belief Segmentation, AB/SK Sub-Sample

	AB/SK Oppose CC Action				AB/SK Support CC Action			
Variable	Coefficient	S-Error	P-Value	Monetized	Coefficient	S-Error	P-Value	Monetized
Entity-Provincial	0.315	0.064	0.000	-$7.18	0.525	0.043	0.000	-$13.44
Entity - Federal	-0.130	0.069	0.059	$2.95	0.524	0.042	0.000	-$13.41
Share (+1%)	0.014	0.001	0.000	-$0.31	0.021	0.001	0.000	-$0.53
ElecBill (+$1)	-0.044	0.002	0.000	$1.00	-0.039	0.001	0.000	$1.00
Intercept	0.208	0.056	0.000	-$4.73	0.117	0.036	0.001	-$2.99

Table A.9 - Climate Change Belief Segmentation, AB/SK, Comparison of 95% Confidence Intervals

	CC NO		CC Yes		
	Lower C.I.	Upper C.I.	Lower C.I.	Upper C.I.	
Entity-Provincial	-$4.26	-$10.09	-$11.24	-$15.65	Sig. Diff.
Entity - Federal	$6.07	-$0.18	-$11.27	-$15.55	Sig. Diff.
Share (+1%)	-$0.24	-$0.37	-$0.49	-$0.58	Sig. Diff.
ElecBill (+$1)	$1.08	$0.92	$1.06	$0.94	Not Sig. Diff.
Intercept	-$2.16	-$7.29	-$1.12	-$4.85	Not Sig. Diff.

Table A.10 - GDC Support Segmentation, CAN Sub-Sample

	Canada Oppose GDC				Canada Support GDC			
Variable	Coefficient	S-Error	P-Value	Monetized	Coefficient	S-Error	P-Value	Monetized
Entity-Provincial	0.016	0.060	0.796	-$0.45	0.309	0.042	0.000	-$8.01
Entity - Federal	0.412	0.056	0.000	-$11.82	0.554	0.039	0.000	-$14.37
Share (+1%)	0.012	0.001	0.000	-$0.34	0.025	0.001	0.000	-$0.65
ElecBill (+$1)	-0.035	0.002	0.000	$1.00	-0.039	0.001	0.000	$1.00
Intercept	0.043	0.049	0.380	-$1.23	0.135	0.035	0.000	-$3.51

Table A.11 - GDC Support Segmentation, CAN, Comparison of 95% Confidence Intervals

	CAN Oppose GDC		CAN Support GDC		
	Lower C.I.	Upper C.I.	Lower C.I.	Upper C.I.	
Entity-Provincial	$3.02	-$3.91	-$5.85	-$10.17	Sig. Diff.
Entity - Federal	-$8.64	-$15.00	-$12.34	-$16.40	Not Sig. Diff.
Share (+1%)	-$0.27	-$0.41	-$0.61	-$0.69	Sig. Diff.
ElecBill (+$1)	$1.09	$0.91	$1.06	$0.94	Not Sig. Diff.
Intercept	$1.57	-$4.02	-$1.71	-$5.32	Not Sig. Diff.

Table A.12 - GDC Support Segmentation, AB/SK Sub-Sample

	AB/SK Oppose GDC				AB/SK Support GDC			
Variable	Coefficient	S-Error	P-Value	Monetized	Coefficient	S-Error	P-Value	Monetized
Entity-Provincial	0.393	0.066	0.000	-$9.94	0.508	0.051	0.000	-$13.37
Entity - Federal	0.054	0.070	0.443	-$1.36	0.465	0.050	0.000	-$12.25
Share (+1%)	0.008	0.001	0.000	-$0.19	0.025	0.001	0.000	-$0.66
ElecBill (+$1)	-0.040	0.002	0.000	$1.00	-0.038	0.001	0.000	$1.00
Intercept	0.090	0.058	0.120	-$2.26	0.140	0.043	0.001	-$3.69

Table A.13 - GDC Support Segmentation, AB/SK, Comparison of 95% Confidence Intervals

	AB/SK Oppose GDC		AB/SK Support GDC		
	Lower C.I.	Upper C.I.	Lower C.I.	Upper C.I.	
Entity-Provincial	-$6.58	-$13.30	-$10.70	-$16.04	Not Sig. Diff.
Entity - Federal	$2.17	-$4.89	-$9.64	-$14.86	Sig. Diff.
Share (+1%)	-$0.12	-$0.27	-$0.60	-$0.71	Sig. Diff.
ElecBill (+$1)	$1.09	$0.91	$1.07	$0.93	Not Sig. Diff.
Intercept	$0.65	-$5.17	-$1.40	-$5.97	Not Sig. Diff.

Appendix G: Supporting Figures – Multiple Regression Analysis

The data structures of the dependent variables for both the CAN and AB/SK models were investigated (Figures A.1 and A.2) and the frequency distribution was determined to be close enough to a normal distribution to proceed with the regression analysis.

Figure A.1 - Frequency Distribution (CAN)

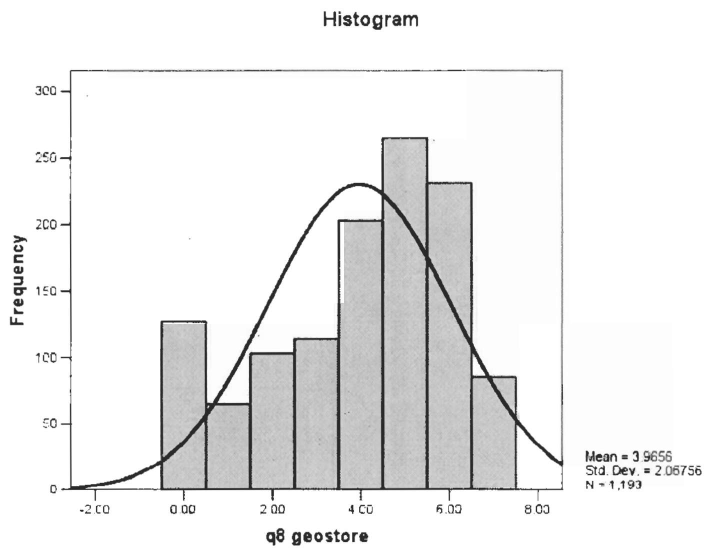
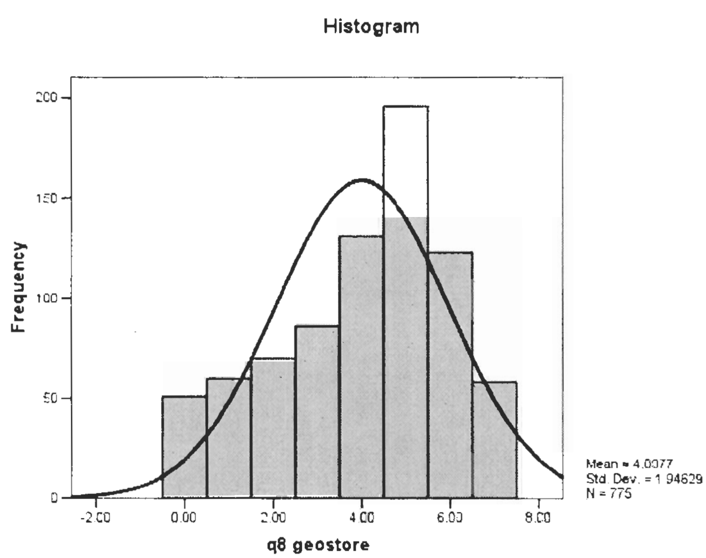


Figure A.2 - Frequency Distribution (AB/SK)



The residuals from both the CAN and AB/SK models were examined in order to identify any problems. Neither set of residuals had a completely random distribution (Figures A.3 and A.4). The scatter plots do not reveal any autocorrelation or heteroskedacity problems (Figures A.5 and A.6).

Figure A.3 - Standardized Residuals Histogram (CAN)

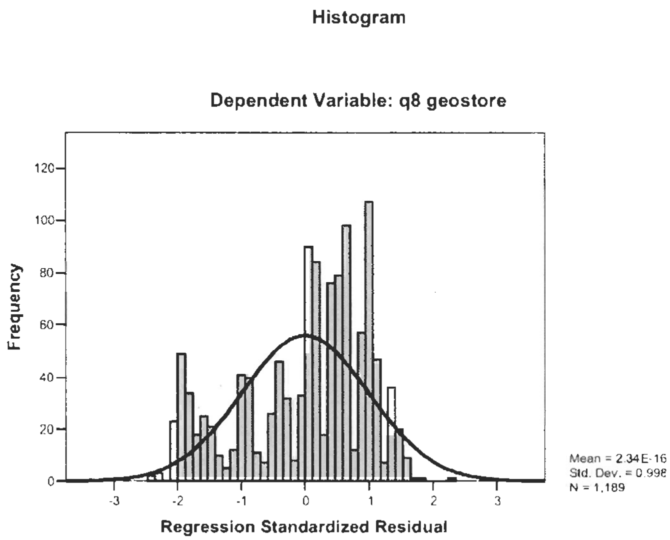


Figure A.4 - Standardized Residuals Histogram (AB/SK)

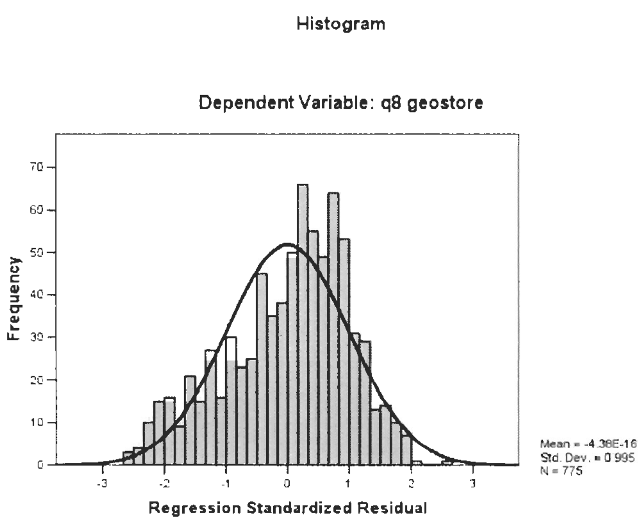


Figure A.5 - Residuals Scatterplot (CAN)

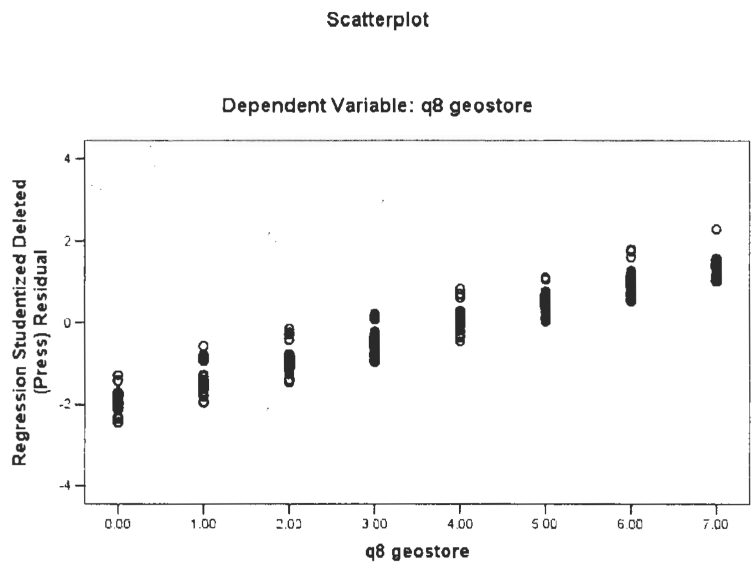


Figure A.6 - Residuals Scatterplot (AB/SK)