Final Draft from:

The ecoENERGY Carbon Capture and Storage Task Force

Canada's Fossil Energy Future

The Way Forward on Carbon Capture and Storage

Report to:

The Minister of Alberta Energy

The Minister of Natural Resources Canada

January 9, 2008

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Foreword from the Task Force Chair

The Task Force on Carbon Capture and Storage was established by the Alberta and Federal Governments in March, 2007. Its mandate is to provide advice on how government and industry can work together to facilitate and support the development of carbon capture and storage (CCS) opportunities in Canada.

CCS presents an opportunity for Canada to develop world-leading technology that can reduce greenhouse gas (GHG) emissions rapidly and on a massive scale. It is not the only solution possible or needed, but our analysis indicates that it must be part of Canada's overall plan to reduce GHG emissions and ensure our continued economic prosperity.

For Canada's energy economy to prosper in a carbon-constrained future, we must find a way to "break" the status-quo equation: economic growth = energy use = GHG emissions. Because of its potential to reduce GHG emissions on an industrial scale, CCS is an important part of the answer.

The long-term benefits of CCS in Canada are huge – Canada-wide potential for carbon dioxide (CO_2) capture and storage may be as high as 600 megatonnes/year, or roughly 40 percent of Canada's projected GHG emissions in 2050 – but we must get started. Other benefits of CCS include the development for export of advanced technology, the international respect and goodwill that will flow from taking the lead on GHG emission reductions, and a new source of long-term economic growth and development. The potential for public benefits from CCS is large.

Success will require a sense of urgency and a commitment by government and industry to work together as they have done so successfully to open up new and important domestic technologies and markets at other critical junctures in our history. In this regard, CCS is on par with other national infrastructure building projects like Syncrude, Hibernia, and the national railways.

I want to thank the Task Force members as well as our observers and contributors from both the Alberta and Federal Governments. They were tireless in their efforts and exemplified the kind of passion and commitment to excellence that success demands. I also want to thank the members of our numerous working committees for their enthusiasm and generosity of time and talent.

On behalf of the Task Force, I want to extend a special thank you to the members of our small but highly capable and dedicated Secretariat. They did the work of a team twice their size, met every deadline and provided superb insight, as well as technical knowledge.

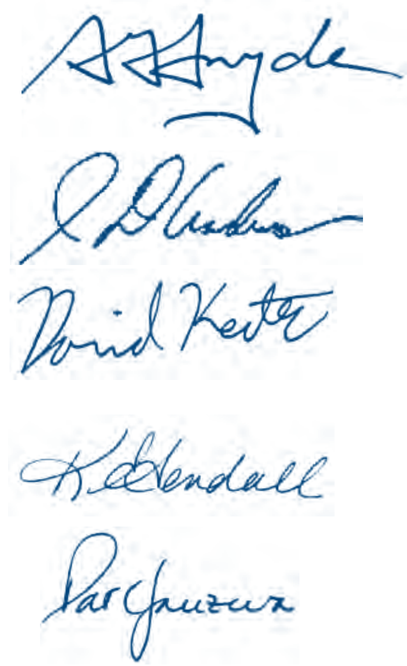
Finally, a large expression of appreciation to Ministers Lunn and Knight for their excellent guidance and support, and to Deputy Ministers Doyle and McFadyen, as ex-officio members of our Task Force, for their unfailing availability and valuable input.

The Task Force looks forward to seeing its recommendations implemented, to Canada taking a world-leading role in the development of CCS technology, and to our nation being a world leader in the reduction of GHG emissions.

Steve Snyder (Task Force Chair)
President and Chief Executive Officer, TransAlta Corporation

The ecoENERGY Carbon Capture and Storage Task Force

Task Force Members



Steve Snyder (Task Force Chair)

President and Chief Executive Officer, TransAlta Corporation

Ian Anderson

President, Kinder Morgan Canada Inc.

David Keith

Director, Energy and Environmental Systems Group, ISEEE,
University of Calgary

Kathleen Sendall

Senior Vice-President, North American Natural Gas, Petro-Canada

Patricia Youzwa

President and Chief Executive Officer, SaskPower

Task Force Secretariat

Joule Bergerson (Team Leader and Co-director of Research)

Shelley Lynes (Operations Manager)

John Van Ham (Lead Writer and Co-director of Research)

Other Participants

The Task Force wishes to acknowledge and thank everyone involved in the work over the past nine months. Many corporations, associations, individuals, and public interest groups participated and contributed through their presentations, feedback, and submissions. A special effort was made by the Institute for Sustainable Energy, Environment and Economy (at the University of Calgary) in pulling together and hosting the Task Force Secretariat.

An acknowledgement is directed toward the individuals who dedicated time and effort through the three Expert Working Groups (see Appendix I). Their research, analysis, and final suggestions helped the Task Force work through its discussions, make decisions, and substantiate the facts in this report.

A special thank you is directed toward the two government departments who commissioned the work. Natural Resources Canada and Alberta Energy initiated and resourced the Task Force and they remained engaged and extremely active throughout the process.

Abbreviations and Units

CAPP	Canadian Association of Petroleum Producers
CCS	carbon capture and storage
CO_2	carbon dioxide
EOR	enhanced oil recovery
GHG	greenhouse gas
H_2	hydrogen
H_2S	hydrogen sulphide
ICO_2N	Integrated CO_2 Network
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
mboe	million barrels of oil equivalent
Mt	megatonne
MW	megawatt
NEB	National Energy Board
NRCan	Natural Resources Canada
NRTEE	National Round Table on the Environment and the Economy
PTAC	Petroleum Technology Alliance Canada
R&D	research and development
RFP	request for proposal
t	tonne
tCO_2	tonne of carbon dioxide
Tcf	trillion cubic feet
U.K.	United Kingdom
U.S.	United States
WCSB	Western Canadian Sedimentary Basin

Canada's Fossil Energy Future - Executive Summary

The Challenge

Canada is experiencing a significant economic surge driven in large part by the natural resources sectors, in particular by the fossil fuel industries in Western Canada. Combined under the banner of fossil energy, Canada's oil, natural gas, and coal resources make the country one of the world's most attractive energy centres for continuing investment and development.

This economic opportunity comes with challenges, such as requirements to mitigate greenhouse gas (GHG) emissions and managing the impacts of climate change. Canadian GHG emissions are up more than 25 percent since 1990. There is growing public concern supported by consensus among the scientific community (the Intergovernmental Panel on Climate Change) that global emissions growth will soon drive atmospheric carbon dioxide (CO_2) concentrations to levels not seen in 10 million years, bringing a growing risk of rapid climate change.

Canadian governments are responding to this concern. The federal government has announced a national objective to reduce emissions by 20 percent from current levels by 2020, and 60 to 70 percent by 2050. Nine out of 10 Canadian provinces have indicated the intent to regulate; Alberta already has regulations for large industry. Some of the targets being proposed present a great challenge to a country that derives 77 percent of its total primary energy from fossil fuels, and much of its wealth from the production and export of these prized resources.

Canada is not alone in facing this issue. Global energy supply is 80 percent fossil-based, and due to growing energy demands in rapidly emerging countries like China it is forecast to be 82 percent by 2030. Meanwhile, many countries and the United Nations are calling for deep global GHG reductions.

The challenge is to strike a balance between reducing GHG emissions and maintaining economic growth

The challenge facing every nation is how to make deep GHG emission reductions while continuing economic progress – a complex task given the direct linkages between economic growth, fossil energy use, and GHG emissions. The magnitude of this challenge was recently noted in the *Energy Pathways* work of the Canadian Academy of Engineering. They note the need for "transformational change", and that the level of effort required "will not be made through the efforts of individual companies, nor governments acting alone; it will require a coordinated national effort."

A Solution

Carbon dioxide capture and storage (CCS) is essential if Canada and the world are to address the carbon challenge. CCS is an innovative process whereby CO_2 emissions from large industrial facilities are separated from the plant's process or exhaust stream and compressed and injected deep underground into secure geological formations.

Along with large-scale renewables and nuclear energy, CCS is one of a limited set of large-scale options to enable an energy-rich, low-carbon future. CCS is unique in that it can be built on the technical and institutional base of the existing fossil energy infrastructure. It can be implemented quickly (within a decade) using existing technology as the world develops next-generation, longer-term energy solutions.

CCS has a role to play in broader GHG regulatory frameworks (both federally and provincially) because of the opportunity it presents. But this requires undertaking an urgent set of actions today to support CCS during its early developmental stages.

CCS is a viable way to achieve significant domestic GHG reductions

The Reward

The magnitude of the reward is clear. Canada-wide potential for CO_2 capture and storage may be as high as 600 megatonnes (Mt)/year, or roughly 40 percent of Canada's projected GHG emissions in 2050.

To get Canada moving towards realizing this potential, the Task Force recommendations challenge the country to achieve the following milestones by 2015:

- Five Mt of annual GHG emission reductions from new large industrial CCS installations
- A first wave of industrial facilities capturing and storing CO_2 (three to five operating projects)
- Global leadership in CCS technical capabilities and expertise
- First-mover advantage in CO_2 crediting protocols, disposal rights and disposition legislation, and long-term liability solutions
- World-class institutions working on the commercial, legal, and regulatory aspects of CCS
- A framework for planning what's next for CCS in Canada

A significant prospect awaits Canada. Success depends on creating the conditions that support the first and subsequent waves of CCS investment while gaining the public's support for CCS as an acceptable way to meet the carbon challenge.

CCS is an opportunity for the country and its industrial sectors to become world leaders in demonstrating that emission reductions, fossil energy use, and economic growth can be achieved together. Achieving the five Mt/year by 2015 goal would virtually guarantee Canada a leading global position in this emerging capability.

Why CCS

CCS is a natural fit for Canada for many reasons.

CCS technology can enable Canada to build on its existing energy infrastructure and its fossil energy endowment while managing the associated GHG emissions. CCS is the only reduction option with the flexibility to either be retrofitted into the existing industrial fleet or be built into new and future facilities.

The technology exists. What's needed is the integration of the components in commercial-scale industrial facilities

The CCS component technologies (capture, transport, and storage) all exist today at industrial scale. What is missing is the full integration and application of these components in commercial facilities at a large-scale. Canada can be among the world's first to build a commercial power plant, bitumen upgrader, or some other fossil energy facility with the capacity for capturing and storing the associated CO_2 emissions.

The co-location of CO_2 sources and sinks in the WCSB makes western Canada ideal for CCS

Canada's biggest advantage lies just underground. Stable sedimentary rock formations like the Western Canadian Sedimentary Basin (WCSB) are ideal for CO_2 storage. The reservoirs that securely held Canada's vast oil and gas reserves for hundreds of millions of years can be used to store CO_2, and the deep saline aquifers underlying these rock units hold several magnitudes more storage potential. The co-location of large industrial GHG sources with this storage opportunity makes the WCSB a world-class location for CCS. Other storage potential also exists in Atlantic Canada, southern Ontario and just south of the Canadian border.

Another opportunity in the WCSB is the potential for enhanced oil recovery (EOR), whereby CO_2 is injected into existing oil reservoirs to extract more resource. EOR using CO_2 injection is already a growing commercial activity and a number of opportunities exist for further EOR development, which helps unlock some commercial value for capturing and injecting CO_2.

CCS has broad application wherever fossil energy is used. It is one of the only ways to manage GHG emissions growth in coal-fired power generation and in the rapidly expanding oil sands sector. CCS is a potential solution for these and other sectors across the nation, as the whole country uses oil, gas, or coal in refining, petrochemicals, manufacturing, cement, and steel.

CCS is a solution for Canada and the world and public investment is required today

If provinces such as Alberta and Saskatchewan lead by building and operating the first commercial-scale fossil energy facilities that incorporate CCS, they will pioneer Canada's efforts as a leading international player in CCS. It is important to remain internationally competitive as the technology evolves and as the market for CCS grows outside of Canada – China, India and other emerging economies require a pathway to continue economic development while reducing emissions.

Why Public Support ?

Collaborative investments between government and industry have a long history in Canada, with many examples of arrangements that opened up new and important domestic markets:

- Syncrude played a pivotal role in furthering oil sands development
- Hibernia was critical to starting Atlantic oil and gas activities
- The national railways, pipelines, transmission grids, and other infrastructure have each connected Canadian markets at critical junctures in the country's history

Each of these "nation-building" initiatives was and continues to be in the interest of Canadians. Each began with public and private support in order to spread the risks associated with the first few projects and to enable action on activities that entailed an upfront capital cost but that were clearly in the public's best interest.

Canada possesses the technology, geology, and expertise to be a world leader in the development and implementation of CCS technology. But as with any new environmental technology a financial gap exists between the cost of a plant with CCS and what would otherwise be built to produce the same industrial outputs.

In the absence of proven integration of CCS technologies at scale, regulatory clarity, and market prices for carbon, among other uncertainties, it is a very difficult proposition for individual private sector players to commit additional hundreds of millions of dollars of investors' money to achieve a public good (such as GHG emissions reductions) for which it may not be compensated with an adequate (or any) return on investment.

This financial gap is what prevents the commercial application of CCS projects today.

Closing this gap and establishing CCS as a major component of Canada's GHG reduction strategy requires a strong collaborative effort by industry and government.

Why Now ?

Taking the lead in developing CCS solutions for Canadian industry requires urgent action. Government must commit public financial support for CCS and industry must commit to building and operating CCS projects immediately.

All large industrial facilities entail long construction lead times, and they require highly specific skill sets. Many of the skills required for CCS exist in the oil and gas and power generation sectors, but CCS-specific capabilities will only come through actual experience. Canada will lose the opportunity to deploy CCS rapidly in response to future GHG emission reduction policies if the country delays the construction of an initial set of commercial-scale CCS projects.

CCS-specific skills must accrue today by building on existing expertise in industry, government, and research institutes

In the meantime, capital investments in the fossil energy sectors continue to be made. Electricity markets across the county, including coal-dependent Alberta, Saskatchewan, Ontario, Nova Scotia, and New Brunswick require new capacity to satisfy increasing demand and to replace plants that are reaching retirement. Over

$150 billion in capital spending has been announced for the oil sands alone. If government fails to demonstrate its seriousness regarding CCS, these facilities will be built with conventional technology, thus making them costly to retrofit with CCS technologies in the future. If on the other hand government provides support and funding for CCS, new facilities can be designed to accommodate CCS and thus avoid the potential for technology lock-in and stranded assets.

Learning-by-doing is essential and will start by building and operating the first commercial-scale projects

Starting on CCS today will initiate a learning-by-doing phase, which will result in cost reductions due to improved materials and technology design, standardization of applications, system integration and optimization, and economies of scale. Only through implementing a first set of commercial-scale projects will the country start its way along the learning curve to success.

Canada is among the leading countries working on CCS, but it is not the only one. Australia, Norway, the United Kingdom (U.K.) and the United States (U.S.) are all forging ahead with public investment and commercial frameworks for the first few projects and are developing the regulatory environments to nurture CCS. Only by remaining part of this leading group will Canada stay relevant and up-to-date on international developments.

Success with CCS depends on a balanced approach to GHG policy. Domestic action on climate change must proceed at the same pace as the actions being taken by Canada's major trading partners. If Canada acts too aggressively to reduce GHG emissions in the near term it risks putting its industrial base at a competitive disadvantage. By the same token, however, if Canada moves too slowly it may also hurt its competitiveness as the rest of the world turns to standards that make GHG-intensive energy sources less viable. The competitiveness of the domestic fossil energy sector hinges on using CCS to satisfy growing GHG reduction obligations while continuing to develop these fossil energy resources.

This is why Canada needs to urgently develop the skills and expertise required for CCS. Inaction may result in a declining role for Canada's fossil energy industry in the future.

Investing in CCS today allows Canada to compete in a carbon-constrained world

Alternatively, by investing today Canada will gain from a leading position in CCS development. More importantly, it enables the option to implement CCS more broadly in the future if increasingly stringent carbon constraints become a reality through international and domestic policy. An investment in CCS is critical to managing the risk that future carbon constraints may place on industry.

The Recommendations

Industry will build and operate the CCS projects, which entails a significant amount of upfront investment risk, for which the main benefit is the potential for reducing the cost of current and future GHG regulations. Any industrial facility with a large capture opportunity (projects that capture on the order of one megatonne of CO_2 per year) requires a total project investment in the hundreds of millions to billions of dollars. Before any decisions are even made on these projects, industry invests tens of millions of dollars on front-end studies. Industry should continue to play this role in CCS deployment but this effort should be complemented by public support.

Industry and governments should work collaboratively to develop the financial and regulatory conditions needed to move CCS forward. Governments already provide support in many ways, including funding for some of the front-end studies; they also need to share in the financing of actual CCS projects. Therefore the following are recommendations to Federal and Provincial governments for their roles in these collaborative efforts.

Three immediate actions are recommended to get Canada on the pathway to successful CCS implementation, and three subsequent actions should be undertaken as next steps. The first three require urgent attention as they are intended to address the two main barriers facing CCS today: the financial gap associated with CCS projects today, and current gaps in regulatory frameworks. Canada must overcome these hurdles, and in short order, to succeed with CCS.

Three Immediate Actions

Immediate Action #1 – *Federal and Provincial governments should allocate $2 billion in new public funding to leverage the billions of dollars of industry investment in the first CCS projects; this funding should be distributed expeditiously through a competitive request for proposals process so that these phase-one projects are operational by 2015.*

Funding the first set of three to five CCS projects will result in five Mt of annual CO_2 reductions from CCS, and will initiate the process for getting the country on the pathway towards a made-in-Canada solution for reducing emissions and towards global leadership in CCS.

Immediate Action #2 – *Authorities responsible for oil and gas regulation should provide regulatory clarity to move the first CCS projects forward by: quickly confirming legislation and regulation related to pore-space ownership and disposition rights; clearly articulating the terms for the transfer of long-term liability from industry to government; and increasing the transparency of regulatory processes.*

Confirming provincial jurisdiction over the ownership and disposition of pore space, and clearly articulating that industry will not face long-term liability obligations associated with CCS will help create a regulatory environment that is conducive for CCS. The time required to make the regulatory changes should not delay decisions or approvals on the phase-one CCS projects.

Immediate Action #3 – *Federal and Provincial governments should ensure as much opportunity for CCS projects under the GHG regulatory frameworks as for any other qualifying emission reduction option. This will require the creation of CCS-specific measurement and crediting protocols.*

Ensuring a role for CCS in meeting emission reductions obligations, and ensuring that any CO_2 credits from CCS are no less tradable or valuable than other credits, will help create some potential commercial value for CCS activities.

Three Next Steps

Next Step #1 - *Industry and both government levels should form a collaborative framework including an advisory group over the next two years to coordinate discussion, to institutionalize learning, and to potentially carry out specific aspects of immediate actions 1, 2, and 3. This may evolve into a more formal organization as future needs are assessed.*

A collaborative effort based on coordinating and institutionalizing the learning gained will foster CCS capabilities in Canadian industry, government, and non-government organizations.

Next Step #2 – *Federal and Provincial governments should provide stable financial incentives to help drive CCS activities beyond the phase-one projects. These may include the continuation of RFPs for phase-two projects, CO_2 storage incentives, and/or the use of tax and royalty incentives.*

Broad-based, phase-two support for CCS is required to drive the country towards deep future GHG reductions, potentially one-third to one-half of Canada's projected GHG emissions by 2050.

Next Step #3 – *Canadian-based research organizations and technology developers should focus research and demonstration efforts on CCS to achieve two goals: to drive down the cost of existing CCS technologies; and to enable the deployment of next generation CCS technology and processes – the Federal and Provincial governments should provide financial support for these activities.*

Canadian-based research on cost-effective and next generation technology will support broader application of CCS in other sectors and locations, both domestic and international.

These recommendations are based on the premise that governments, while remaining cognizant of the requirement for international competitiveness, will continue working towards clearer and more certain GHG emission reductions policy, which is the ultimate driver behind CCS. Only through balanced GHG policy will the country achieve the fundamental objective of all its early-stage investments in CCS, wind energy, and other emission reductions options – a lasting solution to the carbon challenge.

The Way Forward

The technological components for CCS already exist and can be built into industrial facilities today. What is required is financial and regulatory support. A few fully integrated CCS projects will demonstrate to industry and the public the feasibility and safety of integration at scale. These projects will initiate the learning-by-doing curve that leads to cost reductions. The first projects will test the regulatory processes and help pave the way for future projects seeking approvals. Each of these outcomes is essential if CCS is to play its role in reducing emissions.

Canada has an opportunity to be the world's first country to build a commercial-scale power plant, bitumen upgrader, or some other fossil energy facility with the capability of capturing and storing the associated CO_2. Industry and governments should work collaboratively to develop the financial and regulatory conditions needed to move CCS forward.

For its part, industry will undertake a significant amount of investment risk by building and operating the first CCS projects. Industry should play this role, but its efforts should be complemented by a public investment in this critical technology and infrastructure. Governments already provide support in many ways, including funding for some of the front-end studies; they also need to share in the financial investments to accelerate CCS development and deployment.

The Task Force estimates a public investment on the order $2 billion is needed to close the funding gap on an initial set of projects, which will result in five Mt of annual CO_2 reductions from CCS by 2015. This is the equivalent of eliminating the GHG emissions from 1.4 million vehicles per year in Canada. Beyond the first projects (which should be operational by 2015), the Task Force envisions the need for further public support to help sustain CCS activities through an interim stage until the carbon market has matured or other regulatory requirements are at the point where the financial gap facing CCS is sufficiently closed.

An investment in CCS will result in material GHG reductions from Canadian industry

This is a significant initial public investment, but it is an important one because it will more quickly enable Canada to make industrial-scale GHG reductions (using CCS) while remaining internationally competitive in a carbon-constrained world.

Addressing the Carbon Challenge

Canada is experiencing a significant economic surge driven in no small part by a wave of investment in the natural resource sectors, in particular by the fossil fuel industries in Western Canada. This progress also presents a difficult challenge for the country as it plans to implement greenhouse gas (GHG) emission reduction targets and yet carbon dioxide (CO_2) emissions continue to grow. GHG emissions are up more than 25 percent economy-wide since 1990[1].

This carbon challenge is not unique to Canada. It is global. There is growing public concern supported by consensus among the international scientific community that global emissions growth will soon drive atmospheric CO_2 concentrations to levels not seen in 10 million years, resulting in an increasing risk of rapid climate change[2].

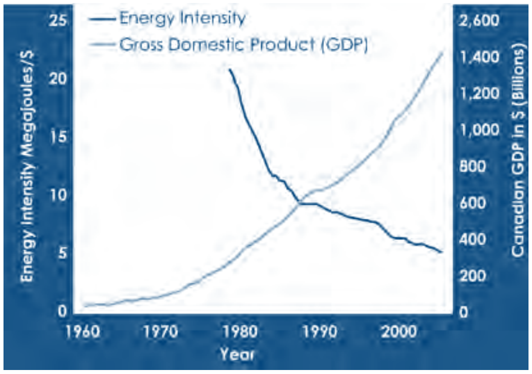
Individual countries are developing their own responses to reducing GHG emissions, and are working through the United Nations Framework Convention on Climate Change to coordinate deep GHG emission reductions globally.

Nine of 10 Canadian provinces have indicated the intent to regulate GHGs. Alberta has regulated targets for large industrial emitters (under its Specified Gas Emitters Regulation), and it is currently developing its post-2012 policy.

The federal government's recent Speech from the Throne notes national reduction objectives of 20 percent below current emissions levels by 2020 and 60 to 70 percent reductions by 2050[3]. As well, the federal government released its Regulatory Framework for Industrial Air Emissions in 2007 and it is currently developing the GHG regulations for industry under the Clean Air Regulatory Agenda, with draft regulations expected in early 2008.

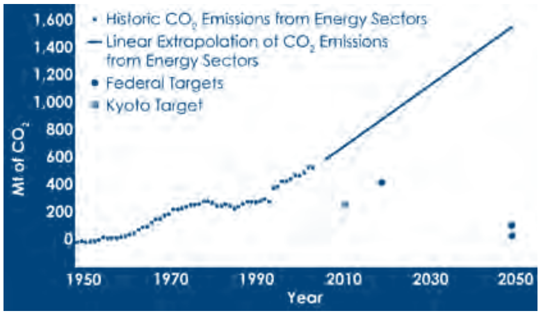
At the same time, industry has made great headway in reducing energy intensity. But when it comes to absolute GHG emissions, the growth in Canadian Gross Domestic Product (GDP) has outstripped the energy intensity improvements made in recent decades (see illustration).

Historic GDP and Energy Intensity [4]



[1] Environment Canada. 2007. *Canada's Greenhouse Gas Inventory*.
[2] Intergovernmental Panel on Climate Change (IPCC). 2007. *Fourth Assessment Report – Working Group 1*.
[3] Government of Canada. October, 2007. *Strong Leadership. A Better Canada*.
[4] Data from: Statistics Canada. December 2007. Statistical Tables: 3800016, 1280002, and1280009.

The Carbon Challenge [5]



The issue is that Canadian economic growth is inextricably linked to fossil fuel production and use, and production and use are in turn linked to GHG emissions. To address the carbon challenge, absolute emission reductions are required. Until the link between economic growth and energy use or the link between energy use and GHG emissions is broken (using options like CCS) it will be difficult to meet Canada's GHG reduction objectives (see illustration).

Meeting Canada's aggressive targets will require substantial changes to the existing energy systems that fuel transportation, electricity, space heating, and other essential energy services. The issue must be tackled on many fronts using all viable options including energy efficiency, renewable and nuclear energy, and low-emissions fossil energy. The magnitude of this challenge requires "transformational change," and the level of effort required "will not be made through the efforts of individual companies, nor governments acting alone; it will require a coordinated national effort.[6]"

Canada has a great endowment of fossil energy resources. It is a large petroleum producer and exporter. The entire country relies on fossil fuels for both personal use and commercial activities. Nearly 77 percent of Canada's total primary energy demand is supplied by fossil energy – oil, natural gas, and coal[7].

CCS provides the option to continue using fossil energy while also making material emission reductions

Carbon dioxide capture and storage (CCS) is essential for Canada to continue to develop and use its valuable fossil resource and meet its emission reduction obligations. CCS is an innovative process whereby CO_2 emissions from large industrial facilities are separated from the plant's process or exhaust stream and injected deep underground into secure geological formations. CCS can reduce CO_2 emissions from existing facilities and infrastructure; it is the only option that can be retrofitted into the current industrial fleet. It can also be built into new and future facilities, to curb the impacts of the rapidly growing oil sands and electric power sectors.

The potential CCS holds for large industrial emissions is enormous. The Canada-wide potential for capturable CO_2 could be as high as one-third to one-half of the country's projected GHG emissions in 2050[8].

The ecoENERGY Carbon Capture and Storage Task Force (the Task Force) was asked to recommend how governments and industry can partner to initiate and sustain domestic CCS activities. The Task Force drew on existing Canadian and international

[5] Data from: Marland, G. Boden, T. A. and R.J. Andres. 2007. *Global, Regional, and National CO_2 Emissions. In Trends: A Compendium of Data on Global Change*.
[6] Canadian Academy of Engineering. Summer-Fall 2007. *Newsletter article on Energy Pathways Project*.
[7] National Energy Board (NEB). 2007. *Canada's Energy Future: Reference case and scenarios to 2030*.
[8] "Capturable CO_2" is the potential amount of CO_2 available for capture.

expertise and previous work such as *Canada's CO_2 Capture and Storage Technology Roadmap*[9] to develop its proposals. It also drew from the research and analysis of three working groups focused on technology, economic and policy, and regulatory and legal issues. The result is a suite of recommendations that if implemented would significantly reduce GHG emissions.

An underlying set of principles guided the Task Force through its workshops and discussions:

- To enable CCS as a tool for achieving deep cuts in actual GHG emissions
- To unlock any commercial opportunities that help facilitate CCS
- To provide regulatory assurance and address industry and stakeholder concerns
- To present potential early opportunities and longer-term options for CCS
- To support opportunities for Canadian leadership in technology and expertise
- To maintain international competitiveness while reducing emissions

CCS is an important opportunity for Canada, and its success hinges on creating the broad-based conditions to support the first and subsequent waves of CCS investment while gaining public support for CCS as an acceptable way to help meet the carbon challenge.

[9] Natural Resources Canada (NRCan). 2006. *Canada's CO_2 Capture and Storage Technology Roadmap*.

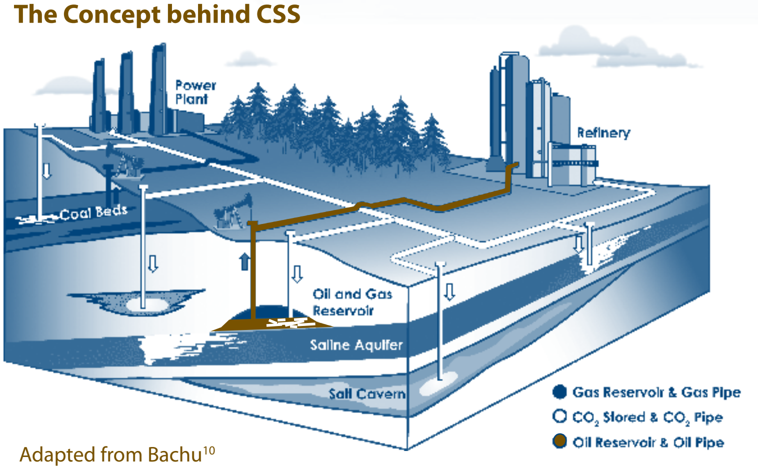
An Innovative Technology

CCS enables the continued use of fossil energy while mitigating the GHG emissions associated with these sources. CCS involves the capture of high-volume, concentrated streams of CO_2 which are then compressed, transported, and disposed of in deep underground geological formations, like those from which oil and gas are produced.

The Components

There are no technological barriers to implementing CCS; all of the components for capture, compression, transportation, injection, and storage already exist at industrial scale. What is missing is the full integration of these components in a commercial facility the size of a typical power plant or bitumen upgrading facility.

The Concept behind CSS



Adapted from Bachu[10]

Capture and Compression

Four primary methods are used to capture and concentrate CO_2 from industrial processes and emissions streams: post-combustion, pre-combustion, oxy-fuel combustion, and industrial separation. *Canada's CO_2 Capture and Storage Technology Roadmap* goes into detail on each of these options[11].

Capture is a particularly difficult challenge for many sectors. For example, the oil and gas sector includes a number of different facilities that may each have several emissions sources with varying quantities and concentrations of CO_2. Not all emissions streams are currently amenable to CO_2 capture. The lower the CO_2 concentration the more costly capture is because of the energy required to separate and purify the CO_2 for it to be compressed to a liquid state for transportation by pipeline.

[10] Bachu, S. Energy and Resources Conservation Board.
[11] NRCan. 2006. *Canada's CO_2 Capture and Storage Technology Roadmap*.

All of these additional processes add up to a high cost of CO_2 capture because each step requires additional capital investment and energy use when operating the facility.

Canada currently has no commercial-scale industrial facilities that capture CO_2. This is a critical gap because capture and compression account for 70 to 90 percent of the cost of a fully integrated CCS project[12]. Since capture and compression (combined) is the primary contributor to the financial gap facing CCS today it is a key area to achieve cost reductions.

Transportation

Trucks or tanks are used today to move small CO_2 volumes for the food and beverage industries, but pipelines are the only option for moving large volumes of CO_2 from source to sink.

Several commercial CO_2 pipelines operate across North America. A 323-kilometre line runs from North Dakota to Saskatchewan, supplying CO_2 to two enhanced oil recovery (EOR) projects – the Weyburn project and the Midale project. Smaller pipelines move acid gas, a mixture of hydrogen sulphide (H_2S) and CO_2, in the foothills of Alberta and British Columbia. A network of pipelines moves 30 Mt of naturally occurring CO_2 annually in the Permian basin (in the U.S.).

Transporting CO_2 is the least risky aspect of CCS, both technically and economically, and it is not a barrier to CCS implementation in Canada.

Injection and Storage

CO_2 can be disposed of in a range of geological formations, such as operating oil and gas fields, depleted reservoirs, and deep saline aquifers.

Injecting CO_2 into existing reservoirs can increase hydrocarbon recovery. CO_2 is being injected at 50 EOR facilities in the U.S. today. In Canada, the Weyburn EOR flood started in 2000 and stores roughly one Mt of CO_2 annually. EOR projects such as this one can be designed so that much of the CO_2 remains underground (as stored CO_2) at the end of the EOR flood[13]. Tapping the commercial value of CO_2 for EOR will help in deploying the first phases of CCS projects.

EOR is one way to get some commercial value for storing CO_2 – it's critical to unlock as much commercial potential as possible during CCS' early stages

However, the EOR market is relatively small compared to the total volume of capturable CO_2 in western Canada, so other storage options are needed. The total size of the EOR market depends on many factors (including the price of CO_2 and the price of oil) but preliminary estimates indicate that 450 Mt of capacity may be currently available[14] (this equates to less than 10 Mt/year of storage for 50 years).

[12] IPCC. 2005. Carbon Dioxide Capture and Storage

[13] The amount of CO_2 that is stored underground comes down to an economic decision; this is not a result of any leakage or seepage from these projects.

[14] Bachu, S. and J. Shaw. 2005. *CO_2 Storage in Oil and Gas Reservoirs in Western Canada*.

Depleted oil and gas reservoirs have a proven record of storing fluids for hundreds of millions of years. Deep saline aquifers underlie the sedimentary basins across Canada and hold even more storage potential. These are deep permeable rock formations saturated with extremely saline fluids that cannot be used as potable water.

Some EOR projects are moving ahead, but no 'direct storage' projects (in either depleted reservoirs or deep saline aquifers) exist in Canada today. It will be important to demonstrate long-term storage in a range of geological settings including deep saline aquifers.

Associated Risks

As with any other large-scale industrial activity, CCS entails some safety and environmental risks. None of these risks are novel as many of the activities associated with CCS are already widely used. Large-scale CO_2 transportation by pipeline, for example, has been in operation for decades in the Permian basin. Similarly, there is a broad base of experience with large-scale deep underground storage or disposal including the disposal of toxic wastes and oilfield brine and the large-scale storage of natural gas.

The Intergovernmental Panel on Climate Change (IPCC) states that the operational safety risks of CCS are likely to be similar to or smaller than the risks of current upstream oil and gas operations[15]. A related concern is the long-term security of storage for which the IPCC concludes that the fraction of CO_2 retained in storage is "…likely to exceed 99 percent over 1000 years"[16]. This timescale is long compared to the retention of emissions in the atmosphere and so the impact of any potential seepage of stored CO_2 (on the climate or public safety) will be negligible.

Integration at Scale

While the specific components of CCS (capture, transport, and storage) are being demonstrated in current applications (such as CO_2 monitoring in the case of Weyburn), what has not been done is the combination of these pieces in fully-integrated, commercial-scale industrial facilities.

A typical 600 megawatt (MW) coal-fired power plant built in western Canada emits roughly 3.8 Mt of CO_2 annually, whether it is supercritical pulverized coal or integrated coal gasification combined cycle. Greater than 90 percent of this CO_2 is technically amenable to capture[17]. A large fleet of coal-fired plants operate across Canada today, many of which are close to retirement[18]. The commercial use of these facilities could be extended by retrofitting them with post-combustion processes, thus enabling many megatonnes of domestic capture opportunity.

[15] IPCC. 2005. *Carbon Dioxide Capture and Storage*.
[16] Ibid
[17] IPCC. 2005. *Carbon Capture and Storage*.
[18] NRCan. 2005. *Canada's Clean Coal Technology Roadmap*.

A bitumen upgrading facility using steam methane reforming to generate 200 million standard cubic feet per day of hydrogen (H2) and with an upgrading capacity of 100,000 barrels of bitumen per day emits roughly 1.3 Mt per year (of which, greater than 80 percent is capturable). A similar sized plant using gasification produces twice as much CO_2 (with greater than 90 percent capturable).

These examples are representative of the large-scale CO_2 reduction opportunities afforded by CCS as a GHG emission mitigation option.

The technological components for CCS already exist and can be built into new facilities today – what is required is financial and regulatory support. A few fully integrated projects will demonstrate to industry and the public the feasibility and safety of integration at scale. These projects will also initiate learning-by-doing which leads to cost reductions. The first projects will test the regulatory processes and help pave the way for future projects that seek regulatory approval. Each of these outcomes is essential if CCS is to play a significant role in reducing emissions.

> The technology exists, what's needed is the integration of components in commercial-scale industrial facilities

Canada could be the world's first country to build a commercial-scale power plant, bitumen upgrader, or some other fossil energy facility with the intent of capturing and storing the associated CO_2. At the same time, the country should continue to work through international forums like the Carbon Sequestration Leadership Forum and the International Energy Agency GHG Research and Development (R&D) Programme, as no single company or nation can tackle CCS in isolation. Canada can and should provide leadership in specific technical areas and through these foster international relations.

The Case for CCS

Domestic Opportunities

A number of viable GHG mitigation options are necessary to meet the federal 20 percent GHG emission reductions objective by 2020, including energy efficiency, renewable and nuclear energy, and fossil energy with CCS. Each choice involves important trade offs between cost and environmental or health and safety risks.

CCS can start to deliver meaningful emission reductions by 2015 from a wide range of industrial sectors. One opportunity is coal-fired power generation. Coal is central to the current North American electricity fuel mix; it has a prominent role in Alberta, Saskatchewan, Ontario[19], Nova Scotia, and New Brunswick, and it is expected to continue to be part of the mix, especially in western Canada, which has abundant, low-cost coal resources.

Low-emission, coal-fired power generation is possible with CCS. In fact, CCS is the only viable option for making significant CO_2 emission reductions from coal-fired power. Opportunities for post-combustion, pre-combustion, or oxy-fuel combustion technology exist in new coal-fired facilities. Retrofit options are available for existing plants based on post-combustion technology.

According to studies by the U.S. Department of Energy and the International Energy Agency (IEA), the capital cost of new electrical capacity is high no matter which energy option (nuclear, wind, or coal with CCS) is selected and where the project is built[20]. These studies indicate that although the cost of power generation with CCS is high compared to the existing base load, this cost is actually well within the range of other current base load options such as nuclear. It is important to note that all capital-intensive projects cost more today because of recent cost escalations, which are primarily due to higher prices for labour and materials.

Power and oil and gas provide the largest potential for significant capture and storage

In the case of coal-fired power with CCS, additional costs could be passed along to the consumer, but this means a significant increase in power prices. And depending on the availability of energy resources in different regions it could result in significant price disparities between provinces.

Other roles for CO_2 capture exist in oil and gas, but the case for oil sands comes with both opportunities and challenges. The oil sands are the fastest growing sector for domestic GHG emissions and so there are real opportunities for reductions. However, oil sands operations are very diverse (both geographically and technically) and

19 Ontario is phasing out coal by 2014. The original plan was 2009, but alternatives have not yet been developed.

20 Energy Information Administration. 2007. Electricity Market Module. Report #: DOR/EIA-0554(2007). and International Energy Agency (IEA). 2006. *World Energy Outlook*.

only a small portion of the CO_2 streams are currently amenable for CCS due to both the size of emissions streams and the concentrations. The problem is that lower-concentration or smaller emission streams are more costly to capture because of the additional unit capital and operating costs (including energy use) associated with the capture, separation, and purification processes.

The earliest oil sands opportunities are the bitumen upgrading facilities that use steam methane reforming or gasification technology and which produce higher-concentration CO_2 streams. Polygeneration is a promising technology in the oil sands and it is very well suited for CCS.

Natural gas processing is another early opportunity as acid gas (a mixture of H_2S and CO_2) is currently separated from sour gas and re-injected into deep geological formations. Existing acid gas projects in Alberta and British Columbia are good analogues for both CO_2 capture and storage processes. A lot can be learned about CCS through the experience of operating these projects.

Many Canadian industries, including oil and gas, compete in international markets, often with international competitors that do not face the same costs associated with their CO_2 emissions. But the issue is much broader than just CO_2. In fact, a variety of policies and regulations continue to increase the fiscal burden being placed on domestic sectors while the international market remains unchanged. Faced with this difficult competitive challenge, domestic firms have no way of recovering the further increases in cost associated with CCS. For these companies to remain in business they must recover their cost of production, including a return on investment that is at least as high as their cost of capital.

Unlike electricity, currently no economically-viable alternatives exist to fully offset the products and services provided by today's petroleum resources. While alternatives such as biomass will likely play an increasing role in the future (for example, in ethanol and bio-diesel production) as the technology matures, petroleum resources are expected to dominate Canada's energy supply needs for the next several decades.

Further applications for CCS exist in the petrochemical, fertilizer, manufacturing, steel, and cement sectors. A few early projects in the fossil energy or other GHG-intensive sectors followed by a period of broader support could eventually benefit many important Canadian sectors. One particularly novel concept is to co-fire or co-feed biomass along with fossil energy inputs (such as coal or other heavy fuels) in conventional energy systems in order to further reduce GHG emissions. This is a particularly interesting concept for Canada considering the size of domestic biomass resources.

Fossil fuels occupy their current market position for very good reason. They are the global standard for low-cost, convenient, high energy-density supply against which all other options are compared. Fossil fuels are used in power plants, industrial processes, and all forms of transport, space heating, and cooling. Fossil energy supplies 80 percent of today's global energy needs (in Canada this number is 77 percent), and they are forecast to supply 82 percent by 2030[21].

If this forecast is realized, then CCS can become a significant contributor to fossil energy-related GHG reductions. It is currently the only option to retrofit emission reductions capabilities into existing energy infrastructure and systems. For fossil fuel dependent economies, like Alberta and Saskatchewan, CCS is a must-have.

For that matter, large quantities of coal, oil, and natural gas are used in industry and homes across Canada. Existing energy systems form the foundational infrastructure of Canada's economy and the well-being of its citizens. These energy systems took more than half a century and hundreds of billions of dollars to construct (nearly $500 billion in the last 10 years alone)[22]. These energy systems are the basis of Canada's low-cost energy advantage. They are important assets that should be built upon.

This is why CCS is essential to Canada.

World Class Fossil Energy Potential

Canada is recognized as one of a few global locations with large, secure energy supplies. The country's energy endowment ranges from conventional sources like uranium, hydro, wind, and biomass, to emerging alternatives such as ocean-wave, geothermal, and solar. However, most of the domestic and international interest in Canada as an energy supply is centered on its fossil energy base of oil, natural gas, and coal.

At 180 billion barrels of recoverable reserves (170 of which are oil sands), Canada is second only to Saudi Arabia in national oil reserves.[23] The oil sands regions of the WCSB have 1.6 to 2.5 trillion barrels in place[24].

Current remaining established Canadian natural gas reserves sit at 58 trillion cubic feet (Tcf)[25], with ultimate conventional potential of 370 Tcf[26]. Beyond this is 2,500 Tcf of unconventional gas-in-place in coal beds, tight-gas and shale-gas deposits; gas hydrates host between 1,500 and 29,000 Tcf[27].

21 Ibid
22 Total capital expenditures for the energy sectors. Statistics Canada. 2007. Statistical Table Numbers 0029-0005, 029-0007, 0029-0008, 0029-0009, and 0029-0012.
23 Canadian Association of Petroleum Producers (CAPP). 2006. *Oil Sands.*
24 Ibid
25 CAPP. October, 2007. *Industry Facts and Information webpage*.
26 Petroleum Technology Alliance Canada (PTAC). 2006. *Unconventional Gas Technology Roadmap*.
27 Ibid.

Canada has 320 billion tonnes (t)[28] of coal-in-place, of which 8.7 billion tonnes are classified as reserves at current market prices[29]. 79 billion tonnes are considered coal resource[30], with more than half of this amount in the sub-bituminous and lignite coals of western Canada, which are used for power generation in Alberta and Saskatchewan.

These reserves and in-place numbers are converted into millions of barrels of oil equivalent (mboe) in the table to illustrate how they compare to one another. The following are a few examples of what these numbers mean in relation to domestic energy consumption: Canadian oil sands reserves (the 180,000 mboe) contain enough energy to drive 2 billion passenger cars over a lifetime of 200,000 kilometres; natural gas reserves are sufficient to heat all Canadian households for 75 years; and coal reserves are enough to provide electricity for Canadian homes for 100 years. The point is that each of these reserves is large and the total potential of all in-place resources is at least an order of magnitude larger in each case.

Fossil Energy Reserves and Potential

	Reserves (mboe)	In Place (mboe)
OIL*	180,000	2,000,000
GAS**	10,000	490,000
COAL	31,000	1,200,000

mboe: million barrels of oil equivalent
* Includes conventional and unconventional sources
** Includes conventional and unconventional sources (except to gas hydrates)

Combined under the single banner of fossil energy, Canada's oil, natural gas and coal resources place the country firmly on the map of world class energy locations. These assets present excellent export opportunities and they also provide an important domestic competitive advantage – the country's low cost of energy makes domestic industries (like refining, smelting, and manufacturing) internationally competitive. It would be costly to forego the economic opportunity locked away in these fossil energy resources when a solution for controlling the GHG emissions is close at hand. CCS presents an opportunity for carbon management from the largest GHG point sources across the country.

World Class Storage Potential

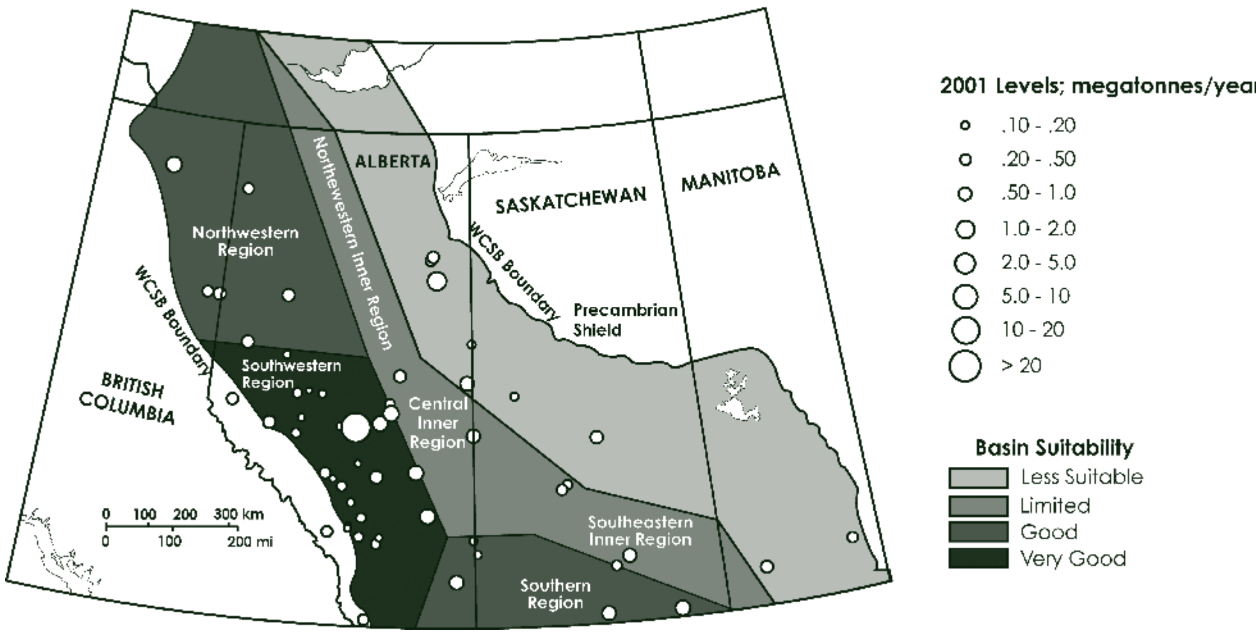
The geological formations containing these energy resources are a solution to the carbon challenge. The reservoirs that securely held oil and gas for hundreds of million years can be used to store CO_2, and the deep saline aquifers underlying these rock formations hold several magnitudes more storage potential.

The Western Canadian Sedimentary Basin (WCSB), a unit of sedimentary rock spanning western Canada[31], is considered a world-class opportunity for proving, testing, and

28 Singhal and Fytas. 1999. *Reclamation of surface coal and oil sands mines in Western Canada*.
29 World Energy Council. 2004. *Survey of Energy Resources*.
30 NEB. 2007. *Canada's Energy Future: Reference case and scenarios to 2030*.
31 The WCSB cuts across several jurisdictions: British Columbia, Alberta, Saskatchewan, Manitoba, and the Northwest Territories. It also stretches into the United States.

implementing the requisite components of CCS on a large scale. Superimposing the capture locations in western Canada onto this storage potential gives a clear picture of the opportunity (see illustration).

The Opportunity in Western Canadian Sedimentary Basin



Adapted from Bachu and Stewart[32]

As previously noted, preliminary estimates indicate that 450 Mt of storage capacity may be currently available in oil fields that are amenable to EOR. Roughly an order of magnitude more storage potential exists in mature oil and gas reservoirs. By far the largest storage potential, on the order one million megatonnes, exists in the deep saline aquifers that underlie the WCSB rock formations and other sedimentary basins across Canada. These deep rock formations are highly permeable, they are saturated with extremely saline and therefore unusable fluids, and they are not connected to ground water sources or other valuable minerals. Saline aquifers offer the greatest potential for CO_2 storage capacity and can easily accommodate many decades and even centuries of storage. For perspective, the large industrial emitters in western Canada emitted 128 Mt of CO_2 in 2005[33].

The WCSB, with its mix of source and sink options, is one of best opportunities in the world to prove that the full-cycle integration of CCS can be done cost-effectively and securely. Other storage potential also exists in Atlantic Canada, southern Ontario and just south of the Canadian border.

[32] Bachu, S. and S. Stewart. 2002. *Geological sequestration of anthropogenic carbon dioxide in the Western Canada Sedimentary Basin*.

[33] Environment Canada. 2007. *Canada's Greenhouse Gas Inventory*.

Canadian Leadership Position

Canada has made a significant effort to lead in the advancement of CCS, but more needs to be done to continue to move the technology forward.

The Weyburn-Midale CO_2 Project is the most prominent of Canada's project activities in CCS. It is the world's first CO_2 measuring, monitoring and verification project, and it operates on the sites of the Weyburn and Midale EOR projects in Saskatchewan. This project is internationally recognized as a ground-breaking activity for its storage and monitoring activities related to CCS. Future projects can build from this expertise by demonstrating the full integration of CCS as well as aspects such as direct storage into saline aquifers.

All of the opportunities and initiatives in the WCSB put Canada in a unique position. With dedicated funding and policy support, the country could lead in developing low-emissions energy systems, and help to drive down the cost while proving the technology and providing assurance that CCS is both technically feasible and safe. Failing to do so will result in lost opportunities, including the loss of existing Canadian expertise in CCS.

Herein lies part of the appeal of deploying CCS in Canada. A real opportunity exists for leading the development of technical expertise, regulatory approaches, and products and services that are internationally marketable to places like China (which constructed the equivalent of a new 1000 MW coal plant per week last year)[34] and other rapidly developing economies.

The task at hand is trans-boundary, cross-jurisdictional, and it touches many sectors. The response must come from governments and industry. Canada must view CCS development as a national responsibility that should start in the west, where CCS is a must-have if the region is to sustain its economic growth while also reducing emissions from its largest industrial facilities. As CCS matures, its application can be applied across the country and around the globe.

International Competitiveness

CCS activities are ramping up around the world. In October 2007 the U.K. announced a competitive process to support a domestic, post-combustion, coal-fired power plant. The U.S. announced Illinois as the location for the FutureGen project in December 2007. Two more outcomes are expected very shortly: an Australian draft regulatory framework for CCS; and a European Union Directive on carbon capture and storage.

Many of these regions are moving quickly to implement GHG policies including instruments like emissions trading. Canada must remain ahead of the curve and build domestic capacities in CCS so that its fossil energy sectors remain internationally

[34] The China Sustainable Energy Program. Nov, 2007. *Program: Electric Utilities.*

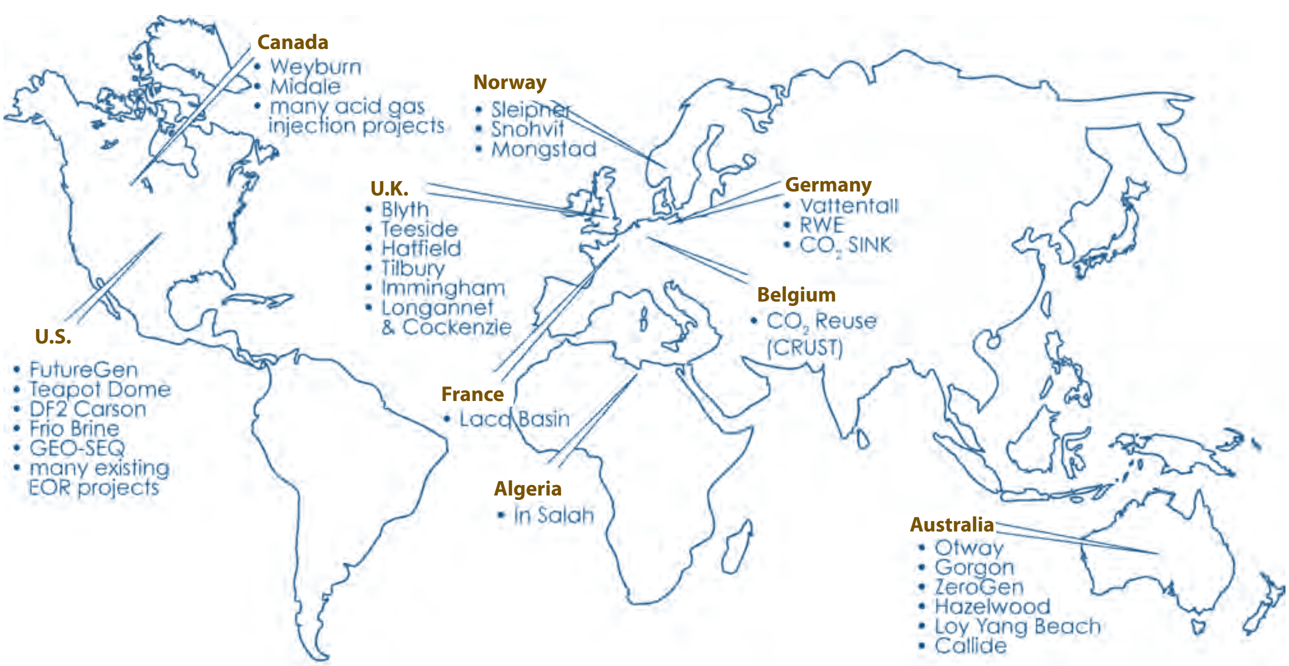
competitive when these instruments take hold. The country will face a long upward learning curve if it simply waits for GHG policy to drive emission reductions. At the same time, other countries will have moved ahead and will have firmly placed themselves in a competitive position by developing CCS.

Other reasons to undertake domestic projects are the unique Canadian 'wrinkles' related to CCS – issues that may not be addressed by other countries. For example, Canada is the only country that has a commercial oil sands industry, which has its own challenges for CCS considering the issues related to variable CO_2 concentrations in different emissions streams and the geographic location of most oil sands operations. To add to the complexity, the oil sands are the fastest growing source of industrial GHG emissions in Canada. Canada also needs solutions for domestic coal-fired generation. Once technology for this application is developed it could be transferred to other places that also rely on sub-bituminous and lignite coal (such as China and India). In short, Canada needs domestic projects to deal with domestic issues, but many of the solutions may be applicable elsewhere.

The illustration provides a snap shot of several active and proposed CCS projects around the world. In addition to these, many countries are conducting R&D and working on policy and regulatory frameworks for CCS.

It is important that Canada remains connected to these and other international CCS initiatives. To gain from the work being done elsewhere, the country needs to be a good partner and shoulder some of the workload by undertaking some domestic projects.

Prominent International Activities



The Task at Hand

Many fossil energy companies are looking at CCS in the context of the compliance options available to meet their current and future GHG reduction obligations, but two important barriers stand in the way of them implementing CCS – the financial gap facing these projects is simply too high to take on alone and the regulatory frameworks are not yet adequately defined.

Some companies are looking to alternative energy options, but as already noted, all mitigation options (including CCS) are high cost and in fact fall within the same range of high costs. In today's business environment, characterized by a growing domestic economy, tightening labour markets, and high capital costs, every option is costly.

The Financial Gap Facing CCS

One of the most significant impediments to the commercial development of CCS is the financial gap facing the first projects. This is the gap between what it would cost to develop a project with CCS versus the cost of developing a project with the same industrial outputs (such as electricity or H_2) but without capturing and storing the CO_2.

As with all large scale industrial facilities, the initial capital cost would be significant for the first industrial CCS installations. The financial gap associated with most commercial-scale CCS projects (ones with one megatonne or more of CO_2 emission reductions per year) is on the order of hundreds of millions of dollars.

In the case of oil and gas any additional cost associated with CCS would simply reduce the competitiveness of Canadian production, due to the global natural of oil markets. Any additional costs simply result in a shift in production to other locations rather than the reduction of domestic emissions. Electricity systems tend to work on the basis of dispatching the next available least cost plant. Therefore, higher cost plants, such as ones equipped with CCS, would be the last to dispatch. Neither of these examples are intended outcomes, but they are what would occur if industry were expected to shoulder the total cost of deploying CCS.

Part of the gap for any single project can be offset somewhat by the sale of CO_2 for EOR or by reducing the compliance costs associated with current and future GHG regulations. However, the magnitude of these two drivers is not currently sufficient to overcome the financial gap facing most CCS projects today. This is because the public benefit associated with CCS is not yet appropriately valued. While the total benefit is difficult to quantify – it includes socio-economic benefits such as the ability to extract the economic value of fossil energy resources and strategic benefits such as global leadership in CCS and the option to implement CCS quickly if stringent global GHG reduction requirements do materialize – these are likely to be orders of magnitude greater than the financial gap facing the first CCS installations. These benefits are not reflected in the current marketplace.

The first set of three to five commercial industrial-scale CCS projects will be critical to the future success of CCS in Canada. To start construction of these projects today requires a public investment to close the financial gap, which the Task Force estimates to be on the order of $2 billion.

This amount is based on cost estimates related to several CCS projects that each face a gap of hundreds of millions of dollars. While significant, such an investment spread across a portfolio of projects is estimated to result in five Mt of annual reductions from CCS by 2015. This is the equivalent of eliminating the GHG emissions from 1.4 million vehicles per year in Canada. Such an investment will position Canada to reap the benefits of GHG emission reductions using CCS over a wide range of industrial emission sources and from locations across the country.

For its part, industry will invest large amounts of capital in the first industrial projects with CCS – the Task Force estimates that the $2 billion in public investment will leverage an industry investment of roughly $2 to $4 billion. Industry will also bear much of the risk of these large capital projects, including any unforeseen impacts or costs they might have on the base facilities, as well as the uncertainty related to EOR demand and CO_2 credit markets.

Government and industry might decide to trade-off different forms of risk for different upfront capital contributions for any individual project through the actual negotiated contracts for the first CCS facilities.

Many factors will influence the financial gap of these projects in the next few years, including learning-by-doing (both from early projects in Canada and internationally), cost escalations, increasing GHG compliance obligations, and variance in EOR revenues. However, the Task Force expects that over time the financial gap for new projects will decrease as a result of capital and operating cost reductions, and potentially higher costs associated with carbon mitigation.

The Potential CCS Effect

It is impossible to forecast the precise contribution CCS will make in the future. Many factors will influence the success of CCS but many have noted that CCS could contribute substantially to GHG emission reductions in Canada in the longer-term.

Previous studies have produced a range of potential values, from 100 to 400 Mt/year. The assumptions for these estimates vary. The National Round Table on the Environment and the Economy (NRTEE) originally estimated that by 2050, 190 $MtCO_2$/year could be potentially captured, but this analysis only considered oil sands installations and western coal-fired power facilities[35]. A more recent NRTEE report has increased the upper bound estimate to 400 Mt/year[36]. The Integrated CO_2 Network (ICO_2N) estimates a potential of 100 Mt/year[37].

The table provides examples of the sectors where CCS could have a significant impact. From these examples the Canada-wide potential for capturable CO_2 may be as high as 600 Mt/year, which represents roughly 40 percent of Canada's projected GHG emissions in 2050. Note that this table is not a prediction of what will happen in each sector but what could happen and therefore provides an upper bound on the potential for CCS in Canada. The actual contribution is expected to be less as it is very unlikely that all of these opportunities will happen at once.

The Potential CSS Effect [38]

Opportunity	Mt/year of CO_2 Avoided by CCS in 2050	Assumptions
Electricity	200	• Electricity demand continues to grow at 1.5 percent per year • Current electricity generation mix continues (17 percent from coal) • 100 percent of all coal-fired power plants operate with capture units
Transportation	55	• Light-duty gasoline vehicles will continue to account for 32 percent of the emissions in the transportation sector • 50 percent of this fleet will be replaced by either electric or hydrogen vehicles • 100 percent of centralized fossil fuel electricity or hydrogen production operate with capture units
Oil Sands w/o biomass *	310	• Oil sector is dominated by oil sands • 5 million barrels per day are produced • No natural gas is used for oil sands production (therefore an emission factor of 0.23 tonnes per barrel is applied) • 75 percent of all production emissions are captured using CCS

* If biomass with capture were included in the oil sands estimate, the potential to capture could double.

35 National Round Table on the Environment and the Economy (NRTEE). 2006. *Advice on a Long-Term Strategy on Energy and Climate Change*.
36 NRTEE. 2008. *Getting to 2050: Canada's Transition to a Low-emission Future*.
37 Integrated CO_2 Network. 2007. *Carbon Capture and Storage*.
38 Data from: Environment Canada. 2007. *National Inventory Report 1990 – 2005*.

The Need for Public Investment

What is needed is a strong collaborative effort between industry and government to help initiate a first phase of CCS projects and set the country on the pathway towards reducing emissions from a potentially large number of industrial facilities.

This type of early-stage public support is familiar territory for Canada – it is an approach that has worked in the past. Syncrude began as a joint venture between industry and government. Hibernia was a critical investment that initiated an oil and gas industry in Atlantic Canada. Infrastructure like the TransCanada Pipeline, Canadian transmission grids, and both national railways required joint efforts between several government jurisdictions and the private sector.

Each of these "nation-building" initiatives was and continues to be in the interest of Canadians. Each began with public and private support in order to spread the risks associated with the first few projects and to enable action on activities that were in the public's best interest.

Canada possesses the technology, geology, and expertise to be a world leader in the development and implementation of CCS. Doing so is in the public's best interest because it enables the option to continue to develop and use valuable fossil energy resources while managing the associated GHG emissions. This will be extremely important to the country if stringent carbon constraints become a reality through international and domestic policy. In addition, this investment will result in actual emission reductions which will in turn reduce the risk of the potential impacts of climate change on Canada.

The Task Force believes that the net benefits befit a public investment on the order of $2 billion. This financial gap is what currently prevents the commercial application of a series of first-phase CCS projects today, as it is simply not possible for private sector players to commit additional hundreds of millions of investors' money on an activity (emissions reductions) that is essentially a public good and that doesn't generate a return on investment. Continued funding and support will be required to sustain CCS development and deployment during longer timeframes. As stated previously, for its part industry will be taking on a number of other risks of building and operating the first CCS projects and it will also invest in these projects.

The $2 billion is the up-front capital required to set CCS on a successful pathway in Canada. As much as possible, this funding should be in addition to any current funding sources (such as the Technology Fund) that are being set aside for GHG emission reduction projects. There needs to be alignment among these funding sources; however, the rules for allocating CCS-specific funding should be tailored to fit the processes described by the "Task Force Recommendations".

This public investment is on the order of what is currently being provided to other important, low-emissions energy options. The Canadian ecoENERGY for Renewable Power Program has a budget of $1.5 billion for renewable energy projects[39]. Many provinces provide further support to renewables through portfolio standards (ranging from 5 to 10 percent across Canada) and by giving renewable power priority in the plant dispatch order; both of these regulatory requirements allow renewable energy to compete with traditional power sources by transferring their additional costs on to the consumer.

It is important to note that CCS is not like other mitigation options such as wind where the funds are spread across a large number of facilities. Instead, near-term CCS funding will be allocated in large "lumpy" sums because scale is essential for CCS. Only by undertaking large, fully-integrated projects will the learning-by-doing begin to drive down the technical and financial risks of CCS while formalizing the regulatory processes.

While the proposed amount is a significant public investment, it is an important one because it will ensure Canadian leadership in CCS development. More importantly, it allows Canada the option to make significant GHG reductions while remaining internationally competitive in a carbon-constrained world.

The importance of CCS to Canada warrants an initial public investment of $2 billion

Early support helps provide a platform from which CCS can develop, by reducing the overall risks associate with a new activity and thereby encouraging quicker development, which will ultimately result in the achievement of both government and industry objectives.

The Time to Act is Now

The world is on a difficult course if it is to quickly stabilize GHG emissions followed by a trajectory toward substantial reductions by 2050. Canada has objectives to help achieve this goal, including the national objective of reducing GHG emissions by 20 percent by 2020, and by 60 to 70 percent in 2050.

CCS has the potential to contribute significantly to these objectives, but realizing this potential requires getting started today. The target of five Mt/year by 2015 is ambitious but without a start of this magnitude the country will struggle to get on the trajectory towards hundreds of megatonnes of reductions. Government must commit financial support for CCS and industry must commit to building and operating CCS projects immediately.

A recent poll lends support to the idea of public financial support for CCS[40]. In an Ipsos-reid poll, 31 percent of Canadians indicated their awareness of CCS, which

39 Government of Canada. December 2007. http://www.ecoaction.gc.ca/ecoenergy-ecoenergie/power-electricite/index-eng.cfm.
40 Ipsos-Reid. November 2007. *Public Views on Carbon Capture and Storage.*

is up from 11 percent in a 2005 study[41]. Nearly two in three Canadians polled (64 percent) noted openness to the idea of government financial support for CCS. It seems that while CCS is a relatively new technology to many Canadians, they generally support the idea of public financial support for the technology. Canadians are growing to expect action on climate change and they seem willing to support CCS if it can deliver GHG emission reductions.

However, the continuation of future public support will likely depend very much on what Canadians learn about CCS as the technology becomes better known[42]. As is the case with most new technologies or processes, communicating with the public on the merits and difficulties with CCS will be important to its overall success.

All large industrial facilities entail long construction lead times, and they require highly specific skill sets. Many of the skills required for CCS exist in the oil and gas and power generation sectors, but CCS-specific capabilities will only come through actual experience. Canada will lose the opportunity to deploy CCS rapidly in response to future GHG emission reduction policies if the country delays the construction of an initial set of commercial-scale CCS projects.

Canada must build on the basic skills inherent to existing sectors, and it must retain and build upon its base of CCS-specific expertise, so that industry, government, and research institutes have the capacity to manage the construction and operation of large-scale CCS implementations. Canada is in a situation where it can no longer delay and then expect to build CCS capacity rapidly in response to GHG emission reduction policy. The country does not currently have the capacity for broad CCS deployment.

In the meantime, capital investments in the fossil energy sectors continue to be made.

Electricity markets across the county require new capacity in order to satisfy the increase in total electricity demand and to match the schedule for replacing base load facilities that have reached their operational lifespan. As noted earlier, the average age of Canada's coal-fired fleet is 25 plus years. This is a particular problem in power constrained regions such as Alberta, Saskatchewan, and Ontario.

More than $150 billion in capital spending has been announced for the oil sands alone. This is the fastest growing sector of the Canadian economy and accordingly the associated GHG emissions are also growing quickest. If the government fails to demonstrate its seriousness regarding CCS, these facilities will be built with conventional technology and it will be costly to retrofit them with CCS technologies in the future. If the government does provide immediate support and funding for CCS, many of the new facilities can be designed to include CCS in their plans and thus avoid the potential for technology lock-in and stranded assets in the future.

41 Sharpe, J. 2005. *Public Attitudes Toward Geological Disposal of Carbon Dioxide in Canada*.
42 Ipsos-Reid. November 2007. *Public Views on Carbon Capture and Storage*.

Starting on CCS today will initiate a learning-by-doing phase which will result in cost reductions due to improved materials and technology design, standardization of applications, system integration and optimization, and economies of scale. Only through implementing a first set of commercial-scale, fossil energy facilities will the country start its way along the learning curve to success.

Learning-by-doing is essential and will start by building and operating the first commercial-scale projects

Canada is among the leading countries working on CCS. Australia, Norway, the U.K., and the U.S. are all forging ahead with public investment and commercial frameworks for the first few projects and with developing the regulatory environments to nurture CCS. Canada can remain part of this leading group by shouldering some of the load and developing domestic projects and regulatory frameworks to help advance CCS. Canada must be in step with other leaders to stay relevant and up-to-date on international developments and to gain from the learning taking place elsewhere.

Success with CCS depends on a balanced approach to GHG policy. Domestic action on climate change must proceed at a pace that is similar to the actions being taken by Canada's major trading partners, but it is difficult to predict what exactly this pace will be. If Canada moves too aggressively to reduce GHG emissions in the near term it risks putting its industrial base at a competitive disadvantage. By the same token, however, if the country moves too slowly it may also hurt its competitiveness as the rest of the world turns to lower-emissions standards that make GHG-intensive energy sources (like the oil sands and other heavy fuels) less viable. The competitiveness of the domestic fossil energy sector hinges on using CCS to satisfy growing GHG reduction obligations while continuing to develop these energy resources.

This is why Canada needs to urgently develop the skills and expertise required to develop and implement CCS. Inaction may result in a declining role for Canada's fossil energy industry in the future.

By investing today Canada will gain from a leading position in CCS development. More important, it enables the option to implement CCS in the future as increasingly stringent carbon constraints become a reality. It is particularly important to note that whatever happens in the U.S. will impact Canada due to the intimate trade links between the two countries. An investment in CCS is critical to managing the risk that future carbon constraints may place on industry.

Investing in CCS today allows Canada to compete in a carbon-constrained world

Task Force Recommendations

Canadian action on climate change requires a balanced approach of reducing emissions while maintaining industrial competitiveness. This is a challenging task, but it is required if Canada's fossil energy sectors are to remain competitive if and when greater carbon constraints emerge. In the absence of CCS, any rapid increase in GHG obligations could have a devastating effect on the Canadian economy. But through the early application and development of CCS Canada actually faces an opportunity to be a technological leader and to develop relevant expertise that is valuable to both domestic and international markets.

Moving forward in this way requires collaboration and joint efforts between industry and government, with the first priority being the deployment of a first phase of fully-integrated CCS applications in a number of commercial-scale industrial facilities, such as power plants, bitumen upgraders, or other fossil energy facilities.

Industry will invest hundreds of millions to billions in each of these facilities, and it will build and operate these projects. In addition, prior to making any project decisions, industry proponents will invest in pre-feasibility studies which cost millions of dollars, front end engineering designs which cost tens of millions, and a number of other up-front cost activities. Each of these roles is important and industry should continue to lead in these activities.

However, something more than industry leadership is required. Industry and governments should collaborate to ensure that appropriate financial arrangements and regulatory frameworks are in place to foster and nurture CCS deployment. Governments already provide support in many ways, including funding for some of the front-end studies. But they also need to share in the financial risks associated with CCS implementations. Therefore the following are recommendations to Federal and Provincial governments for their roles in these collaborative efforts.

The first set of recommended actions below require immediate attention as they are intended to address the two main barriers facing CCS today: the financial gap associated with CCS projects today and current gaps in regulatory frameworks. Canada must overcome these hurdles (and in short order) if it is to succeed with CCS.

Three Immediate Actions

- **Immediate Action #1** – Federal and Provincial governments should allocate $2 billion in new public funding to leverage the billions of dollars of industry investment in the first CCS projects. This funding should be distributed expeditiously through a competitive request for proposals process so that these phase-one projects are operational by 2015.

- **Immediate Action #2** – Authorities responsible for oil and gas regulation should provide regulatory clarity to move the first CCS projects forward by: quickly confirming legislation and regulation related to pore-space ownership and disposition rights; clearly articulating the terms for the transfer of long-term liability from industry to government; and increasing the transparency of regulatory processes.

- **Immediate Action #3** – Federal and Provincial governments should ensure as much opportunity for CCS projects under the GHG regulatory frameworks as for any other qualifying emission reduction option. This will require the creation of CCS-specific measurement and crediting protocols.

Three Next Steps

- **Next Step #1** – Industry and both government levels should form a collaborative framework including an advisory group over the next two years to coordinate discussion, to institutionalize learning, and to potentially carry out specific aspects of immediate actions 1, 2, and 3; this may evolve into a more formal organization as future needs are assessed.

- **Next Step #2** – Federal and Provincial governments should provide stable financial incentives to help drive CCS activities beyond the phase-one projects. These may include the continuation of RFPs for phase-two projects, CO_2 storage incentives, and/or the use of tax and royalty incentives.

- **Next Step #3** – Canadian-based research organizations and technology developers should focus research and demonstration efforts on CCS to achieve two goals: to drive down the cost of existing CCS technologies; and to enable the deployment of next generation CCS technology and processes. The Federal and Provincial governments should provide financial support for these activities.

Milestones for 2015 and Beyond

By following these recommendations the country can achieve the following milestones by 2015:

- Five Mt of annual GHG emission reductions from large industrial facilities
- A first wave of industrial facilities capturing and storing CO_2 (Three to five operating projects)
- Global leadership in CCS technical capabilities and expertise
- First-mover advantage in CO_2 crediting protocols, disposal rights and disposition legislation, and long-term liability solutions
- World-class CCS institutions addressing commercial, legal, and regulatory requirements
- A framework for planning what's next for CCS in Canada

These milestones will help move CCS toward becoming an integral part of the industrial fleet, which in the long-term will result in significant emission reductions from a variety of sectors and across many regions of the country. The reward is the potential to capture as much as one-third to one-half of Canada's total projected emissions for 2050.

Immediate Action #1

Federal and Provincial governments should allocate $2 billion in new public funding to leverage the billions of dollars of industry investment in the first CCS projects. This funding should be distributed expeditiously through a competitive request for proposals process so that these phase-one projects are operational by 2015.

Further Details

Through annual budget announcements, governments should provide public funding for CCS in proportion to the financial gap required to achieve five Mt of annual reductions by 2015. The Task Force estimates this gap to be on the order of $2 billion.

CCS is a large-scale technology and incentives must to be sufficiently concentrated into large single projects on the megatonne-per-year scale. This requires a large financial contribution for each successful project. It is recommended that a request for proposals (RFP) process be used as a mechanism by which the funding can be allocated in the most efficient manner.

The RFP process itself must be transparent, with clearly stated goals and objectives, terms of reference, and implementation procedures. Precedents already exist, the most recent and relevant being the U.K. CCS competition announced in October[43].

[43] Department for Business Enterprise & Regulatory Reform. 2007. *Competition for a Carbon Dioxide Capture and Storage Demonstration Project.*

The RFP process could be managed internally by government departments, or by a third-party, independent organization. However it is structured, a small independent group of CCS experts could advise the decision-making body.

Given the need for rapid action, the Task Force suggests the use of a two-step process: a pre-proposal step; and a full proposal stage. The pre-proposal step can be executed quickly. It will provide governments with hard data about the range of projects that might go forward, enabling adjustments to the design of the full proposal process in response to the suite of pre-proposals and to comments provided by stakeholders. Depending on the depth of responses during the pre-proposal step governments may consider whether a single RFP or multiple rounds are preferred during the full proposal stage. A process with multiple calls for proposals allows for a staged process, whereby an early round could be called rather quickly followed by subsequent rounds. A single process may result in more bids to choose from, whereas multiple-RFPs could be set up to help narrow the bids into somewhat more discrete and comparable sets of project-types. Whether one or several bidding rounds are undertaken, the entire RFP process should be completed within 18-months.

Regardless of the process the following are some potential outcomes of the phase-one RFP(s):

- A total portfolio that adds up to five Mt/year of CO_2 reductions by 2015
- Minimum project thresholds of approximately ½ Mt/year of CO_2 reductions
  - With at least one project greater than one Mt/year of CO_2 reductions
  - With at least one project being direct storage (such as, in a deep saline aquifer)
- The selection of fully-integrated projects (which include capture, transport, and storage)
- At least one retrofit project, and at least one new-build project
- At least one electric power application, at least one oil sands application, and at least one 'other' application (something other than electricity and oil sands)

$2 billion is what is required to cover the incremental financial cost of integrating CCS into large industrial installations, but it may be that governments and industry mutually agree to other arrangements when it comes to the final contract agreements. For example, government may decide to take on some of the technical and project risk in exchange for a smaller upfront capital investment. It is important to note that each contract that results from the RFP process will be different from one another as each will be the result of a negotiation process.

While this initial investment is appropriate to get CCS started more public support will be required to carry CCS through the subsequent phases of implementation (see Next Step #2). Just making the first investment, without any plans for future public support, will not be enough to drive CCS to its full potential.

The Rationale

Although it is anticipated that on a world-wide basis the price of carbon will rise with time, it will not be sufficient in the near-term to offset the financial gap for phase-one CCS projects. In some cases, part of the gap can be closed through the sale of CO_2 for EOR, and, depending on the eligibility of CCS for emission reductions credits, from the use of CCS to meet compliance requirements. However, only in a very limited set of near-term cases will these measures completely close the gap.

Initial public and private investments are essential to start large-scale CCS deployment in Canada. As is the case with other emission reductions options, such as biomass or wind, these projects simply will not proceed in the current market which is being driven by carbon prices in the $15 to $20 per tonne range.

Many options exist for funding allocation: targeted RFPs, direct storage incentives, and tax and royalty incentives. RFP(s) are recommended for phase-one investments because the process:

- Is one in which companies can choose to bid based on their own assessed financial gap and risk tolerance
- Allows financial certainty for government – the total pot of funding is pre-determined
- Results in valuable cost and opportunity information to governments – the pre-proposal step enables learning for both industry and government
- Permits the incorporation of metrics other than just cost, such as technical innovation
- Allows for the allocation of funding to several projects – it results in an investment portfolio

Undertaking a RFP process will result in a number of valuable objectives:

- Prove that megatonne-scale emission reduction projects are possible with CCS
  - Confirm the components (capture, transport, and storage) can be integrated
  - Verify a variety of geological media that work for storage
- Test the existing rules to ensure the appropriateness of regulatory processes
- Initiate learning-by-doing to drive down cost and identify the unknowns about CCS
- Spur innovation and technology breakthroughs
- Ensure that knowledge and technology transfers to other proponents
- Support leadership in important Canadian industrial sectors

Champions

Federal and Provincial governments should allocate public funding for phase-one CCS projects, and they should set-up and oversee the RFP process.

Governments should develop RFP(s) through cooperation between the Federal government and Provincial partners, where the provincial partners are those regions with the greatest potential for CCS (the provinces with large industrial GHG sources and geological storage opportunities).

Milestones and Outcomes

- **Q1-2008** – announce total annual funding support for RFP(s)
- **Q2-2008** – announce terms of reference for RFP process and call for pre-proposals
- **Between Q4-2008 and Q2-2009** – announce all successful RFP bids (phase-one projects)
- **2015** – all funded phase-one projects on stream

Immediate Action #2

Authorities responsible for oil and gas regulation should provide regulatory clarity to move the first CCS projects forward by: quickly confirming legislation and regulation related to pore-space ownership and disposition rights; clearly articulating the terms for the transfer of long-term liability from industry to government; and increasing the transparency of regulatory processes.

Further Details

Regulatory frameworks for CCS should be built from existing legislation and regulations and under the existing authorities that currently govern oil and gas and other industrial activities. Many of the regulatory requirements for CCS are already inherent to existing frameworks and authorities.

However, a number of important gaps do exist in the current frameworks and in particular the following two issues must be resolved as quickly as possible. Legislatures and the relevant regulatory agencies must: first, review and amend existing ownership, disposition, and surface rights legislation to accommodate CO_2 storage rights; and second, articulate liability obligations for all stages of CCS projects. Other important regulatory aspects can be addressed subsequently, for instance the creation of directives or guidelines for CO_2 storage[44].

[44] Alberta Energy and Utilities Board Directives and Saskatchewan Ministry of Energy and Resources Guidelines are official regulatory documents which lay out the requirements or processes to be implemented and followed by licensees or other approval holders.

Appropriate amendments to regulations governing pore space ownership and disposition should take place in jurisdictions that are considering CCS, most notably in Alberta, Saskatchewan, and British Columbia. Appropriate authorities should review and amend as required:

- Relevant oil and gas and water legislation to confirm the ownership of pore space to be used for CO_2 disposal
- Relevant oil and gas and related legislation schemes to create a disposition scheme for CO_2 disposal rights
- Relevant legislation to deal with potential conflicts with other disposition holders
- Surface rights regimes to ensure that storage site operators have access rights for their surface infrastructure

Liability obligations present a risk to CCS project developers. During the operational and monitoring stages CCS projects should be subject to the usual liability rules that govern oil and gas operations. Governments may require the posting of a bond, a letter of credit, or some other insurance or guarantee which would be held until the monitoring stage is complete and an official abandonment certificate is issued.

To support early projects regulators or government agencies should clarify that liability will transfer to relevant government jurisdictions once a project moves to the post-abandonment phase. Resolving this issue is important primarily because the liability timeframes for CCS projects extend far beyond other typical liability timeframes that companies are held to today.

Liability Obligations

Once the issues of pore space ownership and liability transfer have been addressed, regulators should work towards completing the final set of regulatory requirements including any necessary directives or guidelines. In time, if common pipelines or storage facilities become a priority, then so too will the need for relevant standards.

The Rationale

Current regulatory frameworks are an excellent platform to build from but inadequacies in several areas indicate the need for a review and where necessary amendments to support CCS. The gaps in existing regulatory frameworks relate to three key areas:

- Ownership of subsurface pore space and the management of disposition of those rights for the purpose of CO_2 storage
- Articulation and assignment of responsibility for the different liability types (operational, local, and climate) and for the span of timeframes associated with storage
- Specification of requirements to cover the operation of CO_2 storage projects, through issuing directives or guides that include but are not limited to site selection, monitoring, measurement and verification, and other operational aspects of CCS

Regulatory gaps regarding pore space rights and disposition as well as liability are considered to be most important and urgent to move early CCS projects forward.

The regulatory agencies will require time to complete this work, and it is not practical to expect this to be accomplished before any projects can proceed. In addition, the experience gained from early projects will be helpful to inform the development of many of these new regulations. Regulatory agencies should provide approvals on a 'one-time' basis to allow the phase-one projects to move ahead; then they should use the subsequent learning to write the rules for broader application of future CCS projects.

Champions

Provincial authorities (and where appropriate federal regulatory agencies) responsible for oil and gas development should champion these regulatory developments. Policy makers at the provincial and federal level should direct their regulatory agencies to undertake these efforts.

Industry organizations, such as the Canadian Association of Petroleum Producers (CAPP) and the Small Explorers and Producers Association of Canada could be helpful in providing input and feedback to proposed amendments to oil and gas regulations.

Milestones and Outcomes

- **Q2-2008** – finalize ownership rights and disposition schemes for CO_2 storage
- **Q3-2008** – resolve liability obligations for all stages of a storage project
- **Q4-2009** – advance other regulatory aspects, such as directives or guidelines
- **Q4-2009** – identify next set of regulatory requirements for future advancements

Immediate Action #3

Federal and Provincial governments should ensure as much opportunity for CCS projects under the GHG regulatory frameworks as for any other qualifying emission reduction option. This will require the creation of CCS-specific measurement and crediting protocols.

Further Details

The Task Force recommends that CCS should be recognized formally as an eligible activity for generating offset credits, for meeting a regulated entity's internal GHG reduction obligation, or for both. EOR-based reductions should be treated no differently than those from other storage activities such as direct storage into deep saline aquifers.

Federal and provincial governments should make best efforts to coordinate and standardize their measurement and crediting efforts. An equal level of rigour should apply when validating reductions, whether for reduction obligations or for offset projects. Some jurisdictions are already leading the way, such as Alberta's efforts on CCS measurement and crediting protocols.

Finally, the Canadian government should lobby internationally for the recognition of CCS as a valid emission reductions option.

The Rationale

The current federal Regulatory Framework for Industrial Air Emissions scarcely mentions CCS despite the fact it is an option with broad application. Ensuring a role for CCS in meeting emission reductions obligations, and making certain that any credits from CCS are no less tradable or valuable than others, will help to reduce CCS project risk.

EOR projects will have a smaller financial gap than direct storage projects, and any emission reductions credits for the CO_2 that is permanently stored (as part of these projects) will further support early CCS deployment.

Standardized accounting methods are needed to ensure the consistent calculation of emissions and emission reductions for crediting purposes. Although not simple to do, a standard approach is needed because of the potential financial value of the credits.

Even with a domestic role for CCS this activity still needs to be recognized as an acceptable emission reductions option by the international community if CCS-based credits are to have any international value.

Champions

Federal and Provincial environment departments are responsible for creating and implementing GHG regulatory frameworks, including specifics such as eligibility criteria and measurement and crediting protocols.

Milestones and Outcomes

- **Q2-2008** – qualify CCS (including EOR-based CCS) as an eligible GHG reduction option
- **Q4-2008** – publish CCS measurement and crediting protocols sufficient for compliance in all jurisdictions

Next Step #1

Industry and both government levels should form a collaborative framework including an advisory group over the next two years to coordinate discussion, to institutionalize learning, and to potentially carry out specific aspects of immediate actions 1, 2, and 3; this may evolve into a more formal organization as future needs are assessed.

Further Details

Over the next two-years industry and government should work together to coordinate the learning from the first RFP process, as well as any regulatory advances, and learning from domestic and international research projects. An advisory group that provides a centralized meeting place for industry and government to dialogue and work together will be extremely helpful over the coming years. The arrangements for this group should be in place by mid-2008 so it can begin delivering advice and/or recommendations on the next steps for CCS by 2010. This group could also be an enabler of specific tasks under immediate actions #1 through #3.

Depending on what is required, this group may evolve into a larger, new entity (post-2010) – an independent, third-party organization, perhaps an agency or some other stand-alone governance structure that may be empowered to undertake such activities as:

- Provide advice to governments on policy mechanisms to support CCS
- Offer advice on regulatory frameworks for CCS
- Manage incentive mechanisms for phase-two CCS projects and/or common infrastructure components
- Provide a clearinghouse of information on CCS activities in Canada and abroad
- Develop domestic and international alliances on CCS initiatives
- Communicate with key stakeholders and the public on CCS

The Rationale

CCS is currently in the early, developmental stages and the learning over the next two-years should leave industry and governments better equipped to plan for phase-two CCS projects and/or any common physical infrastructure needs (such as pipelines or multi-user storage facilities). All CCS proponents will benefit from a formal collaborative effort dedicated to the development of domestic CCS capacities.

Canada has a successful record of starting with ideas and organically growing them into larger capacities, organizations, and industrial activities. Syncrude was noted earlier for its role in large-scale oil sands development. Hibernia was critical to starting Atlantic oil and gas activities. The national railways, pipelines, transmission grids, and other infrastructure have each connected Canadian markets at critical junctures in the country's history.

Each of these nation-building exercises began with formal government-industry collaboration. All of these initiatives required new entities which offered transitional roles and structures to launch the respective business or market, and all were phased-out or privatized when their original goals and objectives were firmly established.

Champions

Industry and both levels of government are responsible for this recommendation. Each should provide funding to jointly initiate these collaborative efforts and to create the advisory group.

Milestones and Outcomes

- **Q2-2008** – create the advisory group
- **Q4-2009** – advise on or recommend phase-two projects and/or infrastructure
- **Q4-2009** – advise on or recommend governance structures to carry CCS forward

Next Step #2

Federal and Provincial governments should provide stable financial incentives to help drive CCS activities beyond the phase-one projects. These may include the continuation of RFPs for phase-two projects, CO_2 storage incentives, and/or the use of tax and royalty incentives.

Further Details

Financial support for CCS is still likely to be required into the medium term in proportion to the financial gap at that time and the pace of optimal CCS implementation. The phase-one projects will help define the technology requirements and the actual cost to construct projects. In the meantime there will be better definition of a world 'carbon price' and the competitive landscape for Canadian industry. These factors may help develop an understanding of the total size and type of incentives to initiate further CCS deployment.

While breaking ground on the first domestic projects, governments and industry should implement financial mechanisms to spur the next wave of CCS projects and evaluate the case for and timing of the first common infrastructure (multi-user storage facilities or pipelines). While large-scale common infrastructure is not the focus of the immediate actions #1 through #3, the Task Force recognizes the longer-term opportunity for such infrastructure to manage the potential volume of CO_2 to be transported in the WCSB in the 2020 to 2025 timeframe.

The following alternatives should be considered as potential options for phase-two incentives:

- Continuation of the RFP process – at this point, an RFP structure will be in place, companies will be familiar with the process, and there may be strong consensus to continue with RFPs as the primary funding mechanism for CCS projects. If so, the experience gained through the first RFP(s) will help streamline subsequent processes.

- CO_2 storage incentives – depending on the lessons learned during the first RFP(s) (such as actual construction costs and industry's ability to pay and yet remain competitive) careful consideration should be given to direct incentives for CO_2 storage. Learning from the first RFP(s) will help when setting the original levels of CO_2 storage incentives.

  Such an incentive should be allocated on the basis of dollars per tonne of CO_2 emissions avoided[45]. One rate could be used for direct storage and another for EOR. In either case, the incentives would decline over time or as the cumulative amount of storage increases.

- Government loans or equity positions in projects – if, by the medium-term, there is an increased understanding of the merits of certain projects such as shared infrastructure and of a preferred ownership and operating structure, there may be a case for government loans or equity positions in some projects. Loan payback or equity liquidation mechanisms could be tied to criteria like the future price of carbon or the size of the financial gap for CCS implementation.

[45] "Emissions avoided" isn't the same as "emissions stored". Avoided refers to the difference in emissions between a facility with and one without CCS. Stored refers to the total amount of CO_2 stored underground.

- Tax and royalty incentives – while it is unlikely that any combination of tax and royalty initiatives will be sufficient to close the economic gap facing a CCS project, there may be a role for these incentives to help narrow the financial gap in time. Tax and royalty measures help even the playing field for emission reductions projects, and send the signal that government considers these projects to be important.

  Examples of tax and royalty incentives considered by the Task Force include: capital cost allowances; royalty credits; and property tax relief for CCS projects.

The Rationale

It is of paramount importance that the incentives put into place for CCS in the short-medium-and long-term reflect the importance of Canadian industry remaining competitive on the world stage. Burdening Canadian industry with additional costs that are beyond those borne by its international competitors is not an appropriate response to the carbon challenge.

With the first, and each subsequent phase of projects, the Task Force expects that technology will improve, costs will decrease, and there will be better definition of the prevailing and future cost of emissions. The financial gap is expected to narrow and direct government funding may also decrease correspondingly. The ultimate goal should be a situation in which CCS projects no longer require public financial support. However, government may play a role in the future ownership of shared infrastructure. The Swan Hills facility in Alberta is a good example of how governments might be involved in multi-user facilities.

Therefore the Task Force recommends that a number of options be considered for the second phase of CCS projects, either singly or in combination with each other. Continuing to accelerate the pace of bringing projects online will be essential for meeting Canada's carbon challenge.

Champions

Federal and Provincial departments responsible for resource development, in concert with their counterparts in finance, are responsible for the evolution and implementation of the proposed financial incentives. Governments may decide to centralize these activities under a single entity that administers these and other activities (such as the entity described under Next Step #1).

Milestones and Outcomes

- **Q4-2009** – assimilate key learning from phase-one projects
- **Q4-2009** – determine incentive programs for phase-two projects
- **Q1-2010** – define phase-two projects requirements

Next Step #3

Canadian-based research organizations and technology developers should focus research and demonstration efforts on CCS to achieve two goals: to drive down the cost of existing CCS technologies; and to enable the deployment of next generation CCS technology and processes. The Federal and Provincial governments should provide financial support for these activities.

Further Details

The CCS component technologies (for capture, transport, and storage) are not the fundamental barriers facing CCS. Rather, it is the full integration of these components, at the scale of a commercial industrial facility, and the financial gap associated with such a project, that are the barriers. Continual technological advancement is particularly important in bringing down the cost of capture (the most costly component of a typical integrated project).

Canadian research dollars are often allocated by technology type and divided along the different stages of the innovation chain (with different sources of funding for basic R&D, applied R&D, demonstration projects, and so on). As highlighted in another recent study, this approach may lead to substandard results due to the lack of coordination and integration of efforts and due to the funding gaps that may result in certain stages of the innovation chain[46].

For CCS, it is essential to coordinate research funding with a focus on component integration and support through all of the critical junctures of the innovation chain. In particular, CCS demonstration projects are required, which is a challenge because of the size and scale of these.

Research institutes and technology developers should collaborate on CCS-specific research, and governments should coordinate funding for these research efforts to ensure that any opportunities for integration are maximized and that learning is shared across industry and the research community.

With this approach in mind, the following are a few areas that require more focused research:

- Power – with a focus on development and cost reductions for post-combustion, pre-combustion, and oxyfuel-combustion in both current and next generation applications
- Oil sands – with a focus on next generation gasification-based technology and processes
- Petrochemicals – with a focus on centralized post-combustion absorbers or amine regenerators to drive economies of scale and technology advancements

[46] National Advisory Panel on Sustainable Energy Science and Technology. 2006. *Powerful Connections*.

- Advanced material technology – specifically corrosion resistant alloys for infrastructure, is important for managing the effects of H_2S and sulphur dioxide (SO_2) in the CO_2 stream (in the presence of water)

While applications exist today for the injection and monitoring of CO_2 in EOR operations, more study and research is necessary on CO_2 performance and behavior in other geological formations. Detailed matching of CO_2 sources with potential direct storage and EOR opportunities in places like the WCSB will help advance domestic CCS activities.

The Rationale

In the early stages of technology development, improvements to cost and performance are fundamental. This is particularly important when the technology is not yet commercially viable, and that is why appropriate research institutes must focus their efforts on CCS – to get the technology over the pre-commercial cost barrier and on the way to broad implementation.

Today there is some commercial application for CCS in conjunction with EOR projects, but the total potential of these projects is not enough to accommodate the volume of CO_2 that is required to make significant emission reductions in Canada. While some private capital will surface for technology advancement, the lack of clear commercial driver for CCS means that other funding is required. CCS is a technology of national importance and so existing research funding and new sources of public funding should be used to support its advancement.

Champions

Federal, Provincial, and other research institutes (such as universities, colleges, and technical institutes) should lead in re-prioritizing their research efforts to include a prominent role for CCS.

The Federal and Provincial governments should coordinate funding for CCS technology advancement. Private-sector funding and support should be provided for research in relation to industrial applications or commercial-scale demonstration projects.

Milestones and Outcomes

- **Q4-2009** – coordinate research activities and identify phase-two projects to fund
- **Q4-2010** – allocate funding for phase-two research projects
- **Continual** – allocate funding for research efforts on next generation CCS technology
- **Continual** – disseminate learning and experience from research projects

Final Observations

CCS is vital to Canada's future, and it is a must-have for western Canada which relies on fossil energy for commercial and personal activities. These fossil energy resources put Canada on the map of global energy centres, but to extract their full value requires a plan to manage the associated GHG emissions.

By 2050, CCS may be contributing significantly to achieving the country's GHG emission reduction objectives – the domestic potential for capturable CO_2 may be as high as one-third to one-half of the country's projected GHG emissions in 2050.

CCS can be implemented today, as all of the required components already exist. The next step is to build the first few fossil energy facilities that integrate the components (capture, transport, and storage) at the commercial-scale, to initiate the learning-by-doing phase and to begin the first phase of CCS deployment.

CCS enables the building of GHG reduction capabilities into the existing foundational energy infrastructure that Canadians rely on for economic prosperity and well-being. Its success is particularly important in regions with large industrial emissions. It is fortunate that many of these locations also hold the answer to the problem – stable sedimentary rock formations, ideal for CO_2 storage. The co-location of CO_2 sources and sinks in western Canada and the resident CCS expertise make the region one of the top global locations for CCS.

This presents an opportunity for Canada to develop CCS at home (through its fossil energy sectors) and then market the technology and the expertise to the world.

This is a prospect for Canadian leadership but industry and governments must begin working today to create the commercial arrangements and lay the regulatory groundwork to first accomplish the target of five Mt/year by 2015 followed by continued support for CCS deployment in the future.

This led the Task Force to recommend the following immediate roles for government to undertake (before 2010):

- Tender immediate public financial support for the first few commercial-scale projects
- Amend existing legislation and regulations to enable CCS projects to move ahead
- Provide a clear role for CCS in meeting a company's emission reduction obligations

In addition, the Task Force recommended three next steps to help lay the groundwork for continuing to carry CCS forward.

While CCS offers a significant prospect in Canada, its success relies on creating the broad-based conditions that support the first and subsequent waves of investment; and meanwhile, gaining the public's support for CCS as an acceptable way to meet the carbon challenge.

CCS is an opportunity for the country to become a world leader in demonstrating that emission reductions, industrial advancement, and economic growth can be achieved together. Achieving the five Mt of annual capacity by 2015 would virtually guarantee such a leading position for Canada in this emerging capability.

Appendix I – Working Group Members

The following is a list of Working Group Members, all of whom contributed throughout the working group activities. While the discussions of the Task Force were informed by input from the working groups, the final Task Force report does not necessarily reflect the views of individual Working Group Members.

Technical Working Group

Ian Anderson (Co-Chair)
Kathy Sendall (Co-Chair)
Bill Reynen (Co-Chair)
Stefan Bachu
Bill Gunter
Eddy Isaacs
Kourosh Zanganeh
Philip Shum (ex-officio)

Economic and Policy Working Group

David Keith (Co-Chair)
Jim Dinning (Co-Chair)
Allan Amey
Stephen Kaufman
Karl Johannson
Nick Schultz
Adam Hendriks (ex-officio)
Sandra Locke (ex-officio)

Regulatory and Legal Working Group

Patricia Youzwa (Co-Chair)
Malcolm Wilson (Co-Chair)
Ken Brown
Andy Ridge
Nigel Bankes
Anne-Marie Thompson (ex-officio)
Colin Pate (ex-officio)