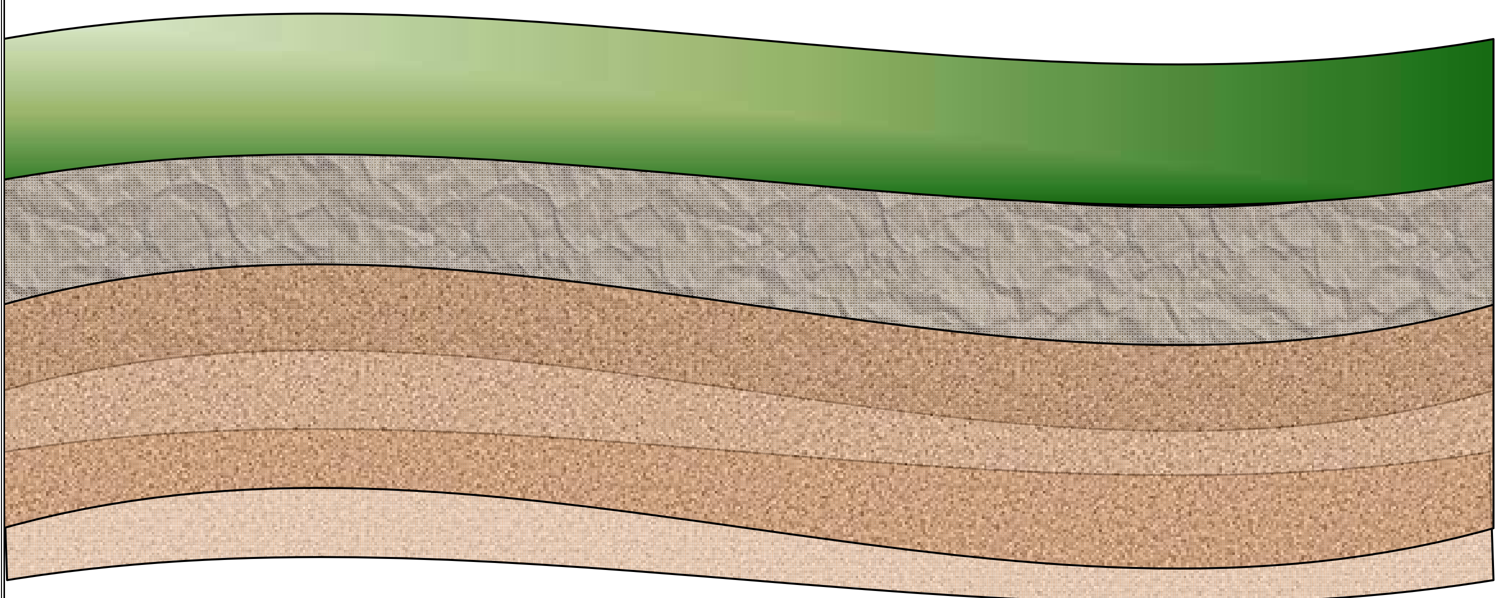
Accelerating Carbon Capture and Storage in Alberta

Interim Report

September 30, 2008



Alberta Carbon Capture and Storage Development Council

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October 3, 2008

Honorable Mel R. Knight
Minister of Energy
Government of Alberta
404 Legislature Building
Edmonton, AB
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Dear Minister Knight:

It gives me great pleasure to forward the Alberta Carbon Capture and Storage Development Council's ("Council") *Interim Report - Accelerating Carbon Capture and Storage in Alberta* for your consideration. We will use the Interim Report to have conversations with select stakeholders as we complete the Final Report by the end of this year.

While there are still some substantive issues to resolve in the preparation of an overall Carbon Capture and Storage (CCS) blueprint for Alberta, the Council has made considerable progress since its April 2008 inception. The Government of Alberta's recently announced $2B "*Carbon Capture and Storage Projects in Alberta"* program, as announced by Premier Stelmach, was an enormous step forward and allowed the Council to focus on other medium- to longer-term components.

Our initial assessment indicates that three critical success factors must become a part of the CCS blueprint: 1) a robust fiscal framework, 2) a clear regulatory framework, and 3) a comprehensive R&D and technology development program. The Interim Report outlines progress in all three of these areas.

More broadly, the Council has identified a number of overarching conclusions that frame these critical success factors:

- Greenhouse gas emissions will continue to grow before they start to fall;
- Large-scale CCS will take time to properly implement;
- Alberta needs to lead in the development of CCS technologies and implementation to meet the needs of Alberta's sustainability challenges;
- Alberta has a unique opportunity to implement a broad-based CCS network given the large number of single point GHG emission sources and potential reservoirs into which carbon can be placed; and
- Alberta has a strong existing base of regulatory experience from which to grow a CCS regulatory framework.

The work of the Council has benefited greatly from the participation of Mr. Len Webber, MLA for Calgary Foothills and Deputy Ministers from both the Alberta and federal governments. This is a collaborative effort between all of the partners and I thank Allan Amey for his work compiling it in the report. I look forward to your comments on the Interim Report as we complete the work of the Council.

Yours truly,

Original signed by:

Jim Carter
Chair
Alberta Carbon Capture and Storage
Development Council

Enclosure

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Table of Contents

Executive Summary

The engine of economic growth and one of the key pillars of Alberta's high standard of living is the continued development and production of its vast energy resources. This development must take place in a manner that recognizes and responds to the carbon-constrained future that likely faces society.

To significantly reduce carbon emissions, Alberta needs to act now and act decisively in the development and application of technologies that contribute to sustainable energy development.

Carbon Capture and Storage (CCS) is recognized globally as a key technology to dramatically reduce greenhouse gas (GHG) emissions in the energy sector. There is agreement among key stakeholders in Alberta that CCS holds the promise to significantly contribute to Alberta's long-term climate change strategy provided the economic and policy hurdles confronting CCS can be overcome. CCS has been highlighted in numerous Canadian and international studies over the past few years and, while contributions from renewable energy development and conservation will also reduce Alberta's carbon intensity, some 70 per cent of Alberta's potential reductions are expected to arise from CCS.

If CCS is going to make a substantial contribution to Alberta's future, immediate steps toward fostering CCS development are needed now. This is driven by a number of factors that influence Alberta's long-term environmental and economic performance – our long-term sustainability. These factors include:

- the continued global demand for energy;
- the continued growth in importance of sustainable energy development;
- the significant growth planned for Alberta's energy production facilities in the next decade;
- assurance for all Albertans and key stakeholders that oil sands and thermal and electrical power generation development can proceed sustainably; and
- a growing global market for CCS technologies.

"No other technology currently has the potential to transform the environmental footprint of our energy economy within the timelines necessary and at the scale required to address domestic and international expectations to respond to climate change and develop energy resources in an environmentally sustainable manner."[1]

[1] Government of Alberta, *Request for Expressions of Interest*, July 2008

Alberta is committed and is taking action to implement large-scale CCS projects as soon as possible and on a continuous basis going forward. These efforts put Alberta at the forefront of jurisdictions actively pursuing CCS technology development and application while developing appropriate fiscal and policy tools to accelerate CCS implementation.

The task to develop a broad-based CCS network in Alberta is immense and requires the collective effort of governments, industry, and stakeholders. Alberta has a long and proud history of taking on challenges and is up to this task.

Safety considerations related to CCS developments are of paramount importance to the public well being and public acceptance of these projects. Industry and government have a strong track record in Alberta of ensuring safety issues are minimized in oil and gas developments and CCS will be no different. To increase the level of understanding of CCS, there is a need to clearly communicate to the public and stakeholders how risks to communities will be minimized and managed.

The Alberta Carbon Capture and Storage Development Council (the "Council") is developing a blueprint of the most expedient approaches to making the broad-based application of CCS a reality in both the short and long term. While the Council's view is clear and the destination is not in doubt, the cost, schedule and overall roadmap are undefined. We will not get to our destination unless we begin the journey.

This Interim Report documents the progress to date of the Council in addressing important short-term issues related to CCS. It represents a milestone in the development of a blueprint to accelerate large-scale CCS in Alberta. The key findings, initial recommendations, and points of consensus are found in this report.

There is considerable uncertainty in the medium to long term as to CO_2/climate change policy development, future carbon markets and carbon pricing.

Given the uncertainties, the following key success factors are essential to position Alberta as a world leader in CCS: ***a robust fiscal framework, a clear regulatory framework, and a comprehensive research and development and technology development program***.
These are the areas the Council is focusing on.

Some initial observations in support of these key success factors include:

- Greenhouse gas (GHG) emissions will continue to grow before they start to fall – CCS emissions reduction is an immediate challenge that requires ongoing and sustained commitment.
- There are technical, economic and schedule risks – large-scale CCS will take time to properly implement.
- Alberta needs to lead in the development of CCS technologies and implementation given the immensity of projected energy developments.
- Alberta has a unique opportunity to implement a broad-based CCS network given the large number of single point GHG emission sources and reservoirs.
- Alberta has a strong existing base of regulatory experience in dealing with hydrocarbon emissions and storage from which to grow a CCS regulatory framework.
- Alberta is rapidly developing a strong CCS research and development (R&D) and technology leadership base that needs to continue to grow to meet Alberta's sustainability challenge.
- Alberta has the opportunity to advance large-scale sequestration through enhanced oil recovery of its many mature oil pools.

Highlights of the preliminary recommendations covered in this Interim Report include:

- a set of principles to consider in providing public support for CCS projects;
- a recommended approach to CCS/CO_2 long-term liability and tenure issues;
- recommended site/operational guidelines;
- a preliminary review of CO_2 supply costs;
- a review of the key CCS technology challenges to be focused upon; and
- a preliminary review of EOR demand and economics.

The Council is actively working toward a Final Report by year end 2008. The final report will address outstanding medium and longer-term fiscal, policy and technology issues that need to be addressed to maintain the initial momentum in the planning and development of CCS projects in Alberta.

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1.0 Introduction

- **The importance of CCS to Alberta's continued economic growth**

The importance of CCS to Alberta's continued economic growth and standard of living cannot be overemphasized. Alberta's economic engine of growth is its vast energy resource base. The continued development of these resources needs to be conducted in a sustainable manner that reflects the tenets of a carbon-constrained future.

The immensity of Alberta's oil resources, its planned development, and its emissions impact are borne out in a number of statistics:

- Canada's estimated oil reserves are 179 billion barrels (second largest in the world after Saudi Arabia) approximately 174 billion barrels lie in the oil sands.[2]
- By 2017, crude bitumen production is expected to triple to 3.2 million b/d and nominal investment expenditure related to oil sands is expected to reach $116 billion.[3]
- By about this same time, oil sands greenhouse gas emissions would more than double without CCS implementation. Significant decreases in emissions intensity are possible through large-scale implementation of CCS.

This economic growth provides jobs and opportunities not only for Albertans but for all Canadians. Alberta has the opportunity to be a leader in sustainable economic growth in Canada, in North America, and globally.

The global demand for energy continues to rise as the economies of China and India grow exponentially and the U.S. strives to meet its goals of energy demand, energy security, and sustainable development.

There is broad recognition of the potential and strategic importance of CCS in dramatically reducing GHG emissions.

Recent reports by the National Round Table on the Economy and the Environment, ICO_2N, the Fraser Institute, the Pembina Institute, and the Canada West Foundation have referenced CCS as a key emission reduction opportunity.

"CCS will provide a significant part of an integrated and sustainable energy strategy by focusing Canadian technology and investment in Canada. It will play a major role in reducing the environmental footprint of the oil sands, electric power generation, and industrial chemicals industries."[4]

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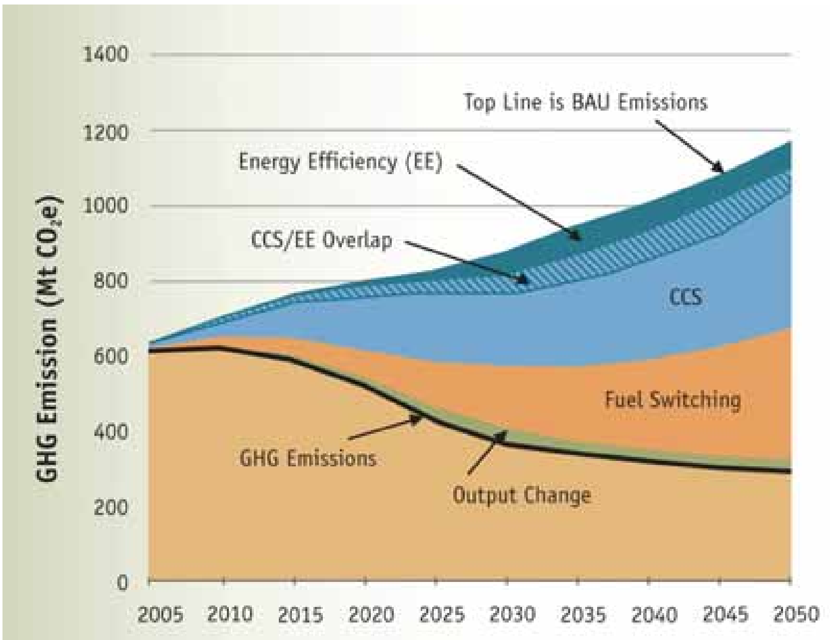
[2] U.S. Energy Information Administration
[3] Energy Resources Conservation Board
[4] ICO_2N Report

"…a well-funded research and development initiative on carbon capture and sequestration could well lead to truly global contributions along with the attraction of expertise and employment to Canada."[5]

The following graph from the 2008 National Round Table report illustrates the relative importance of CCS to Canada's and Alberta's initiatives to reducing greenhouse gas emissions.[6]



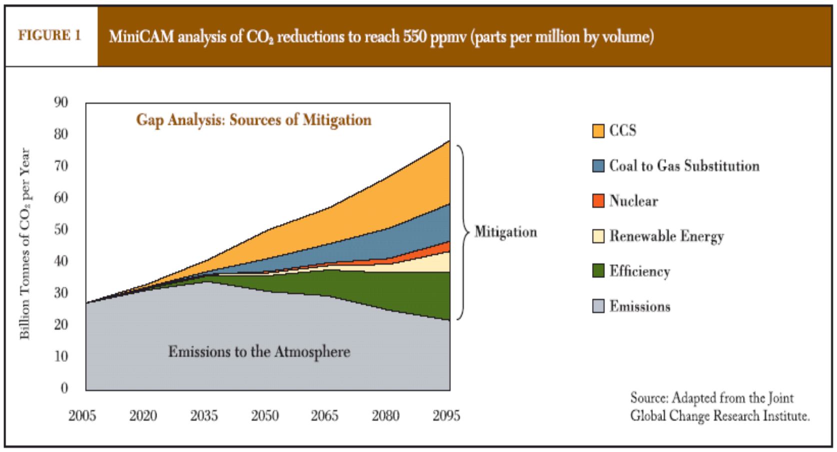
National Round Table on the Economy and the Environment (NRTEE) Note: CCS represents the carbon capture and storage wedge. CCS/EE represents the carbon capture and storage (CCS) and energy efficiency (EE) overlap. The fuel switching wedge represents the contribution of switching from coal to oil products to natural gas to electricity; this portion also includes the contribution of renewables (wind, hydroelectricity, etc.) and nuclear power. The output wedge represents the GHG reductions due to lower physical output. The top line represents business-as-usual emissions.

CCS represents the largest single point source contribution with the other wedges requiring contributions from many distributed actions across Canadian society.

There is a burgeoning market developing for CCS technologies globally. Expertise developed in Canada will be shared with the world in much the same way that Canada's and Alberta's oil and gas skills are at work around the globe.

Significant work is underway in the United States and in Europe on CCS technology options to effectively reduce emissions. Alberta has the opportunity to become a world leader in this rapidly developing field of expertise.

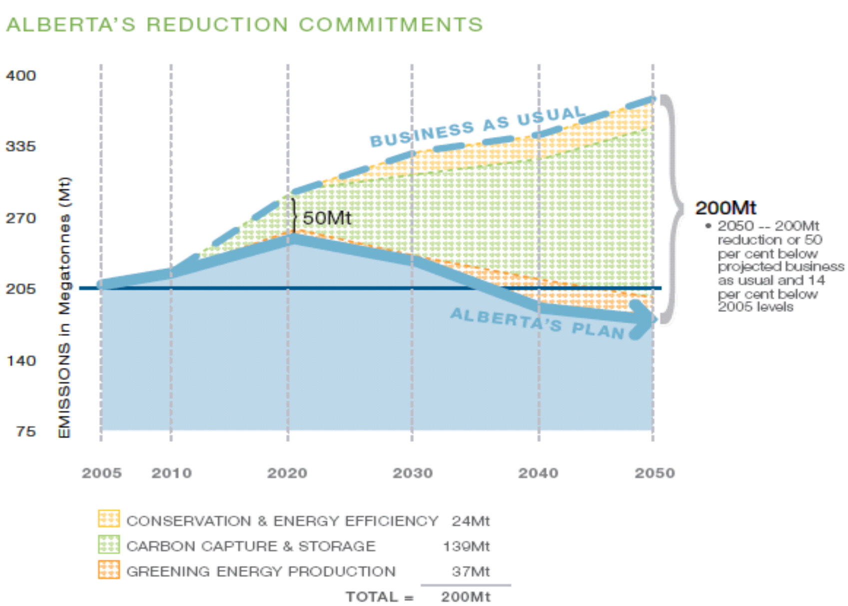
[5] Gibbins, Canada West Foundation
[6] National Round Table on the Economy and the Environment Report



Source: Pacific Northwest National Laboratory, University of Maryland, Battelle Memorial Institute

- **Alberta's climate change strategy**

In January, the Government of Alberta released its 2008 Climate Change Strategy which outlines its longer-term targets to reduce greenhouse gas emissions. A reduction in emissions by 200Mt by 2050 over business-as-usual is required. More significantly, 139Mt or approximately 70 per cent of the emission reductions would be achieved by implementing CCS technology (chart below) on an extensive basis at Alberta's oil sands, power sector, and industrial facilities.



Source: ***Alberta 2008 Climate Change Strategy***

The task of developing a broad-based application of CCS in Alberta is immense. As an initial significant step forward, in July the Government of Alberta announced a $2 billion fund to kick-start CCS implementation.

A key consideration for the mid- to long-term development of CCS will be closing the cost gap between the implied or real cost of carbon and the cost of CCS implementation. Technology, a stable and certain policy environment, and an approach to financing these developments through an innovative fiscal/regulatory framework will be needed.

It is also important to note that a significant initiative, 30 per cent emission reduction contribution, is needed from conservation, energy efficiency, and greening energy production. CCS is an important technology to bring about emission reductions, but is only one of a number of emission reduction approaches that our society must advance in order to meet the challenges of a carbon-constrained world.

CCS has the potential to transform Alberta's energy sector's long-term environmental sustainability and facilitate its continued resource development.

The Alberta Climate Change Strategy also indicated the intent to form the Alberta Carbon Capture and Storage Development Council to accelerate action on CCS.

The Council was established in April 2008, as a dedicated multi-disciplinary public/private working group to drive immediate and long-term implementation of CCS technologies in Alberta.

The development of CCS requires a collaborative approach due to the complex interaction of the economics, technology and regulatory elements of CCS. The Council is working to reach consensus on the approach needed in these areas for the development of CCS in a timely manner. This consensus approach among key stakeholders has proven important in a number of large infrastructure developments in Canada ranging from the construction of the national railroad, to the initial scale-up of oil sands development (Syncrude) and the technology efforts to reduce the cost of oil sands production (AOSTRA).

CCS has the potential to transform Alberta's energy sector's long-term environmental sustainability and facilitate its continued resource development.

This Interim Report highlights the progress to date of the Council in support of the development of initial CCS projects over the next seven years. The Report addresses how to best ignite CCS development in Alberta.

2.0 The Mandate of the CCS Development Council

The key measure of success for the Council is to provide recommendations that will successfully facilitate the immediate, medium- and long-term implementation of CCS in Alberta.

In support of this measure of success, the Council has been mandated to:

- develop recommended approaches to kick-start large-scale CCS projects as soon as possible;
- develop a coherent mid- and longer-term work plan or blueprint for implementing CCS in Alberta;
- develop a set of appropriate timelines, policy, and regulatory requirements to accelerate implementation;
- examine and propose a suite of tools and incentives to ensure Alberta industry maintains a leadership role in implementing CCS technology; and
- respond to the recommendations of the Canada-Alberta ecoENERGY Carbon Capture and Storage Task Force.

The Council is made up of senior industry, academic, and government representatives that have a proven track record for successful implementation of large-scale projects/innovative technologies, an ability to collaborate and have specific interests in CCS implementation.

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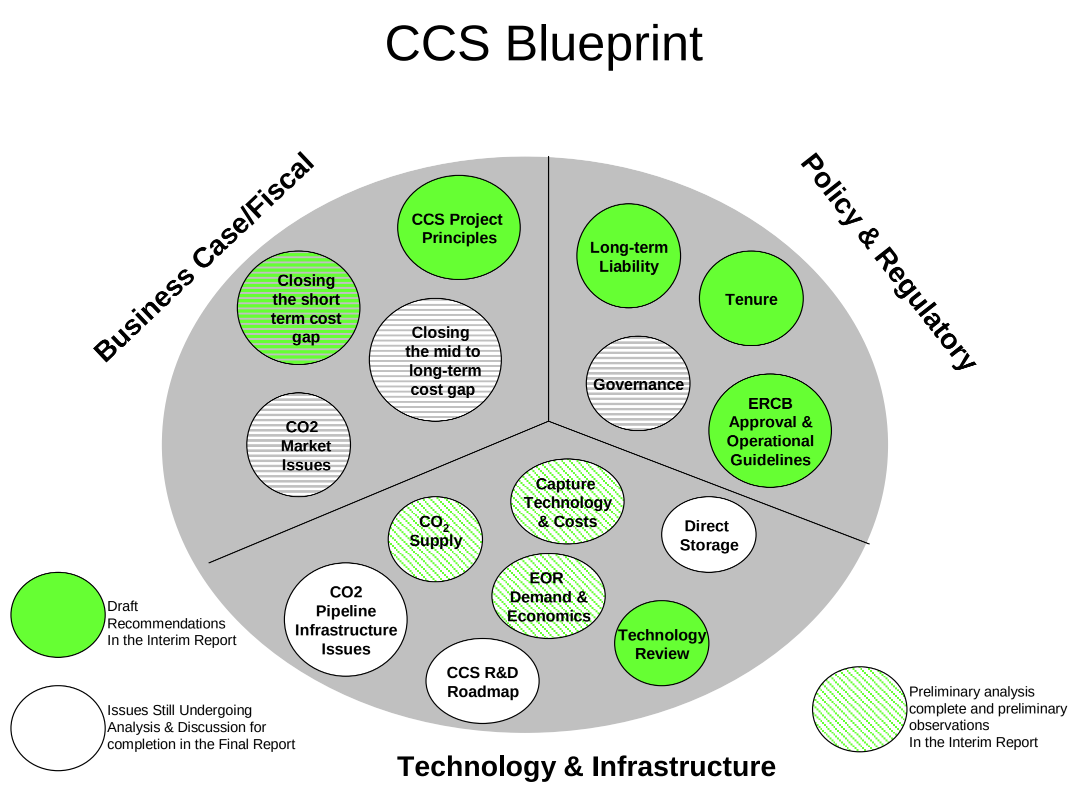
In support of the Council, an Advisory Group of senior government and private sector management was established. The Advisory Group has set up Expert Groups in the areas of the Business Case/Fiscal, Policy & Regulatory and Technology & Infrastructure aspects of CCS.

The Council, Advisory Group, and Expert Group members are listed in the Appendix. The work of the Council and its Advisory and Expert Groups is supported by the Alberta Carbon Capture and Storage Secretariat, the members of which are also listed in the Appendix.

3.0 Development Council Progress to Date

This Interim Report documents the progress to date of the Council at addressing important short-term issues related to CCS. It is a milestone in the development of a blueprint to accelerate large-scale CCS in Alberta. The key findings, initial recommendations, and points of consensus are highlighted below. There remains a series of mid- to longer-term CCS implementation issues that are outstanding and that will be addressed by the Council as part of the Final Report.

The following chart illustrates the issues addressed to date and the issues outstanding:



The work undertaken by the Advisory Group has been divided into Expert Groups addressing the following aspects of CCS development:

- Business Case/Fiscal;
- Policy and Regulatory; and
- Technology and Infrastructure.

A. Business Case/Fiscal Expert Group

As an initial task, the Business Case/Fiscal Expert Group has developed a set of higher level principles that could be used to evaluate or rank potential CCS projects. This effort supports not only the Government of Alberta's announcement of $2 billion to accelerate initial CCS projects, but also the mid- and longer-term evaluation of potential CCS projects. These recommended principles provide benchmarks against which to rank specific projects.

➢ Recommended Principles:

- **End-to-end integrated projects that offer real CO_2 reductions:**

    - At this early stage of the development of CCS infrastructure, it is key that projects clearly demonstrate that CO_2 can be captured and stored successfully and that the costs associated with this activity are clearly understood. Projects that have the potential to capture a significant amount of CO_2 in a near term timeframe (2015) should be highly ranked.
    - Since it will not be possible to support all projects, those which have a higher likelihood of meeting the following criteria should be ranked favourably; the developer has a proven track record of good project management skills, a well developed technology, a proven technology implementation record, proven operational skills, a solid project base, adequate financial capacity, well advanced through the regulatory approval process or the clear ability to achieve regulatory approval in a timely manner; and an appropriate project timeline.

- **Projects that demonstrate promising technologies from more than one industry sector:**

    - Alberta has a vast coal, oil sands and conventional hydrocarbon resource base. There is a strong desire to develop value-added processing within its borders. CCS projects that support development from more than one sector should be highly ranked.

- **Projects that offer cost effectiveness and the potential for broader application:**

    - There are a number of technologies that may be applied in a similar manner in different projects. To the extent that there is the potential for widespread adoption, these projects should be highly ranked.

- Technologies used in the projects should be available to other developers along with acquired project experience (costs, operability, etc.) should be made available to industry after an appropriate confidentiality period.

- **Projects that have the potential to contribute to the cost-effective development of medium-term transportation, sequestration and enhanced oil recovery (EOR) infrastructure within Alberta:**

    - Initial projects will tend to be limited in scope in terms of capture, pipeline infrastructure and sequestration/EOR development due to cost and volume constraints. Projects that have the capacity to contribute to common infrastructure elements that can align with a cost-effective medium-term infrastructure backbone in Alberta in terms of transportation and storage should be highly ranked.

- **Projects that have risk mitigation plans:**

    - There is a range of financial and technology implementation related risks associated with CCS. Projects that address the following risk assessment components should be highly ranked:
        - technology risks;
        - project financing and execution risks;
        - process and operability risks; and
        - the risk of market distortion.

These principles highlight the need for all of Alberta industry to continue to work toward innovative technology solutions that will advance CCS project developments. These efforts will be important to Alberta's economic and environmental future.

B. Policy and Regulatory Expert Group

The Policy and Regulatory Expert Group reviewed the long-term liability issues related to CCS, a potential CCS tenure policy and recommended site/operational guidelines for CCS projects.

The following provides a summary of the results to date of this work:

- **Managing Long-Term CO_2 Storage Liabilities**

There is extensive experience among government and industry in assessing, approving and managing the full project cycle for activities involving underground injection, disposal and storage of a variety of materials, including CO_2. This experience, which is supported by an existing regulatory framework, provides a solid foundation for providing assurances around the safe and reliable storage of CO_2.

With a focus on greenhouse gas mitigation and the potential scale of CO_2 storage, there is a shared appreciation among government, industry, and other key stakeholders that a medium and long-term management framework is required.

Alberta's existing regulatory system covers liability aspects around CO_2 storage during the project life, including decommissioning. The key gap that has been identified, both in the provincial context and as broader issue for advancing CCS globally, is the long-term liability framework once projects have been appropriately decommissioned.

The establishment of such a framework requires distinguishing the project life, which includes site selection, permit application, commissioning, operation and decommissioning, from the post-closure period. While there are key attributes that should apply to the overall management system, the following are core principles that serve as a guide from the proposed long-term management framework:

- Minimize exposure to health, environment and financial risks for operators and governments;
- Support sustainable development;
- Clarity of rules and reasonableness of expectations over the long term;
- Continuous system improvement;
- Data rigor and transparency; and
- Appropriate administrative costs.

This framework represents a starting point to build from through practical experience recognizing that CCS will most likely be implemented in stages…

The following outlines a recommended long-term liability framework for the province. This framework represents a starting point to build from through practical experience recognizing that CCS will most likely be implemented in stages rather than exponentially, thus allowing time for policy evolution and continuous improvement.

➢ Recommended Long-Term CO_2 Management Policy Framework

Project Life Requirements:[7]

The consideration of the longer-term fate of CO_2 would be incorporated into each of the key project life steps. Many of these are already in place, or being

[7] Although this covers elements during the project life, the intent is to include requirements for the purposes of managing the long-term liability of CO_2 post-closure

considered in the process enhancements currently underway. Project approval would be contingent upon having these elements in place to the satisfaction of the regulator. The steps and potential elements could include:

Site Selection and Characterization*:* a detailed assessment of the underlying geology and land features (e.g., abandoned wells) to inform longer-term risk profile. This would support a robust stakeholder engagement plan reflecting the key elements of the site characterization that cover the range of potential liability aspects.

Application and Permitting*:* a proposed decommissioning plan that considers longer-term risks and remediation actions.

Operations*:* monitoring of the fate of the injected CO_2 and comparison with the predictions in the site selection, and application and permitting phases.

Decommissioning*:* a continued monitoring period[8] and an assessment of project conditions against identified performance criteria (pressure levels, per cent of CO_2 dissolved into formations, etc.).

Post-Closure*:* a decommissioning plan being demonstrated to be complete to the satisfaction of the regulator.

Post-Closure Requirements

There is no shift in the existing liability structure until a project has been determined to be closed, which requires completion of the decommissioning phase to the satisfaction of the regulator. With this, consideration then needs to be given to the liability points associated with the post-closure phase (injection and monitoring wells, CO_2 plume, monitoring, remediation, and damages to third party) to assess areas where it would be reasonable and appropriate for liability to be transferred to a long-term management program. These liability points and potential areas that involve a transfer of long-term liability to government include:

Injection and Monitoring Wells*:* an injection well used for initial start-up, operation and/or decommissioning, is selected for use in the monitoring, measurement, and verification (MMV) program for assessing the long-term fate of CO_2 after the closure phase.

CO_2 Plume*:* if the CO_2 plume behaves as expected during decommissioning phase and with consideration of project conditions against identified performance criteria, this element would be satisfied for closure and subsequently transferred to government.

[8] An appropriate duration period will be determined based on the current thinking around appropriate timing to confirm the fate of CO_2 – work being undertaken by current and planned pilots and other experiences will determine the appropriateness of this duration period.

***Monitoring Activity**:* additional monitoring wells for assessing the long-term fate of stored CO_2.

***CO_2 Leak**:* for any aspects of the projects where government takes on the liability post-closure (e.g., monitoring wells), there is a further liability associated with these elements pertaining to remediation in case of CO_2 leakage and for damages to third party. The Government of Alberta may need to assume this liability in the long run.

Monitoring, Measurement and Verification Program

A formal monitoring, measurement and verification (MMV) program would be created as part of the management framework to support the requirements identified in key project life steps, and support the management of the risks identified in the post-closure phase.

While there may be government and other sources of funding, project proponents may also be expected to cover some of the costs.

Longer-Term Management Framework Costs

The management framework will involve a series of costs for all key parties. While there may be government and other sources of funding, project proponents may also be expected to cover some of the costs. Although other areas may be identified, the key potential cost areas associated with addressing the post-closure liabilities, and a potential approach for payment, includes:

Managing Incidences – fund established with payments from the project proponent at an established \$/tonne of CO_2 injected.[9]

Monitoring, Measurement and Verification - program funded through payments from the project proponent at an established \$/tonne of CO_2 injected.[10]

[9] The rate will need to be set with consideration of the range of potential risks and impacts, while also recognizing that a cost gap for implementing carbon capture and storage already exists. It is expected that the rate will be adjusted over time with appropriate notice to industry and based on practical experience. Variations in rate schedules would also be considered (e.g., block rates).

[10] The rate will need to be set based on the structure of the to-be-created MMV program, also recognizing that a cost gap for implementing carbon capture and storage already exists. It is expected that the rate will be adjusted over time with appropriate notice to industry and based on practical experience. Variations in rate schedules would also be considered (e.g., block rates).

- **CCS Tenure Policy Guidelines**

Access to pore space to dispose of CO_2 is a critical issue for CCS. Clarity on pore space ownership and disposition rights has been identified by the Canada/Alberta CCS Task Force as an important step to move the first CCS projects forward.[11]

➢ Recommended Policy Framework:

Section 57(1) and (2) of the *Mines and Minerals Act* confirms that the owner of title to petroleum and natural gas in an underground formation owns the storage rights in that formation, and that the owner of title to a mineral that is evacuated to create a subsurface cavern owns the storage rights in that cavern. Section 9(a)(iii) allows for the entering into of Crown agreements for "the storage of substances in subsurface reservoirs". Section 102 of the *Mines and Minerals* Act allows the Crown to enter into unit agreements that provide for the "use of the subsurface reservoir for the purposes of storage of fluid mineral substances".

Current provisions of the legislation governing ownership relate mainly to oil and gas production and related activities. While this framework is often suitable for CCS, clarity is needed in the legislation to ensure that:

- current references to "storage" in the *Mines and Minerals Act* is expanded to include disposal is necessary;
- owners of freehold disposal rights would be able to grant those disposal rights to others by way of contract; and
- for saline aquifers, all rights belong to the Crown under 3(2) of the *Water Act,*[12] and consequently rights to dispose of CO_2 in saline formations can be granted by the Crown.

The Government of Alberta's Department of Energy has a well established tenure rights issuance process for petroleum and natural gas, oil sands and minerals rights. It is recommended that:

- with some modification, the existing processes can be used for the issuance of disposal rights for CO_2;
- the existing legislation allows for Crown Agreements for tenure rights;
- given the early stage of CCS, it would be more appropriate to use Crown Agreements as opposed to a specific disposal regulation; and

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[11] Immediate Action #2 – Authorities responsible for oil and gas regulation should provide regulatory clarity to the first CCS projects brought 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.

[12] "The property in and the right to the diversion and use of all water in the Province is vested in Her Majesty in right of Alberta".

- experience during the initial years with CO_2 disposal tenure will inform the drafting of regulations if the volume of tenure agreements warrants a more structured approach in the future.

Petroleum and mineral rights are allocated in Alberta by a process of public auction, with rights going to the highest bidder. For tenure rights for CO_2 disposal, a public auction process would also be appropriate, as this supports an open and transparent process. This issue of selecting the highest bidder is one that government should reconsider as it is appropriate for resource extraction, but given the uncertainty around any economic value with disposal rights, may not be appropriate for CO_2 disposal. Consideration of a work commitment bidding process, where bidders commit to exploration work to prove up the disposal capability of a prospect, would be worth exploring.

> ***For tenure rights for CO2 disposal, a public auction process would also be appropriate, as this supports an open and transparent process.***

- **CCS Operational/Site Guidelines**

The Energy Resources Conservation Board (ERCB) is the primary regulator for the upstream oil and gas industry in Alberta and ensures CCS development occurs in a manner that is in the public interest taking into account public safety, environmental protection and resource conservation.

➢ ERCB Approval Process for CCS:

A representative from the ERCB has been actively working on the Council and preparing for company applications to sequester CO_2 in underground reservoirs. The Board now has a regulatory framework in place to manage all stages of CCS development and considers CO_2 under regulation for acid gas injection. The ERCB is ready to accept applications for CCS development and is able to manage decisions regarding such applications. The ERCB considers CCS development under three categories:

- sequestration/disposal;
- storage; or
- use in EOR.

Each of the three categories has a separate regulatory framework although there is overlap. Using CO_2 for EOR is not new to the petroleum industry and the ERCB has regulated such projects for approximately two decades. ERCB focus has been on the more recent development of permanent disposal of CO_2 into reservoirs, often referred to as sequestration. The ERCB considers sequestration the permanent disposal of CO_2 into a subsurface environment. The ERCB's approach to regulation on sequestration is twofold:

- First, the ERCB has a number of detailed regulations focusing on the general technical requirements that will need to be followed by all CO_2 sequestration project applicants. These general regulatory requirements would include specific direction found in such documents as Directive 56 and Directive 65.

- Second, the ERCB will conduct a detailed evaluation of various aspects of each individual CO_2 sequestration application. Based on this evaluation the ERCB may place additional regulatory requirements on any specific CO_2 sequestration approval. These specific regulatory requirements are referred to as “approval conditions” and are intended to manage the unique aspects of a specific proposal. Approval conditions can focus on surface or subsurface situations. Examples of such conditions are the maximum injection pressure or type of subsurface monitoring required to ensure reservoir containment.

The technical aspects of oil and gas regulation can be difficult to understand if a person is not an expert in the specific discipline that the regulation discusses. Given the high level of interest in CCS development, the ERCB is in the process of developing a guide that describes the regulatory steps for submitting a CO_2 sequestration application to the ERCB. This is scheduled to be released by the end of 2008.

C. Technology and Infrastructure Expert Group

The Technology and Infrastructure Expert Group evaluated the key technology considerations for moving CCS forward. These covered five areas:

1. **Capture Technology and Cost Estimates**: Expected costs for capture, based on latest information; learning curve expectations; stages and risks in a pathway to commercial deployment; long-term research and development technology development required.

2. **CO_2 Supply Curve**: CO_2 emission volume forecast, including volume of carbon that can technically be captured; cost to deliver these volumes; and geographic layout of this emission and capture profile.

3. **EOR Demand Curve**: CO_2 purchase expectation by EOR at various oil and CO_2 price points; ultimate market size expected from EOR; and timeline to development.

4. **Direct Storage**: Volume potential for Saline Reservoir storage in Alberta; characterization work completed or underway; potential for depleted gas zones to contribute to storage.

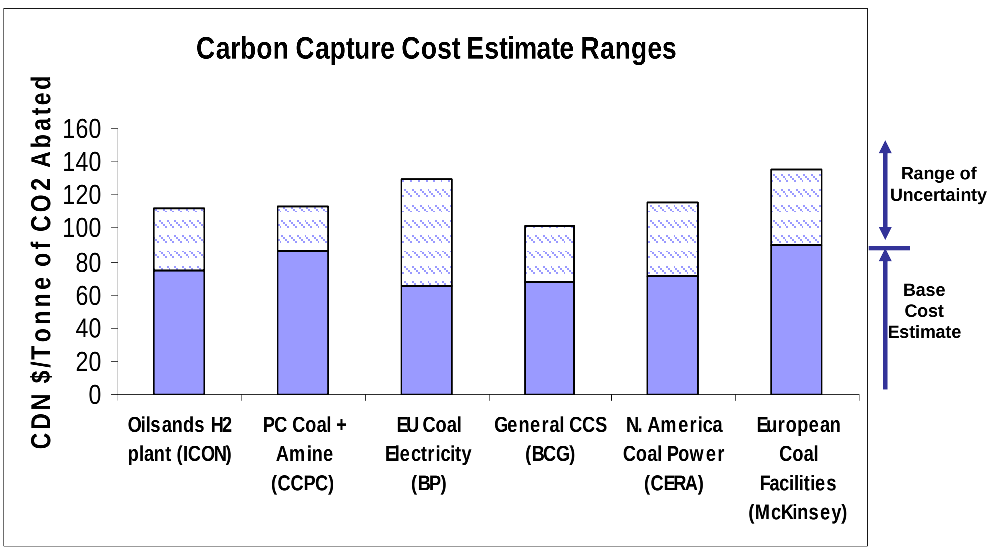
5. **Pipeline System**: Current costs for pipeline construction; review the inherent benefits of a network approach or planned development vs. ad hoc development of required pipelines; special requirements needed in the design and operation of CO_2 liquid pipelines.

Preliminary work has been completed and the preliminary conclusions follow:

➢ Capture Technology and Cost Estimates Initial Review

The ability to refine capture cost estimates from what has already been prepared by other groups is complex and will take additional time. Estimates from previous work completed have large error bands (±40-50 per cent) as shown by the examples below from the ICO_2N group, CCPC, BP, BCG, CERA, and McKinsey.[13] Due to the very site-specific nature of adding capture to new or existing plants, improvement in the quality of these estimates will not be possible without detailed engineering work. There is agreement that the costs of capture technology will decrease over time but uncertainty as to the speed of this cost reduction.

The following chart reflects the broad range of carbon capture costs related to specific plant installations, specific CCS technologies and reductions in the costs over time.



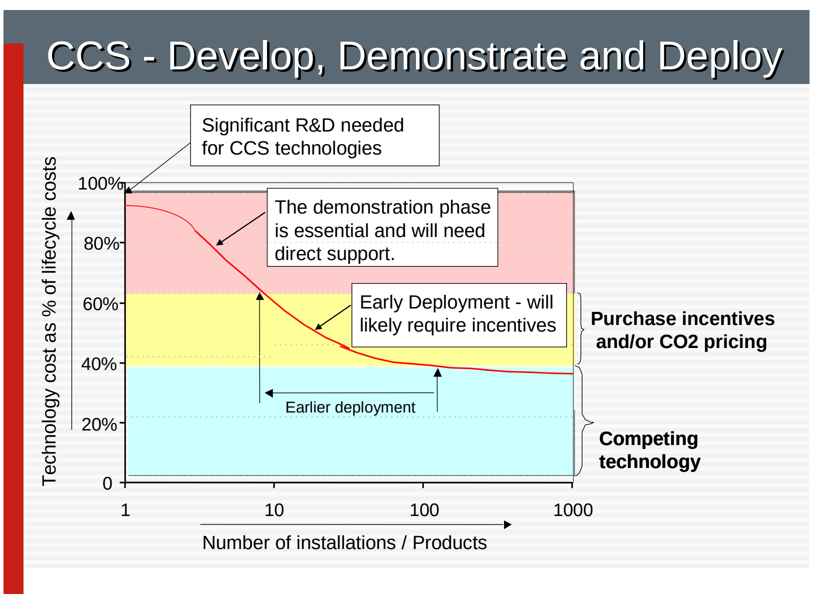
[13] ICO_2N is the Integrated CO2 Pipeline Network, *CCS: A Canadian Environmental Superpower Opportunity, December 2007*, CCPC is the Canadian Clean Power Coalition, *Phase II Summary Report, September 2008*, BP is British Petroleum, *Presentation, September 2008*, BCG is the Boston Consulting Group, *CCS: A Solution to the Problem of Carbon Emissions, June 2008*, CERA is Cambridge Energy Research Associates, *Climate Change Forum web conference, June 2006*, McKinsey Consulting, *Bloomberg reference, September 2008*

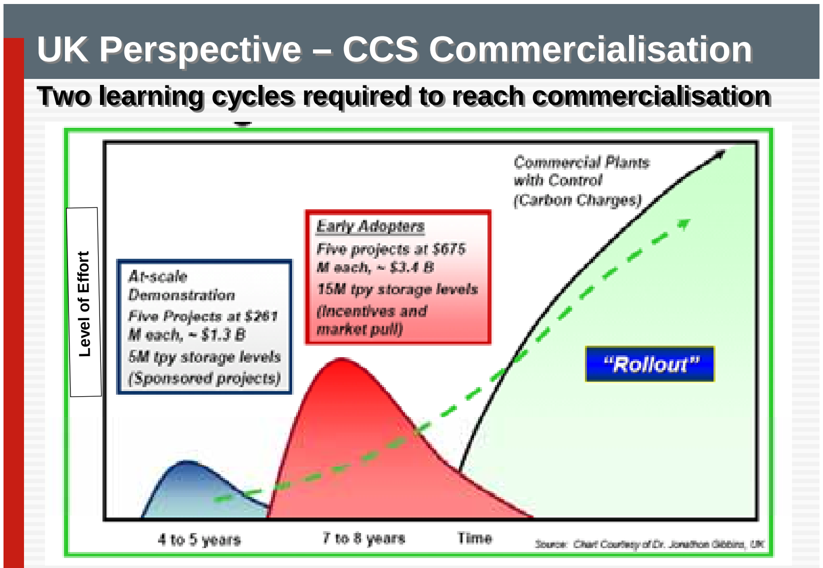
An assessment of the risk and uncertainty in the development cycle has led to the following conclusions.

- Large scale CCS projects have long cycle times and need to progress through development, demonstration, and deployment before becoming commercial.
- CCS technology is currently only at the development stage, and is expected to take 15 years to commercialize and will require a significant number of full-scale facilities be built worldwide.
- Costs are expected to rise in the early stages as attempts to demonstrate the technology suffer setbacks, and require re-design or further development work.
- Ultimately substantial cost improvements are expected but significant direct support is needed until these learning curve benefits appear.

Ultimately substantial cost improvements are expected but significant direct support is needed until these learning curve benefits appear.

These conclusions are illustrated in the following graphs of a typical technology learning curve and United Kingdom perspectives of CCS maturation over time:





Source: Dr. Jon Gibbins, Imperial College London, April 2007

➢ CCS Research and Development Needs Initial Review

The technologies required to capture, transport and store CO_2 exist today. There are only a few large, concentrated and high pressure sources of CO_2 in Alberta and more than 95 per cent of flue gas streams have CO_2 concentrations below 20 per cent. This implies high capture costs and a large requirement for extra energy to capture CO_2. CCS is most effectively implemented when new plants using advanced technologies are built. The business case to proceed on the inaugural plants is challenged because there is no upside profit driver to developing CCS except to avoid offset cost. Faster technology development will allow some of these risks to be mitigated.

The following provides a summary of the carbon capture research and development (R&D) needs as identified by Canada's CCS Technology Roadmap.[14] In the Council's Final Report, these R&D needs will be prioritized to emphasize the critical items:

Capture Research and Development needs:

- assessment of Alberta's CO_2 supply, purity and cost of capture on technology- and site-specific basis and the timing for commercial application of the technology;
- solutions that address the high cost and relatively unproven performance of existing and emerging technologies;

[14] Canada's CO_2 Capture and Storage Technology Roadmap. Natural Resources Canada - March 2006. p 89. http://www.co2trm.gc.ca/

- solutions for energy intensity reductions for capture technologies;
- post-combustion - development and scaling-up of more advanced solvent technologies with increased absorption capacity and reduced energy requirements;
- oxy-fuel combustion - development and integration of the mechanics of combustion and heat transfer, burner development, furnace design, integrated flue gas cleaning and CO_2 gas separation and compression;
- pre-combustion - integration of multi-pollutant capture, improved catalyst/membrane processes for water-gas shift reactions hydrogen/CO_2 separation and novel CO_2 capture processes in natural gas reforming or coal, bitumen and pet-coke gasification; and
- industrial processes - improved understanding of process chemistry to increase CO_2 concentrations in flue gases, and developing process modelling and systems integration tools for industrial processes, conventional oil and gas refineries and the oil sands upgrading operations.

CO_2 Transport/Infrastructure Research and Development needs:

- a better understanding of the effects of transporting liquid CO_2, with or without trace impurities, on the design and operation of pipelines and associated equipment; and
- a database of required purities for different applications.

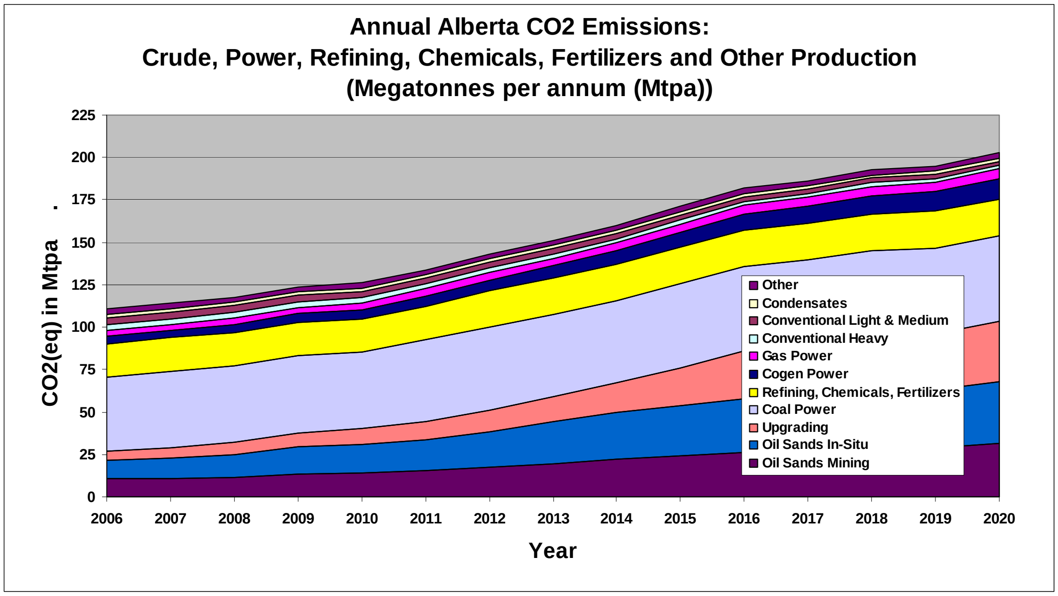
CO_2 Storage Assessment Research and Development needs:

- source-sink matching - identify top storage sites based on their capacity and location of CO_2 sources and infrastructure, geological site identification and characterization, and aggregation for total economic capacity assessment;
- injection – CO_2 flow down wells, near-bore geomechanical and geochemical effects, potential near-well bore formation damage and the impacts of other constituents in the CO_2 injection stream;
- long-term storage – understanding the ultimate fate of CO_2 to determine the long-term integrity of CO_2 containment in natural and man-made geological structures through integrated hydrogeological, geomechanical and geochemical modelling;
- MMV – investigation of monitoring technologies including geophysical, remote sensing, subsurface chemical/biological tools and in-situ tools; and
- developing monitoring and remediation techniques and strategies in case of CO_2 leakage.

➢ Alberta's CO_2 Supply Curve Initial Review

Work was performed to analyze public data on expected emissions growth and the possible level of CO_2 capture which could be achieved. Annual CO_2 emissions from what are considered large Alberta emitters, amounted to 110.7 Megatonnes per year (Mt/pa) in 2006 as highlighted in Alberta Environment's *Report on 2006 Greenhouse Gas Emissions*. Figure 6 of that report shows the total reported CO_2 emissions by facility type.

The chart below projects the change in emissions for the large emitters to 2020 from the 2006 reported emissions.



The projection through 2020 is based on production forecasts recently issued by the Canadian Association of Petroleum Producers (CAPP) in its 2008 *Crude Oil Forecast, Markets & Pipeline Expansions*, for conventional light, medium and heavy crude oil as well as condensates, oil sands mining, oil sands in-situ and oil sands upgrading. The projection also includes forecasts recently issued by the EUB in ST98-2008, for coal, gas and cogenerated electric power.

For both oil sands and power production, there is significant new capacity either under construction, approved for construction or announced/proposed. Refining, chemicals and fertilizer production is projected to remain relatively stable at 2006 levels throughout the period. New capacity additions are regionalized based on site information associated with such capacity additions. The number of new capacity additions, particularly in relation to projects falling into the categories of (i) approved for construction or (ii) announced/proposed, are adjusted to maintain a sector "capacity utilization rate" approximately equal that experienced in 2006.

Developing a forecast of possible emission reductions through CCS from the above data is challenging, but is underway. That work will be done in two ways – firstly with a cost ceiling of $200 per tonne of CO_2 emissions (deemed as the technically achievable reductions) and then with a breakdown of costs that are more specific to certain technologies or facilities. This will allow a supply curve to be developed which can demonstrate the level of capture achievable at various costs. Because of the growth in emissions, the timing of new capacity additions as well as the different facility types to which CO_2 capture technology may be applied, the supply curve will need to be updated on a regular basis.

Alberta has the longest running commercial enhanced oil recovery (EOR) project in Canada.

The cost of CO_2 capture, at any given point in time, will be impacted by a number of of capital and operating cost variables and related effects including (i) level of current estimating accuracy, (ii) facility/design specific costs, (iii) site/location specific costs, (iv) parameters such as power and fuel costs, (v) capacity utilization effects, (vi) derating effects, (vii) cost of capital effects (viii) exchange rates on imported machinery and equipment and (ix) technological advances.

➢ Enhanced Oil Recovery (EOR) Demand Curve Initial Review

Alberta has an opportunity to advance large scale, value-added CO_2 sequestration through enhanced oil recovery of its many mature oil pools. Alberta has the longest running commercial enhanced oil recovery (EOR) project in Canada, at Joffre, but it is small in scale and expansion of this technology has been hindered by limited volumes of CO_2 below $30/T. To spur development, the Government of Alberta has fostered CO_2-EOR piloting technology through its Innovative Energy Technologies Program to mitigate technical risks of large-scale EOR development.

To properly assess EOR demand, a high level screening of Alberta's oil pools has been undertaken to examine the suitability and potential for CO_2-EOR, and this will lead to a more detailed economic assessment of viability. The review is also re-examining previous studies that did not consider a number of reservoirs thought to be unsuitable for conventional CO_2 EOR because the oil was too heavy, the reservoir was not deep enough or had poor rock quality, it responded poorly to conventional waterfloods, or it had been previously miscibly flooded with hydrocarbon fluids.

With higher oil prices and advancement of EOR technology, these may be viable candidate fields in the near future. Initial work indicates that previous estimates of 10-12Mt/yr of EOR market in miscible floods have been confirmed and there is promising potential to increase this number substantially if immiscible flooding can be proven with the less attractive reservoirs.

The key results of this analysis, when completed, will be included in the Council's Final Report. The work will also address the key challenge of timelines for development of capture, pipeline and EOR investments in parallel.

➢ Direct Storage Initial Review

The potential to store CO_2 in empty hydrocarbon reservoirs and saline formations has been reviewed by experts over the past two decades, but has not been subject to rigorous geologic or reservoir modelling. Work has focussed on the overall storage capacity of the Western Canadian Sedimentary Basin, and has not delineated the best reservoirs considering cost, proximity to emissions, geologic security. This is a necessary next step.

There are conflicting views on the merits of direct storage in saline reservoirs as compared to depleted gas or oil fields. Oil fields considered depleted typically have more than 50 per cent of its original oil in place. Although it is not currently economic to produce this oil, it could become viable with future oil price escalation and new production technology. This oil is owned by either the Crown or private interests. Injecting CO_2 may be undesirable and for these reasons oil reservoirs are poor candidates for long-term storage (excluding those with EOR potential).

Depleted gas reservoirs typically have less than five per cent of natural gas remaining and are more promising candidates. They are well understood geologic structures with a demonstrated ability to retain fluids for millions of years.

Depleted gas reservoirs typically have less than five per cent of natural gas remaining and are more promising candidates. They are well understood geologic structures with a demonstrated ability to retain fluids for millions of years. They often have suitable wells which could be used to inject CO_2. An assessment is underway to evaluate the potential storage volume in depleted gas reservoirs.

➢ Pipeline System Initial Review

Pipelines provide the optimum transportation solution for moving large volumes of CO_2 from source to destination. Several commercial CO_2 pipelines currently operate in North America. These include a 320 kilometre long pipeline that runs from North Dakota to Saskatchewan supplying CO_2 to enhanced oil recovery projects and a network of pipelines in the United States moving 30Mt/yr from naturally occurring CO_2 in the Permian Basin. Pipelines are the safest means to transport commodities and the economics are well understood. As with any pipeline activity the key to being cost effective is to achieve the maximum scale and full utilization.

The need for pipelines to move the CO_2 is apparent and the best configuration will depend on three factors:

- the source location, volumes and quality of CO_2 captured;
- the location and capacity of EOR customers; and
- the location of direct storage saline reservoirs.

As with any new infrastructure development, initial segments may be isolated between specific sources and delivery points. As volumes grow, pipeline systems can be looped to add more capacity or interconnected where CO_2 quality is consistent or where variances in quality can be managed.

4.0 Development Council Next Steps

The Council is continuing to work on a number of outstanding issues related to the medium- and long-term development of CCS

The following are some of the issues the Council, assisted by the Advisory Group and the Expert Groups, continues to work on.

Business Case/Fiscal Expert Group

- Reviewing concepts around the market structures/market dynamics for physical CO_2 capture and storage in Alberta and considering options to support market effectiveness.

- Developing scenarios around the evolution of carbon capture costs, transportation and storage costs, EOR opportunities and regulatory systems and attempting to quantify these scenarios in terms of costs to developers and governments.

- Identifying policy options that may be appropriate to support the medium term development of CCS in Alberta.

"Carbon capture holds great potential and promise as a tool in our quest to reduce greenhouse gas emissions. Together, using technology and innovation, we can be good stewards of the environment while at the same time enhancing Alberta's position on the cutting edge of energy production."

Premier Stelmach
November, 2007

Policy & Regulatory

- Alberta Energy will be developing a finalized tenure process and communicating it to industry.

- Long-term liability - A number of steps will be undertaken:

    - A review of liability approaches for CCS in other jurisdictions.
    - Further risk analysis of the impacts of CCS will be undertaken and supplemented by the development of the MMV system. This work will continue into 2009.
    - As noted above further development work will be undertaken related to the MMV system. This work will continue into 2009.
    - A detailed liability program will be developed as the above input pieces are finalized.

- Governance - Alternative approaches to longer-term governance of CCS will be explored and shared in the Final Report.

Technology & Infrastructure

The work of the Technical group will continue to focus on the five key areas previously identified in this report.

- Capture cost estimates are being sought from a variety of sources to update the general data with more site specific, current information. It will be used by the economic analysis team in appraising the level of support needed for early adopters. This cost information will allow completion of the CO_2 supply curve work as well.

- A list of priorities for CCS research and development and technology roadmap for Alberta will be completed.

- The EOR study and a review of saline reservoir potential will be completed.

- A pipeline cost estimate update by the Canadian Energy Pipelines Association (CEPA) will be provided.

- A review of the pipeline requirements, testing of cost assumptions for pipelines and an assessment of the benefits of a network vs. ad hoc development approach will be completed.

Appendix

Alberta Carbon Capture and Storage Development Council Membership

Development Council Members

Jim Carter, former President Syncrude Canada Ltd. (Chair)
Bill Andrew, Penn West Energy Trust
John Brannan, EnCana
Dave Collyer, Shell Canada
Cassie Doyle, Natural Resources Canada
Jim Ellis, Alberta Environment
Dr. David Keith, University of Calgary
Don Lowry, EPCOR
Art Meyer, Enbridge
Dr. Mike Percy, University of Alberta
Kathy Sendall, Petro-Canada
Ian Shugart, Environment Canada
Roger Thomas, Nexen Inc.
Peter Watson, Alberta Energy
Len Webber, MLA – Calgary Foothills, Government of Alberta
Steve Williams, Suncor Energy

Advisory Group Members

Don Thompson, Syncrude Canada Ltd. (Chair)
David Breakwell, Alberta Energy
Shannon Flint, Alberta Environment
Patrick Hanrahan, Kinder Morgan
Eddy Isaacs, Alberta Energy Research Institute
Stephen Kaufman, Suncor Energy
Sandra Locke, Alberta Energy
Don Macdonald, Alberta CCS Development Council Secretariat
Richard Masson, Nexen Inc.
Dave Middleton, Penn West Energy Trust
Andy Ridge, Alberta Environment
Wishart Robson, Nexen Inc.
Rob Seeley, Shell Canada
Kevin Stringer, Natural Resources Canada
Don Wharton, TransAlta

Expert Group Members
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Eric Beynon, Suncor Energy
Doug Bonner, ARC Resources
Rob Craig, Suncor Energy
Nancy Cuelenaere, Alberta Finance
Larry Hegan, Natural Resources Canada
Christian Iniguez, Alberta Energy
Karl Johannson, TransCanada
Leah Lawrence, EnCana
Sandra Locke, Alberta Energy
Paul McKendrick, TransAlta
Bob Mitchell, ConocoPhillips
Jetha Nizar, Syncrude Canada Ltd.
Kristian Tange, Penn West Energy Trust
John Van Ham, ConocoPhillips

Policy & Regulatory
David Breakwell, Alberta Energy (co-Chair)
Don Thompson, Syncrude Canada Ltd. (co-Chair)
Bruce Akins, Natural Resources Canada
Tristan Goodman, Energy Resources Conservation Board (ERCB)
Sandra Locke, Alberta Energy
Don Macdonald, Alberta CCS Development Council Secretariat
Denelle Peacey, Alberta Utilities Commission
Andy Ridge, Alberta Environment
John Van Ham, ConocoPhillips

Technology & Infrastructure
Stephen Kaufman, Suncor Energy (Chair)
Geoff Browning, Environment Canada
Carl da Silva, EnCana
Craig Fairbridge, Natural Resources Canada
Patrick Hanrahan, Kinder Morgan
Larry Hegan, Natural Resources Canada
Eddy Isaacs, Alberta Advanced Education & Technology
Dave Middleton, Penn West Energy Trust
David Pollock, Alberta Energy
Rob Seeley, Shell Canada
Don Wharton, TransAlta

Secretariat
Don Thompson, Executive Director
Patti Humphrey, Office Manager
Don Macdonald, Sr. Policy Advisor
Billy Anderson, Summer Student