ICO$_2$N

CARBON CAPTURE & STORAGE:
A CANADIAN ENVIRONMENTAL SUPERPOWER OPPORTUNITY

A Summary Report by the ICO$_2$N group of companies:

DECEMBER 2007

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EXECUTIVE SUMMARY

Canada has a unique opportunity to be a world leader in the implementation of Carbon Capture and Storage (CCS). CCS is the subject of much discussion and planning around the world, particularly in Europe, Australia and North America. The Governments of Canada and Alberta are actively engaged in this dialog and recognize that CCS has the potential to be the next large-scale Canadian infrastructure development that will enable sustainable growth of our energy industry through the 21st century.

CCS involves capturing carbon dioxide (CO_2) from large industrial sources before it is emitted into the atmosphere. Once captured, CO_2 can be safely and permanently stored in deep geological formations or injected into mature oil fields to enhance oil recovery (EOR). Together, these are key elements of a long-term integrated vision for a CCS system that capitalizes on Canada's unique opportunities.

There are many significant challenges associated with CCS. Governments and industry are already actively involved in defining the appropriate public policy frameworks that will be required, the amount of investment to be shared in implementing projects, and the amount of risk each party should assume related to capturing, transporting and sequestering CO_2.

This report has been prepared by the ICO_2N group of companies to provide an overview of the opportunities presented by CCS in western Canada, its economics and some of the options for implementing a significant, integrated CCS system.

A number of conclusions surface from the analysis in this report:

- Canada has the opportunity to be an energy and environmental superpower. Canada has a unique opportunity in the world to capitalize on the geology of the Western Canadian Sedimentary Basin (WCSB) to effect large scale CCS. The WCSB provides not only significant amounts of CO_2 emissions as a function of hydrocarbon development but also reservoirs in relative proximity with vast potential to store CO_2.
- CCS is vitally important to the sustainability of Canada's oil sands development and to the continued use of cost effective coal-fired power generation as the world searches for lower carbon energy sources.
- It makes environmental and economic sense to develop initial CCS projects within a vision of a long-term, large-scale integrated system. Such a system can be built in phases. Decisions about a phased and integrated CCS system require a long-term focus on Canada's energy and environmental policy objectives (2020 and beyond).
- The economics of CCS implementation are complex and a clear understanding of the technology, costs and supply/demand pricing dynamics is needed in designing appropriate, robust policies to grow CCS over the long-term.
- The ICO_2N group of companies represents a significant cross-section of Canada's large industrial CO_2 emitters. The group has done an extensive amount of work in analyzing the challenges and opportunities for CCS from both an investment and a public policy perspective.
- Close cooperation between industry and government is needed in CCS design, funding, and policies to support this transformative environmental initiative.

INTRODUCTION

As Prime Minister Harper has stated, the continuing development of the oilsands in Alberta offers Canada the opportunity to become an "energy superpower." With the creation of a comprehensive carbon capture and storage (CCS) system, Canada has the potential to be an energy and environmental superpower.

The ability to capture carbon dioxide emissions and safely store them underground is an important technology not only to the oil sands but all coal-fired power generation plants both in Canada and globally. How critical is CCS to Canada (and the world)? The importance has been recognized by a wide range of stakeholders as noted below:

> "If we do not succeed in making CCS viable, the cost of mitigating CO_2 emissions will be much higher."[1]

> "In most scenario studies, the role of CCS in mitigation portfolios increases over the course of the century and including CCS in a mitigation portfolio is found to reduce the costs of stabilizing CO_2 concentrations by 30 percent or more."[2]

> "The best way to make CCS cheaper is for government to provide incentives to use it. Learning by doing is the thing that drives the cost down."[3]

> "The Pembina Institute considers CCS to be one available option among others for achieving the needed deep reductions in Canada's greenhouse gas (GHG) emissions.."[4]

Implementation of CCS is significant for Canada and needs to proceed as soon as possible if Canada is going to continue to grow as a world leader in both energy and the environment.

ICO_2N is an alliance of 15 of Canada's largest industrial companies who represent more than 100Mt of CO_2 emissions, over 60% of Alberta's electricity generation and 95% of the production from the oil sands. The group has been working together for more than two years on carbon capture and storage.[5] ICO_2N stands for Integrated CO_2 Network: a proposed system for the capture, transport, distribution and storage of carbon dioxide. It is not an individual project, but rather a comprehensive way forward for implementing CCS in Canada.

Studies by ICO_2N indicate that through a phased buildup of CCS there is the potential to ultimately reduce CO_2 emissions by more than 20 million tonnes per year over the next decade – the equivalent of annually removing about four million cars off the road. With the right long-term approach, reductions could grow to more than 100Mt/yr, roughly 13% of Canada's current emissions.

Over the past two years, ICO_2N has worked with all levels of government, other industry partners, and similar international initiatives to review the key aspects of CCS. ICO_2N has also been an active participant in the 2007 ecoEnergy Canada-Alberta Carbon Capture and Storage Task Force.

ICO_2N's work to date includes study of the technology challenges, supply/demand projections, analysis of potential costs and infrastructure design. The group has also examined the appropriate policies and incentives that will be needed to kick-start and further develop a long-term carbon capture and storage system in Canada. In support of this work, the ICO_2N group has constructed a detailed economic model to study the costs of capture, transportation and storage as well as the supply and demand balance of an integrated CCS system. Results from the model for some of the contemplated CCS scenarios are highlighted in the economics section of this report.

1 Mandil, International Energy Agency
2 IPCC
3 Hawkins, National Resource Defence Council
4 Pembina Institute: Pembina Perspective on Carbon Dioxide Capture and Storage, September 14, 2007
5 Agrium Inc., Air Products Canada Ltd., Canadian Natural Resources Ltd., ConocoPhillips Company, EPCOR, Husky Energy Inc., Imperial Oil Ltd., Keyera, Nexen Inc., Shell Canada Ltd., Sherritt International Corporation, Suncor Energy Inc., Syncrude Canada Ltd., Total E&P Canada, TransAlta Corporation

CARBON CAPTURE AND STORAGE – A WESTERN CANADIAN SEDIMENTARY BASIN OVERVIEW

CCS uses a combination of processes and technologies, some of which are already technically and economically viable and some of which have not yet been proven at large scale. An integrated CCS system has three distinct components involving capture, storage and transportation:

CO_2 Capture

CCS begins with the capture of CO_2 at an industrial plant or a fossil fuel-fired power plant (often referred to as clean coal). The most common method is to extract the CO_2 from flue gases by contact with amine-based solvents, which are then heated to release the CO_2 at low pressure. This technology is very similar to processes widely used in the Canadian natural gas industry.

Alternative capture methods include cryogenic separation and filtering the gas stream through special membranes, both of which are emerging technologies with good potential, but have less of a proven track record. Once captured, the CO_2 is then dehydrated and compressed to high pressure for optimal pipeline transmission.

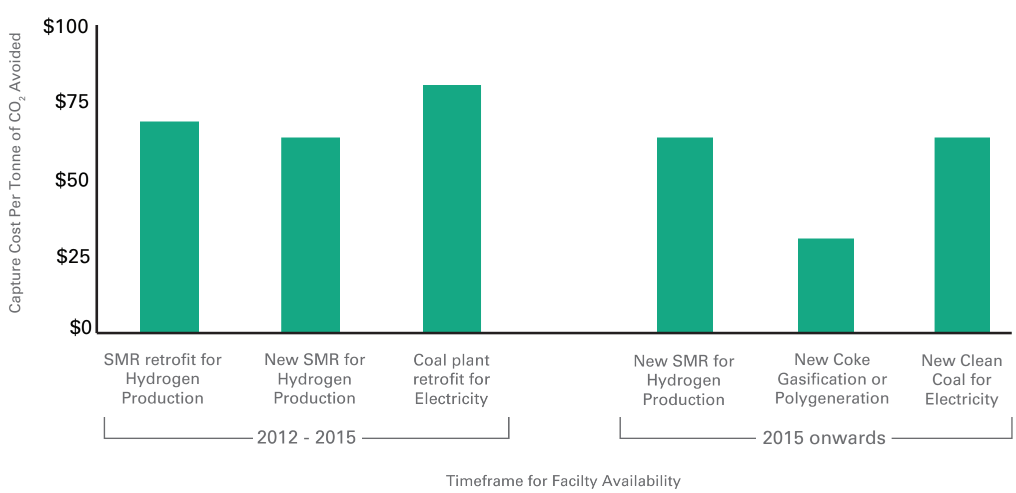
In gasification plants, refinery hydrogen plants, oilsands upgraders and many chemical and fertilizer plants, the CO_2 is in a more concentrated process stream. This greatly facilitates capture and can lower unit costs as compared to capture from flue gas streams at power plants and industrial facilities.

The significant sources of CO_2 in Alberta are the coal-fired power plants (in the vicinity of Edmonton), the oil sands facilities in the Fort McMurray area, the oil upgrading and refining facilities in the Fort Saskatchewan area, and a number of chemical and agricultural industrial facilities in the Red Deer area.

Based on proprietary reports of a number of its members, ICO_2N has reviewed the technology options available and CO_2 capture costs and built these into its comprehensive economic model. CO_2 capture costs represent 70 to 80 percent of the total costs of CCS and for the member companies to capture significant volumes, these costs total in the billions of dollars.

CHART 1

Availability of facilities for CO_2 capture



Looking ahead to what would be possible over the next 10 years there are two broad stages of possible development. As demonstrated in the Chart 1, in the 2012-2015 timeframe CCS could be deployed at new and existing industrial plants, particularly steam methane reforming (SMR) upgrading facilities, which are currently in the planning stages. An initial gasification facility could be running as early as 2012, however major application of this technology will be a few years later. All of the costs that are reflected here are in 2007 and are based on preliminary scoping studies.

All costs presented in this graph are for a tonne of CO_2 emissions that is avoided as compared against the same plant without CCS. The extra emissions that result from running the CCS operation and the extra energy that is required are built into the calculation. These costs are for industrial facilities built in Ft. Saskatchewan and coal plants built in the Wabamum / Genesee areas.

The post-2015 timeframe would also be when the first clean coal plants could be incorporated. These could be facilities that are either pulverized coal or integrated gasification combined cycle (IGCC). On an individual basis, a clean coal plant can provide significant CO_2 reductions and it is anticipated that cost of capture at such a plant will be slightly less expensive than SMRs on a per tonne basis.

CO_2 Storage

Another key component of CCS involves storing CO_2 in secure geological formations.

Canada's unique geography of abundant energy supplies (with accompanying CO_2 emissions) and significant, relatively close at hand, storage reservoirs provides an opportunity to be a global leader in contributing to the world's critical energy needs while actively tackling climate change emissions. It is estimated that several hundred years' worth of emissions could be stored safely throughout the Western Canadian Sedimentary Basin.

A number of geological formations hold promise for secure, long-term storage of CO_2. Direct storage at these locations will be necessary to handle the large volumes of CO_2 associated with capture over the long term. These locations include depleted oil and gas reservoirs, deep and uneconomic coal formations, and deep saline aquifers several kilometres beneath the surface, far below and geologically separated from ground water supplies.

In addition, the development of a commercial market for CO_2 in the early years represents an opportunity to offset some of the costs of capture and storage. In particular, the area covered by British Columbia, Alberta and Saskatchewan has abundant geological storage sites with potential for enhanced oil recovery (EOR).

In 2005, ICO_2N conducted a study on the size of the potential EOR market in Alberta and its sensitivity to the price of CO_2. This ground breaking work was incorporated into ICO_2N's model and provides a basis for defining future CO_2 demand.

It is clear from the ICO_2N study that EOR can serve to help kickstart a potential CCS system. However, over time CO_2 supplies will greatly exceed available EOR applications. There is the possibility that enhanced coalbed methane (ECBM) will provide further market potential, but it is very likely that significant amounts of CO_2 will need to be directed to secure, permanent underground storage.

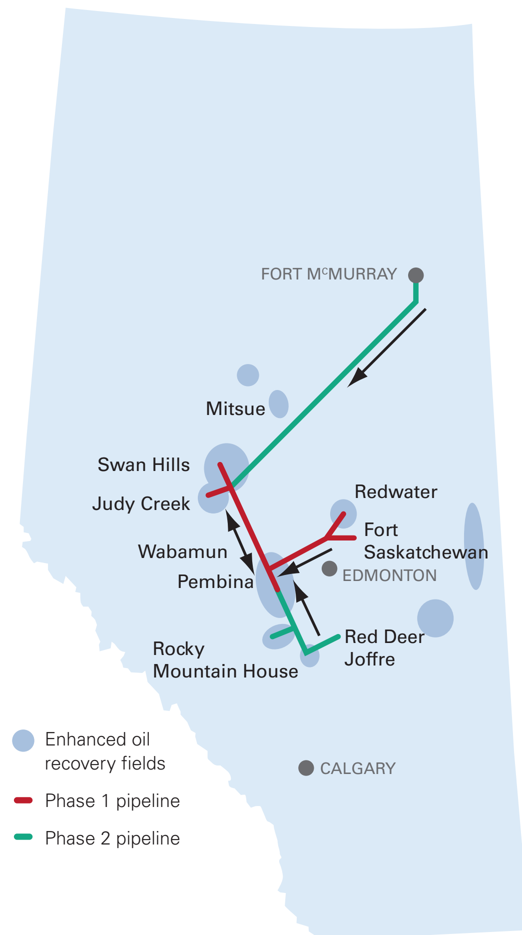
ENHANCED OIL RECOVERY

EOR involves injecting CO2 to "sweep" and extract some 5-15% of the oil remaining in depleted oil reservoirs.

A CO2 market based on EOR in Alberta is in the early stages of development. This market is expected to expand as technology advances and as additional conventional oil fields decline and become candidates for CO2-based EOR. This could result in up to 1.2 billion barrels of incremental oil production and use 10-12 Mt/yr of CO2 emissions reductions.

CO_2 Transportation

Map 1: Possible Integrated CO2 Network pipeline route



The link between capture and storage in a CCS system is transportation. It is the element that involves moving the CO_2 from the point of capture to the intended use or storage site via pipelines. In the United States, pipelines have been transporting CO_2 to oil fields for use in EOR activities for over 30 years. Today, a 325-kilometre pipeline safely delivers 5,000 tonnes of CO_2 per day from a coal gasification plant in North Dakota to a CO_2-based EOR project at Weyburn, Saskatchewan.

CO_2 suppliers, end-use markets and storage locations can be connected by a high pressure, large diameter, long distance pipeline system. The pipeline could consist of a large main line connecting CO_2 capture facilities with the main EOR market and storage locations across the Western Canadian Sedimentary Basin. The pipeline would likely be built to accommodate the needs of first phase individual CCS projects and could be expanded in phases to meet supply.

ICO_2N has conducted a study of the optimal pipeline routing, capital costs, operating costs, and the timing and construction schedules needed to phase in and develop the pipeline system. A key conclusion of this research is that it makes sense to plan a large, integrated system from the beginning and build it in phases. This will enable economies and efficiencies of scale and allow the CO_2 to flow to a variety of end uses (EOR and storage). It is also feasible to design such a system because the CO_2 source locations, the destinations and the projected volumes all are known.

One of several possible pipeline routings for Alberta is presented in Map 1 above. With whichever route is ultimately developed, it will be necessary to design the pipeline sizing and phasing to optimally balance risk, economics and market opportunities.

SAFETY CONSIDERATIONS OF CARBON CAPTURE AND STORAGE

Carbon Capture and Storage consists of both proven and emerging technologies. As noted earlier, the development of a variety of CO_2 capture technologies is underway – some well established and in use, others showing tremendous promise for the future. CO_2 pipelining and use for EOR has been underway in the U.S. and in other countries for decades. CO_2 storage is used in a number of countries and has been extensively studied as to the integrity of the chosen geologic formations to ensure there are no leaks

In Canada, the geological formations being considered as likely candidates for long-term CO_2 storage – namely depleted oil and gas reservoirs, coal formations and saline aquifers – have already proven safe for storing other gases and liquids. These same formations have trapped crude oil and natural gas underground for hundreds of millions of years.

The formations consist of a layer of permeable rock capped by a thick layer of impermeable rock. While the gases and fluids can pass through the pores of the permeable rock, they cannot move past the impermeable rock. As a result, any CO_2 injected into the permeable formation remains trapped there.

Ensuring the safety of groundwater is another key issue. For the same reasons that stored CO_2 could not migrate and be released back into the atmosphere, it also has difficulty migrating into aquifers that provide drinking water. If there were a potential for leakage, any potable water would have already been contaminated by brine or hydrocarbons trapped in the formations.

The International Energy Agency (IEA) recently did an assessment of storage safety:

> Observations from engineered and natural analogues as well as models suggest that the fraction retained in appropriately selected and managed geological reservoirs is very likely to exceed 99 percent over 100 years and is likely to exceed 99 percent over 1,000 years (very likely=90-99 percent probability, likely=66-90 percent probability). [6]

Careful selection and testing of potential storage reservoirs and the development of continuous monitoring standards in Canada will ensure that we safely meet our climate change objectives.

THE BENEFITS TO CANADA OF CARBON CAPTURE AND STORAGE

There are many reasons why Canada and Alberta should pursue a path that encourages CCS and the benefits are widespread. Some of the direct benefits include:

- Environmental Leadership – CCS can achieve significant CO_2 emission reductions in the near term of more than 20 Mt/year. These are real and permanent reductions that could not otherwise be achieved.
- Technology Development – Through the world-scale implementation of CCS Canada can become a world leader on the implementation of CCS technology, something that will be internationally transferable.
- Domestic Investment – CCS can be a major made-in-Canada climate change initiative. With CCS the investment is made in Canada, the infrastructure is built in Canada and the reductions are achieved in Canada.
- Economic and Fiscal Benefits - The inducement of EOR activity will bring about jobs and increased wealth. Monies from this activity will also transfer to governments through taxes and royalties.
- Energy Diversity – The establishment of a functioning CCS network can help support the case for coke and coal gasification. This technology development will supplant valuable natural gas as a fuel source and provide a syngas building block for petrochemical development.
- Coal-Based Electricity Risk Mitigation – CCS allows management of CO_2 compliance risk and cost at existing and future coal power plants

6 Intergovernmental Panel on Climate Change -IPCC

'Carbon Dioxide Capture and Storage' (Summary for Policy Makers) P13

The Strategic Importance of CCS for Oilsands Production

The importance of proactively addressing the environmental challenges of Canada's oil sands can not be underestimated. In 2002, world authorities acknowledged Alberta's economically and technically accessible oil sands reserves were at least 174 billion barrels — a conservative estimate that nevertheless gave Canada the world's second largest oil reserve.[7] The oil sands are and will remain one of Canada's principal economic engines of growth. It is estimated that the oil sands can generate some $885 billion in GDP activity in the 20-year period to 2020. Of this amount, roughly $150 billion will be spent on supplies and services from other Canadian provinces.[8]

Canada, however, is not an energy and environmental island unto itself. It is part of an integrated North American market and there are significant initiatives underway in the United States to address not only their energy security issues but also climate change issues.

Climate change initiatives underway in California, in many other states, and in bills proposed by Congress, have the potential to put a strong environmental spotlight on Canada's production of energy in Alberta. A low carbon fuel standard, has been proposed by California and is now being considered by 13 additional States as well as some Canadian provinces. It would impose a requirement for end users of energy to trace the "lifecycle" carbon intensity of their fuel sources back up the value chain to their original production and meet quotas for CO_2 content or face constraints and penalties. The relative carbon intensity of Canada's major energy production facilities needs to be managed, and CCS offers one significant approach to reducing emissions and emissions intensity.

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.

Because of the large potential volumes that can be captured at large industrial facilities, CCS can be achieved at a significantly lower per-tonne cost than any similar attempts to capture CO_2 from primary combustion sources such as automobiles and furnaces.

The Canadian National Round Table on Energy and the Environment has noted that:

> "Canada's growing role as a major energy exporter is compatible with deep GHG emission cuts; but only if carbon capture and sequestration (CCS) is perfected. Resource extraction in the 21st century needs to take into account GHG reduction and adaptation to a carbon-constrained world economy – this benefits Canada both environmentally and competitively as a leading provider of world energy. As with the oil and gas sector, clean coal technology involving CCS plays an important role."[9]

In addition to benefiting the environment, CCS will generate increased economic opportunities, including the creation of a market through which companies could purchase captured CO_2 for enhanced oil recovery (EOR). This would provide additional volumes of oil produced, increased revenue for the production companies, and increased royalties for government to help offset the costs of carbon capture, transportation, and storage.

7 CAPP
8 CERI
9 NRTEE

Strategic importance of CCS for coal fired electricity

Canadian low cost coal resources are significant, particularly in Western Canada. This supply resource whose availability can be measured in terms of centuries has no alternative market other than fuelling electricity generation. The challenge is to maximize the benefit of this resource while reducing and minimizing emissions of concern including CO_2.

CCS is essential if current and future advancements in carbon capture at coal fired facilities are to be realized. Capturing, transporting and storing CO_2 from coal fired facilities will:

- Maintain and expand the development of low cost coal as a resource with sustainable economic benefit to the mining and electricity industry.
- Allow coal to remain as a fuel option for electricity generation. As a nation Canada should have a broad portfolio of energy / fuel options for electricity production, providing economic stability.
- Encourage coal and other carbon fuels such as petcoke to be gasified, a process that will provide electricity, heat and other chemically derived products. Gasification of these heavier fuels will also provide a substitute for natural gas.
- Provide Canada with an opportunity to lead and advance coal to gas and coal to liquid processes both domestically and internationally.

Canada can and should be a world leader on carbon capture and storage.

THE ECONOMICS OF CARBON CAPTURE AND STORAGE

Key Implications

With the detailed studies of capture, transportation and storage the ICO_2N group has undertaken an integrated analysis of what an entire CCS system could look like. There are four important implications coming out of this work that affect policy decisions:

1. CCS can contribute significant CO_2 reduction volumes
2. The timing to set the stage for investment in CCS is now
3. Direct geological storage is critical to achieving significant emissions reductions
4. CCS capture costs are significant and present an economic challenge

1. CCS can contribute significant CO_2 reduction volumes

The potential for CCS in Canada is very large. It holds potential for both the power generation sector (coal) and Alberta's significant industrial base. the federal government stated that

> "The regulation of greenhouse gas emissions from major industrial sectors is expected to reduce emissions by 60 megatonnes from 2006 levels by 2020"[10]

Industry alone could achieve in the range of 15-25 Mt of annual reductions through CCS by 2020 and the addition of each clean coal plant would further provide reductions of 3-5 Mt/yr. CCS can represent a significant portion of Canada's industrial emission reduction targets.

10 Government of Canada - Regulatory framework for Air Emissions, 2007

ICO$_2$N'S INTEGRATED ECONOMIC MODEL

The basis of ICO2N's economic analysis is an integrated model that demonstrates the interplay between the various elements of an overall CCS system: capture, EOR, storage and pipeline.

The model is a very macro level look at how a system would function and tells the economic story of volumes, timing and costs. It has also clearly shown how capture and EOR balance and the need for direct storage.

The model is robust and many scenarios have been run. For instance the model is sensitive enough to change the structure of the pipeline if the volume of CO2 changes. Some of the scenarios that the model can run are:

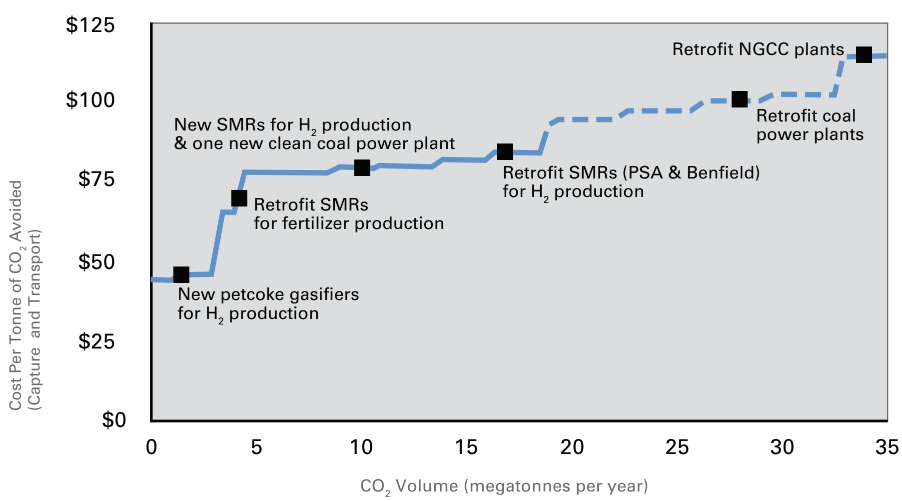
- Inclusion of different types of capture facilities
- Different EOR purchase prices for CO2
- Inclusion of a offset value (avoided costs) for capture companies
- Various pipeline operations structures

Chart 2 below demonstrates the projected capture supply curve for 2015. All costs are based on best available engineering studies and are of +50% / -30% accuracy. This chart represents the volumes that are available at various delivery costs from industrial sources. The delivery cost is a total cost calculation that includes capture, purification, compression and transportation. Storage costs are estimated at a few dollars per tonne and are not included in this cost stack as they will not apply in the case of CO_2 used for EOR. In all cases transportation is assumed to be a nominal $15/t. Actual transportation costs will vary depending on the exact location of capture and storage locations.

CHART 2

CO_2 Supply Potential 2012 to 2015

cost includes capture and transport



What is evident in this chart is that there are several key cost thresholds at which significant volumes of CO_s may become available.

- The first threshold occurs at roughly $45/tonne (~$30/t for capture plus $15/t for transport) where volumes are low in early years as these reductions are mostly associated with future, yet to be committed, gasification facilities primarily used to manufacture hydrogen for upgraders (coal gasification for electricity generation is at a higher cost). These facilities are forecast to come into service in 2012 and later. The economics and likelihood of construction of these plants is based on a number of factors including natural gas price and successful large scale application of this technology with Alberta heavy fuels. However, if companies do decide to pursue gasification plants for hydrogen production they could hold significant capture potential. As this portion of the supply curve represents capture at potential future projects, it does not address any existing industrial emissions.

- The second threshold occurs at approximately \$65/t (~\$50/t for capture plus \$15/t for transport) and represents capture available from existing chemical and fertilizer facilities. This volume could be available within the next 5 years.
- The third threshold commences near \$80/tonne (~\$65/t for capture plus \$15/t for transport) and the rapid increase in volume is due to significant volumes becoming available along a very narrow price band. These volumes represent existing and new facilities using new capture technologies at upgrader related hydrogen production facilities. One new clean coal plant is also included. Much of this volume could begin to be captured as soon as 2011/2012 if a decision to capture is made in 2008.
- The fourth threshold involves potential retrofitting of some of the existing coal fired power generating units in Alberta. This threshold is estimated to occur at a cost in excess of \$95/tonne
- The final threshold portrayed above involves capture at a Natural Gas Combined Cycle facility (NGCC). Costs for this technology are estimated to be in the order of \$120/t (~\$105 for capture and \$15/t for transport).

Emission reductions potential from new clean coal is limited to one plant in the above chart as that is all that is anticipated to occur by 2015. ICO$_2$N has undertaken economic analysis in partnership with the Canadian Clean Power Coalition and the anticipated capture cost threshold for a new clean coal plant is in the range of \$65-\$80/t (plus transportation costs). Future clean coal plants have the potential to provide significant volumes.

The implication of these large volume step changes is that Canada should develop a long-term CCS plan that addresses the industrial emissions that are available in the larger threshold near \$80/t. It is at this threshold that significant industrial emissions reductions can occur and help achieve strategic environmental objectives.

2. The timing to set the stage for investment in CCS is now

Industry in Western Canada, particularly the oil sands sector, is currently in a period of significant expansion which provides an opportunity to include construction of CCS infrastructure as new facilities are built. Furthermore, existing industrial plants could be retrofitted for CCS. In both cases, tangible reductions can be achieved within about four years from a go-ahead decision. Currently this would mean that initial reductions could be seen in the 2011-2012 timeframe with additional reductions occurring in subsequent years as plants are constructed. For new plants to incorporate CCS now is the time for the right policy to be established.

As noted above the power generation industry holds significant potential and reductions could be realized in about an eight-year time horizon. This time horizon is longer as reductions through clean coal investments are expected to involve the construction of new plants that aren't currently scheduled. If capture is pursued at existing coal-fired electrical plants reductions could occur earlier, but the costs are expected to be above \$80/t.

3. Direct geologic storage of CO_2 is critical to achieving significant emission reductions

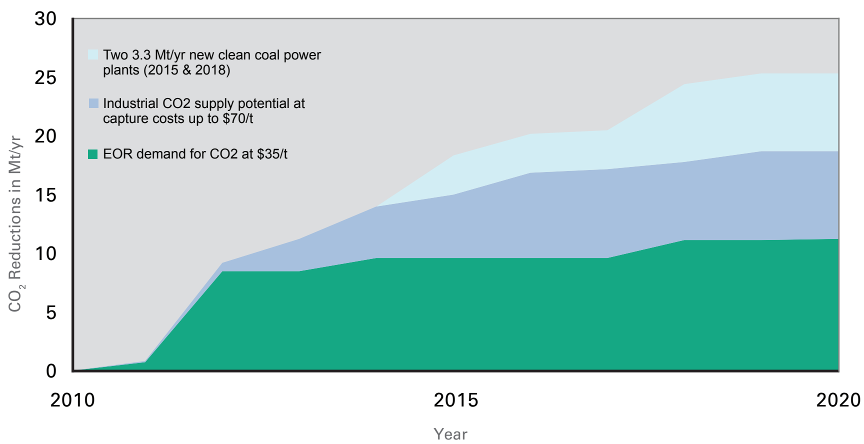
In a carbon constrained world where reduction obligations encourage significant CCS, over time significant volumes of CO_2 will have to go to direct storage, without any associated EOR revenues.

The EOR market, while it can provide an enormous boost to getting CCS deployment started, is not the answer on its own as it does not have the capacity to take all of the CO_2 that may ultimately be captured. The only substantial option to reduce CO_2 emissions into the atmosphere will be to send it directly to permanent storage reservoirs.

For demonstration purposes, if all CCS that was available at a reasonable cost ($70/t or less) came on stream as early as possible, the volume stream would look something like Chart 3. This includes a quick ramp up in the early years that would result from the retrofitting of existing plants (but not coal fired power generating systems) and then a gradual build-up to 2020 as CCS is incorporated in new industrial plants and clean coal electrical generation facilities.

Chart 3

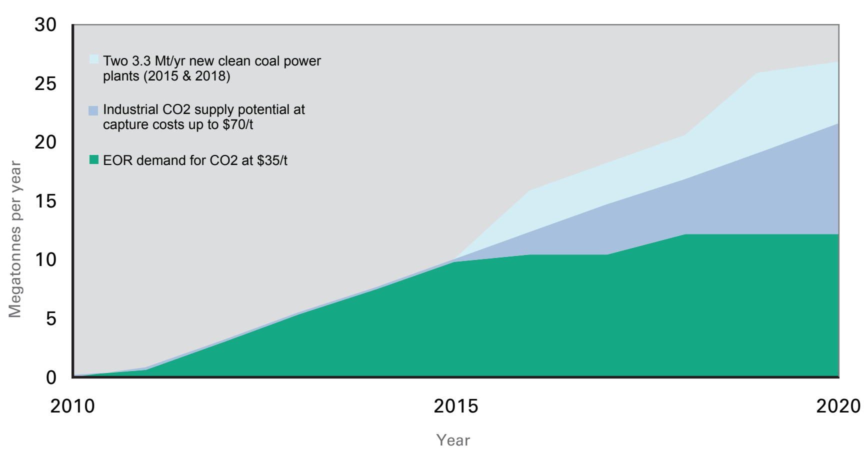
CO_2 Supply & Demand in Alberta: Accelerated Deployment



The ultimate ramp up of CCS will be phased. This would look more like what is illustrated in Chart 4. In this case, CCS is phased in over the next 15 years. Both cases illustrate the need for direct storage capabilities to produce significant CO_2 reductions and the importance of managing oversupply.

Chart 4

Conceptual Phasing of CCS



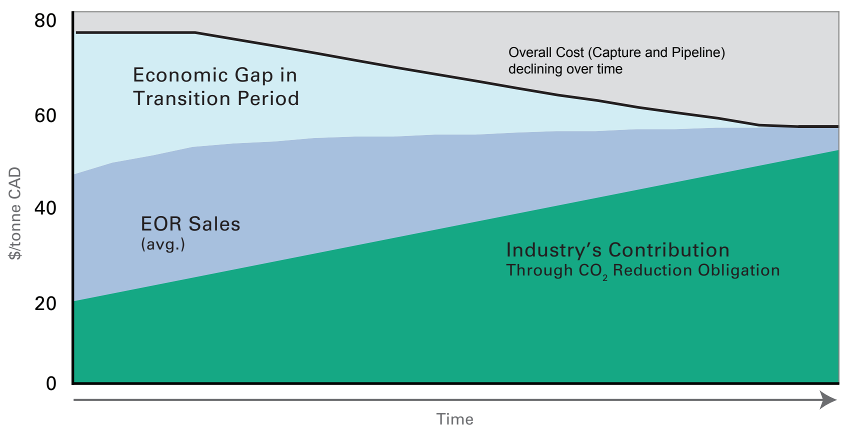
4. CCS capture costs are significant and present an economic challenge

There is an economic and risk gap that must be overcome before investment can occur. Even taking into account the benefit of CO_2 reductions as an internal cost saving for companies (CCS is a path for companies to meet CO_2 compliance obligations and thus avoid other costs such as investing in the presently proposed technology fund), in the early years there is an economic gap that does not justify investment in capture. As stated earlier, 70-80% of the cost of CCS lies in the capture costs.

The conceptual Chart 5 below demonstrates economic challenge related to CO_2 capture. The gap is highest in the initial years, but then declines over time.

CHART 5

Conceptual Portrayal of CCS Economics



This graph clearly shows the initial benefit of EOR to help kick-start CCS in Canada, but also how government incentives are likely required in the early days to encourage uptake. Project economics are then expected to improve as capture costs decline, compliance costs increase and the EOR market remains strong. With a 4-5 year investment and construction timeframes it is important to encourage investment in these early years in order to accelerate CCS deployment and gain momentum for future growth.

The Economics of CO_2 Oversupply

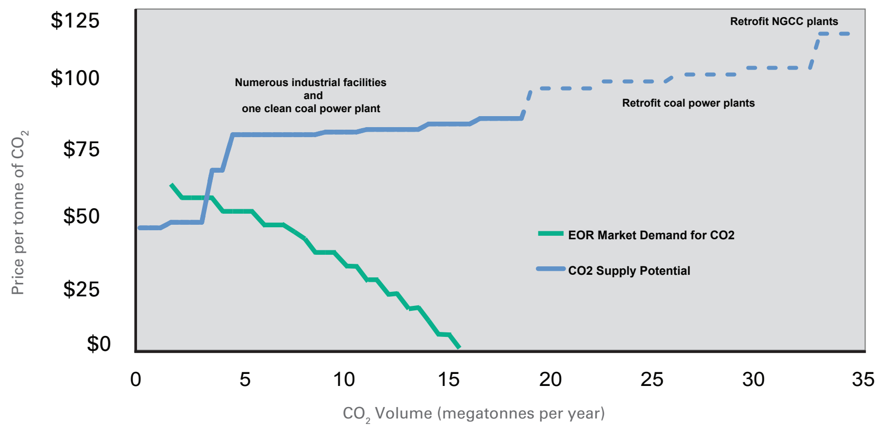
The graph above demonstrates how in a carbon constrained world that encourages CCS, there is an increasing financial gap as potential EOR storage facilities are saturated and EOR revenue falls. The potential of an oversupplied market has several consequences that may in fact serve to further discourage capture. Firstly, CO_2 volumes that don't have an EOR market miss out on the EOR revenue stream which will serve to compensate investments in capture. Furthermore, in an open market situation an oversupplied market will drive down the price that EOR companies are willing to pay. If a capture company's only alternative is to pay for direct storage it is feasible that the price to the EOR market could decline to close to zero.

As the revenue stream from EOR helps to compensate the costs of capture in the early years of a CCS system, erosion, or even the potential of erosion, of the EOR market price will dissuade companies from investing. This market dynamic could delay and ultimately limit growth of CCS: an outcome inconsistent with the goals of achieving large-scale reductions in CO_2 emissions and of realizing EOR market development.

Chart 6

CO$_2$ Supply & EOR Demand Potential 2012 - 2015

(Supply cost includes capture and transport)



Taking another analytical approach to exploring the market dynamics we have attempted to chart how potential supply and demand curves would look when plotted against each other. This can be seen in Chart 6. In this case the demand curve represents EOR market demand for CO_2.

The relationship between CO_2 supply, demand and pricing is important. The potential amount of CO_2 that can be captured greatly exceeds the potential EOR market. As the price (effective cost of abatement) paid for CO_2 rises, CO_2 supply increases but EOR demand decreases. As EOR demand decreases, more CO_2 must be stored in non-EOR (direct) storage facilities.

An open market that is left to balance CO_2 supply solely with EOR demand produces a market equilibrium between supply and demand with very low prices for CO_2 and, as a result, low volumes of CO_2 sequestered.

Summary

ICO$_2$N's key conclusions from the economic analysis can be summarized as follows:

- Large volume reductions of CO_2 are feasible in the near term (starting from 2011/2012).
- The economic gap to produce significant capture volumes (the $70/tonne threshold price on the CO_2 supply curve) must be addressed.
- There is a need for government and industry to work together to share risks and rewards to enable deployment of CCS.
- There is a need for policy mechanisms to manage the risks associated with CO_2 oversupply.

REGULATORY AND COMMUNICATIONS WORK REQUIRED

In addition to balancing the economics of large-scale CCS deployment there are several regulatory items that require attention before any CCS operations can proceed. These include:

- Defining CCS regulations on such items as the ownership of underground pore space and the issue of long-term liability for storage. Work has been done internationally on these issues and Canada should be able to draw from this expertise. However it will take leadership from the province to develop the work plan and establish viable CCS regulation.

- Both the national and provincial climate change policy and regulations must be implemented in a harmonized manner that encourages the large capital investments and extended construction timelines of CCS.
- All interested parties have a vested interest in ensuring that the public is adequately informed and educated on CCS. Both local and national stakeholders need to be engaged to ensure that the deployment process is smooth and timely. Safety is a key concern and must be addressed in a Canadian context.

A ROLE FOR KEY STAKEHOLDERS

It is clear that ICO_2N members and the energy sector in general in Western Canada want to continue take significant steps towards sustainable energy production. Industry is willing to spend billions to capture and sequester CO_2. The work that ICO_2N has undertaken over the past two years illustrates the commitment of some of the largest energy companies in Canada to solving the technical and cost challenges of CCS.

Industry investment alone will not produce a robust, sustainable CCS system in the Western Canadian Sedimentary Basin.

The Alberta government is very committed to developing comprehensive climate change plans and understands the importance of CCS to continued development of the oil sands and future coal based power generation. Alberta has a long tradition of innovation and with the right public policies in place; industry will respond and take action on CCS.

The federal government has indicated there is a need to strongly support CCS in an expeditious manner. The ecoEnergy Canada-Alberta CSS Task Force in partnership with the government of Alberta has a mandate to provide recommendations by the end of 2007 on how to accelerate CCS in Canada.

The supply/demand interactions point to the type of support mechanisms needed to grow a robust CCS system that will provide a significant contribution to reducing CO_2 emissions in Canada:

- CCS clearly requires mechanisms to "close the gap" and reduce investment risk. Without appropriate fiscal and regulatory policies to support the initial capital investments needed for capture, pipeline, and storage facilities, the deployment of CCS will be delayed indefinitely. Industry and government need to work together in the early years to encourage uptake of CCS. As noted earlier, the capture costs alone are 70 to 80 percent of the total CCS costs and represent billions of dollars in investment.
- A guaranteed price floor for CO_2 will be needed to maintain the continued development of CO_2 supply given the extensive need for direct storage once the EOR market is satisfied.
- There is a clear need for industry, the government of Alberta, and the federal government to work very closely together in growing this extremely important, environmentally transformative opportunity for Canada.

Alberta and Canada have a history of working together on importance public policy development in support of economic development. Examples include:

- The development of the Alberta Gas Trunk Line and the TransCanada Pipeline in 1954;
- The initial funding and development of Syncrude in 1978;
- The Canadian Pacific Railway in 1881.

All of these major projects were not without controversy and, yet, significantly transformed Canada's economic potential. And all of these projects ended up being managed by the private sector once the initial impetus from government was no longer necessary. In all cases though, it was the vision and leadership of industry and governments that realized and took action to move Canada to a higher level of economic growth.

THE PATH FORWARD

Society will need hydrocarbon energy sources for many years to come. Canadians are also increasingly concerned and demanding action on climate change and sustainable development. CCS provides industry, Alberta, and Canada the opportunity to demonstrate to Canadians and the international world that we can be an energy and environmental superpower that has collaboratively applied its innovative technological and public policy skills to address the critical needs.

> "Instead of pumping tons of carbon dioxide into the earth's atmosphere, we may be able to collect it from our oil sands operations, our coal-fired electrical plants, and other industrial emitters, and pump it deep underground where it will remain for eternity," said Prime Minister Harper. "This is a promising technology that could leverage Canada's expertise and Canada's geography."[11]

> "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."[12]

The ICO$_2$N group of companies is committed to helping Canada reach its energy and environmental goals. Collectively, the ICO$_2$N group of companies represents billions of dollars in assets and sells billions of energy products in Canada and internationally annually. ICO$_2$N's vision is:

> "To realize Canada's largest single greenhouse gas mitigation opportunity. ICO$_2$N will be a framework for an efficient, environmentally sensitive system of CO_2 capture, transport and long-term storage. It will also explore opportunities for using captured CO_2 to enhance hydrocarbon recovery."

An integrated CO_2 network can be built in stages, but moving forward with large-scale deployment requires development of a long-term strategic plan to provide an atmosphere of policy and regulatory certainty. To get there industry and government must work together to address long-term policy, risk-sharing and regulatory issues. Furthermore, *policy innovation* will be essential to encourage the large investment necessary in the near term. CCS can become a reality and now is the time to act.

11 Prime Minister Stephen Harper
12 Alberta Premier Ed Stelmach

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