Carbon Capture and Storage (CCS)
Risk Management Workshop

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67 Erb St West, Waterloo

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Executive Summary

Carbon capture and storage (CCS) technologies have been applied since the early 1970s, but the formal risk assessment and management frameworks for these are still in preliminary stages of formulation, review and approval by regulatory agencies. The objective of the CMC funded project, “Risk Assessment and Management of Carbon Capture and Storage in a Canadian Context” is to define an appropriate framework for risk assessment and management (RA/RM) of CCS for Canada, in light of similar initiatives internationally as well as Canadian experience in other areas of environmental risk management.

The first day of the workshop was focused on team members\(^1\) presenting and discussing progress of their project modules. The other specific objective of day one discussions was to address the integration of findings from each of these modules into the integrated risk management framework (IRMF).

The intent of the second day discussions was to liaise with the stakeholders and solicit their feedback for developing a credible prototype for the risk assessment of CCS in Canada, representing the RA phase of the IRMF. Presentations were also made by the representative stakeholders describing the work done by their organization/department in the area of CCS.

The workshop was well-received with positive engagement between the academia and stakeholders over the course of two days. There were thirty-one participants in all consisting of eleven stakeholders including Dr. Steve Larter from Carbon Management Canada (CMC). Other stakeholder representation included Alberta Innovates-Technology Futures (AITF), Alberta Department of Energy (ADE), Canadian Council of Academies, CCS Nova Scotia, Centre for Excellence in Mining Innovation (CEMI), Global Carbon Capture Storage Institute (GCCSI), International Performance Assessment Centre for Geologic Storage of Carbon Dioxide (IPAC-CO\(_2\)), Ontario Ministry of Natural Resources (OMNR), and Pembina Institute. Stakeholders from industry, Natural Resources Canada, and Alberta Energy Resources Conservation Board were also invited but were unable to attend.

\(^1\)Principal Investigators and their team are listed in Appendix A.
Day 1: October 4th, 2012

1. Overview of Integrated Risk Management Framework for CCS in the Canadian Context

- William Leiss, McLaughlin Centre for Population Health Risk Assessment, University of Ottawa.

Bill Leiss, along with the other project team members - Patricia Larkin, Maurice Dusseault, Robert Gracie, Mamadou Fall, Zhenze Li, and Joe Arvai briefly presented the work done under their respective project sub-modules and the upcoming deliverables. Later on, the team’s highly qualified personnel (HQPs) further elaborated upon their individual project sub-module findings.

Bill Leiss emphasized the importance of a risk management framework and how it should facilitate and promote important values in risk management by making explicit the steps in the process, identifying all the essential decision inputs, engaging stakeholders, and in general, promoting transparency in decision-making for issues of broad public interest and concern.

The IRMF being developed for CCS is called an “integrated” framework on account of its inclusion of the international and national bodies; key stakeholders and/or interested parties; as well as the consultation and communication activities that are supposed to coordinate the interactions among regulator and stakeholders in the decision-making (DM) process. The use of the framework will have a wide public credibility if it provides a convenient public record of interactions between regulators, cooperating agencies, and stakeholders. One good example is the comprehensive risk assessment for the “FutureGen” CCS project by the United States - the 400 pages long document is publically available.

Patricia Larkin talked about the work done in last 10 years in the Global and Canadian regulatory environment focusing on risk assessment and management (RA and RM). There are
some 27 documents published so far by regulatory and non-regulatory sources focusing on carbon capture, transport, injection and storage. The majority of regulatory documents come from European Union (EU) entities. Less than 1/3rd of these documents mention mandatory requirements for RA/RM. The primary focus is on injection and storage with many documents addressing storage site selection and characterization. Even though most included a four step RA process, namely Hazard Characterization, Exposure Assessment, Effects Assessment, Risk Characterization, descriptions of these steps was not consistent. Although repeatedly noted as a critical component of CCS development, uncertainty, stakeholder communication and consultation, and transparency were discussed only sporadically in the regulatory context.

The material discussed by the other HQPs is provided in greater detail in Sections 2-6.

In the end Bill discussed the integration of all the sub-projects into the RA phase of IRMF (steps 1-5):

• Step 1 (Issue Awareness):
  – Leiss: “Major Challenges” chapter in April 2012 report. He requested feedback from the Co-PIs
  – Larkin: Issue awareness around the world
  – Canadian objectives in light of projects around the world (MIT website)

• Step 2 (Policy and Governance Context):
  – Larkin: CCS regulatory oversight worldwide
  – Larkin: CCS RA/RM frameworks worldwide
  – Fall: Nuclear waste storage experience
  – Integrate N. Bankes work with ours

• Step 3 (Risk Dimensions Analysis) – Need discussion among the PIs
– Fall: Water contamination risks in CO₂ disposal
– Dusseault: Hazards taxonomy April 2012 report

• Step 4 (Risk Estimation): Need discussion among the PIs
  – Dusseault group work
  – Gracie group work

• Step 5 (Risk Control Options): Step 5 is the transition to the Risk Management phase
  – Relevance of Arvai work, in terms of risk perception and public confidence, but not yet developed
  – Can be based on aspects of the Fall/Dusseault/Gracie results: Based on the risk analysis, what risk control options exist for risk mitigation, if mitigation (lower risk) is required in some important dimensions, e.g., leakage to air or groundwater?

Bill emphasized to the group to pay attention to linking the approach and results to the steps in the IRMF. As for the work done by the Arvai group, this work on risk perception and public confidence can be very well applied to Step 5 using inputs on risk mitigation from Dusseault group.

Please refer to Appendix B for Leiss presentation.

2. Connecting Carbon Sequestration Monitoring and Risk Analysis - A Bayesian Framework

- Araz (Mirhamed) Sarkarfarshi, PhD Candidate, Department of Civil and Environmental Engineering, University of Waterloo.

Supervisors: Dr. Gracie and Dr. Pandey

Araz mentioned CCS as one of the most attractive options for addressing the most
pressing issue of 21st century, global warming as it can be carried out with very low disruption to current energy production methods and relevant infrastructure. But CCS can also pose huge risk by leakage (impacting the atmosphere, drinking water, and so on), by inducing seismic activities, by fracturing overlaying geological layers, and by damaging the infrastructure and the reservoir due to pressure buildup. The various sources of uncertainties impacting robust risk assessment are: formation characterizations such as reservoir heterogeneity; leakage pathway characterizations (permeability of the well plug, size and location of cap-rock cracks); consequences of unwanted incidents such as leakage; complexity of mathematical models.

A novel Bayesian framework is being developed, which iteratively conditions model predictions using up-to-date site data from monitoring, results in a detailed and periodically revised system behaviour forecast. Risk assessment is revised after each calibration cycle utilizing up-to-date system behaviour forecast. The framework has been tested for a hypothetical problem where the site specifications were chosen mostly to model the Nisku aquifer properties in Alberta.

Please refer to Appendix C for Sarkarfarshi presentation.

### 3. Injection Strategies to Maximize Carbon Dioxide Dissolution in Deep Aquifers

- Farshad Arfiei Malekzadeh, PhD Candidate, Department of Earth and Environmental Science, University of Waterloo.

Supervisors: Dr. Dusseault and Dr. Gracie

Farshad talked about strategies to maximize CO₂ dissolution in deep aquifers. A semi-analytical solution based on pseudo analytical functions is obtained for simulation of saturation distribution in primary gravity drainage for a tabular porous media. This semi-analytical solution is capable of capturing arbitrary capillary pressure-saturation correlation. This provides a powerful tool to simulate saturation distribution for different J-Leverett functions. A similar
solution for a more general problem is provided that incorporates the nonlinearity of relative permeability functions. These tools are necessary for correct and physical analysis of sensitivity of saturation distribution with respect to physical and model characteristics.

A detailed sensitivity analysis has been done using the semi analytical tool for sensitivity analysis of the position of the tip of plume with respect different physical and model parameters. Based on the provided information from sensitivity analysis, all of the model and physical parameters are ranked based on their influence of the progression of the tip of the plume. This information has significant value for choosing of the site, monitoring and risk analysis of the injection process.

Dissolution of CO₂ in the saline aquifer is very important, and its correct simulation is challenging. Most of the simulators are based on thermodynamic equilibrium assumption, and that implies complete equilibrium in a two phase system. If one wants to use that approach, meshing should be done carefully otherwise the dissolution of gas into water is overestimated. Additionally, phase partitioning is the result of a nonlinear algebraic equation and the easiest solution strategy is iterative Newton-Raphson method. That also makes the calculation very time consuming. An alternative approach is proposed, namely a kinetic approach of mass conservation instead of equilibrium based partitioning and one way coupling of saturation and concentration. In other words, saturation distribution is calculated analytically and mass conservation is calculated numerically based on information from the analytical solution. This provides a reasonably accurate estimation in a relatively short time.

Please refer to Appendix D for Malekzade presentation.
4. Efficient Simulations of Carbon Dioxide Leakage from Abandoned Wells for Risk Analysis

- Chris Ladubec, PhD Candidate, Department of Civil and Environmental Engineering, University of Waterloo.

Supervisors: Dr. Gracie and Dr. Craig

Chris discussed simulations of carbon dioxide leakage from abandoned wells for risk analysis. In his overview he reviewed solution methods for various mathematical model types including: analytical, numerical, finite element method (FEM), and Extended Finite Element Method (XFEM). The current and future work on XFEM-CS simulator was discussed in more detail.

Deep Saline Aquifers are considered as potential sites for CO₂ injection as they possess an impermeable layer that is initially filled with brine. A number of potential sites for deep saline aquifer storage of CO₂ are known (See: http://legalectric.org/f/2006/09/sequestration-potential-co2reservoirs.jpg).

Leakage can occur through abandoned wells (Gasda et al., 2004) through many ways, such as leakage through abandoned wells between well casing and cement fill; between well casing and well plug; through well plug; through cement fill and between cement fill and ground.

For risk analysis various factors need to be considered including the uncertainty surrounding the leakage characteristics of wells, the locations of abandoned wells, the number of abandoned wells and other system properties. Knowing the variables in probabilistic analysis and running simulations thousands of times with different sets of parameters each time requires computationally efficient models.

Chris provided a brief overview of the mathematical modelling process and the ability to obtain analytical solutions, numerical solutions, semi-analytical solutions, and hybrid solutions.
Numerical Solutions (Computer Simulations) appear better suited to dealing with more complex problems but are less computationally efficient for studying leakage than analytical solutions.

The Finite Element Method (FEM) is a numerical model that can deal with very complex problems. The problem is broken down into “blocks” and equations for the blocks are assembled. The system of equations is simultaneously solved to obtain an approximate solution to the problem. The greater the numbers of blocks (problem complexity) results in the lower the computational efficiency. The drawbacks of FEM when applied to deep aquifers include: the scale difference between aquifer and wells results in a very large number of blocks; the requirement for many small blocks needed around wells to obtain an accurate solution; the model’s inefficiency for calculating accurate leakage solutions. A second numerical model type can be used, the Extended Finite Element Method (XFEM). This model has advantages over FEM since accurate solutions do not require a large number of “blocks” near wells and the model can enrich the FEM approximation at well locations. XFEM is estimated to be about 10,000 times more efficient for computational cost.

Ongoing work will include extending the single phase flow version XFEM-CS simulator to include multiphase flow and gravity effects which is a difficult undertaking as the multiphase version implementation is more difficult. Other work will concentrate on incorporation of simulator with risk analysis tool.

Please refer to Appendix E for Ladubec presentation.
5. *A Review of Georisks of Carbon Capture and Storage*

- James Petrosky, Masters Candidate, Department of Earth and Environmental Science, University of Waterloo.

Advisors: Dr. Gracie and Dr. Dusseault

James gave an overview of georisks discussing his contribution and offered some conclusions regarding georisks. Risk analysis involves quantifying the engineering risk variables. Thus the project goal for bounding the potential georisks include: 1) expanding the hazard taxonomy to be as detailed as possible, 2) quantifying the risk posed by each item in the taxonomy (probability and consequences), and 3) based on literature, catalogue the ways in which the risk can be measured and monitored in the field.

Georisk is a geological risk that according to the hazard taxonomy has two hazard forms, inherent georisks, which are intrinsic properties of the rock and secondly, the induced georisks, which are caused by the activities related to the carbon injection process itself.

Geological materials are heterogeneous at all scales. Therefore, inherent georisks include cap rock which may contain fractures missed during drilling/coring or faults that may breach the cap rock. Either of these can result in insufficient dissolution of carbon dioxide as groundwater-SCO\textsubscript{2}. Other examples are insufficient volume, permeability and other geologic properties that affect economic injection. Inherent georisks also include any measurement based on damaged rock near a well which may not be characteristic of the rock mass under consideration. Proper site selection can help mitigate these inherent risk types.

Induced georisk include reactions with cap rock that lead to loss in volume or changes in stress. The dissolution of minerals can also lead to increased permeability, decreased cap rock integrity or fracture growth. Other induced georisks may include loss of the capillary seal, and possible oil - SC-CO\textsubscript{2} interaction which can act to solubilize and transport contaminants. Pore
blockage can occur by heavy oils or bitumen. Induced georisks interactions can be complex, sensitive to pressure, temperature, fluid pressure and pH.

James concluded by underscoring the complexity and diversity of inter-related CCS georisks. Properly addressing georisk requires an integrated understanding of how the components interact. The ability to accurately catalogue and quantify both types of georisks is feasible and essential for the success of the CCS project.

Please refer to Appendix F for Petrosky presentation.

6. **Risk Assessment of CCS: Lessons learned from Experience in Nuclear Power and Groundwater Contamination by CO₂**

6.1 **Risk Assessment of CCS: Lessons Learned from Experience in Nuclear Power**

- Dr. Mamadou Fall, Department of Civil Engineering, University of Ottawa.

The lessons learned from the deep geological disposal of nuclear wastes (DGD) are being applied to CCS because of technical, social, and political similarities between the two activities. Mamadou Fall stressed that leakage and the resulting consequences on the biosphere are the main safety issues in both disposal techniques. The successful disposal site selection procedures for nuclear waste are a valuable source of information and are being reviewed as they pertain to CO₂ disposal.

Among the various lessons learned from DGD are 1) Features Events Processes (FEPs) Methodology; 2) Uncertainties and their Treatment; 3) Stakeholder Involvement; 4) Use of Natural Analogues; and 5) International Collaboration. Some of these are discussed below.

The Features Events Processes (FEPs) Methodology has been developed for identifying and ranking the importance of various attributes of the site, containment approach, and human
behaviour that may affect repository system performance. The Nuclear Energy Agency (NEA) has a comprehensive FEP list that contains 2000 FEPs from 10 International programs in six countries. Similarly, development of FEP database for underground storage of CO₂ is warranted.

Uncertainties occur in three major areas: parameter and data uncertainties are the measurement errors (limited data, data misinterpretation, spatial variation of parameters and scaling issues); Scenarios (completeness of scenarios, probability of occurrence of a scenario, estimation of the consequences); and Modelling (Conceptual model uncertainty for a given scenario, mathematical model uncertainties, computer codes uncertainties). The effect of uncertainties propagates throughout the risk assessment phase. The parameter uncertainties can be dealt with Statistical methods (experimental design procedure and Monte Carlo simulation), Stochastic models, Interpolation techniques (kriging), and Differential analysis techniques.

Stakeholder engagement has always been considered a focal point in public acceptance of issues such as these. Internationally, Nuclear Waste disposal programs as well as at least one CCS project have been abandoned partly because of ineffective communication with stakeholders.

And, finally the use of natural analogues for CO₂ need to be explored. CO₂ is naturally trapped in many rock formations around the world. These formations will be useful for understanding and validating the safety of disposal of CO₂.

Please refer to Appendix G for Fall presentation.

6.2 Groundwater Contamination by CO₂

- Dr. Zhenze Li, Postdoctoral Fellow, Department of Civil Engineering, University of Ottawa.

Supervisor: Dr. Fall

The second part of the presentation was given by Zhenze Li focussing on contamination
risks of underground drinking water (UDW). Potential consequences of CO₂ leakage on groundwater chemistry such as decreased pH, weathering leading to increased alkalinity, release of toxic metals such as Arsenic (As), lead (Pb), Nickel (Ni), and Chromium (Cr), release of organic contaminants, and the movement of saline water into fresh water were discussed. The group is developing a coupled thermo-hydro-mechanical-geochemical (THMC) modelling tool to assess the impact of CO₂ leakage on UDW quality. Validation of this simulator will be tested against laboratory data and will be applied to a Canadian CO₂ disposal site. The group is also busy in the identification of methods to control and remediate contaminated UDW.

Please refer to Appendix G for Li presentation.

7. Shale Gas in North America: Effects on Canada and CO₂ Policies

- Maurice Dusseault, Department of Earth and Environmental Sciences, University of Waterloo.

As an important consideration in the overall energy context, Maurice talked about the proliferation of Shale Gas development as a very germane issue at the present time in North America. Today, 78% of primary energy comes from fossil fuels – coal, natural gas and oil – and consumption of all forms of fuels - liquids, coal, natural gas, and renewables - are predicted to rise with roughly similar slopes over the next twenty-five years. China surpassed the US several years ago in terms of gross energy consumption and the rate of rise is tremendous. The rate of rise is slower for India but nevertheless the rate of rise is greater than that predicted for the US. The US will see a rise in natural gas consumption of at least 15% from now to 2035 while seeing a 10-15% population increase.

In 2010, North America (mainly the US and Canada) produced about one quarter of the world’s natural gas production. The US is the largest producer, Russia is 2nd and Canada is at 3rd
place. Natural gas production from shale gas has risen from 4% in 2005 to 23% in 2011 in the US. And by 2020, this will likely rise to over 40% with China following the same path about 8-10 years later.

About 45% of our natural gas used to be exported to the US in 2007 but these exports have dropped below 30% as America has been successful in developing their own resource. China is at seventh place but with growing investments in shale gas and tight gas will rise to the third place in a matter of 6-7 years, eventually surpassing the US and Russia over the next 25 years.

Natural gas in the USA is used 29% in electrical power generation, the rest in residential, commercial and industrial applications but this will rise. As the CO₂ footprint from natural gas is about half of the CO₂ footprint from coal, natural gas is seen as the bridge between the fossil based society in which we live now and a future society dominated by renewables. It is both cheaper and cleaner to generate electricity from natural gas. The coal industry is currently being affected negatively with Shale gas discoveries.

North America, particularly the US, is very well endowed with unconventional gas resources. Now that we have discovered shale gas we think we have resources for the next 50-100 years – a profound development for the resources industry. The US is importing less gas and using the shale gas technology. Interestingly, the Canadian oil exports to the US have not dropped. Because of shale gas development, an economic downturn, more demanding mileage requirements for automobiles, mandated biofuel use, and several other factors, the US has come closer to meeting its original (unratified) Kyoto requirements than many other countries. The economic power of Russia, Venezuela, and Iran is diminishing. The geopolitical implications because of this shift are huge. This will impact Canada as well – the US may export rather than import natural gas to Canada. In Canada, shale gas production potential is primarily in British
Columbia and Alberta and little bit in Saskatchewan, Quebec, New Brunswick.

There are risks associated with it as well – in 2008, the price of natural gas plummeted and remains below $3.50 today. Drilling has slowed but the gas glut will remain for quite a few years. Canadian natural gas producers are badly hit by the lower prices. Other economic risks to Canada include the underutilization of the Trans Canada pipeline. It is working at 50% capacity and is going to drop further in 10-15 years. In order to exploit shale gas, long horizontal wells are drilled with multiple hydraulic fractures along those wells – a process that is controversial.

Please refer to Appendix H for Dusseault presentation.

8. Decision Support for Energy Transitions

- Joseph Arvai, Institute for Sustainable Energy, Environment & Economy (ISEEE), University of Calgary.

Joe emphasized the importance of a sensible and defensible decision making process for energy planning, one that must consider choices that are significant, expensive, controversial, the subject of public and media scrutiny, and of interest to a diverse array of stakeholders. Having better decision making processes can help to save time, money, and avoid negative public reactions which are all important in the context of energy supply.

Canada has an abundance of fossil fuels and remains poised to play a major role in meeting the energy needs of North America and the world. Because of conflicting perspectives people hold about what matters and risks and benefits, energy decisions will remain controversial.

Multiple stakeholders (government, industry, shareholders, environmental groups, those employed and working in the energy sector, First Nations, and international companies) mean that there are different interests, values, objectives, and concerns for energy decisions.
The goal of decision-focused engagement processes is to provide evidence to policy makers about the risks and benefits of options. Joe reviewed various analytic (e.g. Integrated Assessment, Systems Analysis, Decision Analysis, and Adaptive Management), and deliberative processes (e.g. Risk Communication, Large Group Processes, Focus Groups, and Workshops) that can provide information to decision-makers.

Joe focused on structured decision making, a six step process with elements similar to other well known risk assessment processes (e.g. the Health Canada 2000 decision making framework). The decision making steps include: 1) define the problem, 2) define objectives, 3) develop options, 4) map consequences and uncertainties, 5) provide sound evidence for options not chosen, 6) implement, monitor and adapt to the chosen decision.

A recent transformation of a coal generation plant in Michigan to a wind farm was described as a specific example. The overview of the processes for eliciting objectives and performance measures included considerations of efficiency, cost, employment, land use, emissions, and transparency. The alternatives and consequences explored the efficiency, alternate fuel types, and supporting technologies. Trade-offs and alternatives were ranked by performance measures in relation to the objectives.

Joe concluded that the progress of using structured decision making tools was helpful and will be continued. He emphasized that an organized, structured decision making process is essential to engage stakeholders, and result in better informed choices about energy alternatives. The process must be relatively fast, have the input of energy experts and their expertise, politically neutral, and defensible (logically and morally).

Please refer to Appendix I for Arvai presentation.
Next Steps on Integrated Risk Management Framework

- Team Members

This was a closed session. The project team members discussed their strategy for the day 2 discussions with the stakeholders. The existing slides on IRMF were revised to best suit the needs for discussion on day 2.
Day 2 – October 5th, 2012

The second day of the CCS Risk Management Workshop included participation of external stakeholders in order for the project team to get some feedback on progress to date and solicit advice on potential areas of emphasis and action related to Phase I completions.


- William Leiss, McLaughlin Centre for Population Health Risk Assessment, University of Ottawa.

Bill discussed the progress of the Phase I: Risk Assessment for developing an Integrated Risk Management Framework (IRMF) for Carbon Capture and Storage. At the core of the framework is a ten sequential step flow-chart diagram that is used as a tool for risk management decision-making. It builds upon other recognized frameworks such as the US-NRC “Red Book” flow-charts (NRC, 1983). The framework identifies the key government agencies responsible and as a process should have credibility due to transparency. At critical decision points evidence for the decision should be documented, published, and subjected to independent peer review. All steps in the process are carried out in advance of a final decision.

Such a framework for CCS must integrate international and national bodies, acting independently or cooperatively, as well as other stakeholders and interested parties. Important in the integration is adequate consultation and communication activities which will allow coordination between regulators and stakeholders. A good example of such integration is the Environmental Impact Study for the U.S. “FutureGen” CCS project.

The scientific structure for risk estimation in the CCS project context should include -
1) characterize the CCS repository in quantitative geo-mechanical terms, 2) taxonomy of hazards that will serve as basis for RA and Risk ranking, 3) quantitative tools to evaluate plausible risk scenarios (such as well leakage, anthropogenic paths including well bores and rate of filling of reservoirs), 4) estimate breaching of the geological repository in different ways, 5) evaluate environmental, health, and other consequences of breaching, and 6) consider risk associated with temporary geo-storage such as salt caverns and porous reservoirs.

The project deliverables and the final results from each sub-project team will be disseminated through peer reviewed articles in the disciplinary journals. The team will also be planning a special issue of the International Journal of Risk Assessment and Management (IJRAM), documenting both individual contributions and the integrated risk management framework. The subsequent preparation of an overview paper on risk assessment of CCS, accessible to a general audience is also planned. The final piece in the knowledge dissemination will be a policy uptake workshop with the regulators and the stakeholders. The potential for a tri-partite (US/Canada/Mexico) workshop was discussed, similar to the one occurred for the dissemination of results from the BSE project by PrioNet and the McLaughlin Centre. The workshop proceedings were published in the Environmental Forum. It was noted, however, that Mexico is not a large prospective user of CCS so there is a limited opportunity to have a tripartite policy workshop concerning CCS.

10. Stakeholder Presentations

The stakeholders gave a brief introduction of how their respective organization/departments are engaged in the carbon capture and storage scenario.
10.1  **Tim Weis, Director, Renewable Energy and Efficiency Policy, Pembina Institute**  
(http://www.pembina.org/)

The Pembina Institute is a Canadian non-profit think tank that advances sustainable energy solutions through research, education, consulting and advocacy. It translates science through environmental movement by working through ideological opposition.

Pembina supports CCS as part of a portfolio of solutions for addressing the issue of greenhouse gas emission (GHGE). There are no CCS projects on the go currently. All eyes are on projects Shell Quest and knowledge dissemination from the cancelled Pioneer Project.

10.2  **Steve Larter, Scientific Director, Carbon Management Canada (CMC)**  
(http://www.cmc-nce.ca/about-cmc/)

CMC-NCE is funded through the Federal and Alberta governments. Currently there are 36 projects under four themes (recovery processing; secure carbon storage; accelerating deployment of low carbon emission technologies; and emerging and enabling technologies). CMC’s five year funding ends in 2014. There are already links to international organizations such as in the UK and the US. In Canada, IPAC-CO2 has been a close collaborator of CMC. Canada is one of few countries currently injecting CO₂, other countries have stalled.

Steve showed interest in the group’s research. He mentioned his previous work on similar areas as perception and risk communication. He also talked about the presentations made by the project team. He commented on assessing cap rocks and looking at all monitoring options. He also suggested networking with Don Lawton who is the theme leader for CMC Theme 3 (Secure Carbon Storage). His view was a need to emphasize mitigation strategies and not just ranking the
risk as low and so acceptable. Leaks do happen but the monitoring should be sufficient to pick these up with the capacity to respond to problems.

10.3 Carmen Dybwad, CEO, IPAC-CO2
(http://www.ipac-co2.com/about-ipac-co2)

IPAC-CO2 is an environmental non-government organization (ENGO) created to provide independent risk and performance assessments of CO2 storage projects. It’s funded by Government of Saskatchewan, Shell Canada, and the Federal government. The current funding ends in March 2013. They are exploring other funding opportunities.

CMC’s web portal-Carbon Commons is one of IPAC-CO2 project. Other activities’ include managing the development of a CSA Standard for Geological Storage, public opinion research, and third party audits.

10.4 Doug Wright, Program Director, Council of Canadian Academies (CCA)
(http://www.scienceadvice.ca/en/about.aspx)

The Council is an independent, not-for-profit corporation that supports science-based, expert assessment studies to inform public policy development in Canada. Doug has worked as Director of Policy and Planning with Nuclear Waste Management Organization (NWMO). With this work, Doug noted the importance of framing the discussion and in being transparent in order to help move through a process. His current portfolio involves working on environmental implications of shale gas.

The Council is 5 years old. It receives questions/concerns from Federal agencies on wide ranging topics. The Council completes assessments and produces evidence-based feedback.
10.5 Darryl Seehagel – Alberta Department of Energy (ADE)  
(http://www.solutionsstarthere.ca)

Darryl works on CCS, renewables, and one other portfolio. The following portfolio activities were discussed: 1) the regulatory assessment framework is near completion and will be out soon – comprises of four technical groups, expert panels, steering committee. The report should be a public document; 2) Work on effect of CO₂ on well casings and cements; 3) Monitoring and feeding into federal regulatory process – e.g. coal, petroleum industry.

10.6 Jon Paul Jones - Alberta Innovates - Technology Futures (AITF)  
(http://www.albertatechfutures.ca)

The Edmonton group is making a link between groundwater and CCS. Not involved with policy or public engagement but rather storage, geological characterization, MMV, technical aspects of far field effects. The group is working on the Weyburn and biosphere risk panels regarding surface and some risks to groundwater. Jon Paul referred to the Joint Canada-US Atlas which identifies preferred sites but not pore volumes. He suggested that CMC could possibly help by updating the mapping. For instance, Carmen noted that NRCan created in-depth characterization of CO₂ potential in Saskatchewan and perhaps this could be nationalized.

10.7 Ian Hayhow – Global Carbon Capture Storage Institute (GCCSI)  
(http://www.globalccsinstitute.com/)

The Institute brings together projects, policy-makers and researchers to overcome challenge facing CCS in order to accelerate deployment. The Institute uses the lessons learnt
projects around the world to provide information to a broader audience, thus enhancing
the understanding of technical, economic, financial, commercial, and engagement issues
facing

CCS. GCCSI has a series of workshops planned for next 12 months. In his view, there is a
need to rebrand “CCS” as there is no traction with the current messaging. For instance, the
use of CO₂ for Enhanced Oil Recovery (EOR) is not rebranding for “CCS” because industry
is producing more oil.

Ian found Joe Arvai’s work important.

10.8  Carl Poirier – CCS Nova Scotia
(http://www.ccsnovascotia.ca/)

CCS Nova Scotia is a not-for-profit corporation funded by the Province of Nova
Scotia, Nova Scotia Power Inc. and Dalhousie University. Carl is a Mechanical Engineer
with knowledge on capture side and has a partner who is a geologist. Nova Scotia uses 60%
coal based power; 17% renewables; NG 20% and have a goal to reduce fossil fuel use by up to
40%. It has a working budget of $5M. This is one of the higher targets for renewables in
Canada and options will be gauged by decision makers. Indeed, there are variable targets and
guidelines across the country.

Nova Scotia’s challenge with respect to CCS is geology. Mapping is underway in
sedimentary basins with some potential for storage. A sub basin has been identified for
additional research. Project fruition might be on a 10 year timeline. The plan is for one of four
coal plants to capture CO₂ – approximately 4 Mt potential. Maurice believed that going to full
CCS on the existing plant would increase cost of generating 20-35% (30%), with 33% capture
rate. CCS will be competitive if a long pipeline is not necessary. Offshore might be most appealing.

There is no oil and gas industry and so there is no potential for EOR in Nova Scotia and very limited awareness regarding CCS. To address the issue a communications director has been hired to reach out to the public regarding the available options and the most cost-effective option to reach our reduction goal over next 20 years. Public perception is the biggest challenge as the public is sensitive to any exploration with no experience with oil and gas industry. It’s important to engage the public early on and address the concerns especially related to a desire for competitive pricing, environment quality and preservation. Dan noted lessons learned regarding radon in Manitoba. Payment is made when the risk is really big.

11. Themes of Discussion with External Stakeholders

11.1 General Project Considerations

The risk of CCS was determined to be to Society (global and local) and the Canadian Economy. No catastrophic risk is at play but risks are more long term: potential for valve leaks and seismicity; terrorism is unlikely but would involve deliberate human intervention.

The current project is focused on the geoscience of CCS, to inform the engineering science and develop science-based risk models. This will be accomplished through agreed methodology to quantify and analyze the risks. Probability or rate of escape (of CO₂) will be available using Robert Gracie’s work. Risk estimates for groundwater will be required, possibly from details in US publications. Currently, the view is that the quantity of contaminants
that could enter potable drinking water is unquantifiable, but scenarios could be useful. Overall, the result from a quantitative risk assessment needs to be defensible. Capture and Transport will be discussed on a more limited basis.

To date, a sufficient universal risk document has not been identified. Considerations for the project will therefore include: A risk profile and the change in relative risk over time.

Financial risks of CCS projects were also outlined briefly. Participants discussed the breakdown of costs for each part of the CCS Chain, based on $100 total scenario: Capture $70, Transport $8, and Storage $22. Associated mitigation risk ranking is: Capture (1), Transport (2), Injection (3) and Storage (Long term security) (4).

Risks are more long term.

11.2 Public Perceptions and Project Outreach

The actors in risk assessment need to be corporations, Carbon Management Canada, McLaughlin Centre for Population Health Risk Assessment and government entities. Participants discussed industry engagement. Steve Larter noted that their unavailability to participate in the Workshop does not reflect a lack of interest in the issues being discussed. For instance, the view was that some of Shell Canada’s current needs are monitoring technologies including tracers, and sensors. Regarding capture, however, industry proprietary information is held more tightly because of patenting.

The view from Nova Scotia is that in order to gain public acceptance, a project needs to start at the government level, with a mandate to explain the nature of studies in a publicly accessible way. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia was cited as a good example. It’s not a government department but a separate research organization. Might there be similarities with the National Research Council
The Nuclear Waste Management Office was also noted as having some success. To date, the perception has been in trying to sell the CCS technology.

Shell Quest is viewed as a poster child for public relations; goal to be a leader within their broader corporate strategy related to the oil sands. Their application included engaging a consortium (DNV) to complete an Independent Project Review. Shell Canada also had a detailed public engagement strategy within its communications plan. At the ERCB hearing, three interveners showed up, mainly regarding the government funding and pipeline integrity. The Petroleum Technology Research Centre (Saskatchewan) also completed a third party assessment for their Aquistore Project but it has not been released widely.

Other thoughts were for further discussion on who would communicate the message as well as its components. A focus group approach could include a mock press release. There could also be a Science Communication Workshop on CCS (contacts included Penny Park, Science Media Centre of Canada and Fiona Fox, Science Media Centre, UK). The Council of Canadian Academies was flagged as having a potential role to play in further research and information dissemination.

12. Future work – Phase II

Noted Risk Management considerations included Monitoring (for example, Gas saturations); Tracers; and the use of large geoscience models.

12.1 Workshop Outcomes

i) If anyone sees a user friendly overview of communicating risk or a hazards taxonomy, please provide to a Team member. It was agreed that the hazard taxonomy developed at University of Waterloo will be shared, first with the Team and then with the others.
ii) The next Project update meeting with stakeholders is planned for February 2013 such that input will be integrated into the next interim report.

iii) Ongoing outreach and communication will include all Workshop participants and others who were unable to attend: Global CCS Institute; Government of Alberta – ERCB, AITF, DOE; Nova Scotia CCS; Pembina Institute; CCA; IPAC CO2, OMNR, CEMI; NRCan; Government of Saskatchewan (Section to be identified). [Contact list is provided in Appendix J.]

iv) Feedback to Bill:

- Step 3 (Risk Dimensions Analysis) and Step 4 (Risk Estimation) – Discussion among PIs
- Step 5 (Risk Control Options) - Step 5 is the transition to the Risk Management phase
  - Develop integration of Arvai work, in terms of risk perception and public confidence
  - Integrate aspects of the Fall/Dusseault/Gracie results: Based on the risk analysis, what risk control options exist for risk mitigation, if mitigation (lower risk) is required in some important dimensions, e.g., leakage to air or groundwater?

v) Project Results format

Once Phase I of the CMC project is completed, the question remains as to who the outreach/education will target and what would be the preferred approach.

- Produce 2, 5, 10, 25 page summaries and full report readable to the public, as well as individual journal article submissions. Executive summaries for web could be smaller. McLaughlin Centre has partnerships available for information dissemination (e.g. Penny Parks from Science Media Centre of Canada [www.sciencemediacentre.ca]).

International information dissemination also discussed in preliminary way.

vi) A CMC sponsored event – a Science Communication workshop with CCS as the topic – would be viewed as a positive contribution.