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Integrated Risk Management Framework (IRMF) for Carbon Capture and Storage

Phase I: Risk Assessment

Waterloo

October 5th, 2012

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Canada's university

University of Waterloo

UNIVERSITY OF CALGARY

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Integrated Risk management Framework for Carbon, Capture and Storage (IRMF-CCS)

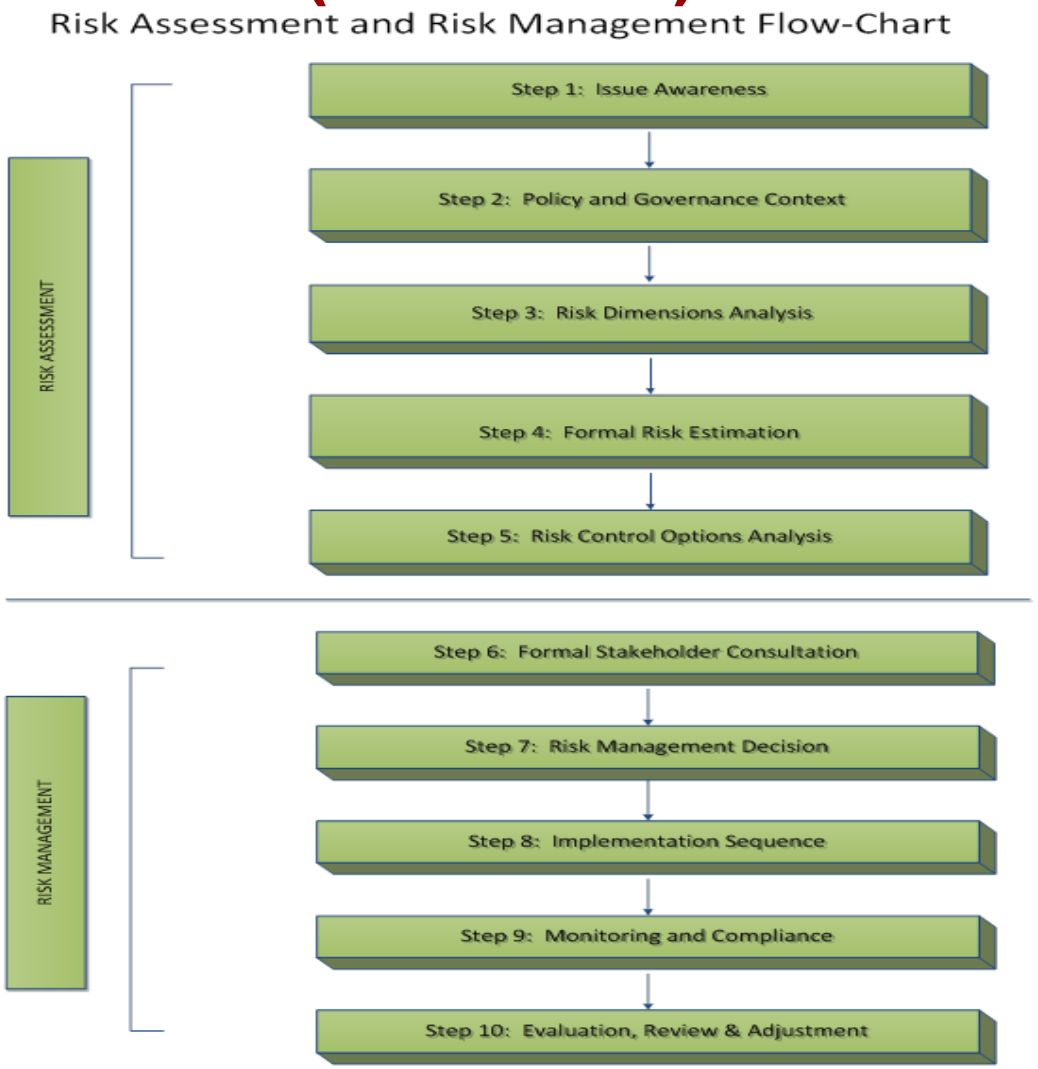

Figure 1

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Integrated Risk management Framework for Carbon, Capture and Storage (IRMF-CCS)

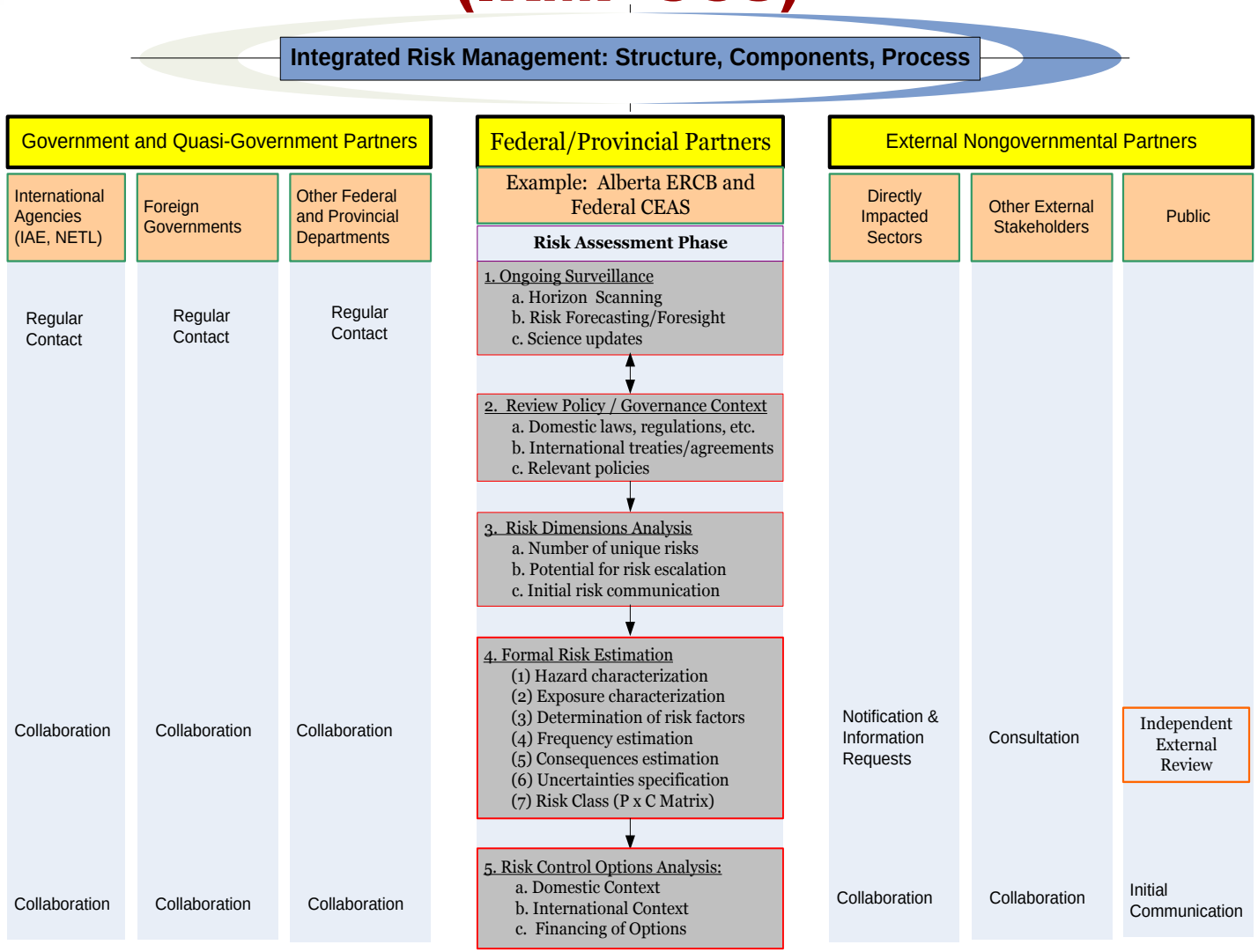

Figure 2

Integrated Risk management Framework for Carbon, Capture and Storage (IRMF-CCS)

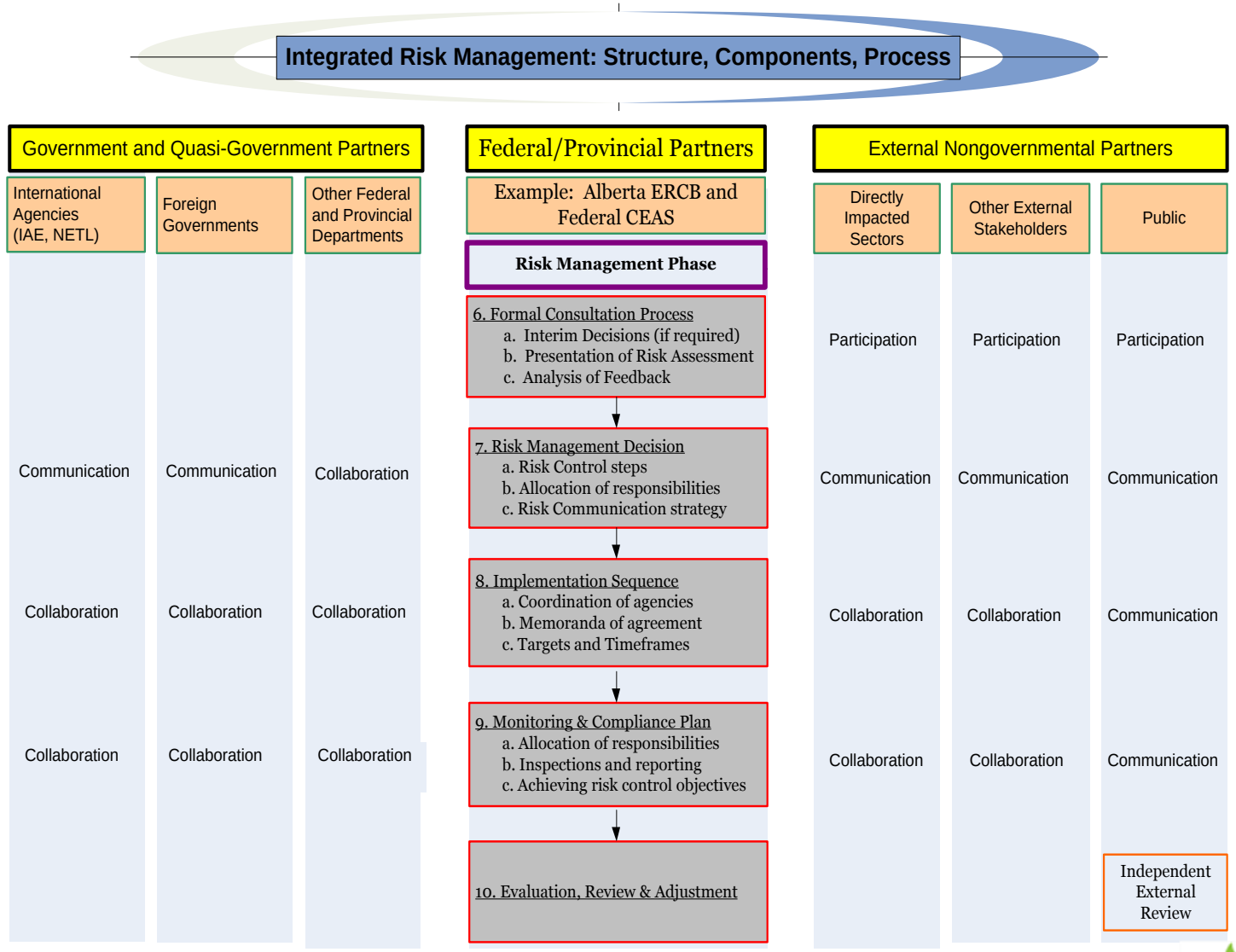

Figure 3

Structure and Strategy of an Integrated Risk Management Framework (IRMF)

- This type of formal flow-chart diagram for the sequential steps in RM decision-making was first explicated in the famous US-NRC "Red Book" (1983) – see Leiss et al. 2010, sect. 8 for a history and analysis of these types of diagrams.
- The central "core" of the IRMF diagram identifies the key government agencies, within a specific country, which are responsible for using and defending a RM approach for regulatory oversight of industries and technologies.
- When all steps in the process are carried out (*in advance of a decision*), documented, published, and subjected to independent peer review (at critical decision points), the finished product should have wide public credibility.

Structure and Strategy for IRMF (2)

- Risk management frameworks are supposed to facilitate and promote important values in RM:
  1. Making explicit the steps in the process;
  2. Identifying all of the essential decision inputs;
  3. Providing for stakeholder notification, consultation and participation opportunities at key steps;
  4. Noting where documentation of analyses are available for review and critique;
  5. Requiring feedback in response to stakeholder inputs;
  6. In general, promoting transparency in decision-making for issues of broad public interest and concern.

Structure and Strategy for IRMF (3)

- We call this an “integrated” framework on account of its expansions on either side of the core mandate:
  - On the left, the international and national bodies, acting independently or cooperatively, which can be many in number for something like CCS;
  - On the right, a listing of 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.
  - U. S. authorities are best at comprehensive and publicly-available exercises of this kind, e.g., the 3000-page EIS for the “FutureGen” CCS project.

Structure and Strategy for IRMF (4)

- The side panels in the integrated framework, when filled in and made publicly available, can have a number of functions:
  1. Providing a convenient public record of interactions between regulator, cooperating agencies, and stakeholders;
  2. Providing the regulator with the opportunity to complete a checklist for essential tasks;
  3. When supporting documents are attached, providing a convenient record of proof of the completion of necessary tasks by the regulator.

Overview of Risk Assessment Phases

- Step 1: Issue awareness
- Step 2: Policy and regulatory context
- Step 3: Hazard and risk taxonomy
- Step 4: Scientific structure of risk estimation
- Step 5: Risk control options (decision support)

Scientific Structure for Risk Estimation I

- Focus primarily on injection and storage phase of CCS
- Characterize the CCS repository in quantitative geo-mechanical terms
- Develop taxonomy of hazards that will serve as the basis for risk assessment and risk ranking
- Develop quantitative tools to evaluate plausible risk scenarios (e.g., well leakage, anthropogenic paths such as well bores, rate of filling of reservoirs)

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Scientific Structure for Risk Estimation II

- Estimate the probability of breaching the geological repository in different ways
- Evaluate environmental, health, and other consequences of breaching
- Consider risks associated with temporary geo-storage (salt caverns, porous reservoirs)

Global and Canadian Regulatory Environment: 10 years of RA/RM in Regulations, Guidance and Standards (P. Larkin)

- A lot has been drafted:
  - Approximately 30 regulatory and non-regulatory organizations have sourced documents; often CCS Chain specific - Capture, Transport, Injection, Storage
  - 8 regulatory and 6 non-regulatory sources have published approximately 27 documents

- RA/RM elaboration varies - may simply mention a requirement, or may spell out specific inclusions or approach

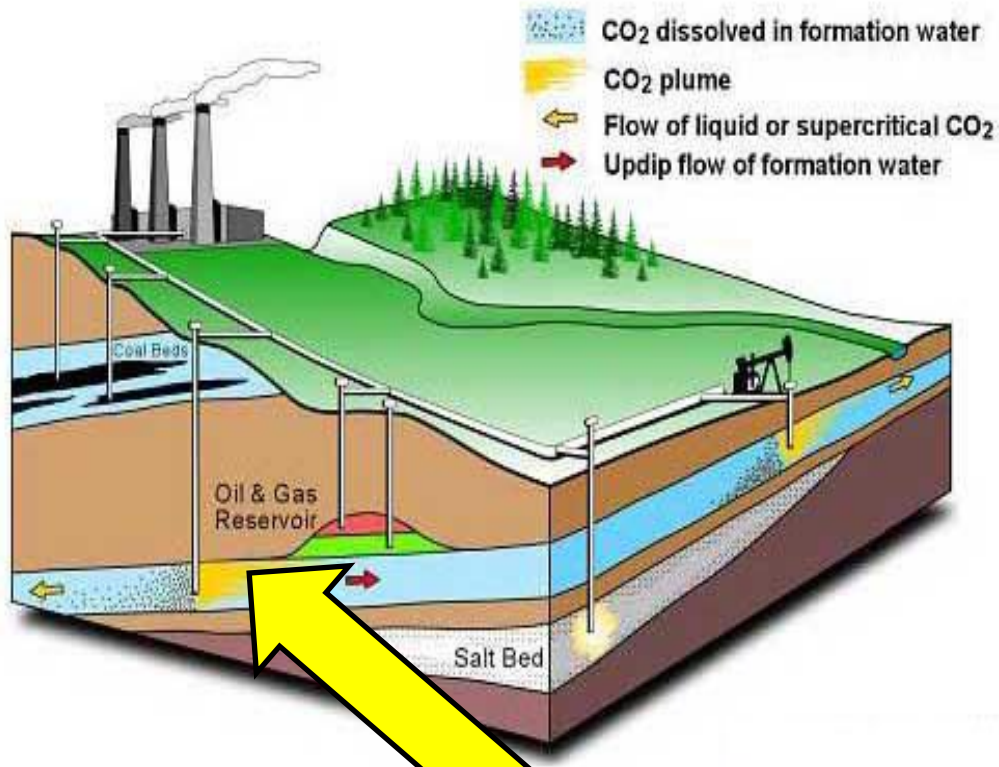
- Most comprehensive documents:
  - Advisory = World Resources Institute (2008), DNV (CO2Qualstore) (2010), US NETL (multiple).
  - Regulatory = UNFCC - Modalities and Procedures as Clean Development Mechanism, 2011.

RA/RM Elaboration

- Primarily regarding injection and storage
- Documents consider site selection and characterization
  - Many include 4-step RA (Hazard Characterization, Exposure Assessment, Effects Assessment, Risk Characterization)
- Few regulatory and no non-regulatory frameworks link with an assessment of emissions, waste or water use; some assess CO2 stream
- Uncertainty, stakeholder communication and consultation, and transparency discussed sparsely in regulatory context and frequently in non-regulatory documents

Canadian Project Oversight

- Often included Federal (CEAA screenings) and Provincial processes
  - Legislation, Guidance continuously being updated
- Specific triggers determine the assessments that are required; oversight is CCS Chain specific
  - Each of the Capture, Transport, Injection, EOR or Storage approval processes considers relatively narrow activities
- Narrow regulatory interests lead to an apparent disconnect between the announcement of "integrated" projects and the nuts and bolts of assessment
- See details in Table 1 (end of slide deck)
- See Nigel Bankes papers for details of Alberta oversight



Where Will the CO_2 Go? (Maurice Dusseault)

Realistically, **Saline Aquifers** are the only alternative for massive CO_2 sequestration by injection of SC-CO_2. Other alternatives are too small…, less secure…

Saline aquifers: >100 × the volume of oil and gas reservoirs → the only rational alternative, proven in practice

CO_2 Injection Models - A

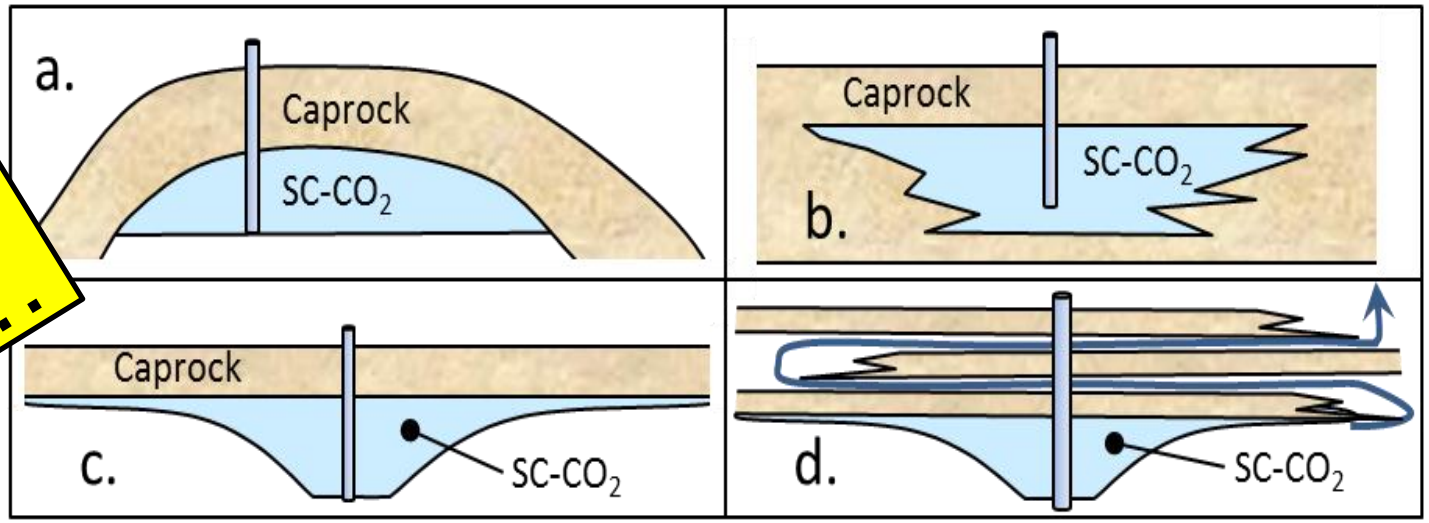
- Improved models for saline aquifer injection, which are much more suitable for modeling supercritical CO_2 injection.
- Models are semi-analytical rather than numerical time-stepping calculations:
  - Immediate solutions for long time injection cases.
  - Excellent for quick assessments, stochastic analysis.
  - To check mathematical models, to do Monte Carlo simulations, parametric impact.
  - To allow rapid comparisons between cases.

CO_2 Injection Models - B

- New models by Farshad Malekzadeh to simulate vertical and horizontal well injection of low density phase into a flat-lying, tabular reservoir.

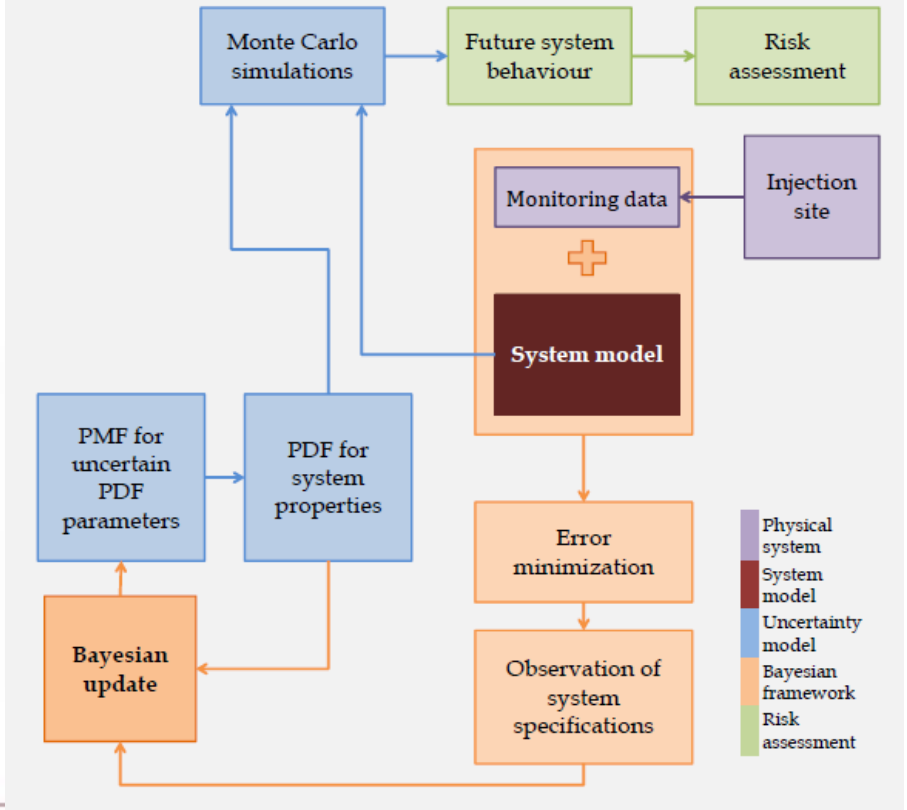
- + effects of differences in density, viscosity, porosity, permeability, residual saturation, etc.

Trap Types…



Overview of Ongoing Work I (Gracie Group)

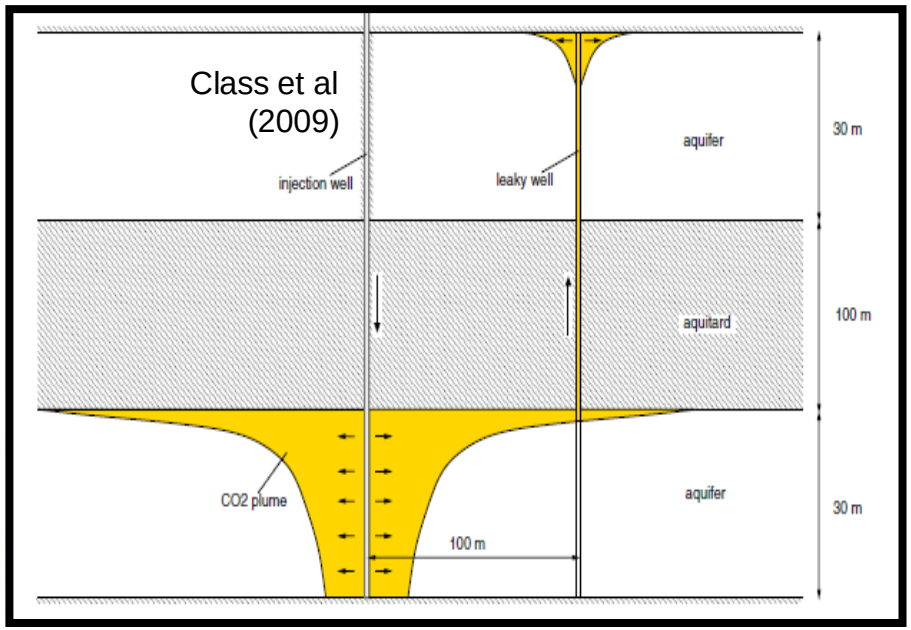
- Quantify uncertainty/risk of CO2 leakage from abandoned wells.
- Mechanisms for leakage from abandoned wells have been tabulated
- Connected to monitoring data in a strong way.
- Computationally efficient system models are critical.



Overview of Ongoing Work II

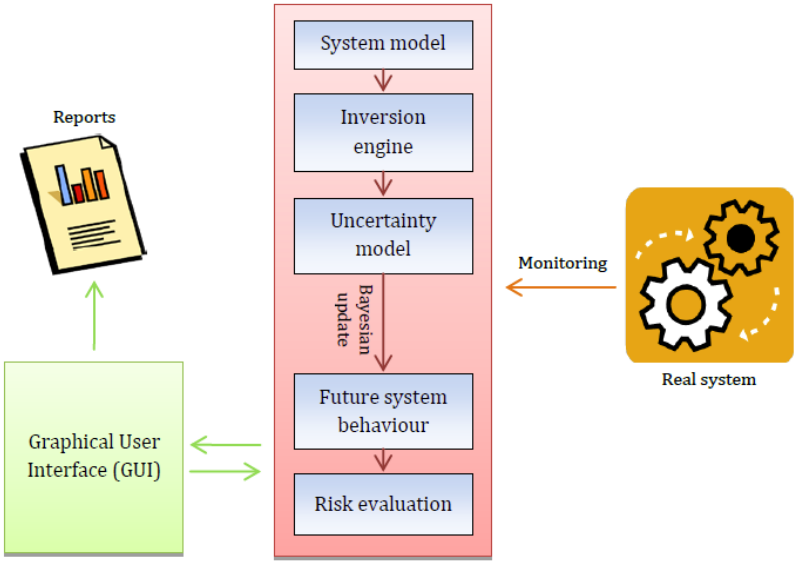
Development of simulator to predict the CO_2 migration in saline aquifers and leakage from abandoned wells.

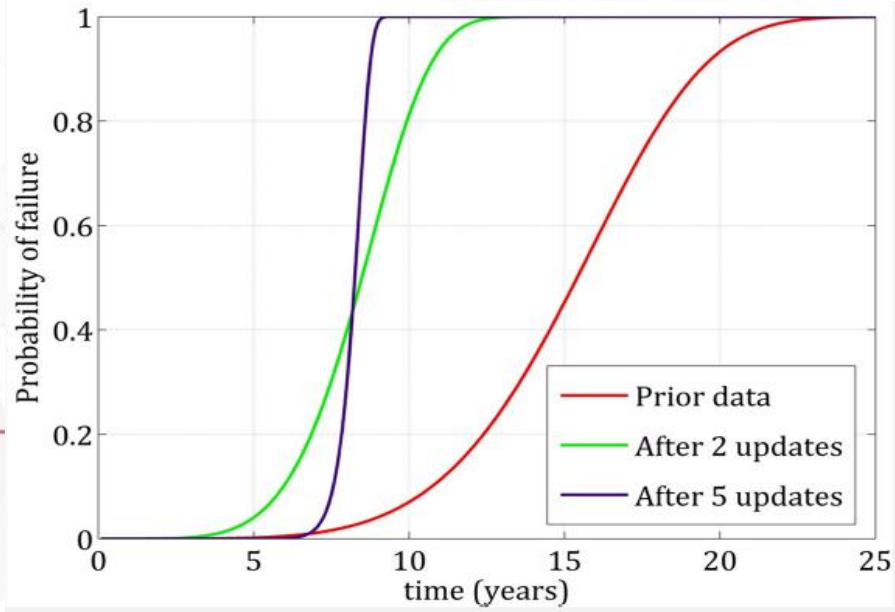
- Given CO_2 injection rate, subsurface lithology, and the location of injection and abandoned wells, estimate CO_2 leakage and migration as a function of time.



Relationship to IRMF

- Bayesian software will link monitoring data to CO2 leakage risk and uncertainty predictions.

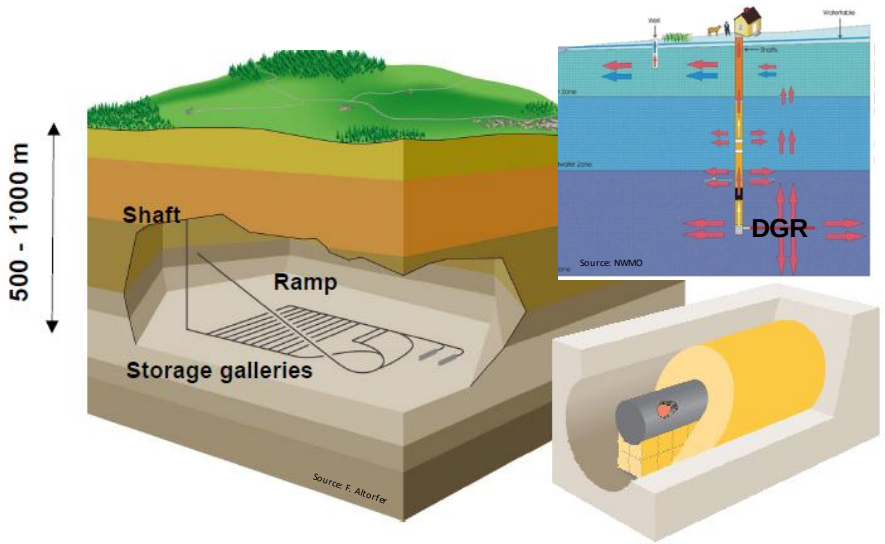




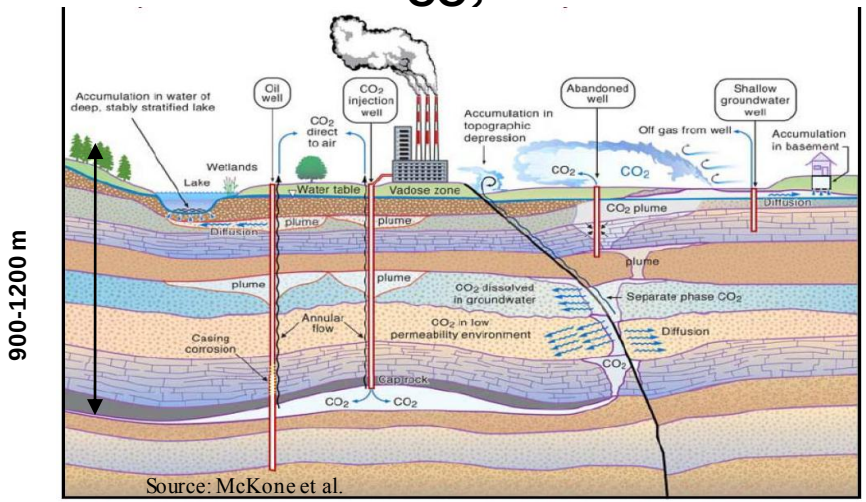
- Monitoring data is not continuously available.
- Bayesian framework must be updated periodically.

Lessons Learned from GD of Nuclear Wastes (Mamadou Fall Group)

Concept of Deep Geological Repository (DGR) for Nuclear Wastes Disposal



Concept of Deep Geological Disposal of CO_2



Part # 1

- Review of nuclear wastes GD (GD-NW) RA methods.
- Review of CO_2 GD (GD-CO_2) RA methods.
- Comparative analysis of RA methods for GD-NW and GD-CO_2.

Part # 2

- Review of GD-NW RM methods.
- Review of GD-CO_2 RM methods.
- Comparative analysis of RM methods for GD-NW and GD-CO_2.

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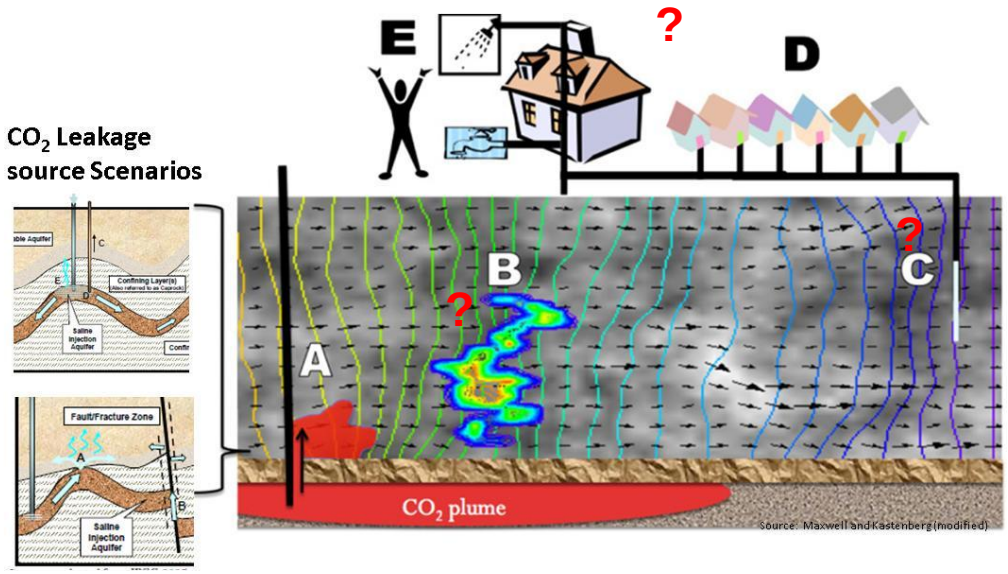
Consequences of CO_2–Aquifer Leakage



Concerns

- Groundwater acidity will increase due to the dissolution of CO_2.
- Increased acidity may mobilize toxic metals and other contaminants.
- Fluid pressure increase could force brine into drinking water.

Ongoing Work

- Identification of the potential consequences of CO_2 leakage on UDW quality.
- Development of a simulator and modelling framework for the prediction and assessment of the consequences of CO_2 leakage on the quality of UDW.
- Application of the simulator to a Canadian CO_2 disposal site.
- Identification of methods of control and remediation of UDW.

Relationship to IRMF

Related to IRMF-Step 1-5 & RM

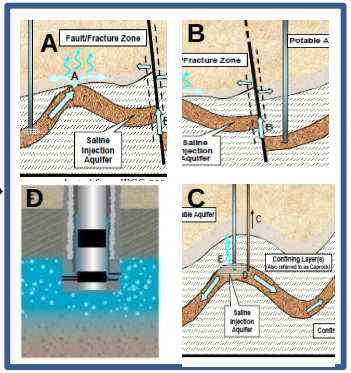
Integration of Lessons learned from Deep Geological Disposal of Nuclear Waste

Issues/Regulations

- Identification of the issues of UDW quality alteration due to CO2 leakage
- UDW quality criteria set by the regulatory agencies

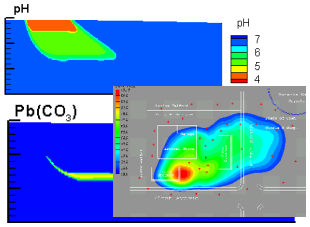
Related to IRMF-Step 1 & 2

Leakage Scenarios



Related to IRMF-Step 4

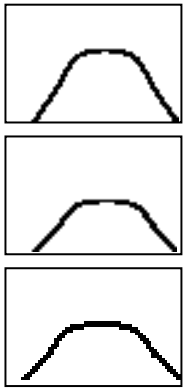
Simulator Develop.



MODELING

Related to IRMF-Step 4

Consequences



[Contaminant]

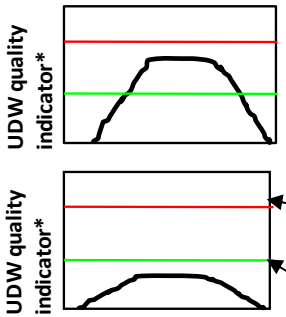
Acidity (pH)

TDS

Related to IRMF-Step 4

Comparison with

Regulatory quality criteria



Unacceptable

Acceptable

Unacceptable

Acceptable

* [contaminant]; pH; TDS

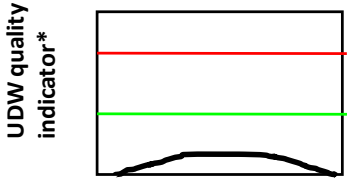
Relat. to IRMF-Step 4 &5

Control/Reduction

- UDW contamination control and reduction methods
- UDW acidity control and reduction methods
- UDW TDS control and reduction methods

Related to IRMF-Step 5

Adequate UDW Quality



* [contaminant]; pH; TDS

Related to IRMF-RM

Integration of Lessons learned from Deep Geological Disposal of Nuclear Waste

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Ongoing Work I (Joe Arvai Group)

- Survey to assess public familiarity, knowledge, and risk perceptions of CCS deployment.
  - Within-Canada comparison (BC, AB, SK).
  - Transnational comparison (Canada, Switzerland).
- Familiarity with CCS differed significantly across study regions.
- Risk perceptions were stable across study regions and were unrelated to familiarity.
- Knowledge was a consistent predictor of risk perception at all of our study sites.
- National differences were found in terms of benefit perception.

Ongoing Work II

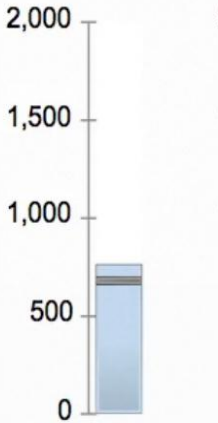
- Research and development of an interactive, systems-level decision support tool for energy transitions.
- Decision support tool includes technological options that incorporate CCS.
  - Large scale, facilitated pilot study completed in Summer 2012 (in Michigan).
  - Second, large scale (non-facilitated) pilot study to be conducted in Winter 2012/13.
- Key aspects of the tool include:
  - Energy portfolio builder
  - Energy systems model
  - Tradeoff analysis module

Whenever you are ready, please build your portfolio.

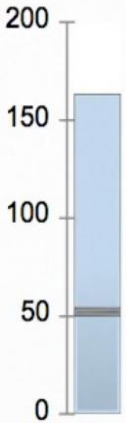
Efficiency Options	Power Plant Options					Decentralized Energy Options			Off-Campus Options	
Energy Eff. Prog.	New Nat. Gas	New Nat. Gas	New Nuclear	Not Used	Not Used	Distr. Solar PV	Distr. Gas	Not Used	Offsite Wind	Not Used

Demand Requirements

Steam
000 lbs/hr



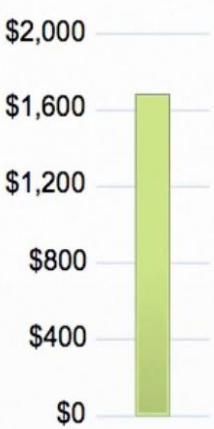
Electricity
MW



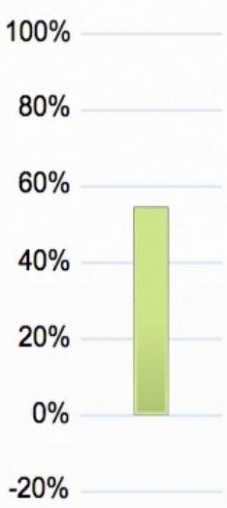
You have met the demand requirements of the campus

Performance Indicators

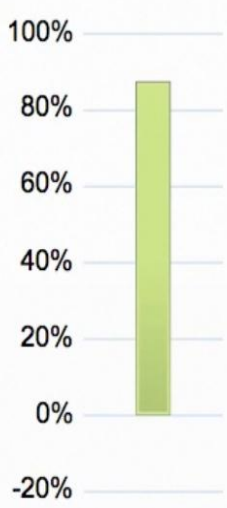
Cost
annual tuition premium



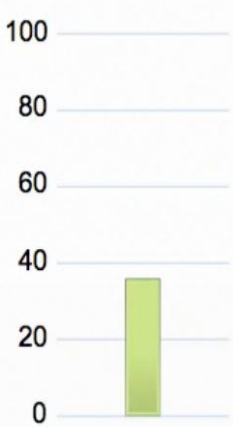
GHG
% reduction from current



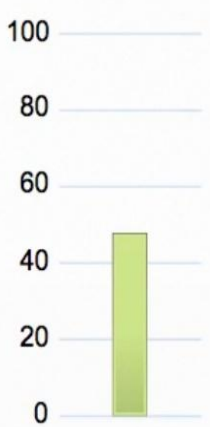
Air Emissions
% reduction from current



New Local Jobs
full time equivalent



Land Use
increase in acres



Innovation
relative scale

Survey Progress :

Next

Reporting of Results

- Disciplinary journal articles are currently being prepared by each of the sub-project teams
- These results will be incorporated into the next draft of the integrated risk management framework for CCS (to be submitted to CMC by March 31, 2013)
- Planning of a special issue of the *International Journal of Risk Assessment and Management*, documenting both individual contributions and the integrated risk management framework
- Subsequent preparation of an overview paper on risk assessment of CCS, accessible to a general audience
- Policy uptake workshop to be scheduled with regulators and stakeholders

Regulatory Oversight of Canadian Projects

Project and Goal	Primary Regulatory Oversight			
	CEAA Screening	AB or SK Provincial EA	Alberta ERCB	Saskatchewan OGCA
Larger Projects				
Weyburn and Midale EOR Operations 1997, 2005	Yes Transport	Yes Transport	NA	Yes
Boundary Dam Integrated CCS Demo Capture approved 2012 [Transport and EOR/Storage approvals not yet begun]	No	No EIA Capture Clearance letter	NA	Capture None required
Alberta Carbon Trunk Line Approved 2010-2011	Yes Transport EOR	Yes Transport	Approved without hearings	NA
[Reported elsewhere] Shell Quest Upgrader with saline sequestration Approved 2012	Approved Joint Application Federal/Provincial		Approved with hearings	NA
Smaller or Research Projects				
Weyburn IEAGHG Monitoring Project - Started 2000	No	No	NA	None required
Aquistore Phase 1 Research Approved 2012 [Phase 2 Saline sequestration not yet begun]	Yes Access Injection well	No EIA Clearance letter Injection well Test storage	NA	Yes Injection
Swan Hills Unit #1 EOR Injection Pilot 2004-2006	Yes	No	Approved without hearings	NA
Zama CO2 EOR Start 2006	Yes	EPEA Amendment	Approved without hearings	NA
Projects at earlier phase of development (information available to date)				
Swan Hills Synfuels ISCG and CCS for EOR Application expected 2012	No	Yes	Need for hearings to be determined	NA