Understanding risks associated with deployment of carbon capture and storage

Project risk assessment for carbon capture and storage

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Outline of Presentation

I. What is risk?

1.Risk is partly subjective. Policies can address that aspect.
2.RA methodologies must address both measurable and unmeasurable
3. Complex problems require careful assessments to integrate and address concerns

II. CCS crucial technology to global mitigation strategies

1. CCS is not fully vetted compared to other mitigation technology options.
2. Financial issues tied to massive "scale-up" needed to deal with climate change.
3. Serious analysis shows there is no choice but to include CCS.
4. Cost of control in power sector may be more cost effective than elsewhere!

III. Due to the complex nature of problem, elements of risk and means to treat vary

1. Project risk does not exist in a vacuum: attention to larger issues is important
2. Intent to reduce emissions at national may not directly bear on project design or cost.
3. Unintended consequences of law and regulation may confound problem
4. There are specific issues for CCS projects that must be recognized

IV. What is sound risk management for CCS to support deployment?

1. Risk assessment and risk management can create opportunities.
2. Well-structured RA can be useful through project lifetime
3. Trusted communication of sound information can reduce liability
4.. Summary – focus on the greatest uncertainties.

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What is risk?

- Recent IPCC 4th Assessment Working Group III[1] report (TAR Chapters 2 and 3) discussed risks associated with developing and implementing climate mitigation strategies. Authors acknowledged that there are knowledge gaps to be addressed.

- Frank Knight[2] offered early and widely recognized definition of risk: "To preserve the distinction…between the measurable uncertainty and an unmeasurable one we may use the term 'risk' to designate the former and the term 'uncertainty' for the latter".

- Risk is understood to require both uncertainty and exposure – possible consequences. Glyn Holton[1] supplied a more general definition of risk that might apply to almost any action with the two essential components: exposure and uncertainty: "Risk…is exposure to a proposition of which one is uncertain."

- **Risk is partly in the eye of the beholder particularly when dealing in situations where there is balance between subjective elements and objective elements. Development of long-term strategies for dealing climate change may be just such a case.**

[1] IPCC 4th Assessment, WG III TAR, Chapters 2 and 3
[2] Knight, Frank H. 1921."Risk, Uncertainty, and Profit", Hart, Schaffner, and Marx (NY) as quoted in Holton, Glyn A. 2004. "Defining Risk", Financial Analysis Journal, Vol. 60,No. 6 (Nov/Dec 2004)

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CCS projects engender risks from technical and non-technical issues.

- Implementation of one project or a complete mitigation “portfolio” requires assessing point of view of various actors with a stake in climate change.
- Climate change may be one of the most complex problems that human societies have ever addressed.
- Interests of general population, of governments and of non-governmental organizations in developing “solutions” to climate change differ from those of project performers or investors.
- Investors are seeking an acceptable return on investment perhaps while encouraging outcomes consistent with social goals – and this is becoming increasingly important.
- Project performers seek to build a project with the specific intent of “profitably” producing and selling power.
- Interests of those charged with protecting public health and welfare or with ensuring public receives fair value from those providing essential services to the public (electricity, water, natural gas, telecommunications) differ from these other groups.
- Collective actions of the various interest groups do impact investments and this impact partly determines investment risk.

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Strategies for dealing with climate change: Mitigation and Adaptation

- Assessing risk in the context of climate change requires one to be specific about who is facing the risk (exposure) and how that person (or institution) understands and assesses risk.

- The dangers faced by human societies (and nature) include many unmeasurable uncertainties. At present, there is no objective standard for assessing impacts. Recommendations to "protect" may not address cost/benefit analysis. How much change can be tolerated through adaptation?

- As we move "down" the scale of complexity, scope (nation vs. a single site) and time, uncertainties and exposures may become more measurable or better understood even if still not quantifiable.

- However, ultimately the intersection or combination of these different types of uncertainty and exposures create a cumulative sense of risk. Whether we seek to address a problem globally, within a single country, at some smaller scale, these different "risks" have an impact on which strategies we pursue.

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Worldwide costs for mitigation[1]

- Peer-reviewed estimates of the SCC for 2005 have an average value of US$43 per tonne of carbon (tC) (i.e., US$12 per tonne of carbon dioxide) but range around mean is large. In a survey of 100 estimates, the values ran from US$-10 per tonne of carbon (US$-3 per tonne of CO_2) up to US$350/tC (US$130 per tonne of CO_2).

- Current work cited in the IPCC WG III 4th Assessment report indicates that a carbon value of $20 - $50/US per tCO2-eq applied over decades would result in a low-GHG emissions power sector by 2050. The technology mix in this sector would include deployment of a substantial amount of carbon capture and storage.

- Modeling studies indicate that CCS would of necessity be a major technology option in efforts to stabilize atmospheric concentrations at 550ppm and would contribute greater reductions world-wide than renewables.

- Large range of estimated SCC is due, in part, to differences in assumptions regarding climate sensitivity, response lags, the treatment of risk and equity, economic and non-economic impacts, the inclusion of potentially catastrophic losses and discount rates.

- Globally aggregated figures may underestimate the damage costs because they cannot include many non-quantifiable impacts. These estimates often assume "perfect", global markets and other idealizations.

1. IPCC 4th Assessment Report, Summary for Policy Makers and TAR's for Working Groups II and III

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Why is this important?

- For a problem as large and as complex as climate change, developing effective strategies in response is complicated by tremendous uncertainty in possible outcomes and assessment of benefits to costs.
- We are acting at a great distance – costs to mitigate and adapt are likely to be incurred before full impact of climate changes are noted. How quickly or how slowly these impacts arise and can be assessed make calculating cost/benefit ratios difficult.
- Estimates of aggregate net economic costs of damages from climate change across the globe (i.e., the social cost of carbon (SCC)) are expressed in terms of future net benefits and costs that are discounted to the present.
- Calculated (modeled) costs and benefits are often more sensitive to parameters such as discount rate and timing of regulations than costs of individual actions.
- Estimated costs assume universal emissions trading, transparent markets, and low transaction costs.
- Recent IPCC reports show the importance of CCS as an element of sound mitigation strategies.
- Let’s spend a minute looking at estimates of mitigation costs.

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Worldwide costs for mitigation

- A recent report from WRI[1] – citing data from the IEA World Energy Outlook for 2006 includes an estimated investment in the energy infrastructure between today (2006) and 2030 of $20 trillion (US).

- **Other estimates[2] also include global annual costs per year through 2300 that range from $0.3 trillion to $1.5 trillion (current dollars) with outlays being higher on average in the earlier years.**

- What share of the required investment will come from global capital markets including commercial Banks or equity investors? What share from stock value?

1. World Resources Institute, Scaling-up: Global Technology Deployment to Stabilize Emissions (2007)
2. IPCC 4th Assessment Report, Working Group III, and Cline in Global Crises/Global Solutions, Cambridge Press (2004)

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Impact of policy on project risk

- Technology-neutral policy design is strongly preferred from economic and environmental perspectives. The role of government is to set social and political boundaries, leaving the market to innovate[1].
- Technology-specific policies is likely to remain important for two reasons:
  - Price signals may emerge gradually, and take time to command investor confidence. For some technologies there may be a role for government support to bring new technologies to the point where carbon prices set by policy are sufficient to let the market take over.
  - Some technologies serve other public goods or political constituencies, and in such cases policy makers may wish to single them out.
- Climate policy risks[2] may be reduced compared to other risks if policy is set over a sufficiently long timescale into the future…Investment risk premiums are significantly lower when the price jump representing the policy uncertainty is shifted from only five years in the future out to 10 years to coincide with the planning cycle in that industry.
- Climate policy risks is more important for technology investments for which climate policy is a dominant economic driver, for example carbon capture and storage (CCS).

1. WRI (see citation on previous page)
2. Yang and Blyth, Climate Policy Uncertainty and Investment Risk, 144 pages, ISBN 978-92-64-03014-5, OECD (2007)

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Key drivers of risk[1]

A report issued by the Institute of Risk Management (IRM), the Association of Insurance and Risk Managers (AIRMIC) and ALARM, the National Forum for Risk Management in the Public Sector seeks to offer standards for risk assessment and risk management. This document lists a number of different types of risk, some of which can be understood and assessed as internal to the organization doing the evaluation of risk and others that are primarily external or outside the control of the organization assessing the risk incumbent to a particular decision.

[1] "A Risk Management Standard, AIRMIC, ALARM, IRM (2002)

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What constitutes a CCS project[1]?

Fundamentally, there are three broad areas within CCS. These are the activities of capturing the carbon dioxide (CO2), transporting the CO2 to its storage facility, and the act of storing the CO2 . There are numerous processes within each of the three general activities such as compression of the captured CO2 and injection at the storage facility.

[1] CO2CRC Cooperative Research Center for Greenhouse Gas Technologies

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Definition of a project

- Carbon sequestration projects consist of several process implementation phases. Each phase has a unique set of risks which can vary from project to project, depending on size, location, plant design, storage location, storage site characteristics, etc. Successfully passing one phase (say permitting) does not guarantee continued success in negotiation through subsequent phases.
- Carbon sequestration projects can include single, small project or may encompass a very large activity handling many power plants.
- For each of the technological subsystems there are potential health, safety, and environmental risks which need to be considered during project assessments.
- Some elements of CCS are not addressed by current regulatory frameworks. ***These vary from country to country.*** Lack of complete regulatory frameworks for CCS adds a degree of uncertainty in performing the risk assessment (RA).
- RA should be performed as soon as possible in the process to minimize unanticipated events.
- In some cases, anticipated risk(s) for the project (power plant, pipeline, and storage site) may provide justification to change the aspects of a project, or in extreme cases, relocate the project.

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Project Risk Assessments

- Detailed risk assessments are beneficial in developing input for risk management of project(s). Demonstrated commitment to practice of risk management can have positive consequences.
  - Results of the RA for a particular project may be beneficial if the results are above average. Lower insurance and finance rates may be in order for lower risk CCS projects.
  - Higher rates may result and raise financial risks to an unacceptable level for a high risk CCS project that lacks mitigation plans or risk management strategies.
- Carbon capture and storage projects need to have risks assessed at every phase. Drivers that may require on-going risk assessments include:
  - Changing business environment
  - Changing regulations
  - High cost of project, general escalation of costs in the industry, fuel price volatility
  - Safety, Health, Liability
  - long-term storage requirements (measurement, monitoring, and verification)
  - Who are the project performers (Have they changed?)
  - Who is responsible for each phase?

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Risk Assessment and Risk Management

Perform risk assessments for each implementation phase & technology subsystem of a CCS project following four (4) fundamental steps:

- Identification and description of risk factors,
- Develop risk models,
- Calculate the risk for each phase with an applicable risk analysis method, and
- Develop options, including expected impacts, to decrease or eliminate risks as practical.

Note: There is a different time horizon for the assessment of risk for the first four phases - capture, compression, transport, and injection – compared to the final phase –long-term storage. The first four phases are consistent with conventional operational periods - a time frame of approximately 40 years. The storage phase has both short-term and long-term risk components. The short term coincides with operational periods – injection for 40 years – while the long term phase require assessment of risk up to and beyond, 1,000 years.

- Risk management[1] is the term applied to a logical and systematic method of identifying, analyzing, evaluating, treating, monitoring and communicating risks…Risk management is as much about identifying opportunities as avoiding or mitigating losses.

1] Ministry of the Premier and Cabinet, "Guidelines for Managing Risk in the Western Australian Public Sector." Government of Western Australia ISBN 0 7307 0101 8 , 1999

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Risk Management Process

Subsystems of a CCS project may include:
Capture
Compression
Transport
Injection
Storage (Monitoring & Verification)

Documentation for risk calculations for any subsystem must provide descriptions of inputs and resultant outputs and facilitate performance of subsequent revisions that would need to incorporate updated CCS project data.

Role of Risk Assessment at Different Phases of a CCS Storage Project[1]

[1] Stenhouse, Mike, "Approach to Building Confidence Concerning Geological CO2 Storage: Risk Assessment Perspective." Monitor Scientific LLC, METI/IEA GHG Workshop, Mitsubishi Research Institute, Tokyo, Japan January 24-25, 2007

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Detailed Risk Assessments

- Detailed RAs are performed and provide input for risk management of project(s). Risk models tabulate a list of variables and act as a checklist in order to ensure that nothing is taken for granted and that analyses are performed on a consistent and repeatable basis. Variables in risk models usually have a range of values.
- Without RAs, projects may be unable to secure adequate insurance or even funding from investors, financial institutions and/or government programs. RAs need to incorporate mandated requirement(s) in regulations.
- Risks are to be calculated for each subsystem in the CCS project. The first four phases will involve many of the same types of risk components such as system integrity failures, external interference, and environmental factors.
- The system integrity failures would involve equipment-piping, valves, instruments, etc. Human interaction (human error) would be a direct risk factor during operation of the actual equipment or an indirect risk factor by externally affecting the system.
  - An indirect risk factor example would be the inadvertent drilling into the storage area due to poor record keeping and causing a release of $CO2$.

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Capture and Compression Risk Factors

Examples of capture and compression risks include:

- The system integrity could fail. The number of failures is relative to the number of variables such as the quantities and complexities of the components in the system. The more valves, the higher potential for chance of leakage. The more welds, the higher the chance for leakage due to weld failure.

- Risk can be encountered in achieving the expected percentage of operational time or percentage of CO_2 capture from the technology process due to performance, operator, or equipment problems/difficulties.

- For compression of the CO_2, high pressure boundary equipment (pump, valves, piping, tanks, cylinders, etc.), high speed rotating equipment, noise, power supply reliability, maintenance, and operator performance are sources of risk.

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Transport

- For pipeline route selection, the risk factors may include political concerns, environmental problems, commercial considerations, financial parameters, technical considerations, and taxes.

- Transport risk would include the terrain, waterway crossings, probability of seismic events, erosion, flooding, accessibility, nearby population and industry, etc.

- An article by Barrie, et al[1], listed a number of design concerns: "…a major CO2 release has potentially devastating consequences, and the design of the piping system must reflect the risks involved…Examples of additional specific design considerations in place for CO2 pipelines are effect of cooling from pressure changes; requirement for dehydration of CO2; routing topography; dispersion pattern; valve materials; compressor, seal, and auxiliary materials; requirement to minimize flow transients; and risk assessment focused on impact of rupture on human health."

1] Barrie, J. *et al*., "Carbon Dioxide Pipelines: A Preliminary Review of Design and Risks", http://uregina.ca/ghgt7/PDF/papers/peer/126.pdf

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Storage – Injection phase

- Injection risks are primarily limited to the local area of injection, unless a major blowout/rupture occurs. Mitigation of a major blowout/rupture would involve a system of backup checks or shut-off valves and controls/instrumentation.

- During injection, safety monitoring equipment would be necessary to check the amount of CO_2 in the immediate area of the workers' environment and to protect against public exposure to elevated levels of carbon dioxide.

- Input-variable categories may include: public perception considerations, government approvals and permits, ecological and cultural parameters, health and safety considerations, and evaluation of preexisting damage. Primary risk concerns with storage facilities include public health and safety and impacts to the environment.

- Environmental impact in the short term would consist of CO_2 leakage at the storage site and along CO_2 migration pathways.

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Storage – risk management overview[1]

[1] Heidug, Wolfgang, "Risk Management for CCS and CO_2 Policy." Shell International Renewables SBSTA 24, Bonn Presentation, WBCSD/IETA side event, 19 May 2006

Long-term Storage - MMV

How do we ensure that long-term storage of carbon dioxide is safe?

- A report published by the Tyndall Center[1] explored issues related to CCS for the UK. The authors felt that the greatest uncertainty…"with respect to CCS is whether the CO2 will leak from the reservoirs…The impacts of any potential leakage upon global climate change…are also somewhat uncertain… A regulatory framework for CCS will need to include risk assessment of potential environmental and health and safety impacts, accounting and monitoring and liability for the long term."
- Both the authors of the Tyndall study and an IOGCC [2]report suggest some form of government involvement in assuring the safety of long-term storage and to underwrite liabilities associated with the site or its abandonment.

1. Clair Gough and Simon Shackely, An Integrated Assessment of Carbon Capture and Storage in the UK, Technical Report 47, Tyndall Centre for Climate Change Research (October 2005)
2. Carbon Capture and Storage: A Regulatory Framework for States, IOGCC report (January 2005)

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Risk assessment must be an iterative process

Risk Acceptance

Risk acceptance criteria is necessary to define what risks are acceptable versus unacceptable.

- For the capture and compression phases, risk acceptance criteria developed on a health and safety basis. For example, in the vicinity of selected capture and compression equipment at a source, more leakage could be tolerated in specific areas of the facility where personnel will be barred from entry or physically shielded.
- High traffic or personnel exposure areas near other equipment may require more stringent risk acceptance criteria.
- However, to keep matters simple, the more stringent risk acceptance criteria may be adopted everywhere within the capture and compression facilities.
- Regulations can be a source of the risk acceptance criteria.
- Company policy may require risk acceptance criteria superseding that which is based wholly on safety and health considerations.

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Carbon Markets

Carbon markets are in their infancy:

- Volatility in European Unions Emission Trading System (EU ETS) carbon market demonstrates complexity of emissions commodity markets.
- EU ETS and has shown significant volatility in Phase I. EU ETS Phase II envisions more stringent emissions cap and will be more complex.
- Other carbon markets of various sizes are forming around the world and will operate during the EU ETS Phase II period increasing pressure to rationalize processes.
- Carbon markets seem to be headed towards continued volatility for many years.
- Carbon markets will have scope far larger than the SO2 allowance market in the United States. (EU ETs Phase II - $37 billion (US); US SO2 - $2.25 billion (US))
- Study[1] of the EU-ETS by Hepburn et al, offered the following suggestion:

  "*Auctioning may also provide a hedge against projection uncertainties, reduce price volatility, and increase investor stability. The recent EU ETS market collapse is a dramatic manifestation of uncertainty in emission projections. Reserving some allowances for periodic auctions:*
  could assist transparency and liquidity
  offers a potential price cushioning mechanism (as in US transmission auctions), to create a more stable EU ETS market
  might facilitate ex-ante agreed target price ranges, thereby increasing predictability for investors"

[1] Hepburn, Cameron, et al. "Auctioning of EU ETS Phase II Allowances: How and Why." Jun 2006. *United Kingdom Electricity Policy website*. Accessed 4 Jun 2007 http://www.electricitypolicy.org.uk/pubs/wp/eprg0621.pdf.

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Incentives and Insurance

- Innovations in policy and creation of new instruments to encourage investment are needed.

- Might include regulatory exemptions for demonstration projects, use of special purpose vehicles, bond issues or privatization initiatives to underwrite development, operation, and legacy management of key infrastructure needed for a sequestration industry

- These incentives or risk-sharing and risk management approaches might produce most efficient results if applied globally meaning that risk, incentives, and risk management would flow across whatever boundaries are crossed by the project or series of projects.

- Trends in infrastructure privatization suggest that CCS could be viewed as an infrastructure that allows continued use of fossil fuels - an essential need for society - through a substantial portion of this century[1]
  - For example, notions of government ownership of stored CO2 after site closure have been suggested in the Tyndall Centre report[2].
  - Weather hedging strategies or risk-sharing amongst insurers has been proposed for catastrophic losses

1. IPCC WGIII, 3rd Assessment Summary for Policy- Makers; and Ryan Orr The Privatisation Paradigm, the Infrastructure Journal at www.infrastructurejournal.com;
2. Clair Gough and Simon Shackely, An Integrated Assessment of Carbon Capture and Storage in the UK, Technical Report 47, Tyndall Centre for Climate Change Research (October 2005)

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Communications are essential

- Beyond the need to perform best-in-class risk assessments, there is a need to communicate the results of such analyses.
- Much has been written about the importance of communications…
  - The Tyndall Center report cited earlier explored issues related to CCS for the UK. The report focused on off-shore disposal in inactive oil and gas fields and in saline formations. The authors found that, given the sense of urgency that they found for dealing with climate change – and surveys of public attitudes was a key part of this study – CCS was viewed as an acceptable alternative if done off-shore.
  - An report prepared for NETL suggested that local concerns are often focused on practical and less philosophic concerns so there may be opportunities for a different sort of discussion or risk communication[1].
  - Experience in a risk communication for other environmental issues confronting industry has resulted in a widespread understanding that the issue is not about facts, it is about trust[2]: "…On the other hand, one thing that you must assume is that the general public is well educated... The primary objective of risk communications is not to change public opinion about the size of the risk but rather to build trust about the corporate commitment to contain and control it."
- Early and thorough communications aimed at building and maintaining trust is essential.

1. Adler and Kranowitz, A Primer on Perceptions of Risk, Risk Communication, and Building Trust, the Keystone Center, Feb 2005
2. AWMA Publications, http://gcisolutions.com/bertawma02.htm

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Maintain an overview of risk and liability for CCS

- Many authors are examining risk, liability, and risk management strategies. The papers cover issues ranging from technology-specific risk assessment guidance through risk issues and incentives relevant to sector-wide implementation of CCS to, finally, assessment of CCS as an option compared to other mitigation options. Good answers will emerge but will they be effectively and rapidly communicated?

- Information needed to evaluate the likelihood and benefits of carbon sequestration technologies is rapidly increasing. Analysts are looking at issues such a technology-neutral vs. technology-specific policies, and targeted incentives for demonstration or deployment. There is much yet to be learned before we can be sure that CCS can help meet anticipated greenhouse gas reduction goals.

- Evaluations of factors contributing to risk, assessments of the impact of perceived risk on carbon markets, assessments of frameworks for assigning liability, compilation of lists of existing incentives and suggests of actions to reduce risk or to craft effective incentives and to otherwise encourage and accelerate deployment of CCS need to be updated regularly.

- Effective communications strategies are an essential part of managing risk for CCS and of communicating what risks are acceptable.

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How do we tell a complete story?

‘Risk” relates to many things and each instance may be treated via different frameworks. Investments in projects for climate change mitigation will be made in the face of great uncertainty. Investment choices including evaluation of risk are somewhat in the eye of the beholder.

CCS a relatively new “option” in GHG mitigation technology portfolio but an essential one.

IPCC reports recognize different sorts of concerns and barriers may exist when looking at macro-level issues compared to those that apply to power sector or to decisions regarding an individual plant. Consistency may be lacking.

High level policies can efficiently promote beneficial technologies; or they can effective block their implementation in favor of other technologies; legislation can result in unintended consequences that have substantial negative impacts. Note: IPCC assessments assume we do it exactly right.

To succeed, we must link the flow of information on authorities, policies, incentives, liability frameworks to barriers that they erect or to opportunities that can be created to further the cause of climate mitigation. We must use this knowledge base to create a level playing field for CCS

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Conclusions…

- Risk assessment and risk management are essential actions. Demonstrated commitment to practice of risk management can have positive consequences. Risk management is as much about identifying opportunities as avoiding or mitigating losses.
- As most risk is part perception, an aggressive communication strategy is essential.
  - Communications must be clear and tailored to each stakeholder group
  - Communications must come from or through trusted sources
  - Clearly define what constitutes "Acceptable risk"
- Knowledge development must support actions to ensure a level playing field for CCS compared to other mitigation options.
  - Incentives for near-term deployment of CCS are important but are they enough?
  - Investors pursue sure money provided by legislative mandates and strong tax incentives.
  - Policies and incentives must recognize all concerns vis-à-vis CCS and address them
- The unanswerable question of long-term storage and the liability that might attach to it may require special instruments – including investment vehicles – to manage this particular risk.
  - Assurances of long-term safe storage must be backed by some financial guarantee that remediation of any leakage or other failure will occur.

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Discussion

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